The Integration of Large-Scale Solar Thermal and Heat Pumps in District Heating Systems

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PlanEnergi

- Consulting Engineers
- >30 years working with renewable energy
- 30 employees
- Offices in
  - Skørping
  - Aarhus
  - Copenhagen

- District heating
  - Solar thermal
  - Seasonal storages
  - Heat pumps
  - and other renewables
- Energy planning
- Biogas
- Planning of wind and PV farms

Solar Thermal

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2016
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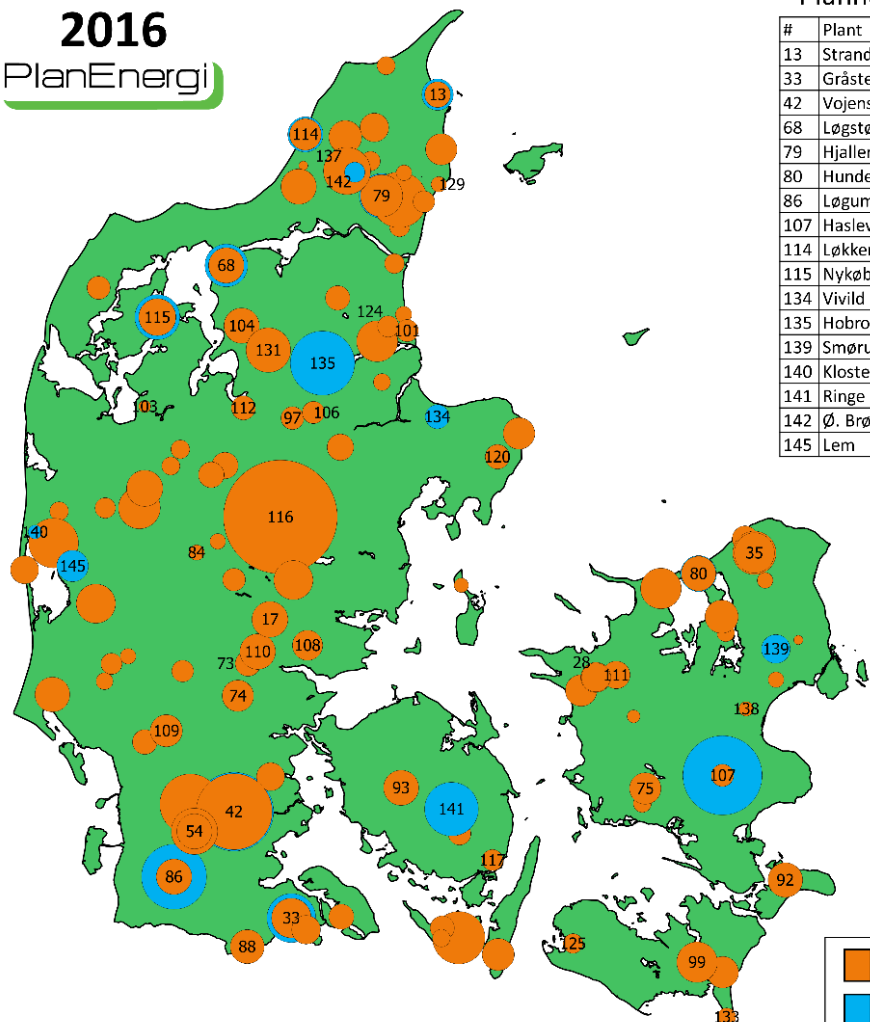


Planned new & expansions

#	Plant	Collector area (m2)
13	Strandby	(8019)+4000
33	Gråsten	(19024)+11189
42	Vojens	(17500+52492)+5000
68	Løgstør	(15208)+7000
79	Hjallerup	(21546)+2500
80	Hundested	(14465)+1200
86	Løgumkloster	(9699+5576)+36000
107	Haslev	(6010)+70000
114	Løkken	(12096)+3000
115	Nykøbing Mors	(16708)+8000
134	Vivild	7000
135	Hobro	50000
139	Smørum	10000
140	Kloster	2300
141	Ringe	35000
142	Ø. Brønderslev	5000
145	Lem	12000

