Solar District Heating

Inspiration and Experiences from Denmark

Danish District Heating Association / PlanEnergi

English version for IEA SHC Task 55 – January 2018

Contents

Foreword

This document brings together some of the most important experiences from the inspiring development of solar district heating systems that have been seen in Denmark in the past years. The document is an adapted translation of "Solvarme – Inspirationskatalog" from February 2017, elaborated by PlanEnergi for the Danish District Heating Association. Some of the conditions and regulations described might be specific Danish.

The target groups for this document includes:

- Boards and Operators at district heating plants
  - District heating plants that have not yet solar and considering the establishment of a solar district heating system
  - District heating plants with solar considering extension of the solar part and/or seeking exchange of experience with other solar plants
- Municipalities considering establishment of solar district heating systems

The document is structured in order that target groups may find useful information to facilitate the process of establishing solar district heating systems:

- Solar district heating in general
  - The history of solar district heating in Denmark
  - Main phases in a solar project
- Pointers for board members
  - What should be considered in the early stages?
- Pointers relevant to municipalities
  - The municipality's role and benefits for the municipality?
- Pointer relevant for district heating plants
  - Primary operating experience, which may also affect the design of the plant

The main objective of this document is to inspire and qualify the district heating companies (board members as well as operating personnel) as well as representatives from municipalities with respect to the specific processes in the project development phases.

This is not a proper guidance in the establishment of solar installations. More specific guidance can be found in IEA SHC Task 45 and Task 55 guidelines and fact sheets and in the Europeran SDH projects – see last section in the document. This document thus complements these guidelines with specific Danish experience.

After the summing up for the main actors/stakeholders follow descriptions of six specific Danish solar district heating plants – and some experiences gained here.

Thanks to the Danish EUDP programme for supporting Danish participation in IEA SHC Task 45 and Task 55.

1 The phases of a solar district heating project

Solar heating has in recent years made great progress in the Danish district heating systems - and Denmark has the highest number and the biggest plants in the wold.

There are several reasons for this development; taxes on natural gas (no taxes on the sun), the ban on new biomass on natural gas-fired CHIP plants, plus the fact that first year's heat production can be counted as energy saving (gives basis for some small subsidy).

It is also essential that the technology has shown very reliable over the last 25-30 years, and that the actors including industry have been sharing experience.

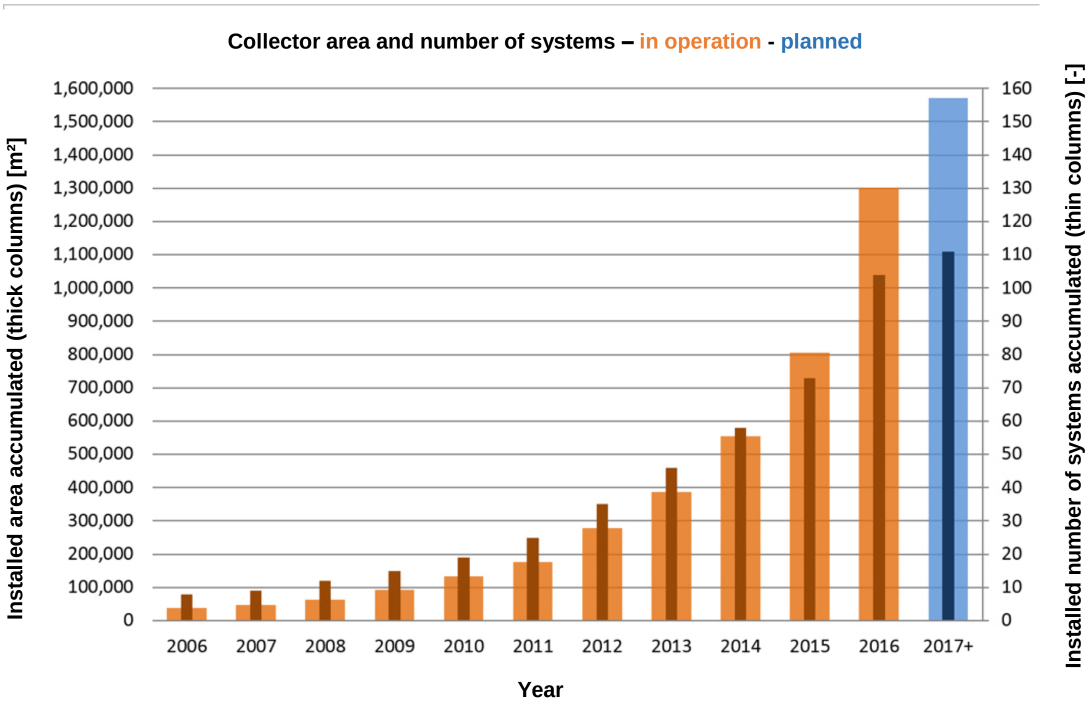

Figure 1 Solar heating plants in Denmark. The hatched bars show installed solar heating area, the narrow bars show the number of plants. The tendency is towards bigger plants - the broad pillars overthrow the narrow columns in recent years. [http://planenergi.eu]

The first Danish solar district heating system were established in Saltum in 1988, then came Ry and Herlev in 1990 and Marstal in 1996. The latter was 8,000 m^2 of solar collectors - at that time the world's largest. Variable flow control was now introduced to keep forward flow temperature to the district heating network constant. The plant in Marstal was later several times extended – now to a total of 33 300 m^2 - and seasonal heat storage(s) were introduced, which allowed a for high solar fraction.

Until 2007, all solar district heating systems combined with boiler plants were primarily biomass, but in 2007, the first solar heating plant was made in combination with natural gas-fired cogeneration (CHP) plant in Brædstrup. This plant and the next plant in Strandby got subsidies from Energinet.dk.

In 2005-06 an investigation was elaborated, which showed that solar combined with natural gas fired cogeneration (CHP) could be an environmental benefit in the Danish power system with the liberal electricity market.

An increasing performance and a lower investment cost enabled the establishment of the first plants without subsidies in Sønderborg and Hillerød.

Still now, there is tendency towards higher performance and lower plant cost so that solar heat is expected to remain competitive – and it is now so competitive that it is worthwhile to establish solar heating combined with straw and wood chips boilers (and CHP)..

In the future, we will probably see solar district heating systems combined with heat storage dimensioned for 80 % solar fraction (solar radiation varies from 10 to 15% year on year – so dimensioning for 100 % is not feasible).

Dronninglund has at approx. 40 % solar fraction, Vojens approx. 50% and Gram 60%. The plant in Vojens was until 2016 the world's largest with 70,000 m^2 of solar collectors and a pit storage of 200 000 m^3. The present largest system is in Silkeborg, it in operation in late 2016; it is 157,000 m2 (solar fraction about 20 % - and no seasonal storage).

Solar heat may combine with several other heat sources in systems that interact with the electricity grid. Heat pumps are entering the district heating plants because it integrates electricity and heat generation, but solar is still competitive in the summer, so combinations with heat pumps will be one of the solutions to come. Ry CHP has entered into service, first heat pump system with ground water as a heat source. Heat pump systems in Broager, Dronninglund and Farstrup-Kølby is underway. Larger and larger heat pump systems are expected being specialized in delivering high temperatures for the district heating.

