

# Monitoring results from large-scale solar thermal plants with long term storage in Marstal, Brædstrup and Dronninglund, Denmark

Thomas Schmidt

Steinbeis  
Research Institute  
for Solar and  
Sustainable  
Thermal  
Energy Systems  
[www.solites.de](http://www.solites.de)

Meitnerstr. 8  
70563 Stuttgart, Germany  
[www.solites.de](http://www.solites.de)

solites

## Introduction | Plant overview

Plant	Marstal	Dronninglund	Braedstrup
<b>Solar collectors</b>	33,300 m <sup>2</sup>	37,600 m <sup>2</sup>	18,600 m <sup>2</sup>
<b>Seasonal storage</b>	75,000 m <sup>3</sup> PTES	60,000 m <sup>3</sup> PTES	19,000 m <sup>3</sup> BTES
<b>Short-term storage</b>	2,100 m <sup>3</sup> tank	-	5,500 m <sup>3</sup> tank 2,000 m <sup>3</sup> tank
<b>Boiler</b>	4 MW biomass 18 MW bio-oil	15 MW bio-oil 8 MW gas	10 MW el. 13 MW gas
<b>CHP</b>	750 kW <sub>el</sub> ORC	3.6 MW <sub>el</sub> gas	8 MW <sub>el</sub> gas
<b>Heat pump</b>	1.5 MW <sub>th</sub> CO <sub>2</sub>	3 MW <sub>th</sub> absorption	1.2 MW <sub>th</sub>
<b>DH heat demand</b>	32,000 MWh/a	40,000 MWh/a	45,000 MWh/a

PTES: Pit Thermal Energy Storage; BTES: Borehole Thermal Energy Storage

75 000 m<sup>3</sup>  
Pit thermal energy storage

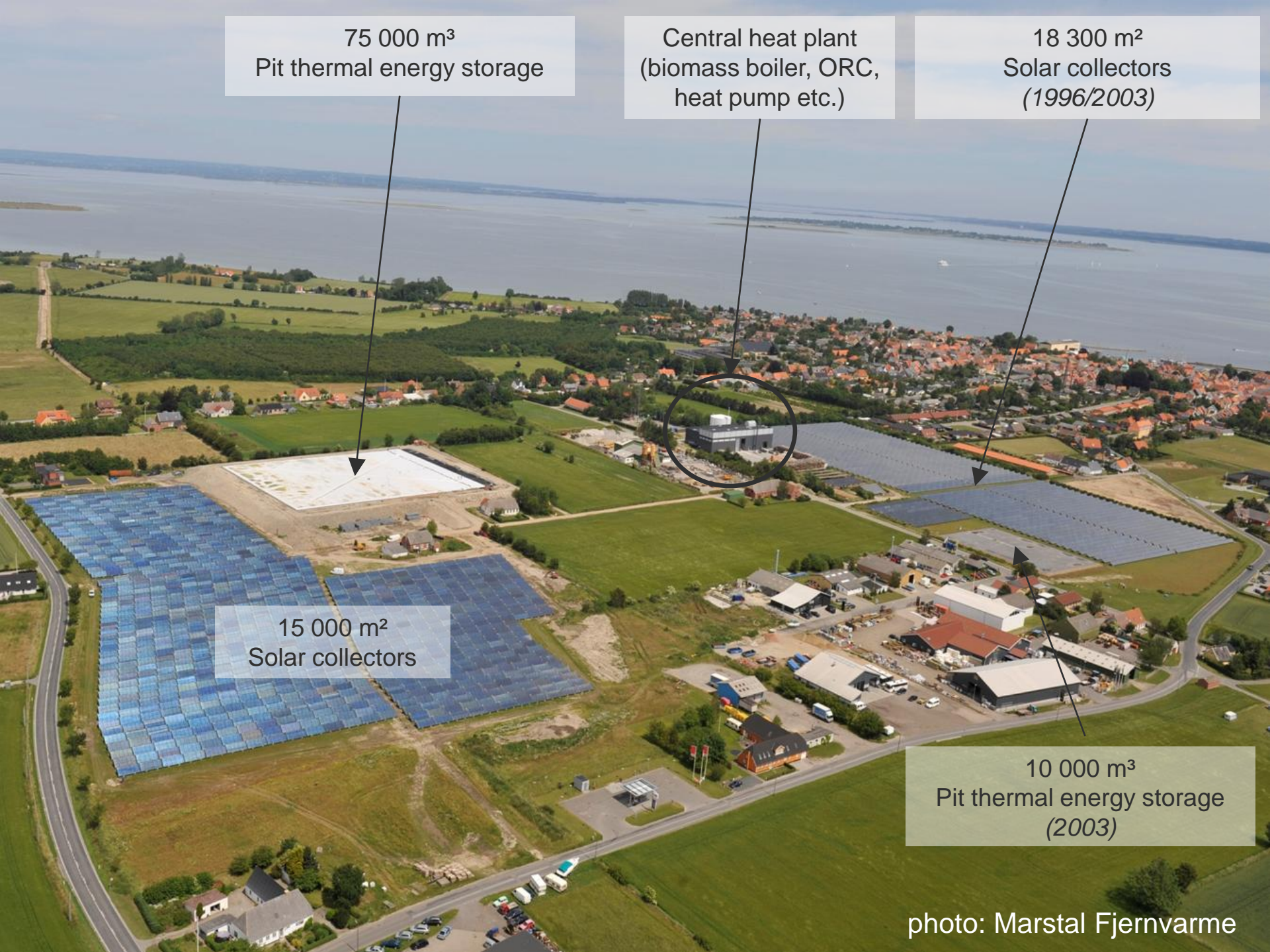
Central heat plant  
(biomass boiler, ORC,  
heat pump etc.)

18 300 m<sup>2</sup>  
Solar collectors  
(1996/2003)

15 000 m<sup>2</sup>  
Solar collectors

10 000 m<sup>3</sup>  
Pit thermal energy storage  
(2003)

photo: Marstal Fjernvarme



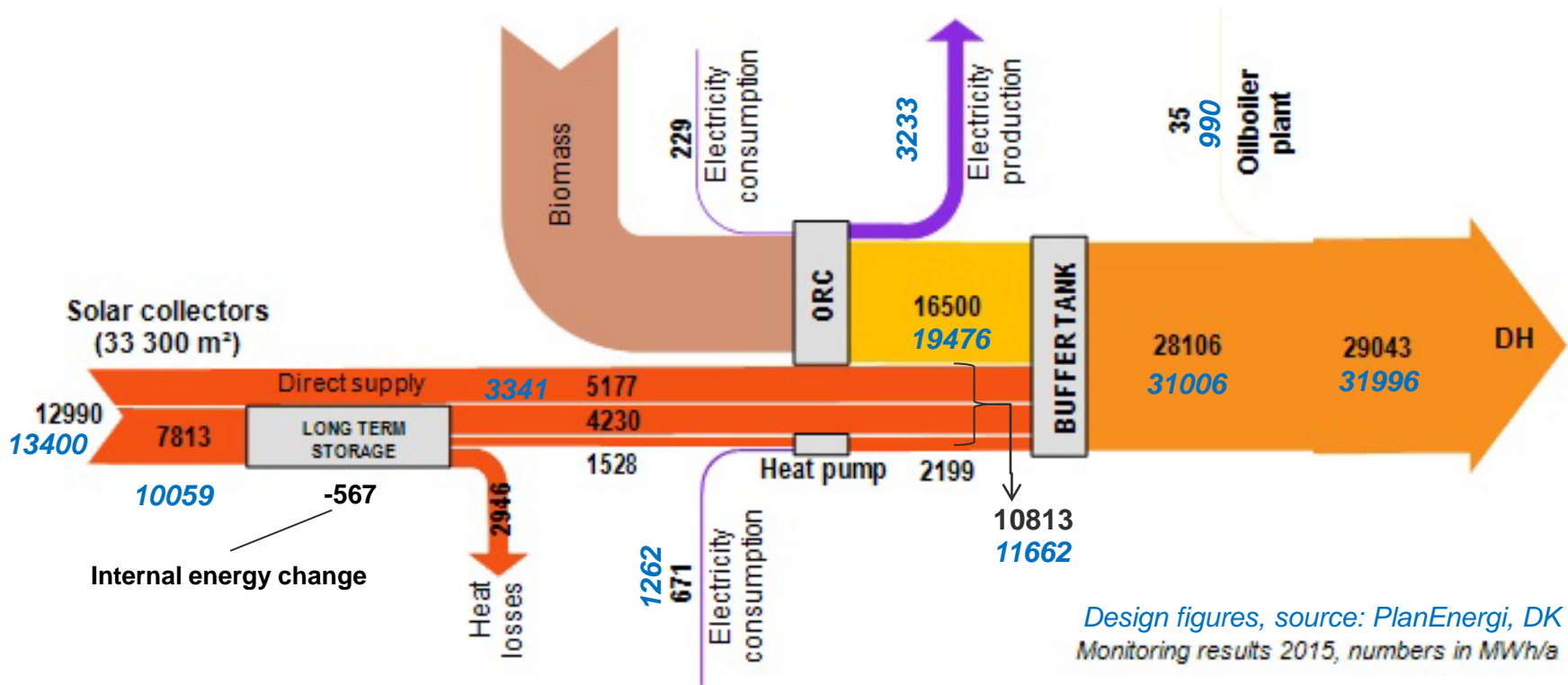


# Marstal | Energy flow diagram 2015

Solar fraction: 41 %

RES fraction: 100 %

Solar gain: 395 kWh/m<sup>2</sup>a



Design figures, source: PlanEnergi, DK  
Monitoring results 2015, numbers in MWh/a

