

Final report

1. Project details

Project title	Integrate 2
File no.	64020-2025
Name of the funding scheme	EUDP
Project managing company / institution	PlanEnergi
CVR number (central business register)	74038212
Project partners	VEKS, Hjørring Kommune, Ea Energianalyse og JKU Linz
Submission date	19 July 2024

2. Summary

Project summary

The purpose of the project

Until 2029 pit heat storages had only been established as storages charged by solar heat. In 2029 Høje Taastrup Fjernvarme and VEKS decided to establish a pit heat storage facility that would offer flexibility to CHP plants and reduction of peak load. The purpose of the Integrate 2 project was to develop pond storages to handle these functions.

Results, conclusions and perspective

In the project, new storage solutions have been developed and materials tested in collaboration with JKU Linz as well as by using experiences from the construction project in Høje Taastrup and from two case studies in Copenhagen and Hjørring/Hirtshals, respectively.

The main results of the project have been:

- Further development of the insulation product Nomalén. In laboratory tests, the product showed an expected lifetime of less than 20 years at 90 °C, regardless of whether in dry or humid air. Therefore, the supplier Termonova developed a new product with added stabilizers. This product is used in the lid solution in Høje Taastrup and is tested by JKU Linz. The tests have not been completed yet, but it seems, that a lifetime of more than 20 years can be achieved at 90 °C.

- Development of a new lid solution. The lid solution can be used in storages up to 1 million m³ and it can ventilate away moisture coming from the water side to the insulation material and prevent water accumulation on the lid. The newly developed lid solution will be offered for a storage of 700,000 m³ for Fjernvarme Fyn.
- Improvement of the calculation tool Balmorel and comparison of the results from Balmorel and energyPRO, which show good consistency of calculations for Copenhagen

The results will be used in a number of construction projects that are underway, as well as in the IEA-ES project Task 45, Accelerating the uptake of Large Thermal Energy Storages and the EU Horizon project TREASURE, Demonstrating Large Pit Thermal Energy Storages. The TREASURE project includes 7 demonstration projects.

Projektesumé:

Formålet med projektet

Damvarmelagre havde ind til 2019 kun været etableret som lagre opvarmet med solvarme. I 2019 besluttede Høje Taastrup Fjernvarme og VEKS at etablere et damvarmelager, som skulle tilbyde fleksibilitet til kraftvarmeværker og reduktion af spidslast. Integrate 2 projektet har haft som opgave at udvikle damvarmelagre til at varetage disse funktioner

Resultater, konklusioner og perspektiv

I projektet er udviklet nye lagerløsninger og testet materialer i samarbejde med JKU Linz samt ved at anvende erfaringer fra anlægsprojektet i Høje Taastrup og i to case studier i henholdsvis København og Hjørring/Hirtshals.

De vigtigste resultater af projektet har været:

- Videreudvikling af isoleringsproduktet Nomalén. Produktet viste ved laboratorietests en forventet levetid på under 20 år ved 90 °C uanset om det var i tør eller fugtig luft. Derfor udviklede leverandøren Termonova et nyt produkt tilsat stabilisatorer. Dette produkt er anvendt i lågløsningen i damvarmelageret i Høje Taastrup og testes af JKU Linz. Testene er ikke afsluttet, men det ser ud til. At der kan opnås en levetid på over 20 år ved 90 °C.
- Udvikling af en lågløsning. Lågløsningen kan anvendes på lagre op til 1 mio. m³, og den kan bortventilere fugt, som kommer fra vandsiden til isoleringsmaterialet og forhindre vandansamlinger på låget. Den nyudviklede lågløsning vil blive udbudt til et lager på 700.000 m³ til Fjernvarme Fyn.
- Forbedring af beregningsværktøjet Balmorel og sammenligning af resultaterne fra Balmorel og energyPRO, som viser god overensstemmelse for beregninger for København

Resultaterne vil blive udnyttet i en række anlægsprojekter, som er undervejs, samt i IEA-ES-projektet Task 45, Accelerating the uptake of Large Thermal Energy Storages og EU Horizon projektet TREASURE, Demonstrating Large Pit Thermal Energy Storages. I TREASURE projektet er inkluderet 7 demonstrationsprojekter.

