Large-scale heat storage for solar heating plant

Jianhua Fan

Associate Professor

Department of Civil and Mechanical Engineering
Technical University of Denmark

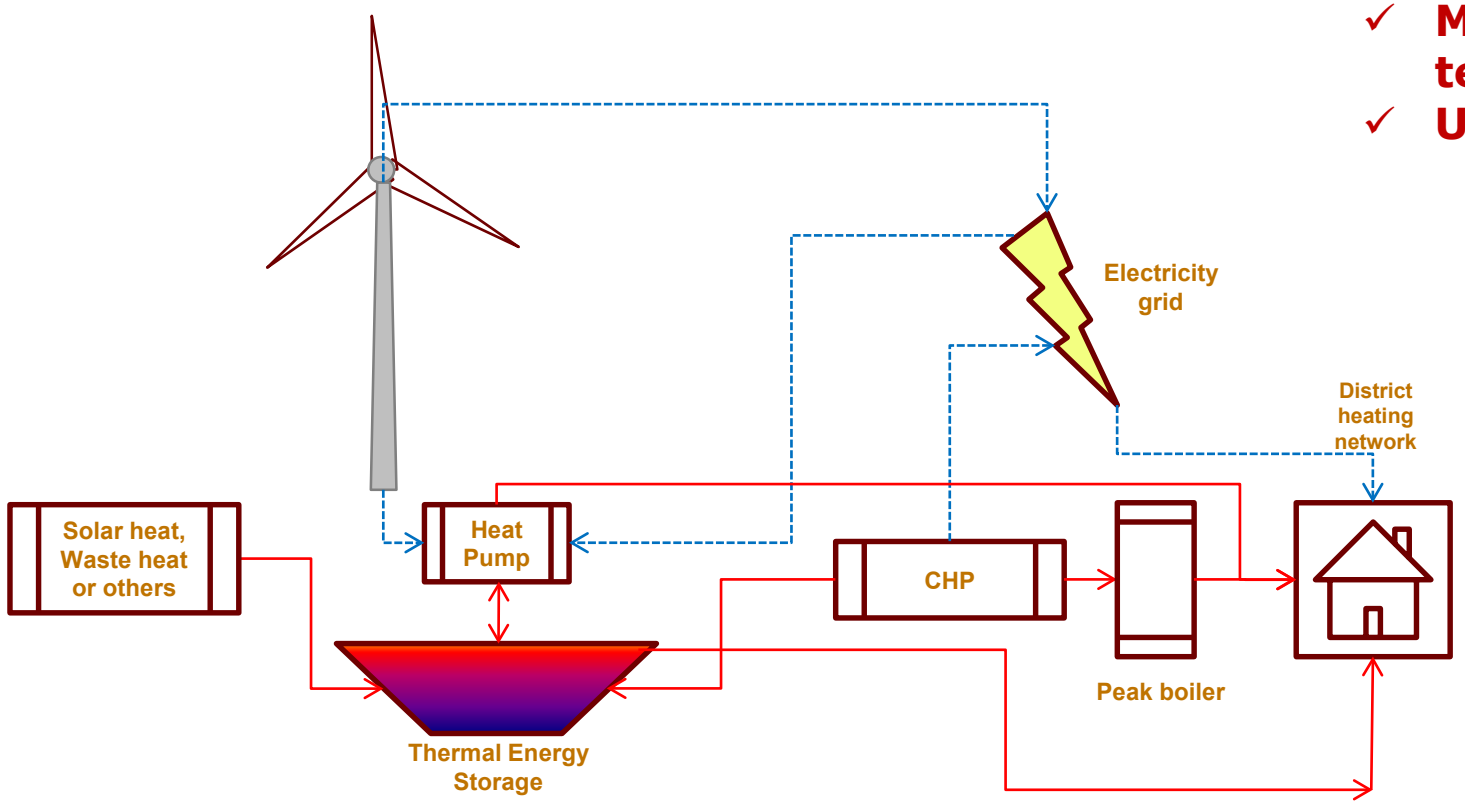
jifa@dtu.dk

The benefit of a smart heat storage

Combined renewable technologies and smart heat storage interacting with the electricity grid …

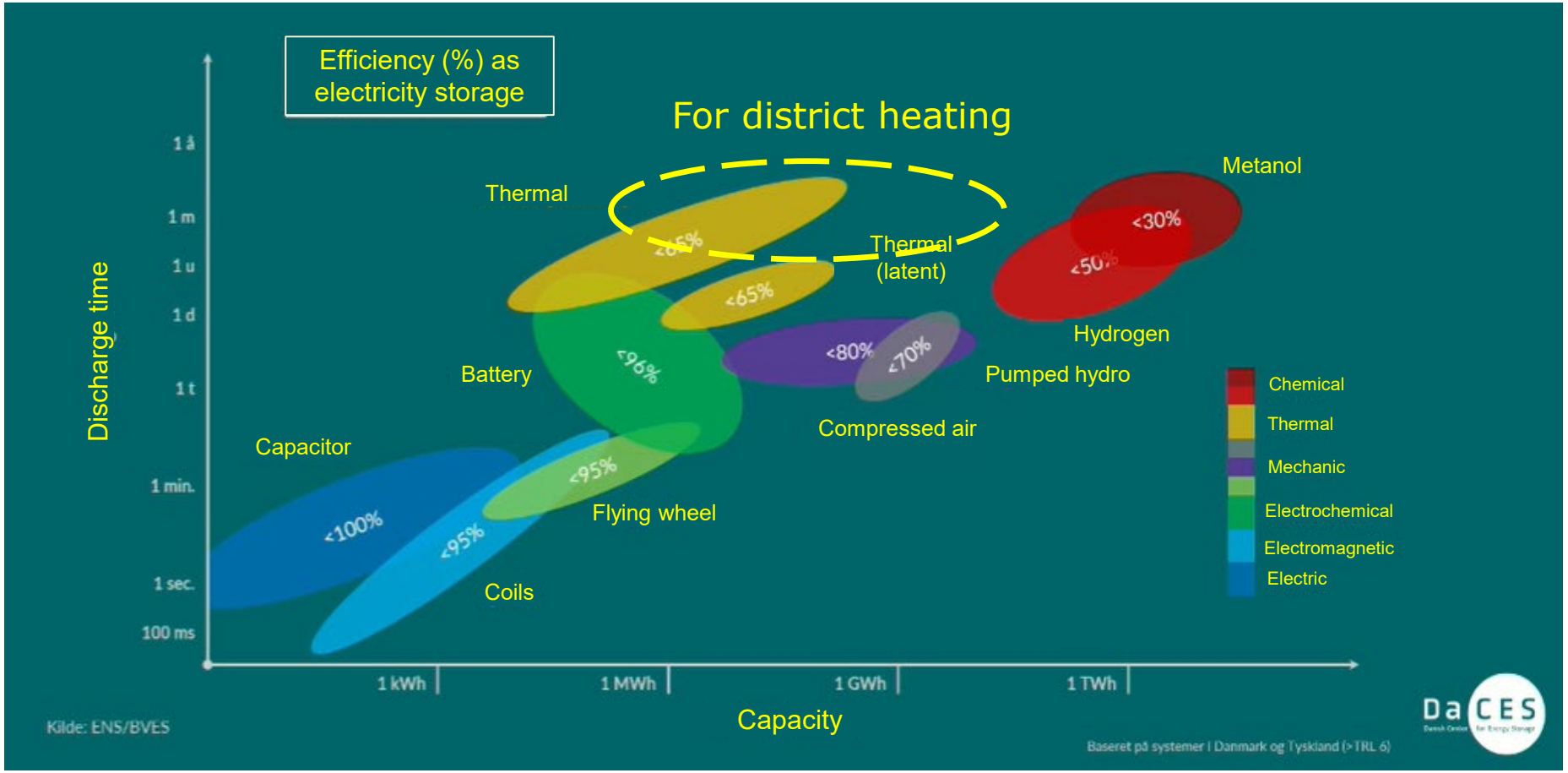
Smart heat storage:

