solar district heating

SDHplus

Solar District Heating in Europe

Guideline for end-user feed-in of solar heat

Prepared by

Jan-Olof Dalenbäck,

CIT Energy Management AB

June 2015

Co-funded by the Intelligent Energy Europe
Programme of the European Union

LIST OF CONTENT

INTRODUCTION

Large-scale solar heating systems were introduced in the late 1970's. At present (end 2013) there are more than 200 plants in operation in close to 20 EU-countries. Out of these about 70 plants have a nominal thermal power of 1 MW_{th}, or more. The present developments include mainly large-scale plants with diurnal storage for residential heating, but there is a growing interest for solar heat in industry processes and heat driven cooling applications, especially in Southern Europe [Dalenbäck, 2013b].

The majority of the large-scale solar heating systems in district heating (DH) systems are installed in connection to a central heating plant. However, a number of the solar systems are connected directly to the heat distribution system far away from the main heating plant. These plants can be described as “grid-connected”. The first of this kind of systems was probably built in Skive, Denmark, in the 90's. The next ones built in Malmö, Sweden, in 2001. Since then a number of smaller and larger systems have been built in Sweden and Austria [Dalenbäck, 2013c].

There are two main drivers for “grid-connected” solar heat. First, it is a rather suitable option to use solar heat in cities with large existing DH networks. Second, is the introduction of the Energy Performance of Building Directives (EPBD), where the on-site energy supply of a solar system is considered to improve the energy performance of a building. The first being the driver in Austria and the second being the driver in Sweden [Dalenbäck, 2013c].

A heat distribution network, i.e. a DH system, is an infrastructure that can be used to move heat from one place to another in an urban area. Solar heat is, besides heat from biomass and geothermal plants, the main option to use renewable heat in DH systems and it is available everywhere.

There are a number of advantages with this type of “grid-connected” solar heating systems. Here are a few:

- The solar collector array can be placed and sized for a suitable location (e.g. utilize the whole roof, large roofs, waste lands, etc), as it does not have to be designed for a specific load.
- It involves a rather simple system, as it does not require buffer storage.
- The alternative cost is the DH cost for the costumer, not the usually much lower cost for fuel (natural gas, wood chips) in the heating plant.
- It allows distributed ownership of the heat supply.

All together these advantages should make it possible to build solar systems that can be cost-effective, at least in some niche markets in DH systems using solid biofuel or natural gas boilers during the summer period.

One identified barrier is that it requires an interest from the DH provider to be involved in such developments, as well as an agreement between the building owner and/or the system owner/operator (third party) and the DH provider. There is however also the possibility for the DH providers to build solar plants on suitable locations and sell solar heat to their customers in other parts of the city in a similar way as renewable electricity is traded, from one place to the other, on the electricity grid.

These **GUIDELINES** are outlined as follows:

First, the prerequisites and consideration for three different plant ownerships are described.

- BUILDING / REAL ESTATE OWNER
- DISTRICT HEATING PROVIDER
- ENERGY SERVICE COMPANY (ESCO)

Additionally a short presentation “**An Intro to Feed-in of Solar Heat**” is appended.

Second, there are descriptions of the basics related to:

- SYSTEM DESIGN
- PARTNER AGREEMENT

Third, the experiences from existing plants developed based on two different drivers are summarized in:

- SWEDISH PLANTS AND EXPERIENCES
- AUSTRIAN PLANTS AND EXPERIENCES

Additionally “**Samples of Existing Plants**“ with their appearance is appended.

Those who are interested to take part in the development of solar DH systems and are interested to get more detailed information about existing systems, are encouraged to have a look on the material provided by on www.solar-district-heating.eu, the web site of the IEE-project SDH (Take-Off and Plus).

BUILDING / REAL ESTATE OWNER

Prerequisites

1. Heat supplied by district heating (or a district heating system in close connection).
2. Inclined (to south) or flat unshaded roof area or a piece of unshaded land area suitable for solar collector mounting.

Considerations

One can build a solar collector array and feed the solar heat into the district heating system, either for own use or for sale to the district heating provider (or another district heating customer on the network, i.e. a third party).

The solar heat may improve the building performance in one way or another depending on how EPBD has been implemented.

Feed-in of solar heat requires an agreement between building / real estate owner and district heating provider.

