# PIT THERMAL ENERGY STORAGE

# PRACTICAL EXPERIENCES FROM DENMARK


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Main areas: PTES and large solar thermal plants
Started at Ramboll in 2008


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# AGENDA

- **Introduction**

  Ramboll and Pit Thermal Energy Storages

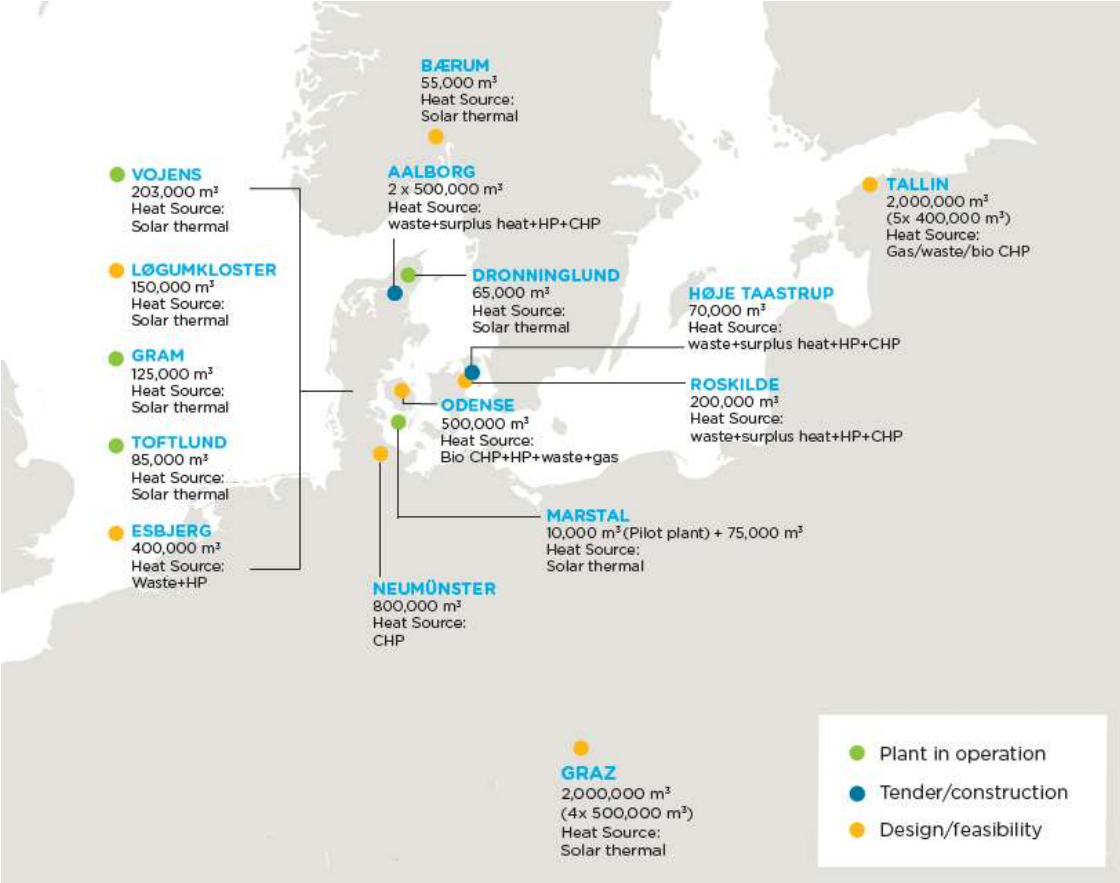
- **Lessons learned – Practical experiences**
- **Case Toftlund**

  Key facts

  Main experiences

  Update on the performance

# INTRODUCTION




Ramboll has, since the first 10,000 m3 pit thermal energy storage (PTES) was established in Marstal in 2004, been involved in the majority of the planned and constructed PTES in Denmark and abroad.

# THE 5 DANISH PTES IN OPERATION

Toftlund – 85,000 m3 (2017)

Gram – 120,000 m3 (2015)

Vojens – 205,000 m3 (2015)

Dronninglund – 60,000 m3 (2014)

Marstal – 75,000 m3 (2012/2020)

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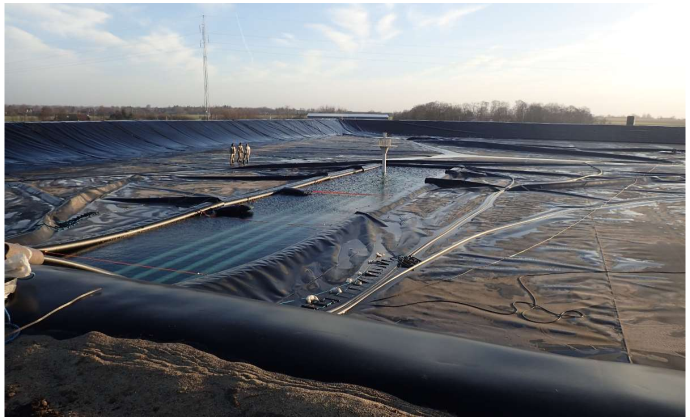
# CONSTRUCTION OF A PTES

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# LESSONS LEARNED – PRACTICAL EXPERIENCES

The PTES works in general fine, when they are constructed correct, like they are in:

- Dronninglund, Toftlund and hopefully now in Marstal.

