SOLAR DISTRICT HEATING GUIDELINES

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1. Introduction

Solar district heating (SDH) stands in front of a potentially very large upswing in the near future. However in some countries there are significant barriers blocking the way for solar energy to cover a large(r) share of the heating demand. An international project involving both consultants and district heating companies from six different countries takes up this issue and focuses on overcoming the barriers for the development of solar district heating in Europe.

Fig. 1: Project logo and website URL.

The project is supported by Intelligent Energy Europe and is called "SDHtake-off – Solar District Heating in Europe". It includes training schemes, support structures and workshops held in different European countries where people can exchange experiences and learn more about the possibilities of SDH. Another outcome of this project is a series of written guidelines for the industry. They are aimed at utilities from across Europe who may be considering investing in solar district heating. These guidelines will be published on the project website in the autumn of 2011.

2. Guideline format

The guidelines are split in different documents called *fact sheets* each describing a topic in a short, concrete way. The fact sheet configuration provides a quick overview of the different subjects so the reader can easily pick out the desired information on solar district heating. That being said, the fact sheets may also be used as a "read through"-report if the reader wants a broader perspective on the entire subject of solar energy used for district heating.

The fact sheets include both technical and "non-technical" topics. The goal is to bridge the gap between *wanting* a plant and actually *having* a plant, i.e. describing both the processes and which obstacles that might occur as well as how to avoid or overcome them.

The barriers for SDH can be split into four categories: knowledge & understanding, technical, financial and political barriers. The fact sheets address these barriers by describing the following general points:

- Possibilities and how to proceed step by step through the process of realizing an SDH plant.
- The technical solutions available on the market today.
- How to make preliminary feasibility studies considering the total economy of a project during its lifetime instead of focusing on the large investment costs.
- How lowering of a country's CO_2 emissions can be made in an economical favorable way.

3. List of fact sheets

The "non-technical" subjects (below to the left) describe what to be aware of when considering investing in a solar district heating plant – from the idea is formed until the actual plant is constructed and operating.

The technical subjects (below to the right) describe the plant design, its components and the control of the operating plant.

Introduction to SDH:

- Overview of SDH implementation steps

Preliminary investigations:

- Solar heat combined with other fuels
- Where to place the solar collectors
- Questionnaire for SDH site assessment
- Feasibility study
- Ownership and financing

Permissions, tendering, contracts & guarantees:

- Permissions from authorities
- Tendering and contracts
- Performance guarantees

Implementation:

- Supervision of construction and commissioning
- Monitoring

System:

- Interaction between SDH plant and district heating network
- Decentral integration of solar thermal energy in district heating network
- Control strategies

Components:

- Solar collectors
- Storage
- Pipes & pumps
- Heat exchanger

Precautions:

- Temperature variations
- Safety equipment

Fig. 2: Example of fact sheet layout. Header and logo make the fact sheets easily recognizable and an info-table on each front page gives a quick overview of the document.

4. Description of the fact sheets

4.1. Preliminary investigations

- ***Solar heat combined with other fuels***

Technically speaking solar heat can be combined with all other fuels for district heating, but it is not always economically feasible to do it. The production price from a solar heating plant will in Northern Europe be at least 3 € cents/kWh and in Southern Europe at least 2 € cents/kWh. This price has to be compared to heat production prices from other sources.

A lot of Danish SDH-systems are installed in combination with natural gas fired CHP-plants since this way the CHP-plant can be turned off a large part of the summer months and utilized most efficiently when both heat *and* power is needed.

- ***Where to place the solar collectors***

For ground mounted collectors, normally large collectors units (10-15 m^2) placed in parallel rows of up to 20 collectors are used. For 1 m^2 solar collector 3-4 m^2 land is needed. The distance between the solar collector rows is normally at least 4.5 m (depending on the collector height) – measuring from the front of a collector row to the front of the next row – allowing people to move around between the rows. Larger distances give higher production because of less shadowing but also higher costs for ground and piping. A calculation example of shadow losses and the optimum tilt of a ground mounted SDH plant is seen in figure 3.