# Marstal | Pit Thermal Energy Storage (PTES) 75 000 m<sup>3</sup>, 2015

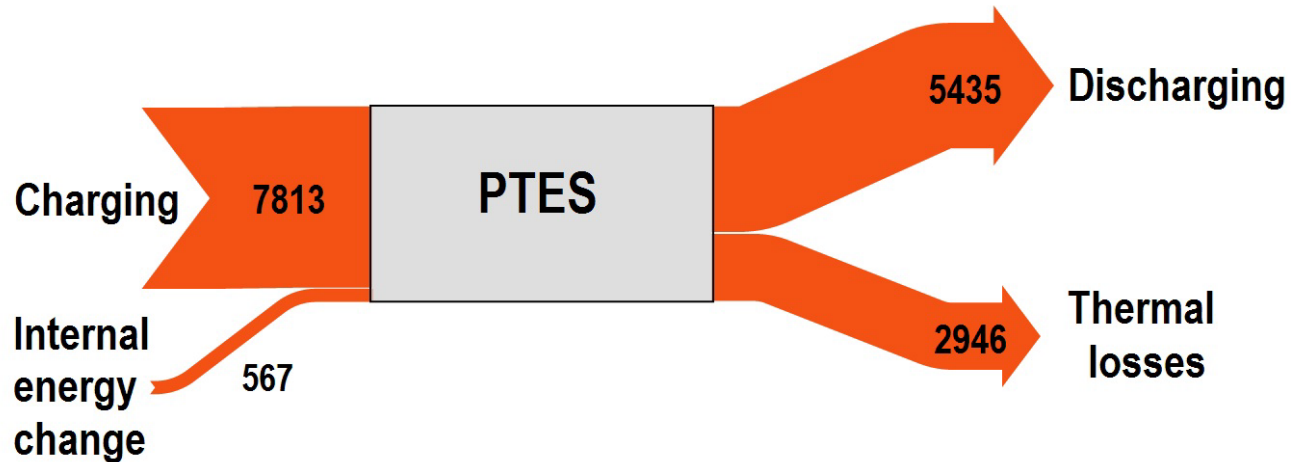
Storage efficiency: 62 %

T-max: 84 °C

No. of storage cycles: 1.0

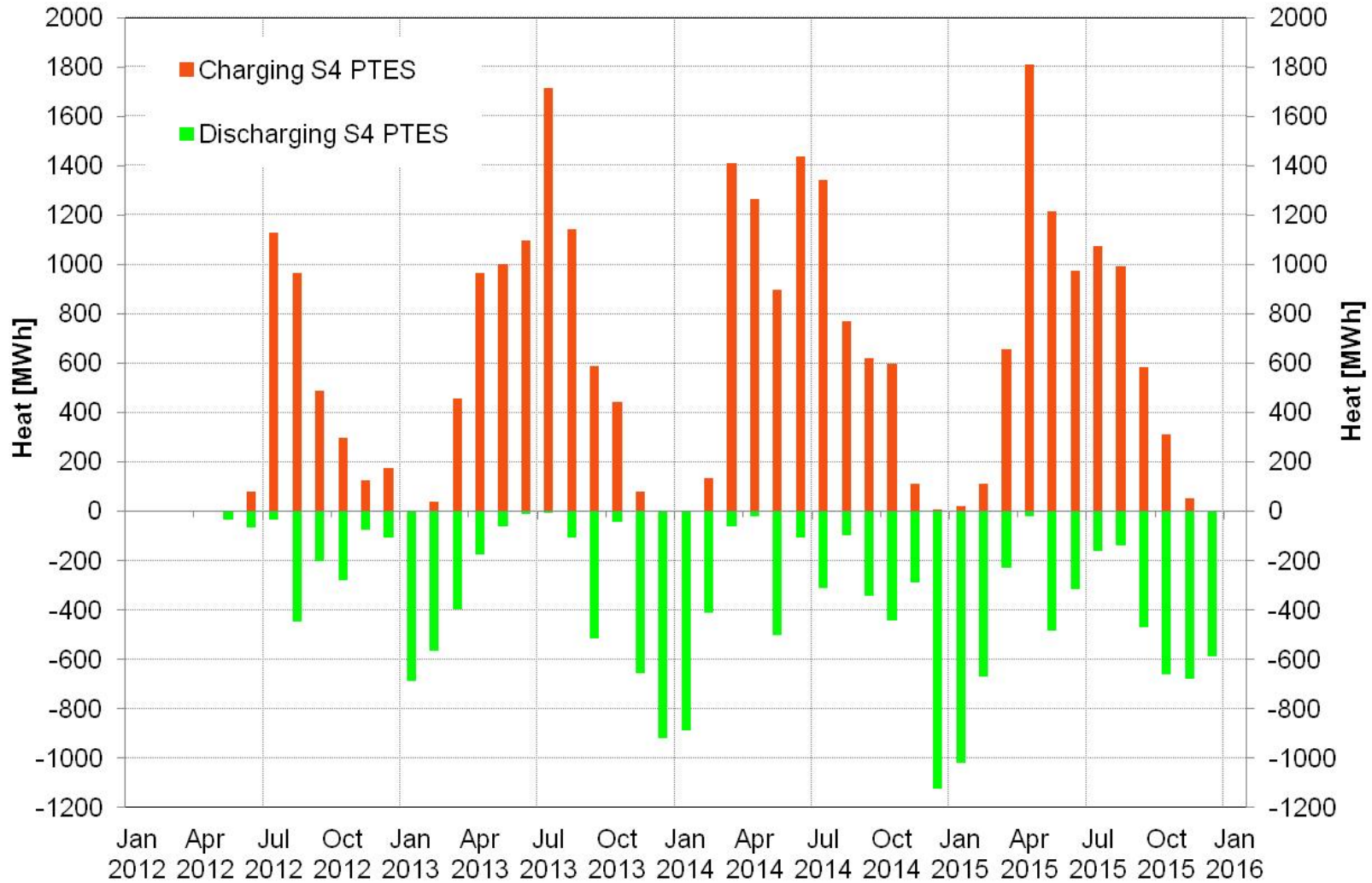
T-min: 20 °C

Heat capacity (64 K): 5 430 MWh



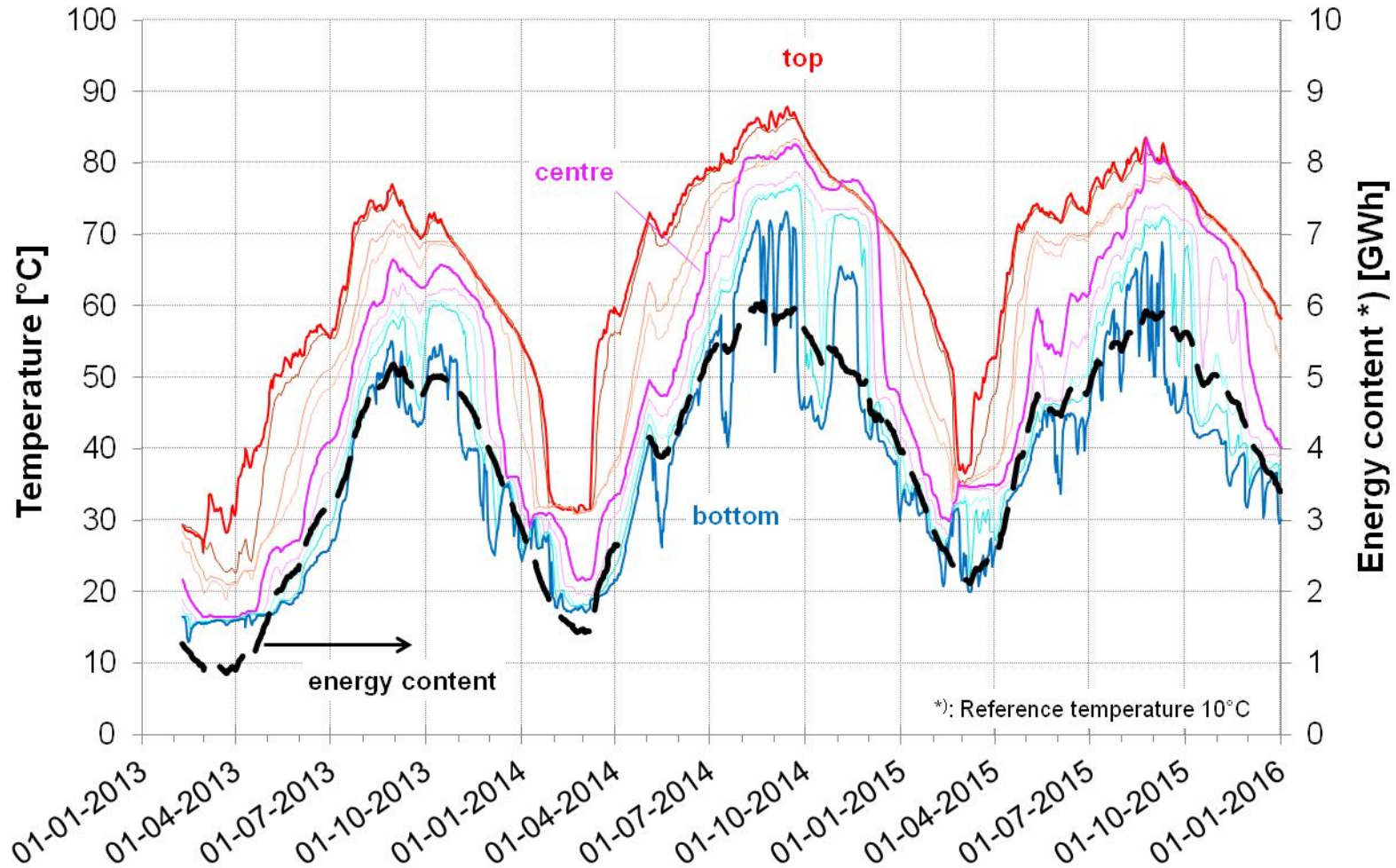
*Monitoring results 2015, numbers in MWh/a*

