European Commission

Case study on Solar-heating plant in Silkeborg, Denmark

Annex A.4 to Part 1 *of the Study on the competitiveness of the renewable energy sector*

ENER/C2/2016-501

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Abstract

The European Commission aims to analyse the competitiveness of the European heating and cooling industry. Four case studies of successful and competitive deployment of heating and cooling solutions at a city level from selected organizations support this analysis. The case studies aim to illustrate how competitive are renewable energy technologies such as solar-thermal, biomass, biogas and heat pump in the context of different local factors across Europe, and what are what are the impacts from their deployment to the local communities.

The case study is based on the desk search, field visit and interview with project owners. This case study presents a solar-heating plant in Silkeborg, Denmark.

1 Introduction

The world's largest solar-thermal plant is currently located in Europe (Denmark, near Silkeborg)[1]. In the case of Silkeborg, solar collectors have been the most cost-effective technology to supply 22 000 households with renewable heating, and help the area reach the goal of 100% carbon neutral heat by 2030. The commissioning of the project illustrates that a renewable energy transitioning in the heating sector can be realized cost-efficiently and in less than a year.

Figure 1 Solar-thermal plant near Silkeborg, Denmark

Source: Arcon-Sunmark

The commissioning of the plant is part of Silkeborg's municipality's carbon neutrality transition. Silkeborg Supply[2] (a municipally owned utility supplying heat in the area) took a step in this transition by constructing the solar-thermal plant (at Sejling Hede, near Silkerborg), which reduces CO_2 emissions by approx. 15 000 tonnes per year.

The solar-thermal plant supplies approximately 20% of Silkeborg's annual district heating demand[3] via the district heating network. In sunny days, the plant has supplied as much as 100% of the heating demand. Surplus heat is stored in tanks for later use[4]. The solar-heating plant has a minimum lifetime of 25 years and its heat production covers the total annual heat consumption of 4 400 households (from a total of 22 000 connected to the district heating network). The plant consists of 12 436 solar collectors, covering a size of 156 694 m2. On a sunny summer day, there are 2.7 million liters of water per hour circulating through the system, which is connected to the district heating network via 1.2 kilometer of pipes.

[1] http://arcon-sunmark.com/cases/fjernvarme-silkeborg-danmark
[2] The utility operates in the areas of water, waste and recycling, wastewater, industry, and heating.
[3] 20% is a maximum which is limited by the storage capacity
[4] On a sunny day, there are 2.7 million litres of water per hour through the plant, whose 12,436 solar collectors are connected with 24 kilometres of wire

During 2017, other important energy transition technology upgrades in Silkeborg included a heat pump and flue gas condensation system reducing CO_2 emissions further by approx. 14 000 tons of CO_2. With those emission reductions, Silkeborg Municipality has already reached the goal of reducing emissions by 45% by 2020.

An overview of the technical characteristics of Silkeborg's solar thermal plant are summarized below.

Table 1 Key technical characteristics

Location	Silkeborg, Denmark
Total sqm. solar plant	156 700 m²
Number of collectors	12 436
Heat storage (steel tank without pressure)	4 x 16.000 m³
Performance of collectors (Capacity)	110 MW
Calculated solar heat	80 000 MWh
Calculated Solar heat coverage	20%
CO_2 Saving	15.000 Ton/year
Expected lifetime of solar system	Minimum 25 years
Installation/Commissioning	2016 (Dec)
Number of households supplied	22 000
Additional heating source	Natural Gas
Operation temperature (Summer)	82°C / 47°C
Operation temperature (Winter)	47°C / 12°C
Pipes	22 km (300 km in the whole network)