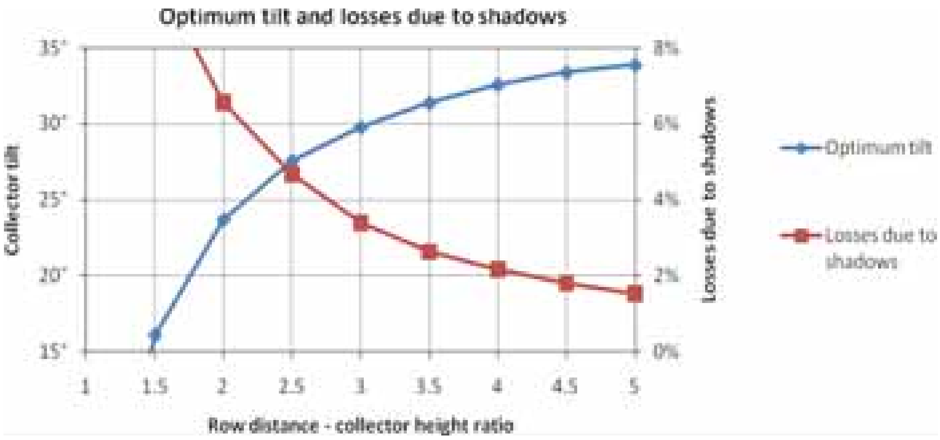


Fig. 3: Optimum tilt and losses due to shadows as function of the ratio between row distance and collector height. In the example a ground mounted SDH plant in Tørring, Denmark is used.

- ***Questionnaire for SDH site assessment***

In order to be able to make an investigation on the most profitable energy generation mix and the possibility of having a large scale solar collector field and thermal energy storage, a questionnaire has been developed to help gather all the required information. Several conditions such as electrical and thermal loads of consumers, heat and electricity price, climatic and economical boundary conditions, present heat distribution system properties and the available area for the collectors have to be evaluated for the specific site.

- ***Feasibility study***

By means of rough calculations of the costs and expected yield from a solar district heating plant, the feasibility of a given plant project can be investigated. The calculations include variables for

- availability of solar radiation
- locations available for collectors and storage
- cost of land (for ground mounted collectors)
- distance between collector field and district heating network connection point
- approximated operating temperature in the district heating network

When the approximated costs (€) and yield (MWh) is found, the estimated heat price (€/MWh) will show if the project can compete with alternative energy solutions (with or without subsidies).

In figure 3 an example of the cost distribution shows that the collectors represents the largest part of the plant costs by far, in the case of a ground mounted SDH plant in Denmark (without a long term storage).

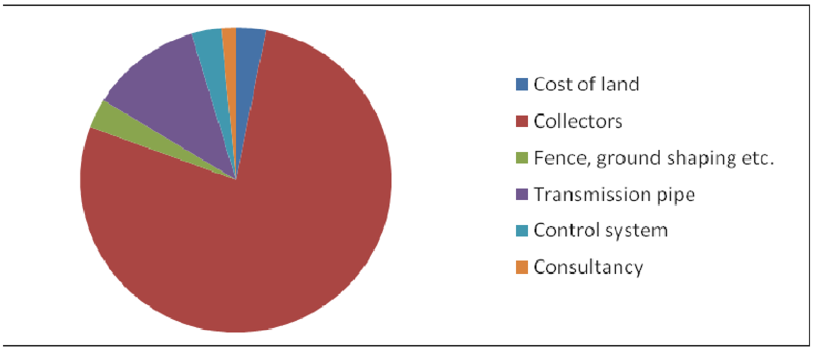


Fig. 4: Example of cost distribution for an SDH plant in Denmark with a collector area of approx. 7000 m^2. Note that storage is not included.

- ***Ownership and financing***

Several examples of ownership solutions are described along with an example of "ownership interface" for roof mounted solar collectors when the collector owner and house owner is not the same person. The fact sheet also includes the most important issues in case a contract between the utility and the plant owner is needed (including feed in tariffs for delivering heat to the district heating network).

4.2. Permissions, tendering, contracts and guarantees

- ***Permissions from authorities***

To make sure that all the necessary legal permissions are granted, a check list is developed including a description of its different points:

- Check the local plan (the area might already be pointed out for other use e.g. apartment building)
- Environmental permission
- Check that there is no conflict with the heat plan / energy planning
- Building permission (if mounted on roof).

- ***Tendering and contracts***

This fact sheet includes a list of things which the tender document should specify in order to be sure that the quality of the plant in the end *will* be as expected when it was ordered.

The plant construction may be handled by one total contractor or more contractors. A check list for a total contractor is also found in this fact sheet.

- ***Performance guarantees***

The procedures for the following four scenarios are described in the fact sheet:

- How to *give* performance guarantees for large collector fields
- How to *give* performance guarantees for heat exchangers
- How to *check* performance guarantees for large collector fields
- How to *check* performance guarantees for heat exchangers

The measurements needed to perform the performance checks and the requirements for data logging are listed in the fact sheet as well. Besides this, templates for taking notes of the equipment used for data logging and for taking notes of the solar collector fluid properties are included.

