Technology Collaboration Programme
by iea

IEA Technology Collaboration Programme

International Energy Agency

Technology Collaboration Programme on Energy Storage

(ES TCP)

Task 39 - Large Thermal Energy Storages for District Heating

Subtask A: Application Scenarios, Assessment of Concepts, Integration aspects

Deliverable A2: LTES project development - Case studies

AUTHORS

Pierre Garcia, Newheat

Nathan Fournier, Newheat

CONTRIBUTORS

Julian Formhals, Vattenfall

Morten Vang Bobach, Bobach Solutions

Nico Franco Pinto, IF Technology

Stéphane Mériau, Newheat

Per Alex Sørensen, PlanEnergi

Geoffroy Gauthier, PlanEnergi

Bas Godschalk, IF Technology

Olof Andersson, Geostrata HB

Publication date 03/04/2024

CONTENT

Introduction

This document introduces project development case studies for the four technologies studied in IEA ES Task 39 (see Figure 1): Tank, Pit, Borehole and Aquifer Thermal Energy Storages. It serves as an illustration of deliverable A1 "Method to carry an LTES project, important questions & KPIs - Synthesis.", with real-life project development examples. The full report, deliverable A4 ("Method to carry out an LTES project, important questions & KPIs - Synthesis."), includes this document and gives a more thorough look at LTES project development.

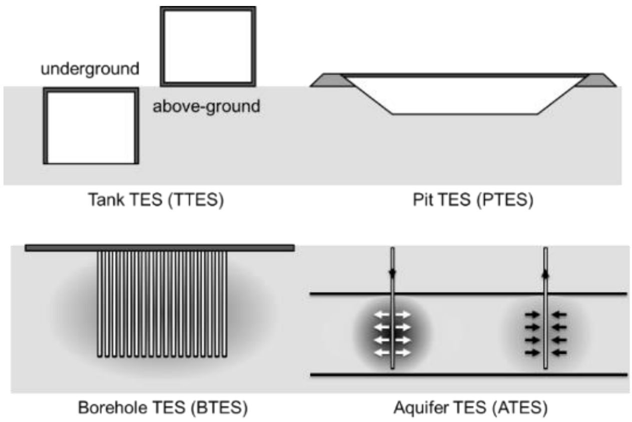

Figure 1. The four LTES technologies considered in IEA-ES Task 39 (source: Solites).

1. TTES case study

1. Project ID: Berlin (Germany)

Type of usage: daily storage of heat
Year commissioned: 2023
Owner: Vattenfall

Technical details	Water volume: 56'000 m^3 Storage capacity: 2'750 MWh Charge-discharge capacity: up to 200 MW_{th} ~70-120 cycles of charge/discharge per year Max operational temperature: 98°C (atmospheric)	Dimensions: Ø 43 m x h 45 m

2. Modelling and sizing

The demand for storage was assessed in a study assessing different sites, LTES technologies and possibilities based on the District Heating (DH)-demand and plant/network boundary conditions (http://dx.doi.org/10.5445/KSP/1000023676). During this project stage, techno-economic simulation and optimization was conducted on a system level using an internal MILP[1] tool for energy system optimization as well as the software Bofit. Data for boundary conditions (heat load curves, weather, DH-Network integration points, etc.) was already available internally for other purposes. For the design of the storage a feasibility study was concluded to specify used technologies and design parameters. During this stage Excel and Ebsilon were used to analyse the storage and the site integration.

3. Storage materials

Conventional materials were selected based on operation and environmental boundary conditions (temperature / mechanical resistance / insulation properties…) and under consideration of the tank dimensions.

4. Land

Different power plant locations (operator owned) were compared before selecting the final location. The location was selected primarily based on its proximity to the generation units and availability of space. The chosen plant site is located at a river and therefore groundwater is found relatively shallow. A soil survey was carried out to determine the requirements of the foundation.

