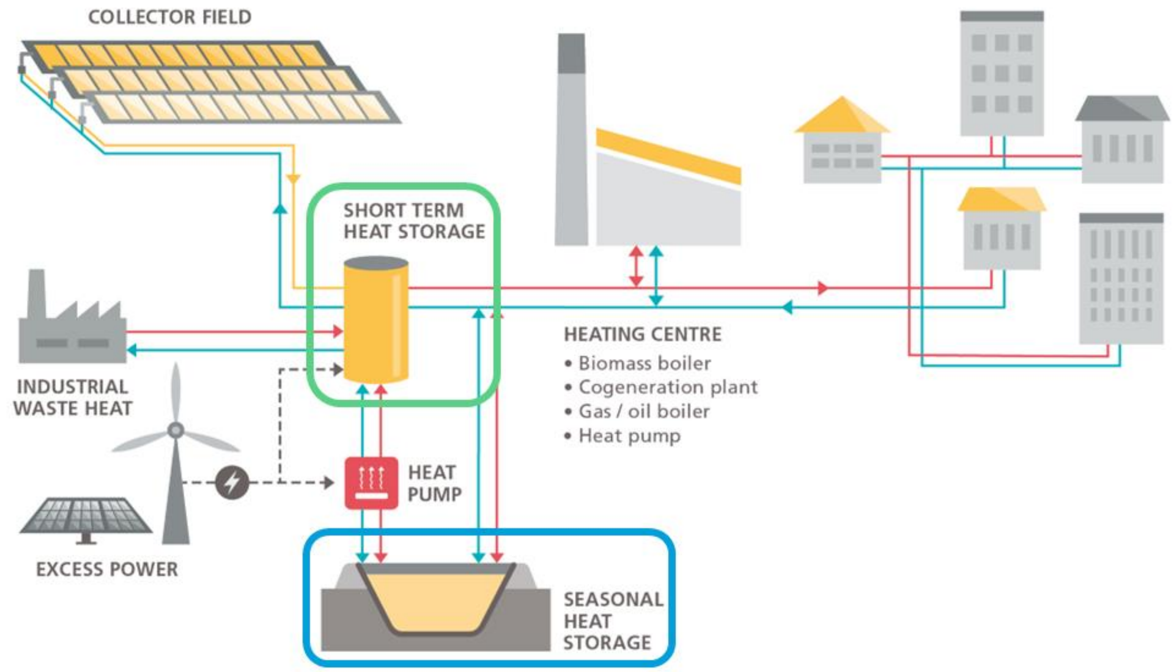
IEA-ES Task 39 brochure
Large Thermal Energy Storages for District Heating

Introduction



IEA SHC TASK 55

The purpose of this leaflet is to **introduce** Large Thermal Energy Storages (LTES) and answer **key questions** such as:

- What can be called ”LTES”?
- What is the competitor of LTES?
- Why are LTES needed for the energy transition?
- Where can LTES be found?
- What do LTES look like?
- What are the main implementation steps?

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“IEA-ES” is the Technology Collaboration Program (TCP) from the International Energy Agency (IEA) focused on Energy Storage (ES)

energy storage
IEA Technology Collaboration Programme

IEA-ES Task 39 is the group of experts working on Large Thermal Energy Storages for District Heating (DH) within IEA-ES TCP

Large Thermal Energy Storages Introduction & Key Messages

Definition

Large Thermal Energy Storages (LTES) in IEA-ES Task 39 are defined as:

- sensible (no phase change) Thermal Energy Storages (TES)
- designed to store at least **1 GWh** heat per year
- at atmospheric pressure (no pressurized system)

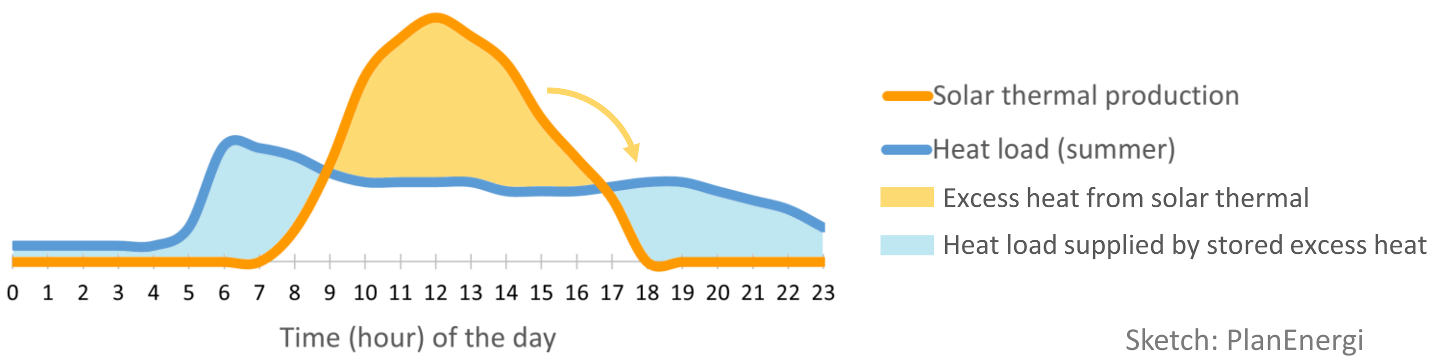
The stored heat should be suitable for discharge into District Heating Networks (DHN), at temperatures higher than 50°C