Solar heating has many advantages: Heating prices, reliability and the possibility of combination with other technologies.

Concerning area requirement, compared to fossil fuels solar heating needs of course much more area nearby. However, if the premise is a renewable energy supply - as is the case - the area need for solar heating is only approx. 3% of the area need for biomass (for Danish conditions). Although biomass, do not have to be grown in close proximity to the application of heat, there will be a transportation impact.

Figur 1 The solar heating plant in Silkeborg is 156,694 m2 - the world's largest in 2017. It covers 20% of the annual heat demand in Silkeborg. [http://www.silkeborgforsyning.dk/]

A solar heating plant - and seasonal storage - must be fitting into the landscape. With larger and larger plants, it becomes a correspondingly greater task to ensure this integration. A point in relation to the solar district heating system is that it does not have to be a "closed" area, i.e. there may be public access to areas between solar panels, which actually often is grazed by sheep.

The following sections describe the phases of a solar project. This is followed by an overview of experiences targeted respectively board members, municipalities and operating staff. The first phase, "Preparation and planning", relates primarily to board members and municipalities, while the other phases, "Establishment", "Start" and "Operation and maintenance" primarily relates to the operating person at the district heating plants.

1.1 *Preparation and planning*

Considerations on establishing of a solar district heating system can have different starting points, but typically it is based on the wish - on the one hand a low and stable heat price - and on the other a higher share of renewable energy. Solar district heating can deliver to both hands. It is not strictly necessary to build the full maximum/optimum size from the very beginning – the establishment can be done in stages, and next stage(s) can then be done when one have good operational experience with first stages (although full size in one go most probably will have the best economy).

There will then be a need for a “basis for decision”, analysing the influence of a solar system on the present system performance and comparing heat price with and without solar. The uncertainties in the analysis should exposed.

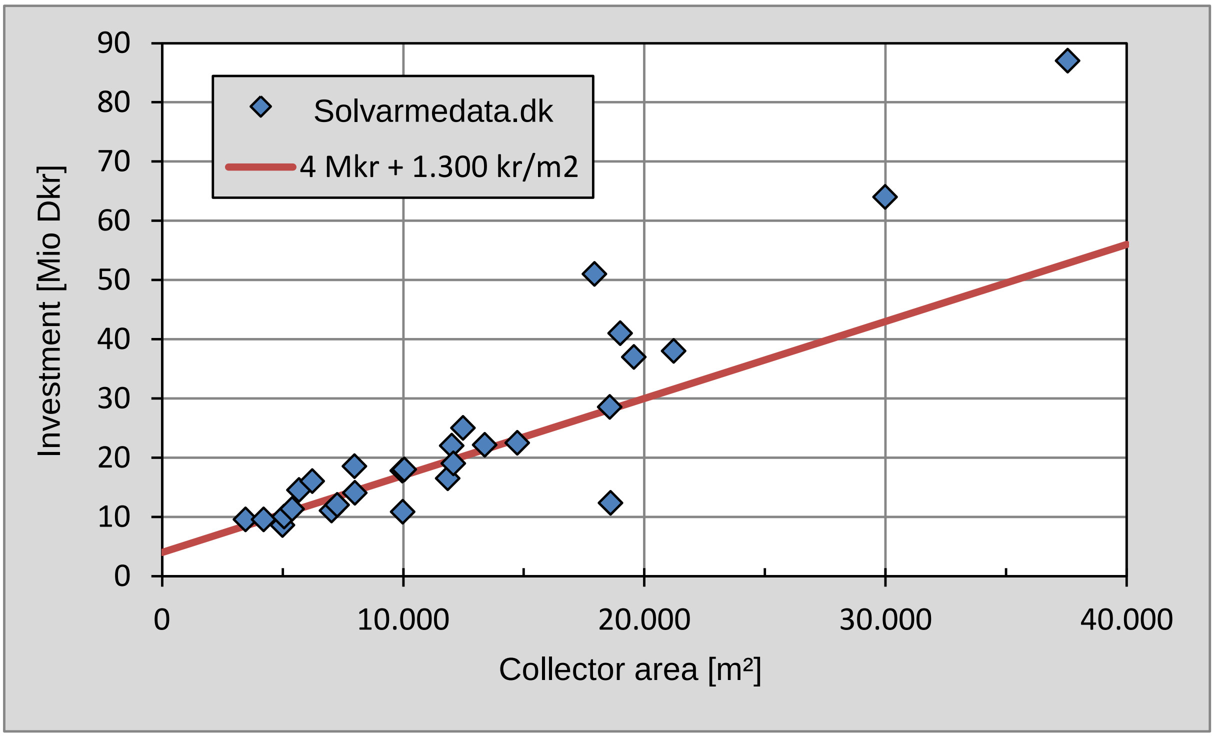

Figure 2 Investment costs for solar thermal plants as a function of solar collector area. The formula indicates the price level of the collector plant based on realized plants, i.e. the approximated price function is: 4 mill. DKK + 1,300 DKK per. m² solar collector area. A trend towards lower prices and / or higher efficiency per m² is expected. The plant on the far right of the graph is Dronninglund and includes seasonal storages. Some variations in prices are seen. [PlanEnergi]

When examining how much solar is optimal, it is recommended to look at the heat price for the total system. This is illustrated in the following figure, showing heat price as a function of the solar fraction.