**But they can be improved**

Focus for the coming projects should be:

- Liner (HDPE and/or PP)
- Pipe material for the diffusor system
- Which insulation materials should be used.
- Sectioning of the lid – improving rainwater handling and leak detection.

# MAIN EXPERIENCES – LESSONS LEARNED

After the construction and commissioning of the 5 large PTES in Denmark we have gained many experiences, and below is listed some of the main lessons learned:

- ✓ **Mounting of the floating liner**
- ✓ **Lid design**
- ✓ **Materials -** For the liner, insulation of the lid and the pipe installation in the storage

- ➢ **Geotechnical and ground water conditions on site – impact on CAPEX and heat loss**
- ➢ **Diffusor design/CFD modelling**
- ➢ **Water quality**
- ➢ **Air accumulation below the lid**
- ➢ **Water ponding and rainwater handling on top of the lid**

# LESSONS LEARNED - MOUNTING THE FLOATING LINER

The mounting of the floating cover has carried out in two ways.

**Method 1: After the storage is completely full of water, the top liner is mounted/dragged over the water.**

**Pro:**

Low cost, simple to install.

**Con:**

As the **water filling can take from 1 to 6 month** depending on the available water supply, dirt and other impurities will enter the water.

The experience from the project in Marstal was that the diffusor system was corroded properly due to a bacteria growth in the water.

**Method 2: On top of the liner covering the bottom and sides of the storage, the floating liner is mounted, and the water is filled in between the two layers.**

**Pro:**

Reduces the risk of dirt entering the water, which increases the risk of bacteria growth etc.

**Con:**

Due to the excess material that occurs when the storage is filled up with water, wrinkles of the liner must be handled by weight pipes. The weight pipes have caused some issues with difficulties finding leakages and creates internal vertical barriers for the water flow to the top diffusor.

**Lessons learned:**
**A combination of the two methods is recommended to be used**

Instead of floating up the permanent liner a cheap temporary liner should be used. When the storage is full the temporary liner is removed, and the permanent liner installed.

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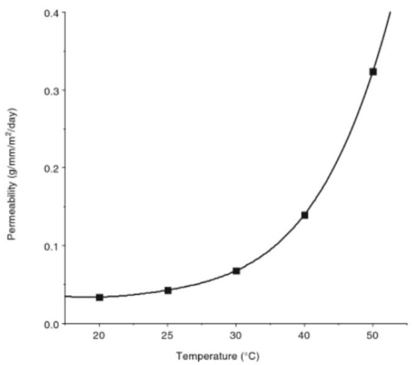
# LESSONS LEARNED
## LINER MATERIALS AND MATERIALS FOR THE PIPE/DIFFUSOR SYSTEM

Liner materials

HDPE and PP materials can be used, but with some challenges.

- The lifetime of the liner depends very much on the temperature. A lifetime of 30 years can be expected for constant temp. of ≤90 °C with short peaks up to 95 °C.
- Challenge 1: Oxygen seems to enter the storage through the liner or openings like manholes etc.
- Challenge 2: Water vapor diffusion through the liner increases with the temperature, which needs to be handled in the design of the lid.




The choice of pipe materials depends very much on the level of water quality. In the existing projects the water is either softened and one also treated by reverse osmosis. pH-value adjusted to 9.8.

The water is de-aerated, but not oxygen free.

Pipe materials used for the diffusor system

- **Carbon steel** is used in Marstal – pronounced corrosion, but now under control.
- **Stainless steel** AISI 316 is used in Dronninglund – no corrosion.
- **Carbon steel with special coating** as surface treatment has been used in Gram, Vojens and Toftlund. – some corrosion, but under control.

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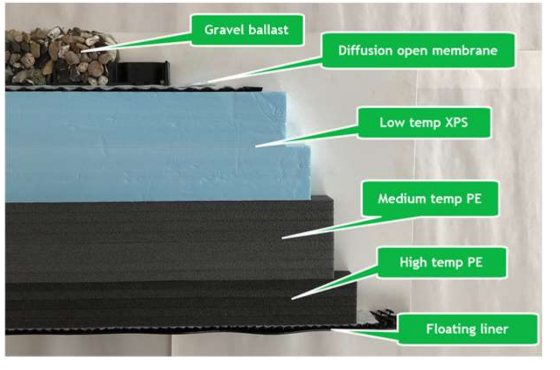
# LESSONS LEARNED - INSULATION MATERIALS

**The challenge today:** No standard for testing insulation materials which takes in to account the operating conditions inside the lid construction.