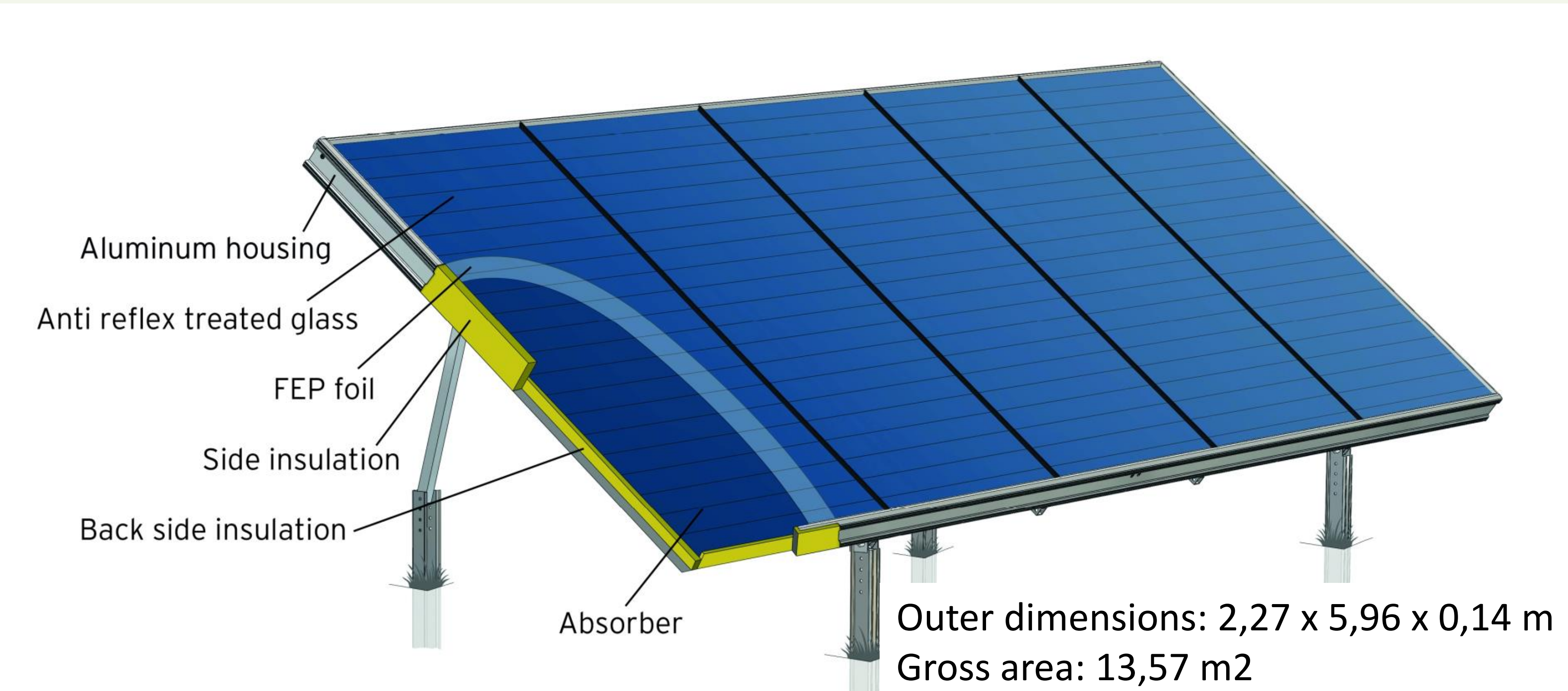
New plants & expansions in operation

#	Plant	Collector area (m2)
17	Tørring	(7284)+8467
28	Svebølle-Visking.	(7035+3000)+1000
35	Helsinge	(4733+14855)+3276
54	Toftlund	(11000)+15000
73	Bredsten - Balle	7800
74	Egtved	12000
75	Fuglebjerg	12000
84	Kølkær	2873
86	Løgumkloster	(9699)+5576
88	Padborg	13961
92	Stege	14515
93	Tommerup	15000
97	Ørum	6375
99	Øster Toreby	20000
101	Als (Mariagerfj.)	5947
103	Ejsing	1800
104	Farsø	15120
106	Hammershøj	6000
107	Haslev	6010
108	Hedensted	11000
109	Holsted	12500
110	Jelling	15290
111	Jyderup	9239
112	Løgstrup	7031
114	Løkken	12096
115	Nykøbing Mors	16708
116	Silkeborg	156694
117	Skårup (Sydfyn)	5418
120	Trustrup-Lyngby	7245
124	Veddum (VSV)	5500
125	Søllested	4701
129	Voerså	2873
131	Aalestrup	24129
133	Gedser	4000
137	Brønderslev	26929
138	Havdrup	2569

In operation	Total collector area (in operation): 1 302 331 m^2
Planned / planned expansion	Total collector area (planned): 269 189 m^2

http://solarheatdata.eu/

Solar district heating in Denmark



Outer dimensions: 2,27 x 5,96 x 0,14 m
Gross area: 13,57 m2
Weight without liquid: 250 kg
Fluid content: 10,6 liter
Transparent area: 12,60 m2

Modul from Arcon-Sunmark,

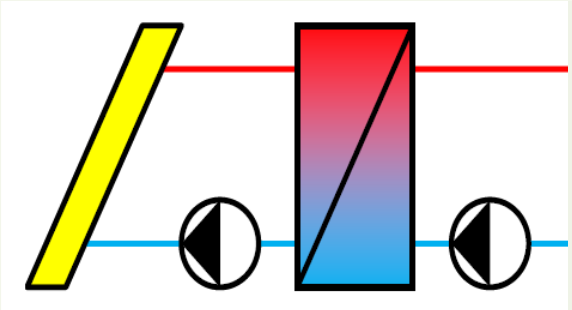
Solar district heating in Denmark

So far - mostly simple systems for low solar fractions (< 25 %)

Collector field

Heat exchanger

But it seems cost effective too, to go for higher solar fractions & long term storage:



Why?

- Why this good development in Denmark?
  - Subsidies ? – Only partially
  - Optimal climate conditions ? - No
  - Tax on fossil fuels
  - Low production price for solar heat*

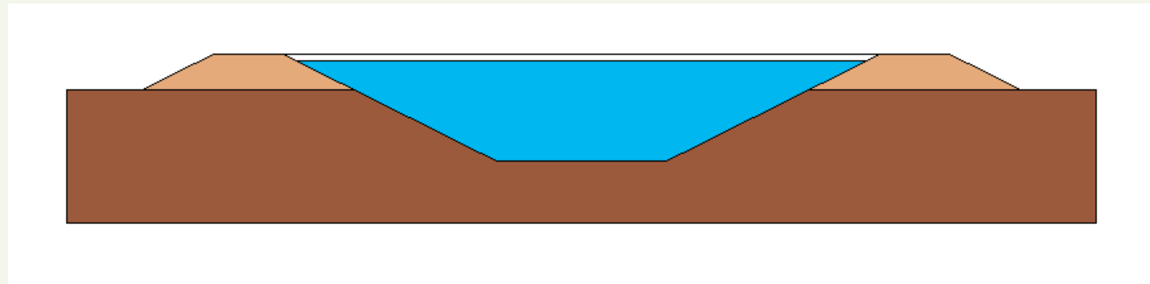
} Solar heat competitive to natural gas in DK

- * < 30 - 55 €/MWh (20 years loans and 3% interest rate)

- Long tradition for district heating - low distribution temperatures

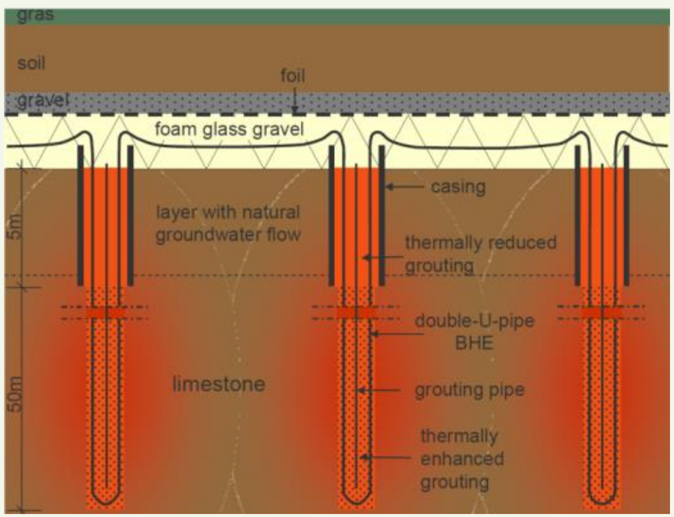
- Small user-owned district heating companies supplying even small villages in the countryside