Figure 1. Multifamily buildings with roof-integrated solar collectors connected to the DH system in Karlstad, Sweden. Plant operated by municipal housing company KBAB. Photo: KBAB

DISTRICT HEATING PROVIDER

Prerequisites

Inclined (to south) or flat unshaded roof area or a piece of unshaded land area suitable for solar collector mounting in connection to the district heating system.

Considerations

One can

1. Rent the roof or the land area and build a solar collector array connected to the district heating network.
2. Allow the building or the land owner (or an ESCO) to build a solar collector array connected to the district heating network.

With suitable business models it can be possible to sell (1) or transfer (2) solar heat to district heating customers.

Feed-in of solar heat requires an agreement between district heating provider and the building / land owner and/or an ESCO.

Figure 2. Buildings with integrated solar collectors connected to the DH system in Västra Hamnen (Bo01), Malmö, Sweden. Plant operated by DH provider E.ON. Photo: E.ON

ENERGY SERVICE COMPANY (ESCO)

Prerequisites

Access to an inclined (to south) or flat unshaded roof area or a piece of unshaded land area suitable for solar collector mounting, in connection to a district heating system.

Considerations

One can

1. Rent the roof or the land area and build a solar collector array connected to the district heating network.
2. Sign an agreement either with the building / land owner or the district heating provider to build a solar collector array connected to the district heating network.

One can sell the solar heat to the district heating provider or any district heating customer on the network, i.e. a third party.

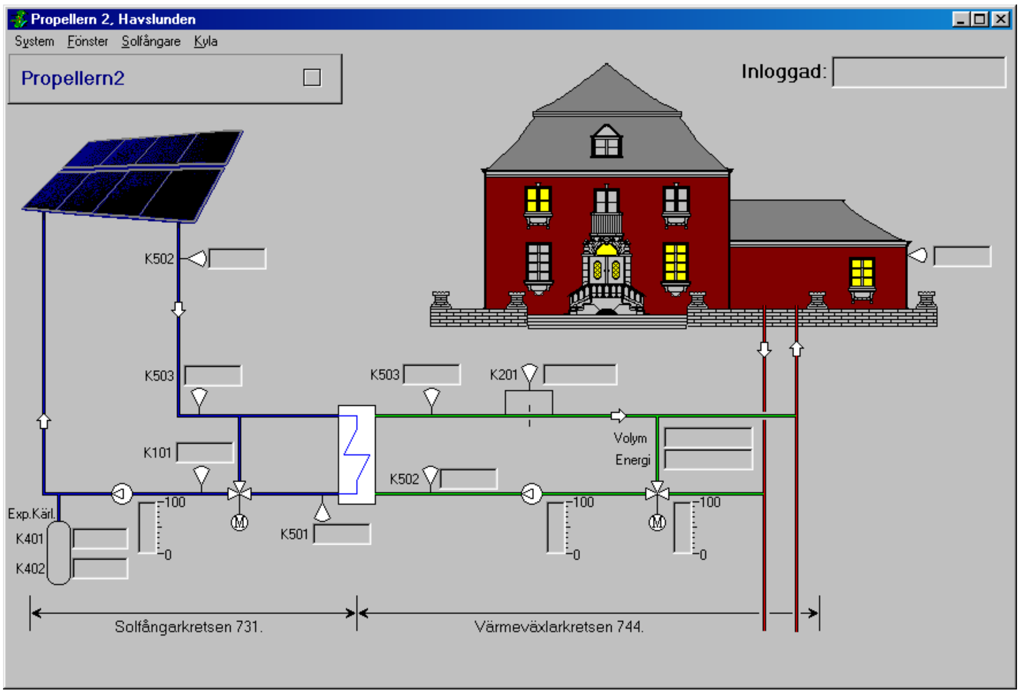
Feed-in of solar heat requires an agreement between ESCO, district heating provider and building / land owner.

Figure 3. Buildings on a waste management site with roof-mounted solar collectors connected to the DH system in Graz, Austria. Plant operated by an ESCO. Photo: AEVG.

SYSTEM DESIGN

The collector area can be designed based on own heat demand in connected buildings or available area suitable for collector mounting, but is limited by the dimension of the district heating connection pipes. Pipe dimensions DN50, 100 and 150 can handle 400, 2 000 and 5 500 m^2 collector area as the design power of the solar collector array is limited by the maximum allowed volume flow in the heat distribution pipe (limited by the maximum fluid velocity).