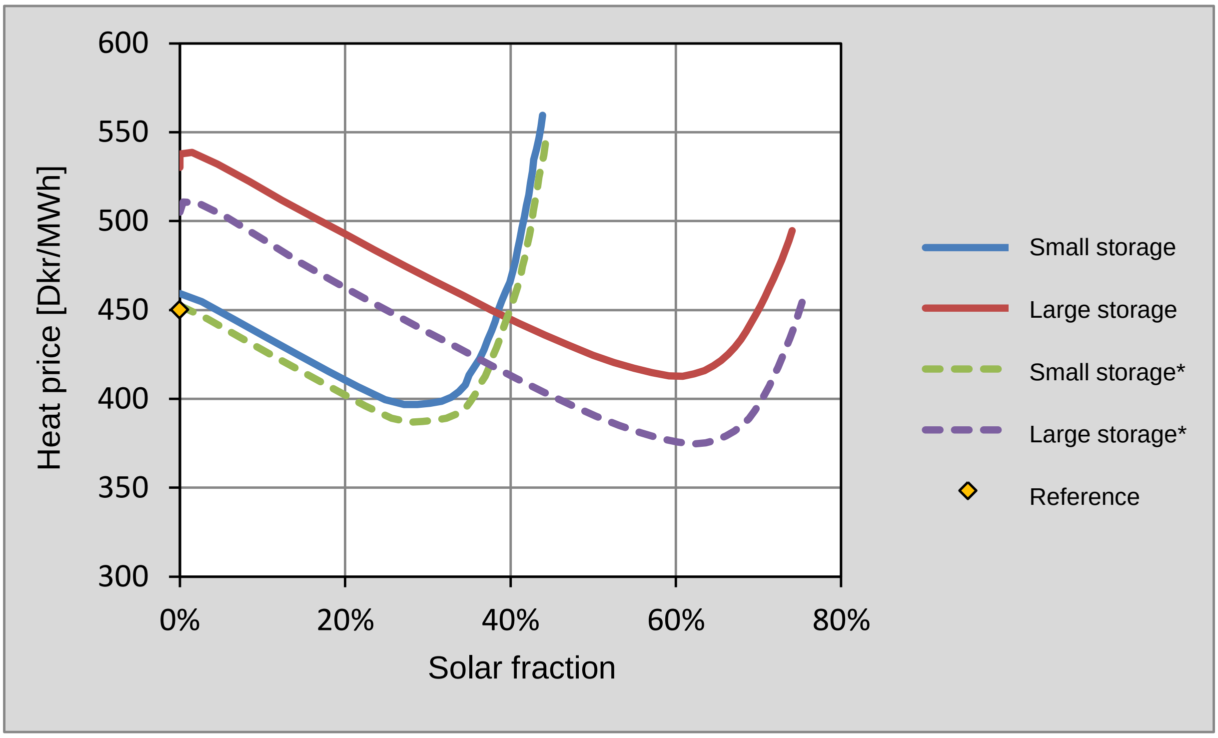

Figure 3 **Heat price as a function of solar fraction for respectively small storage tank and large seasonal storage. The dotted lines show the heat price for a four times greater system and heat demand. Interesting to see that for large systems with seasonal storage the optimum solar fraction is quite high (> 60 %) [PlanEnergi].**

For solar fractions below 30 % seasonal storage will typically not be feasible – so here only “small” storage tanks are relevant. For larger solar fraction seasonal storage should be considered.

Heating Prices of Figure 4 is compared with the heat at rates other alternatives for improving the district heating system. Anticipating the price development of natural gas or biomass the next 20 years, an optimal solar fraction can be calculated. Again uncertainties should be exposed.

The greater the heat demand, the better the economy. This is seen by the lower-lying dotted curves in Figure 4. This means that there is a scale advantage of solar heating systems - and especially for seasonal pit storages. Solar fractions more than 60 % are technically and economically possible. The combination with heat pumps can improve the economy, but shall be analysed specifically for each project.

The optimal plant size should be investigated based on the local characteristics of the specific district heating supply and network. The size could be limited by the available land area. For larger solar thermal systems it is possible to establish a longer transmission line, as the economy for the bigger solar system can better carry an increased investment for a longer transmission line.

The solar system can be expanded in stages. If so, it is appropriate to take this into account when planning the first stage, e.g. by positioning the first field in a way that expansion is easy - and design transmission lines to cope with future expansions. Furthermore, it is suitably to keep free space for an extension of the mechanical and electrical installation of the following stages. Accumulation tanks and seasonal storages should preferably be designed in the expected final size.

When the “basis for decision” is available, and if the board wants the project initiated, the proposal is put forward to the general assembly. Before this meeting it is important to inform the users (the public), the municipality and possibly the landowners touched by the project.
The content of the “basis for decision” will often be partially coincident with a project description where the economy for the project is illuminated.

A project proposal must be prepared according to Danish regulation, which imposes formal requirements for illuminating certain aspects of the project (economy, environment, …). A project proposal must be approved by the local authority and submitted in public consultation before the solar system can be established.

So dialogue with the municipality, as early as possible in the process, is very important. The municipality plays an important role in the coordination of the project, assessment of optimal location, local and municipal regulation, acquisition of land - is municipality willing to expropriate? Environmental screening, environmental permit and building permit is also important elements prior to establishing the solar district heating system.

1.1.1 Environment

In connection with the establishment of a solar system an environmental investigation/screening might be obliged. In this connection there will be focus on the “solar fluid” i.e. the anti-freeze liquid used in the system.

The "Solar fluid" is composed of three components:

1) Water (typically about 70%)
    - It is important that clean, demineralized water is used
2) Glycol (typically about 30%)
    - Typically propylene glycol ($C_3H_8O_2$), which is biodegradable and only toxic in large quantities. Used in order to reduce the freezing point.
3) Inhibitors (very small amounts, <1%)
    - The main potential environmental impact is the inhibitors. Can be a challenge to identify do to factory secrets.

These components have an impact on water chemistry, including microbial corrosion and pH-value.

Typically heat transfer medium is purchased as a ready-mix from a manufacturer that supplies a data sheet for the liquid incl. indication of the composition of the contents.

Always check central/regional/local regulation related to the solar fluid.

In 2015, there was a release of about 2 000 litres of solar fluid in Sveboelle. An analysis was made and the conclusion was that there was no evidence of soil contamination. The municipality (Kalundborg) withdrew on this background an initial requirement for excavation of land, i.e. the glycol release was not considered as a significant environmental impact.

The establishment of a solar district heating system will typically require the development of a new local plan for the area. The local/regional authorities will prepare and approve the local plan based on background material provided by the district heating company and its consultants. A visualization of the system may in some cases be a desire from the municipality to demonstrate the visual impact in the landscape.

It is essential to draw up a realistic timetable for development and approval of the new local plan for the area. This period might be used to prepare tenders for the establishment of the plant.

1.2 Establishing the system

After approval of the project proposal and new local plan - and having obtained the construction and environmental permits - the tender process can get started. Threshold values of EU procurement (DIRECTIVE 2014/25/EU) shall be observed and fulfilled (2017: EUR 414 000 for supply and service contracts as well as for design contests; a EUR 5 186 000 for works contracts).

For each project it must be assessed whether it is construction work or a supply/service. However, the establishment of a solar district heating systems typically is considered as a construction task.

The detailed project planning starts now and the activities include:

- Elaboration of tendering material – turnkey or not:
    - The work can be tendered as a turnkey contract, where a number of functional requirements is described – or as number smaller part contracts with functional requirements defined as well
    - The district heating company can act as developer doing (together with his consultants) the detailed project design and plan and hire in for specific work tasks.

- The tender documents should at least contain a description of the following:
    - The basis for the contract
    - Building permit
    - Time schedules and maybe the daily fines if time schedules are not met
    - Labour agreement
    - Liability, insurance matters and disputes
    - Payment conditions and collateral
    - Performance guarantee
    - Description of how the system should be started, commissioned, tested (check of performance guarantee)
    - Guarantee on the plant and 1 and 5 year inspection
    - Construction site and safety conditions
    - Requirements specification for the facility with description of functional requirements
- Contracting, preparation of construction contract
- Detailed time schedules indicating the milestones for plant establishment
- Preparation of a detailed control description for the solar district heating plant for best possible operation together with existing system.
- Earthworks, installation of solar panels, pipe work, the establishment of heat storage and connection to the existing plant m. v.
- Security
- SRO / control / monitoring

The final delivery of the solar system happens after verification of performance guarantee.

1.3 Commissioning

When running in the solar system it is important so show and check that solar system works together with the rest of the system in all operational modes.

Before commissioning, glycol shall be filled, de-aeration shall be done, water quality shall be checked and the rows of solar panels shall be flow/pressure balanced.

