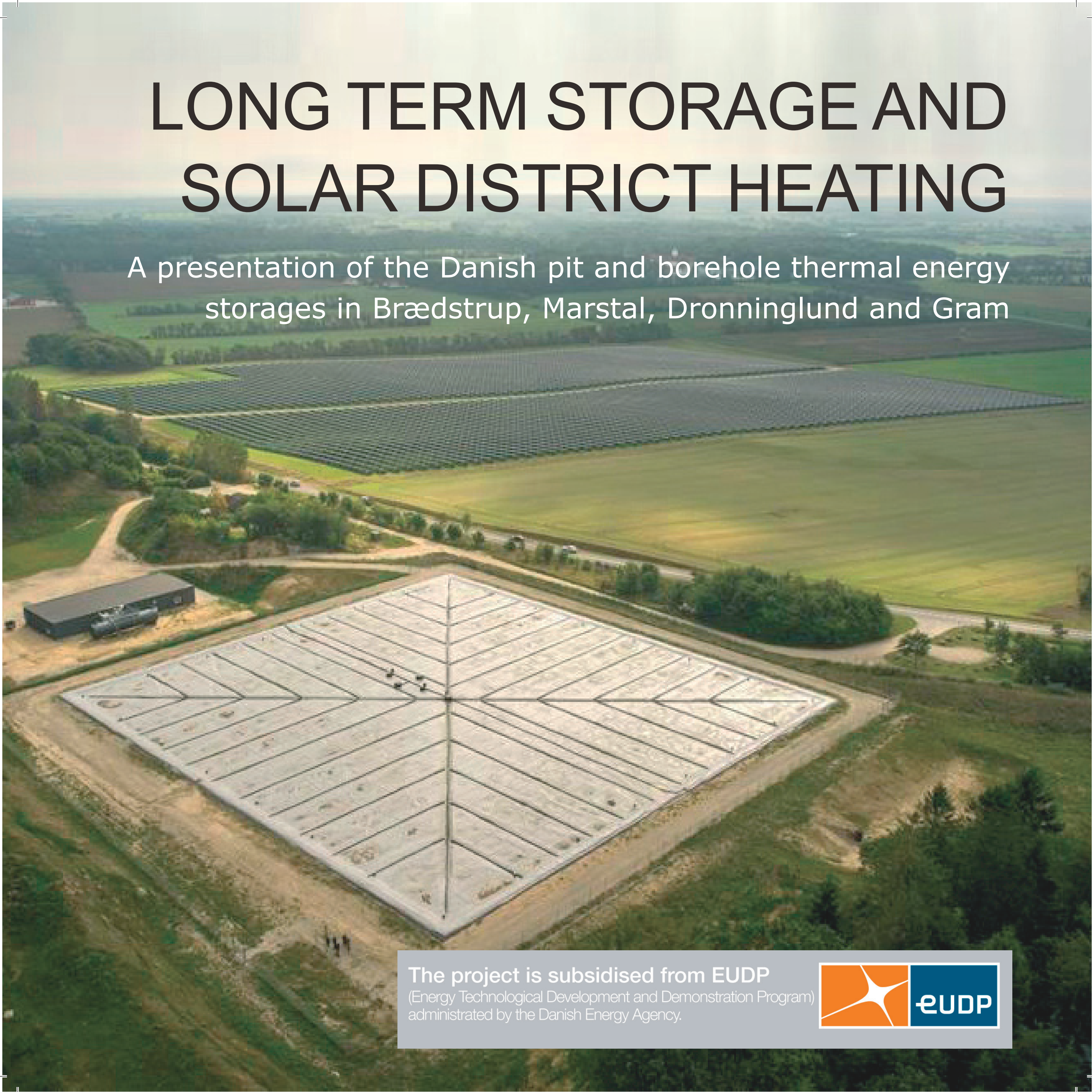
LONG TERM STORAGE AND SOLAR DISTRICT HEATING

A presentation of the Danish pit and borehole thermal energy storages in Brædstrup, Marstal, Dronninglund and Gram



The project is subsidised from EUDP
(Energy Technological Development and Demonstration Program)
administrated by the Danish Energy Agency.