3. Project objectives

The main objective of the Integrate 2 project has been to develop Pit Thermal Energy Storages (PTES) solutions that can be utilized in all kinds of existing district heating and cooling networks and in combination with

sustainable industrial areas. This will make it possible to utilize all kinds of renewable sources for heating and cooling and at the same time offer regulation facilities to the electricity sector. The objectives should be reached through design of representative projects in Copenhagen and Hjørring-Hirtshals respectively.

The following energy technologies have been developed and demonstrated:

Better polymer solutions

We have tried to find better alternatives to the newly developed PP-liner, but the PP-liner is still the best solution for high temperatures (up to 90 °C). For low temperatures the PP-liner has to be protected and in the Integrate 2 project a protection system was developed and demonstrated in Høje Taastrup.

Laboratory tests showed lifetimes less than 20 years at 90 °C for the polymer insulation mats used in the PTES in Dronninglund. A new version with stabilizers was developed by the supplier Termonova and implemented in the lid in Høje Taastrup. This version is now tested at JKU Linz. The tests are not finalized but seem to show lifetimes more than 20 years at 90 °C. See D2.3 for further explanation.

Corrosion free in- and outlet

PP-pipes and diffusors might be a solution. The supplier, AGRU, is convinced that it is possible to use PP, also for large diffusors (more than 100 MW). Still, this has to be further investigated and demonstrated. Corrosion free in- and outlet will make it possible to use softened tap water saving app. 6 €/m³ storage water and avoid expensive stainless-steel solutions.

High capacity of in- and outlet

Stainless steel solutions with 150 MW capacity has been designed for Fjernvarme Fyn. CFD calculations show an ok stratification for up to 3,000 m³/h in- and outlet. Monitoring results from Høje Taastrup show perfect stratification for 30 MW (600 m³/h)

High temperature heat pumps

In the case in Copenhagen, it was expected to use HT-heat pumps to be able to export storage water to the transmission system but calculations showed blending with hot water from the waste incineration plant ARGO was a better solution. Thus HT-heat pumps were not needed but in a separate project with VEKS, market dialogs showed that heat pumps using CO₂ as refrigerant, hydrocarbons as refrigerant or water/ammonium all could be solutions when rising temperatures up to 120 °C.

4. Project implementation

The project evolved as planned but with some exceptions

- The demo project with 70,000 m³ pit storage in Høje Taastrup was delayed and had just had a crack in the P-liner when the Integrate 2 project started. That meant the development and protection of PP-liners and development of polymer mats as insulation material could be directly utilized and demonstrated in the project in Høje Taastrup.
- For the Copenhagen case heat pumps were not needed since mixing with hot water from KARA was a better solution. That meant that investigation of high temperature heat pump solutions was not needed, but took place in a separate project.

- For the Hjørring-Hirtshals case the industrial area in Hirtshals was not planned in detail. It meant that it was unsecure if for instance production of liquid biomethane or methanol would take place and in which size. Therefore calculation of utilization of surplus heat from future sources had to be based on more theoretical assumptions.
- The idea of using PP as material for corrosion free in-and outlet was discussed very early in the project but not further detailed because it was explained that the pipes could not stand the pressure. A few months before finalizing the project an expert from AGRU explained that this was a mistake, and PP-diffusers and pipes may be a solution for in- and outlet. More detailed investigations of this solutions remain.
- Dissemination activities have not been exactly as described in the application, but results are as promised

Risk associated with conducting the project

The risks mentioned in the application were:

That insulation in new lid solutions cannot stand 95 °C in 20 years.