1 GWh

1 GWh (1'000 MWh) is enough heat to supply the demand of 62 households for 1 year*

Storage Principle

TES systems can store heat or cold to be used later (see below for an illustration of daily solar thermal storage principle). The heat or cold can be stored in various **storage media**: e.g. water, soil, stone, etc., and for a variable duration (hours, days, weeks, months)



Sketch: PlanEnergi

LTES technologies

The 4 most common and mature technologies of LTES are studied within Task 39 and are: **Tank** TES (TTES), **Pit** TES (PTES), **Aquifer** TES (ATES) and **Borehole** TES (BTES)

Storage thermal capacity , charging, discharging and energy content

In a TES, the storage **capacity** is proportional to the amount of storage medium available, as well as the temperature difference between the maximum and minimum available temperatures

To **charge** a TES with heat, the most common process is to circulate a hot heat transfer fluid through the TES, either directly through the TES, or indirectly, in a closed-loop, through a heat exchanger located inside the TES

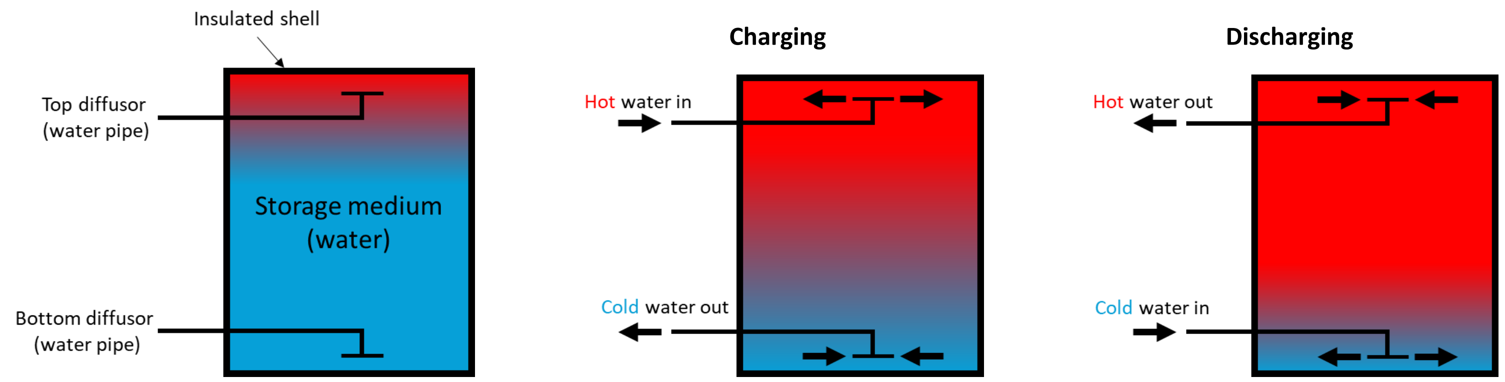
The heat transfer fluid should have a temperature equal or above the TES temperature

The hot heat transfer fluid brings the TES storage medium to a higher temperature: the **energy content** of the TES increases

To **discharge** heat from the TES, the high temperature from the TES is used to heat up a fluid. Usually, this is achieved by circulating that fluid directly or indirectly through the TES

The heat transfer brings the TES storage medium to a lower temperature: the **energy content** of the TES decreases

Illustration of a TTES charging and discharging process



Sketch: PlanEnergi

Each of the 4 technologies mentioned on the left has different capabilities with respect to storage capacity, storage efficiency, possible capacity rates for charging and discharging, requirements on local ground conditions and on system boundary conditions [1]

This leaflet is your guide through these 4 main technologies of LTES

*Households in Denmark consume on average 16 MWh/year for space heating and hot water in 2020. Source: Danish Energy Agency

[1] Introduction to thermal energy storage (TES) systems, L.F. Cabeza, I. Martorell, L. Miró, A.I. Fernández, C. Barreneche