Control and regulation of the solar thermal system shall be adapted and adjusted continuously in when running in the system - and the various control principles shall be tested.

When operation has started, a monitoring program shall collect operational data for checking the performance guarantee.

Emergency plan must be in place, including the management plan of optionally glycol leakage/release.

The plant can be connected to www.solarheatdata.eu, which is a website for gathering monitored data for solar district heating systems.

1.4 Operation and maintenance

When the solar district heating system is established and commissioned, the operation should be simple. There must of course be an online production monitoring that continuously controls and regulate the plant.

For the control and regulation of the system, a number of temperature, flow and solar radiation measurements is used.

There is normally need for only very little maintenance, it consists in checking/filling glycol and control of the state of the glycol.

The collector field ground area can be maintained by sheep grazing on the land.

2 Summary

2.1 Boards

Strategic reflections with respect to continuously competitiveness of the district heating supply - and increasing the fraction of renewable energy - could be starting points for the process of establishing a solar district heating system.

2.1.1 Strategy, analyse opportunities

- Assistance from the consultant, highlight the possibilities

The board defines - maybe in cooperation with a consultant - which scenarios to be investigated further. This can lead to a decision basis, guiding the further progress.

2.1.2 Support from the municipality and the citizens

- Information
- Contact person in the municipality

Alongside the concretization of the project, i.e. even before the decision basis has been finalized, it's a good idea to start the dialogue with representatives of the municipality and its citizens. It is strongly recommended to have appointed a contact person in the municipality, which can help coordinate the various processes in which the municipality is involved concerning the planning of the solar project. This ensures good communication.

In relation to the citizens - as well as the municipality – information about solar district heating system and the consequences for the local area should be provide. Including, of course, that it contributes to a more stable (and lower) heat price based on renewable energy.

2.1.3 Organization of the project

- Project developer
- Consultant
- Turnkey supplier

Once the solar project is decided and approved by the district heating company and the municipality, the board must consider how the project is organized. Do they want to do the project themselves or do they want contract with a consultant and/or a turnkey provider.

There are examples of both, typically it depends if the operational staff have necessary resources (time and knowledge).

2.1.4 Financing

- Insurance: Is the board sufficiently insured if the project goes wrong!
- Tax on land

Finance, insurance and taxation of land are examples of important considerations that can significantly affect the profitability of the project. It is a relatively large investment and a district heating plant typically makes seldom such large investments. So it is important to involve the relevant competencies of the board and even optionally include financial advisors.

2.2 Municipalities

The municipalities are an important partner for the district heating company – indeed also when establishing a solar district heating system.

For the municipality, a solar district heating system can help achieve the municipality's climate goals. In addition, it will be beneficial for the municipality to have low and stable heat prices. Thus, there are some significant overlapping interests of the municipality and the district heating company.

- Engagement early in the process, contact person in the municipality
- Experience from other municipalities

The municipality should designate a contact person who coordinates the dialogue with the district heating company and the various processes in relation to planning and approval for which the municipality is responsible. Participation in visits to existing solar district heating system and contact with colleagues in other municipalities that have already experience with solar district heating systems can be a big benefit.

2.2.1 Heating planning

The municipality is responsible for the heating planning, and should include the option of solar district heating in the heat planning.

2.2.2 Municipal plan, local plan

Integration of the solar district heating system in the municipal plan and local plan is also an important part of the process. It is important to have a long time horizon for the plans, to account for the possible future extensions of the solar district heating systems, for example a seasonal storage. A solar district heating system can be extended/expanded in several phases. It is therefore important to include possible expansion in the local area plan. The collector field can be placed in some distance from the district heating supply area - and then be connected with a transmission line. This will increase the cost of the project, but allows some flexibility with respect to location.

The seasonal storage must be designed to the expected final size. However, it can also be connected with transmission lines to the district heating network and can therefore added with a certain flexibility, too.

2.2.3 Land use, protected areas, public access

A solar district heating system does not need to be "closed" to the public. Other use of the area (except for sheep or other animals) are limited, but public access could be allowed - for example for runners and dog walkers.

A discussion related to a solar district heating systems will be the area requirement. Assuming that the district heating is be based on renewable energy, this should be viewed in relation to the area need for e.g. biomass - if the heat produced by the solar district heating system were to be produced on the biomass the needed area will be approx. 30 times bigger (but could of course be located elsewhere) – value valid for Danish conditions.

Other advantages of the solar heat is that it is of course not noisy.

No issue with reflections:

- In connection with the establishment of the solar power plant in Vojens, an investigation of risk of reflections (for air traffic to and from a nearby military air base) was made – concluding: No risk for reflections (partly due to the use of anti-reflection glass in in solar panels).

These investigations are referred to in international projects where very large solar district heating systems are underway.

2.2.4 Project proposal, socio-economic costs and other requirements

A project proposal calculating the socio-economic costs of the project (and clarifying fulfilment of legal other requirements) is mandatory in Denmark, could be a good argument for establishing the solar district heating system.

2.2.5 Environmental Impact Assessment (EIA) and environmental permits

The establishment of a solar district heating system requires in Denmark the project's EIA screened. There is usually no need for a full environmental impact assessment of a conventional solar district heating systems. But, as a solar district heating system usually contains glycol an environmental permit for the plant is necessary.

It is important to identify special conditions, where the national authorities has a veto. This could be for instance, drinking water interests.

The EIA screening might show that some special issues should be investigated in more detail. Then for these issues a full EIA might necessary. Therefore it is appropriate to have items that require special investigations identified when the application for EIA screening is received and to agree on the points that are important.

An EIA screening is an important part of the process, and a thorough action in this stage may be appropriate in relation to the timing of the entire solar project. Therefore it would be a good idea to describe why a given issue is not a problem - and not just write that you do not think there is any problems – i.e. give thorough descriptions and documentation if possible.

2.2.6 Building permit

Building permission is asked usually immediately after the approval of the local plan and project proposals. Application for a building permit can be handled by the contractor in charge of construction of the solar district heating system. The processing time must be taken into account in the detailed time schedule.

2.3 Operators

There is considerable experience in the operation of solar district heating systems in Denmark, and exchange of experience is an important part of the continued development and improvement of solar district heating systems. Danish District Heating Association has “exchange of experience group” for solar district heating systems, and it's six members of this group, which has contributed with most of the descriptions of the six solar systems described later in this document, see chapter 5 " Examples of solar district heating system in practise".

This section contains some of the operating experience with solar heating, and some of these may be very helpful to know when designing solar systems, and help starting with the correct solutions right from the start.

2.3.1 Solar radiation meters

In especially larger solar installations, there is a need for several solar radiation meters due to drifting clouds (and to improve measurement security). As minimum three solar meters located different places in the collector field is recommended. In addition, three solar radiation meters assist in a more stable operation of the main pump. Various models of solar meters are being tested in Løgumkloster.

2.3.2 The storage tank

It is recommended to establish several inlets/outlets in the storage tank, so you can load with different temperatures - ensuring the possibility of flexible operation with respect to the handling different temperatures from the collector field.

