Smart Heat Storage for solar heating systems

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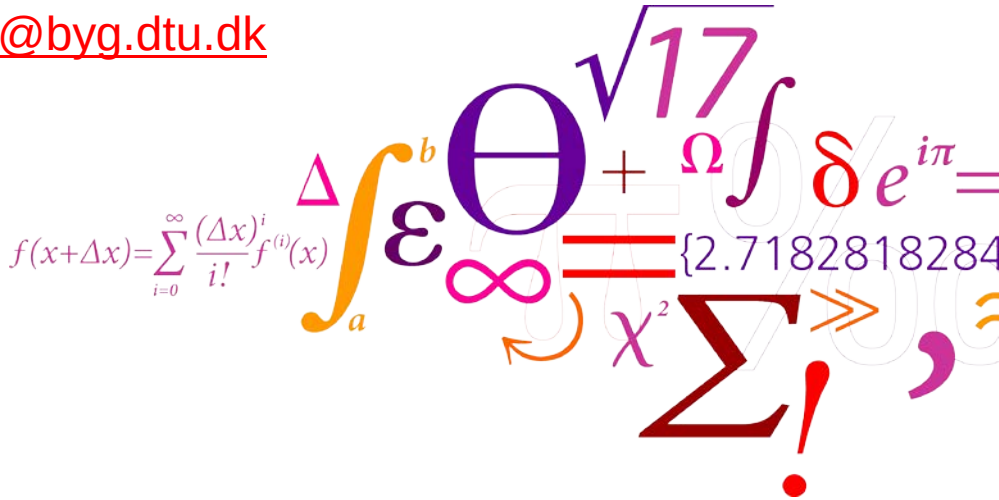

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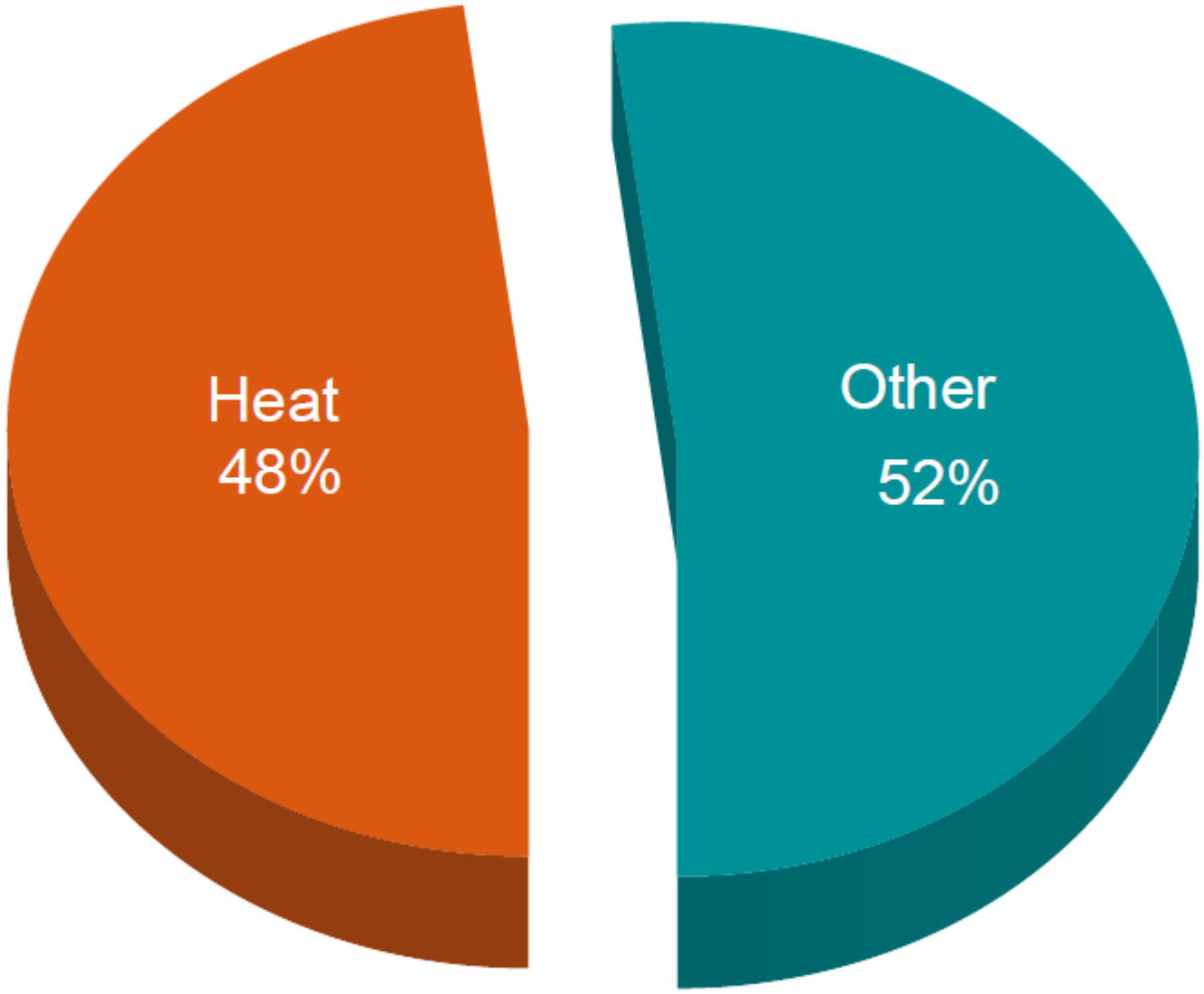
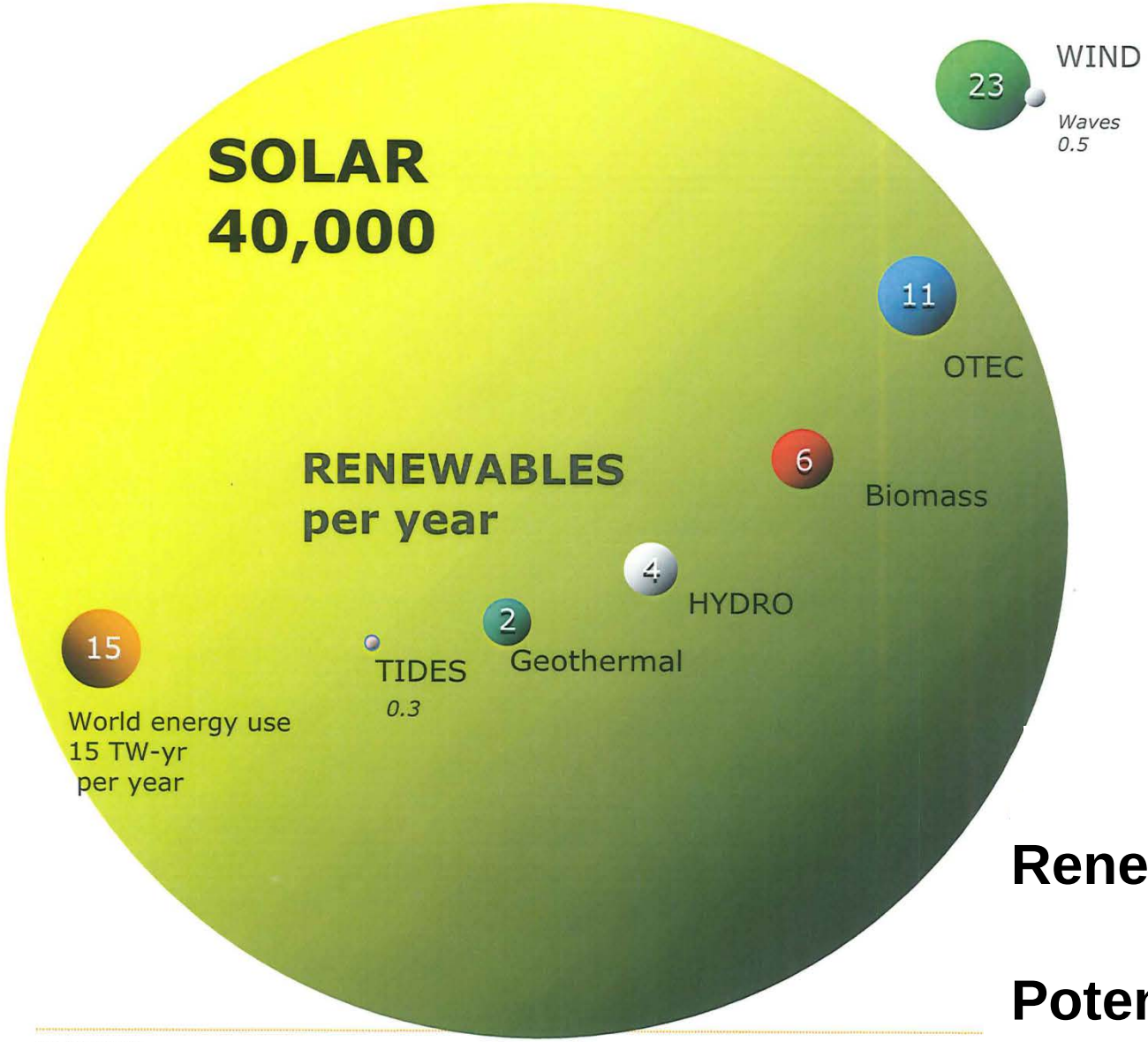


