SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

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"Solar energy supply concepts for buildings and districts in an international context"

Solar energy supply concepts for buildings and districts

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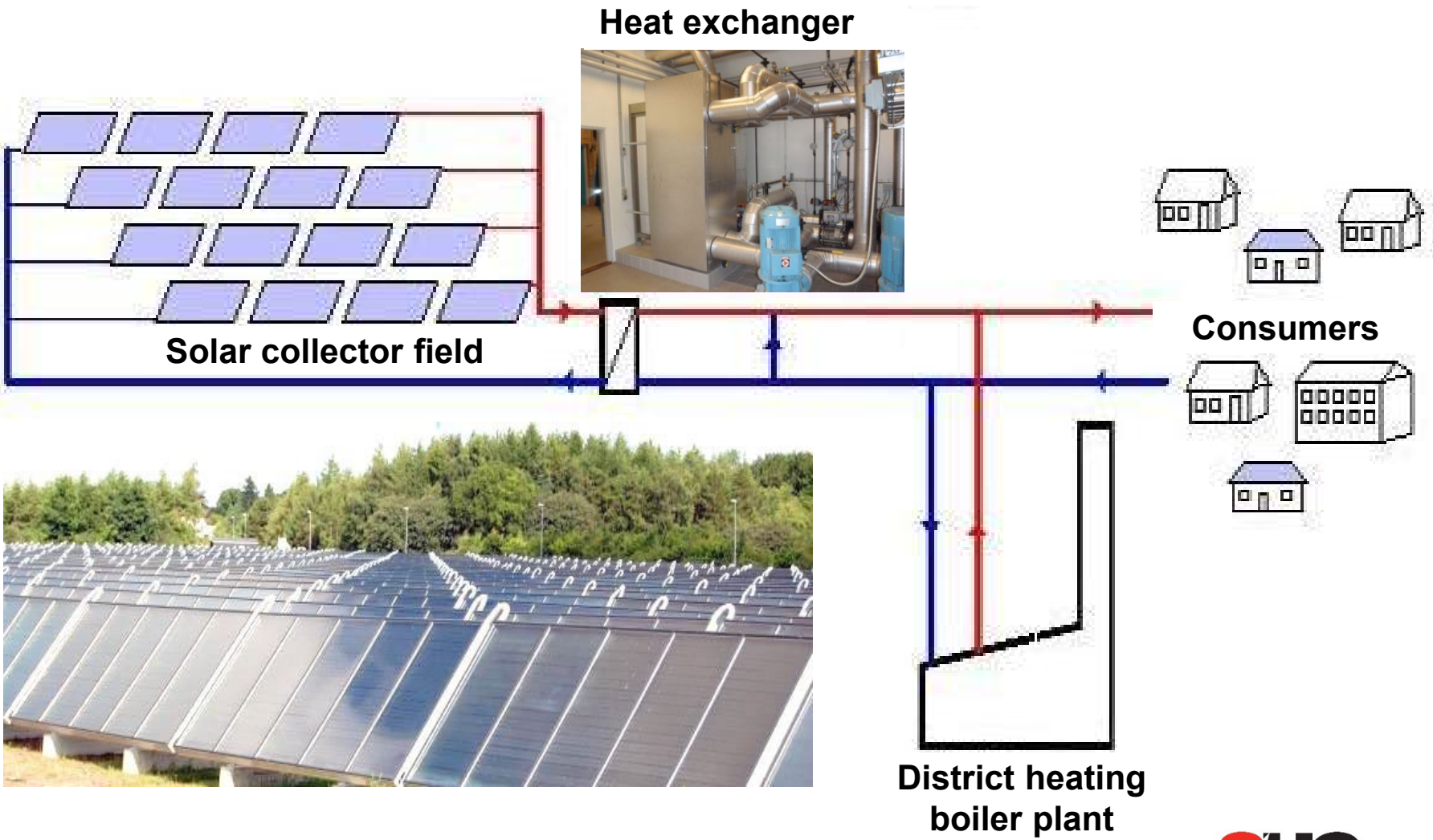
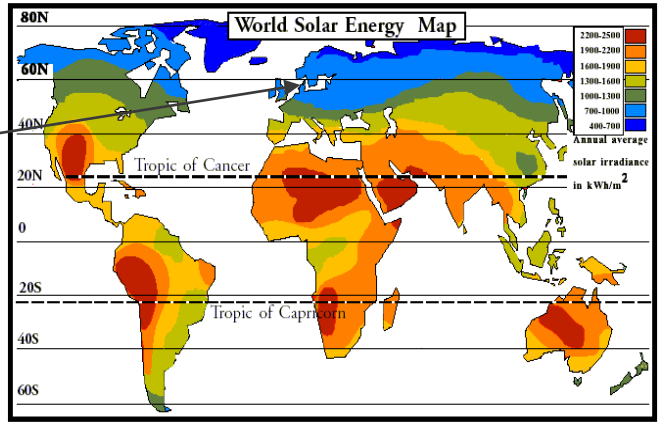
Solar heating plant - principle



Solar district heating plants in the World by end of 2022:

- **571 solar heating plants > 500 m². 123 in Denmark, 22%**
- **3,100,000 m² in operation. 1,606,591 m² in Denmark, 52%!**

Denmark



Large-scale systems for solar district heating
Collector area, Capacities installed and number of systems by country (2022)