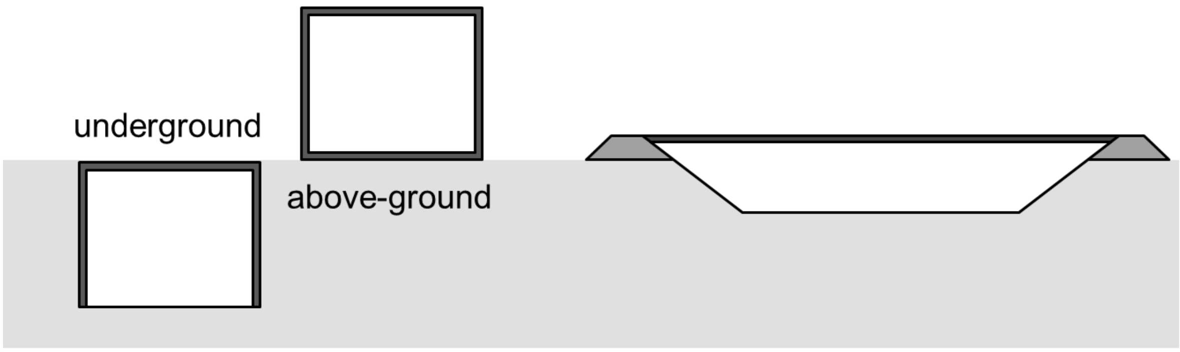
Large Thermal Energy Storages
Introduction & Key Messages

What do the 4 types of LTES from Task 39 look like?

The 4 different technologies of LTES are different constructions, adapted to different geographical and geological contexts

TTES are large tanks (usually cylindrical) filled with water and thermally insulated at the top and to the sides. Most examples are implemented above ground, but they can also be underground. The storage medium is water

PTES are pits dug in the ground, filled with water and thermally insulated at the top and sometimes on the sides as well. The storage medium is usually water, but can also be in some cases a mix of sand, gravel and water

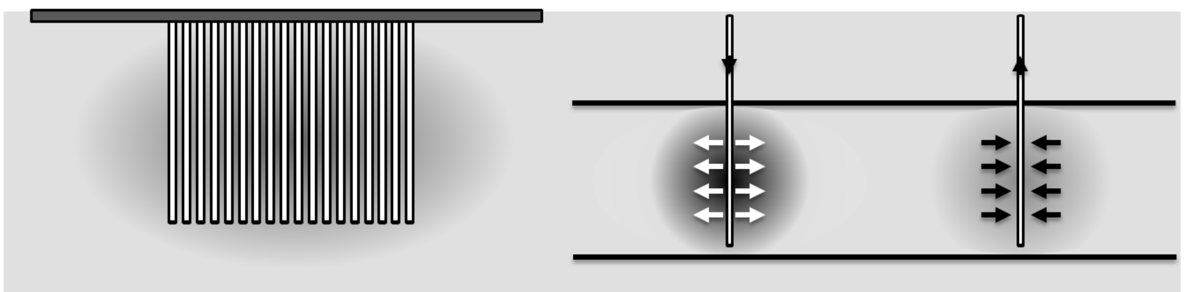


Tank TES (TTES)   Pit TES (PTES)

Sketch: Solites

BTES are a series of boreholes dug in the ground, where a series of heat exchangers are inserted to circulate a heat transfer fluid (usually water). The storage medium is the ground itself

ATES are aquifers directly used to store heat: wells are drilled into an aquifer layer, one for the cold side and one for the warm side. The storage medium is water and ground in the aquifer



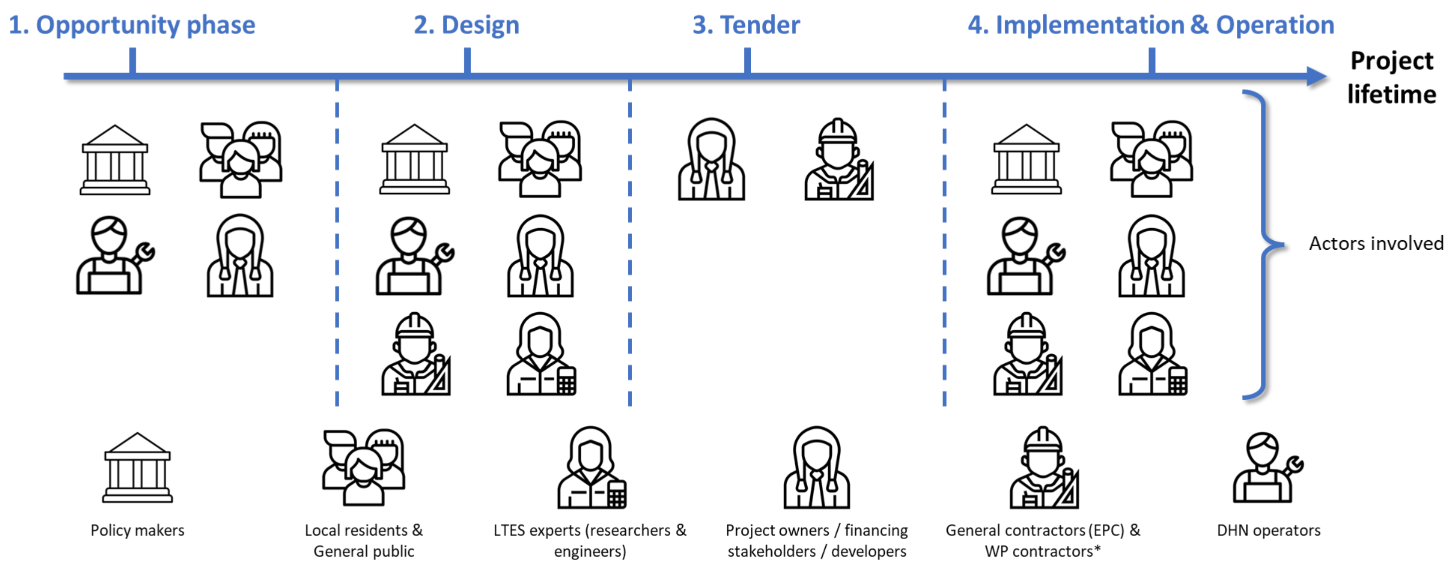
Borehole TES (BTES)   Aquifer TES (ATES)