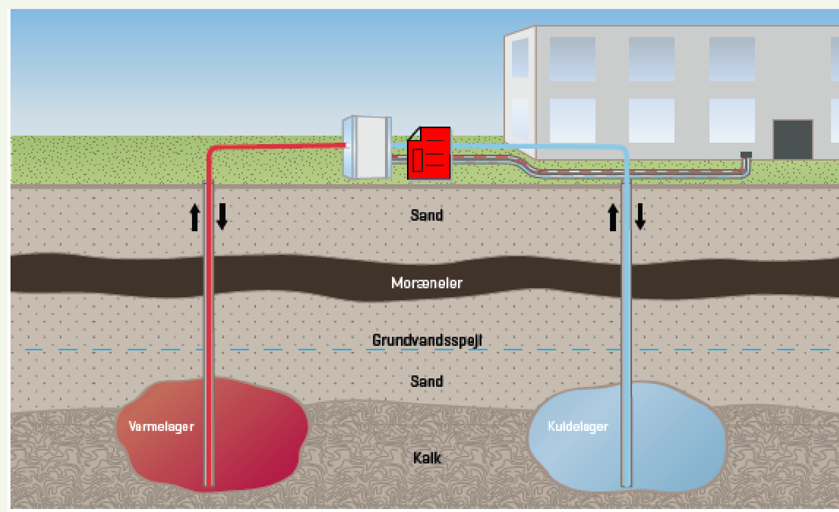
Thermal Energy Storage types



Tank (TTES)
Borehole (BTES)

Pit (PTES)
Aquifer (ATES)