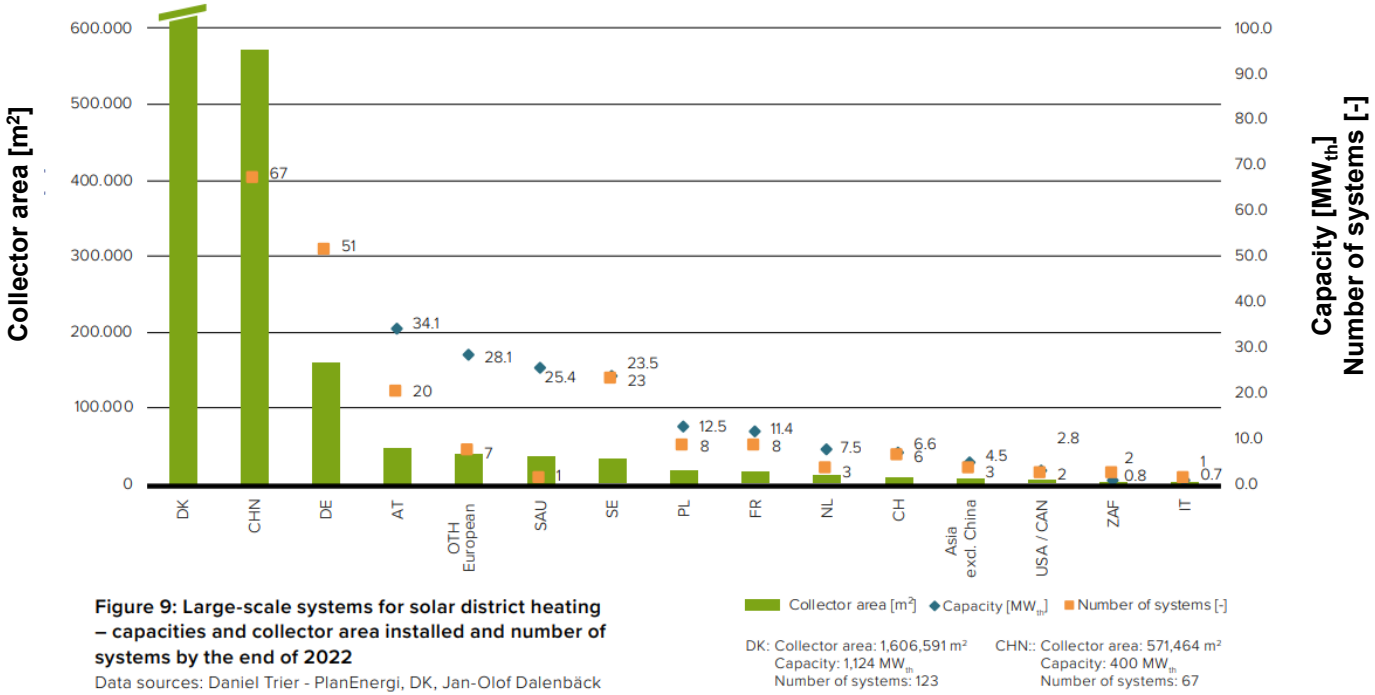


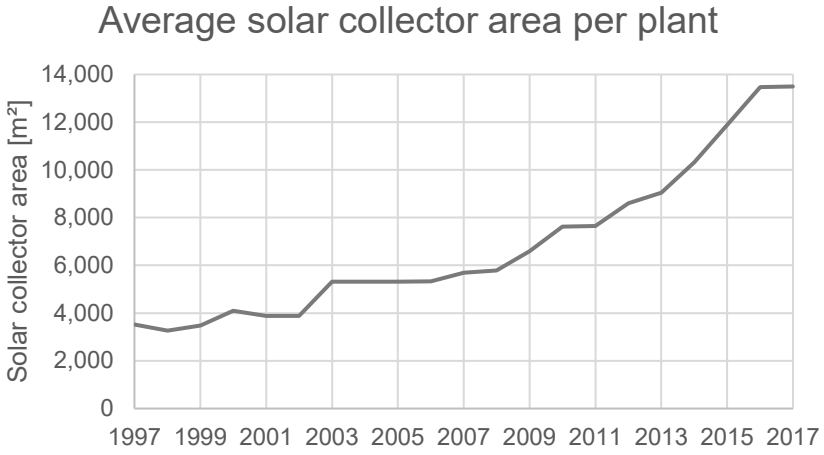
Figure 9: Large-scale systems for solar district heating – capacities and collector area installed and number of systems by the end of 2022

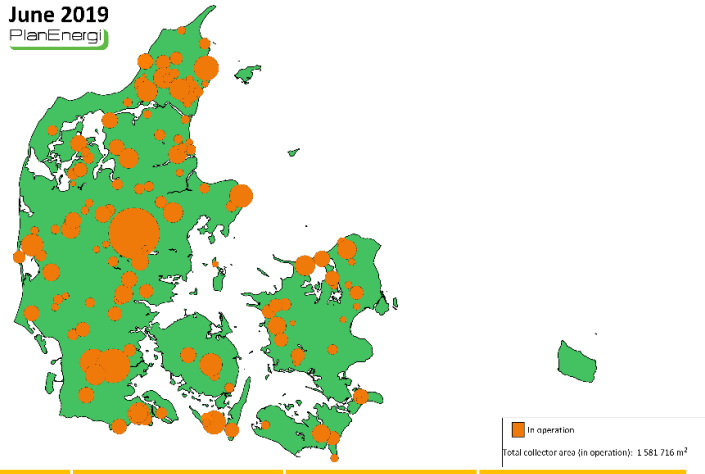
Data sources: Daniel Trier - PlanEnergi, DK, Jan-Olof Dalenbäck - Chalmers University of Technology, SE, Sabine Putz - IEA SHC Task 55, AT, Bärbel Epp - solrico.com, DE[9].

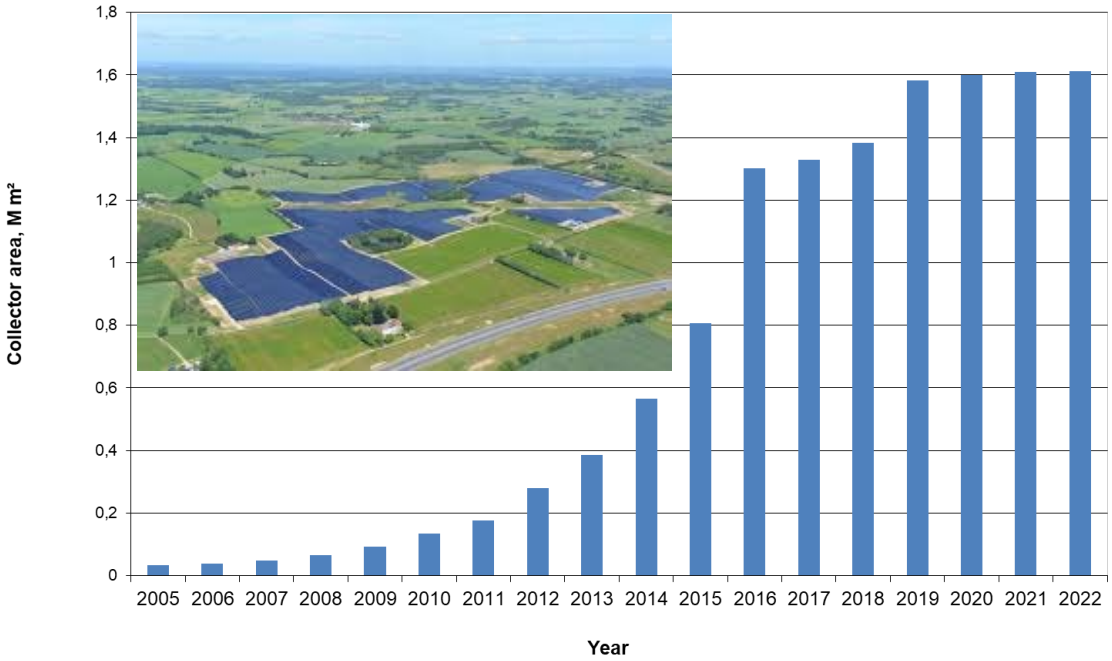
DK: Collector area: 1,606,591 m²
Capacity: 1,124 MW_{th}
Number of systems: 123

CHN:: Collector area: 571,464 m²
Capacity: 400 MW_{th}
Number of systems: 67

Solar heating plants in Denmark







Year	Total district heating, PJ/year	Solar district heating, PJ/year	Solar district heating, %
2011	132	0.33	0.3
2012	136	0.55	0.4
2013	135	0.68	0.5
2014	122	0.98	0.8
2015	130	1.26	1.0
2016	135	2.03	1.5
2017	136	1.93	1.4
2018	132	2.47	1.9
2019	131	2.59	2.0
2020	127	2.87	2.3
2021	141	2.58	1.8
2022	145	2.97	2.0