2.3.3 Expansion tank for glycol - type and location

It is important to choose the right type expansion tank for glycol for to insure reliability. The municipality's requirements related to a potential leak must be clarified so that it is incorporated in the project.

2.3.4 Avoid pipe fracture - tube with lyres

The temperature fluctuations in a solar system must be taken into account. These have great influence on the underground pipes, and the heat/cold impact makes it extremely necessary with lyres on the buried pipelines. Unfortunately plants without lyres are seen, with observations of pipe displacement of up to 50 cm in the ground.

Alternatively, the tubes could be above ground, so they are more accessible for reparations, but this would give the solar system another expression in the landscape. And some local area plan could require that pipelines and cables are buried.

2.3.5 Control, breakdown of the collector array

For very large solar fields it is recommended to sub-divide the collector array and establish separate control for each e.g.. 10,000 m^2 collector array.

2.3.6 Fluid quality

The quality of the solar fluid is an important parameter. Many solar installations have fluid sampled once a year, to keep an eye if the fluid has changed composition. An analysis of the inhibitor content indicates whether corrosion is going on in the system. It is important to take a sample immediately after the commissioning of the plant – as a reference for future samples.

2.3.7 Glycol concentration

The glycol concentration in the heat transfer medium is important for the efficiency. The system in Ejstrupholm used a 50% concentration, which can keep the solar fluid frost-free down to - 25 ° C. But this relatively high concentration leads to a higher viscosity, which has consequences for efficiency. How much this reduction in efficiency is not known. Danish Technical University has performed experiments to elucidate the efficiency change when the glycol mixture is changed. The experiment indicate that 10% change in the glycol concentration results in 1 % change in efficiency.

The reduction in efficiency should be compared to the cost of emergency heating (used in e.g. Jægerspris). Such consideration will be site-specific, and include the possibility of emergency heating from the very beginning is cheaper than to include it when the systems is established.

The solar district heating system in Jægerspris is freeze-safe down to - 9 °C, at colder temperatures the emergency heating is activated. Dronninglund has frost protection to - 10 ° C, but at this temperature the viscocity is relatively high, i.e., there is a need to increase the flow.

Glycol concentration must be included as a design parameter.

2.3.8 Performance guarantee

The performance of the solar collector field is of course a very important parameter. A procedure for checking a guaranteed performance is therefore relevant . PlanEnergi has developed procedure for checking the guaranteed performance. Such procedures for giving and checking the guaranteed performance is given in the IEA SHC Task 45 fact sheets http://task45.iea-shc.org/fact-sheets.

3 Examples of solar district heating systems

This section provides brief descriptions of solar district heating systems. The mentioned system is within the solar-ERFA-group under the Danish District Heating Association. There are many solar installations in Denmark in connection with district heating networks – the best overview is found at www.solvarmedata.dk – but still not all systems are included here.

3.1 Løgumkloster

By operating manager of Løgumkloster District Heating, Peter Gjelstrup Andersen . With contributions from Henrik Hansen, Aabenraa Municipality
http://www.lgkfjernvarme.dk/

3.1.1 Planning

In the preparations, it is important with the possibility of sparring between operators and the board. This may be one or more board member with direct knowledge of the technology.

Løgumkloster is special, as it is a demonstration project with support from the government programme EUDP. The demonstration is concerning "establishment of aluminium solar collectors in full scale installations". There have been two consultants involved, which has worked well and given a balanced solution.

It is important to get access/permit to the land area for the solar district heating system. This applies both in relation to landowners and local area planning. In the Løgumkloster case is was not possible use the original planned area, as the municipality did not want to expropriate, so it is important to clarify the possible areas in an early phase.

It is important to have good cooperation with the municipality, having an ongoing dialogue and defining a timetable for the whole process. A permanent contact person in the municipality is an advantage.

As part of the considerations before deciding on a solar district heating system, the operating staff and the board visited existing installations (Brædstrup, Marstal and Gram). This gave a good basis for understanding and deciding. Other district heating companies experiences are useful and should be utilized. Representatives from local authorities did not participate – but that might have been a good idea.

Today Løgumkloster has all permits for seasonal storage in place. However, the economy is challenging, so the decisions on the extension of the solar system is not taken yet, but the economy will be reassessed if frame conditions change.

An aspect in relation to the location of the solar district heating system is the appearance in the landscape. Normally sheep keep the grass down between the solar collectors, but in this relation it can be critical if the field is classified as urban zone.

Figure 5 Loegumkloster http://www.lgkfjernvarme.dk/projekter/solvarmeanlaeg gives description and pictures of the process of establishment of the solar system in Løgumkloster.

In Loegumkloster the collector field is open for thepubli and there is a pavilion with information about the solar district heating system.

Løgumkloster conducted a full environmental impact assessment for the entire solar system. This comprehensive and time-consuming process should not be necessary for a solar district heating system.

Glycol is one of the possible environmental impacts from a solar district heating system. In Løgumkloster there is established a collecting tank with room for up to 50 m^3 and from the storage place is installed a valve to the sewer, which can be closed in case of leak of glycol.

An active ingredient in glycol is an inhibitor, which is available in four approved types. The solar heating panels in Løgumkloster in made of aluminium, which requires a specific type of inhibitor used.

We use 30% glycol, as a higher concentration of eg. 40% would lead to a very viscous liquid in the solar panels. The glycol was described for the local authorities as part of application process.

The decision to establish a solar district heating system, started by considerations of different technologies, including biogas and geothermal energy. Savings in these other options were too small compared to the savings, which could be achieved with solar. Solar heating was chosen and the target is 50% solar fraction, which will include a seasonal storage.

Løgumkloster District Heating has focused on communicating about the project, especially about the influence on heat price. At the annual general assembly, the solar project to 20 mill. Euro was up for vote - it was unanimously agreed among the 100 participants. This great support indicates a high degree of confidence, which is based on transparent figures and continuous information. The latter happened via the website and Facebook profile, and not least by articles in the local paper, which has followed the project from the beginning.

It is obviously important that there is confidence in the consultants who is responsible for the design, but specific experience from other specific district heating systems should be included too. It is important to involve the operation staff in these preparations.

The building for pumps, heat exchanger etc. should be made large enough so that there is room for later extensions. Piping may be put above the pump and the accumulation tank should be large.

3.1.2 The municipality's perspective

The following sections describe the process seen from a municipal point of view:

Løgumkloster was is in the Tønder municipality, which in addition to the solar district heating system in Løgumkloster also has a solar district heating system in Toftlund. The plant in Løgumkloster is scheduled to include a seasonal pit heat storage including an expansion of the solar system - these are not realized yet – but the seasonal storage has become relevant also due to excess of waste heat.

The background for the establishment of solar district heating system in Løgumkloster was a movement from an old district heating plant inside the city to a new heating plant outside the city. City areas converted from natural gas to district heating and solar heating was included. Wood pellets boilers were also established, and a part of the projects was funded as a development and demonstrations project covered partly by the EUDP support programme.