- ✓ Gives flexibility
- ✓ Makes combinations of technologies possible
- ✓ Use cheap electricity



Energy storages

Different energy storage technologies should work together

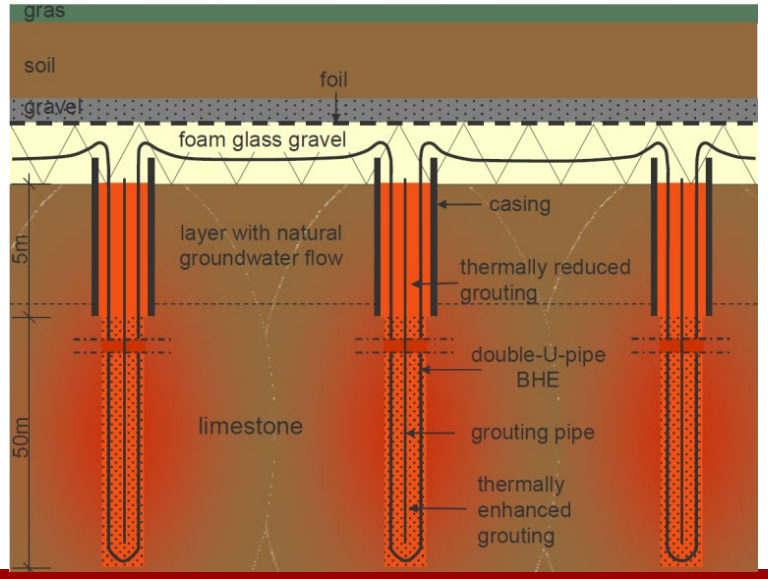


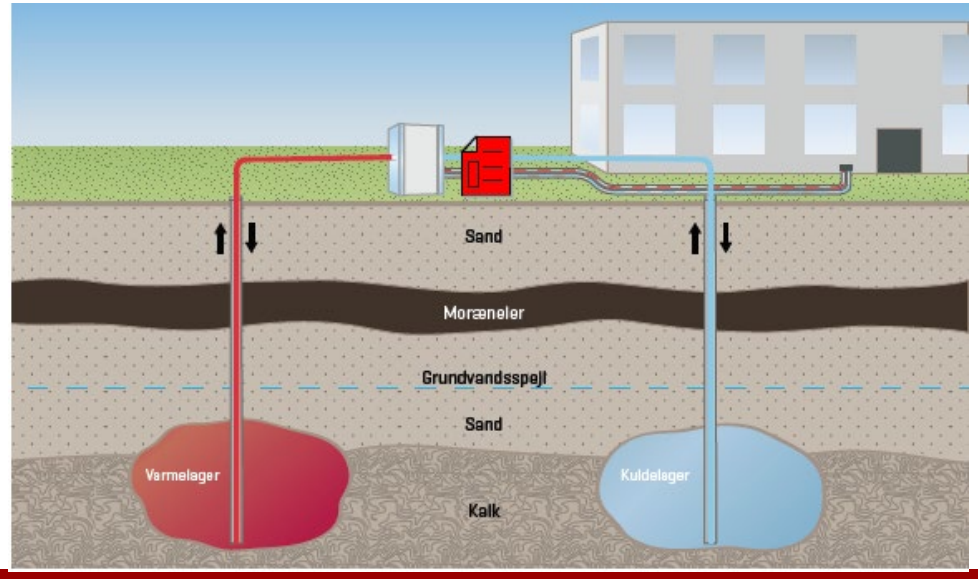
Different types of heat storages for district heating

Tank heat storage (TTES)

Water pit (PTES)

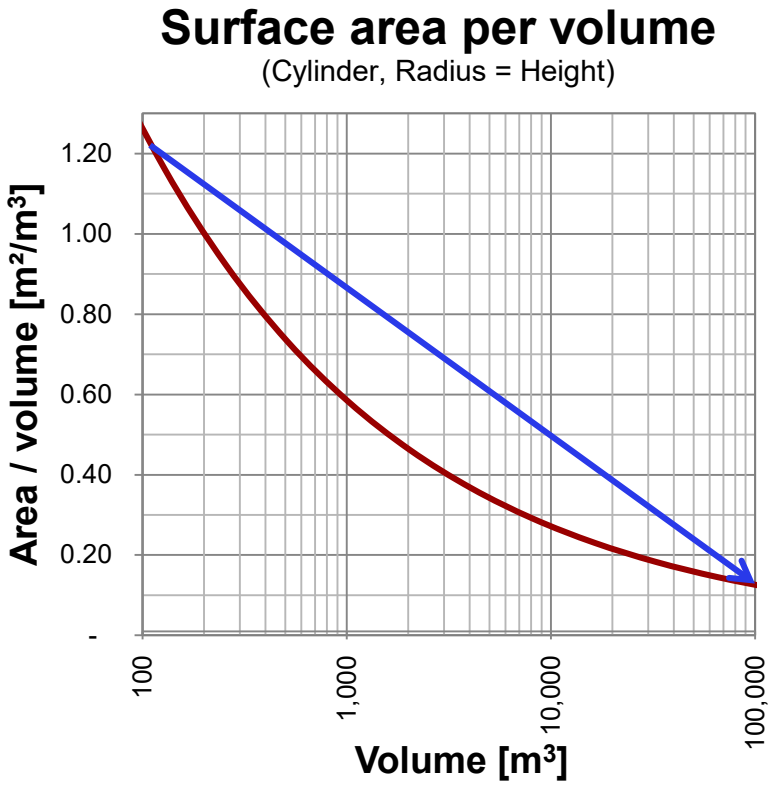
Borehole storage (BTES)