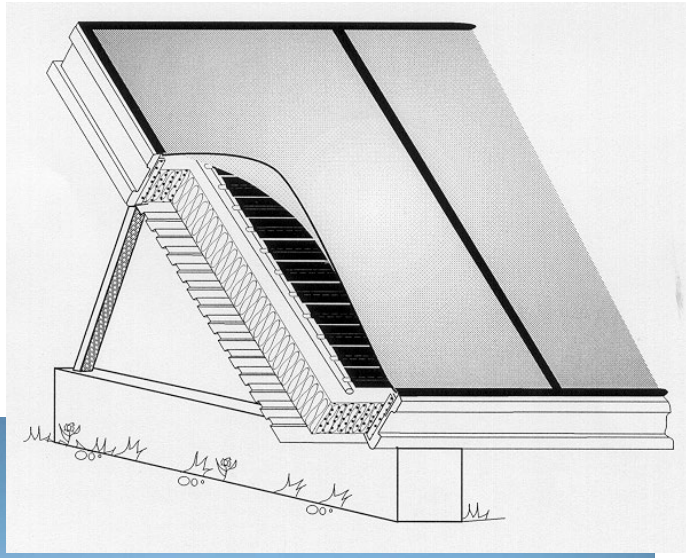
Corresponds to about 1% of Denmark's total yearly energy consumption

Solar heating plants

Flat plate solar collectors from GreenOneTEC, Austria

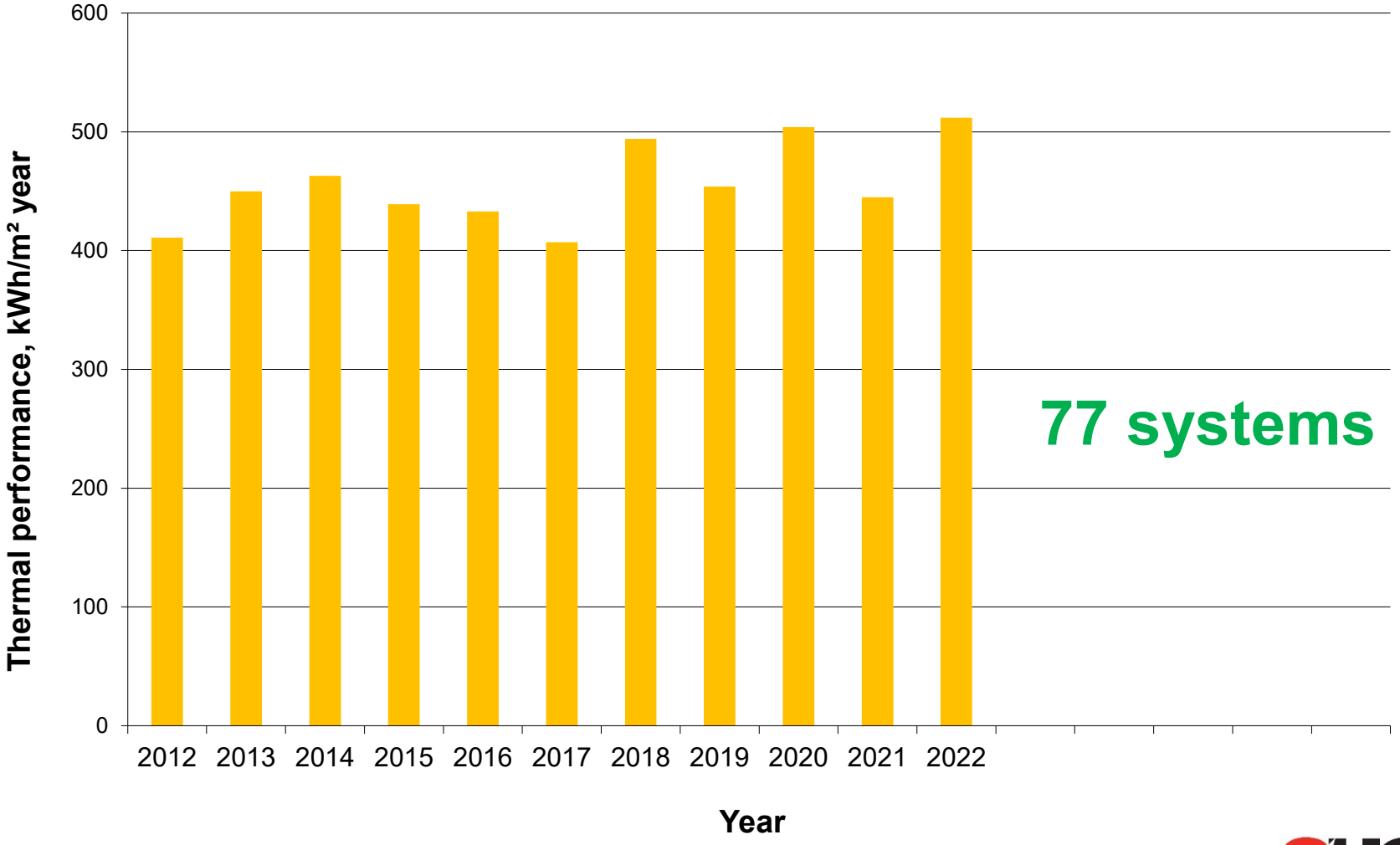
Collectors with foil between absorber and glass

Collectors without foil between absorber and glass



- ☺ Easy installation
- ☺ Easy start up
- ☺ Simple piping with low heat loss and low heat capacity
- ☺ Cheap and reliable
- ☺ Few employed

Average yearly thermal performance for Danish solar heating plants



Measured yearly thermal performances and solar radiation - summary

- Thermal performance: 313 - 638 kWh/m² collector
  Average thermal performance: **407 - 512 kWh/m² collector**

- Solar radiation on collectors: 843 - 1625 kWh/m²
  Average solar radiation on collectors: **1101 - 1246 kWh/m²**

- Utilization of solar radiation: 26 - 58%
  Average utilization of solar radiation: **36 - 45%**

Lifetime for solar collectors

Investigations:

- 13 and 15 years old solar collectors from solar heating plants investigated

Conclusions:

- Reduced thermal performance after about 15 years of operation mainly due to wrong installation of the foil:

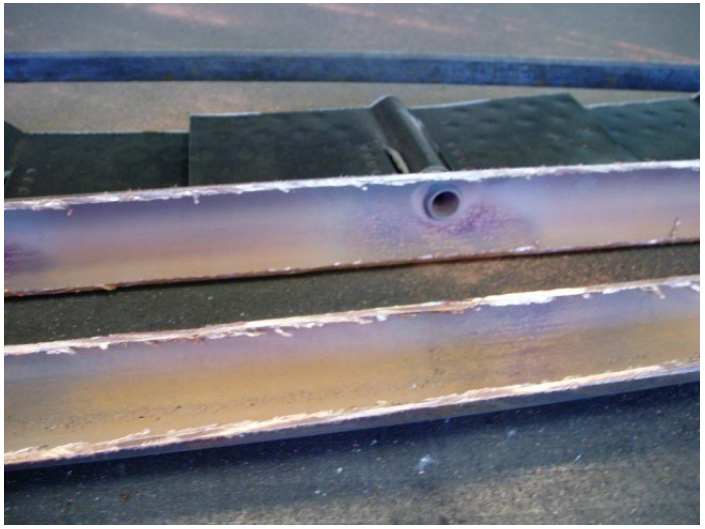
  40°C: About 2%

  60°C: About 10%

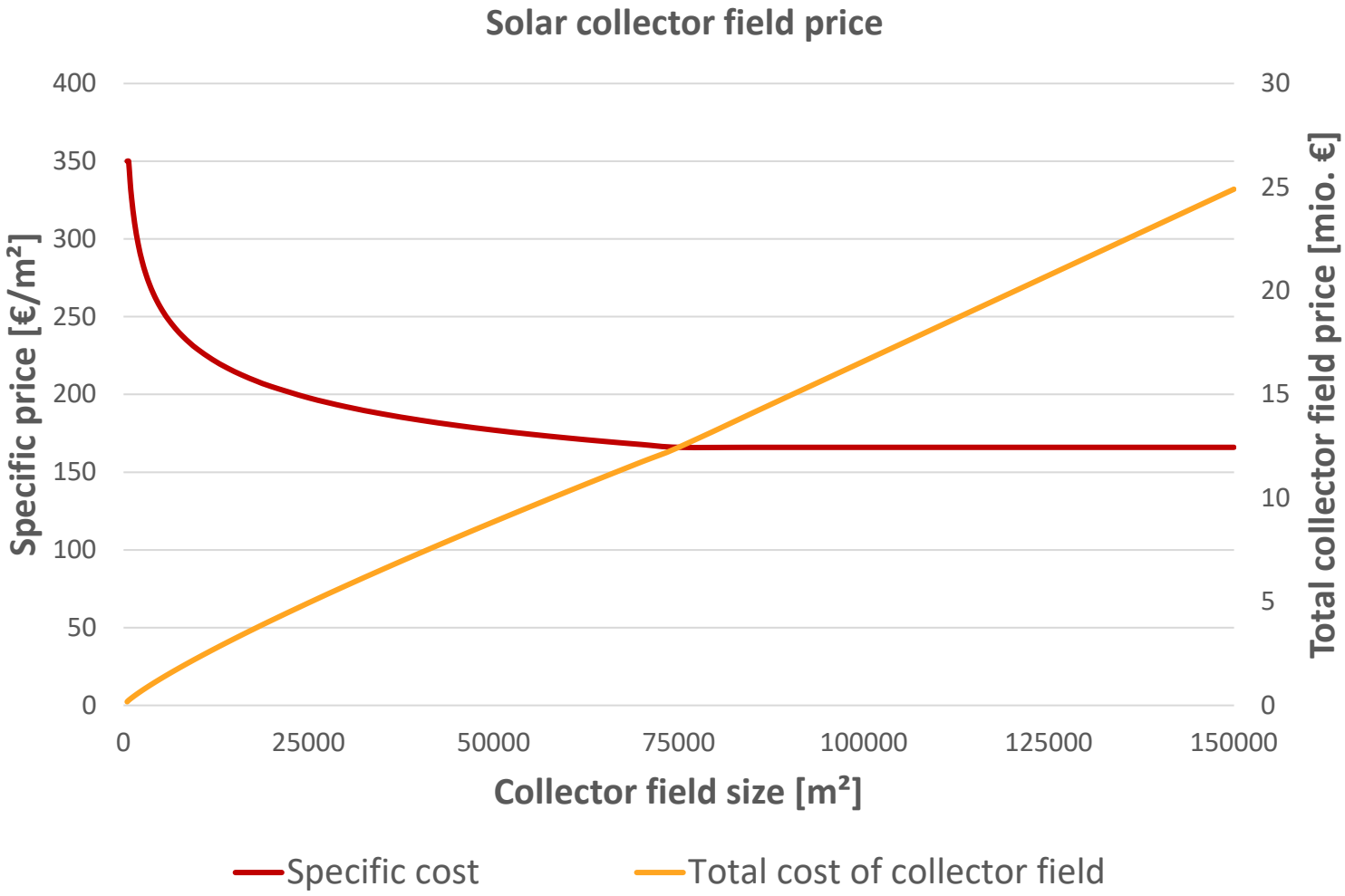
  80°C: About 25%

☺ Life time of solar collectors: > 30 years!

☺ Most likely: New collectors without foil problems



Investment cost per m² collector



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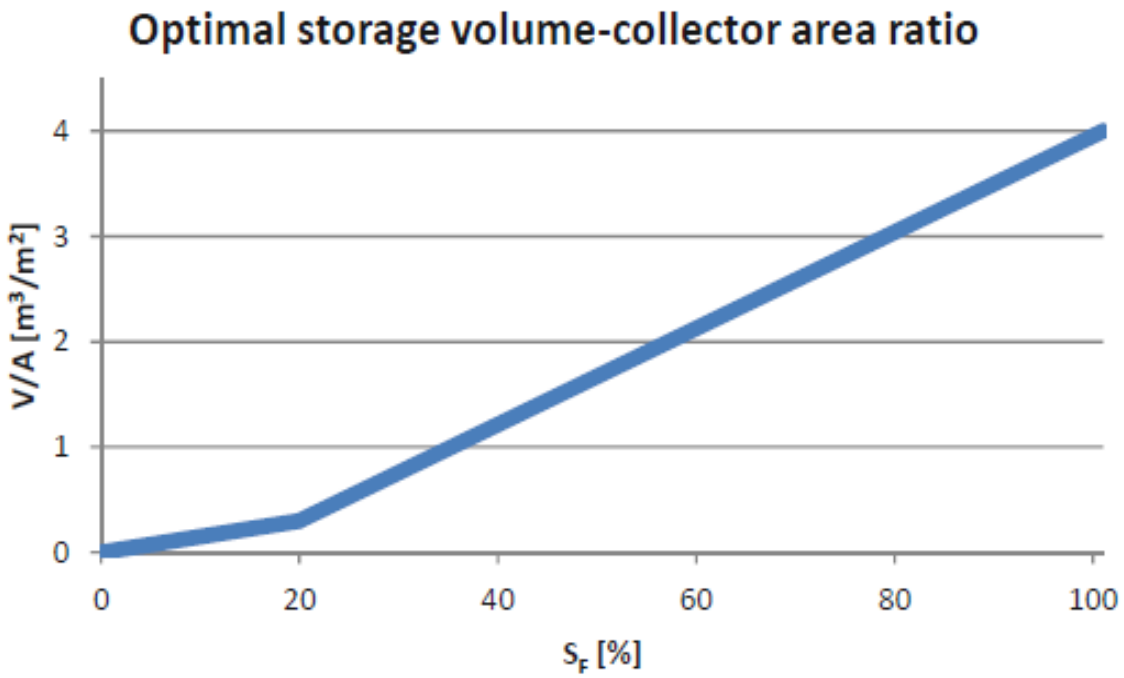
How large heat stores are needed?

Solar fraction (SF): Solar heat produced/total production of the entire heating plant

