Case study : Nacka (Sweden)

Name of the project:	Implementing a Solar District Heating facility combined with a seasonal storage within the City/South DH networkt in the Nacka area in south-east Stockholm
Adress of the project:	Nacka, Sweden
Name and type of the owner:	AB Fortum Värme, district heating company
Owner contact person:	Andres Hill, Business Developer at AB Fortum Värme

Context of the study

As part of Fortum´s vision of a future Solar Economy a feasibility study of integration of a large SDH system in an existing DH system in Stockholm region in the AB Fortum Värme network has been conducted. The focus of this study has been to analyse the possibilities to install large scale solar collector field combined with a seasonal thermal storage in the district heating network in Nacka in South-east Stockholm. Nacka is an own municipality with around 94 000 inhabitants. The district heating network in Nacka has a heat demand of around 350 GWh. The district heating network in Nacka is supplied by the plant in Hammarby in the west as a base load and the peak production plant in Orminge in the East. The Hammarby plant consists of seven heat pumps and two boilers operating on Mixed Fatty Acids. At the Orminge plant bio oils (18 MWth) and pellets (10MWth) are utilized and annual production is around 21.0 GWh. During summertime, the heat pumps at Hammarby plant are providing district cooling to the district cooling network in the south and central parts of Stockholm. The heat obtained at the condensers is used to cover the base heat demand (heat load during summer months is around 15GWh) and the excess is dumped in the canal next to the plant. The new solar system would support the district heating network in Nacka area and it is assumed that the production from bio-oils and pellets is considerably reduced in the peak production plant in Orminge.

Support

There are no national incentive programs supporting this kind of study. It is assumed to be quite likely that subsidies can be given to development and demonstration projects in the SDH field project from the Horizon 2020 program.

SDH plant

SDH system concept

There is potentially 120 000 m2 of unused land in Nacka where the solar collectors can be installed on. The land is separated into one smaller area of 30 000 m2 (area 1) and one larger area of 90 000 m2 (area 2). There are also eight existing rock caverns under the Peninsula of Kvarnholmen that could be utilized as a rock cavern thermal energy storage. The total volume of eight caverns is around 300 000 m3. Three different cases has been studied, where the first is based on the utilization of the total available land area of 120 000 m2. In the second case, solar collectors is placed on only the smaller land area of 30 000 m². The first two cases has been divided into two separate parts, one in which the seasonal thermal storage is a borehole storage (BTES) and one in which a new cavern storage (CTES) is utilized. In the third case, the land area was assumed to be utilized together with the six smaller existing rock caverns under the peninsula of Kvarnholmen. In that case, the heat being dumped from the Högdalen CHP and the Hammarby HOB was also included and assumed to be stored together with the produced solar thermal energy in the rock caverns. The supply temperature from both storage technologies to the DH network is kept constant in all cases, at 90C. In the cases of a borehole storage a heat pump must be utilized continuously throughout the discharge period to increase the supply temperature to the required DH network temperature. For the CTES cases heat pump is used to maximize the utilization of the storage. The system configuration containing solar collectors, distribution pipes and pumps, heat exchangers, heat pump and the borehole therma storage for the first two cases (BTES and CTES case) are shown at the end of this factsheet.

SDH technical data

Flat plate collectors are used in the all of the case study analysis. In Case 1, when the entire available area will be utilized, the total collector area is determined to be 37 500 m2 (ca 3000 collectors will be installed). The borehole storage is dimensioned as a cylinder. In Case 1A the depth of each borehole is set to 75 m and the diameter of the cylindrical storage is 76, the total bedrock volume of the storage is around 1 371 000 m3. In the Case 1B the depth of each borehole is set to 50 m and the diameter of the cylindrical storage is 49 m, the total bedrock volume of the storage is around 373 000 m3. It is estimated in the calculations that the initial losses from the borehole storage decreases from around 90% to 25% over a six year period. Heat pump will be utilized throughout the discharge period of the storage. In the Case 1B and 2B the storage consists of a cylindrical cavern with a height of 46 m and diameter 45 m in Case 1B and with a height of 30 m and diameter 28 m in Case 2B. It is estimated in the calculations that the initial losses from the cavern storage decreases from around 90% to 10% over a six year period. The heat pump is assumed to be operational 60% of the total discharge time. In the Case 3 the generated excess heat from the heat pumps in Hammarby HOB and the Högdalen CHP has been assumed to be distributed through the existing district heating network and stored in the rock caverns.

SDH energy balance (MWh)

Annual production from the different configurations of the system is provided in the table below. The distributed energy from the system configurations in the three cases would represent less than 10% (minimum 1.2% and maximum 9.4%) of the total annual heat demand in Nacka.