Figure 1 – Form of final energy consumption in the EU

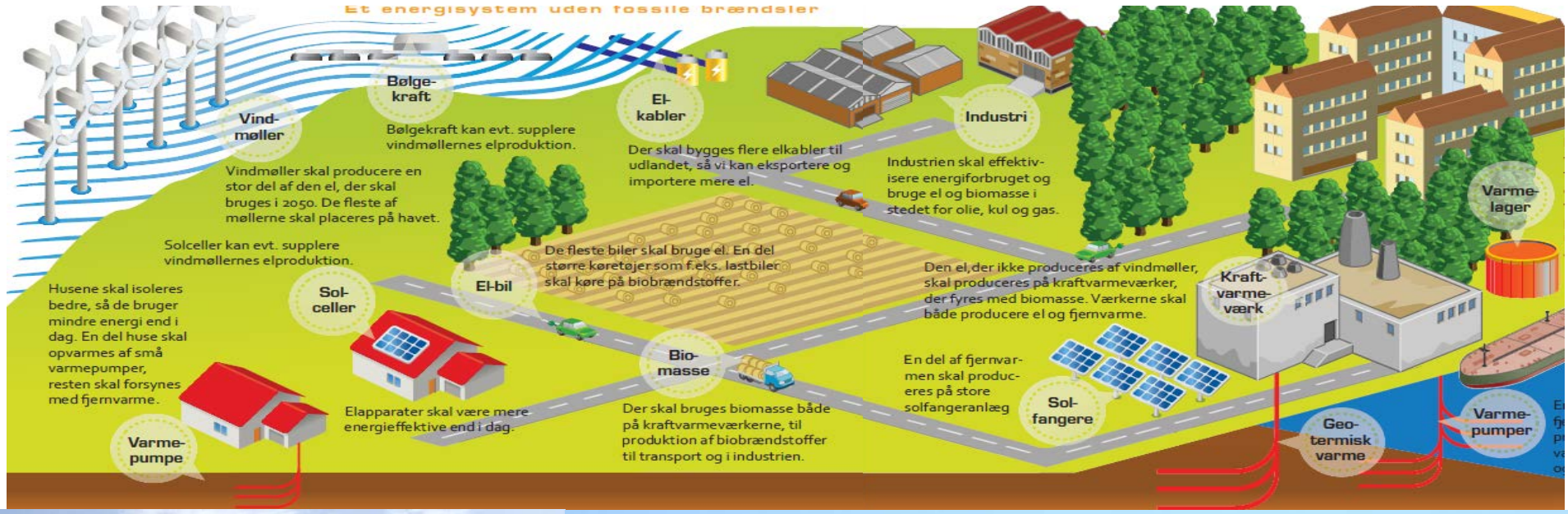
Source: Common Vision for the Renewable Heating & Cooling sector in Europe
European Technology Platform on Renewable Heating and Cooling



Renewables

Potentials

Denmark 2050: All fossil fuels phased out - 2035: All heat and electricity from renewables



Wind energy:

2014, first 6 months: 41% of electricity consumption

2020: 50 % of increased electricity consumption (incl. transport, heat pumps, …)

Solar heating:

2030: 15% of decreased heating demand

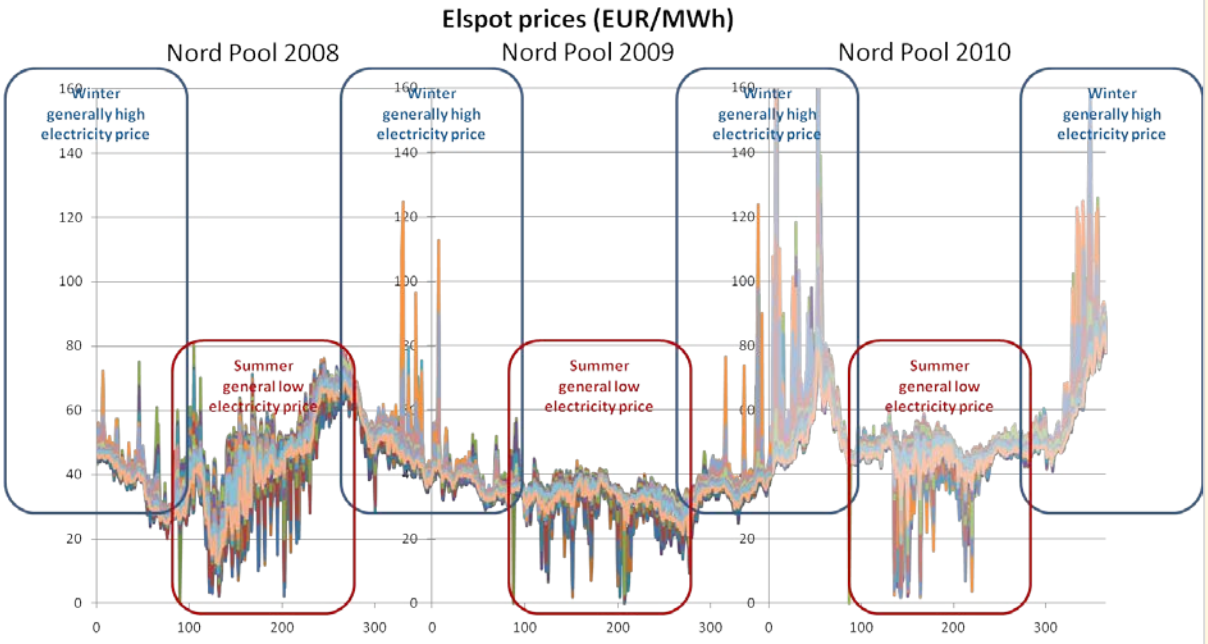
2050: 40% of decreased heating demand - 80% of this by solar heating plants & 20% individual systems