$$SF = Q_{solar\ output} / Q_{total,production}$$

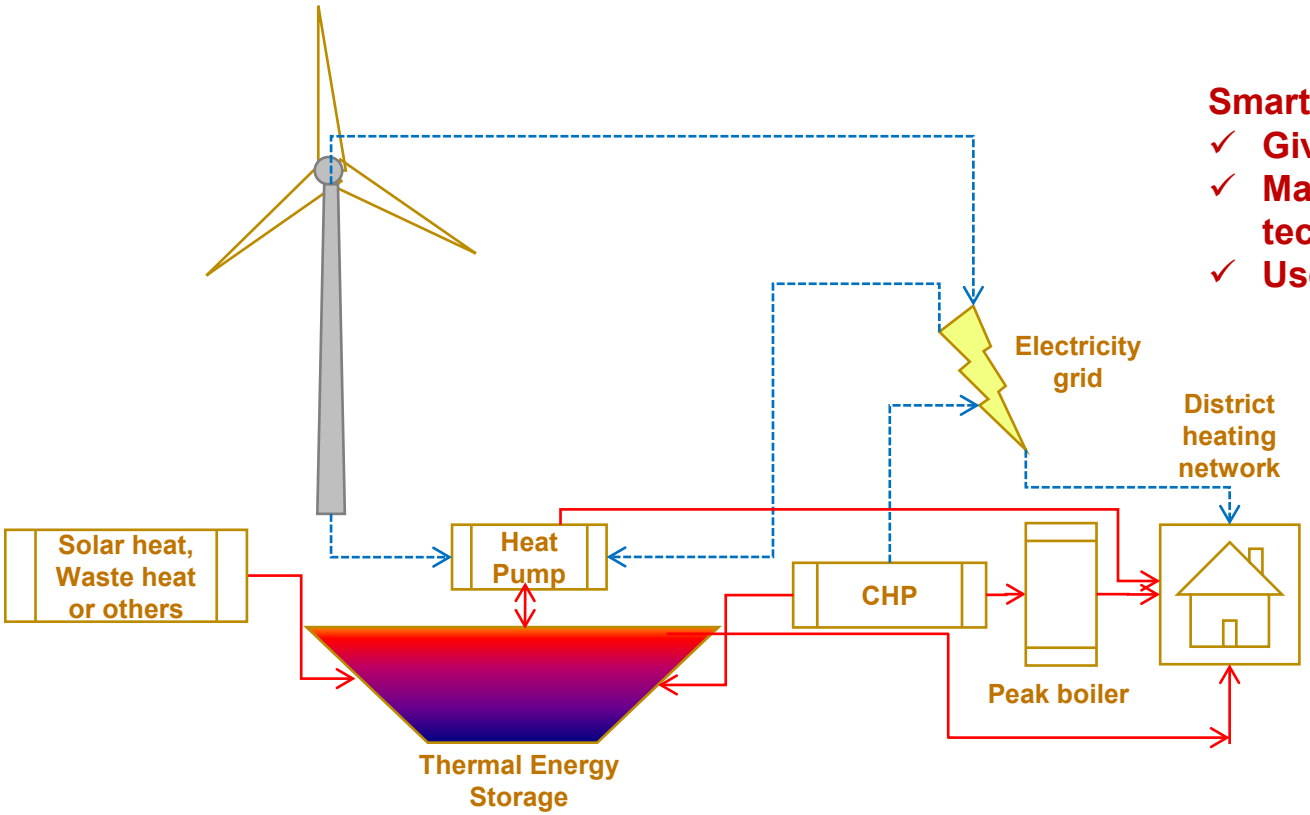
In Denmark, SF>20% can be achieved if long-term heat storage is installed



Especially for large SF - and if combined with a heat pump - the storage volume should be determined with detailed calculations/simulations.

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

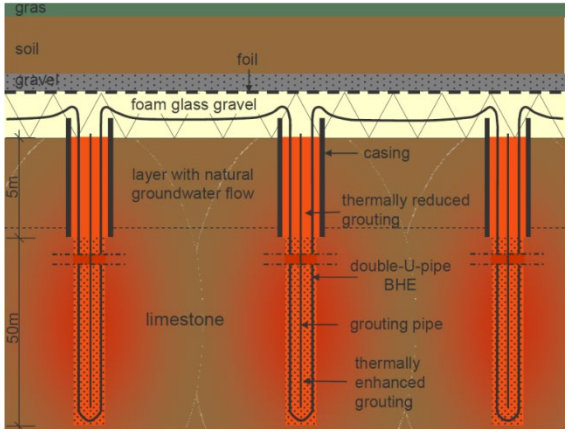
Different types of heat storages for district heating

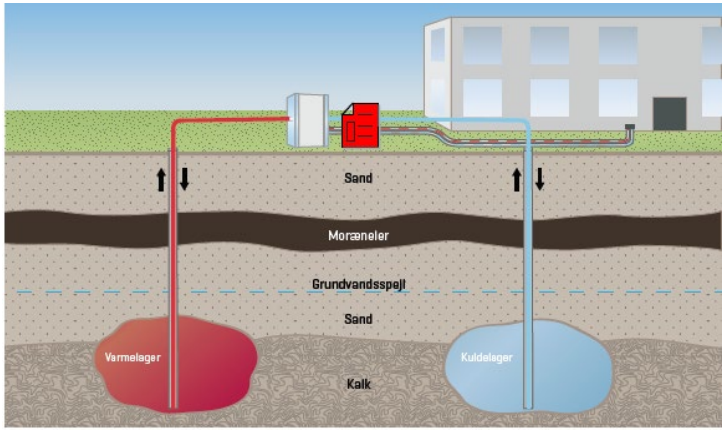
Tank heat storage (TTES)

Most attractive in Denmark

Water pit (PTES)

Borehole storage (BTES)



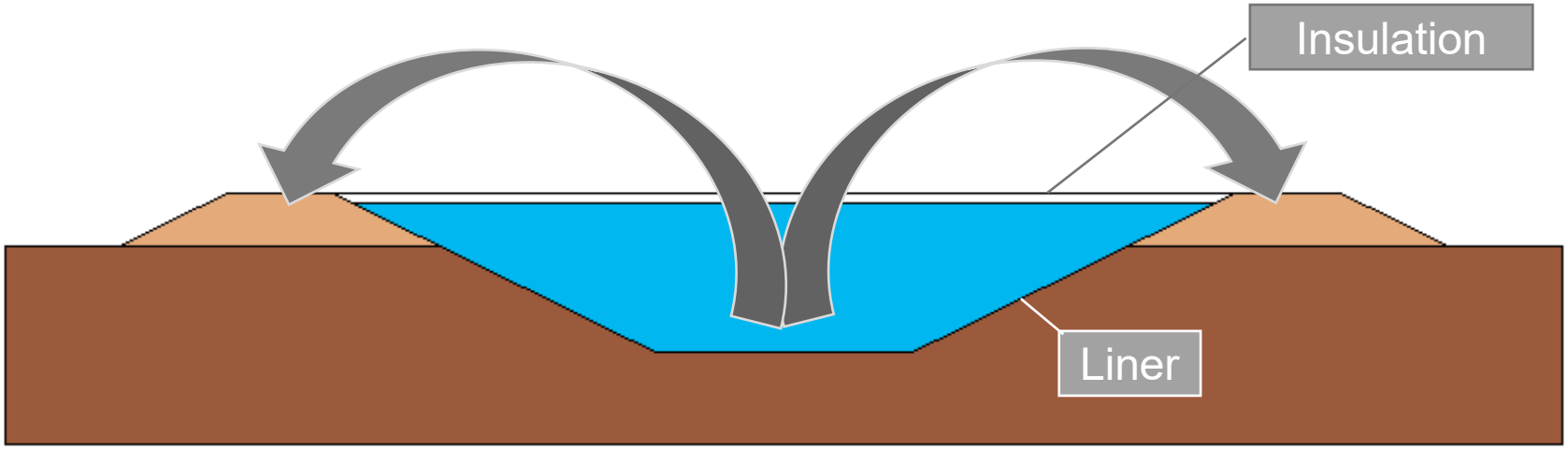


Aquifer storage (ATES)