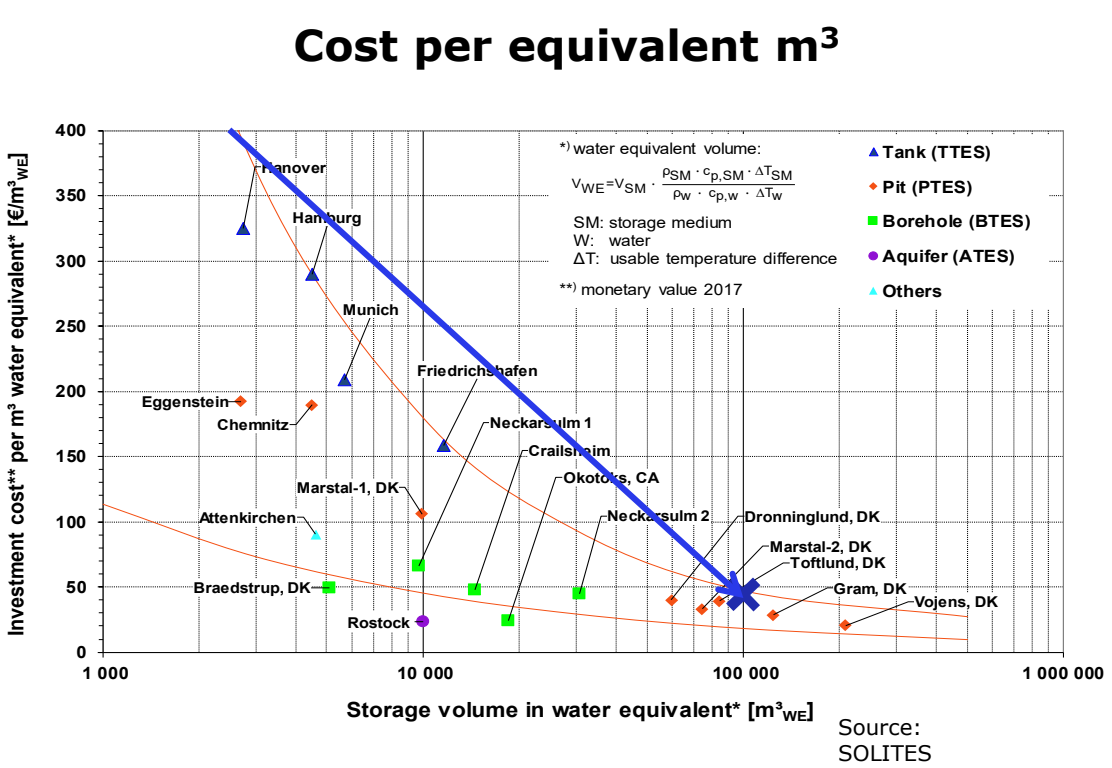




Aquifer storage (ATES)

Thermal energy storage: Big is beautiful





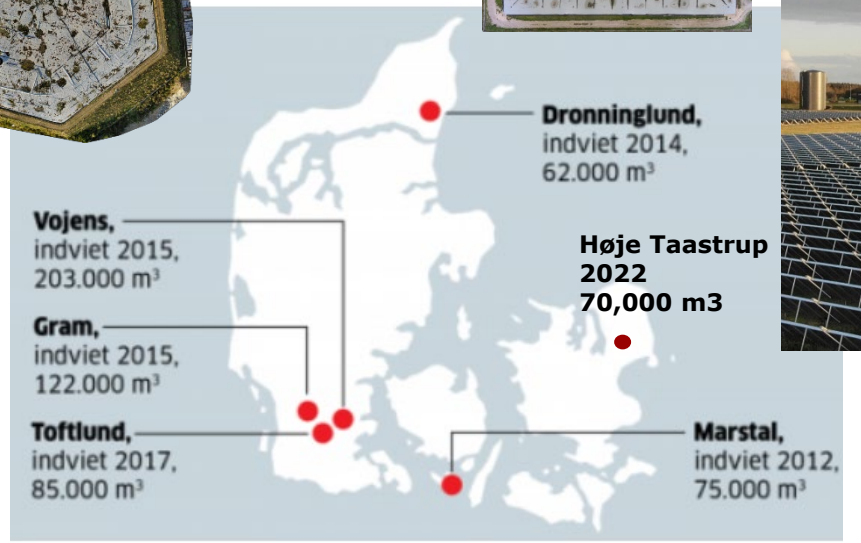
Source:
SOLITES

1.2 → 0.1 ➔ Factor 12 on surface area/volume (heat loss/storage capacity)

400 → 40 ➔ Factor 10 on costs/volume (cost/storage capacity)

Existing water pit heat storage (PTES) in Denmark

- PTES for district heating:
  - Dronninglund
  - Vojens
  - Gram
  - Toftlund
  - Marstal
  - Høje Taastrup



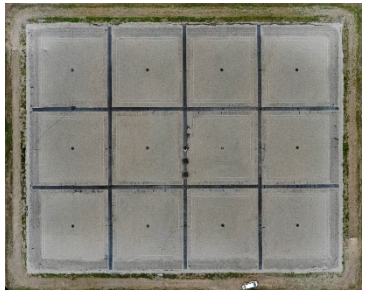


Photo copyright: DTU

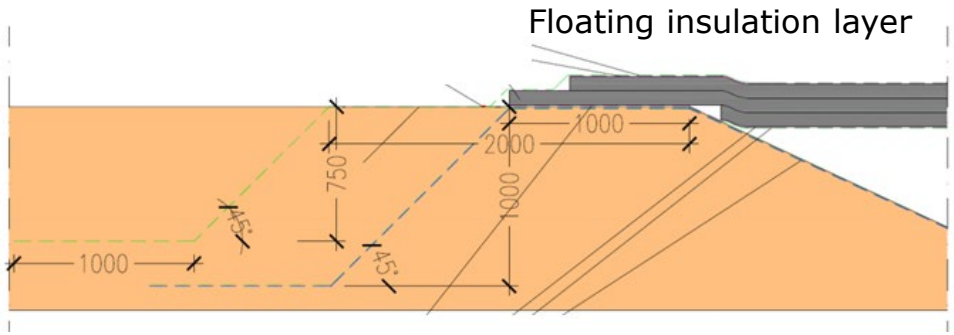
Design type 1: Construction of the PTES in Dronninglund

Design type 1: Floating layer with foam insulation

Cases:

-Marstal

-Dronninglund



Pros:

- Good insulation property
- Water proof, durable
- Can be fixed

Cons:

- Higher installation cost
- Not load bearing

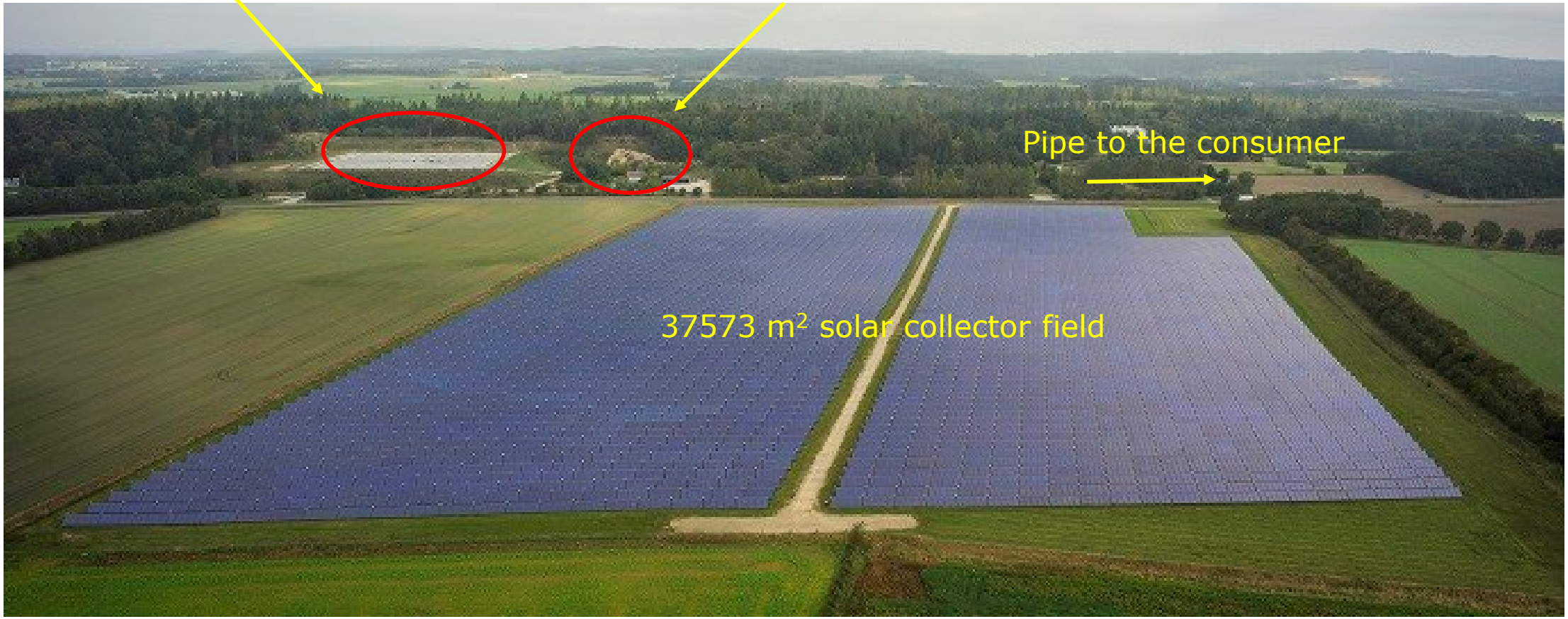
Cost:

- Relative higher cost, 25-35 Euro/m^3 storage volume (large scale)

Design type 1 Example: Dronninglund solar heating plant

63000 m^3 PTES

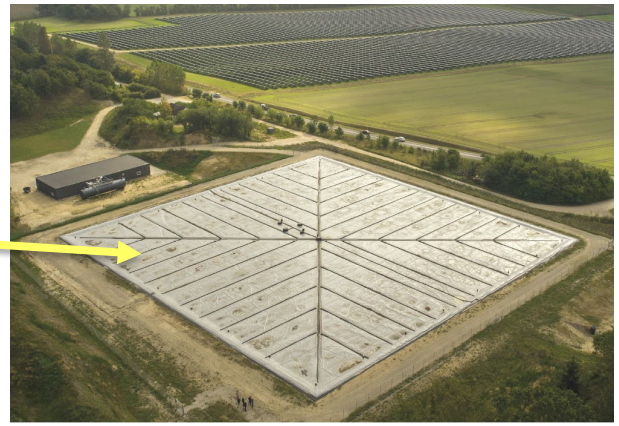
Technical room (heat exchanger, pumps, control room, etc)

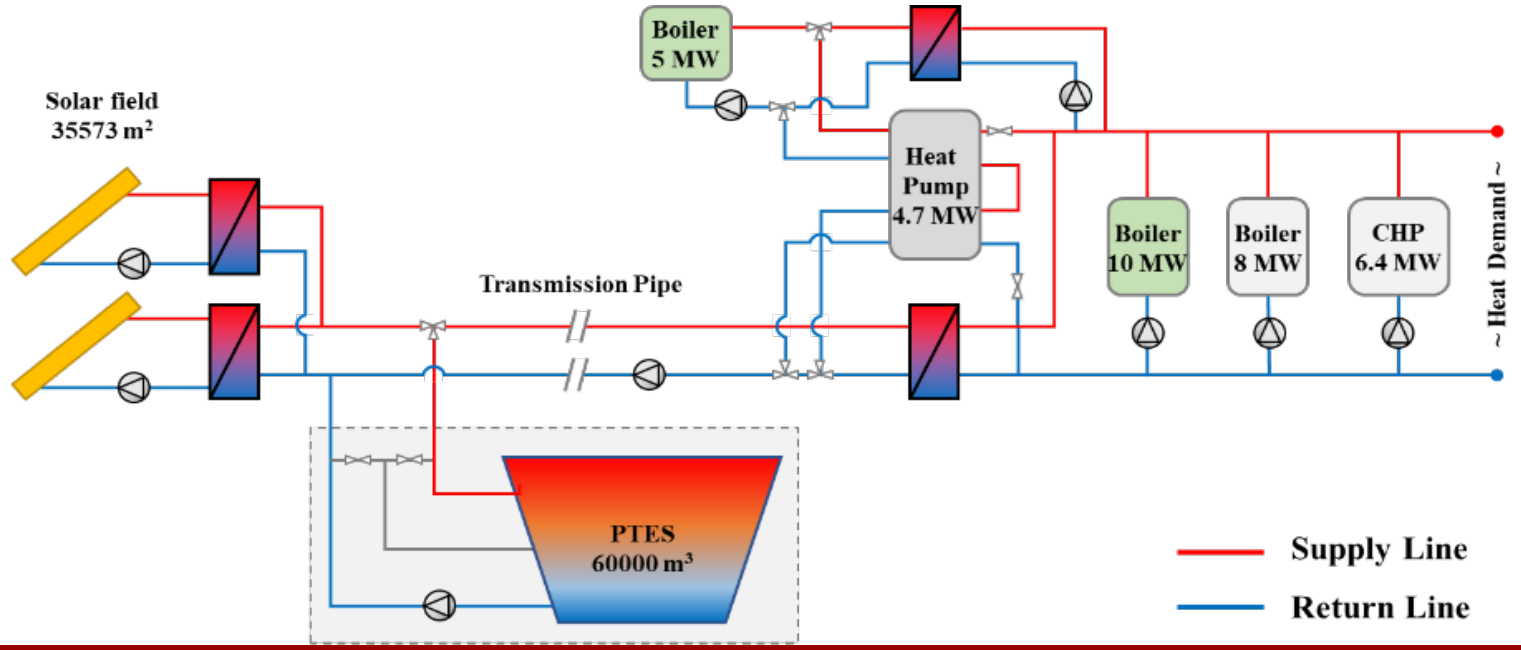


There is no short term heat storage tank

Design type 1 application Example: Dronninglund

- Solar collectors: 375730 m2 flat plate solar collector
- Pit heat storage: 63000 m3
- Absorption heat pump requires fuels to drive the process





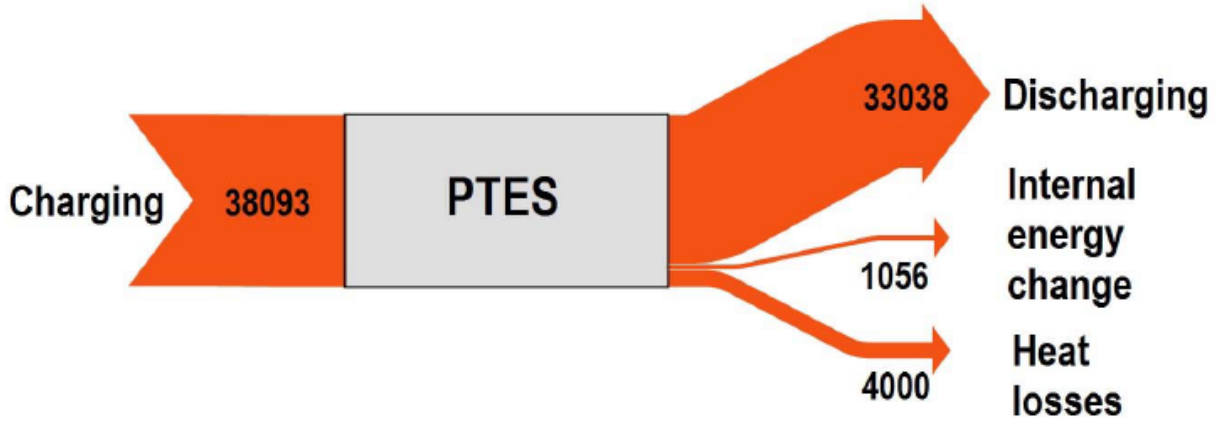
Thermal performance of the PTES in Dronninglund

- Project: *Follow up on large scale heat storages in Denmark* funded by the Energy Technology Development and Demonstration Program
- Heat losses, efficiency and feasibility depend highly on the use of the storage
- Preliminary results from this project (source: Solites):