There are different possible system solutions. Figure 4 shows a simple and basic system schematic from a Swedish plant. The solar system comprises two circuits, the solar collector circuit and the district heating circuit, separated by a heat exchanger. The district heating circuit draws water from the heat distribution return pipe and feeds in heated water in the district heating supply pipe. This means that it is connected in parallel to the connected buildings and the main as well as other heating plants in the district heating system.



Figur 4. Sample system schematics (Bo01, Malmo, SE)

The solar system is designed with a temperature control (variable flow) to meet the temperature in the district heating supply pipe. The system performance will thus depend on the return and supply temperatures in the district heating system. The solar system is further designed to overcome the pressure difference in the district heating system where it is connected.

PARTNER AGREEMENT

A feed-in plant requires a partner agreement between the plant owner, building owner (if mounted on a building), land owner (if mounted on land) and the DH provider.

The most important topics to be treated in the agreement are as follows:

- Partner(s) who pays for the physical connection of the solar system, e.g. 50% each by plant owner and DH provider.
- Special DH requirements on the installer contracted to make the connection in the DH system.
- Special DH requirements on the connection itself, e.g. pressure, temperature, etc.
- Requirements regarding commissioning.

- Partner responsible for operation and maintenance (O&M), alarms, etc.
- Partner responsible for metering and evaluation of performance.

- DH fee paid by the system/building owner (SEK/MWh), e.g. fixed, variable (quarterly, monthly, annual).
- Solar fee paid by the DH provider (SEK/MWh), e.g. fixed, variable (quarterly, monthly, annual), for example 80% of the DH fee.

- Duration of the agreement and procedure for cancellation.
- Measures to be taken when there is a disagreement.

The partner agreement can be based on the same type of agreements that are used when a DH provider buys waste heat from an industry.

SWEDISH PLANTS AND EXPERIENCES

Introduction

There are about 30 solar heating systems connected to DH systems all over Sweden, out of which 22 with varying sizes have been documented and evaluated with support from the Swedish DH Association [Dalenbäck et al, 2013]. See Tables 1 and 2 for an overview. The main experiences were presented by Dalenbäck [2013a] and Rosén [2013] at the 1st International conference on Solar District Heating in Malmö.

Figure 5. School building with roof-mounted solar collectors connected to the DH system in Malmö, Sweden. Photo: Malmö stad

First of all, there are 14 systems in the city of Malmö, out of which 10 systems with solar collectors mounted on new buildings and 4 systems with solar collectors mounted on existing buildings. The majority of the systems in Malmö are owned and operated by E.ON, the DH provider in Malmö, as a part of the “Bo01” building project. A sample building is shown in Figure 2. The rest of the systems in Malmö (e.g. as shown in Figure 5) were built 2005-2008 on existing buildings and are owned and operated by the city of Malmö (Malmö stad).

Out of the remaining eight systems of those evaluated, all built 2009-2011, six are connected in large DH systems while two are connected in small local DH systems. The plant ownership is divided on six municipal housing owners and two private cooperative owners, while the DH ownership is divided on five municipal companies, one E.ON, one Fortum and one small private company. See appendix for more information.

Table 1. Solar feed-in systems in Swedish DH systems - Ownership.

	Location	Plant	Year	DH provider	Owner
1	Timrå	Brf Örnen	2009	E.ON	Brf Örnen (HSB)
2	Växjö	Vislanda	2009	Alvesta Energi	Allbohus
3	Eskilstuna	Måsta	2009	Eskilstuna Energi	Eskilstuna kommun
4	Molkom	Molkom	2011	Molkom Biovärme	Karlstad Kummun
5	Göteborg	Gårdsten	2010	Göteborg Energi	Gårdstenbostäder
6	Helsingborg	Björka/Ödåkra	2010	Öresundskraft	Helsingborgshem
7	Stockholm	Glottran	2010	Fortum	SKB
8	Karlstad	Nya Järpen	2009	Karlstad Energi	KBAB
9-17	Malmö	Bo01	2001	E.ON	E.ON
18	Malmö	Kockum	2002	E.ON	E.ON
19	Malmö	Augustenborg	2005	E.ON	Malmö stad
20	Malmö	Helenholm	2007	E.ON	Malmö stad
21	Malmö	Stensjön	2008	E.ON	Malmö stad
22	Malmö	Sege Park	2008	E.ON	Malmö stad

Table 2. Solar feed-in systems in Swedish DH systems - Technical data.