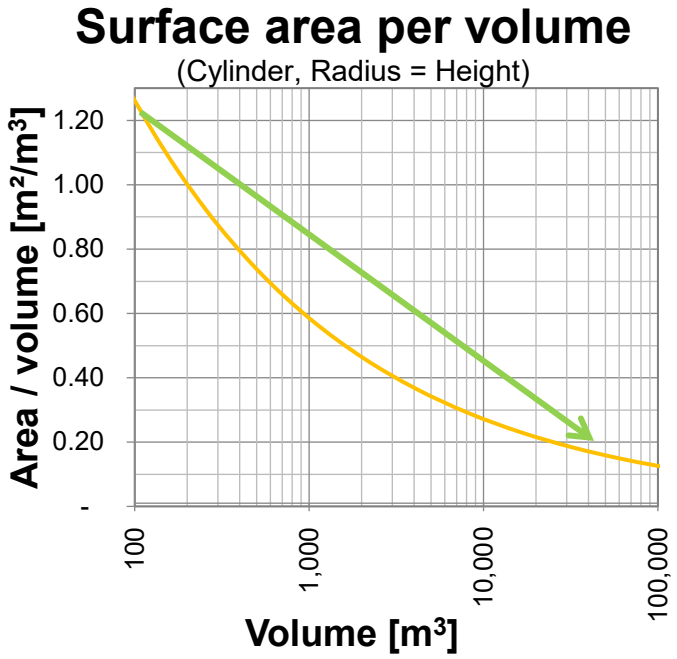
Design of the water pit storage

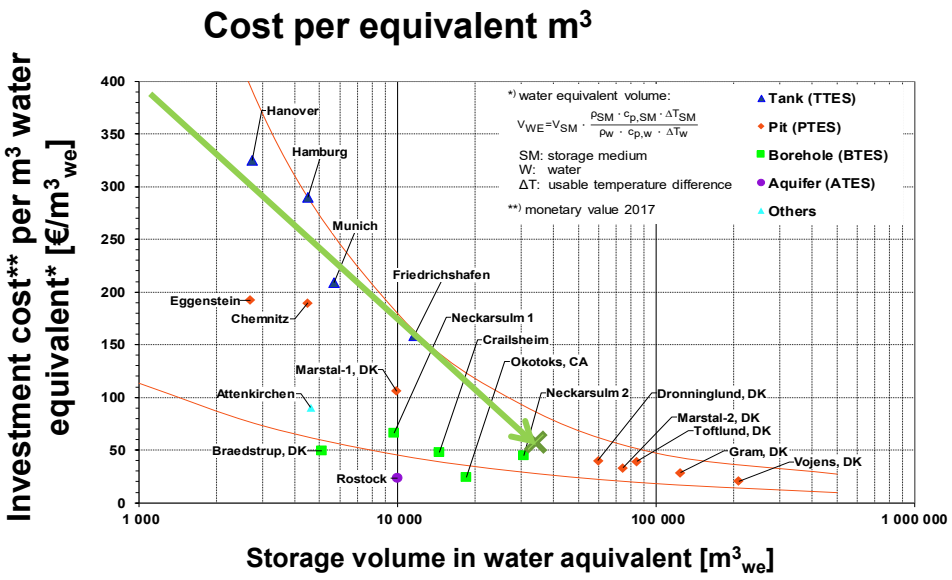
Shape and soil balance

The soil excavated from the bottom part of the storage is used as embankments around the upper part of the storage.



Thermal energy storage:
Big is beautiful





Source: SOLITES

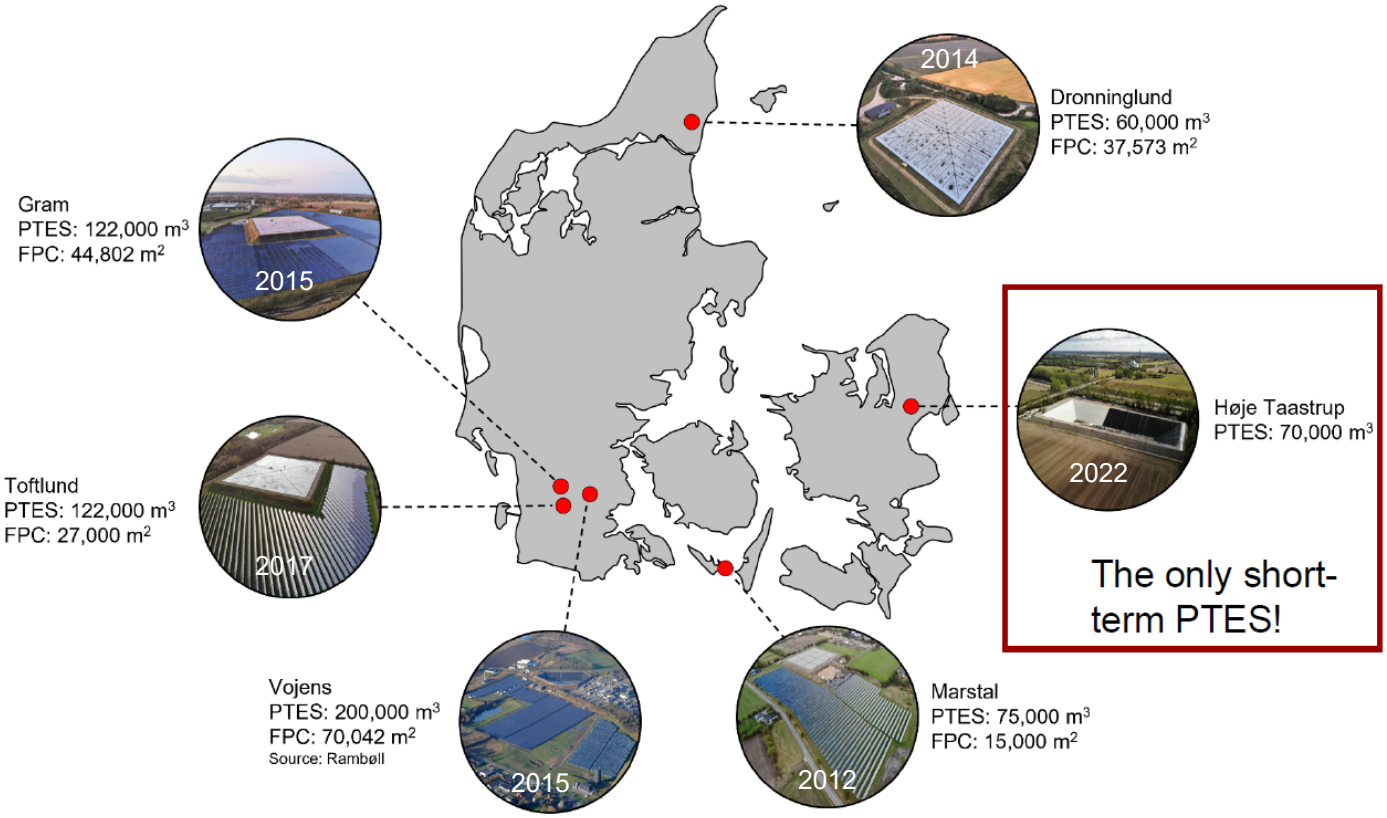
1.2 → 0.1 ➔ Factor 12 on surface area/volume (heat loss/storage capacity)

