Summary and description for the project

PTES in Høje Taastrup

Owners of the plant (50%/50%)
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Summary
VEKS (municipality owned heat transmission company) and HTF (consumer owned heat distribution company) has implemented a Pit Thermal Energy Storage (PTES) in Høje Taastrup to provide flexibility to the electricity production system and the heat production system in Copenhagen.
The project was developed 2017-2018 and implemented 2019-2022. During implementation material tests were carried out and new implementation methods were developed.
Size of the storage is 70,000 m^3, storage medium is water, in- and outlet capacity is 30 MW and storage content is 3,300 MWh.

The project has several innovative elements

- It is the first PTES of it´s kind serving with flexibility and heated up to 90 ^oC constantly
- The storage is charged and discharged 25- 30 times a year – as opposed to already existing seasonal storages
- A new business model had to be developed to integrate the storage in the heat and electricity production system in Copenhagen.
- A new developed PP-membrane is implemented. It is used for tightening of bottom and sides and for floating membrane under the lid. Implementation methods for membranes had to be modified because the membrane is vulnerable to low temperatures.
- In- and outlet system and lid have innovative elements

The storage serves four CHP plants and three waste-to-energy plants. Optimization of electricity production (sector coupling) and saved peak production result in 27.4 TJ saved fuel/year and a total CO_2-reduction of 6,200 tons/year.

The total investment is 10.7 Mio €. Simple payback period is 12 years and IRR is 7.5%.
The PTES is commissioned end of December 2022 and in commercial operation from 15th February 2023.

The story

The scenario planning in the ”Heating plan greater Copenhagen” developed by the transmission companies CTR, HOFOR and VEKS in 2014 pointed out, that if CO_2 neutrality in district heating in Copenhagen should be reached, large-scale thermal storages would have environmental and economic benefits in an energy system with a huge fraction of electricity from wind power because thermal storages can store district heating when it is cheap to produce and optimize the total electricity and heating production system in Copenhagen.

Follow up calculations showed that a thermal storage of 70,000 m^3 could be economically feasible implemented in the existing production system. HTF found a suitable area for the storage and HTF and VEKS decided to start the project investigations and design. It was decided to implement at Pit Thermal Energy Storage (PTES) because this kind of storage was already demonstrated in Denmark and investment costs were 25-30% of the costs for steel tanks in similar sizes. Prices for excavation, in-and outlet system, membrane work, lid construction and connection system was found during 2017 and 2018. Also Danish Energy Agency (EUDP) was asked for subsidies through the funding program EUDP because the project is innovative. Funding of 17% of the total costs (1.8 Mio. €) was accepted.

HTF and VEKS took the final investment decision end of April 2019, when the final authority’s permissions were given.

Excavation to the PTES started April 2020. Polymer membranes were implemented during summer, and in- and outlet were implemented in autumn 2020. After that water filling started, but during winter, the polymer membrane broke and could not be repaired. A new membrane was implemented from July 2021 until autumn 2021 and water was filled in during winter. From April 2022 started welding and implementation of the floating membrane and lid construction took place from July 2022 to November 2022. During December commissioning took place end of 2022.

After tests of functions and running in commercial handover took place 15th February 2023.

The construction of the storage

The PTES in Høje Taastrup is constructed with soil balance where excavated soil is used as banks in the storage. Since the area is limited between a highway and a huge drinking water pipe, the shape was forced to be as shown in Fig 1

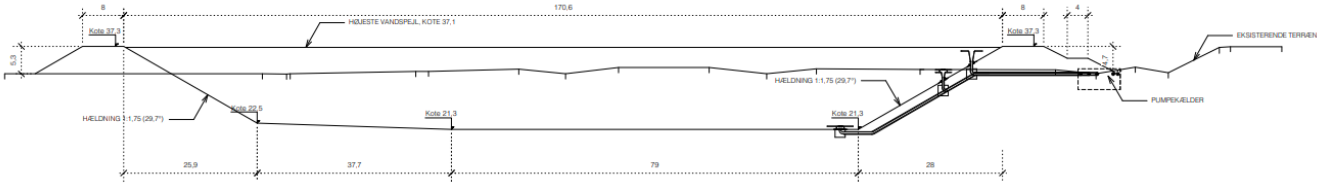

Fig 1. The storage from the side

The function

The PTES is charged from VEKS´ transmission line and discharged to HTFs distribution network. Charging and discharging capacity is 30 MW and the storage capacity is 3,300 MWh. VEKS´ transmission line is connected to the total transmission system in Copenhagen. The PTES services four CHP plants of a total of 2,050 MW_{heat} owned by Ørsted, HOFOR and VEKS and three waste-to-energy plants of a total of 400 MW_{heat}. Beside that, the DH production system has 1,900 MW reserve and peak load plants. In Fig 2 DH in Copenhagen and connection pipes are illustrated.

