EUROSUN 2008
1st International Congress on Heating, Cooling, and Buildings
7th to 10th October, Lisbon - Portugal

511 - Water Storages, Solar thermal and Heat pumps in District Heating

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Abstract

In 1996 Marstal Fjernvarme (Marstal District Heating) established 8.000 m2 solar collectors that covered 13% of the yearly consumption. The solar fraction in later built district heating plants goes up to 25% covering the total summer load, but several district heating companies especially natural gas fired combined heat and power plants want a higher solar fraction in order to replace expensive natural gas. Therefore new projects with solar fractions of 50% are designed and are expected to be implemented in 2009. Design calculations show that the production price for heat from solar thermal plants with 50% solar fraction can compete with heat prices from natural gas fired CHP plants.

1. Introduction

This paper explains the Danish development in solar thermal plants for district heating from 1996-2008 and gives an opinion on future possibilities for solar district heating and cooling in Denmark and Europe.

2. The development 1996-2007

In the period 1996-2007 solar district heating plants were established at 6 places in Denmark. All projects were supported by the Danish Energy Agency and/or by The European Union and all plants consisted of ground mounted flat plate collectors of 12,5 – 14 m2 and has pumps with variable flow making it possible to decide a fixed production temperature from the solar collectors.

In the period the production price/MWh heat has been remarkable reduced for the same or higher solar fraction.

Plant	Collector areal	Established	Production MWh/year	Price Mio. €	Solar fraction %	Prod. price €/MWh Annuity 0,1	Prod. price €/MWh 2006 level
Marstal	8038 m^2	1996	3472	2,23	13	64	87
Ærøskøbing	4890 m^2	1998-2000	2103	1,24	16	59	83
Nordby	2500 m^2	2002	1100	0,63	25	57	63
Ulsted	5000 m^2	2006	2400	1,28	21	53	53
Brædstrup	8000 m^2	2007	3729 (calculated)	1,68	9	45	44

Table 1. Price development 1996-2007 (examples calculated without investment support)

Marstal combines solar with waste oil. Ærøskøbing combines solar with straw, Nordby combines solar with wood chips, Ulsted combines solar with wood pellets and Brædstrup combines solar with natural gas utilised in a combined heat and power (CHP) plant.

The latest development in natural gas price has now resulted in implementation of one more solar district heating plant combined with natural gas fuelled CHP in 2008 and two plants are ordered for 2009 and more plants are expected to follow. These plants are implemented without economical support.

Fig 1. Brædstrup implemented 2007

3. Higher solar fraction

Most Danish natural gas fuelled CHP-plants are now operating in a free electricity marked, where one of the main sources of income comes from regulation of electricity production. The regulation is needed because of a large fraction of windmill produced electricity in the Danish system.

That means normally less running hours for the engines and 25-50% of the heat produced in a natural gas boiler. Natural gas is an expensive fuel that very often means production prices of more than 60 €/MWh.

Therefore solar heat is an attractive alternative, but if the solar fraction exceeds app. 10%, the accumulation tank is too small for electricity regulation. The CHP-plants are thus eager to find solutions making it possible to increase the solar fraction and at the same time keep the regulation possibility. In the following 4 new projects with higher solar fraction are described.

3.1. Marstal Fjernvarme

The latest extension of the solar production plant in Marstal means that they in 2008 have a solar fraction of 30% coming from 18.300 m^2 of solar collectors combined with a 10.000 m^3 pit heat storage and a 2.000 m^3 steel tank. The rest of the fuel is biooil where the production price/MWh is app. 65 €. Marstal has therefore investigated the possibilities of a larger solar fraction. Design calculations shows that an extension with another 4.000 m^2 solar collectors, a 10.000 m^3 steel tank or pit heat storage, a 1,5 MW heat pump (to cool the storages and use outdoor air) will rise the heat production with 4.800 MWh/year and increase the solar/heatpump fraction to 45%. The production price for the extended production is calculated to 66 €/MWh with an annuity factor of 0,1 and without electricity tax. The extension is planned to be realised in 2009.
Investment costs are 2,8 mio. €.

3.2. Strandby

Strandby Varmeværk is a consumer owned district heating company producing 16.000 MWh/year with natural gas fuelled CHP and boiler. In the summer 2008 Strandby Varmeværk is implementing 8.000 m^2 solar collectors, 1.500 m^3 steel tank and an absorption heat pump. The solar collectors will cover 18% of the annual heat production and the absorption heat pump will cover another 5%. The absorption heat pump is cooling fluegas from CHP, and boiler and utilising low temperature heat form the solar collectors. The production price for heat is calculated to 55 €/MWh (annuity 0,1).
Investment costs are 2,2 mio. €

3.3. Ring Søpark, Brædstrup

Ring Søpark is a new housing area outside Brædstrup with app. 500 single family houses. The first part (100 houses) will be supplied with district heating, but in a way that makes it CO2 –neutral. Altogether the houses will have app. 1.000 m^2 roof, integrated solar collectors (50-100 m2/roof), 2.000 m2 ground mounted solar collectors, 1.000 m^3 accumulation tank and a compressor heat pump to cool the ground mounted solar collectors. Surplus heat in the summer period will be “lent” to the district heating system covering the rest of the city and “barrowed” again in the winter period. One of the topics of the project is to show that collective solutions for bringing down CO2 –emissions from houses are cheaper than individual solutions in the house.

The project will demonstrate

- Roof integrated solar collectors delivering to the district heating network.
- CO_2 –neutral houses to lowest costs for the society.
- Extended regulation possibilities for electricity.
- Optimises district heating network with a heat loss of 15-20% in new areas with single houses.
- Central control of heat demand from the district heating system to each house making it possible to lower the forward temperature in periods.