Things to be aware of in the process:

- Local plan
- Environmental conditions, including environmental approval
- Building permits
- Project proposals

Drinking water interests must be identified in the planning - the national authorities have veto right, so it is important to pay attention to whether there may be issues in relation to the location of collector field (and seasonal storage).

After the first considerations in the planning process and the environment assessment, a building permit can be applied, which however may be issued only when the other approvals are given . Here you must take into account a number of local aspects, for example churches, airport (reflections) and others.

The project in Løgumkloster was divided into two local area plans. It was not included in the municipal plan.

Approval of the project proposal with respect to socio-economic costs etc. is a long political process. So is the application process for a municipal loan guarantee.

Glycol and the possible impact on the environment is mentioned as an important issue. One way to deal with this is that the local authority requests a memorandum on the subject from a relevant consultant.

3.2 Jægerspris

By operation manager at Jægerspris Heat & Power, Hans Christian Kjærgaard . With contributions from Peter Ryborg, Frederikssund Municipality.
http://www.jp-kraftvarme.dk/

3.2.1 Planning

Jægerspris Heat & Power experienced in 2009 increasing heat prices due to increasing gas prices. This started the considerations/investigations for alternative fuels. Use of biomass was investigated and applications was submitted to the EUDP support programme - but without success. Solar was also considered. In collaboration with a consultant and a supplier various proposals for solar heating systems was elaborated.

As part of the preparations visited the whole board the solar district heating system in Brædstrup. This visit was important both in relation to preparing the basis for decision for the solar project in Jægerspris – it gave good impression about the operation of a solar system too.

In May 2009, a few months after cooperation with the consultant and the supplier had started, an extraordinary general assembly was held with about 130 participants. Five voted against a solar project, primarily motivated by the relatively high solar heat price at that time - no resistance to solar heating as such.

In cooperation with the supplier brochures were made with pictures from other solar district heating systems, which described the advantages and disadvantages of solar energy. The local press was positive to solar project - of great importance to the positive sentiment on the solar project among the heat consumers.

The timing of the project with solar heating was good; Frederikssund Municipality had an ambition to become a "Climate municipality" and as "open-field plant" (the largest) Jægerspris Heat & Power had a challenge with high heat prices. The solar district heating system could both contribute achieving the municipality's climate change goals and reducing the heat price.

There has been good cooperation with the municipality, it has been the same people over the years. However, Jægerspris Heat & Power experiences now a greater distance to the municipality after the merger of municipalities.

Figure 6 Jægerspris http://www.jp-kraftvarme.dk/firmaprofil describes Jægerspris Heat & Power, which in three consecutive years (2014 to 2016) has reduced the price of heating.

The process of the project was initiated. It was drafted by the same consultant who Jægerspris Heat & Power had already had dialogue with.

The result of the tender was that the supplier - already in dialogue with at the start of the project - was chosen because it was the cheapest offer. A turnkey contract was made with this supplier, who used Jægerspris Heat & Power usual supplier as a subcontractor. This organization worked well.

Shortly after the Annual General Assembly May 2009, when the solar project was approved, Jægerspris Heat & Power held a meeting with the municipality, and in the middle of June, the municipality was requested to prepare a local plan for the area. Before, there had already been dialogue with the municipality about the timetable for the process.

In February 2010, the local plan was approved. This relatively long processing time - they would like to have been started six months earlier in August / September 2009 - was due to the process coincided with a new municipal plan, i.e. the old municipal plan could not be changed.

3.2.2 Establishment

The purchases of land was handled in parallel. The municipality was willing to expropriate, it was not necessary, but the land was sold on expropriation similar terms. The archaeological investigations were relatively extensive, and they were associated with relatively high costs and delays to the project.

The costs may vary in different parts of the country due to differing practices in the local museums, although it is the same national authority (Heritage Agency).

This cost to archaeological studies will likely be less now that solar panels mounted on the profiles and not concrete foundations. The soil should therefore only have be examined in relation to the pipe to be put in the ground.

It was a harsh winter, delaying the excavation work, which was conducted from March 2010 and seven weeks ahead.

The contract with the turnkey supplier did not foresee these delays. The foundations were produced in Vietnam at the supplier's risk (i.e they initiated the production before the project was finally approved), however Jægerspris Heat & Power had a small part of the risk.

There was carried out an EIA screening that was sufficient for this project, i.e. there was no need for a full EIA report. Lifting the obligation of agricultural use of the land and regulations related to the drain piping are examples of conditions , which should be handled in connection with the processing of the project.

Jægerspris Heat & Power continues to experience a very positive attitude to solar district heating system from consumers - both existing consumers - and several new district heating consumers, which have chosen to convert to district heating due the solar contribution.

3.2.3 Operation

The operational experience is generally positive. However, the expected performance was a little too optimistic. The solar plant was commissioned in July, which meant that it was necessary to fill with liquid at night (as the plant is running as soon as the sun rises). It is important that the control is simple and stable.

Operational reliability is important. E.g. having multiple power supplies to the control system (PLC). And that the pumps can be operated manually and without the inverter.

It must be decided which reliable mode to use under for example power failure. An extra power supply for PLC should be considered, so that the analogue and digital part each have their own power supply. If an error occurs in one power supply, the pumps have to run and some valves must be open, thereby reliability is secured and optimization can be done from there.

The solar district heating system was established very simple, without any electrical installations or measurements in the collector array. This proved to be a challenge in situations with drifting clouds, since the measurement of the solar radiation at the district heating plant is about 300 m from the collector array. Therefore additional measurement of solar radiation was set up, one at the power plant and one at the collector array. There are examples of other solar district heating system having several measurements solar radiation positioned around the facility .

There is flow regulation control at all solar panel rows. This is balanced once.

In general the solar system just runs. However, the solar system in Jægerspris has a manually adjustment related to the shadowing effect. This could be automated.

An operational challenge has been the distribution of heat from the solar collectors. From the begining, there were two pressurized storage tanks (á 740 m^3) which could be coupled in series or in parallel. There is now established a third – de-pressurized - storage tank with pressure holding valves and pumps in the supply and return. The pressure-less tank is used as high temperature tank, storing water from the collector field, when the water temperature is above the forward temperature to the town, the two existing tanks used for stored medium temperature water.

Jægerspris Heat & Power has had a good dialogue with the supplier of the control system. It is important to have such good dialogue and quick reactions. The system uses the supplier of the solar system control system, and there is an interface to another SCADA based control system, which is also used in Jægerspris. Running-in of the control system in the existing system is important so medium temperature water etc. can be distributed correctly in the existing plant, e.g. to bypass circuits or storage tanks. Control with respect to the other production units is also important, i.e., controlling the parallel operation of the solar district heating system with gas engine and the gas boiler.

The control functions well in Jægerspris. Some installations may find it difficult to distribute the heat, because the pipes in the existing plants are too small. A solar heating system is running with high flow, and one must be aware that this fits with rest of the district heating system.

Weather compensation unit provides the temperature set point for the solar district heating system, so that the solar district heating system is not running at higher temperatures than are needed.

In the design of pumps, heat exchangers, etc. a possible extension of the solar system was taken into account.

It is important to ensure that the low temperatures of the solar district heating system can be utilized, e.g. in the shunt circuit to the city.