System configuration	Calculated solar collector gain GWh/a	Calculated gain from storage GWh/a	Heat pump production GWh/a	Total heat production GWh/a	Thermal power, MW	Distributed energy from the plant compared to the total demand in Nacka, %
Case 1A	20.6	15.4	17.5	32.9	11.3	9.4
Case 1B	18.1	13.8	2.4	16.3	5.6	4.6
Case 2A	5.1	3.9	4.3	8.2	2.8	2.3
Case 2B	4.5	3.5	0.3	4.1	1.4	1.2
Case 3	4.5	3.4[1)]	5.6	8.9	3.1	2.5

SDH economics

The results from the economic calculations for the three cases is presented in the table below. The economic results clearly show that it is more feasible to invest in a Solar District Heating facility with a borehole storage than with a cavern storage. This especially if a new rock cavern needs to be excavated, due to the major initial investment cost, and if the existing caverns under Kvarnholmen is unavailable. But it has also been proven that the borehole systems are more economic feasible in Case 1 and Case 2, even if the existing caverns under the peninsula of Kvarnholmen would be utilized. Though, none of the three cases can be seen as profitable, from the requirements set up by AB Fortum Värme, without any given subsidies or other reduction of initial costs.

	Case 1A	Case 1B	Case 2A	Case 2B	Case 3
Investment cost (million €)	19.95	73.75	5.16	18.46	3.50
Annual revenue (million €)	2.35	1.16	0.58	0.29	0.64
Annual operating cost (million €)	0.45	0.15	0.11	0.03	0.14
Annual net income (million €)	1.90	1.00	0.47	0.26	0.50
LCOE (€/MWh) [1)]	98.7	655.8	102.9	653.9	70.0
IRR (%)	9.6	-5.0	6.3	-6.2	10.6
NPV (million €)	5.71	-10.07	1.39	2.47	1.85
Payback time (years)	10.5	73.4	10.9	70.6	7.0

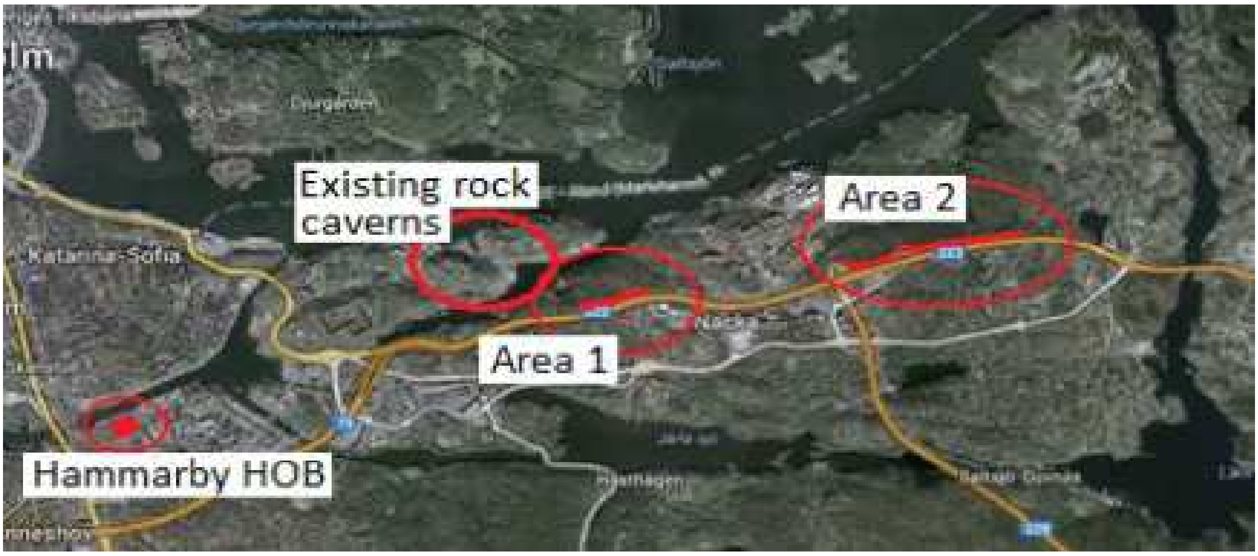
SDH plant opportunities & threats, benefits & limits

It is technically viable to implement a Solar District Heating facility within the City/South network in Stockholm. The produced thermal energy from the solar collectors is preferably stored and distributed during December to March and will thus replace some of the production at the HOB in Orminge. The distributed energy from the system configurations in the three cases would represent less than 10% (minimum 1.2% and maximum 9.4%) of the total annual heat demand in Nacka. Additionally, if the Solar District Heating facility were to be built, the produced thermal energy could for instance be labeled and sold as green district heating at a higher rate.