5. Permitting process[2]

Local urban plan can restrict the maximum height of a construction, which was not the case for this project; however, the city hall requested that the TTES be moved due to its visual impact for the neighbourhood, which creates little shadowing on the solar field sometimes of the year.
The storage has been built above drinking water collection areas, thus a hydrogeologist had to control that the foundations construction would not impact the aquifers.

[1] Mixed-Integer Linear Programming
[2] Those parts are written based on Newheat's projects in Narbonne to complete data gathered from Berlin project.

6. Contractual Scheme

Vattenfall owns and operates the plant, the contractors built it. The contractors provided both performance and mechanical warranties.

7. Tendering process

The tendering process was divided into 3 main work packages (lots):

- Civil works including the heat storage plant, pipe bridge and pump station building,
- Design, construction, and erection of the heat storage tank,
- A general contractor for basic and detailed Engineering of the pumping station plant, auxiliary systems, procurement, erection, and commissioning.

8. Construction[2]

During the construction, some neighbours showed concerns regarding the visual impact of the project, as no other significant construction are visible in this area.
A truck crane and baskets are used to erect the storage, thus if the wind exceeds a certain limit, the operation must be paused.
No performance test measurements have been realized but CFD studies have been conducted on a similar project to verify that the storage would respect the contract requirements.

9. Operation & maintenance

The TTES, which is currently still in commissioning phase, is thoroughly instrumented. The measurements generally work as expected so far and will provide insightful and useful information about its operation. Additionally, a special optical temperature measurement is installed in the storage tank so that together with TU Dresden, real temperature profiles and operation models can be read and studied as soon the storage goes into operation (see Project TWINopt). Currently there are no maintenance activities planned in the short-term since the TTES is not yet in operation.

2. PTES case study

1. Project ID: Dronninglund (Denmark)

Type of usage: seasonal storage of heat
Year commissioned: 2014
Main heat source: Solar thermal
Owner: Dronninglund district heating (Denmark)

Technical details:	Water volume: 60’000 m^3	Lid dimension: 91 m x 91 m
	16 m deep	Slope 1:2
	Storage capacity: 5’000-5’500 MWh	Charge-discharge capacity: 27 MW_{th}
	2-2.5 cycles of charge/discharge per year	
	Max operational temperature: 85-90°C (in summer)	

2. Modelling and sizing

It was relatively easy to access data regarding the existing DH-Network as well as load curves and temperature requirements from the control system at the plant. Weather data is also easily accessible through meteorological services. The difficult part was the boundary conditions on geotechnical

parameters such as soil parameters, and ground water flow. Geotechnical conditions were estimated from knowledge on the soil type as well as geotechnical drillings/investigations.
PTES technology was selected for this project because of the following reasons:

- ATES was not considered due to limitations of temperature and the fact that there is no cooling demand,
- TTES was not relevant due to size and cost considerations and due to the high solar fraction target for the project (close to 50% coverage from the system solar + storage + heat pump),
- BTES was considered but PTES was chosen due to higher flexibility (fast charge/discharge) and higher temperatures giving more direct utilization of the storage without permanent heat pump operation.

TRNSYS modelling was used for sizing the PTES and assessing its performance. The models used evolved through opportunity and design phases: system was changed and (re)optimized a few times due to change in expectations to legal framework (electricity taxes, taxes on fuel – bio-oil, natural gas etc.). Consequently, an electric heat pump was replaced by a heat-driven heat pump in the design phase.

3. Storage materials

The liner material was chosen based on high expectations and guarantees from the supplier regarding service life at 90°C. Insulation material and properties were chosen based on experience from earlier pilot storages (Marstal 10’000 m^3 storage, Ottrupgaard 1’500 m^3 storage). The lid was replaced in 2021, with a new design of the cover based on experience from original design in Dronninglund as well as experience from other PTES in Denmark. Material was selected based on moisture simulation and diffusion principles.