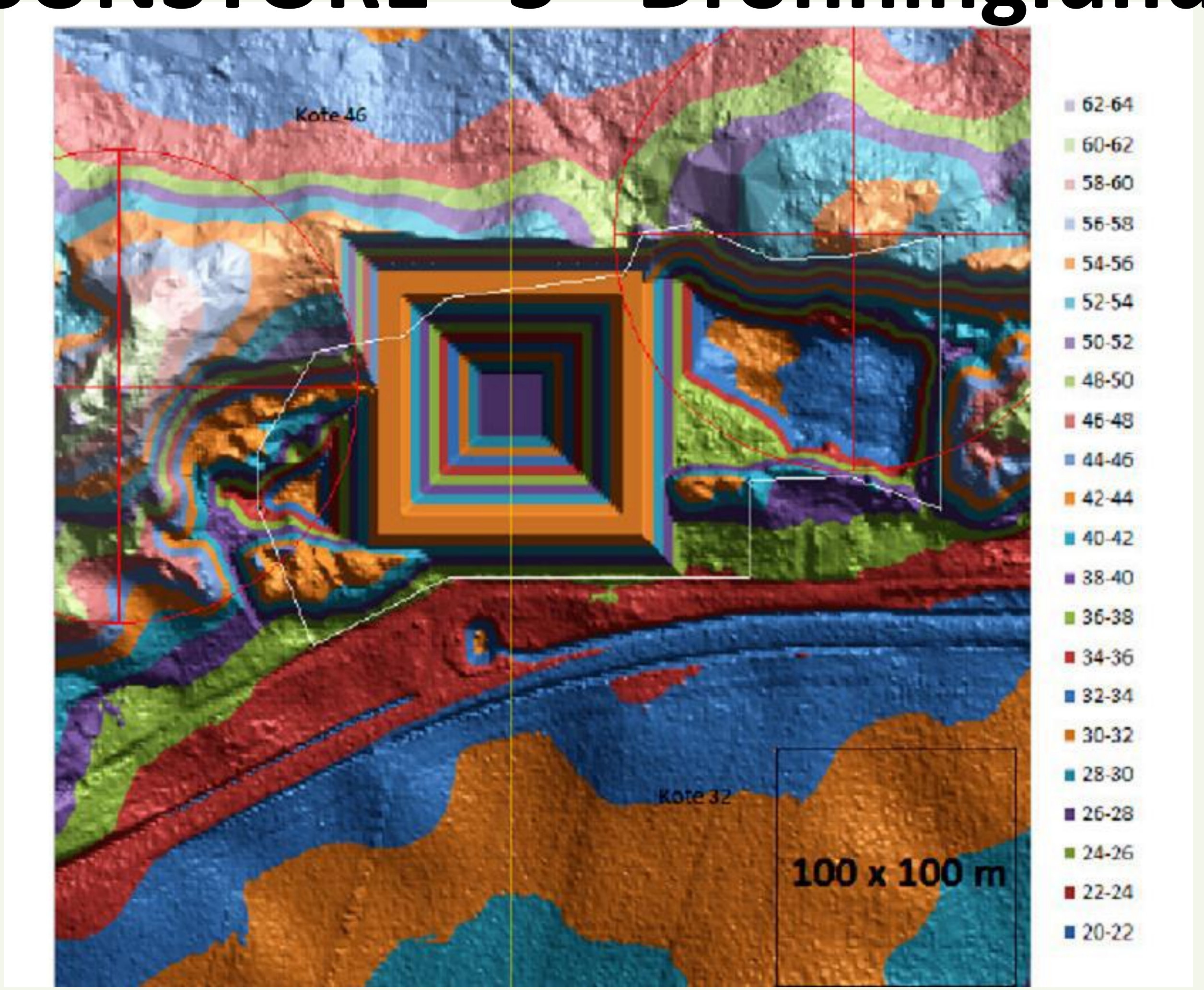




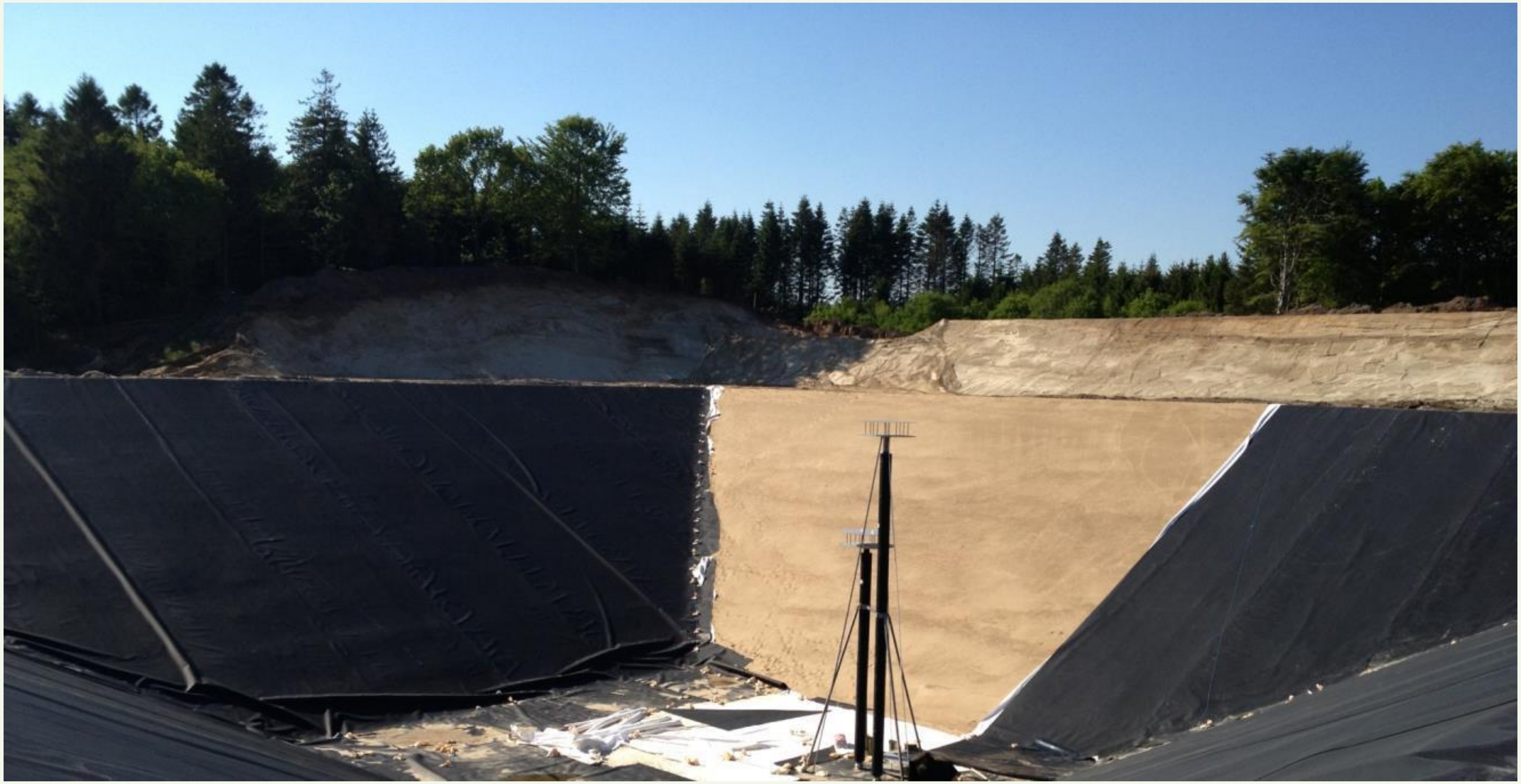
SUNSTORE® 3 - Dronninglund

- 37.500 m^2 solar panels
- 60.000 m^3 pit heat storage
- 2,1 MW (cooling) absorption heat pump
- Combined with existing bio oil boilers and natural gas CHP