Sketch: Solites

Task 39 is a group of experts that have extensive experience with all 4 technologies of LTES
Reach out to them (see companies' logos end of the leaflet) if you want to evaluate the potential of LTES in your local area

What are the main stages to establish a LTES, and who is involved?

The implementation of a LTES takes place in 4 main stages/phases: the **opportunity** phase (also called pre-design phase), the **technical design** phase, the **tender** phase, and the **implementation & operation** phase of the LTES



The **opportunity** phase is where the potential of implementing a LTES in connection with a DHN is studied. During this phase, project developers are often involved because they have an interest in a successful realization of the project, and policy makers determine the regulations that will apply. Whether it is about facilitating screening, establishing a procedure to follow for permitting, or to make the conduction of a pre-feasibility study for LTES mandatory, policy makers can have a great influence on the early stage of LTES projects. The type of LTES technology is also pre-selected here

The **design** phase is where the details are established for the LTES: detailed boundary conditions about the DHN are gathered and analyzed, and an (often) detailed techno-economic feasibility study is carried out. To calculate the performance (charge/discharge capacity, heat losses, yearly amount of heat charged/discharged), specialized simulation tools should be used to accurately predict the behavior of the LTES. Researchers and engineers are actively involved and the LTES size is determined

The **tender** phase is led by project developers, after gathering technical information from the design phase. The technical specifications and requirements of the LTES are prepared, and a tender process is started, to get several offers from different contactors for the construction of the LTES. In this phase, contracts are signed based on a clear and balanced distribution of responsibilities

The **implementation & operation** phase is where the LTES is built, commissioned, operated and maintained. Policy makers set the rules that should be respected during construction and operation of the LTES, which can include monitoring or documentation of environmental impact

*"EPC" stands for "Engineering, Procurement and Construction", and "WP" stands for "Work Package". EPC contractors coordinate all the work to be done, while WP contactors manage one work package in particular.

Large Thermal Energy Storages Introduction & Key Messages

Why LTES?

Heating and cooling accounts for **half** of the energy consumption in Europe and worldwide. To further reduce our fossil energy production and **decarbonize** our energy supply we need **more LTES** to store intermittent renewable **heat**. Decarbonization of our activities must also include heating and cooling

Heat is:

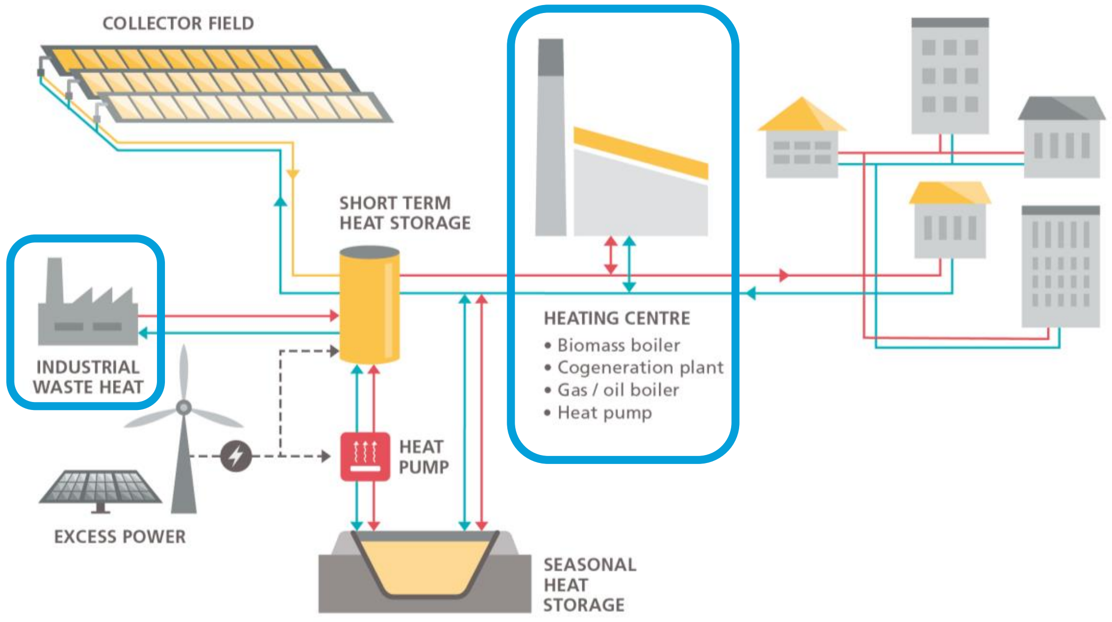
- **Easy** to produce
- **Easy** to store at **large scale** (GWh)
- Easy to store over **long periods**
- **Inexpensive** to store (large scale)