Foreword

Solar District Heating

District Heating is a well-known technology in Denmark. Over the years the distribution network has been rolled out to a large percentage of the population. With solar thermal plants providing the energy, production at the district heating plant is fossil free. In Denmark the need for electricity is bigger in the winter where the hours of sunshine are limited. Therefore, storing the energy from summer to winter is the next step towards a more flexible electricity and heat production and higher fraction of solar thermal energy.

Contents

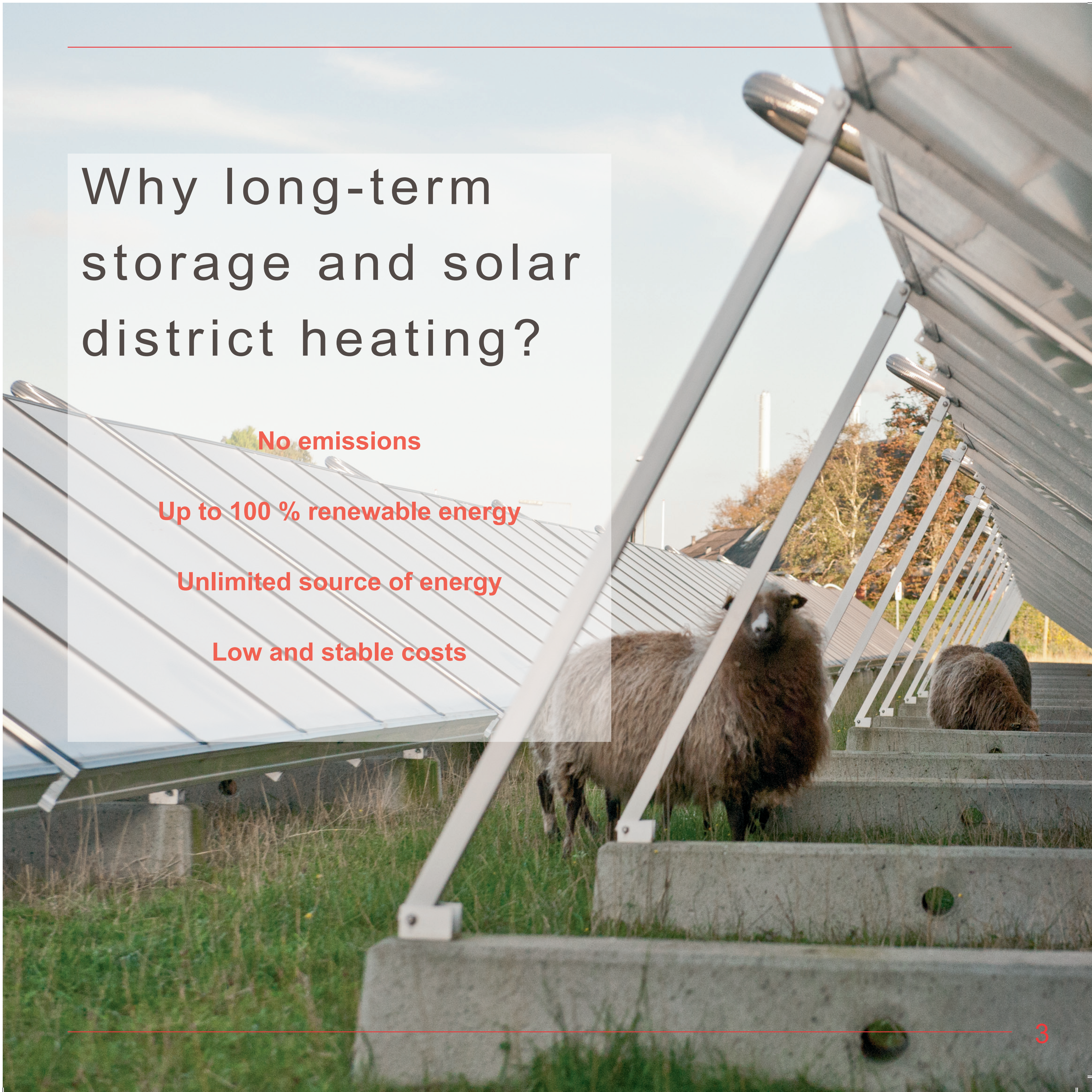
Why long-term storage and solar district heating?