4.3. Implementation

- ***Supervision of construction and commissioning***

During the building process the plant owner (and/or the consultant company) has to follow the process and gather all contractors in a meeting which should be held at least every second week. This gives the opportunity to discuss state of the art of the implementation, unsolved problems and the work in the coming weeks while keeping the time table in mind.

After implementation the contractors has to show, that the plant works as promised. At the delivery day the plant owner and the contractors have to agree upon that the work is performed according to the contract. From that point on the guarantees apply.

- ***Monitoring***

The minimum time resolution of the monitoring system should be 10 minutes when logging the following data:

- Logging of heat meter data
  - Heat
  - Thermal power
  - Flow rate
  - Supply / return temperatures
- Solar irradiation
- Temperatures in the storage(s)
- Ground temperatures and heat flux sensors (for this, the resolution could be 30-60 minutes)

4.4. System

- ***Interaction between SDH plant and DH network***

This fact sheet deals with the subject of handling the unstable solar heat as it feeds into the district heating network which should always maintain the desired supply temperature.

- ***Decentral integration of ST in DH networks***

In this case “decentral” means that the solar thermal plant is not close located to another major heat generator like a biomass or fossil fuel fired plant. The different possibilities for the position of the solar collector field in the district heating network is described along with the different options for feeding in the solar heat into the grid. This can be done by:

a. Heating up the return water of the DH network and feeding in the heat in the flow direction.

b. Heating the return water and feeding it into the return pipe.

c. Heating the flow water and feeding it into the flow pipe.

- ***Control strategies***

The energy output of the solar district heating system is highly dependent on the conditions on which it is operated. In order to get the most out of the plants potential, it is necessary to consider what the optimum control strategy will be for the given system, i.e. pros and cons for every control setting.

There are several more or less contradicting points in the optimization of a solar district heating plant control:

- Obtaining the required temperatures for the district heating grid
- Avoiding stagnation in the solar system
- Minimize heat losses in collectors, pipes and storages
- Minimize wear of the solar plant, i.e. reduce changes in temperature and pressure
- Minimize electricity consumption of pumps
- Minimize requirement of human intervention
- Optimize use of other heat sources like heat pumps, and boilers.

4.5. Components

- ***Solar collectors***

Different types of solar collectors are described in terms of efficiency expressions, the effect of operating temperature and flow rate and comparison of approximated annual yield.

The choice of collector type depends on a combination of several factors:

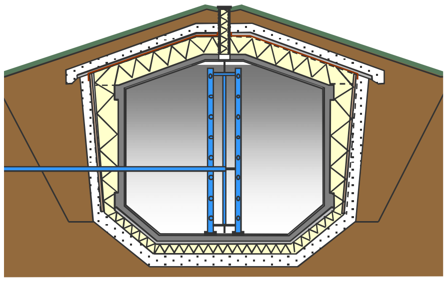
- Collector price (which also depend on the number of collectors in the plant – the bigger the collector field is, the lower is the cost per m^2)
- Other costs (piping, ground shaping, storage etc.)
- Collector efficiency expression
- Operating temperature
- Location (which tells the available solar radiation and the ambient temperatures)

- ***Storage***

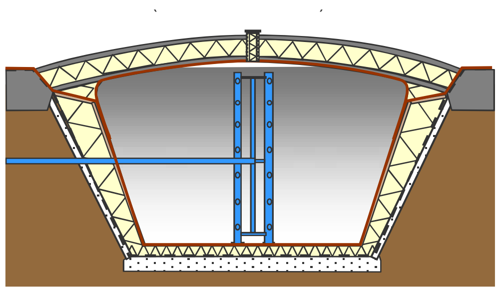
There are four main types of seasonal thermal energy storages. These are shown in figure 5 below and include tank thermal energy storage (TTES), pit thermal energy storage (PTES) both with and without liners, borehole thermal energy storages (BTES) and aquifer thermal energy storages (ATES).

To make the right choice of collector type and size, it is necessary to take into account the local geological situation, system integration, required size of the storage, temperature levels, power rates, no. of storage cycles per year, legal restrictions etc. In the end the decision can be taken when an economical optimization of the different possibilities has been developed.