	Location	Plant	Unit	Collector	Size [m^2]
1	Timrå	Brf Örnen	Armatec	Aquasol	262
2	Alvesta	Vislanda	Armatec	Aquasol	344
3	Eskilstuna	Måsta	Armatec	Aquasol	230
4	Karlstad	Molkom	Armatec	Aquasol	501
5	Göteborg	Gårdsten	Armatec	ARCON	150
6	Helsingborg	Björka/Ödåkra	Armatec	Sol&Energiteknik (ET)	106
7	Stockholm	Glottran	Armatec	Aquasol	202
8	Karlstad	Nya Järpen	SWEP	Aquasol	227
9-15	Malmö	Bo01	Site built	Solsam	42 - 403
16-17	Malmö	Bo01	Site built	Viessmann (ET)	56 / 150
18	Malmö	Kockum	Site built	Aquasol	1 050
19	Malmö	Augustenborg	SWEP	ARCON	426
20	Malmö	Helenholm	Armatec	ARCON	1 128
21	Malmö	Stensjön	ExoHeat	ExoHeat (ET)	46
22	Malmö	Sege Park	Armatec	Sol&Energiteknik (ET)	230

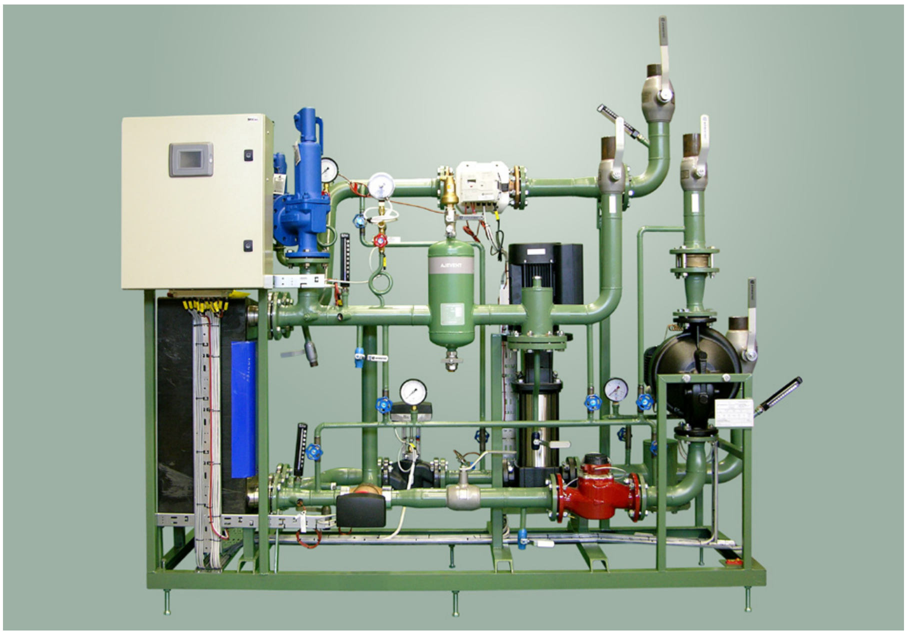


Figure 6. Pre-fabricated sub-station connecting the solar collector circuit and the DH system. Photo: Armatec.

The majority of the evaluated systems have flat plate solar collectors placed on roofs, five systems have evacuated tube (ET) solar collectors and two systems are mounted on facades. All systems are connected to the primary district heat distribution systems using a plate heat exchanger, 12 systems have site-built connections and 10 systems have pre-fabricated connections. The pre-fabricated unit from Armatec is shown in Figure 6.

Political initiatives need supporting frameworks

The majority of the evaluated systems are initiated by local political municipal initiatives to introduce solar heating systems on buildings in DH systems. The Bo01 project was one of the first projects with the aim to create a new building area with 100% locally generated energy supply based on renewable energy.

All evaluated systems work more or less as expected, but there are a number of possible improvements related to planning, design and installation, as well as to operation and maintenance (O&M). All plants are introduced in a framework with poor experience among building owners and consultants, together with the lack of established contractors. On top of that there are of course also different local conditions were the plants have been installed (e.g. types of building, etc.). These differences also makes it difficult to evaluate the investment costs.

All systems in Bo01 (Malmö) have been designed and are operated by E.ON. All other systems have been designed, contracted, installed and commissioned in different ways and are operated by different companies. Restraints on the investments costs in most cases, together with small contractor margins, have also influenced system design.