Until now laboratory tests of the insulation material used in Dronninglund show 11 years lifetime at 90 °C. A new version with stabilizer is still under test at JKU Linz. We expect it will have a lifetime of more than 20 years at 90 °C. To reach 20 years at 95 °C will probably not be possible. The lifetime calculations are made for 300 mm insulation and lifetime is defined as the time when 20% extra heat loss is reached. 20 years at 90 °C will be OK for most storages.

That corrosion free in-and outlet will not be developed.

We have not found a final solution. This mean that water quality has to be district heating water quality with oxygen and stainless steel has to be used for in- and outlet.

High capacity of in- and outlet not possible.

Monitoring in Høje Tastrup and CFD calculations for Fjernvarme Fyn show that up to 3,000 m³/h corresponding to 150 MW is possible. DTU will investigate this further in the TREASURE project.

Only expensive high-temperature heat pumps can be found.

High-temperature heat pumps was not needed in the cases in Copenhagen and Hjørring-Hirtshals but a separate market dialog has showed that affordable heat pumps using natural refrigerants (nearly same prices/MW as for heat pumps up to 90 °C) are available at the market.

Development according to milestones

The project developed more slowly than foreseen. The main reason was the corona situation in the beginning of the project

Problems not expected

A lot of recalculations caused by changes in preconditions and wishes from VEKS and Hjørring Mommune took place. This was not foreseen, but maybe we should have known?

5. Project results

The overall objective to develop a PTES that can stand 90 °C constantly in 20 years and then be utilized in DHC systems providing flexibility to CHP plants and reduce peak load production from fossil fuel sources is obtained. Lifetime of insulation material and possibilities to find corrosion free in-and outlet systems was not fully obtained as described in the application which will cause more expensive solutions according in-and outlet systems and maybe a small reduction in maximum temperature from 95 °C to 90 °C.

The obtained technological results are described in chapter 3. What was not expected in the application was the possibility to use the solutions already in the Høje Taastrup storage. It was not expected that the PP-liner had to be protected against minus temperatures and therefor development of a protection system had to be part of the Integrate 2 project. Also, it was not expected that test of insulation mats should include also a new version with stabilizer. Calculation of PV on the lid was not expected in the application phase but came up as a wish from especially German utilities.

The project has produced commercial results as expected. By the end of the project VEKS and Hjørring Fjernvarme want to continue with PTES projects and Fjernvarme Fyn is expected to make a call for tender for 700,000 m³ PTES during autumn 2024. Beside that PlanEnergi is involved in five PTES projects in Germany, one in Poland, one in France and one in Kosovo. In the TREASURE project it is expected that the total need in EU will be 2,000 PTES. There has already now been a huge interest for the concept resulting in several delegations visiting the PTES in Høje Taastrup.

The target groups are still the same as mentioned in the application European utilities and cities with existing DHC systems.

Dissemination has included:

To Danish utilities and municipalities: Temadag om energilagring arranged by Danish District Heating Association and DACES <https://danskfjernvarme.dk/kurser-og-arrangementer/temadag-om-energilagre>

To German utilities and municipalities:

Participation in Dänische Fernwärme Allianz through the Danish Consulate in Hamburg

Participation in 27th Dresdner Fernwärme Kollokvium 29.-30. September 2022

Præsentation at ASEW webinar 24.04.2024: Erdbeckenwärmespeicher für die Wärmenetze. ASEW is a co-operation of German municipal owned utilities

Education seminar for planners arranged by the German association of Engineers, VDI, 12.-13th June 2024 in Karlsruhe

Direct contact to German utilities

In France:

Cooperation with DBDH and the Danish embassy in "District Heating Alliance"

Direct contact to French district heating providers (Dalkia, Newheat, Engie)

To Sweden through the project "SDH & PTES for Swedish conditions" led by Dalarna University where PlanEnergi has supported with costs of PTES and connection to DH systems

To Europe:

Through the EU Horizon project TREASURE <https://www.treasure-project.eu/>

To IEA

Through IEA-ES Task 45 <https://iea-es.org/task-45/>

In general:

By presentations at 12th International Conference on Geosynthetics 17.-21.th September 2023 in Rome and Enerstock 2024 05-07.06 2024 in Lyon

6. Utilisation of project results

The obtained commercial results will be utilized by Danish utilities: Fjernvarme Fyn, VEKS and Hjørring Fjernvarme in their process for implementing PTES in their respective systems and primarily European utilities and industries, where at least 10 projects from 20,000 m³ to 2,000,000 m³ are in progress and many others have declared they might be interested.