Who uses LTES? What is the competitor?

LTES are used by large-scale heat producers, District Heating Network (DHN) operators, as well as some industrial actors. They store heat and deliver it to a DHN, or in the case of industrial actors, the heat is used directly in industrial processes or for space heating. LTES are therefore often located at the border of the city, close to a heat production unit

The alternative to LTES is to have large peak-load heat production units to make sure the heat demand is always supplied, and extra cooling capacities for dissipating excess heat. Another alternative to LTES is flexible heat demand, or the use of individual thermal storage

All alternatives are usually more expensive and technically more complex than LTES



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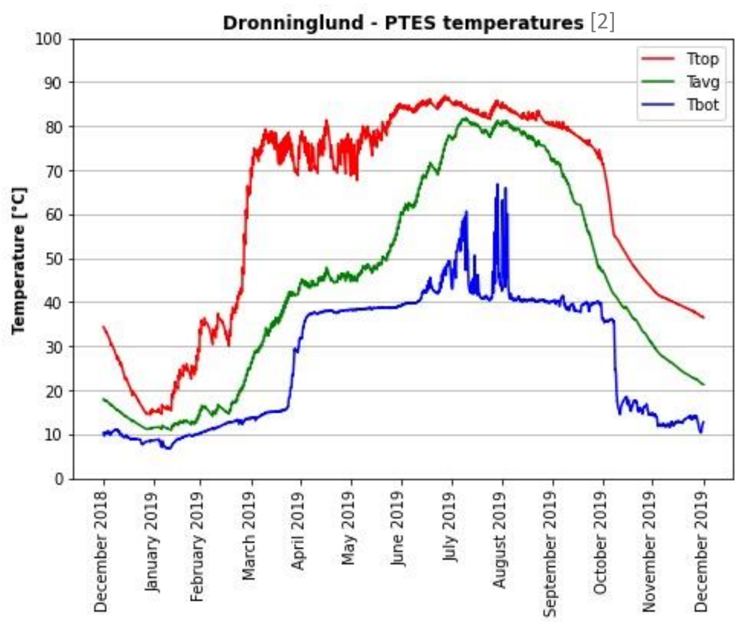
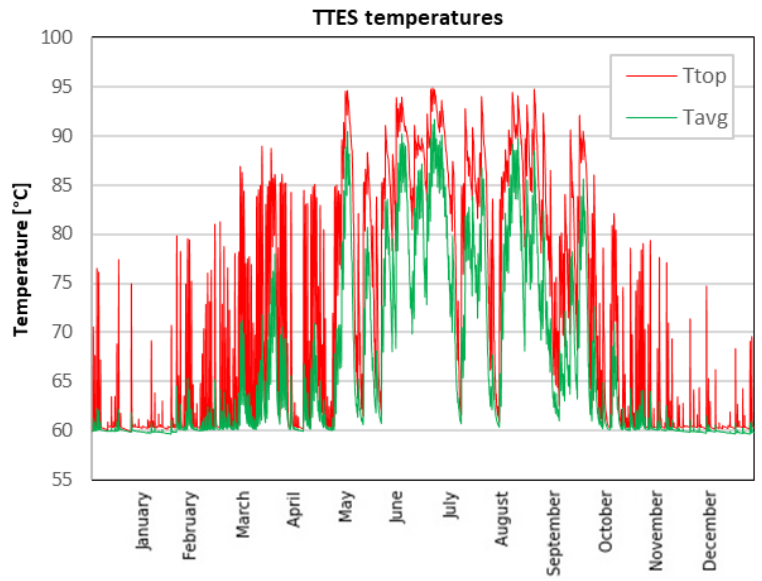
[2] Danish HEATSTORE theme day on 27/10/2021, Heat storage and monitoring results by PlanEnergi

Different uses of LTES: daily/weekly or seasonal storage

LTES can be TES with a very large thermal capacity (GWh-scale) charged/discharged once or twice a year. This use is called seasonal storage of heat (see example of Dronninglund below*)

LTES can also be TES with a relatively small thermal capacity (10 MWh-scale) charged/discharged many times a year. This use is called daily or weekly storage of heat (see illustration below* on the right with a TTES used for solar district heating, charged/discharged about 30 times per year)