Rambøll has joined a developing program with the focus to develop a catalogue and test paradigm for materials suited for PTES.

<u>Main technical requirements:</u>

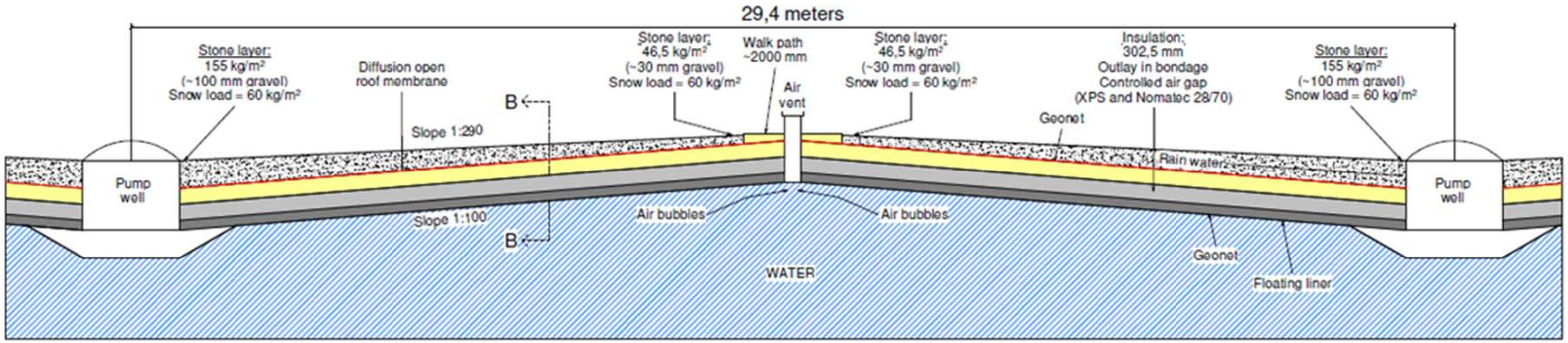
- Temperature resistant +95 degrees
- Can handle to be exposed to moisture/water and be dried out without permanent degrading of the insulation capacity.
- Load resistant in a warm and sometimes humid environment.




# LESSONS LEARNED – SECTIONING OF THE LID CONSTRUCTION

Advantages of sectioning

- Easier rainwater handling
- Reduces the impact on the lid insulation in case of a leakage.
- Easier leak detection



# TOFTLUND PTES - KEY FACTS

| Fact | |
|---|---|
| Put in operation | June 2017 |
| Size | 85.000 m3 |
| CAPEX total | 21 mio. DKK (˜247 DKK/m3) |
| CAPEX (Lid construction) | ˜800 DKK/m2 water surface<br>(Incl. in the 21 mio. DKK) |
| Charging capacity | 18 MW |
| Discharging capacity | 8 MW |
| Heat source | Primarily solar thermal and secondary heat from an electrical boiler and a 7,2 Mwheat CHP plant. An absorption heat pump cools down the storage in the winter period, reducing the heat loss and increases the energy capacity of the storage. |
| Lid construction | 1.5 mm HDPE liner as top liner<br>Insulation – 600 mm Leca (Expanded clay)<br>2.5 mm HDPE liner as floating cover |

# TOFTLUND - MAIN EXPERIENCES

**Permanent floating liner** should not be installed before water filling – a temporary liner should be used instead – Weight pipes should be avoided.

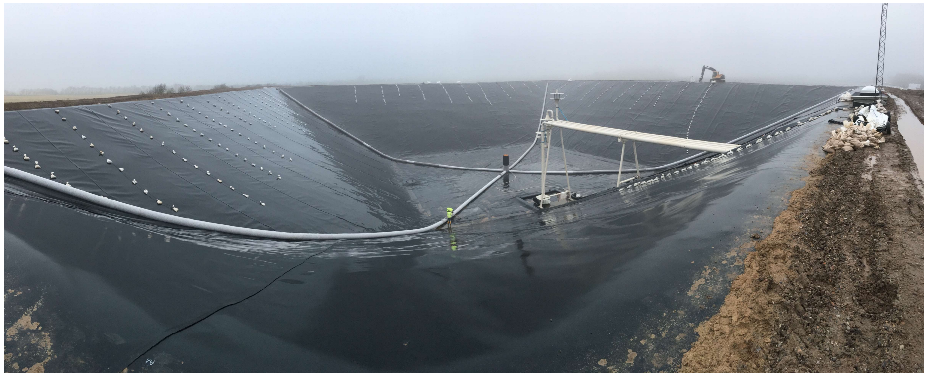
**Lid construction** works as intended,

- Approx. 2/3 of the insulation was flooded in the commissioning phase, due to extreme heavy rain.
  In the following phase it has shown possible to completely dry-out the insulation **and the insulation properties is restored without replacement of the insulation material**.