No emissions

Up to 100 % renewable energy

Unlimited source of energy

Low and stable costs



Danish projects

Danish projects with long term storages

Long term storages has so far been implemented at five district heating plants in Denmark: Four of those are participating in a common monitoring program:

Brædstrup:

- 37,200 m^2 solar collectors
- 48 boreholes

Marstal:

- 33,300 m^2 solar collectors
- 75,000 m^3 pit storage

Dronninglund:

- 37,573 m^2 solar collectors
- 62,000 m^3 pit storage

Gram:

- 44,800 m^2 solar collectors
- Steel tank and seasonal storage: 122,000 m^3

The four projects are described in this folder.

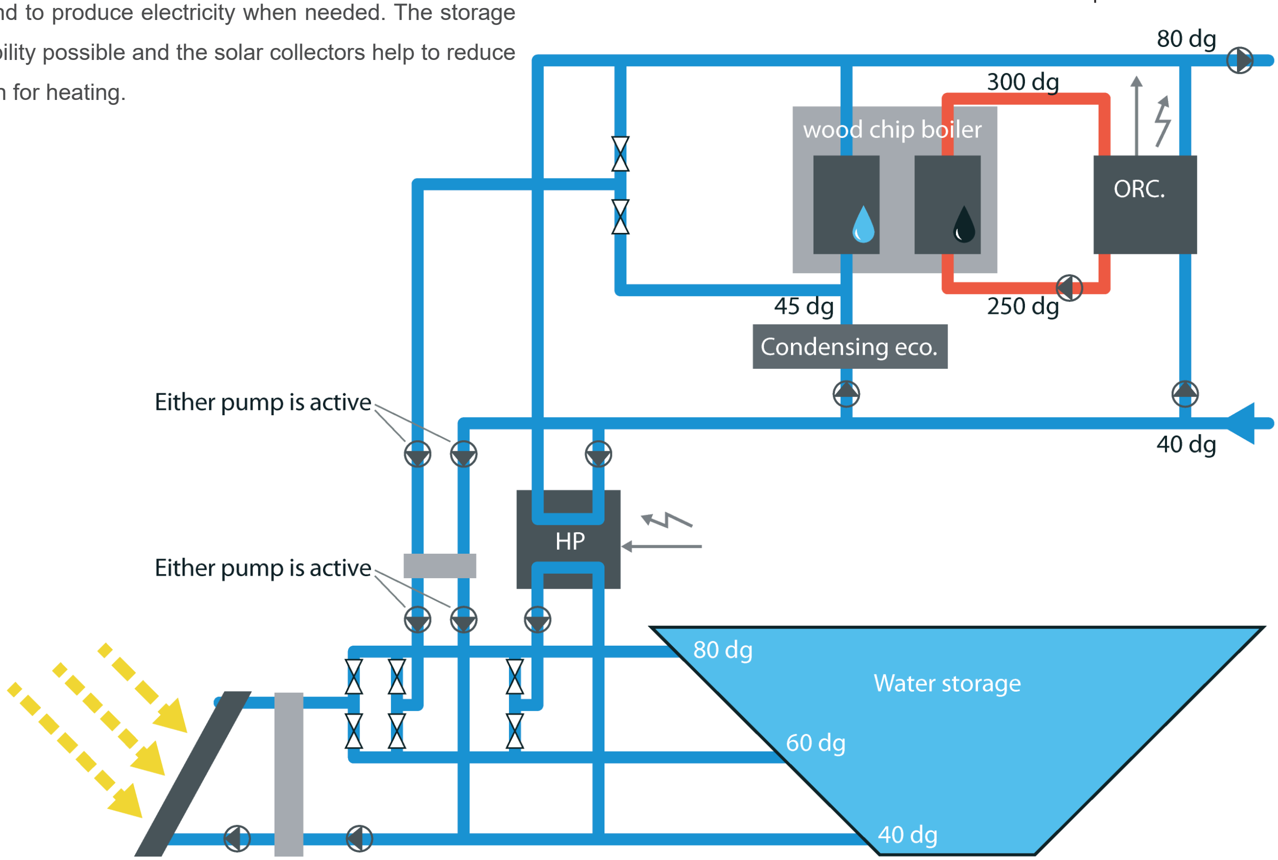
Map of Denmark with the location of Brædstrup, Marstal, Dronninglund and Gram.