SUNSTORE® 3 - Dronninglund



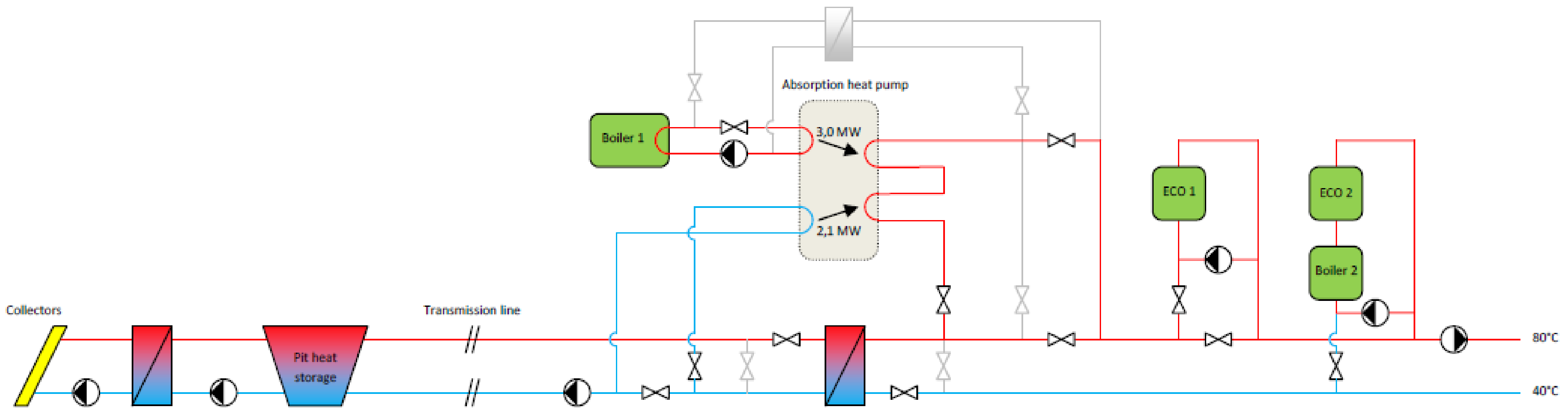
Dronninglund – Pit storage



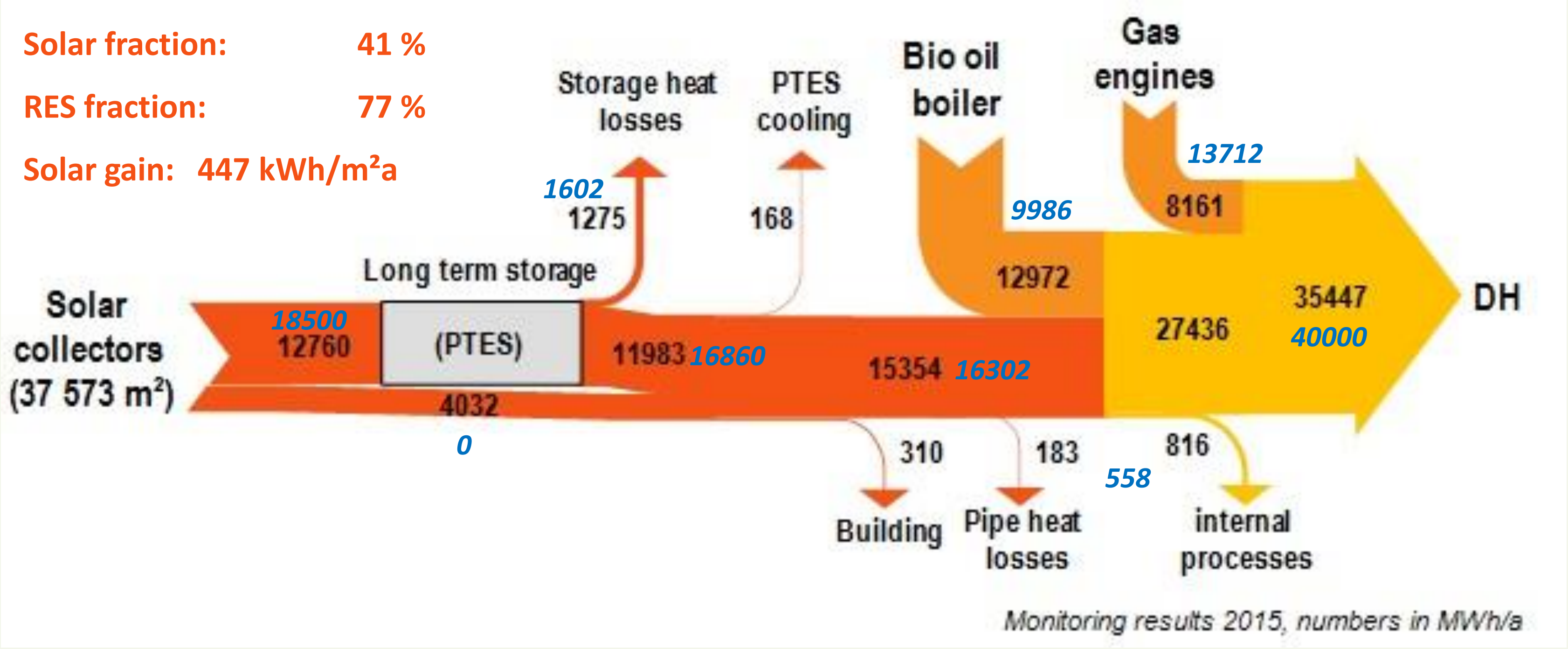
Dronninglund – Pit storage

Dronninglund – Sunstore®

System diagram - Dronninglund



Energy flow diagram for 2015 – Dronninglund (Source Solites)



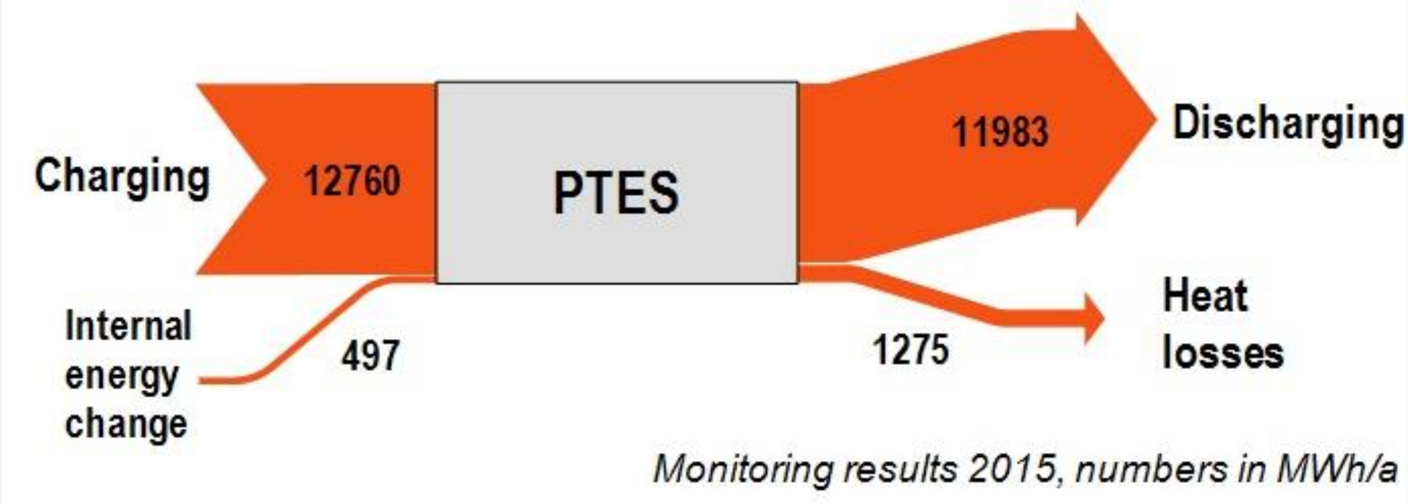
Design figures, source: PlanEnergi, DK

Energy flow pit storage for 2015 – Dronninglund (Source Solites)

Storage efficiency: 90 %   **T-max:** 89 °C

No. of storage cycles: 2.2   **T-min:** 10 °C

Heat capacity (64 K): 5 500 MWh



Possible heat (pump) sources

- Excess heat from industrial, cooling and freezing processes
- Waste water
- Fluegas
- Geothermal heat
- Ground water
- Water from rivers, lakes and sea
- Air
- Ground

Storages?

Solar thermal?

Heat pump projects

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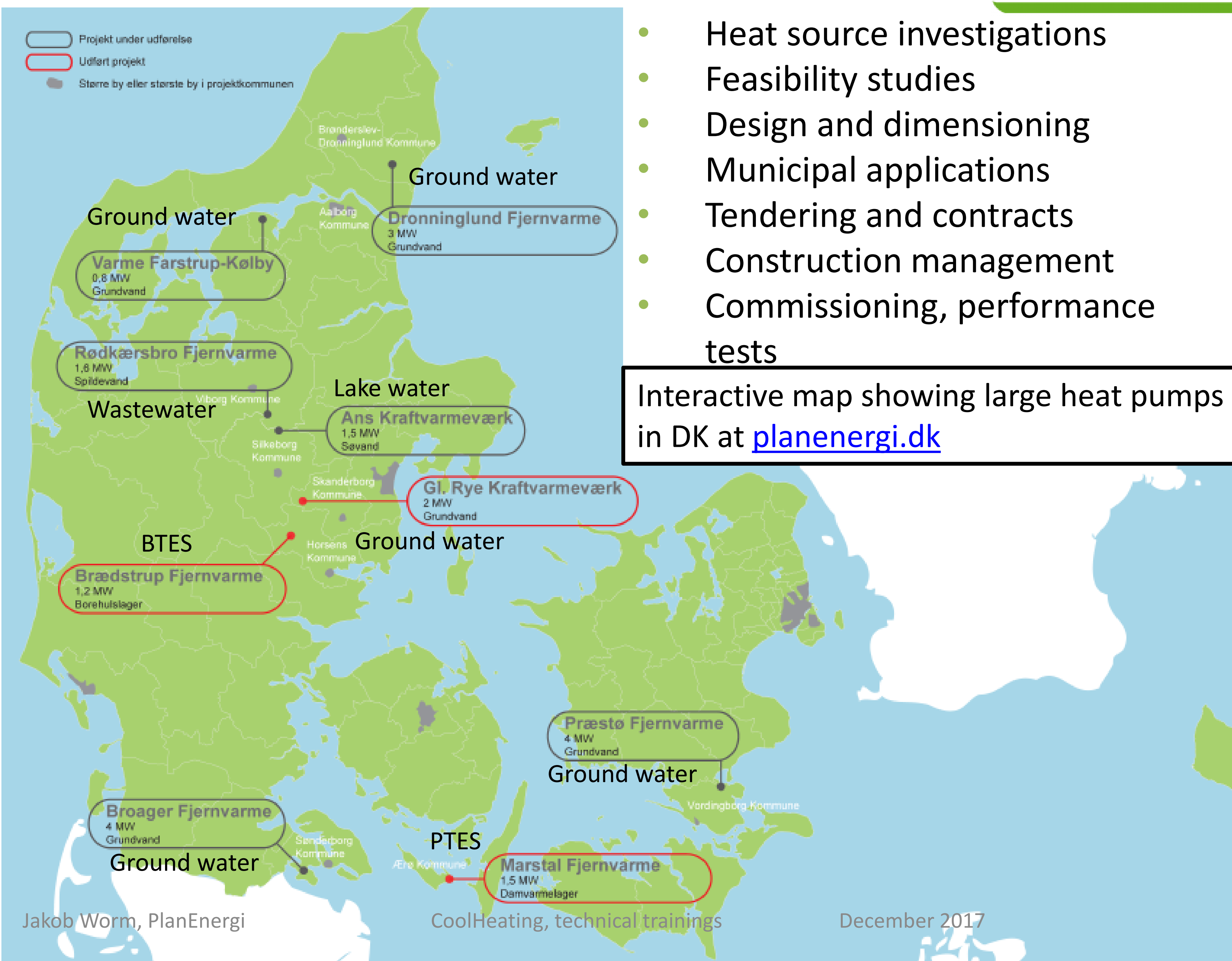