Furthermore, the evaluation has required a considerable effort to get and evaluate the thermal output from a majority of the plants. This is in many cases due to a lack of interest from building owners, as well as DH providers, to keep track of the plants as it is not in their main focus to have and operate solar heating systems.

There is a large variation with regard to size, inclination and orientation of the solar collector arrays, which together with rather long connection pipes, explains the low output in several cases. Second, poorly adjusted controls resulting in increased collector operating temperatures and poor supervision (plants out of operations during short or longer periods) are other explanations. Third, fairly high collector operating temperatures in a few systems, due to high return temperatures in the DH systems, has also resulted in lower than expected output.

All together the result is that the thermal output is far from what should be possible to achieve in this type of installations. The Bo01 systems have the highest availability but the lowest average output, about 200 kWh/a.m^2 collector area. They are all operated in the same way but comprise small systems mounted with different and unfavourable inclinations. The other systems have about 20% higher average output, about 240 kWh/a.m^2, while some systems yield well above 300 kWh/a.m^2. The evaluation is carried out for 2011 and 2012 which were fairly close to average with regard to solar radiation.

However, all documented and evaluated systems have more or less the same system design (Figure 1), a solar collector circuit with a pump, a heat exchanger and a DH circuit with a pump, a heat meter and one or several valves. The basic principle in all systems is that water in the DH system return pipe is heated to a more or less constant temperature and fed into the DH system flow pipe. Depending on the amount of solar heat, the solar heat will either be regarded as covering part or all of the building heat load, or as delivered to the DH system.

All cases involve an agreement between the building owner and the DH provider. In most cases the building owner is compensated for the feed-in solar heat based on the DH fee, i.e. in some cases the agreement comes close to net-metering of solar and district heat.

Recommendations

First of all, to achieve a for Swedish conditions required and feasible thermal output between 300 and 400 kWh/a.m^2, one should be more careful to choose an appropriate collector orientation and inclination, and investigate the DH system operation. There should further be a national framework program with a series of systems built in order to show a favourable cost development.

The solar collectors should be placed tilted (30-60° from horizontal) and directed to the south (within South-east to south-west) without any major shading from March to September. Furthermore the distance between the collectors and the connection to the DH system should be as short as possible, as a long distance introduces heat losses and complicates the controls.

The operating temperatures in the DH systems should be fairly low, well below 70° C, ideally below 50° C, at least during the summer half year. Measures to reduce the return temperature in a DH system do not only improve the performance of the solar collectors, they also result in decreased heat distribution losses and increased efficiency in the main heating plant. DH fees based on flow and/or return temperature are suitable measures to improve DH system performance.

The solar systems should have an appropriate design and an appropriate control system in order to keep a more or less constant temperature. This requires a control that is able to adjust the flow rate to manage the variations in solar radiation and differential pressure in the DH system connection point.

Solar collectors have a well-documented thermal performance and the thermal output of a solar heating plant is decided by the amount of solar radiation, the system design and the characteristics of the connected heat load. As a reference, the majority of solar heating systems installed in Danish district heating systems yield about 400 kWh/a.m^2. The reasons are more unified collector orientations and inclinations (collectors placed on ground), larger plants, better controls, lower return temperatures in the DH systems (direct connection to radiators, DH fee based on flow, etc) and better supervision by engaged and experienced plant owners.

Future plants are recommended to be installed within one total contract that includes plant commissioning and test operation. It is possible, but rather complicated; to guarantee the annual thermal output from a specific plant (as it depends on the load characteristics), but it is fairly easy for an experienced commissioner to judge the performance during a well-designed inspection.

The plant should further be operated and supervised by a staff with the appropriate experience. Here it might be a better alternative that the DH provider is responsible for O&M instead of the building owner, e.g. as done by E.ON in Malmö. Especially if the building owner does not have a computerized system for supervision.

It should be noted that many of these recommendations are already taken care of by the way the feed-in systems have been developed in Austria.

AUSTRIAN PLANTS AND EXPERIENCES

Introduction

The Austrian approach is a bit different from the Swedish case as the plants have been initiated and developed by professional project developers. Furthermore, the majority of solar heating systems are owned and operated by an Energy Service Company (ES-CO) that sells solar heat to the DH company and/or the connected building facilities. Figurer 4 shows a plant on the roof of a waste management plant.

Figure 4. AEVG plant with roof-mounted solar collectors connected to the DH system in Graz. Photo: AEVG.

Table 3. Solar feed-in systems in Austrian DH systems.