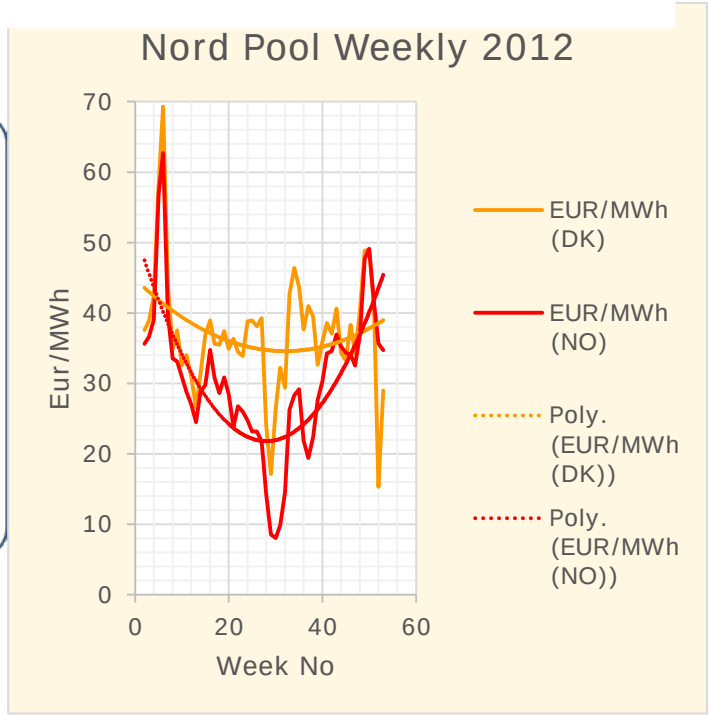
Solar heating systems must have a good interplay with liberal electricity market

Problem:

As renewable electricity production increases:

- **mismatch of production and load will increase**
- **dynamics of the elctricity price will increase**

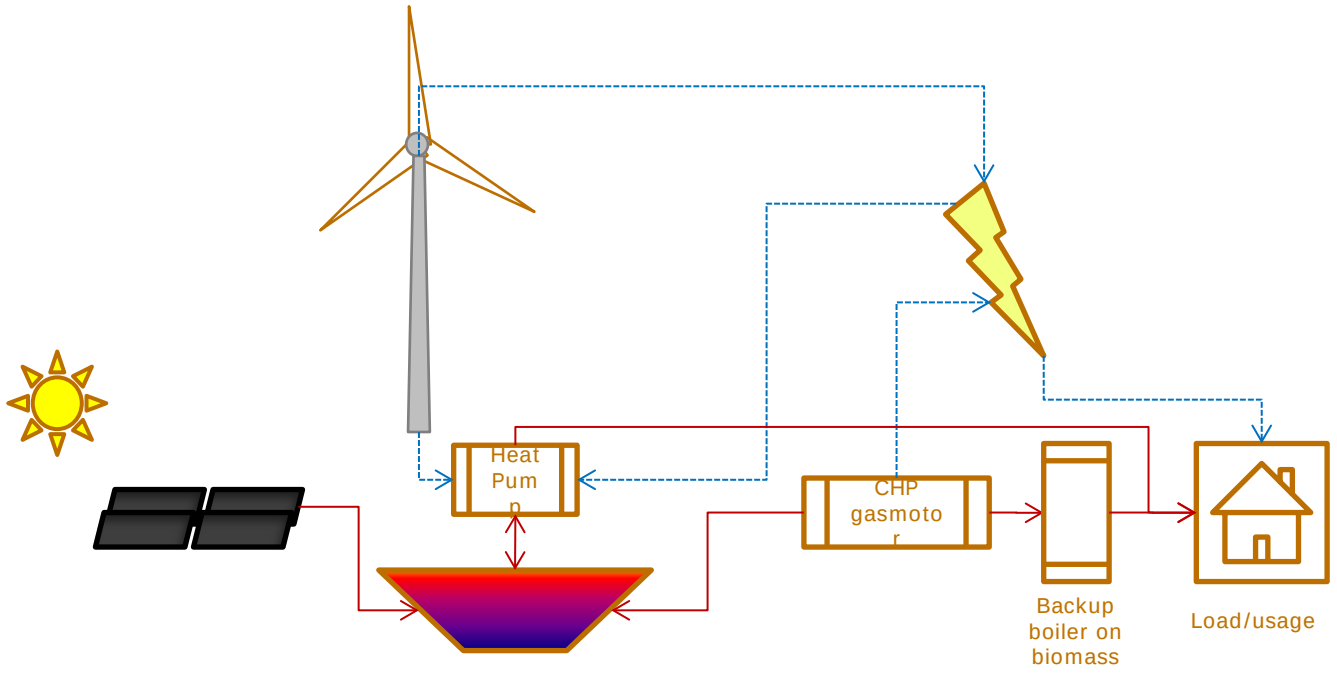




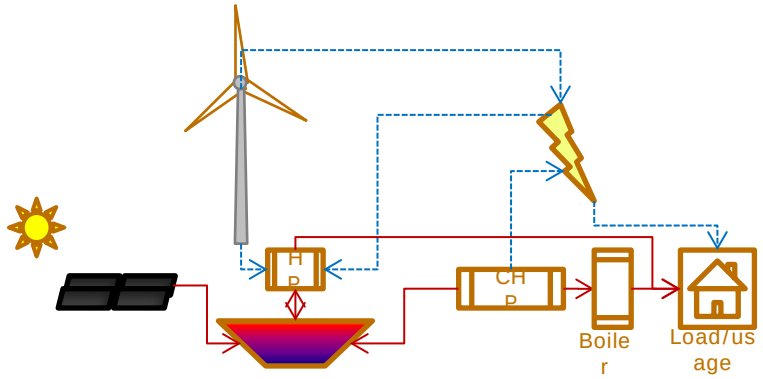
Interplay with liberal electricity market

Solution:

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



Benefits from combining technologies and using heat storage



Solar:
- ✓ Produce free heat

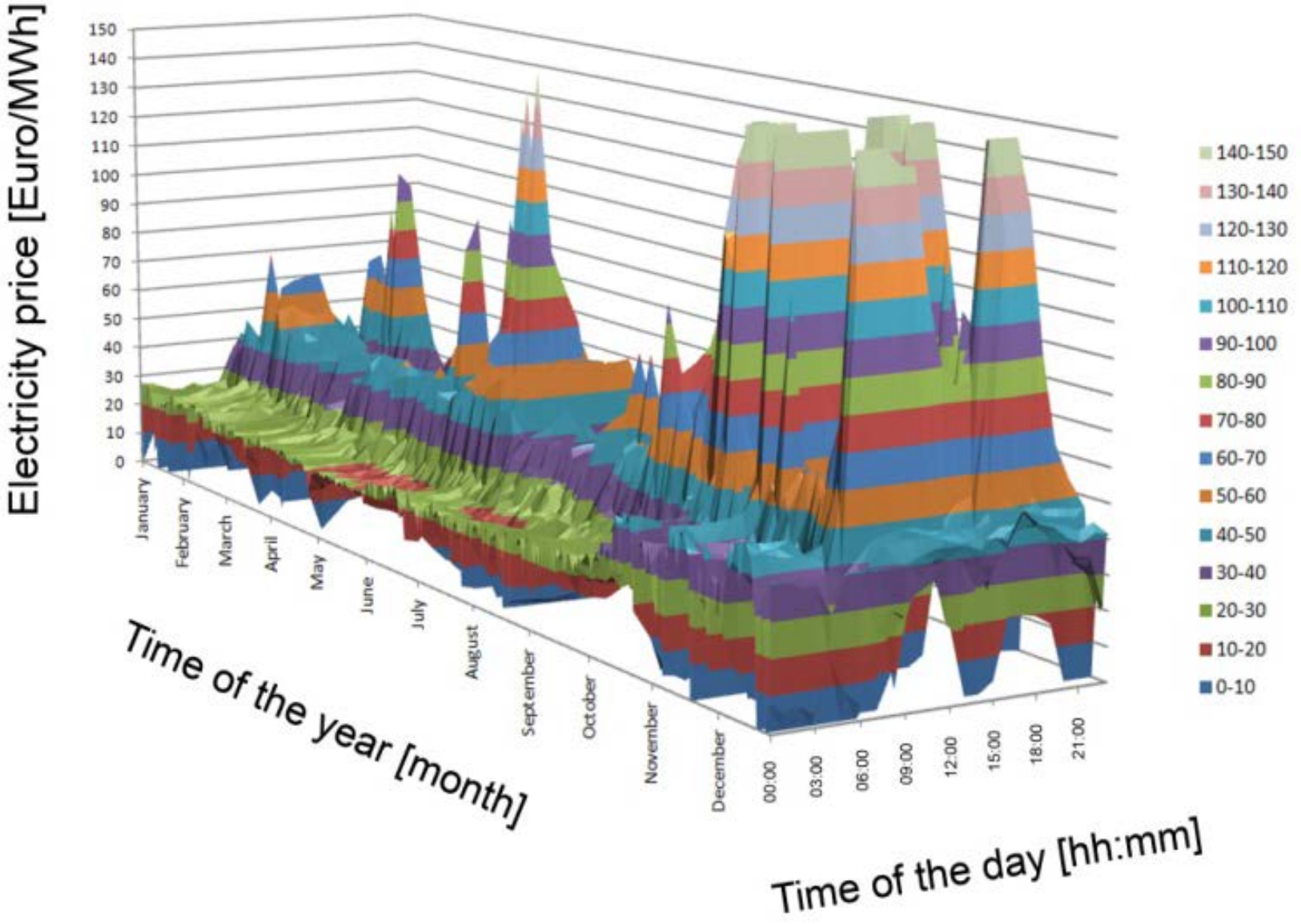
CHP:
- ✓ Produce valuable electricity → earn money
- ✓ Fast capacity regulation (prod.) → earn money

Heat pump:
- ✓ Produce cheap heat
- ✓ Fast capacity regulation (load) → earn money
- ✓ Reduce storage volume

Smart heat storage:
- ✓ Gives the flexibility
- ✓ Makes the combinations of technologies possible

Danmark west, 2007 - from Nordpool

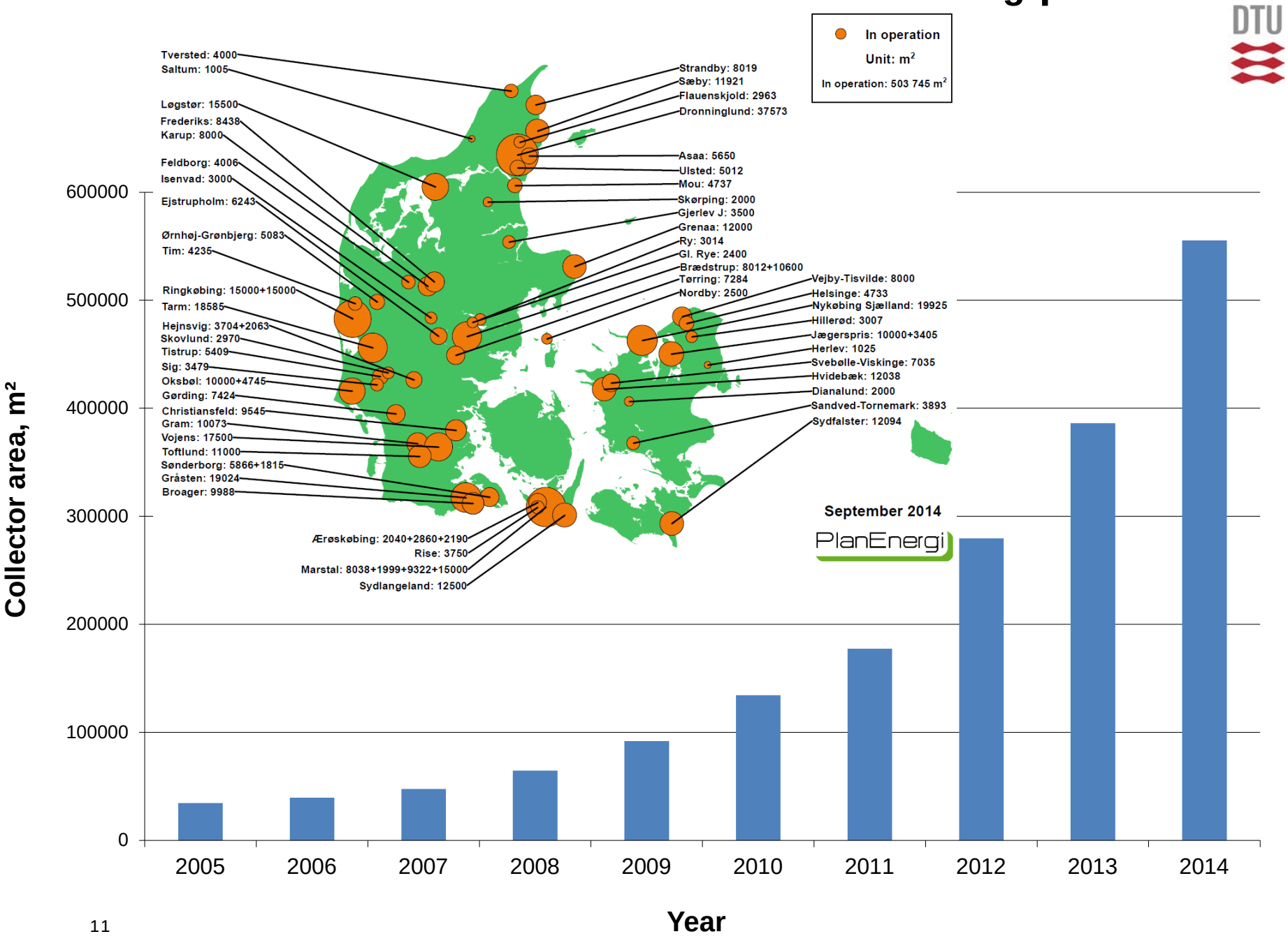
Electricity price variations during one year