- Heat source investigations
- Feasibility studies
- Design and dimensioning
- Municipal applications
- Tendering and contracts
- Construction management
- Commissioning, performance tests

Interactive map showing large heat pumps in DK at planenergi.dk

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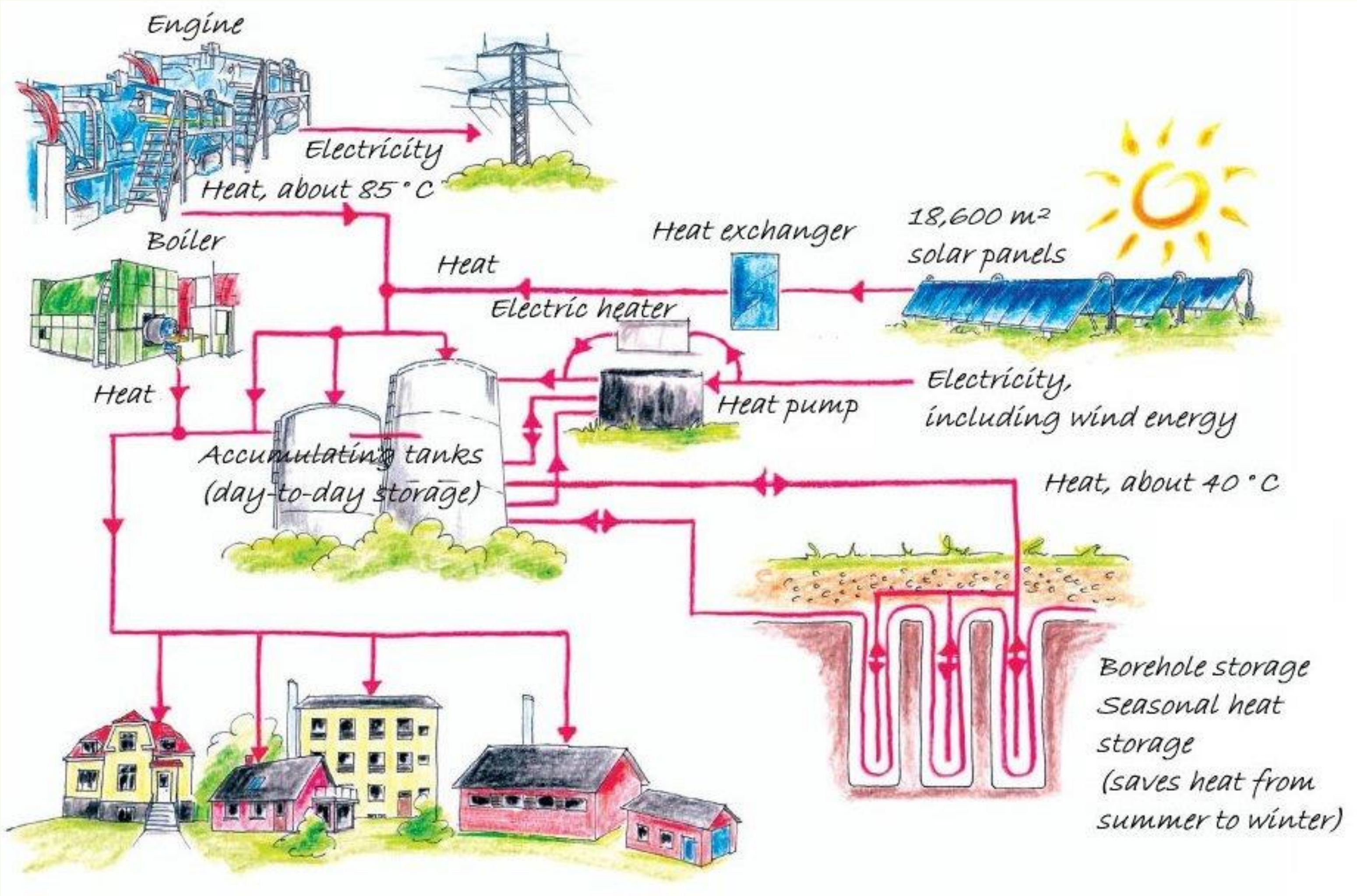
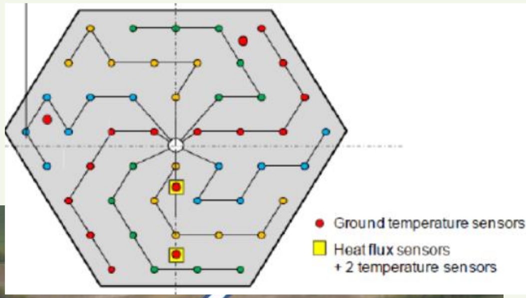
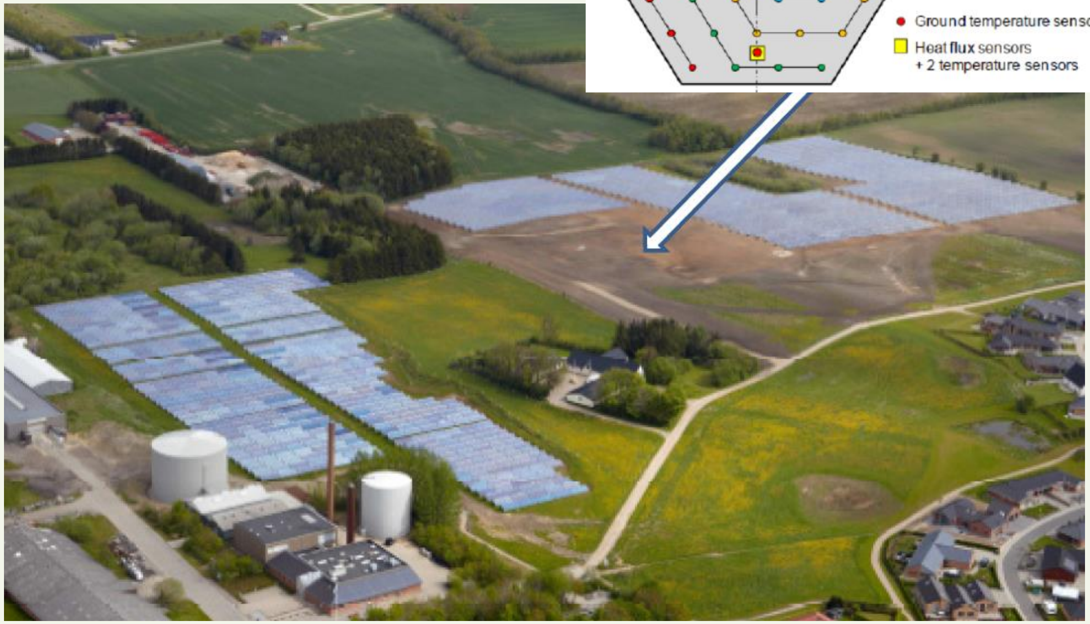
Example 1: Braedstrup