Location	Plant	Year	Developer	Owner	Size [m^2]
Graz	UPC Arena	2002	S.O.L.I.D.	solar.nahvarme.at	1 407
Graz	Berliner Ring	2009	S.O.L.I.D.	solar.nahvarme.at	2 417
Graz	AEVG	2007 2014	S.O.L.I.D.	solar.nahvarme.at	4 960 2 490
Graz	Wasserwerk	2009	S.O.L.I.D.	solar.nahvarme.at	3 855
Wels	Messehalle	2011	Ritter XL (ET)	Fernvärme Wels	3 400

Table 3 summarizes the Austrian plants. The city of Graz has two solar heating systems that feed into the DH system, UPC Arena and AEVG (waste management plant), and two systems, Berliner Ring (residential area) and Wasserwerk, connected in sub-nets with the possibility to feed into the main DH system when there is an access of solar heat. All systems are designed and built by the same project developer using large module collectors. Furthermore, there is a system with evacuated tube (ET) collectors feeding into the DH system in Wels. See appendix for more information.

Recommendations

The solar collectors should be placed tilted (30-60° from horizontal) and directed to the south (within South-east to south-west) without any major shading from March to September. Furthermore the distance between the collectors and the connection to the DH system should be as short as possible, as a long distance introduces heat losses and complicates the controls.

The Austrian feed-in systems are here in a way more like the large Danish systems, with more careful chosen collector orientations and inclinations, and do not show the same problems as the smaller Swedish feed-in systems.

The operating temperatures in the DH systems should be fairly low, well below 70° C, ideally below 50° C, at least during the summer half year. Measures to reduce the return temperature in a DH system do not only improve the performance of the solar collectors, they also result in decreased heat distribution losses and increased efficiency in the main heating plant. DH fees based on flow and/or return temperature are suitable measures to improve DH system performance.

The solar systems should have an appropriate design and an appropriate control system in order to keep a more or less constant temperature. This requires a control that is able to adjust the flow rate to manage the variations in solar radiation and differential pressure in the DH system connection point.

The plants should be operated and supervised by a staff with the appropriate experience. One way to achieve this is that the solar heating systems are owned and operated by an dedicated Energy Service Company (ESCO) as is the case for the Austrian systems.

REFERENCES

Dalenbäck, J-O. et al (2013) *Solvärme i fjärrvärmesystem*. Rapport 2013:26. Fjärrsyn, Svensk fjärrvärme.

Dalenbäck, J.O (2013a) *Decentralised SDH systems – Swedish Experience.* Presentation at the 1st International conference on Solar District Heating. www.solar-district-heating.eu

Dalenbäck, J-O. (2013b) An Emerging Option - Solar District Heating and Cooling. *EuroHeat&Power*, English edition, Vol. 10, III/2013.

Dalenbäck, J-O. (2013c) An Emerging Option – Grid-connected Solar Heat. *EuroHeat&Power*, English edition, Vol. 10, IV/2013.

Rosén, P. (2013) *Solar Heat in District Heating Systems: Experiences of Western Harbour/Bo01, Malmö.* Presentation at the 1st International conference on Solar District Heating. www.solar-district-heating.eu

SDH solar district heating

WP4 – D4.3 Appendix

An intro to ”Feed-in of solar heat”

Jan-Olof Dalenbäck
Professor
Chalmers University of Technology
CIT Energy Management AB

Prepared for SDH meeting 2013.11.14-15

SDH solar district heating

DH - An infrastructure

- **Solar heat can be fed into DH in same way as heat from any other DH plant ..**
- **DH providers can sell green heat in same way as green electricity is sold ..**
- **DH providers can transfer and store heat ..**
- **Why not buy and sell solar heat ?**

DH providers can ..

- Improve image .. Keep/attract users ..
- Build plants where suitable .. e.g. on roofs of industries, waste land, etc.
- Sell solar heat from any site to a customer in any other site ..
- Have different fees for different parts of there energy mix ..
- Likely be paid more for solar heat than heat based on fossil fuels ..

DH users can ..

- Rent out their roof to the DH provider ..
- Build their own plant and sell solar heat to the DH provider ..
- Build their own plant and net meter solar heat and used heat ..
- Improve their building energy performance if indicator based on bought heat ..
- Transfer solar heat to other buildings ..

SDH solar district heating

Different plant ownerships ..

- DH providers ..
- DH users ..
- ESCO's .. i.e. third parties ..
- Allows new business models ..

SDH solar district heating

System design ..