An important consideration is how much cooling the “night cooling” can provide in warm periods when the heat consumption is low, the output from the solar district heating system is high and the storage capacity is not is sufficient. There are no problems with this in Jægerspris.

The design of the solar system focuses on handling situations where solar fluid gets too hot. There is not the same focus on situations where there is a risk of freezing because the solar fluid cannot circulate. In Jægerspris a 30% glycol solution is used, which ensure that the heat transfer medium can circulate down to - 11 ° C . At minus - 9 ° C or - 10 ° C is added heat via a partial stream of the solar fluid until the temperature is - 2 to -3 ° C in the flow line to the installation. 0.5 MW is used in these situations. It has happened that the solar fluid has frozen at the flow regulation valves in the collector rows, but there was no frost damage.

Due to rime, there may be difference in the temperature measurements of 5 degrees, i.e., there may be significant varying parameters at different locations in the facility. This must be taken into account in the anti-freeze control.

The quality of the solar fluid, is an important parameter. In Jægerspris samples are analysed once a year, to keep an eye on if the solar fluid has changed composition. After first filling of the liquid a sample should be taken e.g. after 1 week, in order to have a reference. The analysis examines among other things the content of inhibitor and can thus conclude whether there has been corrosion in the plant.

There is sheep fence around the solar system in Jægerspris. There is not established public access. Location of the solar thermal system does not make it relevant to establish this access.

3.3 Ejstrupholm

By the operating manager of Ejstrupholm District Heating AmbA, Jan Michael Grarup
http://www.ejstrupholmvand.dk/varmevaerk

Ejstrupholm established in 2011 a solar district heating system - plus in 2015 a minor expansion - so that it now produces about 20% of the annual heat demand.

Figure 7 http://www.ejstrupholmvandogvarme.dk/ gives a description of Ejstrupholm District Heating.

5.3.1 Operation

Only two inlets/outlets have been installed in the tank - one at the top and one at the bottom. It would have better with 5 to cope with the temperature deviations from the collectors. In this case – as an emergency solution an extra tank has been installed for “leveling out temperatures”. Multiple inlets/outlets can for be an advantage in joint operation with a heat pump that can use medium temperature water.

The solar district heating system in Ejstrupholm has 22 panels in each row. It will be easier to regulate the flow if less panels in each row.

Care must be taken of the temperature changes a solar collector field. These have big influence on the pipes that are buried in the ground and heat / cold movements makes it extremely necessary with lyres in the buried pipes. Unfortunately plants without lyres have been seen - with observation of displacements of 50 cm of the buried pipes.

Ejstrupholm had only one solar meter from the beginning - which is not enough. The controller uses the solar radiation in the algorithm for starting and stopping (and regulating) the flow in the collector field. A minimum of three solar meters is recommended, to be distributed across the collector field so measurement error is minimized and when drifting clouds don't influence the control too much.

Upon the establishment of the storage tank, the municipality required a specific grey colour, which was found to fit well into the landscape.

There was good understanding in the municipality of handling of glycol. Ejstrupholm sent information to the municipality (including the report from leakage in Svebølle).

Glycol concentration in the heat transfer medium is important for the efficiency. In Ejstrupholm is used a 50 % concentration, which can keep the heat transfer medium frost-free to - 25 ° C. This is a relatively high concentration and leads to a higher viscosity, which affect the efficiency. How much the efficiency is reduced is unknown.

In Ejstrupholm was from the beginning three expansion tanks for glycol fluid(2 * 600 l and 1 * 1000 l). The 1,000 l tank was broken when it was filled with glycol and there was air entering in the glycol circuit. There was an automatic air vent installed, but it could not manage the air venting under these conditions. The air was located 1 m from the main pump, causing the pump housing to be filled with air, so it could not pump anymore - three hours without flow in the solar panels. This triggered an alarm, the primary pump could be started and make flow, so the heat of the solar panels could be transported away.

The choice of expansion tanks must therefore be considered, the liquid should be on top of the bellows, so that it is detected if the bellows breaking.

Now Ejstrupholm has four expansion tanks á 600 l, giving a better reliability, if one of them should fall out. Another solar system had the same incident with a broken expansion tank. Ejstrupholm still have the original type expansion tank, but now has better reliability by having four containers.

In 2015 Ejstrupholm had a storm damage to some of the solar panels. This led to an agreement with the insurance company to establish storm protection on the solar panels with an earth rod of 1 m. This now ensures to wind velocity till 35 m/s, earlier this was from 25 m/s. This initiative led to Ejstrupholm did not have any premium increase.

3.4 Marstal

By the operating manager of Marstal District Heating, Lasse Kjærgaard Larsen . In addition, input from Niels Aage Gregersen, former longtime chairman and former operating manager Leo Holm .
http://www.solarmarstal.dk/

3.4.1 Planning

Marstal was one of the first solar district heating systems in Denmark. Marstal is extended in several stages and now has seasonal heat storage(s) and a solar fraction of about 50-55% of the annual heat supply for the 1,600 consumers. Marstal District has been visited by numerous delegations from abroad who were interested in getting inspiration from the ambitious renewables-based district heating in Marstal. The solar district heating system in Marstal has tourist importance.

Figure 8 **http://www.solarmarstal.dk/ and http://sunstore4.eu/ describes the Marstal project 's support through the EU, which included the development of calculation tool for calculating profitability of similar plants elsewhere.**

Marstal District Heating has evolved from being based 100% on oil (6 oil boilers in 1987) to produce district heating using fish oil, waste oil, bio-oil, wood chips and solar heat.

Authority treatment on the establishment of the solar system in Marstal went smoothly and there were no neighbour protests. All consumers have ownership of the solar system, which is a significant difference compared to example most large wind turbines. The process of establishing solar heating system started in 1993 and the opening was in 1996, 51 weeks after the project was approved at a general assembly.

Marstal District took early in the process contact to the municipality and had a good dialogue in relation to the tasks of the municipality, especially how Marstal District Heating could make this work easier for the municipality e.g. by providing information. A permanent contact person in the municipality is good for ensuring good communication.

A high level of information - what are the activities and why - is an important element in creating confidence in the project. This open approach is an important prerequisite for a successful project - both in relation to the municipality and citizens. It was also giving confidence that it was representatives from Marstal District Heating who directly involved themselves, and not only the consultants informing municipality and the public.

The location of the solar system was no problem. Marstal District bought the land that was needed.

Marstal District had some focus on the solar systems apperance into the landscape. E.g. the fields were levelled out, so the solar field is in level. Representatives from Marstal District Heating visited some solar heating systems in Sweden in the early 1990s, where among other things they became aware of this landscape issue.

There was invested about 130,000 € in the integration of the solar thermal system in the landscape. In addition to the levelling, windbreaks were established. Good investment to have a good relation with the municipality and citizens / consumers. The collector field has free access to the public using the established paths, now partlly wind protected by the panels. An information pavilion and benches/tables to make it interesting to visit the collector array and use the area for recreational purposes. Organization of education for school classes is an example of an activity that helps to have good relations to the public.