# Marstal | Pit Thermal Energy Storage - energy balance 2012 - 2015

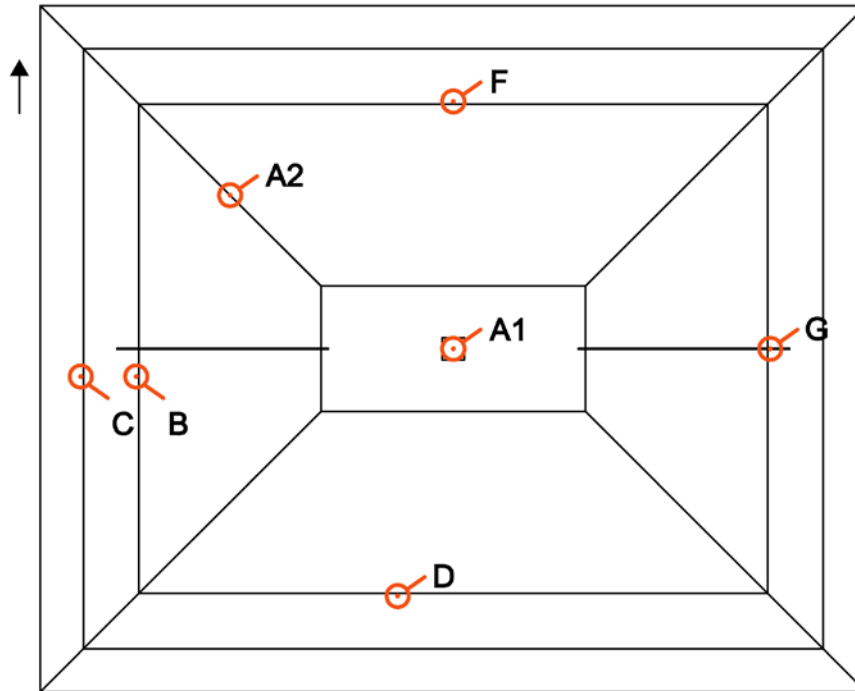




# Marstal | PTES temperature development



# Marstal | PTES ground temperature sensors



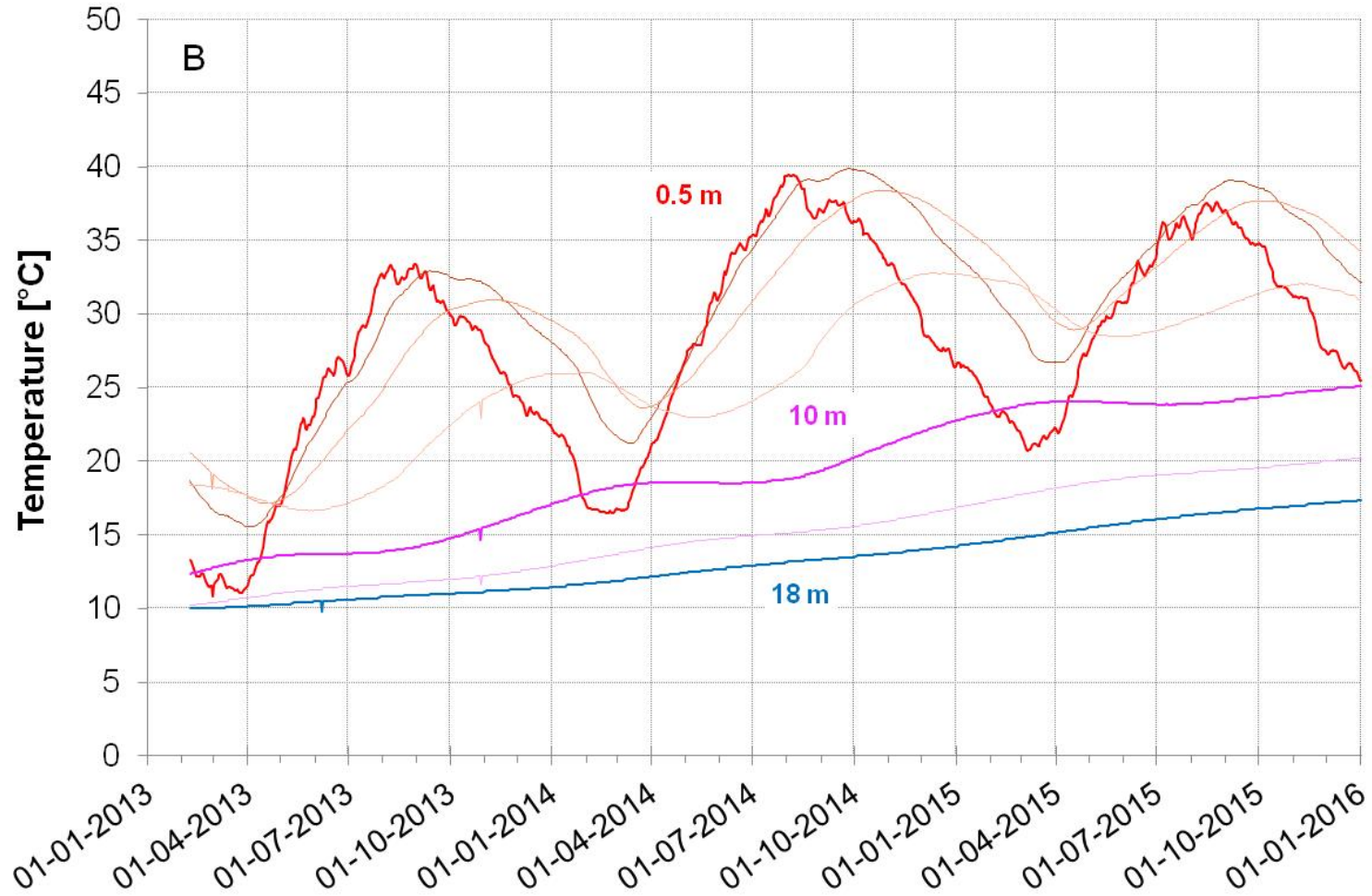
top view



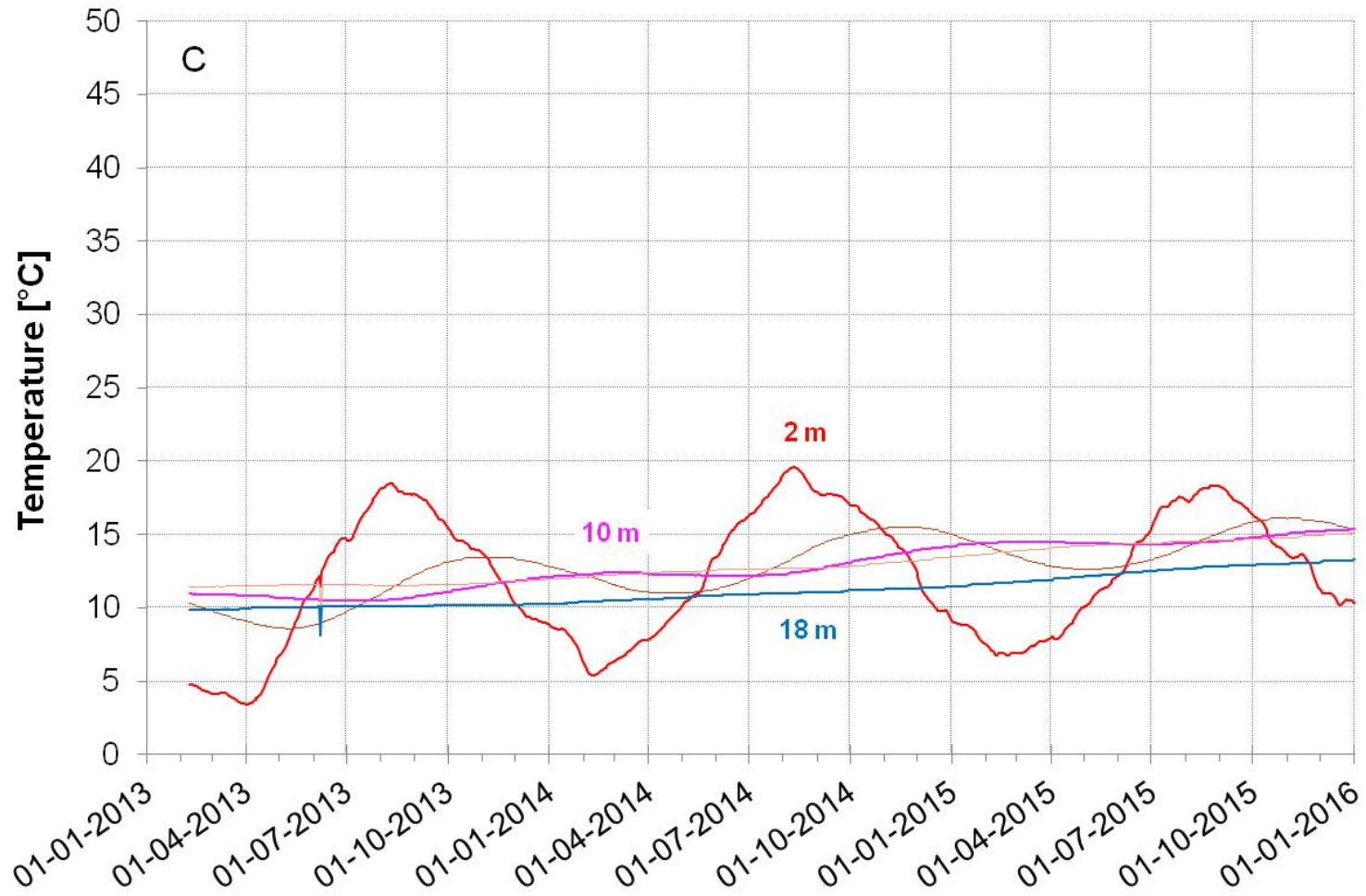
vertical section



# Marstal | PTES ground temperature development „B“



# Marstal | PTES ground temperature development „C“

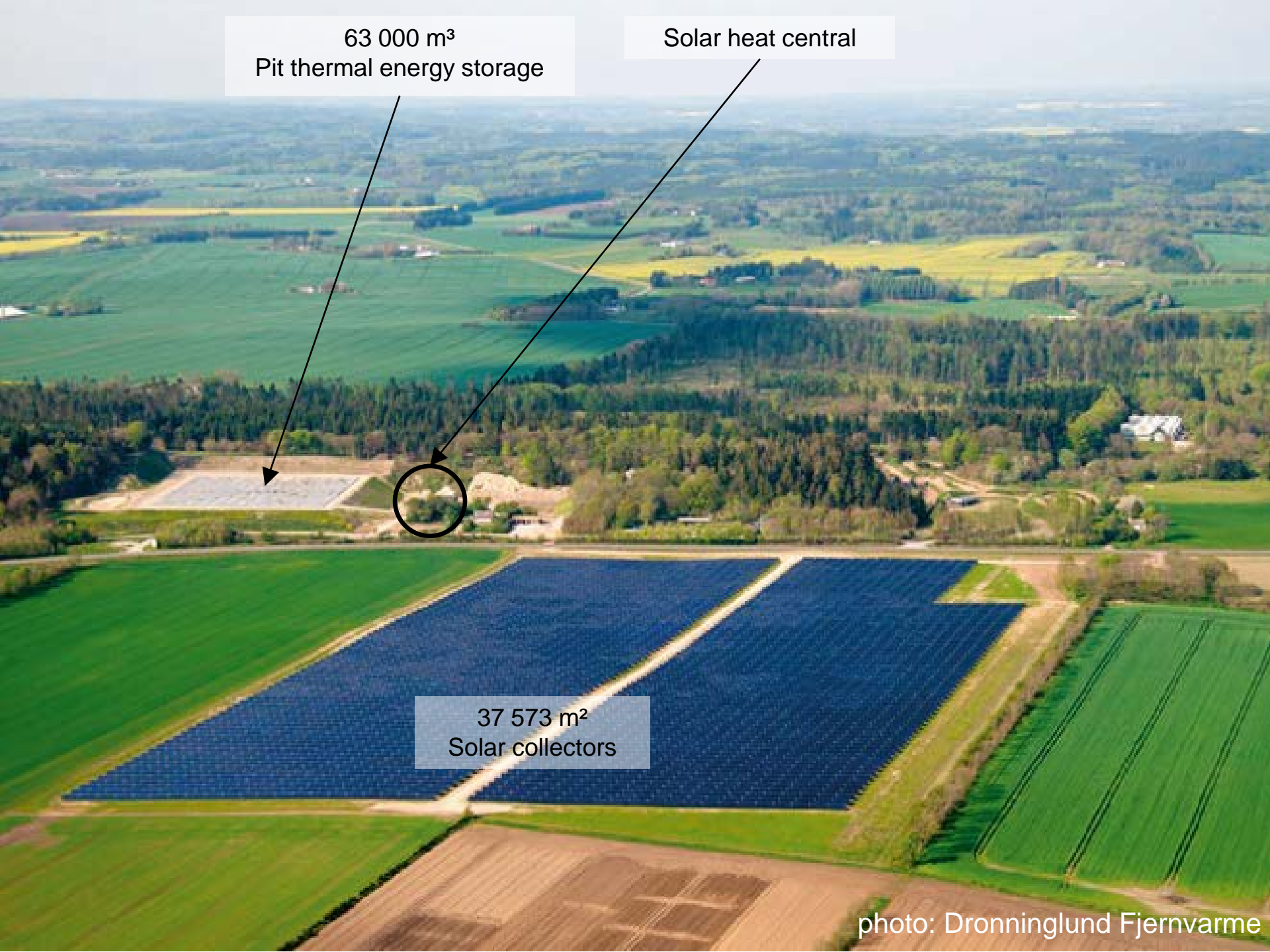


63 000 m<sup>3</sup>  