Example 1: Braedstrup

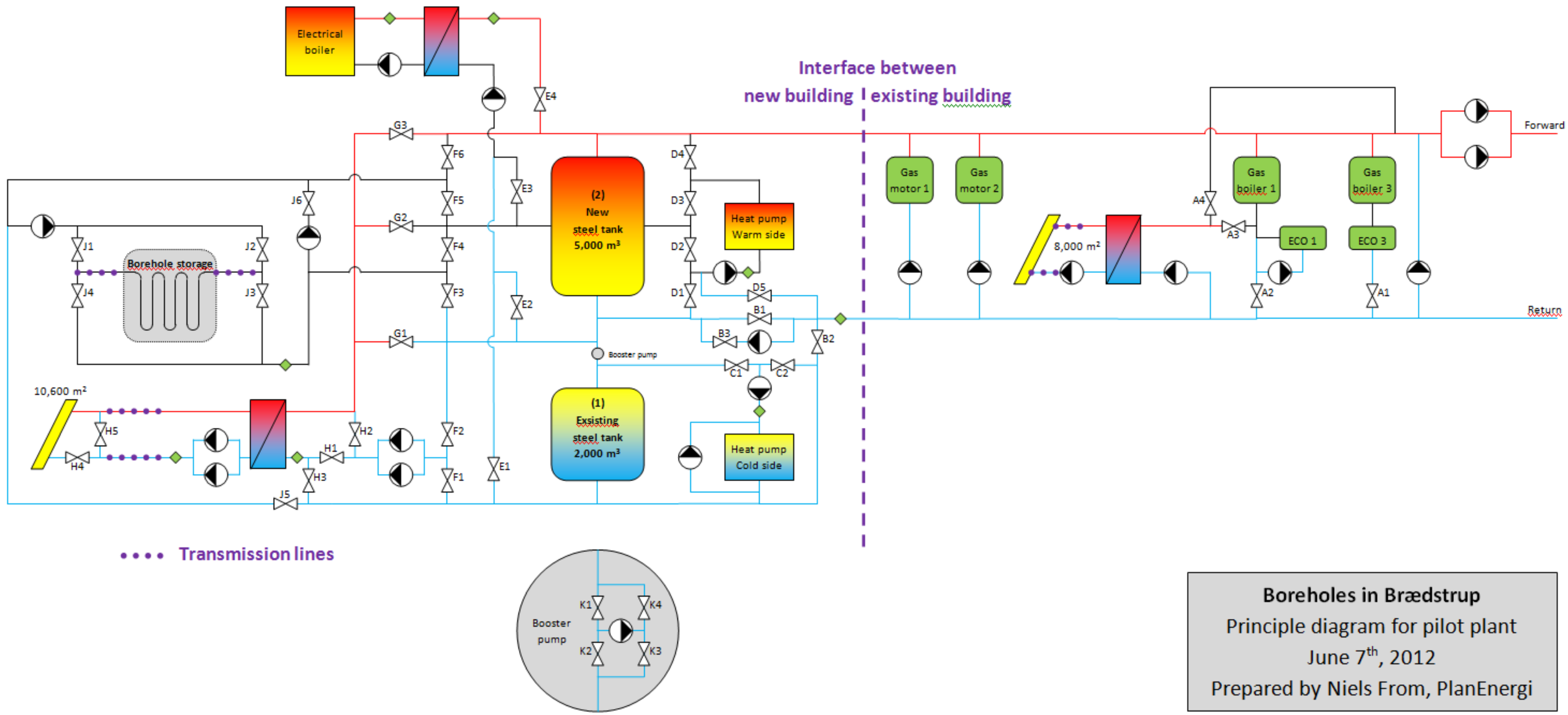
- Solar collectors (18,612 m^2)
- Borehole heat storage (BTES) of approx. 19.000 m^3 heated soil (~ 8000 m^3 of water equivalent)
- Tank storages (2000 m^3 + 5500 m^3)
- Electric HP (1 MW_{th})
- Electric boiler (10 MW)
- Natural gas CHP
- Natural gas boilers