- For the next project with a lid construction with Leca, the lid should be installed with ventilators, for a more controlled ventilation of the insulation. Primarily to handle the water vapour diffusion from the storage.

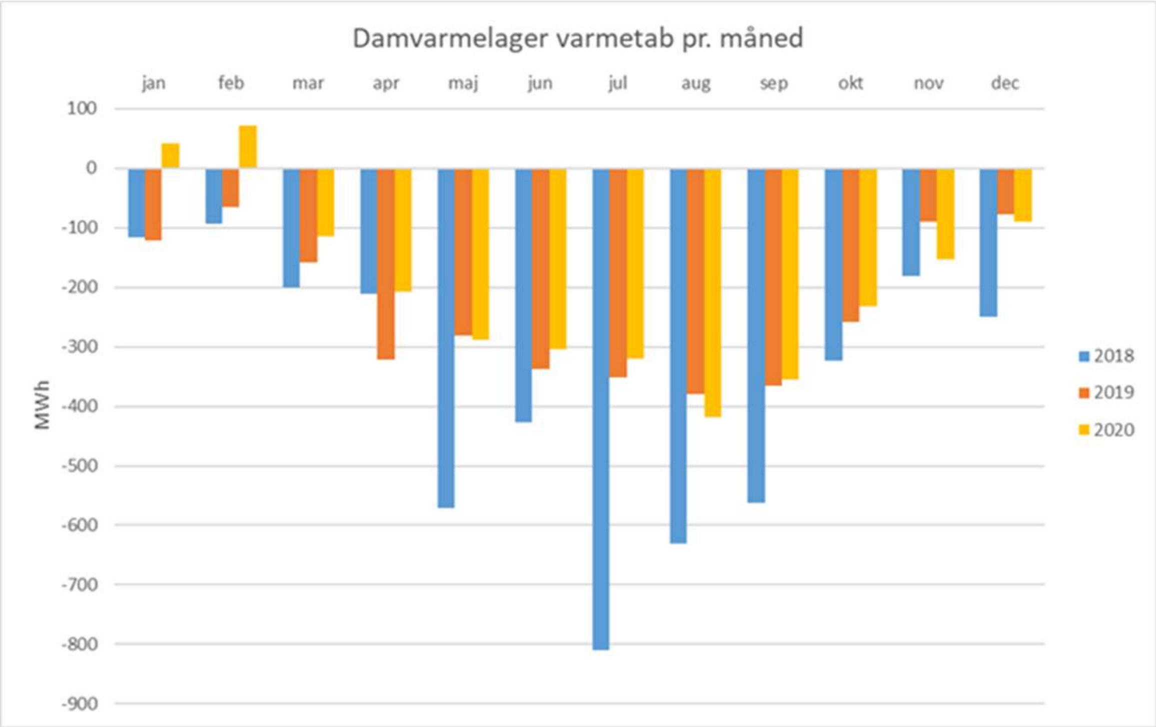
**Rainwater handling system** works satisfactorily in accordance with the operator.

- Some puddles need to be drained manually, but in general the system works automatically.



# TOFTLUND - UPDATE ON THE PERFORMANCE

## DATA FROM TOFTLUND (85,000 M3 STORAGE/27,000 M2 SOLAR/CHP/EL BOILER/GAS BOILER)




### Total realized heat loss

- 4,377 MWh in 2018 – wet insulation – rainwater entered the lid construction during the commissioning phase.
- 2,808 MWh in 2019 – active drying of the insulation until April/May.
- 2,374 MWh 2020 – corresponding to the design.

### Calculated heat loss

Approx. 2,650 MWh/year – calculated based on the operating profile for 2019.

# TOFTLUND - UPDATE ON THE PERFORMANCE

## DATA FROM TOFTLUND (85,000 M3 STORAGE/27,000 M2 SOLAR/CHP/EL BOILER/GAS BOILER)

| Period | 2018 | 2019 | 2020 |
|---|---|---|---|
| Energy to the storage | 10,136 MWh | 7,028 MWh | 8,458 MWh |
| Energy out of the storage | 4,367 MWh | 4,752 MWh | 5,977 MWh |
| Heat losses | 4,377 MWh | 2,808 MWh | 2,374 MWh |
| Efficiency | 43 % | 68 % | 71 % |

The heat loss has the last 6-7 month stabilized at the current level of 2,350 MWh, when seen 12 months back.

**Conclusion: The storage is now performing in accordance with the design.**

# QUESTIONS?


**Contact informations**

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## THANK YOU!