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

Existing water pit heat storage (PTES) in Denmark

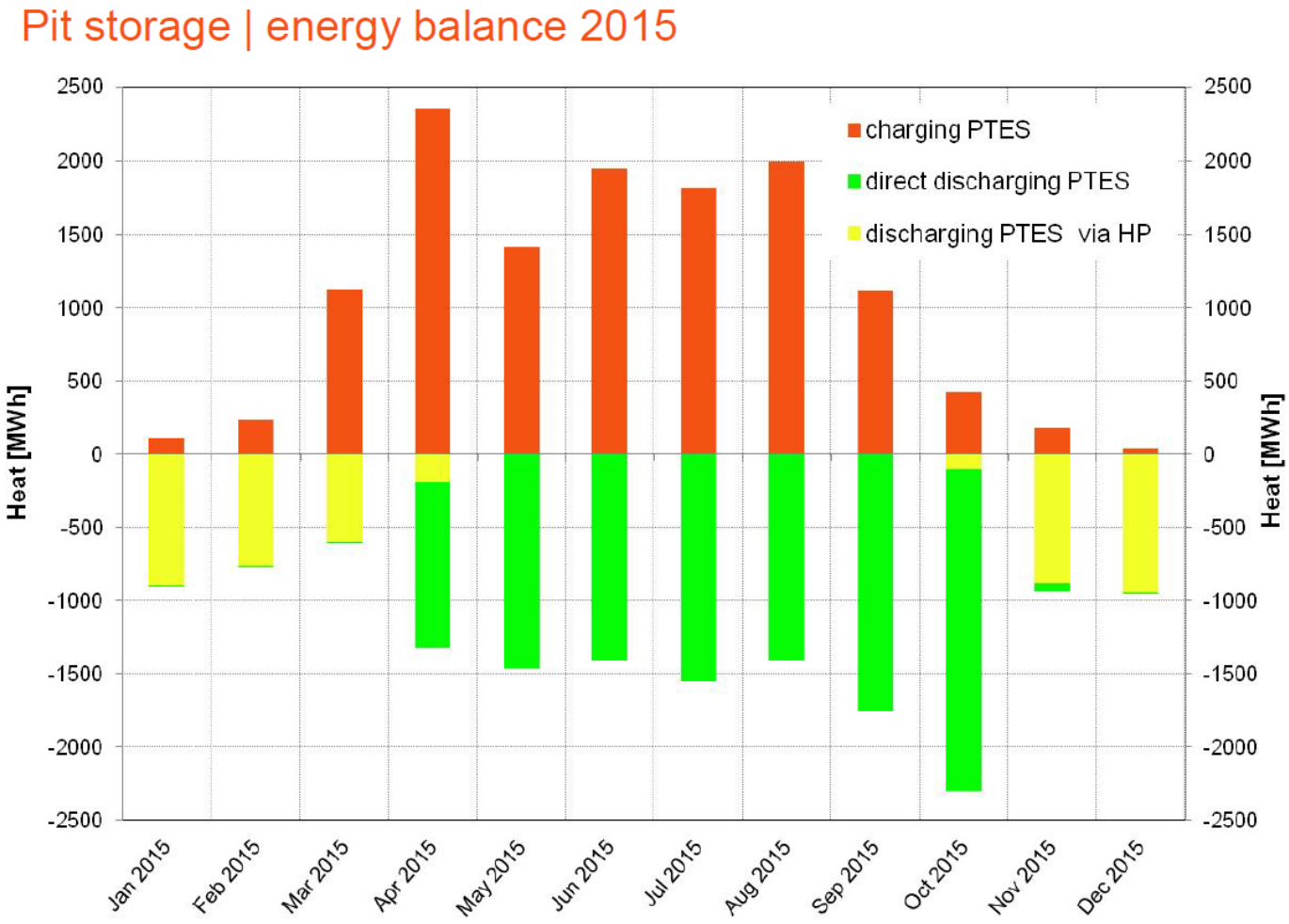
Characteristics

- Seasonal heat storage
- Connected to solar thermal collector field
- Storage operation
  - Direct supply to DH grid
  - Source of heat pump
- Efficiencies of PTES vary from 60 – 90%

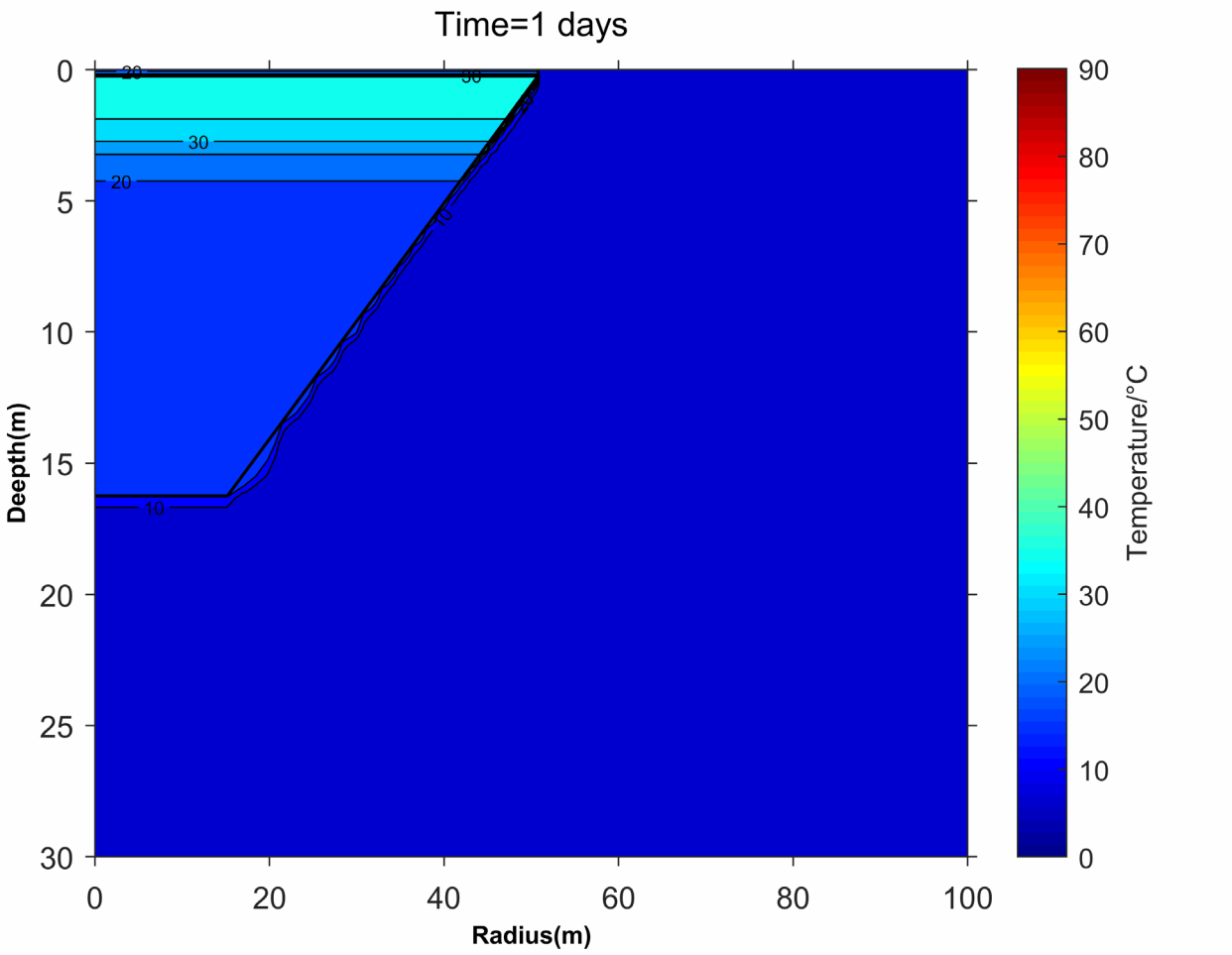


Construction of the PTES in Dronninglund

Charge /discharge of the PTES in Dronninglund



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



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Measurements for water pits for solar heating plants

	Water pit storage, Marstal	Water pit storage, Dronninglund	Water pit storage, Gram
Size	**75000 m^3 water**	**62000 m^3 water**	**110000 m^3 water**
Maximum storage temperature	**90°C**	**90°C**	**90°C**
Heat recovered from heat storage during first year	**18%**	**78%**	**55%**
Heat recovered from heat storage during second year	**65%**	**90%**	**50%**
Heat recovered from heat storage during third year	**66%**	**91%**	**50%**
Heat recovered from heat storage during fourth year	**66%**	**96%**	**42%**
Heat recovered from heat storage during fifth year	**39%**	**85%**	

Water pits - challenges

- Floating lid - water in insulation
- Removal of rainwater from the top of lid
- Water quality/corrosion/lifetime
- Liner/lifetime
- Construction
- Inlet arrangement
- Optimal operation

What is important?