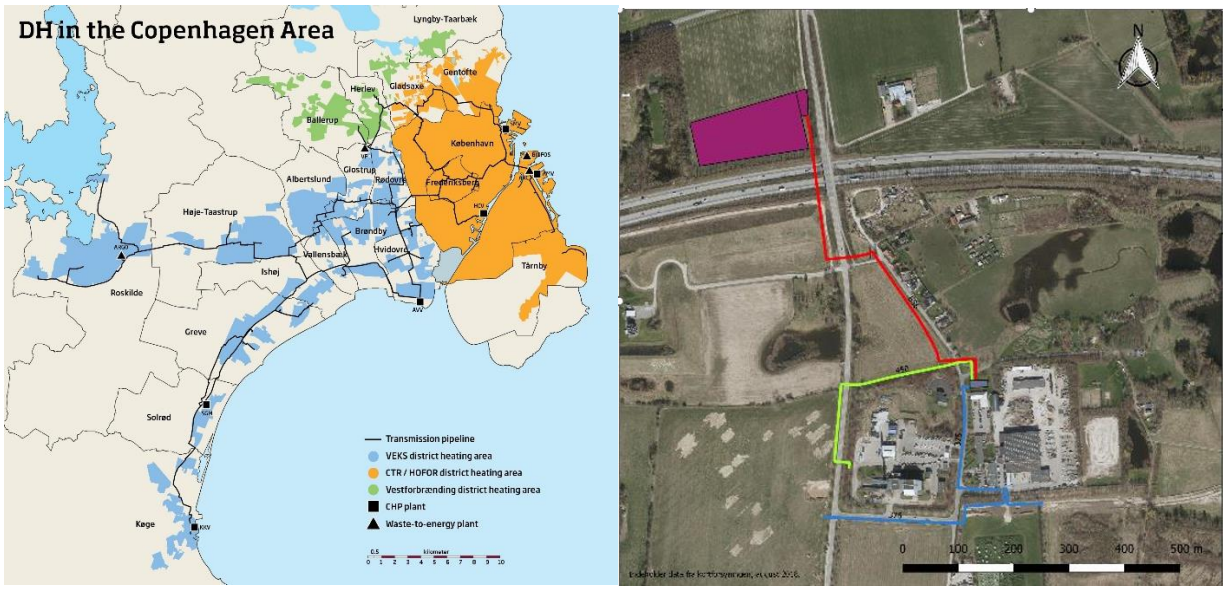

Fig 2 DH in Copenhagen and transmission pipes to the PTES. Yellow is VEKS´ transmission pipes, blue is HTF´s distribution pipes and red is charging and discharging pipes between heat exchanger building and PTES.

The function of the storage is to optimize the heating and electricity production in Copenhagen in three ways

- Optimization of CHP production according to the electricity market (sector coupling)
- Reduction of peak load production on natural gas boilers
- Extend the heat production from the waste-to-energy plants in the summer period

Innovative parts

Until now PTES have been implemented in connection to solar thermal plants where the PTES is heated up in summer and cooled down in winter. In Høje Taastrup the PTES is implemented to provide flexibility to electricity and heat production. It means that the PTES will be continuously charged and discharged and that the top temperature in the water will be 85-90 ^{o}C constantly. **This function and temperatures are new for PTES.**

High Density Polyethylene (HDPE) membranes has been used for tightening PTES connected to solar thermal, but HDPE will according to the supplier brake down after app. 12 years if the storage temperature

is 90 °C. HTF and VEKS therefore had either to implement a double layer of HDPE (proposed by the supplier) or find a new membrane material. The result was to use a **new developed Polypropylene (PP) membrane**. This membrane was developed in the Austrian research project giga_TES and laboratory tests at JKU Linz showed a lifetime of more than 30 years at 90 °C.