From Denmark PlanEnergi and/or Aalborg CSP are involved in nearly app. 80% of the projects. In the implementation phase other Danish companies might be involved. Primarily companies who was also involved in the project in Høje Taastrup (Aarsleff, PBJ Miljø..) and later also other Danish consultants. Niras is already involved in Hjørring.

So far, the increased turnover in PlanEnergi has been more than 5 mio. DKK and extra employment of 3. It is expected that the yearly expansion in turnover in PlanEnergi will be 30-40% within design and implementation of PTES.

Competing solutions on the marked is primarily steel tanks. The m³ price for steel tanks is app. a factor 3 higher than for PTES, but steel tanks are well known, does not require so much land area, and have longer expected lifetime than PTES. It is also possible to go up to 95 °C in a steel tank.

The main barriers for PTES are:

New technology: we need demos, to convince utilities about the advantages and reliability of PTES. Høje Taastrup already works as a reliable demo and 7 more demos will hopefully be the result of the TREASURE project. In the TREASURE project life cycle analysis will be carried out comparing PTES to steel tanks. This will probably show a larger climate cost for steel tanks.

Land area requirement. The larger the PTES the better possibilities to pay for transmission pipes and place the PTES outside cities (Like in Høje Taastrup). Also, utilisation of the lid area for PV, will reduce this barrier.

Lack of knowledge. PlanEnergi is disseminating Danish experiences through the TREASURE project and IEA-ES Task 45. That will result in other consultants and developers will get excess to our know-how. PlanEnergi and other Danish consultants and suppliers will therefore have to continuously be involved in research and development projects to gain the advantages from being forerunners with PTES in Denmark.

Thermal storage makes the overall Danish energy system more flexible and cheaper. Similar calculations have been carried out in IEA-ES Task 35 for Germany, where a doubling of thermal storage capacity by 2050 will result in fuel savings of 1.29 TWh/year and an economic gain of €20 million/year. The storage facilities are also a necessity for the use of surplus heat from e.g. future PtX plants. In the TREASURE project the needed PTES capacity in 2040 is estimated to 54 TWh or app. 1,500 PTES of 1 mio. m³.

7. Project conclusion and perspective

The conclusion from the project is, that the PTES technology for storages heated up to 90 °C constantly can be constructed with a lifetime of at least 20 years and have reached TRL 8. Still the last results from test of insulation mats remains, but the preliminary results looks convincing. The technology can still be improved for instance by further develop in- and outlet with use of PP pipes and diffusers.

The next steps is to implement the next generation of demo projects. Projects in Pristina, Kosovo and Fjernvarme Fyn are near the tendering phase and other projects in DK and Europe are in the developing phase. Some of them included in the TREASURE project, where Danish experiences are basis for 7 demo projects.

Results from the Integrate 2 project will be utilized in the TREASURE project and in IEA-ES Task 45 and thus be a crucial element in the future development and demo projects.

8. Appendices

Følgende er uploadet sammen med slutrapporten:

D2.1, 3.4 og 4.4. Guidelines for interessentinddragelse

D2.2 Guidelines for modeling in Balmorel

D2.3 New design of lid and in- and outlet system

D3.1 og 3.2 Kortlægning og designstudier for København

D3.3 Forretningsmodeller for varmelagre i København

D4.1 Kortlægning Hjørring-Hirtshals

D4.2 Scenarieberegninger Hjørring-Hirtshals

D4.2A Scenarieberegninger i Balmorel

D4.3 Forretningsmodeller Hjørring-Hirtshals