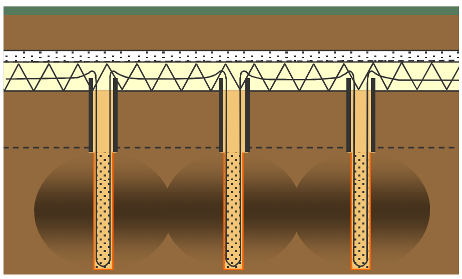
Tank Thermal Energy Storage (TTES)



Pit Thermal Energy Storage (PTES)



Borehole Thermal Energy Storages (BTES)



Aquifer Thermal Energy Storages (ATES)

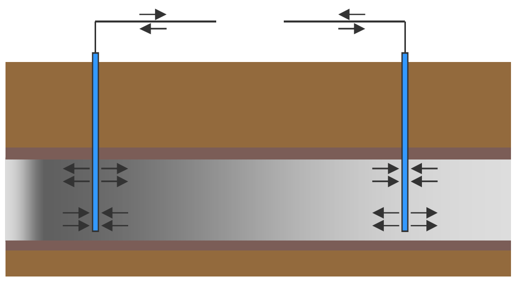


Fig. 5. The four main types of storage used as long term heat storages (Solites).

- ***Pipes & pumps***

The pipes in an SDH plant have to cope with daily temperature variations. This means that – due to the thermal expansion and contraction of the pipe materials – the conditions for these pipes are far more demanding than the conditions for the pipes in a conventional district heating system.

The dimensioning of the pipes and the pumps has to be done simultaneously since the pump in the solar collector loop (“primary side” of heat exchanger) has to be powerful enough to overcome the pressure losses and still maintain the desired flow rate. At the same time the total sum of the following should be minimized:

- Buying and installing pipes
- Buying and installing pumps
- Electricity costs for the pumps during operation throughout the lifetime.

In other words the optimal balance between the following scenarios must be found:

a. Small pipe diameter → large pressure loss → low costs for pipes but high electricity costs for pumps

b. Large pipe diameter → low pressure loss → high costs for pipes but low electricity costs for pumps.

The pump on the secondary side of the heat exchanger (i.e. in the district heating network) has to be able to maintain a capacity rate similar to the one in the primary loop, to have the most efficient heat transfer in the heat exchanger.

- ***Heat exchanger***

Normally a counter flow plate heat exchanger is used for large SDH systems. The heat exchanger unit transports the actual useful performance of the system. It is the sole component linking the solar heat to the district heating network. Therefore it is crucial for the overall plant efficiency to have a well performing heat exchanger with a properly balanced capacity flow on both sides. The capacity flow is the power which can be transferred to or from the liquid per degree (K) in difference between inlet and outlet temperature of the heat exchanger for one side – e.g. primary side (unit: W/K).

In this fact sheet the calculations of both the capacity flow and the heat exchanger factor (which is the efficiency of transferred energy from the primary to the secondary side) are described.

4.6. Precautions

- ***Temperature variations***

This fact sheet describes the thermal expansion and contraction of both the system components and the collector fluid and how the system is configured to be able to handle this cyclic behavior.

- ***Safety equipment***

It is necessary to take precautions in terms of extreme temperatures which may damage the system, i.e. in case of freezing and boiling. In most large scale systems an antifreeze mixture is used in the solar collector loop to avoid freezing. Typically a mixture mainly consisting of water and glycol is used. In case of stagnation the system must be able to cope with the pressure which occurs, but only to the extent where a safety valve releases the pressure by letting some or all of the fluid out of the loop if necessary. A collecting vessel must be able to contain all overflowing liquid since it is normally not allowed to pour the most commonly used solar collector fluids into a drain.

To avoid continuous boiling in the collectors in case of stagnation (which could be caused by a power failure, pump failure or an overheated buffer storage) the collectors can be made in a way that ensures quick emptying of the collector fluid. Examples of collector configurations with good emptying behavior are also described in this fact sheet.

5. Conclusion

With these guidelines made available, the solar district heating technology will hopefully seem less strange to the readers and it may even be the last ‘push’ for some utilities or investors to move on with the idea of having their own solar district heating system. If these guidelines will help break down some of the barriers solar district heating faces today, then perhaps we have only seen the beginning of a blooming industry so far. In any case there is no doubt that the potential is huge and even today we see a significant (and increasing) number of good examples of economically feasible solar district heating plants in operation.

6. References

Jan Erik Nielsen, to be published 2011 (draft from August 13, 2011). Solvarmehandlingsplan.
EUDP-program 2008 (in Danish).

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Deliverable D.3.1 & D.3.2 in the SDH*take-off* project.

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