The first version of the PP-membrane broke during winter 2020-21 because it was vulnerable to temperatures below zero. The total membrane therefore had to be changed to a version with additives and **protected against minus degrees during water filling** by use of warm charging water spread from the edges. Se Fig 3

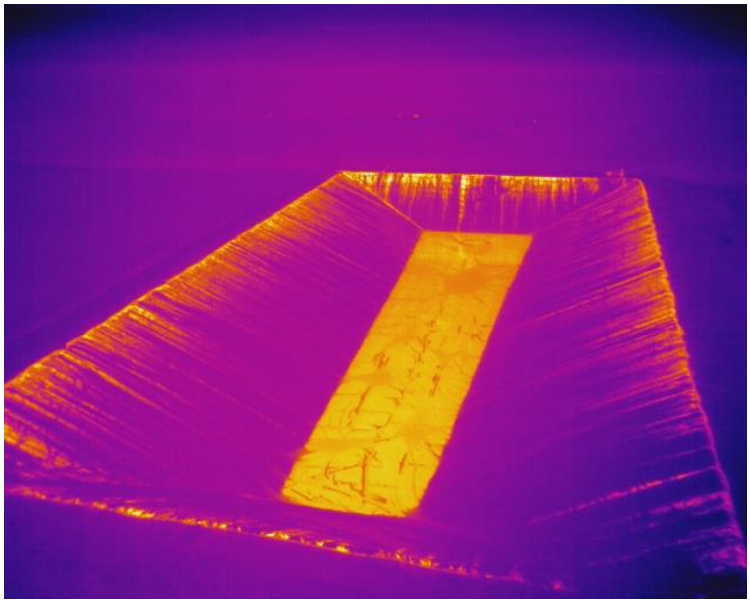

Fig 3. Protection of PP-membrane with warm charging water

In storages cooled down in winter the water surface will drop because of the temperature drop. This drop is smaller in Høje Taastrup. The top diffusor is therefore changed so that the **bottom of the lid is the upper part of the diffusor**. This solution was laboratory tested and described in Urbaneck et al. Radiale Diffusoren in Warmwasserspeichern. Teil 1-3. Heiztechnik 2016. Also the diffusors had to be placed in the end of the storage because of the narrow area as illustrated in Fig 1.

The lid construction is in principle similar to the refurbished lids in Marstal and Dronninglund, but tests at JKU Linz showed lifetime could be less than 20 years for the insulation material Nomalén. **The supplier developed a new version** with additives, that seems to prolong the lifetime with app. 70% according to tests at JKU Linz.

Last but not least **a new business model is developed**. The PTES is owned by VEKS and HTF (50%/50%). VEKS has bought the right to HTF´s share of the storage capacity for 20 years by paying an annual compensation to HTF. The partners have made a cooperation agreement where it is stated that HTF takes care of the daily maintenance and monitoring of the PTES

All partners which have an economic benefit from the storage pay a fixed annual amount for this availability for 20 years according to their share of the economic benefit. Transmission companies (VEKS and CTR/HOFOR) hold 56% of the benefit due to saved peak load. Four CHP producers holds 28% and three waste-to-energy plants holds 16% of the benefit. VEKS has made agreements with all parties.

The daily operation is optimized by Varmelast (a common owned company operating for the daily load dispatching in Copenhagen). Instead of daily forecasts now weekly forecasts for heat requirements, operational production capacity, power prices, fuel prices etc. are needed to optimize the system with PTES.

Fuel consumption and environmental benefits

In total the PTES will result in extra fuel consumption of 52.3 TJ for heating in Copenhagen and saved fuel of 79.7 TJ in the electricity sector or a total of 27.4 TJ saved fuel.

The CO_2 reduction is app. 6,200 t/year (3,000 t in the heating sector and 3,200 t in the electricity sector). See calculation in Table 1

	Heat in TJ, change	El - GWh	Fuel - TJ		CO2-factor (kg/GJ)	CO2 - tons
Woodchips CHP	31,0	4,3	38,8		5,6	215
Wood pellet CHP	11,0	2,0	20,0		5,6	111
Waste to energy	41,0	2,8	51,3		0,0	0
Straw boiler	-6,0	0,0	-6,7		5,6	-37
Geothermal, ATES, heat pumps	-15,0	-1,4			116,7	
Peakload gas	-51,0	0,0	-51,0		63,9	-3258
Peakload wood pellets	0,0	0,0	0,0		5,6	0
Sum	11,0	7,8	52,3			-2969
					El	-3255
	El, TJ	27,9				
	Saved fuel in the e	79,7			Sum	**-6224**
	Saved fuel in total	**27,4**				

Table 1. Calculation of CO_2 emission and saved fuel

Economy

The total investment amount is 10.7 Mio. €. See calculation below:

Activity	Investment, Mio. €
Soil expenses	0.55
Design and supervision	1.14
Storage and pumping station	6,05
Heat exchanger building	2.42
District heating pipeline	0.94
Electricity etc.	0.44
Water	0.51
Total	12.04
EUDP subsidies	1.34
Total incl. subsidies	10.70

Income/year is calculated to 1.05 Mio € and operation costa are estimated to 0.16 Mio €/year. This results in a simple payback period of 12 years and an IRR of 7.5% calculated for 20 years. The lifetime for the PTES is expected to be more than 20 years.