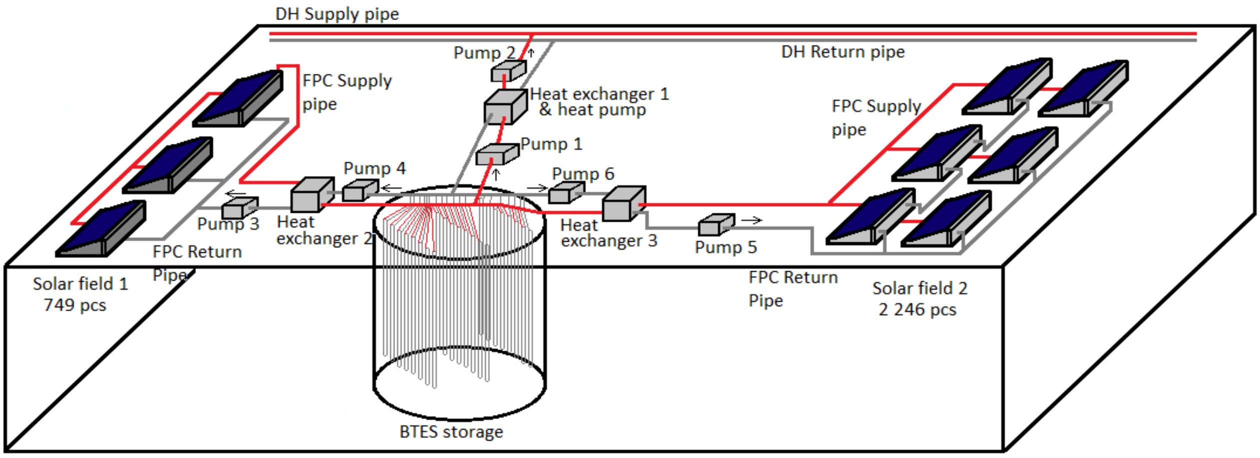
The economic results show that it is more feasible to invest in a Solar District Heating facility with a borehole storage than with a cavern storage, due to the major initial investment cost, and if the existing caverns under Kvarnholmen is unavailable. The analyses showed that the most economically viable system is Case 3, which utilizes the dumped heat from Högdalen CHP and Hammarby HOB in the existing caverns under the Kvarnholmen peninsula. Though, none of the three cases can be seen as profitable, from the requirements set up by AB Fortum Värme, without any given subsidies or other reduction of initial costs. The environmental impact of production is highest for Case 3, since the heat pump is operated during a long time period and at a high electrical power. In Case 1 and Case 2, the operation of the borehole systems leads to a higher environmental impact than the CTES systems, this when compared to production at the Orminge HOB. The major risks include that there is no guarantee that subsidies could be given from the EU, that the existing rock caverns under Kvarnholmen will be available for free and that there are customers willing to pay more for the district heating. There are also other variables that would have an effect on the economic profitability, such as decreased investment costs of boreholes and solar collectors.

Photos

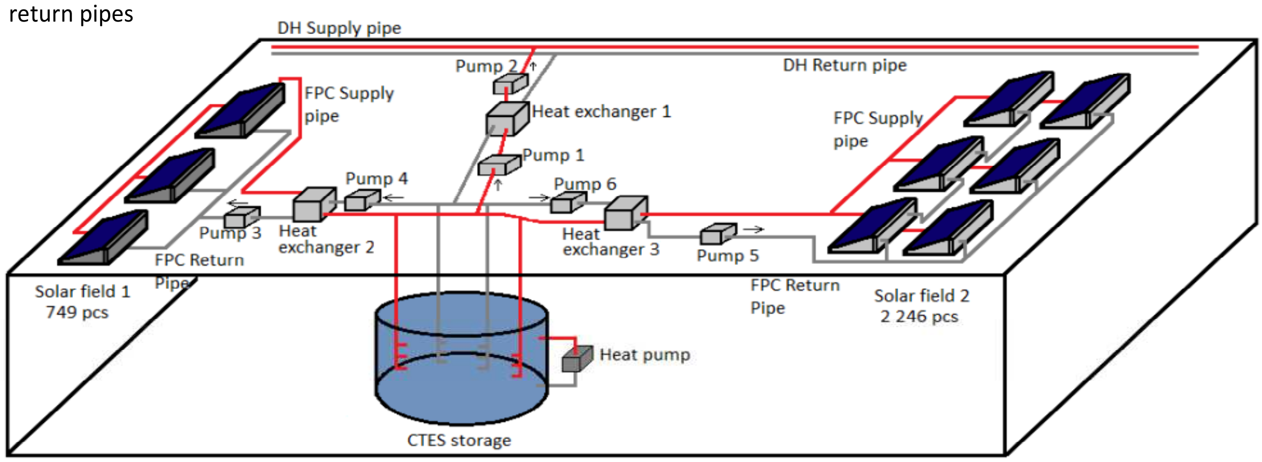
Available area for solar collectors and existing rock cavern storages in the Nacka area



System configuration for Case 1B with CTES.



System configuration for Case 1A with BTES. The red lines indicate supply pipes and the grey indicate return pipes



Authors

This factsheet was prepared by Mari-Liis Maripuu and Jan-Olof Dalenbäck

The feasibility study was conducted on behalf of and at AB Fortum Värme by Anders Tonhammar as part of his master thesis in Uppsala university. Jan-Olof Dalenbäck has provided background information from SDHplus, has taken part in the thesis development with comments and suggestions and has commented the final result.

Anders Tonhammar

Solar District Heating - the potential of a large scale solar district heating facility in Stockholm

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