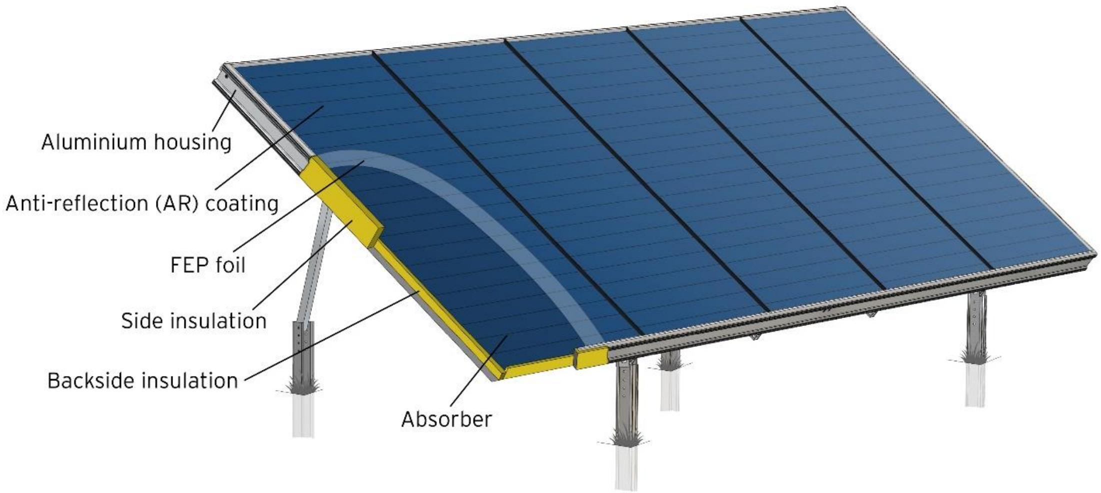
2 Technology

Solar collectors are designed to produce heat and sometimes confounded with solar cells, which are designed to produce electricity. The common denominator is that both technologies transform the sun's rays into energy, with the main difference being their energy output. Solar cells produce electricity that can be used directly or sold to the grid, whereas solar collectors produce energy in a liquid form, which can be used for the heating of district heating water, hot water and industrial process heat.

For heating, the efficiency of a solar collector is 3-4 times higher than of a solar cell. The solar collectors are made of materials such as aluminum, copper, glass, mineral wool and rubber, which can be recycled when the solar collector is not in use anymore. The components consist of a sun absorber that captures the sun rays and converts it to heat. The absorber is treated with a selective coating, which limits the sunray's reflection. A maximum of 5% of the rays affecting the absorber's surface are reflected again (in comparison, a black surface reflects approx. 40%).

The absorber lies on a bottom of hard mineral wool (75 mm), which minimizes the heat loss. Over the absorber, there is a cover layer of glass specially designed to capture as much sunlight as possible. The glass is anti-reflection, which means that all rays are led into the collector. A teflon film between the absorber and the glass can be stretched out. The heat from the absorber is moved out of the collector via a copper tube (10 mm) on the back of each absorber strip. All pipes are assembled in a manifold pipe on each side of the collector. The components of a solar collector are illustrated in the figure below.

Figure 2 Components of a solar collector



Source: Silkeborg Supply website

3 Value chain

The municipality of Silkeborg owns Silkeborg Supply. The value chain of the solar-thermal plant starts with construction activities. Once operational, solar collectors pump heated water into the district heating network, which distributes renewable heating to the households. An overview of Silkeborg Supply's value chain is illustrated below.

Figure 3 Solar-thermal plant near Silkeborg, Denmark overview

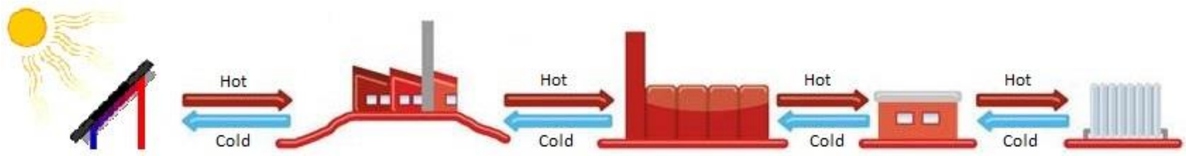


Table 2 Project´s value chain

Inbound logistics	Operations	Outbound logistics	Sales activities	Service provided
Delivery of technology components produced in Europe (solar collectors, pipes, pumps and others) necessary for the construction. Raw materials like	Producing renewable heating energy from the solar radiation. No fuels are needed to maintain the operation (expect a minimum of electricity for powering the pumps and	Pumping heated water from the solar-heating plant into a district heating network. Then pumping water from the households or industrial customers back to the solar-	Delivery of heat to existing customers. Expansion of the district heating system to small towns (in which households currently have small-scale gas fired boilers). More than half of the households in a given	Space heating delivered through radiators and hot water. In addition, advice on heating efficiency in households.

steel, copper and brass have been used in manufacturing the components.	supporting the technology which automatically regulates the water circulation).	heating plant for re-heating. The water circulates in a closed system.	community must agree and pay upfront to make the infrastructure investments economically feasible.	