SUNSTORE®

The SUNSTORE® concept consists of a large heat storage (pit heat storage, borehole storage or tank storage), solar collectors to heat up the storage, a heat pump to use the storage as heat source (and at the same time extend solar production, reduce heat loss from the storage and extend the storage capacity) combined with a CHP plant.

The concept makes it possible to use electricity in the heat pump when needed and to produce electricity when needed. The storage makes this flexibility possible and the solar collectors help to reduce fuel consumption for heating.

Illustration of the SUNSTORE® Concept in Marstal



Brædstrup

Brædstrup

The plant in Brædstrup

Brædstrup District Heating (DH) is consumer owned and has almost 1,500 consumers.

History

The district heating plant started as a traditional co-generation plant including CHP and boiler units using natural gas.

Over the last 10 years Brædstrup DH has been a frontrunner in Denmark in how to make district heating efficient, cheap for the consumers and environmentally friendly at the same time. In 2005 no Danish natural gas fired CHP had solar district heating. Brædstrup DH made design calculations showing that solar district heating combined with CHP in an open electricity market could be a feasible solution. In some periods the electricity prices are so low, that the engine is stopped and the heat is produced in natural gas boilers, making solar district heating a feasible solution.

Technology

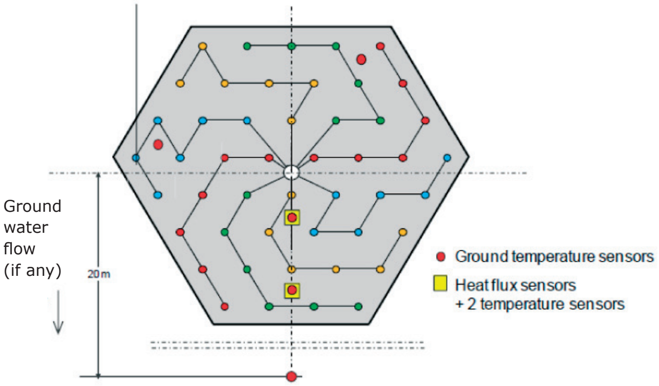
Based on these calculations a total of 8,000 m^2 of solar collectors were commissioned in 2007. It was the world's first solar thermal plant in combination with natural gas fired CHP. In 2008 Brædstrup DH decided to take the second step towards 100 % renewable energy. It was decided to implement another 10,600 m^2 of solar panels, 5,500 m^2 buffer tank, 19,000 m^3 pilot borehole storage, 1.2 MWth heat pump and a 10 MW electric boiler. The consumers' benefits are less pollution due to a reduction in natural gas consumption and low heat prices; Brædstrup DH is among the 25 % cheapest DH plants in Denmark.

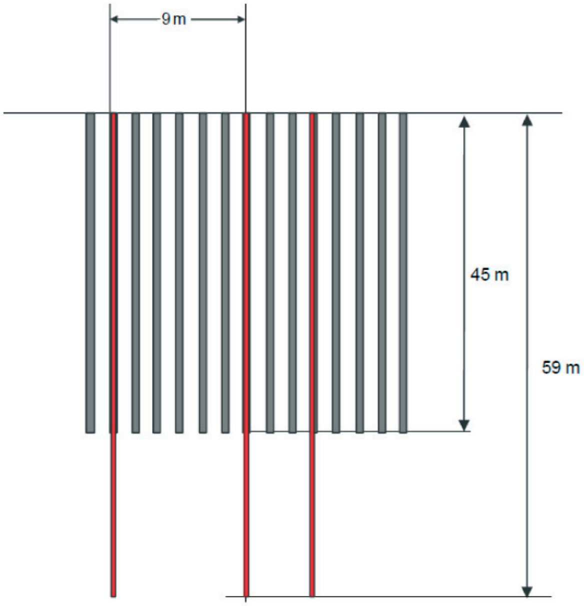
The long term Storage in Brædstrup

The long term storage in Brædstrup is a borehole thermal energy storage (BTES) where the boreholes are placed in a honeycomb pattern. Each borehole is equipped with a double U-pipe, and six boreholes are connected in series in a string from a center of the storage towards the periphery.

From an economical and heat loss point of view the boreholes should be as deep as possible without entering the groundwater. The groundwater level is more than 50 meters below the surface and the boreholes are 45 meters deep.

