High Temperature Aquifer Thermal Energy Storage (HT-ATES)

GENERAL DESCRIPTION

Mode of energy intake and output

- Heat-to-heat
- Power to heat

Storage process

Aquifer Thermal Energy Storage (ATES) is a large-scale open-loop energy storage system that uses subsurface aquifers up to several hundred meters below surface and (ground)water as the carrier for thermal energy.
The systems comprise of at least two tube wells (a doublet) which tap into an aquifer. One well is used for heat storage and the other well is used for cold storage. This way, energy can be either extracted from or injected into the aquifer through these wells, which are coupled with hydraulic pumps and heat exchangers. Heated or cooled groundwater can be extracted depending on heating or cooling demands.

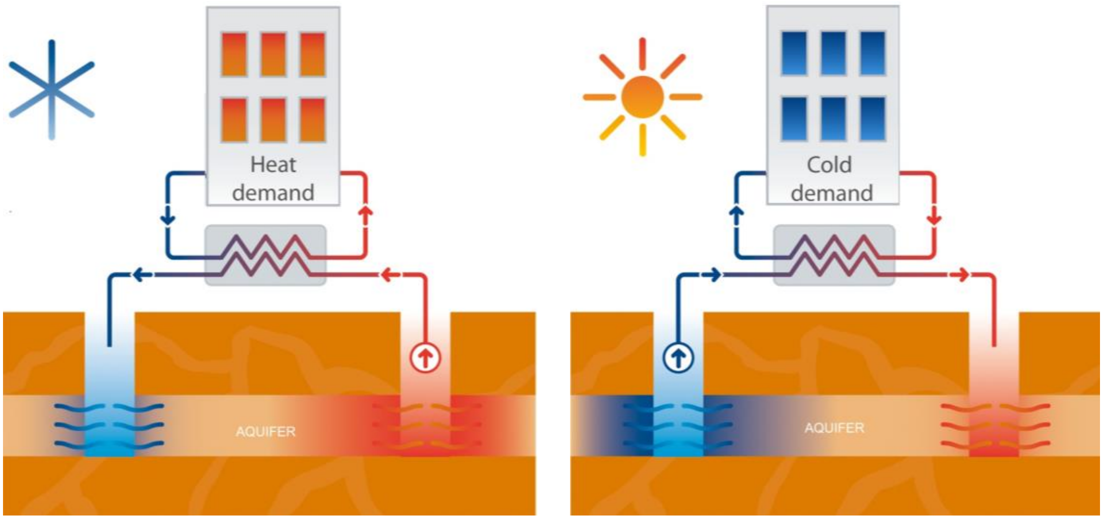

Figure 1: ATES working principle

The systems are adequate for large-scale seasonal storage and are divided into two end-members:

1) Low-temperature Aquifer Thermal Energy Storage (LT-ATES) usually applied in conjunction with a heat pump, resulting in injection temperatures between 5°C and 10°C for the cold well and 13°C to 30°C in the warm well. The very efficient direct cooling with groundwater is what makes this type of storage economically competitive.
2) High-Temperature Thermal Energy Storage (HT-ATES) used for large scale heat storage with injection temperatures in the hot well between 40 and 90°C. The injection temperature of the 'cold' well can be anywhere between 5°C and 60°C, depending on the soil composition and requirements/limitations from the delivery systems.

ATES requires a suitable aquifer with permeability conditions which allow for extraction and injection of groundwater. To access the groundwater, tube wells need to be installed with perforated screens at the target aquifer. Electrical submersible pumps (ESP) are used to extract and inject the groundwater. ATES systems can be used for hourly or daily cycles. The power output per well is limited by the local geological conditions and the applied temperature range. A combination with other technologies like tank storage (TTES) can compensate for the limited power output, wherever necessary.

