Annex 17

Action A2. Analysis of energy storage and interaction between solar facility and district heating plant

Reports and surveys:

- Analysis on capacity for energy storage
- Report on capacity of district heating plant
- Report on culvert and connection points

2012-12-17
LIFE11 ENV/SE/837 NOISUN

Innehåll

1. Action A.2

1.1. Objective

The objective of Action A2 is to analyse and determine needs and capacity for energy storage and the capacity for the district heating plant to accept energy from the solar collector facility.

2. Analysis on capacity for energy storage

2.1. Where to store sun energy?

Various alternatives have been discussed on how to supply the heat from the solar collectors to the district heating system. Due to restrictions on the return temperature from Lerum Fjärrvärme it is not possible to connect the solar collectors to the disctrict heating return pipe. Other alternatives such as connecting the solar collectors to the district heating supply pipe and using the existing storage tank have therefore been discussed.

Building a new storage tank next to the solar collectors is too expensive hence Lerum Fjärrvärmes existing storage tank was considered as an alternative. Although calculations show that this alternative isn't energy efficient neither cost effective due to the distance between the solar collector field and the storage tank. A calculation of this can be seen in Annex 5.1. Therefore the project since project meeting 10 September 2012 is focused on that the solar collectors shall be connected on the district heating supply pipe.

3. Report on capacity of district heating plant

3.1. Lowest power from boiler?

The average power from boiler in July is 1,1 MW (75 °C) and the lowest power at boiler is 1,0 MW. Below 1,0 MW the boiler can be damaged and environmental emissions cannot be guaranteed from the boiler manufacturer.

3.2. What will be peak power?

When evaluating peak power it´s depending on the size, angle and orientation. The peak power capacity of the solar collectors will vary quite largely. The concerned area where the solar collectors will be built is 400 m long. Using this 400 meters and standard measures of these types of large collectors and standard thermal performance of these kinds of collectors the peak power capacity will vary between 0,7 MW and 0,48 MW depending on the slope and the temperature difference between the solar collects and ambient air. For calculations see Annex 5.2.

One solar collector in the size we calculate with is at 8 kW. We calculate with 67 solar collectors. It means 0,536 MW installed power. With more detailed calculations from partner SP in December 19 2012 and January 25 2013 the produced power the best hours might be 0,6 MW or even 0,7 MW a real hot day.

Lerum Fjärrvärme wants at all-time during the summer the accumulator tank to hold at least 70% of its storage capacity to secure heat deliveries if boiler stops due to any cause. The accumulator tank at Aspedalen can store about 20 MWh. 20 MWh is at temperature difference 55-95° C.

This means that during a hot period the boiler produce 1,0 MW per hour and the need is in average about 1,1 MW per hour. If the solar collector facility works at maximum an additional 0,5 MW heat is produced per hour. In best case 30% (6 MWh) of the capacity in the accumulator tank is free. 0,4 MW (1,0+0,5-1,1) per hour has to be stored in the accumulator tank when the solar collector facility works at maximum.

With data from SP an example can be calculated. A sunny day in summer the boiler produces 1 MW per hour in 24 hours. The solar collector facility produce some 5,7 MW (hour nr 4493-4510). The need might be 1,1 MW per hour, maybe less. We produce 24+5,7=29,7 MWh during a time when the need is 26,4 MWh. 3,3 MWh heat are stored in the accumulator tank this day.

With this as a background it is clear that the peak power capacity of the solar collectors is higher than the minimum demand in the district heating ne with the boiler operating at minimum capacity. From the calculations it can also be seen that the result of choosing 90 ° slope in relation to the horizon will not decrease the peak power as much as it decreases the yearly energy output. A significant decrease in yearly energy output is of course not preferred, therefore a solution with the solar collectors in 60° slope is preferred from an energy output point of view (45° would of course give the highest yearly energy output but is not interesting for several reasons such as lower noise reduction and too high peak power).

3.3. We can store sun energy from two days

If the free capacity in the accumulator tank is 6 MWh there is storage capacity for not even two days during a sunny summer period.

Lerum Fjärrvärme has no detailed duration charts for capacity needs during summer time for the plant in Aspedalen.

Result of the analysis on capacity for energy storage is that we can store sun energy from less than two days during a sunny summer period or 6 MWh.

3.4. How to handle sun energy that not can be used or stored?

The estimated production for the solar collector facility is some 300 000 - 350 000 kWh per year. During summertime this is a problem in hot summer days, major problem in half June, July and August.

We have discussed different options to handle the problem:

- Absorption cooling: a cooling system operated by the heat produced in the solar collectors. This is not optimal, it would be better to operate with photovoltaic.
- Buy a smaller boiler, estimated cost: 7 - 10 Mkr. This isn't possible for the project.
- Stop the boiler during long warm periods. This is not an option.
- Emergency cooling facility, air or water. This is an cost efficient solution.
- Put the solar collectors in 90° inclination. This will not solve the problem.

On project group meeting 16 January 2013 we decided in order to avoid stagnation in the solar collectors, we need a cooling system, probably a plate heat exchanger.

4. Report on culvert and connection points

The top of the district heating pipes in Lerum are located about 60 cm below ground level with reservation for ground level changes during time. It´s about 1 m to shaft bottom. (Rörhjässan ligger ca 60 cm under mark med reservation för markändringar under åren. Ca 1 m till schaktbotten.)