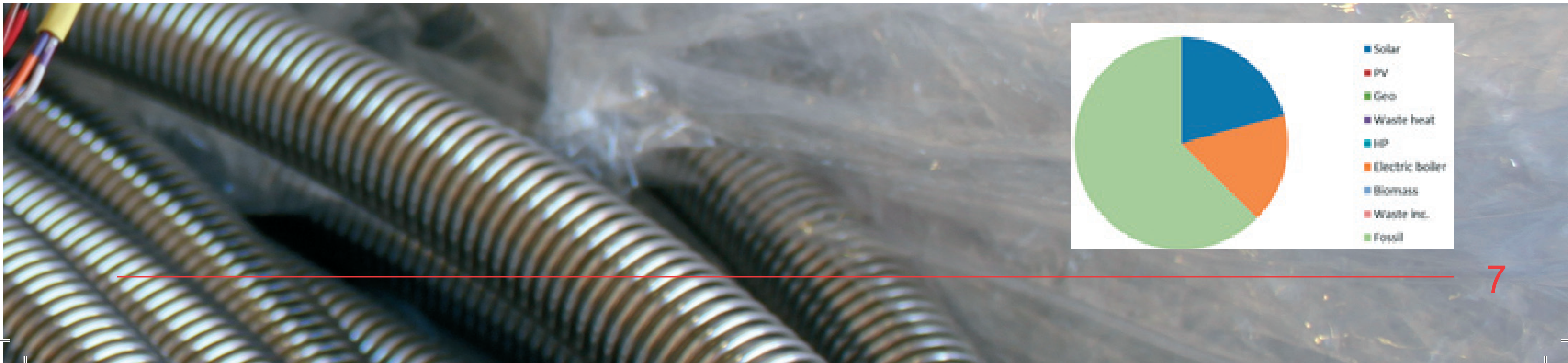
The storage is heated up to 55-60° C during summer and cooled down to 15° C by the heat pump during winter.





Technical data, Brædstrup:

Heat production technology / fuel / heat capacity / year of installation:	• 18,600 m² solar collectors, 2007 (8,000 m²) and 2012 (10,600 m²) • Electric boiler, 10 MW, 2012 • Heat pump (high pressure screw compressor), 1.2 MW, 2012, COP 3.1 • Boiler 1, natural gas, 13.5 MW, 2006, efficiency 104% • Boiler 2, natural gas, 10 MW, efficiency 100% • Engine 1, natural gas, 4.1 MW, η(heat) 47%, η(el) 42% • Engine 2, natural gas, 4.1 MW, η(heat) 47%, η(el) 42%
DH network:	• 27.9 km distribution • 21.1 km service pipes. Network age 17 years
Seasonal storage:	• 48 bore holes • Probes lowered to a depth of 45 meters • 5 x 60 meters deep holes for temperature sensors • 19,000 m³ soil is heated • Steel tanks, in total 7,500 m³ (2,500 m³ plus 5,500 m³)
Consumers / total annual heat sales, 2015 numbers	• 1,481 consumers • 296,378 m² connected floor area • 39,633 MWh heat produced • 31,100 MWh heat sold
Variable heat price Total heat price	• 63 EUR/MWh • 1,721 EUR/year (standard house 18.1 MWh; 130 m² incl. VAT)
Ownership	Private (consumer owned)



Marstal

Marstal

The plant in Marstal

Marstal District Heating's nearly 1,600 consumers receive district heating based on 100 % RE sources with a solar fraction of 41 % and biomass to cover the remaining.

History

Marstal District was established in 1962 and currently supplies district heating to nearly 1,600 consumers in Marstal.

The implementation of renewable energy started in 1994 where Marstal District Heating developed a project to install solar collectors on a swimming pool.

The success of this installation formed the basis for a plan to install a large scale solar heating plant of 8,000 m² connected to the district heating plant. With more than 18,000 m² of solar panels Marstal Solar Plant was in 2003 the largest solar installation in the world.

Sunstore 4

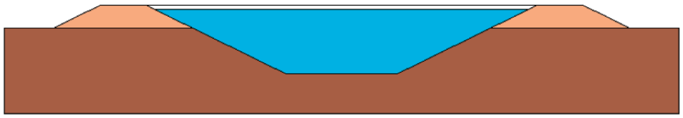
In 2010-12 the solar panels were expanded by another 15,000 m² and new pit heat storage of 75,000 m³. The project also included a heat pump which uses the energy storage as a heat source and an ORC (Organic Rankine Cycle) which is an electricity producing device that uses the energy from the flue gas produced in the biomass boiler.