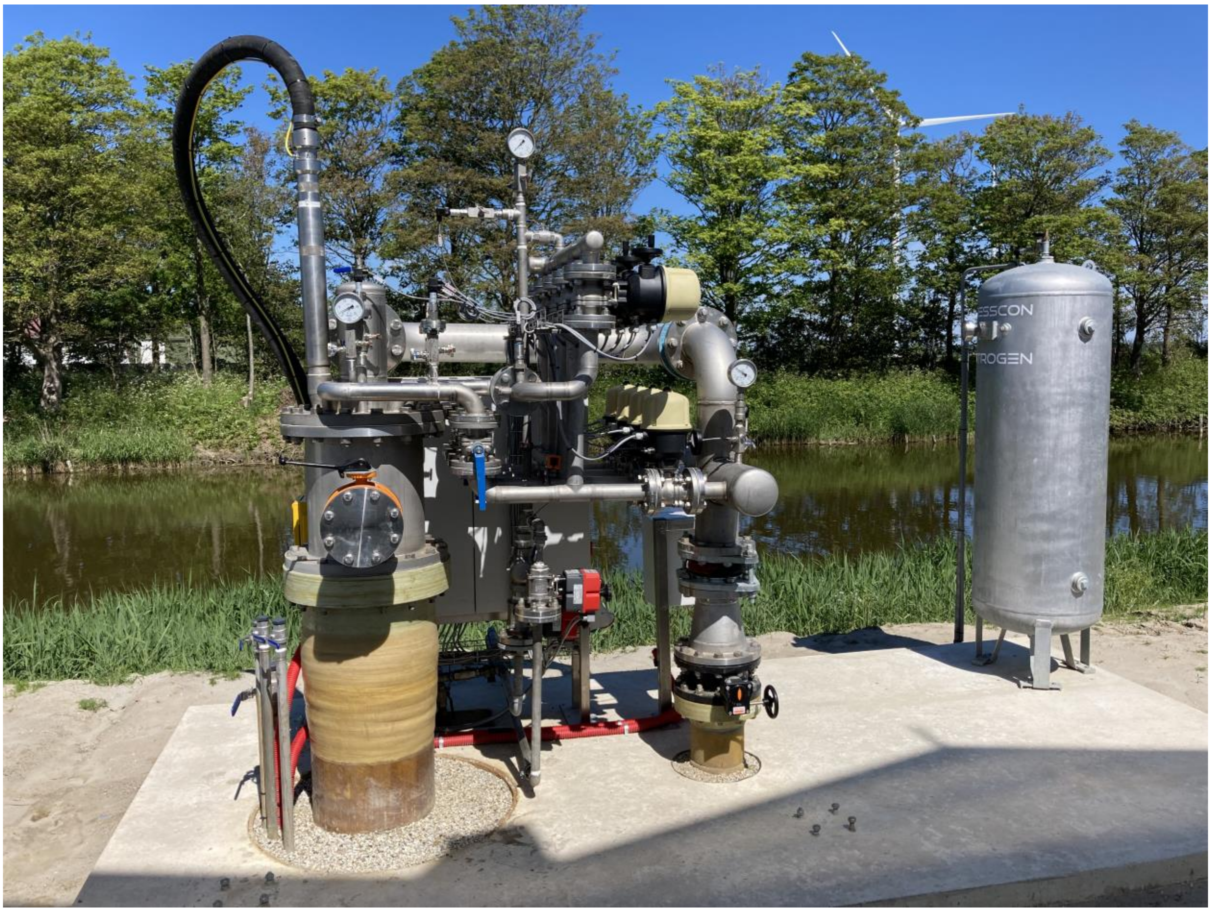

Figure 2: Well head HT-ATES system (source: HT-ATES in Middenmeer)

Fields of application

HT-ATES is typically used where there is a large seasonal heating demand, like district heating or greenhouses.

It needs a seasonal source of excess heat, typically in summer months. Possible sources are for example waste heat, solar collectors, geothermal heat, power to heat, etc.

A HT-ATES can also function as a balancing buffer when there is a local excess of sustainable electricity.

Technology readiness level (TRL)

6-9

State of development / commercial availability

By 2022 around 4000 ATES systems are operational, of which about 3500 are in the Netherlands. The vast majority of these ATES systems are LT-ATES systems, with maximum injection temperatures of 25-30°C. A handful of HT-ATES systems handle temperatures above 50°C. The technology is market ready and there are currently various projects in various stages of development.

Topics that require additional research (TRL 6 and above) are: increasing efficiency, integration with various heat sources and heating systems, optimizing operational expenses.

TECHNICAL SPECIFICATIONS

The values below apply to a single HT-ATES doublet (two wells). It is possible to cluster wells, or to increase the total capacity by connecting multiple systems to the same district heating network.

	HT-ATES
Temperature range	5°C – 90°C
Maximum output power range	1 – 15 MW

Operating range	20% – 100%
Storage size	0,6 – 40 GWh
Discharge Time	Hourly - seasonal
Service life	Multiple decades
Response Time	minutes
Storage efficiency	40-90%
Specific energy storage density	10 – 70 kWh/m^3

ECONOMIC SPECIFICATIONS

Specific investment costs

The highest temperature in the system plays an important role in the investment costs. The main differentiating factors are piping material for higher temperatures and water treatment. These two different temperature ranges are considered for estimating the investment costs:

Specific costs up to 60°C	0,1 – 1,3 €/kWh
Specific costs from 60°C to 90°C	0,1 – 1 €/kWh

Specific investment costs are very dependent on the properties of the underground aquifers. The main limitation is power delivery for both loading and unloading.

Operating and maintenance costs

Here the distinction in temperature ranges still applies. Note that the absolute costs for operation and maintenance are still low, when compared to other types of seasonal storage, as the specific investment costs are usually significantly lower.

O&M costs up to 60°C	2% to 5% of investment
Operating costs from 60°C to 90°C	1% to 3% of investment

FURTHER INFORMATION

- B. Drijver et al. High-temperature aquifer thermal energy storage (HT-ATES): sustainable and multi-usable; https://www.iftechnology.com/wp-content/uploads/2018/05/Drijver-et-al-2012-High-temperature-aquifer-thermal-energy-storage-HT-ATES-sustainable-and-multi-usable-1.pdf
- Schmidt T, Pauschinger T, Sørensen PA, Snijders A, Djebbar R, Boulter R, et al. Design aspects for large-scale pit and aquifer thermal energy storage for district heating and cooling. Energy Procedia 2018;149:585–94; https://doi.org/10.1016/j.egypro.2018.08.223