4. Permitting

A local plan has been elaborated, which introduces the new energy plant and describes all consequences for landscape and environment. It includes permissions regarding the Law of Heat Planning, the Law of Nature Protection, the Law of Environmental Protection, and the Municipal Plan. On top of that, a screening of environmental consequences was elaborated to assess the need for an Environmental Impact Assessment report.

The first decision stated that there was no need for such a report, but following a complaint the report was requested, as the consequences of using groundwater for filling the storage was not described.

5. Tendering process

The tendering process was divided into 5 main work packages (lots):

- Excavation/soil works,
- Piping, diffusers, technical installation,
- Liner installation,
- Water filling,
- Cover installation.

The contractualization with contractors was based on standard Danish building contracts (ABT 93/ABT18).

6. Construction

The weather conditions had a minimal impact on the construction works.
Mainly functional tests were done for commissioning.

7. Operation & maintenance

There has been issues with different sensors:

- Level sensors and moisture sensors showed short service life,
- Temperature sensors work properly, but some of them inside storage have been changed due to lightning damage.

Relatively strong focus was given on instrumentation and data analysis as it was a public funded project. It has also been part of other funded projects with continuously monitoring of performance between 2014 and 2021, and live data has been uploaded on https://varmelagerdata.dk/.
The main maintenance activities planned were monitoring and inspection of water level and rainwater pumps. Unexpected maintenance activities had to be conducted on the original cover to remove rainwater and replace insulation due to combination of heavy loads from rainwater puddles and high temperature/moisture in insulation.
The LTES is performing as expected regarding main KPIs (energy balance, efficiency…).

3. BTES case study

1. Project ID: Emmaboda (Sweden)

Type of usage: seasonal storage of heat
Year commissioned: 2010
Main heat source: Industrial waste heat
Owner: Xylem Water Solutions AB
Technical details: Boreholes configurations: 140 boreholes of 150 m depth
Underground volume: 336’000 m^3
Storage capacity: 3’800 MWh (for a ΔT of 20°C)
Storage temperature: 60-40°C (design), 40-20°C (actual)

2. Modelling and sizing

Historic energy data was available in the control system and used for the design of the BTES. Only the BTES technology was considered for this project.
Based on a couple of Thermal Response Tests in two exploration boreholes the thermal parameters of the rock were evaluated and used for simulation in a model named DST. The DST simulation results were used for design of number of boreholes, the depth, and distance between the holes.

3. Storage materials

As borehole heat exchangers a thermal resistant plastic was used (PPE) that could withstand temperatures up to +80ºC.

4. Land

For land selection, a grass field area inside the industrial property was chosen as the only possible alternative.

5. Permitting process

A minor environmental risk analysis was sent to local and regional authorities according to Swedish regulations. No objections were received from their side.

6. Contractual Scheme

Xylem Water Solutions Ab is the owner, the operator, and the heat user of the BTES.

7. Tendering process

There were tenders for two external contracts (1) the drilling of boreholes and (2) fabrication and installation of borehole heat exchangers and connection pipes.

8. Construction

The weather conditions did affect the construction work, as the boreholes were drilled in the harsh winter 2009-10, that was slowing down the performance and increased the cost by some 15 %.

9. Operation & maintenance

The BTES was instrumented for control purposes, no additional measurement was added to further assess its performance. The instrumentation works properly.
No heavy maintenance activities are planned, but some unexpected maintenance activities had to be conducted at the early days of operation: the circulation pump was replaced, the heat exchanger was cleaned, and an additional gas separator had to be installed.
The BTES has been performing as expected regarding main KPIs (energy balance, efficiency…) for the last five years.