Application\Duration of storage	Daily/Weekly	Seasonal
Flexibility for DHN	X	
Solar District Heating (SDH), Geothermal heat	X	X
Storage of excess heat from waste incineration plant	(X)	X
Flexible use of biomass boiler or Combined Heat & Power (CHP) plants	X	(X)
Storage of excess electricity as heat (process called “Power to Heat”)	X	(X)

*Graphs presenting the temperatures of the water respectively at the top of the storage (red curves), the bottom of the storage (blue curve), as well as the average storage water temp. (green curves)

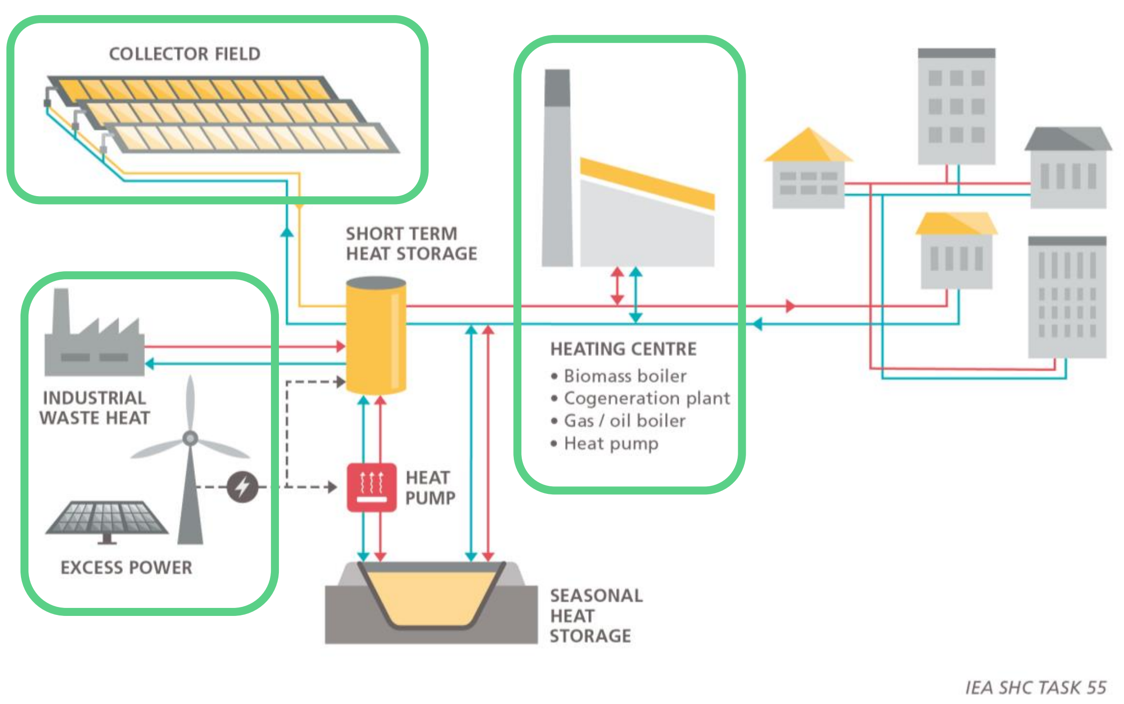
Large Thermal Energy Storages Introduction & Key Messages

What can LTES be used for?

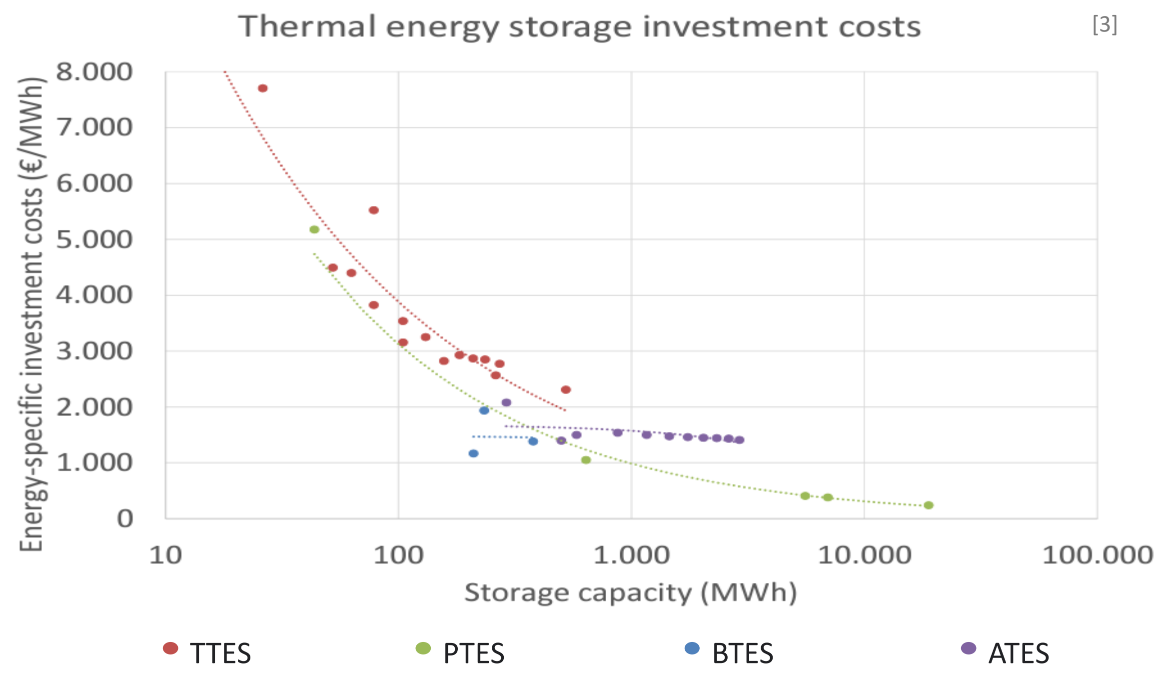
The different technologies of LTES give the possibility to chose the large-scale thermal energy storage that fits best a given context: some are below the ground, some can be placed anywhere where space is available, some can deliver a great heating power (see table next page). The main potential usages for LTES are introduced in the following list:

- Peak power shaving
- Valuation of underused or intermittent energy sources
- Increased network operation flexibility
- Increased potential for renewable heat
- Enabling sector coupling
- Securing energy independency
- Ramp-up stabilization

LTES can store renewable heat and other renewable energies, and are a key enabler for sector coupling and energy independency



Advantages of the different types of LTES	
TTES	**PTES**
• Well-known technology • Quick charging and discharging with high capacity • Low thermal losses • Do not require specific underground conditions	• High storage capacity possible • Quick charging and discharging with high capacity • Low-tech solution • Significant economies of scale
BTES	**ATES**
• High storage capacity possible • Underground: limited visual impact • Surface usable after implementation • Expandable solution • Long lifetime	• Suitable for high storage capacities • Underground: limited visual impact • Limited space required aboveground • Long lifetime • Relative low investment costs per stored MWh



Fact: the bigger the better

- For all 4 technologies of LTES, an increase in the size/capacity of thermal storage reduces the specific investment costs of the storage system (see graph beside)
- LTES are much more cost efficient than small-scale TES (more than 100 times cheaper) and give the possibility to increase the amount of renewable heat used [4]

[3] https://www.coolheating.eu/images/downloads/Jakob_Worm_The_integration_of_large_scale_solar_thermal_and_heat_pumps_in_district_heating_systems.pdf

[4] The Status of 4th Generation District Heating: Research and Results. Presentation by Henrik Lund made at the 4th International Conference on Smart Energy Systems, 13-14 November 2018 in Aalborg, Denmark