- Plant sized based on available area for solar collectors and DH pipe dimensions ..
- Site built or pre-fab unit with heat exchanger, pumps and controls ..
- Connected return-forward pipe .. controlled to supply flow temperature ..
- Additional storage in DH system if needed ..

SDH solar district heating

Experiences ..

- > 30 plants small and large plants in Sweden ..
- Several large ESCO plants in Austria ..
- Pilot plants in Denmark and Germany ..
- Requires an adapted agreement between stakeholders ..
- Requires professional operation ..

SDH solar district heating

CONTACT & INFO

Jan-Olof.Dalenback@chalmers.se

www.solar-district-heating.eu

www.rhc-platform.org

WP4 – D4.3 Appendix

Samples of Existing Plants - Sweden

E.ON - Malmö City

Bo01 – Feed-in systems
<u>Main project partners:</u>
Swedish Energy Agency, Vattenfall, Sydkraft (later E.ON) and misc. actors.

The feed-in systems were pioneered by Sydkraft in 2001 in connection to "Bo01", a new residential area in Malmö with 100% renewable energy supply. The municipality wanted to support/allow solar heat used in the district heated buildings and Sydkraft designed, built and operates the systems.

Evacuated tube collectors (ETC) on roof and façade on one of the buildings in Västra Hamnen (Bo01), Malmö.

Sydkraft rents the roofs were the collectors are mounted. All together 9 systems, out of which 2 with evacuated tube collectors (ETC), with collector areas from 42 to 403 m^2 of solar collectors each.

A number of projects built and operated by the municipality (city of Malmö, see below) followed in 2004. Sydkraft was later bought by E.ON. The feed-in systems in Bo01 were presented by E.ON during the 1st International conference of Solar District Heating in Malmö in 2013 (Rosén, 2013).

The feed-in systems is now applied by **E.ON** in relation to EPBD requirements in new residential areas in Malmö in order to support DH in new building areas with 100% renewable energy supply. Feed-in systems using photovoltaics is also marketed by E.ON in new building areas.

Diligentia (building developer) has recently installed a system on new building close to the original "Bo01" site (see below)

Malmö City

Malmö stad – Feed-in systems (2002-2008)
<u>Main project partners:</u>
Malmö city building facility division, misc. consultants and contractors.

Kockum Fritid (2002): Sports Hall renovated with all together 1 050 m^2 of façade-integrated solar collectors to east, south and west. DH provider: E.ON:

Heleneholmskolan (2007): All together 1 128 m^2 of solar collectors mounted on a school building. DH provider: E.ON:

Sege Park (2008): Roof-mounted evacuated tube collectors, 230 m^2, mounted on the roofs of an old hospital area turned into a small business area. DH provider: E.ON:

	After the implementation of the EPBD directive in around 2006, "**Solar heat EPBD**" has been applied by a couple of municipal housing companies in cooperation with misc. DH utilities since 2009. These projects were further eligible for a governmental investment subsidy for solar systems (2000-2011). All together 22 feed-in systems that were in operation in 2011 and/or 2012 were evaluated within the Swedish District Heating Associations R&D program "Fjärrsyn" and resulted in a published report in Swedish (Dalenbäck et al, 2013). All together there are now more than 30 feed-in systems put in operation between 2001 and 2015, half of them based on Swedish building performance requirements and/or building certification (BREEAM, LEED, Miljöbyggnad) both based on the EPBD.
KBAB - Karlstad	 Roof-integrated solar collectors (227 m^2) on a renovated multifamily building (Nya Järpen) in Karlstad (2009).
Allbohus – Vislanda, Växjö	 Mounting of roof-integrated solar collectors (344 m^2) on an existing multifamily building in Vislanda, Växjö (2009).

<table>
<tr><td>Brf Örnen - Timrå</td><td>The HSB housing society “Brf Örnen” has installed solar collectors on their buildings and connected them to the local DH system in Timrå north of Sundsvall (Latitude 62). DH provider: E.ON:
 
Mounting of roof-integrated solar collectors (262 m^2) on an existing multifamily buildings in Timrå (2009).</td></tr>
<tr><td>Gårdstens-bostäder – Gårdsten, Gothenburg</td><td>Gårdsten – Feed-in system (2010)
<u>Main project partners:</u>
Gårdstensbostäder (municipal housing), Göteborg Energi (municipal DH provider), Andersson & Hultmark (engineering consultant), Armatec (prefab unit).