This SUNSTORE4 project received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 249800.

The project is, along with 10 other European projects selected to be a part of the so-called "EU flag projects". Further information can be found at: http://sunstore4.eu/background/project-brief/.

The long term storage in Marstal

The long term storage in Marstal is a pit thermal energy storage (PTES) with water as storage medium. The storage is a truncated pyramid upside down. The size is 75,000 m³. The excavated soil from the lower part of the storage is used as an embankment around the storage.



The storage is covered by an onsite welded HDPE liner. On top of the storage the water is covered by a floating insulating cover. Charging and discharging of the storage is done through an in- and outlet-arrangement with three in/outlet pipes to the pit heat storage. The storage is charged to 80-85° C during summer and discharged down to 10° C during winter. The storage is used directly and as a heat source for the heat pump.

Technical data, Marstal:

Heat production technology / fuel / heat capacity / year of installation:	• 18,300 m^2 solar system + 15,000 m^2 solar system • 8.3 MW bio-oil boilers • 2,100 m^3 steel tank water storage • 75,000 m^3 pit heat storage • 4.0 MW wood chip boiler producing thermal oil for ORC. Heat output 3.25 MW, η(heat) 82%, η(el) 18% • 750 kWel ORC (Organic Rankine Cycle) • 1.5 MWth heat pump using CO_2 as refrigerant, COP 3.4
DH network:	• 19.5 km distribution • 17.7 km service pipes
Consumers / total annual heat sales	• 1,481 consumers • 296,378 m^2 connected floor area • 32,000 MWh heat produced • 24,640 MWh heat sold
Variable heat price Total heat price	• 107 EUR/MWh • 2,525 EUR/year (standard house 18.1 MWh; 130 m^2 incl. VAT
Ownership	Private (consumer owned)

Dronninglund

Dronninglund

The plant in Dronninglund

Dronninglund Fjernvarme is consumer owned and has almost 1,350 consumers.

History

In 1989, Dronninglund Fjernvarme was the first Danish district heating company to install natural gas driven engines for combined heat and power production.

Around 2005, the board and the general assembly of Dronninglund Fjernvarme realized that they should replace natural gas with renewable energy.

At that time, several Danish district heating companies had installed solar thermal plants that covered approximately 20 % of the annual heat production. However, Dronninglund Fjernvarme wanted to take it a step further and aspired to cover up to 50 % of the annual production with solar thermal.

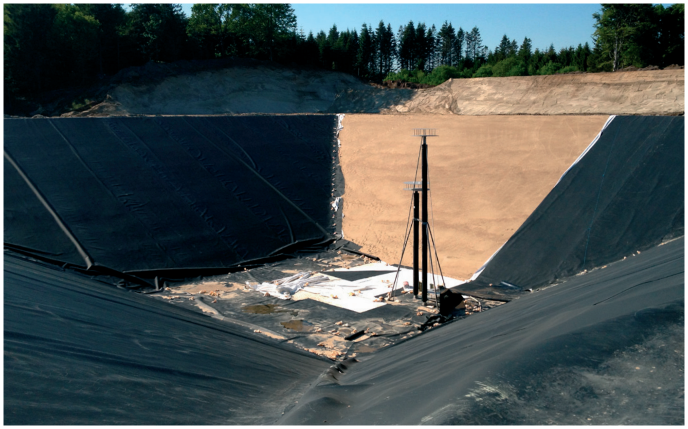
Dronninglund Fjernvarme applied for subsidy from EUDP (Energy Technology Development and Demonstration Programme), a program financed by the Danish state. The subsidy was granted for detailed design and for investments in long term storage, piping, heat exchangers and a control system to connect the production units.

Technology

The main components in the new production plant are a large solar thermal plant and a pit heat water storage. At the opening in May 2014, the solar collector field was the largest in the world.

The long term storage in Dronninglund

The Dronninglund storage is a pit thermal energy storage (PTES) of 60,000 m^3. The design is similar to the storage in Marstal, but the in- and outlet enters through the bottom of the storage where the pipes in Marstal enters through the side.