Pit storage | energy flow year 2014 - 2016

Storage efficiency:	90 %	T-max:	89 °C
No. of storage cycles:	6.0	T-min:	12 °C
Heat capacity (80 K):	5 500 MWh		

Seasonal + weekly heat storage

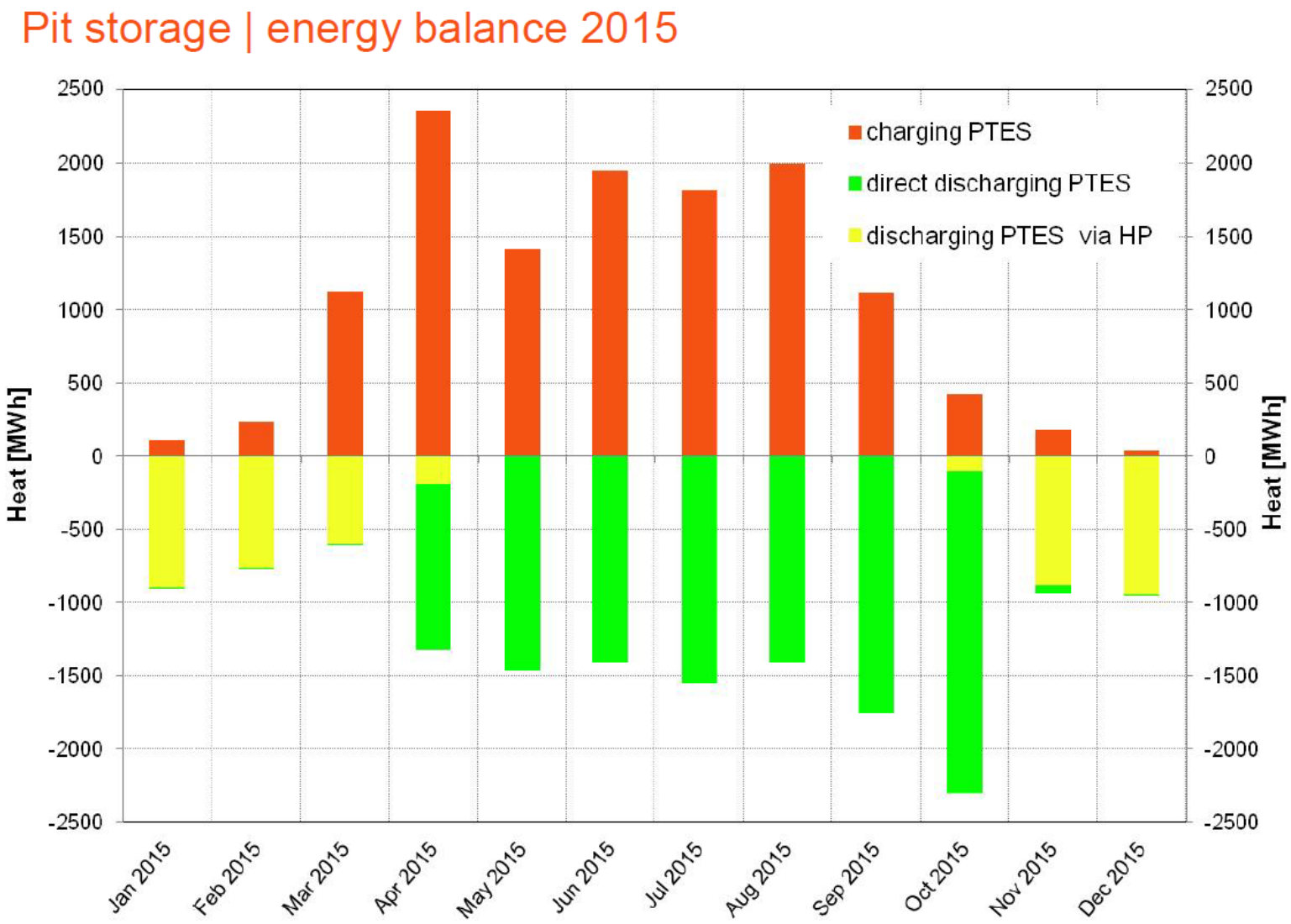


Monitoring results 2014 - 2016, numbers in MWh/a

Note: Numboer of storage cycles = annual charged heat/ TES capacity

The larger the number of storage cycles, the larger the storage efficiency

Charge /discharge of the PTES in Dronninglund



Design type 2: Construction of the PTES in Vojens

Design type 2: Floating insulation layer with Leca stones

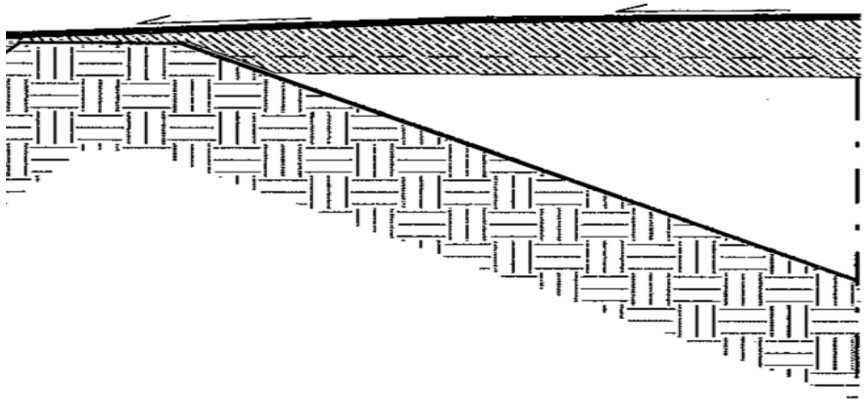
Cases:

PTES in Vojens

PTES in Gram

PTES in Toftlund

Floating insulation layer



Pros:

- Cheap
- Easy installation
- Insulation material easy to transport

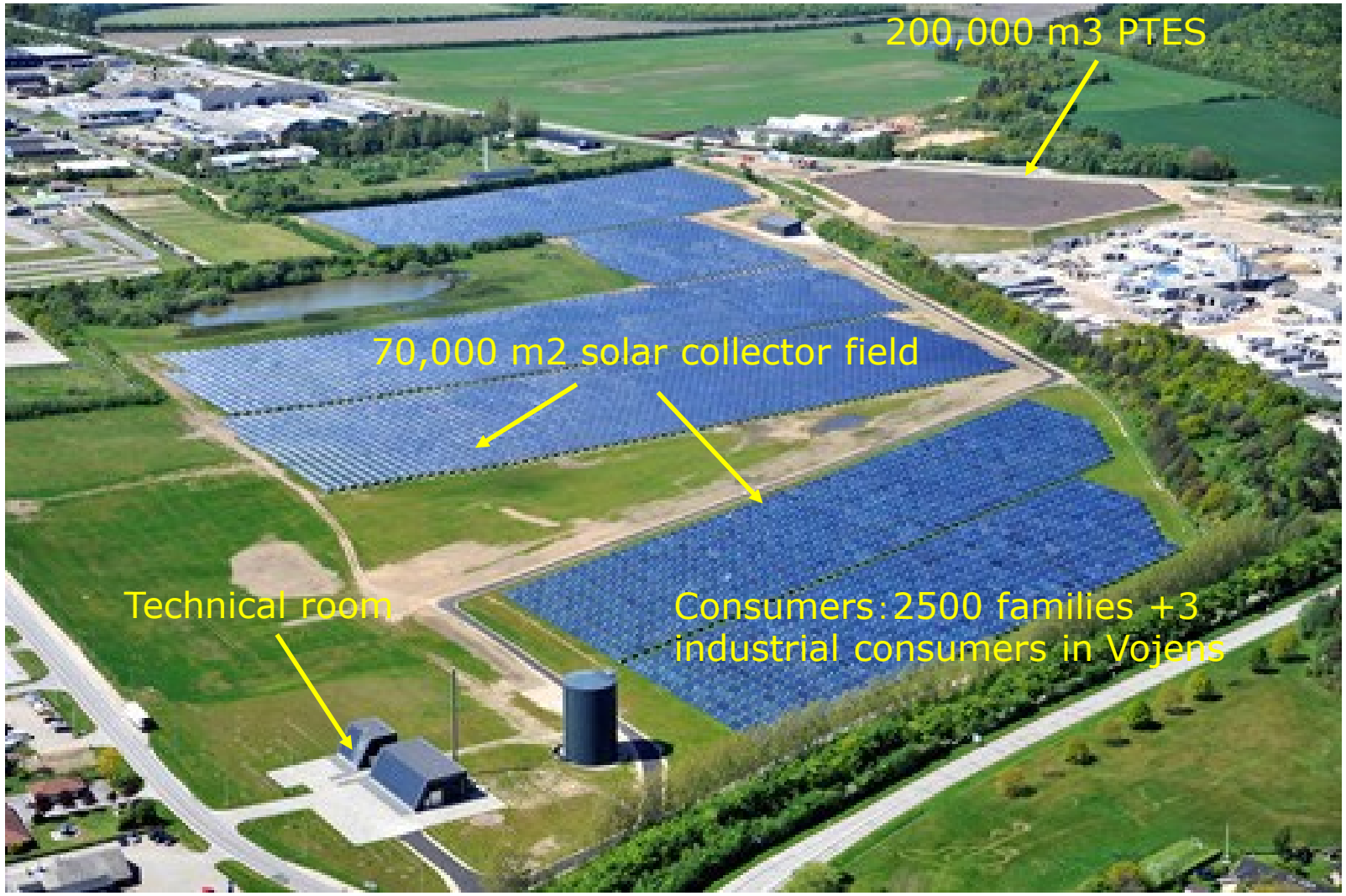
Cons:

- Average insulation property
- Not water proof
- Movement of insulation material

Cost:

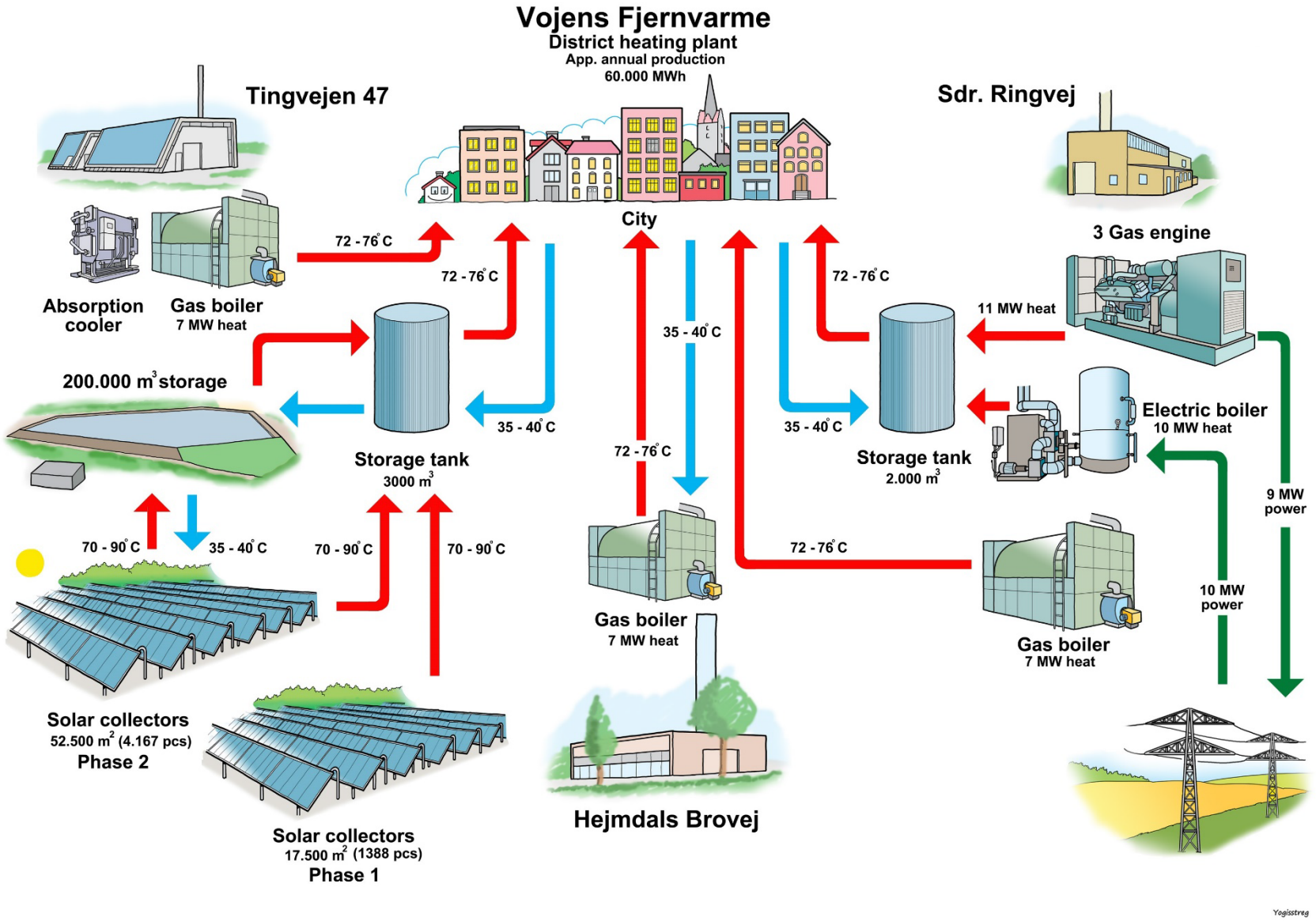
- Relative lower cost, 15-25 Euro/m^3 storage volume (large scale)

Design type 2 example: Vojens solar heating plant



The world largest PTES

Design type 2 example: Vojens solar heating plant



Synergy is key

Solar:

- ✓ **Produce almost free heat (once installed)**

CHP:

- ✓ **Produce heat & electricity**
- ✓ **Fast capacity regulation (production)**

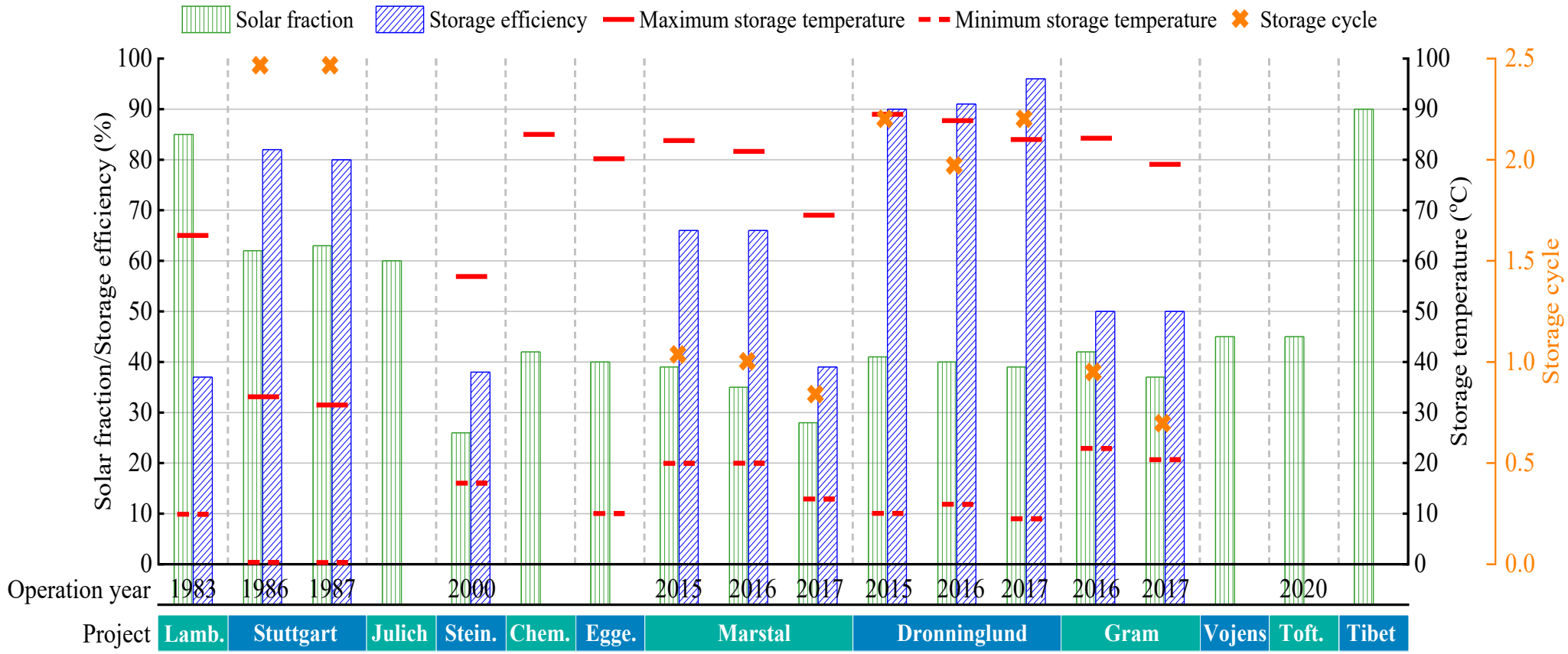
Heat pump:

- ✓ **Produce cheap heat**
- ✓ **Fast capacity regulation (load)**
- ✓ **Reduce storage volume**

Storage:

- ✓ **Gives flexibility**
- ✓ **Makes combinations possible**

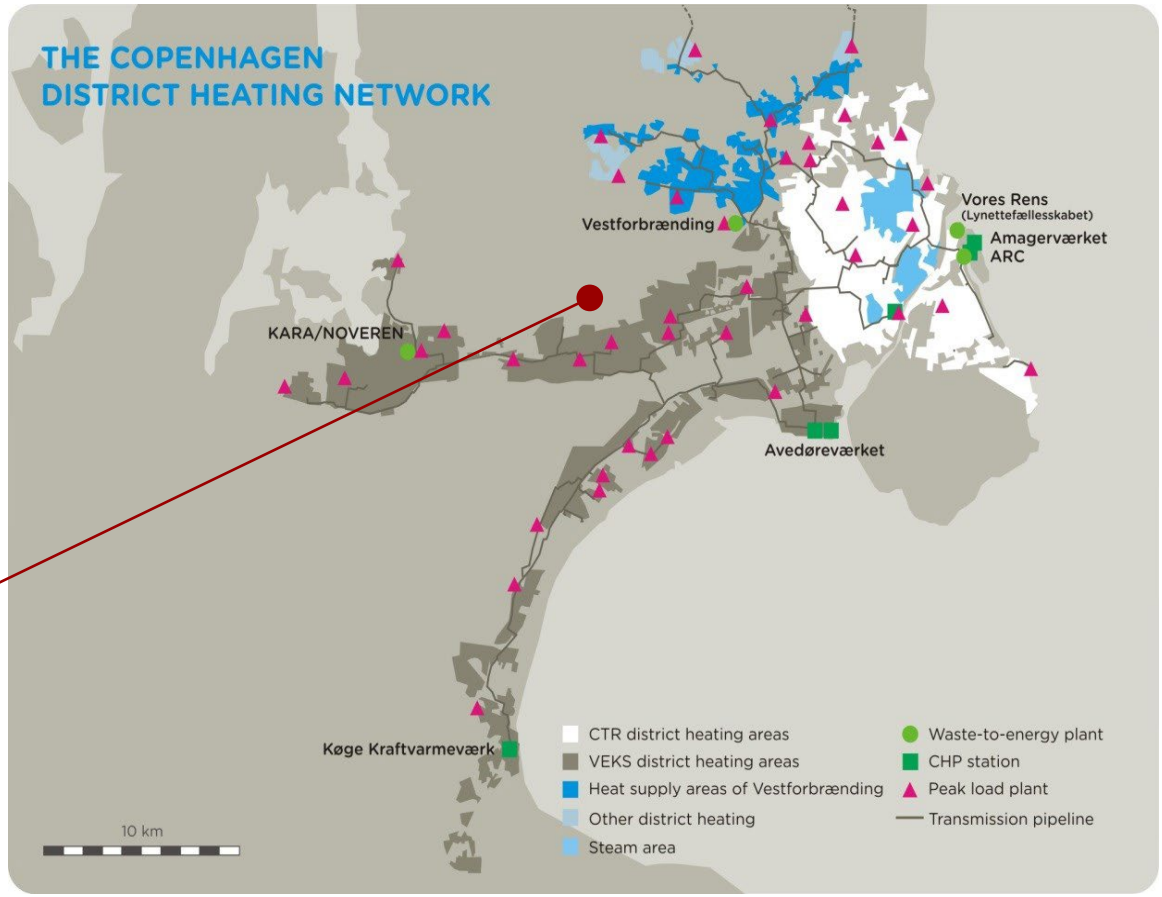
Comparison of solar heating systems with PTES world wide