Pit thermal energy storage

Solar heat central

37 573 m<sup>2</sup>  
Solar collectors

photo: Dronninglund Fjernvarme



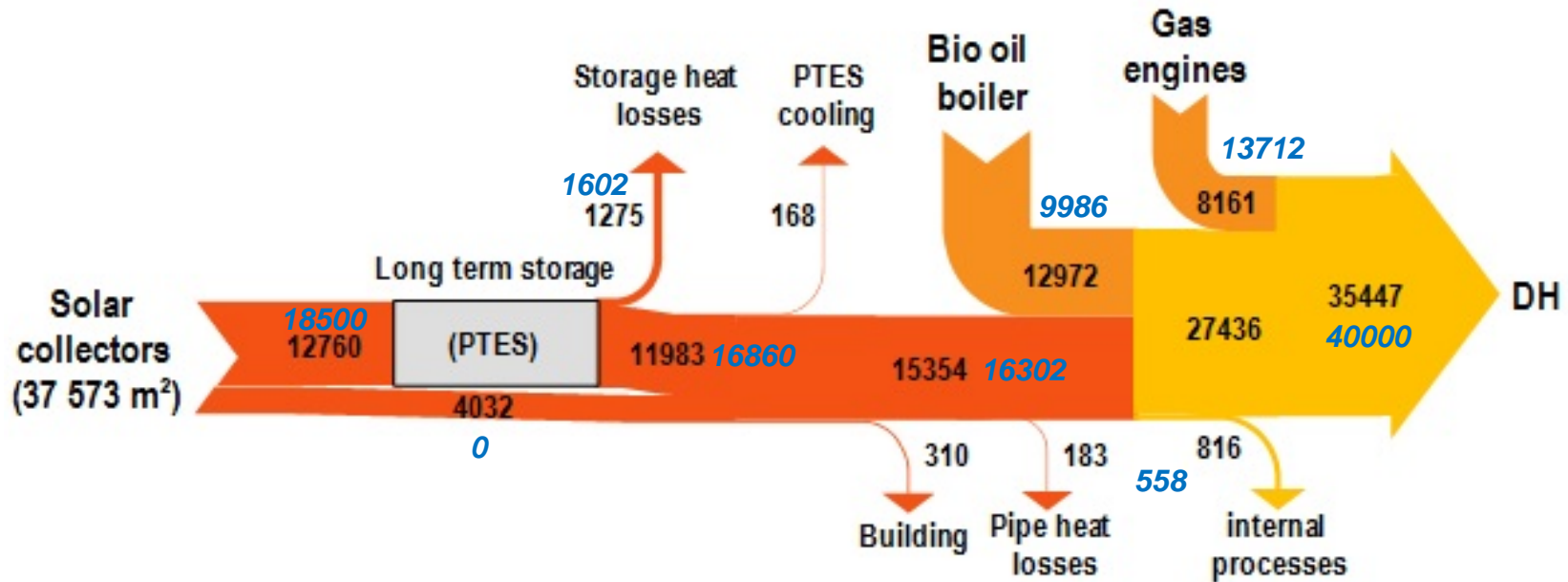


# Dronninglund | Energy flow diagram year 2015

Solar fraction: 41 %

RES fraction: 77 %

Solar gain: 447 kWh/m<sup>2</sup>a



Monitoring results 2015, numbers in MWh/a

Design figures, source: PlanEnergi, DK

# Dronninglund | Pit storage energy flow 2015

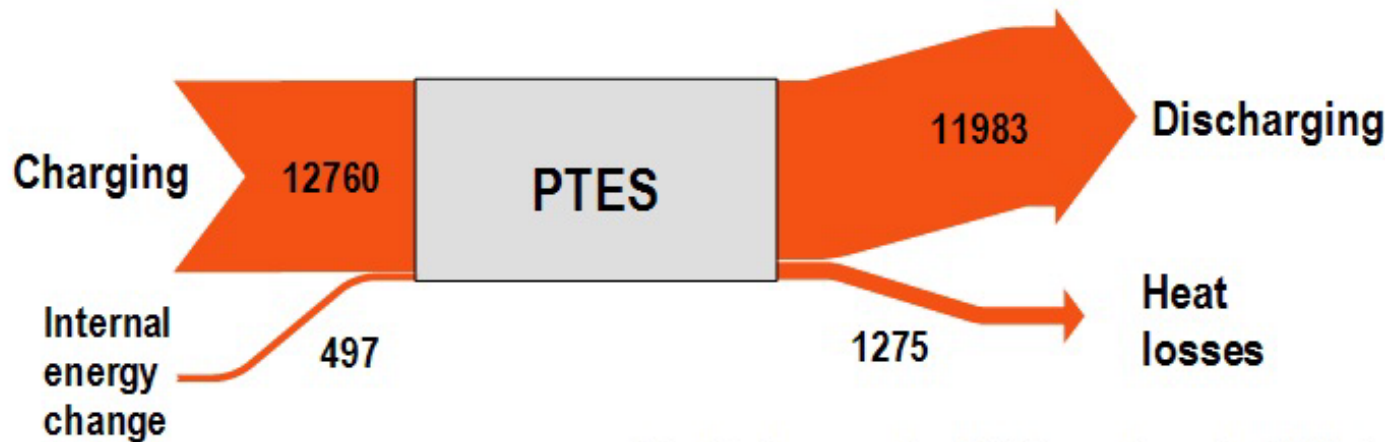
Storage efficiency: 90 %