4 Local factors

Overall, the key factors underpinning the decision to invest in large-scale solar can be summarized as:

- Legislative incentive (energy savings allow for funding via the national Energy Savings Agreement)
- Municipal target for carbon neutrality by 2030
- The heat production price is more predictable and unaffected by natural gas price fluctuations

On a national scale, legislative factors impact the decision. For example, Danish energy legislation such as the "*Executive Order of the Act on Heat Supply*", requires heat suppliers to use natural gas as a fuel (unless a positive social economic impact can be demonstrated via other technologies) and to generate a combination of heat and power (when fuel is used as an energy input). These requirements to some extent limit the choice of other fuel combustion technologies, like biomass given that the objective of Silkeborg Supply was to supply only heat.

When planning the system upgrade, Silkeborg Supply considered three key renewable heating technologies, namely: large-scale solar-thermal; large-scale heat pumps; and biomass. Large-scale solar thermal was seen as the most attractive because it does not require fuel. Thus, it is not ruled by the above-mentioned Executive Order (which would require the generation of combined heat and power)[5].

The following two national factors have played a role in making the solar-thermal the most attractive technology:

- *The Executive Order of the Act on Heat Supply*[6] which aims to reduce the dependence of fossil fuels by promoting the most socio-economic and environmentally friendly use of energy for heating and hot water supply, through co-production of heat and electricity, as much as possible.

  In accordance with this order, the solar-thermal technology has been the most attractive choice to supply renewable heating in the Silkeborg's area. Biomass has been less cost-effective, as it should also support CHP (in particular) electricity, which has not been an objective of Silkeborg Supply.

- *The Energy Savings Agreement (2016)*[7]*,* between the Danish government and energy companies which aims to increase energy efficiency and to minimize the energy waste and energy consumption of all sectors. It established a

[5] There ongoing policy discussions in Denmark which may result in changes of the Executive Order on Heat Supply and the Energy Savings Agreement

[6] https://www.retsinformation.dk/Forms/R0710.aspx?id=190081#id3431e3cb-697a-4f61-ae60-7475c1ca44b4

[7] https://ens.dk/sites/ens.dk/files/Energibesparelser/energispareaftale_161216mbilag_6_eng.pdf

framework and principles for energy savings in Danish industries and companies operating within the distribution of electricity, natural gas and heating.

In accordance with the Energy Savings Agreement, the solar-thermal plant has fallen under the scope of an investment with a cost-effective fulfilment of energy savings commitments. Silkeborg Supply has achieved ambitious energy savings targets during the first year of operation, which has qualified the solar-thermal plant for receiving public funding support. Thus, government support has covered expenses in the order of 5-10% of the capital costs (via a supplement to the revenue cap after the first year of operation), necessary to achieve the energy savings.

In addition, regional factors such as the municipality target to become carbon neutral by 2030 has been driving the transition.

Furthermore, local factors such as reduced-price fluctuations have supported the maintenance of a lower heat production price of the utility. This combined with the resulting CO_2 emissions reductions were the two key determining factors for choosing solar-thermal in this case.

5 Impacts

The technology upgrade to solar-thermal ensures a stable development in the district heating price that applies to local communities. It supports Silkeborg Supply in becoming less affected by the price fluctuations of traditional energy sources such as natural gas. Over a 20-year period, the project is estimated to provide natural gas savings equivalent to 2,280 TJ of energy. Thus, the project supports that district heating consumer prices are maintained stable and predictable. Further, the project contributes significantly to CO_2 emissions reductions and to reducing the consumption of fossil fuels (in this case - natural gas).

The solar-thermal plant in Silkeborg also contributes to reaching Europe's 2020 targets.