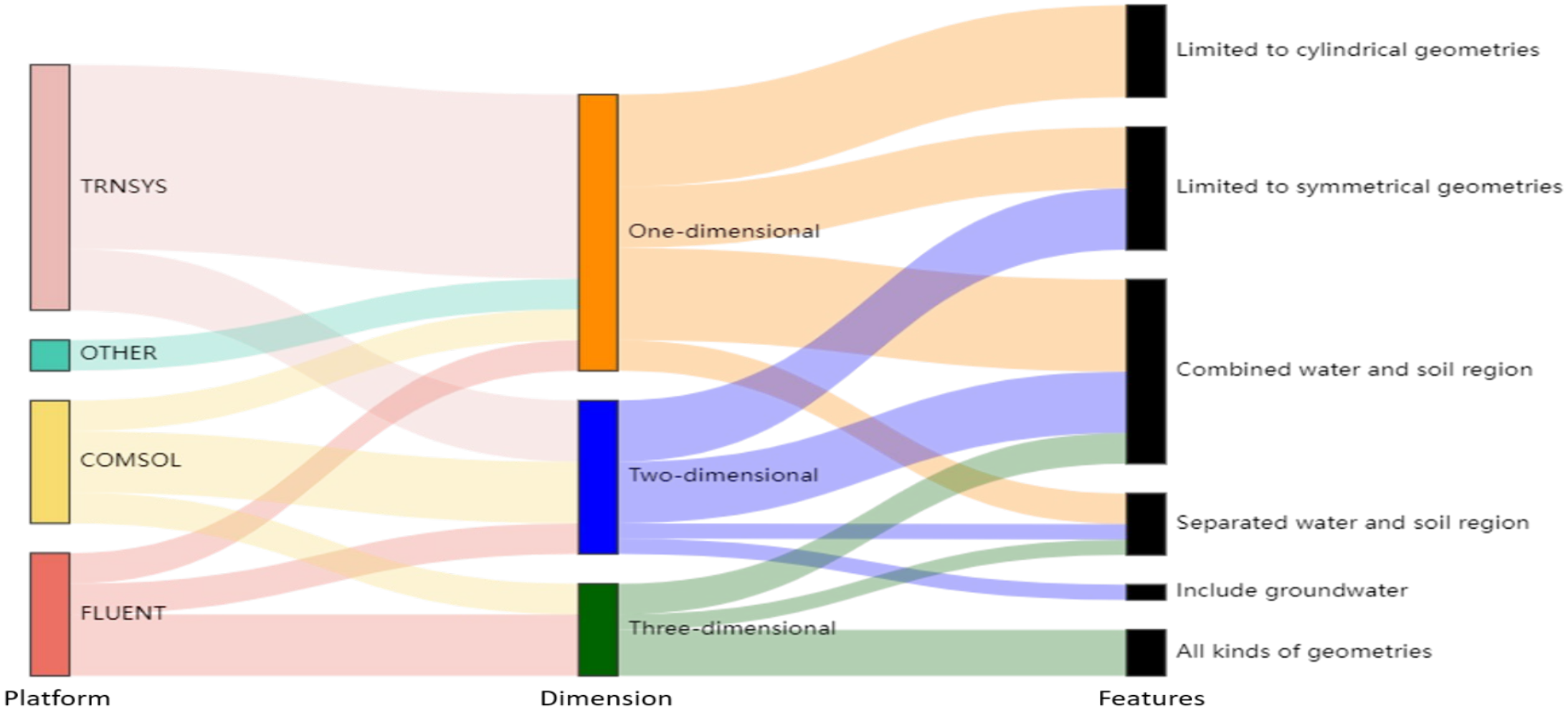
Høje Taastrup PTES for Copenhagen district heating

70,000 m3 water pit heat storage for waste heat

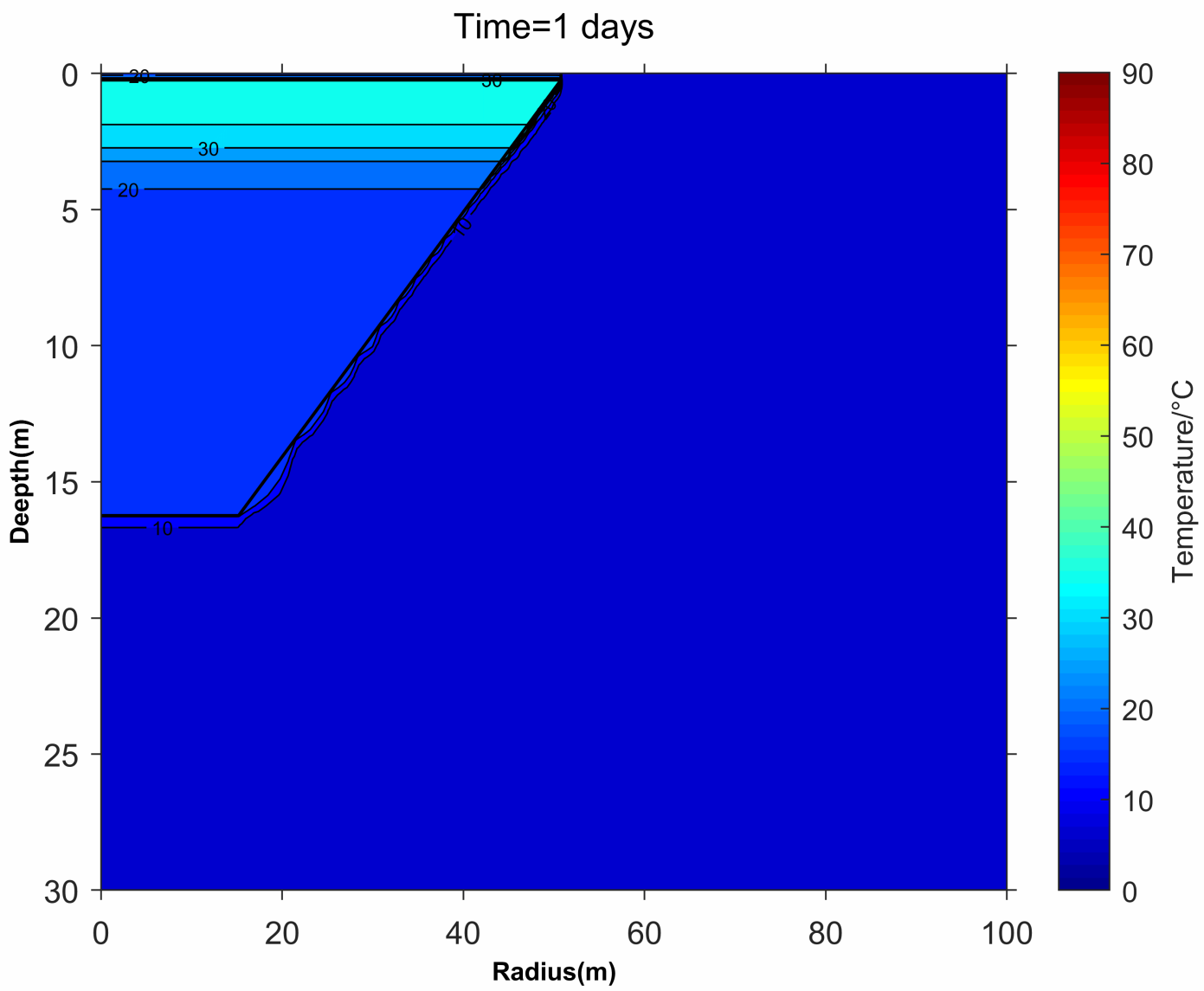
- 19 cities
- 4 district energy systems
- 160 km. heating pipe
- 25 district heating companies
- 500,000 consumers
- 34,500 TJ (9,600 GWh)
- 20% of Danish heat consumption



Numerical investigations of PTES



Temperatures in and around the PTES in a year calculated using TRNSYS



IEA ES TCP Task 41 Economics of energy storage

	What is to be done?	Subtask Lead
Subtask 1 Methods to evaluate energy storage economics	Collect and classify methods to evaluate storage economics	KTH, Sweden Felipe Gallardo
Subtask 2 Acceptable energy storage costs from application perspective	Extend top-down approach to all types of energy storage (both capacity and power)	ZAE, Germany Christoph Rathgeber
Subtask 3 Success stories and difficult cases of energy storage systems	Collect and analyse economically viable and non-viable examples	DTU, Denmark Jianhua Fan
Subtask 4 Energy storage valuation framework	Elaborate a method to develop business cases for energy storage systems	TNO, The Netherlands Joris Koornneef

energy storage
IEA Technology Collaboration Programme

NEWLY LAUNCHED

Duration of the project:

10.2022-09.2025

Kick-off meeting:

Berlin, September 14-16, 2022

Danish partners:

PlanEnergi

Aalborg CSP


Thank you
jifa@dtu.dk