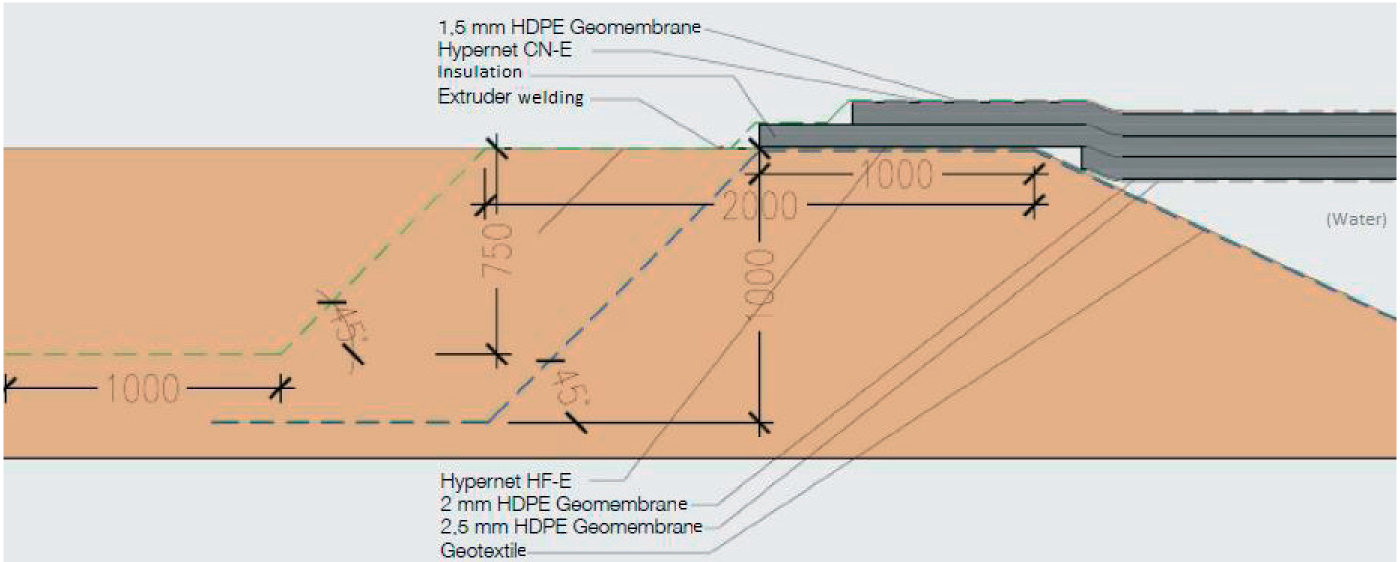


The storage in Dronninglund is situated in an abandoned gravel pit. This made the excavation easy compared to Marstal, where clay caused problems as excavation took place in a rainfull summer.

Rainwater flows to the lid's center because several pipes with concrete are placed on top of the lid. The storage is charged to 85° C during summer and discharged to 10-15° C during winter. The storage is used directly and as heat source for the absorption heat pump.

Technical data, Dronninglund:

Heat production technology / fuel / heat capacity / year of installation:	• 37,573 m² solar collectors, 26 MW, 2014 • Water storage 60,000m³ • Bio oil boiler driven heat pump, 2.1 MW cooling • 8 MW natural gas boiler, 1989 • 6 MW Engines: η(heat) 60%, η(el) 34.5%
DH network:	• 46 km main network
Consumers / total annual heat sales	• Around 1,350 consumers • 294,432 m² connected • 38,700 MWh heat production • 29,700 MWh heat sold
Variable heat price Total heat price	• 71 EUR/MWh • 1,690 EUR/year (standard house 18.1 MWh; 130 m² incl.VAT)
Ownership	Private (consumer owned)



Gram

The plant in Gram

Gram Fjernvarme is consumer owned and was until 2009 based on natural gas with a CHP unit and two boilers. The heat capacity of the CHP unit is 6.5 MW and the heat capacity is 5.0 MW for each boiler. The annual heat demand is around 30,000 MWh.

History

The first phase of the solar field of more than 10,000 m^2 was established in 2009. The solar field covered around 15 % of the heat demand and was connected to the existing steel tank of 2,300 m^3.