The district heating pipe closest to the facility is located to a grass lawn at the western part of the facility.

There will be a technic house here where the sun energy will get connected to the district heating system.

5. Annexes

5.1. Estimation of energy losses from culvert

Calculations shows that there will be 88 668 more useful kWh per year if we connect the solar panels via a culvert to the accumulator tank compared to connect to the flow line in the district heating system. The distance to the accumulator tank is about 500 m. The energy losses in the culvert is about 75 000 kWh/year. Due to the distance and energy losses we cannot see it would be energy efficient neither cost effective to connect via a culvert.

Estimation of energy losses from culvert

Data solar collector	
area	866 m^2
Thermal efficiency η_0	0,830
optical efficiency (f')	0,847
diffuse efficiency	0,866
a1	3,2 W/m^2/K
a2	0,015 W/m^2/K^2
azimut	south
slope	60 °

Yearly energy exchange for the solar collectors					
	Temp water				
	25°	50°	60°	75°	
	614 653	421 865	355 263	266 595	kWh/yr
Difference				88 668	kWh/yr

Calculation		
Energy losses culvert	150	kWh/(m*yr)
Length culvert	500	m
Energy losses culvert	75 000	kWh/yr

5.2. Calculation of peak power from the solar collectors

Assuming standard measures of these types of collectors and using peak power figures from a well-known supplyer of collectors gives the following peak power calculation.

Panel efficiency (W/panel) for standard collectors

	Irradiation (W/m2)			The peak irradiation to a 90° slope and 60° slope	
Tm-Ta °C	**400**	**700**	**1000**	**900**	**1100**
10	4182	7644	11106	N/A	N/A
30	3201	6663	10124	8393,5	10989,25
50	2066	5528	8989	7258,5	9854,25

Tm-Ta °C			
30	Peak power 67 panels in 60° slope	**736279,8**	kW
	Peak power 67 panels in 90° slope	**562364,5**	kW
50	Peak power 67 panels in 60° slope	**660234,8**	kW
	Peak power 67 panels in 90° slope	**486319,5**	kW

5.3. Yearly energy exchange from the solar collectors for various conditions

The yearly energy exchange has been estimated with the software Solar Collector Energy Output Calculator (ScenoCalc) for 60° slope and 90° slope. The software is well-known software that is used in the Solar Keymark certification process for estimating the yearly energy output of solar collector. Below is a calculation at °60 slope followed by a calculation at °90 slope.

Results from the Solar Collector Energy Output Calculator (ScenoCalc)

Version 3.10 (June 2012)

Identification label for the solar collector: Not specified

Date of evaluation: 18 December, 2012

Evaluation method: Steady state

Thermal yield per collector module (kWh/module)

	Total irradiance	Yield for three collector mean temperatures		
		25°C	50°C	75°C
January	15 952	5 542	1 981	402
February	36 195	15 263	7 225	2 161
March	78 973	43 846	30 123	18 614
April	103 173	61 506	41 082	25 121
May	135 741	88 086	60 686	39 205
June	138 376	94 620	66 977	45 137
July	131 823	93 931	64 524	42 423
August	113 465	80 475	55 308	36 614
September	81 678	53 024	35 178	22 471
October	43 730	23 042	13 149	6 599
November	15 740	5 455	2 668	1 033
December	10 245	2 704	439	0
Year	**905 090**	**567 494**	**379 339**	**239 781**

Location: Stockholm

Longitude: -18,08 *(positive longitude = west of the prime meridian)*

Latitude: 59,35

Time period for climate data: 1996-2005

Collector parameters (based on the aperture area)

Aperture area	866 m^2
η_0	0,830
$F'(\tau \alpha)_{en}$	0,847
$K_{\theta, d}$	0,866

a_1 3,2 W/m²/K

a_2 0,015 W/m²/K²

Type of tracking: No tracking
Tilt angle: 60°
Azimuth angle: -45°

IAM Type: Simple, one-direction

Results from the Solar Collector Energy Output Calculator (ScenoCalc)

Version 3.10 (June 2012)

Identification label for the solar collector: Not specified
Date of evaluation: 18 December, 2012
Evaluation method: Steady state

Thermal yield per collector module (kWh/module)

	Total irradiance	Yield for three collector mean temperatures		
		25°C	50°C	75°C
January	15 123	5 474	2 010	420
February	32 689	13 513	6 387	1 821
March	66 848	35 193	23 301	13 584
April	81 536	43 895	26 821	14 582
May	102 148	59 604	35 343	19 167
June	101 519	63 116	37 942	21 258
July	98 199	65 193	37 756	21 290
August	87 611	58 594	35 362	21 138
September	67 086	41 563	25 935	15 835
October	37 866	19 443	10 997	5 356
November	14 140	5 112	2 677	1 053
December	9 963	2 919	579	14
Year	**714 728**	**413 618**	**245 112**	**135 519**

Location: Stockholm
Longitude: -18,08 *(positive longitude = west of the prime meridian)*
Latitude: 59,35
Time period for climate data: 1996-2005

Collector parameters (based on the aperture area)
Aperture area 866 m²

η_0	0,830
$F'(\tau\ \alpha)_{en}$	0,847
$K_{\theta,\ d}$	0,866
a_1	3,2 $W/m^2/K$
a_2	0,015 $W/m^2/K^2$

Type of tracking: No tracking
Tilt angle: 90°
Azimuth angle: -45°

IAM Type: Simple, one-direction