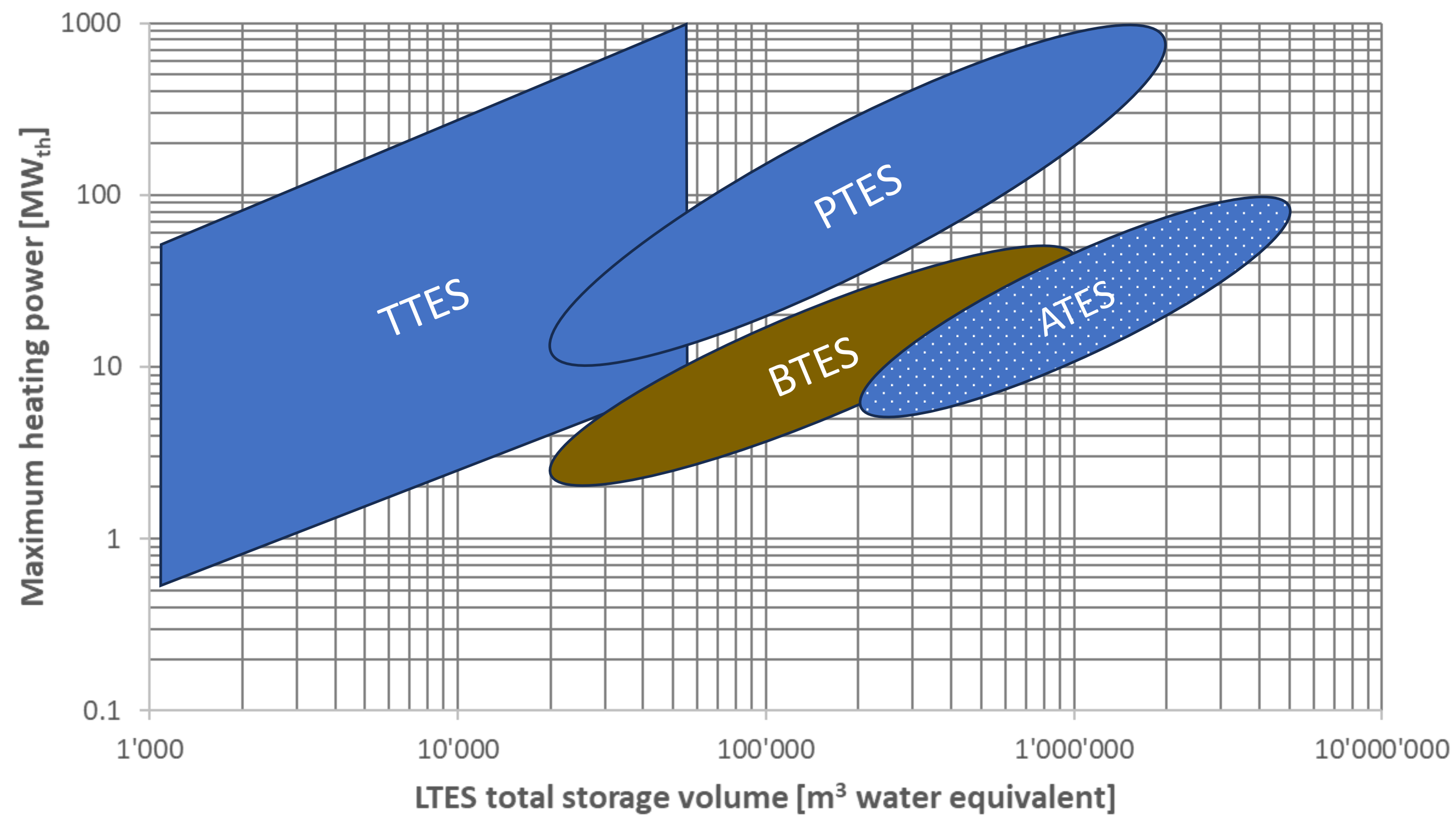
Large Thermal Energy Storages Technologies Overview

Summary of main technical characteristics of the different types of LTES

	TTES	PTES	BTES	HT*-ATES
Storage medium	Water		Soil/ground surrounding the boreholes	Groundwater & ground in aquifers
Geological requirements	• stable ground conditions	• stable ground conditions • preferably no groundwater • 5 -20 m deep	• drillable ground • high heat capacity • high thermal conductivity • low hydraulic conductivity 30 -150 m deep	[*ATES geology*]
Application	Daily/weekly storage	Daily/weekly or seasonal storage	Seasonal storage	Seasonal storage/ shorter is possible

[*ATES Geology*] a HT-ATES requires the presence of an aquifer, preferably included between thick clay layers on top and below the aquifer

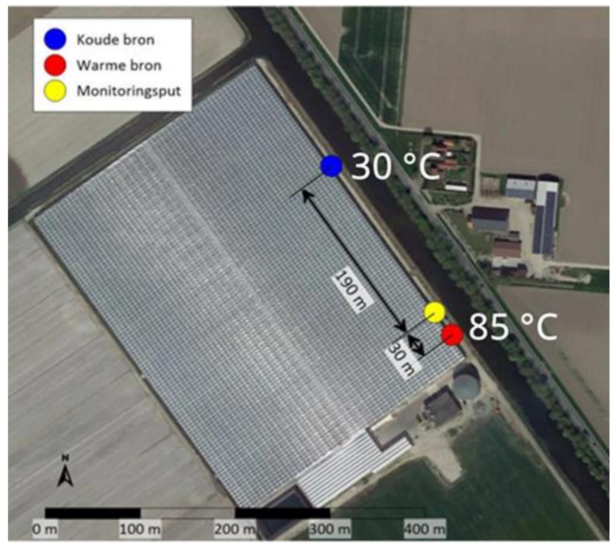
Overview of the range of heating power available** from the different types of LTES



TTES from Stadtwerke Detmold
1'850 m^3 of water

PTES from Gram district heating
122'000 m^3 of water

BTES from Brædstrup district heating
18'000 m^3 of soil



HT-ATES from ECW / Ennatuurlijk
Aardwarmte, 700'000 m^3 reservoir

*HT stands for "High Temperature". Many ATES are used as a heat source for a heat pump (geothermal heat) but do not store any heat. A HT-ATES is actively charged with hot water to be reused later, and as such is a thermal energy storage

**These graphs are estimates based on the knowledge of IEA-ES Task 39 experts, not the result of a technical study. For PTES and ATES, several single pits or pairs of wells are assumed to be used to achieve higher total water eq. volumes

The experts of IEA-ES Task 39

This leaflet is intended as a toolkit for policy makers, project developers, researchers and engineers (main stakeholders of LTES projects). It is made such that the main information about LTES is available in one place: definitions, project examples, guidelines & references

For more information, you can visit the homepage of IEA-ES Task 39:
https://iea-es.org/task-39/