Solar heating plant - principle

Solar heating plants

Total solar collector area of Danish solar heating plants



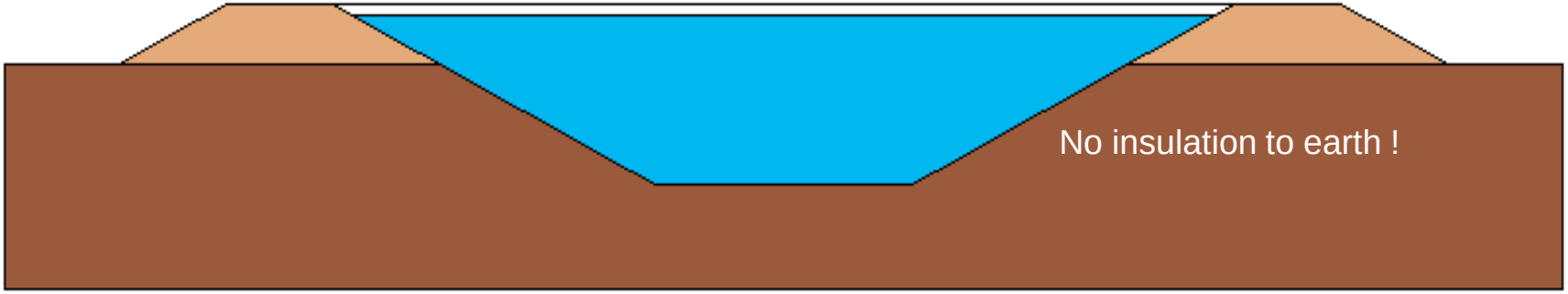
Interaction with dynamic electricity production

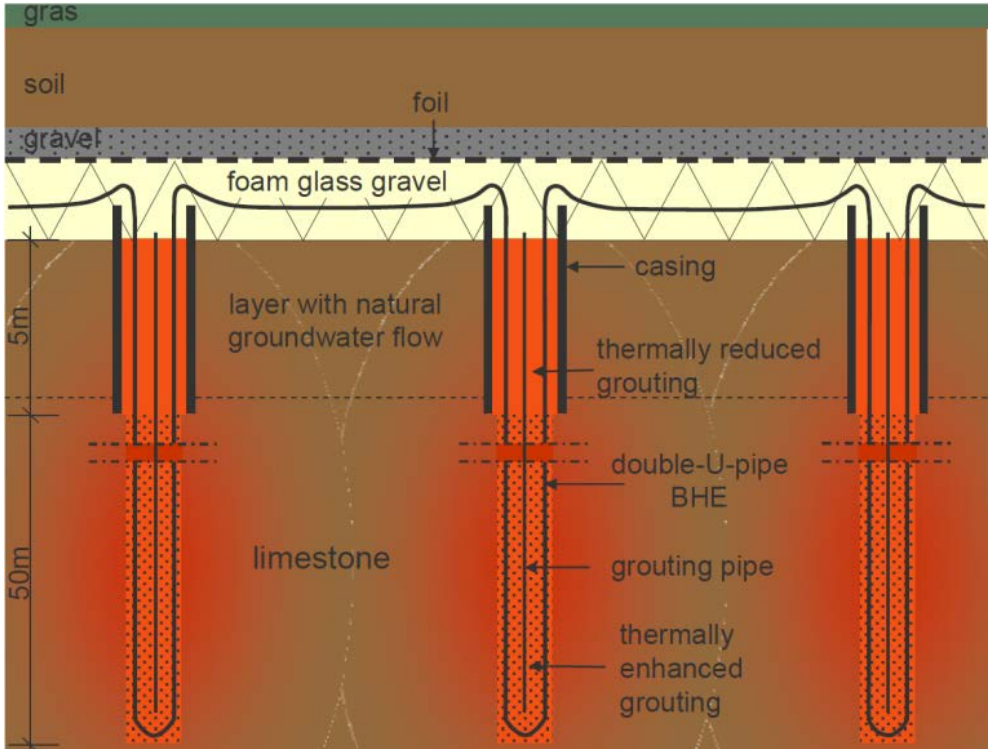
Simple solar heating plants with solar fractions of 5-25% are most common so far, collector areas about 10000 m²

But it seems also to be cost effictive to go for higher solar fractions/**long term heat storage** due to:

- Simple heat storage technologies
- Large heat storages with small heat losses and low costs per volume
- Interplay with liberal electricity market
- Advantages by combining technologies

Cheap storage technology, water pond and borehole storage





Heat capacity per volume:

- Water: 4.1 MJ/Km^3
- Soil: About 2.7 MJ/Km^3

Marstal - seasonal heat storage - 75000 m^3 water pond

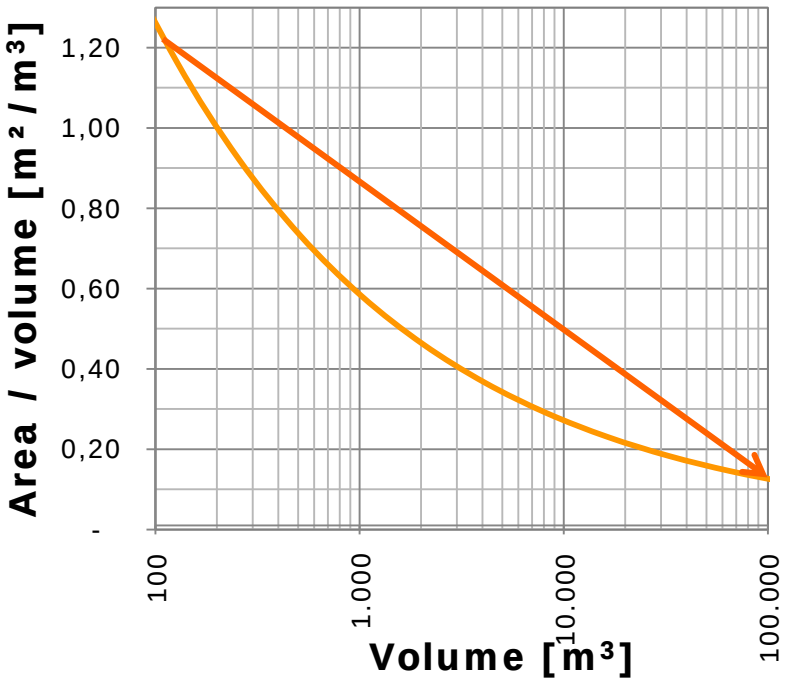

04/24/2012

Dronninglund - seasonal heat storage - 60000 m^3 water pond

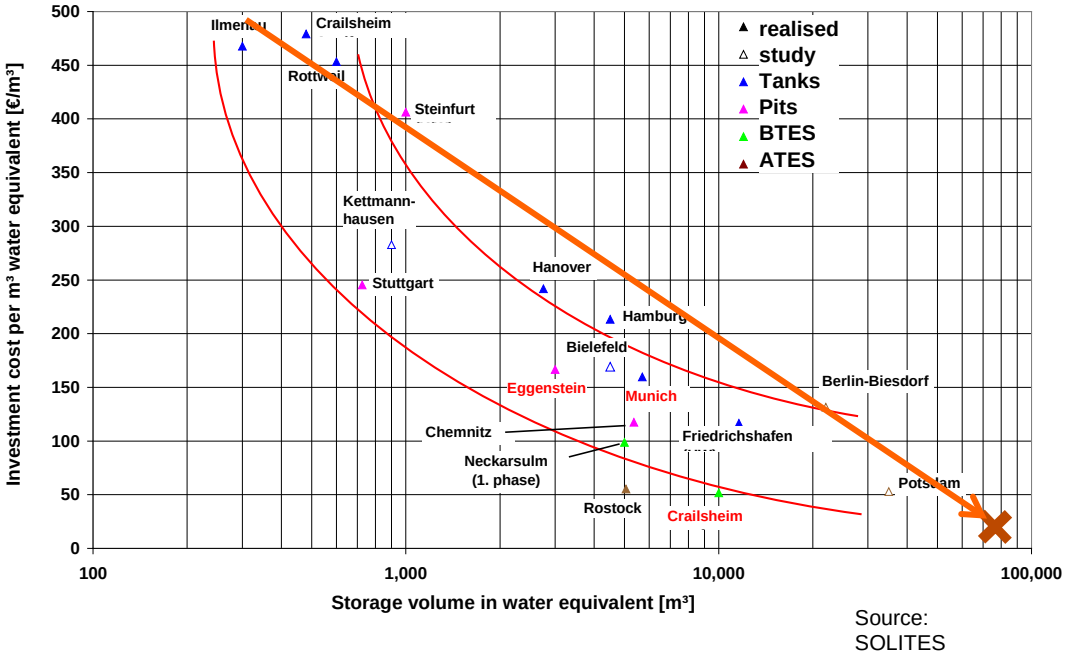
LARGE SYSTEMS → small storage losses & lower specific costs

Surface area per volume

(Cylinder, Radius = Height)



Cost per equivalent m³



Source: SOLITES

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

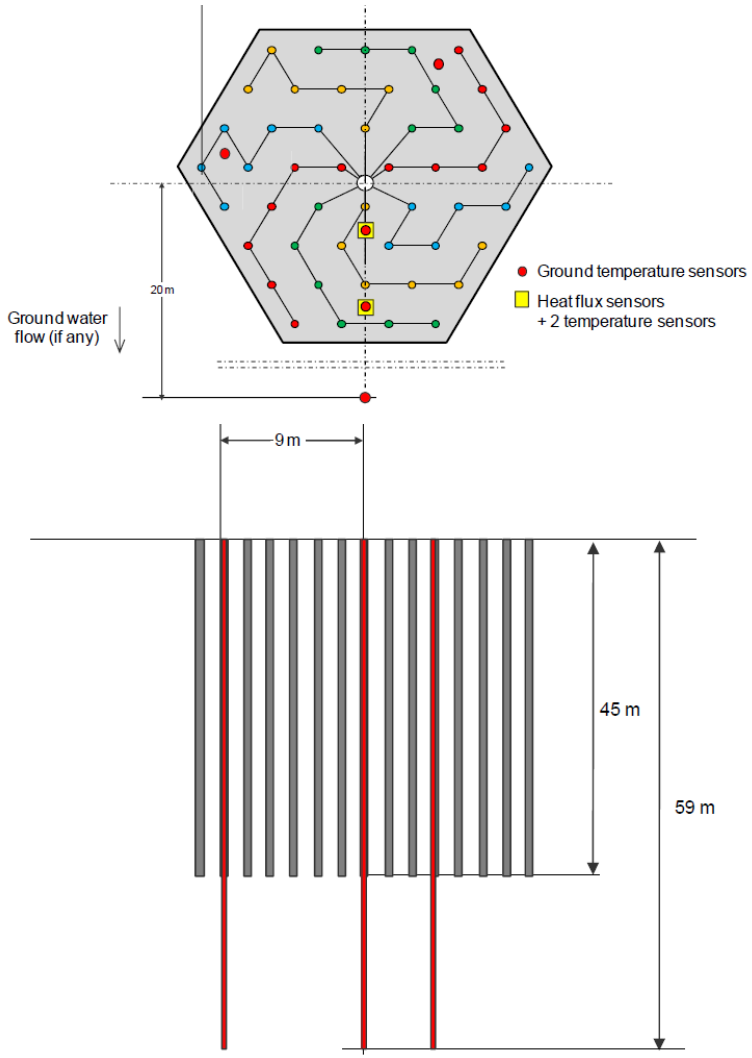
500 → 20 ➔ Factor 25 on costs/volume (cost/storage capacity)

•Water ponds under construction:

- Vojens: 200000 m^3
- Gram: 110000 m^3

19000 m³ borehole storage in Brædstrup

Design and implementation, Brædstrup



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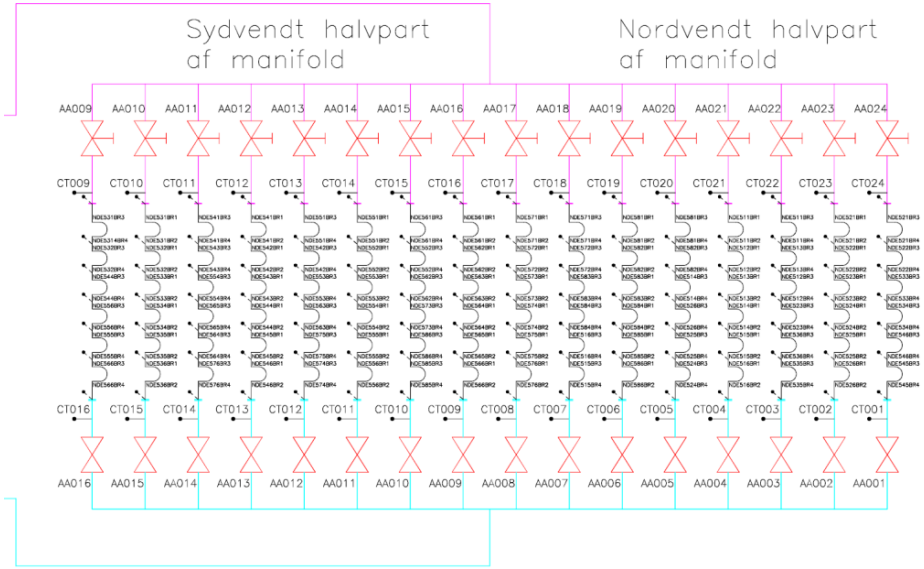
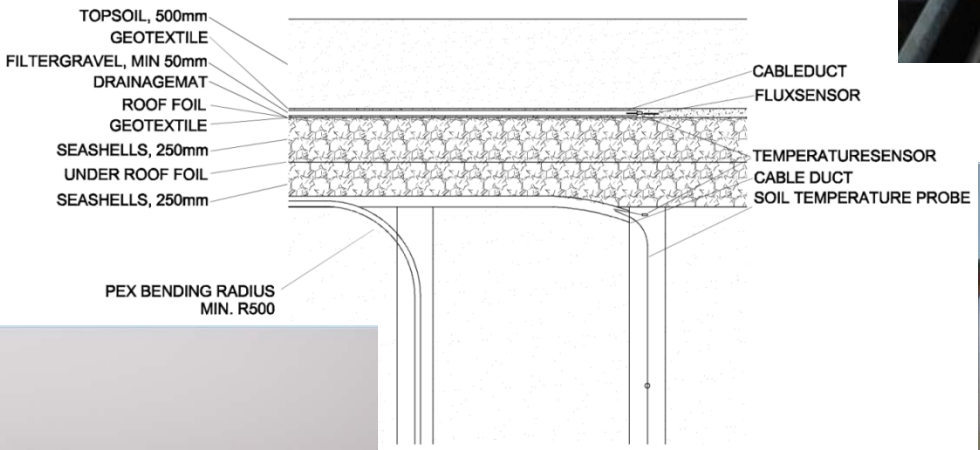