Temperature level of district heating system low – for decreasing temperature the thermal performance is increasing

Before investing in a solar heating plant:

- Optimize the existing energy production units
- Focus on consumer installations – low return temperature is of vital importance for high thermal performance of a solar heating plant

What is optimal size?

Depends on your focus

- Highest performance/m²: 2-5% solar fraction
- Highest solar fraction with existing production system/heat storage: 15-20% solar fraction
- Highest solar fraction achieved until today: 40-45% solar fraction - long term heat storage needed
- Remember the interplay with the whole energy system

Future

The first % is the most difficult to achieve

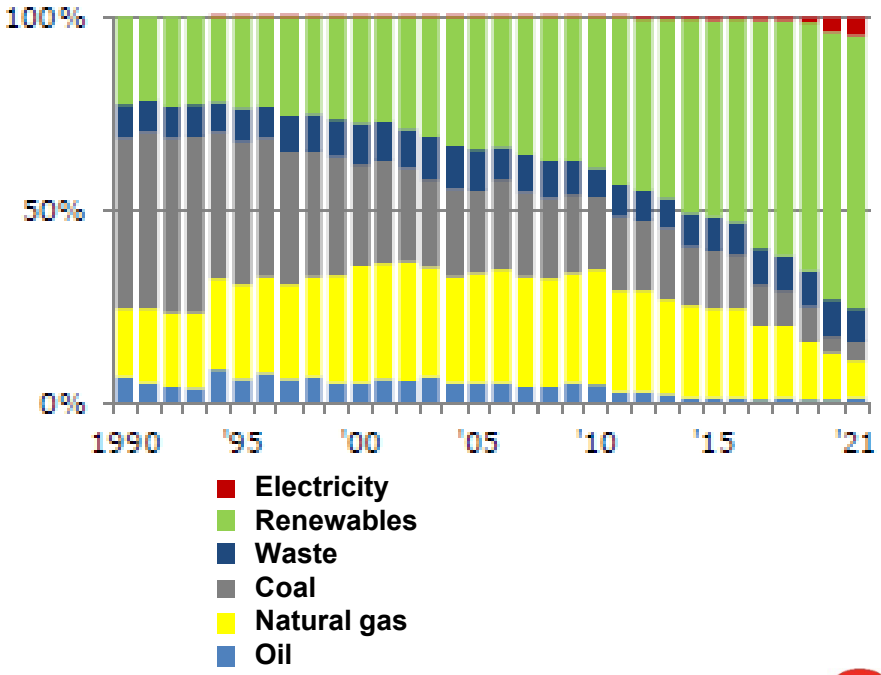
Reasons for rapid growth of Danish solar heating plants

- Ambitious Danish energy plan. By 2050, independent of fossil fuels
- A lot of district heating. Today 66% of all Danish buildings are heated by district heating
- Low temperature levels in district heating systems. A typical forward temperature to towns is about 80°C and a typical return temperature from towns is about 40°C
- Solar heating plants considered as energy saving measure used to achieve local energy saving targets
- District heating companies often nonprofit cooperatives
- High taxes for fossil fuels. Typical tax is about 0.035 euro/kWh produced heat
- Decentralized energy supply system
- High share of wind energy for electricity production. In 2022, 53% of the Danish electricity consumption was produced by wind turbines.
- Low costs for marketed solar collector fields installed on the ground, about 150 euro/m²
- Relative low ground costs
- High efficiency of marketed solar collectors
- Simple, well proven, and reliable technology
- Good cooperation between solar heating plant owners. Regular meetings with experience exchange
- Good thermal performance of existing solar heating plants: About 405-510 kWh/m² year
- Long lifetime of marketed solar collectors, > 30 years
- Low heat price for solar heating plants, about 0.04 euro/kWh
- Ongoing efforts to develop solar collectors and solar collector fields
- Ongoing efforts to develop and demonstrate seasonal heat storage and to improve the interplay with the energy system

Reasons for slow down of Danish market for solar heating plants

- No taxation on biomass
- Today: Heat pumps are installed in large numbers due to good economy
- Danish Energy Agency supports district heating companies installing large heat pumps in district heating systems. Total support in 2021 and 2022: **13.3 M €**
- Taxation of electricity for district heating companies reduced from the start of 2021: From 0.0028 €/kWh to 0.00054 €/kWh - **98% reduction!**

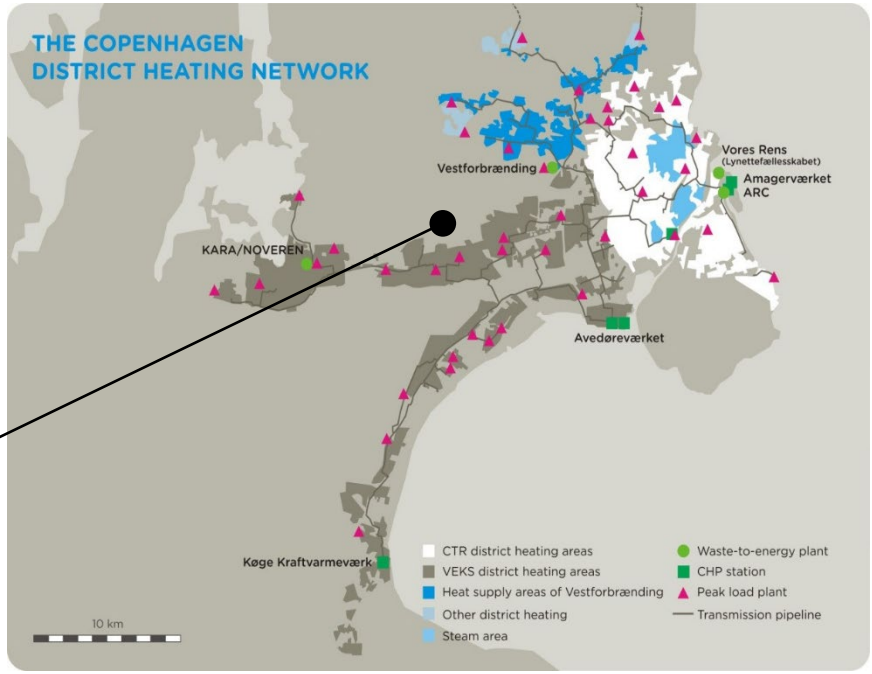
District heating mixture:



Høje Taastrup PTES for Copenhagen district heating

70,000 m^3 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



Thanks for listening!
Questions?

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