The solar collector field was expanded in 2015 to an area of 44,800 m^2 in total. After the expansion the system is expected to be able to cover about 60 % of the heat production.

The high solar fraction is only possible through the establishment of a seasonal pit storage, an absorption heat pump and an electric heat pump which allow the collectors to operate at a lower temperature, whereby the efficiency increases significantly.

Technology

The solar collector field is connected to the plant by a transmission line that is approximately 200 meters and has a dimension DN200.

The purpose of the electrically powered heat pump is to cool the bottom of the seasonal heat store. By cooling the bottom of the heat store the operating hours of the solar plant are increased which increases utilization of the solar system. The CHP unit delivers the driving energy to the absorption heat pump. This is done by replacing the high temperature flue gas heat exchanger with an approved exchanger for heated water above 150° C.

This results in an excess of cooling water that can be recovered for further optimization of gas boilers, solar heating and an electric driven heat pump.

Gram District Heating is neighbor to a carpet factory. The carpet factory currently has two processes that have delivered surplus heat to Gram District Heating since June 2016. It is expected that 2,000 MWh/year can be obtained. To deliver excess heat is part of the factory´s commitment to the concept of cradle to cradle.

The long term storage in Gram

The Gram storage is a pit thermal energy storage (PTES) of 122,000 m^3. The storage design is similar to the storage in Marstal but the construction of the lid is altered since expanded clay is used as insulation material.

The storage is charged to 85° C during summer and discharged to 10° C during winter. The storage is used directly and as heat source for the compressor driven heat pump.

Technical data, Gram:

Heat production technology / fuel / heat capacity / year of installation:	• 10,073 m^2 solar collectors, 6.5 MW, 2009 • 34,727 m^2 solar collectors, 31 MW in total for all 44,800 m^2 solar collector field (3,556 panels), 2015 • 2 Boilers, natural gas, 10 MW, 100% • Engine, natural gas, 6.5 MW, η(heat) 50%, η(el) 41.2% • Electric boiler, 8 MW • Electric driven heat pump, 900 kW, 2015 • Steel tank (in connection to CHP and first solar collectors) 2,300 m^0 • Seasonal storage: 122,000 m^3
DH network:	• 21.1 km main network • 13.3 km service pipes
Consumers / total annual heat sales	• Around 1,200 consumers • 25,000 - 30,000 MWh
Variable heat price Total heat price	• 80 EUR/MWh • 1,925 EUR/year (standard house 18.1 MWh; 130 m^2 incl. VAT)
Ownership	Private (consumer owned)

Future prospects

Market

For heating to be converted 100% to renewable energy sources (RES) the future sources for heating willneed to be excess heat from waste incineration and industrial processes, biomass, solar thermal, geothermal heat and RES electricity.

Biomass will be utilised for heat production only until the transport sector has to be converted to RES. RES electricity will primarely be used in heat pumps.

Geothermal heat will also very often be used as a heat source for heat pumps.

District heating will very often be the most efficient way and sometimes the only way to utilize RES.

Conclusion: Future district heating production will be expanded and come from excess heat, solar thermal and heat pumps. Still, CHP using green gasses will be part of some of the DH plants and thermal storages will be part of the plants to add flexibility.

CO_2

The solar thermal production from a plant in Denmark with long term storage is 0.4 MWh/m^2 solar collector. Replacing natural gas, the CO_2 reduction will be 82 kg/m^2 solar collector and for replacing oil it will be 106 kg/m^2. In Southern Europe the reduction will be higher.

For one m^2 of solar collector 3-4 m^2 of land is needed. But solar collectors can be placed on farmland and the production of energy/m^2 farmland is 30 times higher for solar thermal compared to energy crops.

Potential

Since solar thermal, heat pumps and long term storages is one of the few future solutions for heating using 100% RES the potential is huge.

Plant no. 5 in Denmark is already implemented in Vojens and further plants are in the pipeline. Outside of Denmark design calculations have been carried out for plants in Austria, Germany and Italy and several countries have shown their interest in the concept.

Contact

For further information, please contact:

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www.planenergi.dk

Photo front: Dronninglund District Heating, NIRAS
Photo page 8-9: Marstal Fjernvarme
Photo page 13: Gram Fjernvarme
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