Measurements

	Borehole storage, Brædstrup	Water pond storage, Marstal
Size	19000 m^3 soil, corresponding to about 12000 m^3 water	75000 m^3 water
Prize	240000 euro, coprresponding to about 20 euro/m^3 water	2400000 euro, corresponding to 32 euro/m^3 water
Maximum storage temperature	50°C	90°C
Heat recovered from heat storage during first year, 2012-2013	44%	18%
Heat recovered from heat storage during second year, 2013-2014	38%	65%

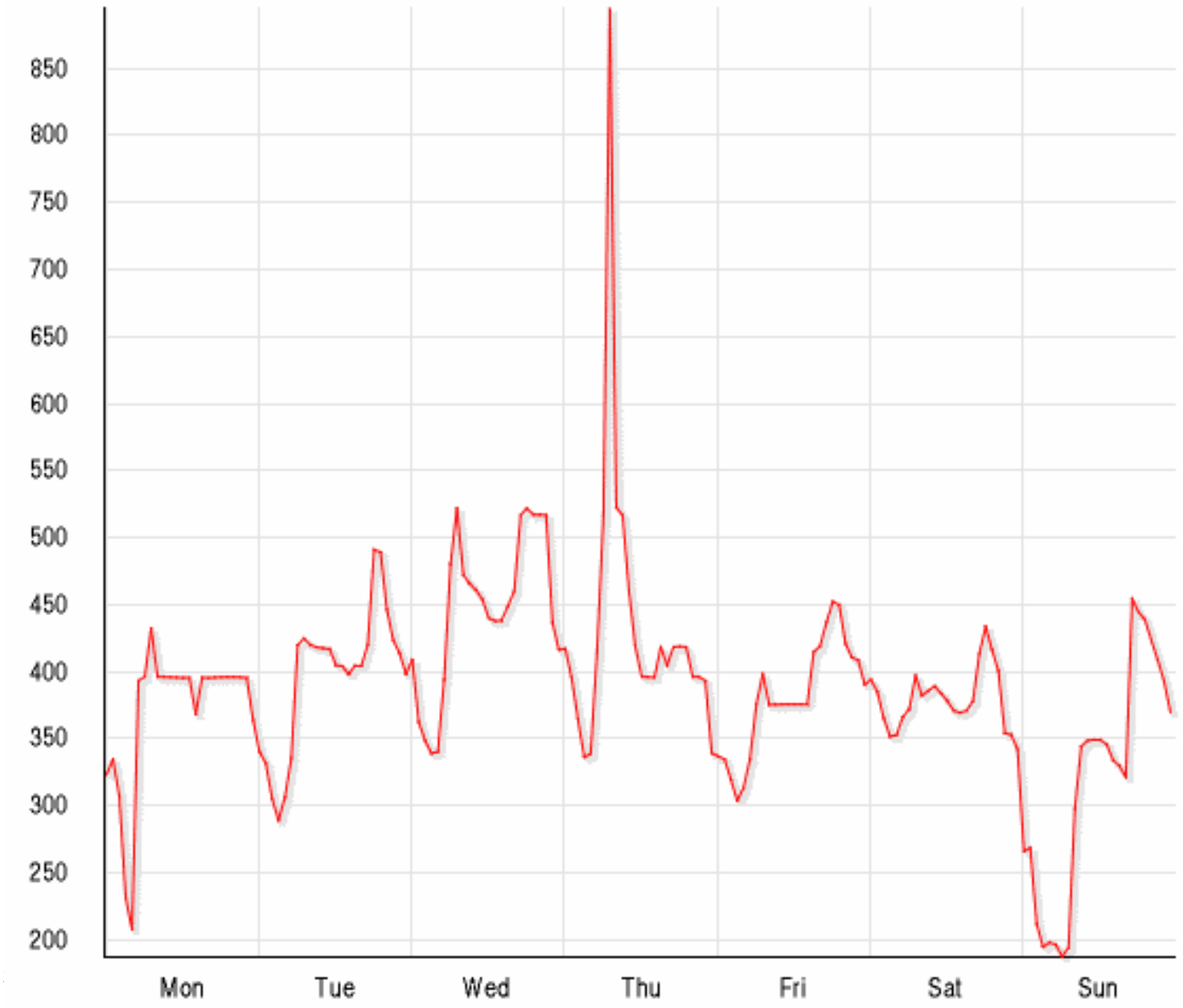
Individual solar/electric heating system for the future smart energy system

Individual solar/electric heating systems with smart heat storages, which can be heated by solar collectors and by electricity in periods with low electricity prices

- Heat is produced by solar collectors and by electric heating elements or a heat pump
- Electric heating elements/heat pump if possible only in operation in periods where solar heat can not fully cover heat demand and where the electricity price is low
- System equipped with a smart heat storage (variable auxiliary volume) and a smart control system based on prognoses for:
  - heat demand
  - solar heat production
  - electricity price