4. ATES case study

1. Project ID: Middenmeer (Netherlands)

Type of usage: seasonal storage of heat
Year commissioned: 2021
Main heat source: geothermal heat of 90 °C from 2’400 m
Owner: Ennatuurlijk Aardwarmte
Technical details: Average water volume: 440’000 m^3 Average energy stored: 28 GWh
Charge-discharge capacity: 12-10 MW_{th}
1 cycle of charge/discharge per year
Max operational temperature: 90°C (infiltration temperature)
Maximum allowed storage volume: 600’000 m^3 groundwater (38 GWh capacity)
Maximum allowed extraction: 700’000 m^3 of groundwater
Thickness of aquifer: 20 m
Distance between wells: 220 m
Storage aquifer depth: 385 m

2. Modelling and sizing

The data for heat delivery (heat load curves, weather, DH-Network integration points, etc.) were not easy to acquire, as part of the delivery system already existed, and another part had yet to be designed at the same time. The data for heat storage were readily available, but unforeseen external factors influenced the initial real world storage capability.

The ATES technology was chosen because a large seasonal storage was desired for increased use of geothermal heat. Additionally, the soil composition was suitable for that. Besides, there was already a TTES on the site for daily cycle storage.
HST and Matlab modelling tools were used to design the ATES. Matlab was used for various custom calculations, including FEM[3] thermal modelling of heat conduction and simulating flow with a complex custom-made injection system.

3. Storage materials

The following materials were selected for the storage construction:

- Glass-fiber Reinforced Epoxy (GRE):
    - Straight tubing and large radii,
    - Corrosion resistant,
    - High pressures possible,
    - Resists temperatures up to 120°C,
    - Smoother than stainless steels (less hydraulic losses),
    - Lower heat conduction than metals.
- Stainless steel 316L
    - Based on specifications, corrosion resistant up to present levels of salinity and applied temperatures,
    - Shorter bends possible than GRE,
    - Easier for strength calculations than composite materials.
- Titanium plate heat exchangers provide more certainty for corrosion resistance than SS 316L

4. Land

The land was selected because of the presence of underground aquifers with vertically limited groundwater dispersion. 6 m² of outside floor area is needed per well. The technical room with heat exchangers, electrical components, filtering, monitoring, and water treatment requires roughly 1,5 m² for each 1 m³/h of flow. So, if maximum flow is 100 m³/h the necessary area is roughly 150 m². When the technical room includes heat pumps for high temperature delivery (65°C and above), the required floor area will be roughly double that of the technical installation without heat pumps.
For this project, land is privately owned. There were no issues with the selected land, but if soil is contaminated, it needs to be collected and disposed of at an appropriate facility.

5. Permitting process

No urbanistic rules compliance applies to existing systems in the Netherlands, but such rules may be applicable for future projects.
Significant heat leaks to higher groundwater layers could induce a risk for the environment (bacteria growth), so this aspect must be monitored. No risk for people is identified, except while building the system and while doing large maintenance with cranes. Local acceptance is an issue to be considered. For instance, it is important to inform people in the neighbourhood that there is no risk of seismicity. Besides, the well housing can be up to 3 meters tall, so these may stand out in urban areas.

6. Contractual Scheme

The energy provider is the owner and the operator of the ATES. It was responsible for building the technical room and remains in charge of heat storage, heat delivery and maintenance to the system.

[3] Finite Element Method

The contractor dug the wells and corresponding piping and is now responsible for the maintenance of the wells. An engineering consultancy firm monitors the groundwater system and gives advice on performance improvements. They also execute groundwater tests to determine the effects of heating on the groundwater composition. The heat user can give inputs about the required energy for its needs and is committed to consume a minimum amount of heat while the system is active.

7. Construction

Weather conditions did not affect the construction work. During commissioning, all systems were extensively tested. It took two weeks of collaboration between producers of subsystems, owner of the system, user of the system and engineering firm.

8. Operation & maintenance

The LTES and its instrumentation system is performing as expected. A lot of effort was put into adding monitoring possibilities to the system to determine its technical and energy performance.
Regular maintenance of wells is planned twice a year: it consists in visual inspection of the wells, measurement of hydraulic performance and electrical resistance of the pump. No unexpected maintenance activities had to be conducted so far.