The project is supported from the Danish state to make it feasible compared to the present heat production price from the district heating plant, but when the energy frame for buildings will be lower, the costs can be fully paid by the consumers because the investment costs for reduction of fuel consumption are lower than the investment cost in the single house for the same reduction.
The first part is expected to be build in 2009.

3.3. Dronninglund

Dronninglund Fjernvarme is a district heating company producing 40.000 MWh/year with natural gas fuelled CHP and boilers. Dronninglund has got support to design an energy system with app. 35.000 m2 solar collectors, 50.000 m^3 pit heat seasonal storage and 3 MW compression heatpump (thermal output) covering 50% of the yearly consumption. The heat pump uses CO_2 as medium and can produce hot water at 80 ^oC as needed for forward temperature in the district heating system.

The pit heat storage will be of same type as the 10.000 m3 storage in Marstal, but the floating cover construction will be changed to a solution where LECA is uses instead of mineral wool and EPS as insulation and where the cover can be parted in sections making it possible to construct large covers and reduce problems if the constructions is not tight

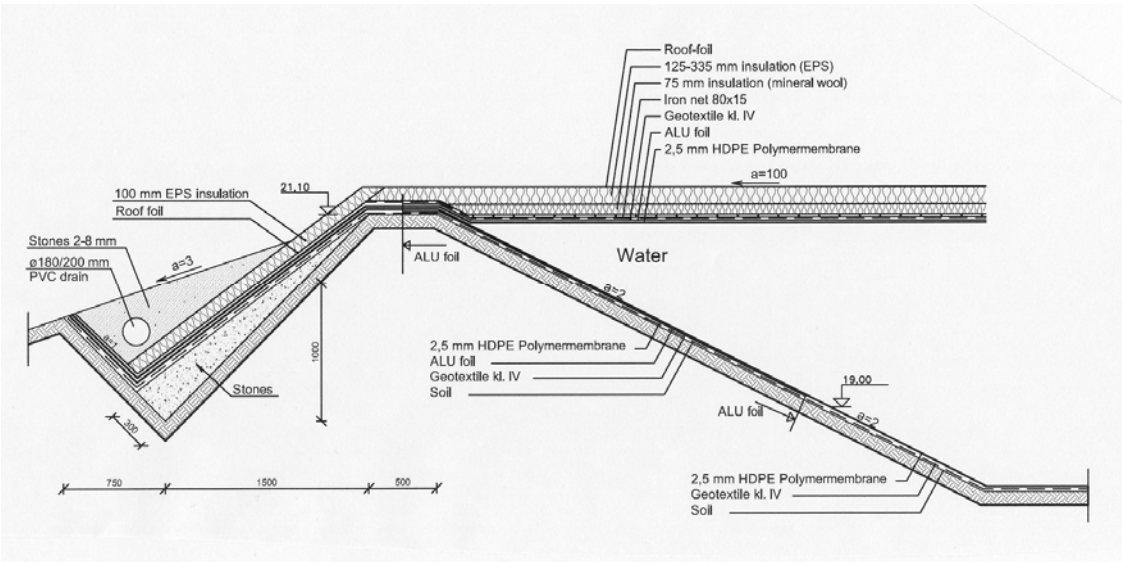

Fig. 2. Construction cross section, Marstal

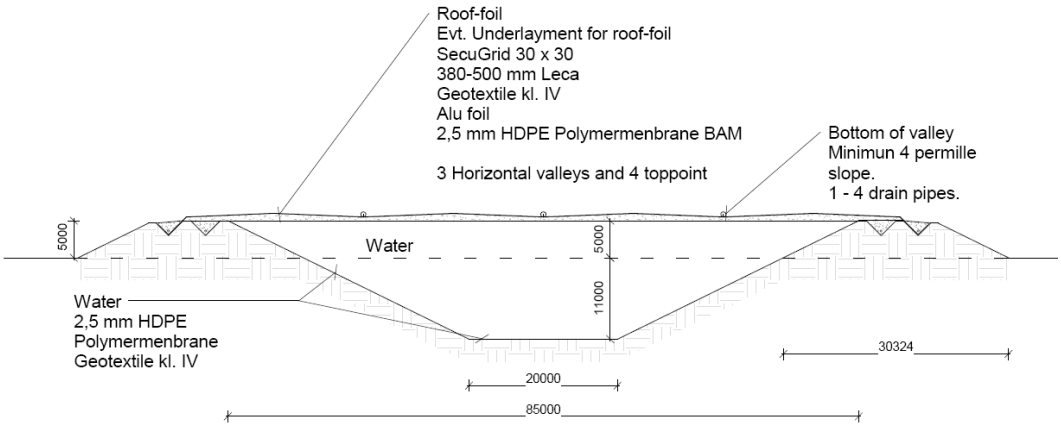

Fig. 3. Contruction croos section, Dronninglund

The heat production price is calculated to 70 €/MWh (annuity 0,1). Investment costs are app. 11. mio. €. The Danish Energy Agency is applied for support.

4. What will the future bring?

The authors expect that the future will bring

- Limited resources of natural gas
- Increased demand for biomass to gas and liquids for the transport sector
- Increased windmill capacity (+photovoltaic and wavepower)
- Increased demand for electricity regulation

That means that heat production mainly has to come from renewable energy (not biomass) and "waste" heat from electricity regulation.
The most efficient systems to solve these problems are district heating systems. So a main part of the solution of the above mentioned problems will be

- District heating (and cooling) systems with solar, seasonal storage and heat pumps in Northern and Eastern Europe.
- District cooling (and heating) systems in Southern Europe. Not only in new building sites but also in existing cities.

Fig. 4. Marstal implemented 1996-2004.