T-max: 89 °C

No. of storage cycles: 2.2

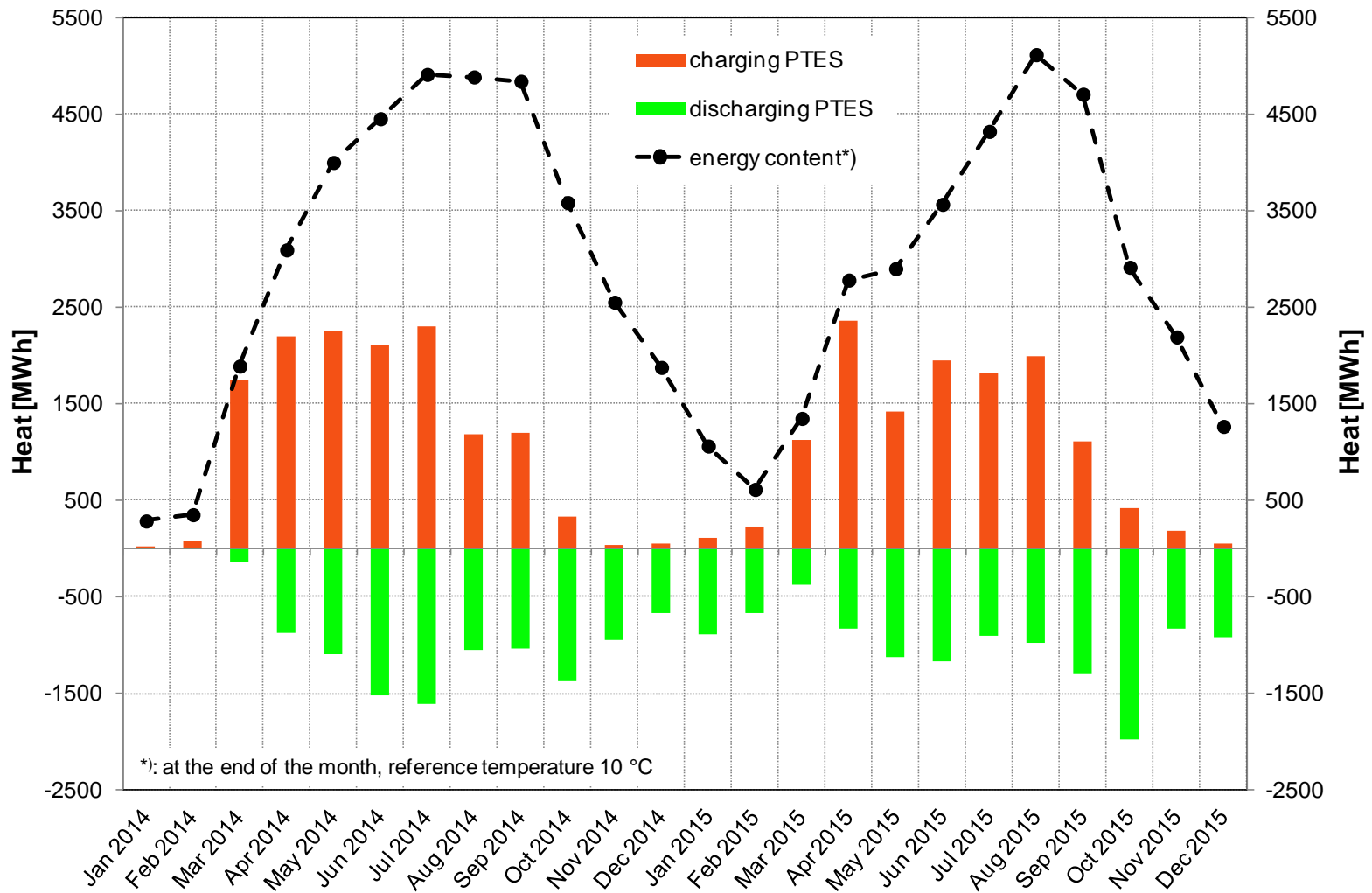
T-min: 10 °C

Heat capacity (64 K): 5 500 MWh



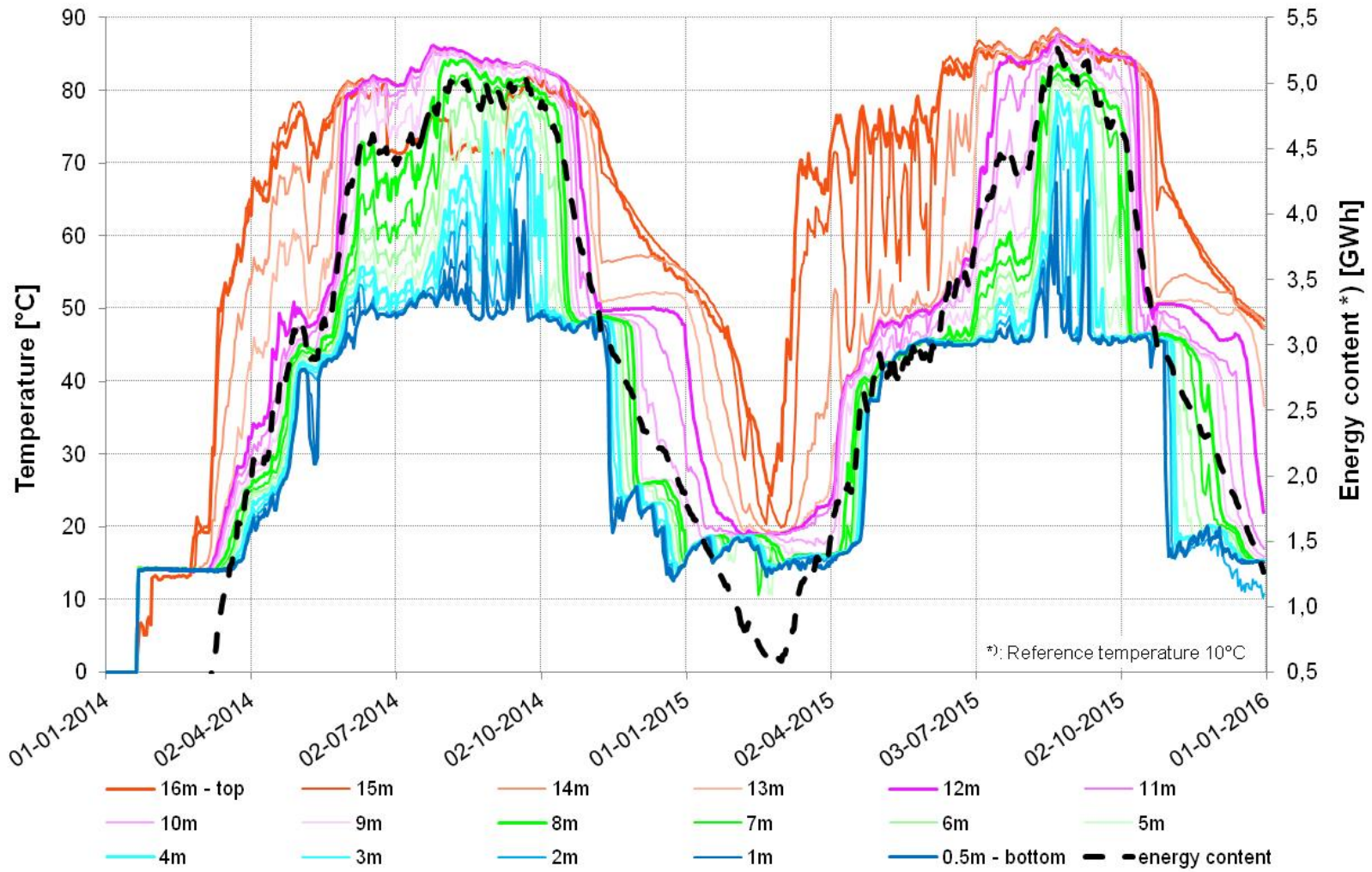
*Monitoring results 2015, numbers in MWh/a*

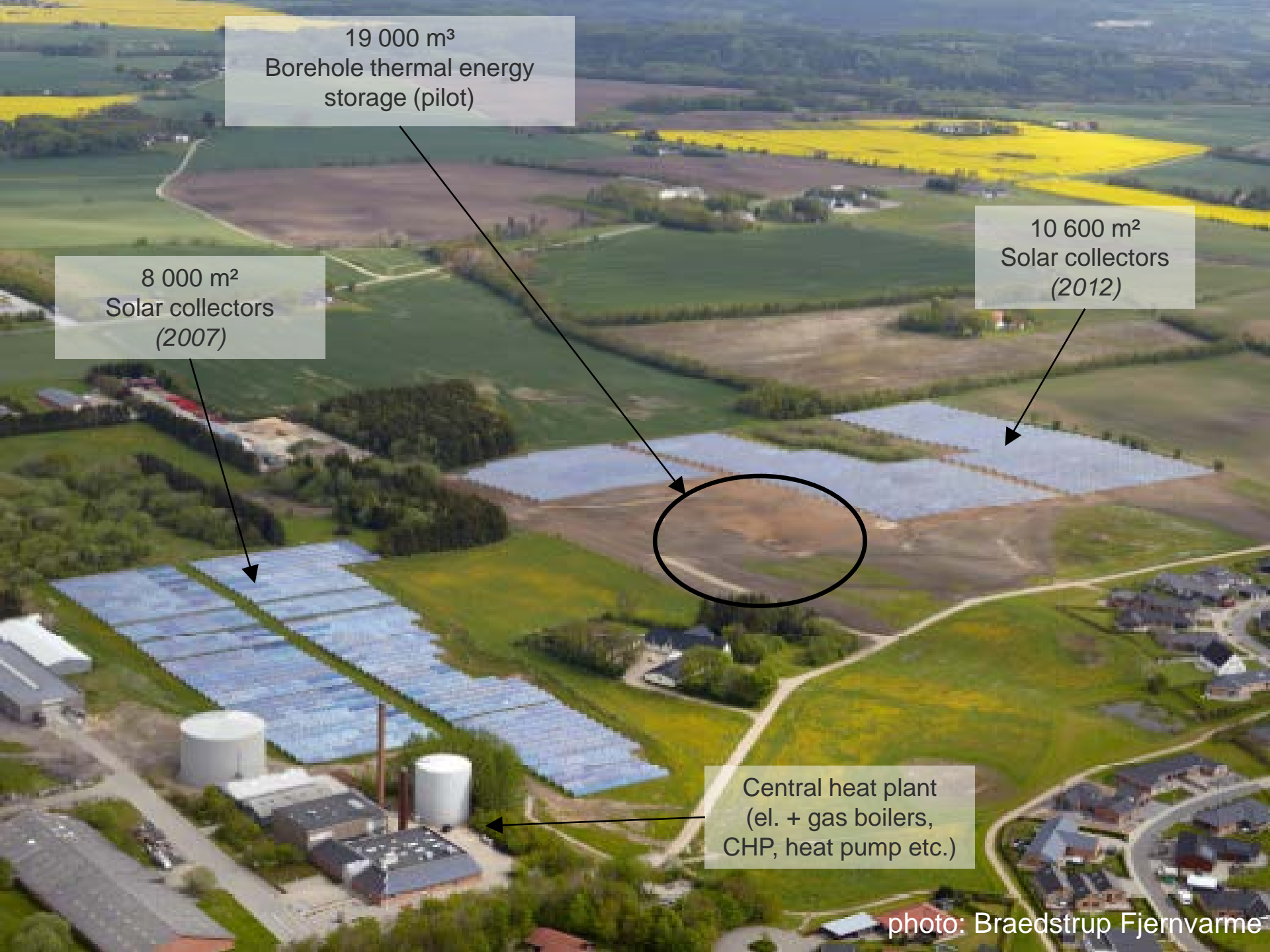
# Dronninglund | Pit storage energy balance 2014 + 2015





# Dronninglund | Pit storage temperature development





19 000 m<sup>3</sup>  
Borehole thermal energy  
storage (pilot)

10 600 m<sup>2</sup>  
Solar collectors  
(2012)