CIT Energy Management AB initiated a feed-in system demo on a multifamily building in Gårdsten, Göteborg, realised in 2010. The plant comprises 150 m^2 of large module collector mounted the roof of a high-rise multifamily building.

The demo plant is now marketed within the Smart City project “Celsius” (Coordinator: Göteborg City).</td></tr>
</table>

Karlstad City - Molkom	 Karlstad municipality have installed solar collectors (501 m^2) on a sports hall and connected them to a local DH system in Molkom (2011). DH provider: Molkom Biovärme
SKB - Stockholm	 The housing cooperative SKB have installed roof-integrated solar collectors (202 m^2) on new multifamily buildings in Glottran, Årsta, Stockholm (2011). DH provider: Fortum.

Lerum municipality - Gothenburg

Lerum Minicipality – Feed-in systems (2011-2015)

Main project partners:

Lerum municipality, Förbo (municipal housing), Energianalys (engineering consultant), misc. contractors.

Förbo (local municipal housing) has built “PlusEnergyHouses” (in this case “PlusHeatHouses”, i.e. the annual yield from solar collectors on the building should exceed the heat used in the buildings during one year). Förbo has an agreement with Lerum Fjärrvärme where Förbo can buy district heat when needed and feed solar heat into the local DH system when needed.

Two out of four “PlusHeatHouses” with 450 m^2 of roof-mounted solar collectors.

Lerum municipality initiated the Life-project “Noisun” with the intention to mount solar collectors as/on a sound barrier between the railroad and buildings in Lerum. The project is developed in cooperation with Trafikverket (national agency for roads, railroads, etc.), SP Technical Research Institute of Sweden (Sound and solar collectors) and Lerum Fjärrvärme (as the solar collectors to the local DH system). The project is operation 2015 and presented at www.noisun.eu.

Solar collectors (850 m^2) on a sound barrier in Lerum.

<table>
<tr><td>Vattenfall – Solna, Stockholm</td><td>Vattenfall's new head office in Solna (Stockholm) is equipped with a feed-in system with 430 m^2 of roof-mounted solar collectors in order to improve building energy performance according to the EPBD. The plant was put in operation in 2012. DH provider: Norrenergi.

Solar collectors on one out of two roofs 60 m above ground – Vattenfall, Solna.</td></tr>
<tr><td>Diligentia - Malmö</td><td>A new feed-in system was recently installed on a new building (Masten 3), in a block close to Bo01 in Malmö. Diligentia is the building owner, the solar feed-in system is motivated by the requirements that the building should be certified according to BREEAM and is in operation since Spring 2015. DH provider: E.ON.

Solar collectors on new building close to "Turning Torso" – Diligentia, Malmö.</td></tr>
</table>

Samples of Existing Plants - Austria

<table>
<tr><td>UPC Arena - Graz</td><td>The solar collector array mounted on the roof of an ice hockey rink next to the UPC Arena in Graz is the first Austrian solar heat feed-in system.

The collector array amounts to 1 400 m^2 of large module collectors and has been in operation since 2002.
http://www.solid.at/de/referenzen/solares-heizen/fernwaermespeisung</td></tr>
<tr><td>Berliner Ring - Graz</td><td>
Large module collectors mounted on the roofs of a number of multifamily buildings is connected to a local network in Berliner Ring. The total collector area amounts to 2 400 m^2 and excess heat is feed into DH system in Graz since 2009.
http://www.solid.at/de/referenzen/solares-heizen/fernwaermespeisung</td></tr>
</table>

AEVG - Graz	Close to 5 000 m^2 of large module solar collectors were mounted on roofs on the AEVG waste management plant (AEVG) in Graz in 2007.  The plant was (in cooperation between five different collector manufacturers) extended with close to 2 500 m^2 of ground-mounted collectors in 2014 to a total collector area of close to 7 500 m^2. The solar heat is sold to Energie Steiermark Wärme GmbH, Graz. http://www.solid.at/de/referenzen/solares-heizen/fernwaermespeisung
Wasserwerk - Graz	 http://www.solid.at/de/referenzen/solares-heizen/fernwaermespeisung

Messehalle - Linz	 The roof of the exhibition hall in Wels is equipped with 3 400 m^2 of evacuated tube collectors (ETC) connected to the local DH system. The plant came into operation in 2011 and delivers heat to Fernvärme Wels. http://ritter-xl-solar.com/en/applications/district-heating/wels-austria/