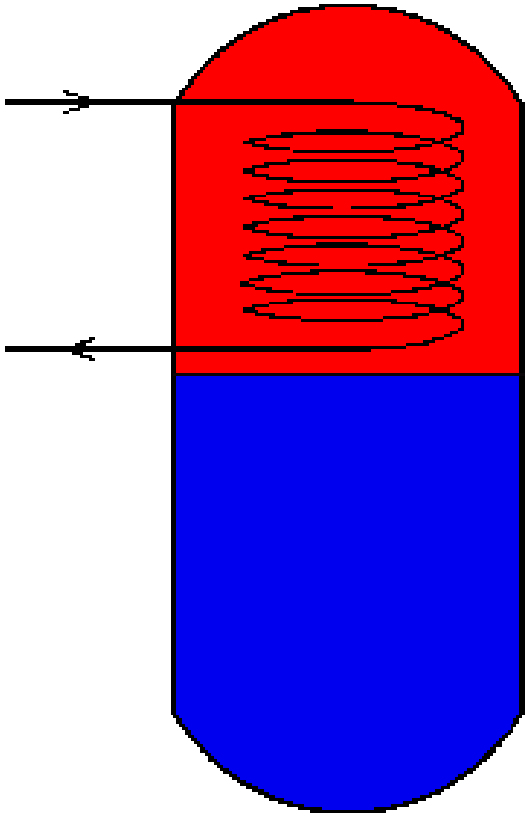
Electricity price, DKK/MWh

Denmark west, November 3.-9., 2008

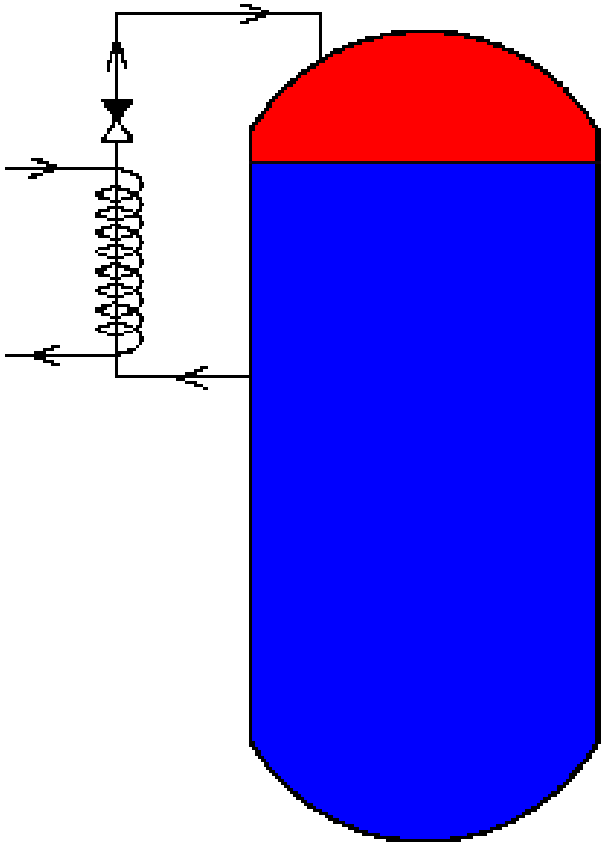


Smart solar tanks for solar heating systems

Marketed Solar tank



Smart solar tank



TANK HEATED FROM THE TOP

INDIVIDUAL FLEXIBLE
TIMER/ENERGY CONTROL SYSTEM

Solar heating systems with smart solar tanks

Increased thermal performance by up to 35% due to:

☺ Decreased tank heat loss

☺ Increased solar heat production

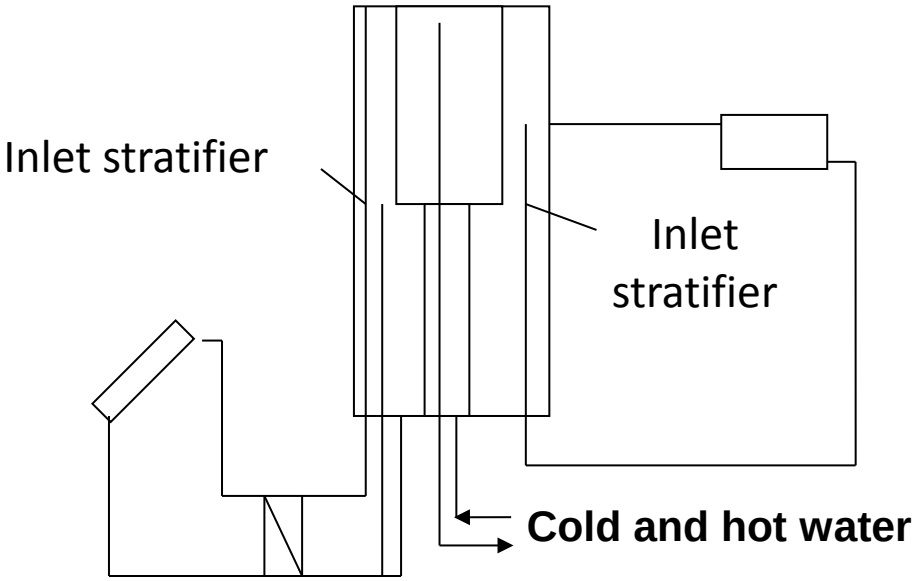
Further, also additional improved cost efficiency due to:

☺ Use of low electricity price

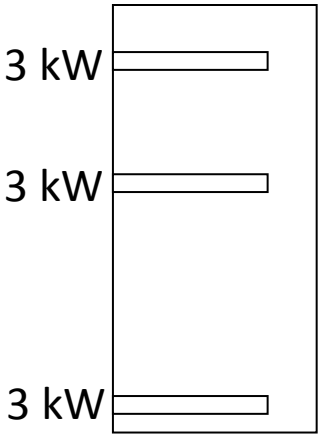
Systems tested side by side

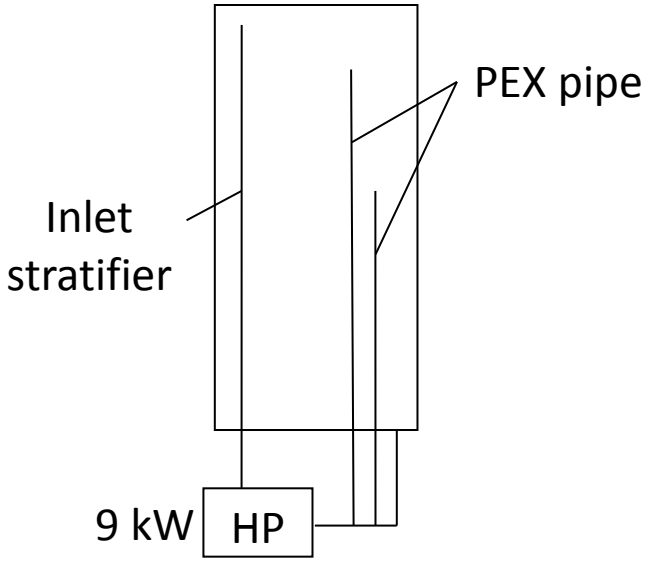
- 9 m² solar collector
- 735 l smart solar tank. Auxiliary: One electric heating element, three electric heating elements, heat pump
- Smart control system - heat content in tank, weather forecast, coming heat demand, coming solar heat production, coming electricity prices from NORDPOOLSPOT

Solar collector loop & discharge loops



Auxiliary heating principles





Measured results for spring 2013

- Electricity consumption of system with electric heating element(s) = 2.2 x electricity consumption of system with heat pump

- Heat price for systems with electric heating element(s) = 2 x Heat price for system with heat pump

Theoretical calculations - results

Home owner

- Heat price for house: 100%
- Heat price for house with 10 m² solar combi system: 70-80%

Strongly influenced on policy on tax on electricity:

- Heat price for house with 10 m² smart solar heating system with electric heating elements and variable electricity price: 65-75%
- Heat price for house with 10 m² smart solar heating system with heat pump and variable electricity price: 35-40%

Society

- Socio-economic benefit of smart solar heating systems compared with a reference scenario with oil and gas boilers: The total benefit: 2200 - 6100 DKK per system per year

Conclusions

Centralised solar heating systems with smart long term heat stores

- Water pond and borehole storages promising technologies for solar heating plants

Individual solar heating systems with smart solar heat stores

- Individual smart solar heating systems with electric heating elements/heat pump and variable electricity price are more cost-effective than traditional solar heating systems

- Individual smart solar heating systems with electric heating elements/heat pump can help integrating wind power in the energy system and contribute to an increased share of renewable energy

Recommendations

Increase research, development and demonstration efforts on:

- Water ponds
- Borehole storages
- Individual smart solar/electric heating systems for low energy buildings
- Individual smart solar/heat pump systems for normal houses

Thank you for your attention