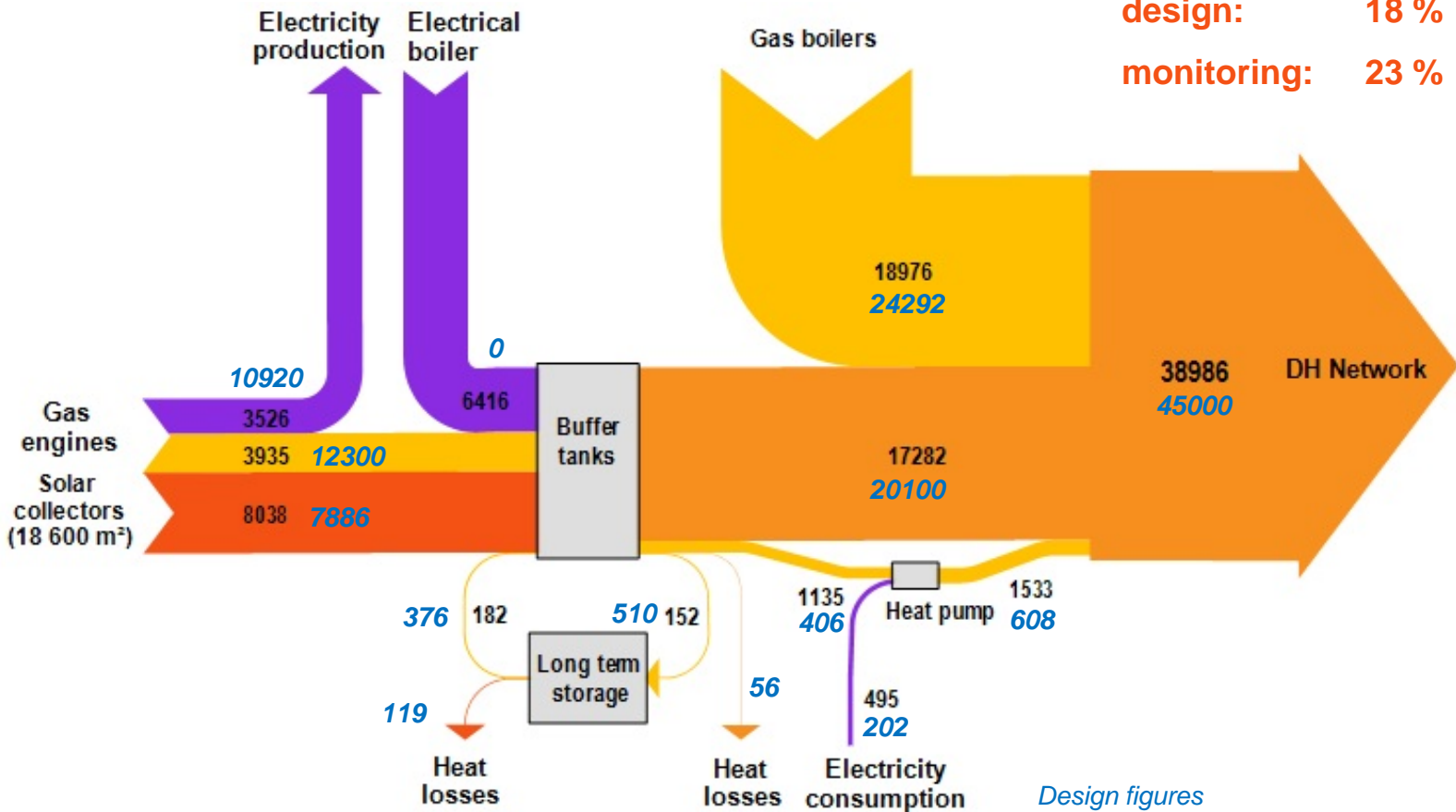
8 000 m<sup>2</sup>  
Solar collectors  
(2007)

Central heat plant  
(el. + gas boilers,  
CHP, heat pump etc.)