Table 3 Impacts from the solar-thermal plant on Europe's 2020 targets

Energy from renewables	80 000 MWh/year
Increase in energy efficiency	20% of fuel savings
CO_2 reductions	15 000 Ton/year
Employment	50+ employees (during construction)
Poverty and social exclusion	22 000 household with a decreased risk of poverty as the technology supports lower heating prices

Furthermore, the solar-thermal plant demonstrates socio-economic benefits of DKK 127 million over the next 20 years, while contributing financially to the utility. A breakdown of the socio-economic benefits outlook is presented below. The "reference" represents a business as usual scenario and "the project" shows the benefits to be achieved through the upgrade.

Table 4 Socio-economic benefits (in DKK million)

	Reference	Project	Project benefit
Fuel costs	2 888	2 631	256

OPEX	219	209	10
CAPEX	0	611	-611
Environmental costs	22	8	14
CO_2 costs	338	300	38
Tax distortion	-236	-128	-108
Electricity sales	-1 545	-2 073	529
Total	**1 686**	**1 559**	**127**

Source: Proposal for establishment of solar-heating and optimization of requirements[8]

Finally, the project has provided inspiration for other large solar-thermal investments in the EU[9]. For example, the Latvian city Salaspils has recently announced plans to invest EUR 6.9 million in solar district heating to transition away from gas (40% of the investment is covered by the EU's Cohesion funds), inspired by a district heating conference in Denmark.

6 Summary

The investment was motivated by Silkeborg's municipality's target to become CO_2 neutral by 2030. The solar-thermal technology upgrades ensure a stable development in the district heating price for the local communities that are connected, as they support Silkeborg Supply in becoming less dependent on the price fluctuations of traditional energy sources, such as natural gas. Specifically, the increased income to the utility from the solar-thermal plant mean that no increase of the heating price to the final consumers will be necessary, as the fuel costs savings offset the depreciation of the project. In addition to the benefits from fuels cost savings, there are reduced operational costs, environmental costs and CO_2 costs. Without government support covering 5-10% of capital costs (via a supplement to the revenue cap after the first year of operation), the technology would not have been competitive. However, the solar-thermal technology has been the most attractive choice among a group of renewable heating alternatives involving biomass and large heat pumps for the utility (Silkeborg Supply) owned by the municipality due to a combination of local factors such as laws, taxes, fuel prices, availability of infrastructure and others which influence the heat prices from each individual energy source. Specifically, the Danish Executive Order of the Act on Heat Supply and the Energy savings agreement have played a significant role in framing the conditions.

[8] The table takes into account a larger optimization of the heating system, including also heat pumps and upgrades to the Utility's CHP plan, as no data was provided only for the solar-thermal plant upgrade by the utility.

[9] "We have been working on this project since we attended a district heating conference in Denmark in 2014", Ina Berzina-Veita, a Member of the Board of the municipal utility Salaspils Siltums

CASE STUDY

Solar-thermal in Silkeborg, Denmark (A4)

Source: COWI (2019)

Source: Arcon-Sunmark (2019)

Solar-thermal in Silkeborg, Denmark

Overview and value chain analysis

Key figures

- 12 436 solar collectors
- Components: sun absorber that captures the sun rays and converts it to heat
- Installation: 2016
- Yearly heat output: 80 000 MWh
- Supplies 20% of Silkeborg's annual district heating demand via the district heating network

Value chain

Inbound logistics	Operations	Outbound logistics	Sales activities	Service provided
Delivery of technology components produced in Europe.	Producing renewable heating energy from the solar radiation.	Pumping heated water from the solar-heating plant into a district heating network.	Delivery of heat to existing customers and expansion of the district heating to small towns	Space heating advice on heating efficiency in households.

Solar-thermal in Silkeborg, Denmark

Factors and impacts

Enablers

- Municipal target for carbon neutrality by 2030
- The Energy Savings Agreement of the Parliament allow for funding because of the achieved energy savings
- About 5-10% of investment costs have been covered by government support
- Inclusion of solar-thermal next to natural gas allows the CHP to maintain more predictable consumer prices
- District heating infrastructure in place already

Other factors

- Land can be a challenge to acquire for the construction of the solar plant

Impacts

- CO_2 emissions reduction of about 15 000 tonnes per year
- More stability of district heating prices
- Contribution to savings in the use of natural gas fuel equivalent to that necessary to produce 2.280 TJ of energy