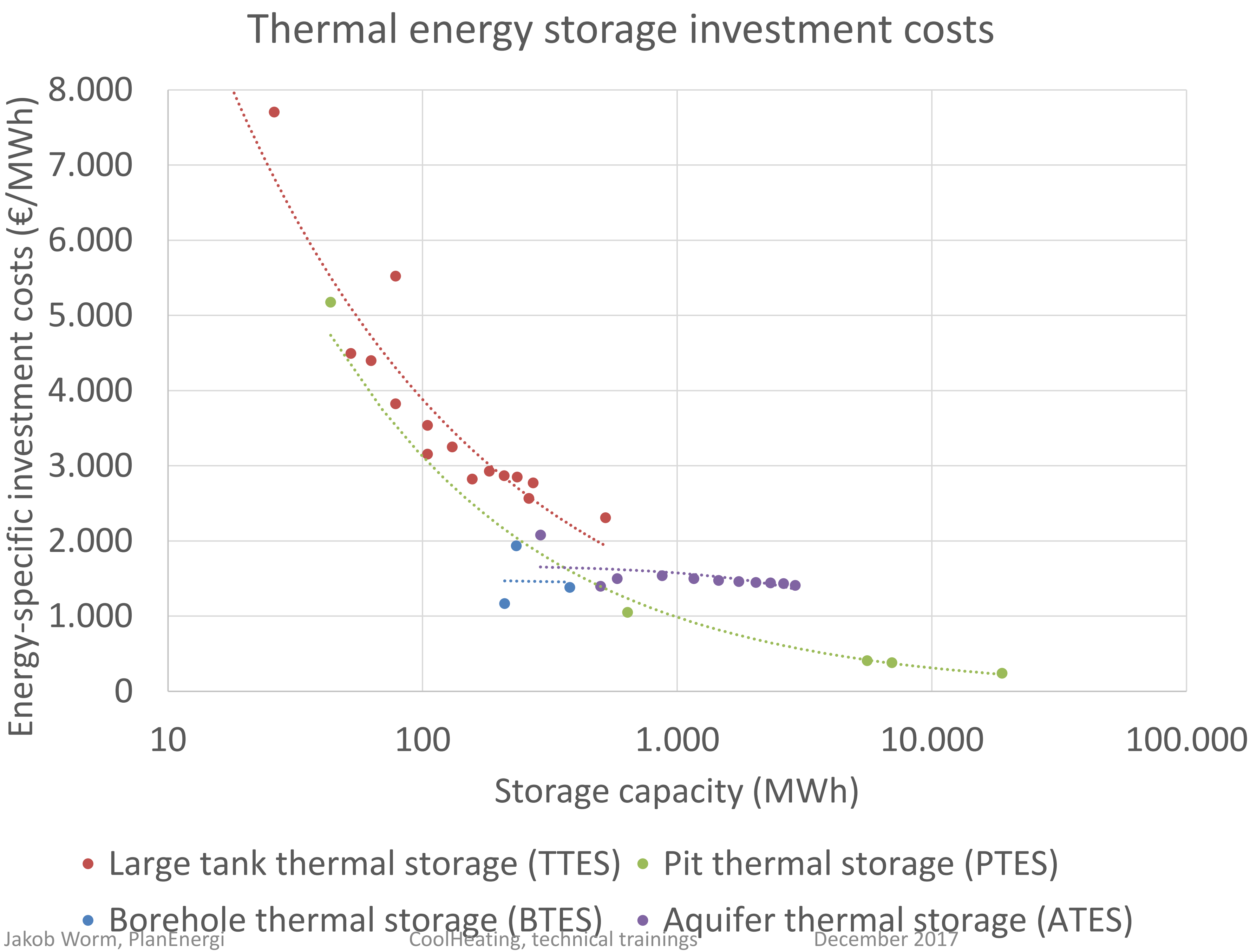


Brædstrup – Heat pump

Brædstrup – Principal diagram



Boreholes in Brædstrup
Principle diagram for pilot plant
June 7th, 2012
Prepared by Niels From, PlanEnergi



Thermal energy storage investment costs
Energy-specific investment costs (€/MWh)
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0
10
100
1.000
10.000
100.000
Storage capacity (MWh)
Large tank thermal storage (TTES)
Pit thermal storage (PTES)
Borehole thermal storage (BTES)
Aquifer thermal storage (ATES)

Type	TTES	PTES	BTES	ATES
Storage medium	Water	Water (Gravel-water)	Soil surrounding the boreholes	Groundwater in aquifers
Specific capacity [kWh/m³]	60 - 80	60 - 80 30 - 50 for gravel-water	15 - 30	30 - 40
Water equivalents	1 m³ storage volume = 1 m³ stored water	1 m³ storage volume = 1 m³ stored water	3 - 5 m³ storage volume = 1 m³ stored water	2 - 5 m³ storage volume = 1 m³ stored water
Geological requirements	• stable ground conditions • preferably no groundwater • 5 - 15 m deep	• stable ground conditions • preferably no groundwater • 5 - 15 m deep	• drillable ground • groundwater favourable • high heat capacity • high thermal conductivity • low hydraulic conductivity ($k_f < 10^{-10}$ m/s) • natural ground-water flow < 1 m/a • 30 - 100 m deep	• high yield aquifer
Application	Short-time/ diurnal storage, buffer storage	• Long-time/ seasonal storage for production higher than 20,000 MWh • Short time storage for large CHP (around 30,000 m³)	Long-time /seasonal for DH plants with production of more than 20,000 MWh/year	Long-time /seasonal heat and cold storage
Storage temperatures [°C]	5 - 95	5 - 95	5 - 90	7 - 18
Specific investment costs [EUR/m³]	110 - 200 EUR/m³ (for TTES above 2,000 m³)	20 - 40 EUR/m³ (for PTES above 50,000 m³)	20 - 40 EUR/m³ (for PTES above 50,000 m³ water equivalent incl. buffer tank)	50 - 60 €/m³ (for ATES above 10,000 m³ water equivalent) Investment costs are highly dependent on charge/discharge power capacity
Advantages	High charge/discharge capacity	• High charge/discharge capacity • Low investment costs	Most underground properties are suitable	• Provides heat and cold storage • Many geologically suitable sites
Disadvantages	High investment costs	Large area requirements	Low charge/discharge capacity	• Low temperatures • Low ΔT

Future prospects: Synergy

- ✓ District heating is a good argument for solar heating
- ✓ Solar heating is a good argument for district heating

- ✓ Renewable electricity production
  - ❑ Solar (PV, CSP)
  - ❑ Wind
  - ❑ CHP (biomass)

FITS VERY WELL WITH:

- ✓ Renewable heat production
  - ❑ Solar (thermal)
  - ❑ Excess heat
  - ❑ Geothermal
  - ❑ CHP (waste heat)
  - ❑ STORAGE and HEAT PUMPS

Conclusions

- District Heating future:
  - Solar thermal, heat pumps and long-term storages
- Seasonal storages might be feasible to reach high solar fractions (>30 %)
- Heat pumps are necessary for BTES and ATES
- Detailed (dynamical) simulations are needed to calculate the heat production of energy systems with solar heat and seasonal storage with/without heat pumps

Thank you for your attention!

Dronninglund, DK

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