# Brødstrup | Energy flow diagram 2015

## Solar fraction

design: 18 %  
monitoring: 23 %



Design figures

Monitoring figures 2015, numbers in MWh/a



# Brædstrup | BTES energy flow 2015

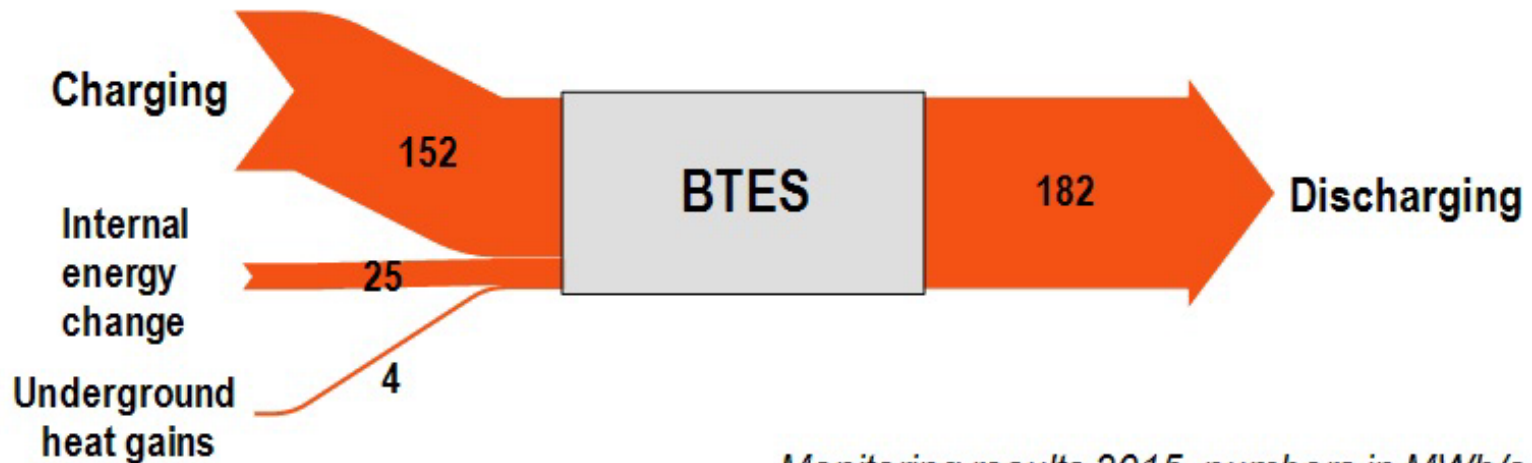
Storage efficiency: 102 %

T-max: 49.2 °C

No. of storage cycles: 0.5

T-min: 11.2 °C

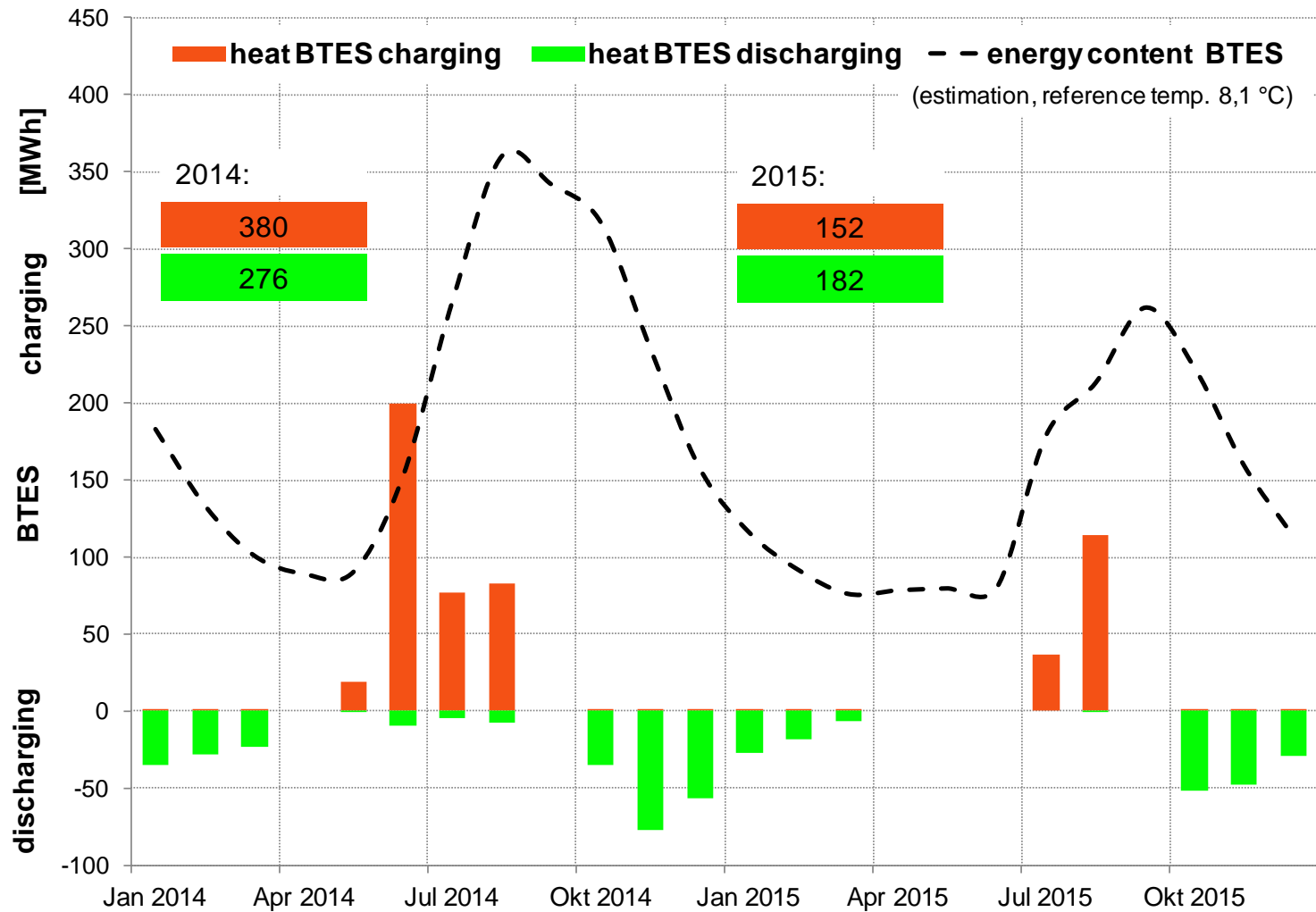
Heat capacity (38 K): 400 MWh



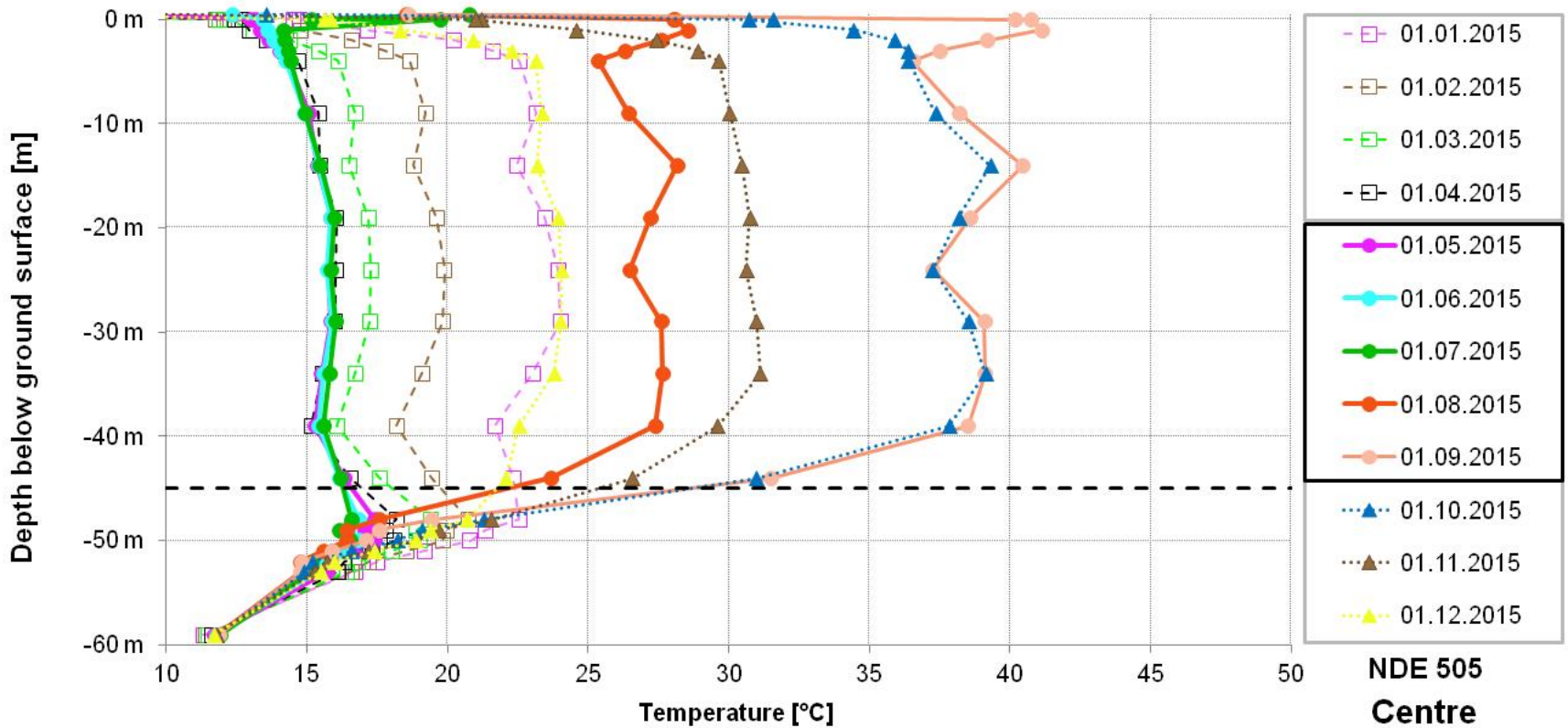
Monitoring results 2015, numbers in MWh/a

*(Estimation of BTES internal energy by simple BTES mean temperature)*

# Brædstrup | BTES energy balance 2014 + 2015

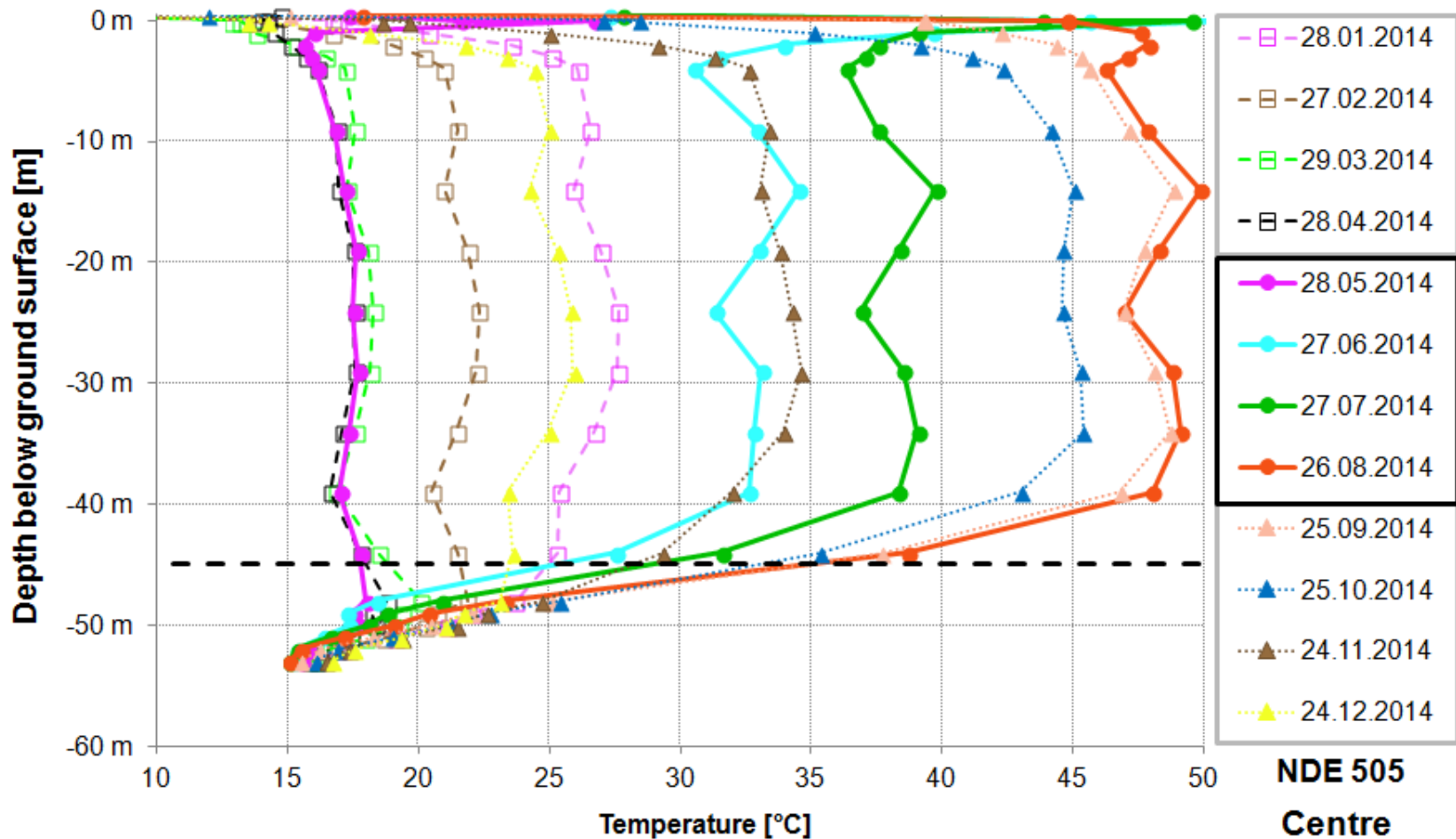


# Brædstrup | BTES ground temperature development 2015





# Brædstrup | BTES ground temperature development 2014



Thank you for your attention...

More information:

[www.solvarmedata.dk](http://www.solvarmedata.dk)

[www.sunstore4.eu](http://www.sunstore4.eu)

[www.solar-district-heating.eu](http://www.solar-district-heating.eu)

[www.solites.com](http://www.solites.com)



This work was financially supported by eudp.  
The authors gratefully acknowledge this support.

Photo: Marstal Fjernvarme