In Marstal it was chosen - when extending the system - to maintain a dirt road which goes right through the collector field. And in other places you keep lakes and ponds, so the establishment of solar systems do not substantially alter the landscape, flora and fauna.

There are sheep (there is an agreement with a local farmer) and about 500 different kinds of plants, so it can be argued that the solar system has both landscape and natural positive importance.

3.4.2 Conditions for efficient operation of solar collectors

The combination of solar, seasonal pit heat storage and heat pumps makes it possible to increase the efficiency of the solar collectors as the fluid has a lower temperature due to the heat pump cooling of the fluid. The storage capacity is increased - or the size can be reduced - when the store can be cooled with a heat pump.

Marstal District performed as early as the 1990s energy consultancy to their customers, which resulted in a reduction from 3,600 oil equivalent / year per 1,000 consumers till now 3,000 oil equivalent / year per 1,600 consumers – i.e. reduction of energy consumption with 1/6 to 60% more consumers. The initiatives included the insulation and balancing of user installations allowing good cooling.

Efficient operation of the solar heating is made possible by the reduction of the forward flow temperature, reduced from 85°C to 72°C and the reduction of the return temperature from 65°C to 35°C degrees. Thus, the pipe losses have been reduced significantly.

The row distance in Marstal is twice the height of the solar collector, and the tilt is 35-40 degrees. The shadow effect is relatively large, resulting in that the solar panels are not fully utilized. Row distance should be bigger. When designing one has to must consider whether to optimize production in summer or in spring and autumn where heat demand is greater, and the solar heat can be used directly and not through heat storage. A general criterion could be the largest annual production.

Another design criteria could be to 100% of the heat demand covered in summer. Meteorology is another parameter - for example can cloud formation in the afternoon and evening affect the design in relation to the slope and row spacing.

It is advantageous to consider possible extensions of the solar system, already in the design of the first phase. So later subsequent phases not fits into an overall plan for landscape etc..

3.4.3 Operation

The solar district heating system runs smoothly and it has the same performance now as in the beginning. The control is effective and stable, so that the right temperature is achieved. The first fields have now been operating for 20 years - and can probably run 20 years more. It is important to continuously monitor the fluid quality to avoid corrosion, and especially glycol content and additives are important to watch.

When collectors are once taken out of operation, the most of the material is recycled, for example copper and aluminium.

There have been a few breakages in the pipes in the collector field. It is due to the large temperature variations (0-100 degrees) which result in large expansions and contractions of the pipes. Alternatively, the pipes could be placed in the air, so they are more accessible for repairs, but this would give another appearance in the landscape.

Marstal has a relatively small need for re-filling of glycol, which in total comprise about 50 tonnes, of which 1/3 is in the solar panels. There are yearly samples of the solar fluid, to assure that it can withstand more than 100 degrees, that the additives are not aggressive, and that the pH is stable on correct value.

Experience from Svebølle showed that 65% of the glycol was degraded 14 days after the leakage. Glycol, i.e. the additives, is one of the major challenges for solar heating. There are environmentally friendly products, but factory secrets is a challenge.

Solar thermal heating systems should be designed so that the risk for - and consequences - of leakage of glycol is minimized. Solar district heating system should not be placed close to water wells, drainage piping - and analysis should be done of other safety aspects. The latter relates to mechanical aspects, including the pipe systems, which is also improved in relation to withstand many cycles of temperature variations.

The possible environmental impact is not dependent on the glycol concentration. It is the content of inhibitors that matters in relation to environmental impact. There might be the same content of inhibitor in e.g. a 25% or 30% glycol concentration.

A high glycol concentration results in lower efficiency. The exact correlation is not known.

The purpose of adding glycol is to prevent freezing of the heat transfer medium and thus freeze related breakage. This can too be prevented by ensuring the circulation. Solar heating plants are created today with emergency heating, which ensures circulation when risk of freezing.

Cooling is also important and is possible with the same control. Cooling has become more important with more efficient solar panels. Typically, 25-30% of a day's production from solar panels can be cooled over night; this percentage was higher in the past.

3.4.4 Pit heat storage

The establishment of the large seasonal pit heat storage started with digging July 1 due to pending clarification on EU subsidies. It is more appropriate to start in the spring, so excavation work can be completed in the autumn.

Related to the seasonal pit heat storage, there have been some "childhood diseases", which is very natural as Marstal got the first major storage of this type in Denmark - and in the world. Water treatment is one of the parameters that are now handled differently. Marstal started with normal fresh water and then subsequently established a desalination loop. Half of the water is not softened, which implies that there is a rest hardness. There was no added chemicals, which meant that the metal parts were exposed.

At the commissioning of the pit heat storage it is important that the pipes are flushed, so heat exchangers are not clogged.

The pit heat storages in Dronninglund, Gram and Vojens has water treatment and added chemicals. There is thus an important experience in relation to the design of seasonal heat stores. Still knowledge is not complete about the durability of many of the components of the pit heat storages. E.g. it could be considered to place a new base/bottom foil on top of the original one – without removing the original one, as this would involve emptying the storage. A design without any components inside the pit heat storage is another consideration, i.e. having holes through the side instead of a tower in the middle. The top foil has hardest conditions due to the high temperature - but is easier to replace than the base/bottom foil.

Marstal makes a diving survey in the pit storage each February. Here was been identified some corrosion, which was mitigated with zinc anodes.

Some considerations on the top insulation material: The styrofoam insulation in the lid of the old pit storage could not be recycled (Marstal has two pit storages) and courses a dumping charge of 50,000 €. It is relatively large quantities of material: 100 * 100 m in 300 mm thickness, and the cost to dispose read must be included in the budget.

The annual budget for operation and maintenance of the pit heat storage in Marstal is 13,000 €, including e.g. reparing foils and purchase of submersible pumps. The annual time required for maintenance is about 200 hours. The four employees can manage to do the draining work after a heavy rain, but less staff would require outside assistance. Storage losses has been as expected.

A renovation plan for pit heat storages is one of the tasks to be solved. Designing better and more stable lids with long-term durability are another focus area in the future development of pit heat storages.

3.5 Gram

By operation manager for Gram District Heating, Lars M. Damkjær. In addition, input from Peter Erfurt and Kaj Wieslewski, Haderslev Municipality.
http://www.gram-fjernvarme.dk/

In Gram it was the increase in heat prices in 2005 due to the free liberal electricity market, which started considerations on other ways to produce heat, including solar. The solar district heating system in Gram was established in two stages (10,073 m^2 in 2009 and 34,727 m^2 in 2015, a total of 44,800 m^2), both times it was a challenge to find land, and both times was ground to the solar system sold on expropriation like terms. So the dialogue and cooperation with the municipality was crucial for the implementation of the project.

Figure 9 : The solar district heating system in Gram with damvarmelager [http://www.gram-fjernvarme.dk/]

Information to consumers was from the very beginning a high priority to ensure support for the project. A public meeting with 200 participants (out of 1,100 consumers) resulted in only positive feedback. At the meeting was informed about the solar district heating project and experience from other projects; including participating representatives from Marstal District Heating. Afterwards, frequent newsletters to consumers, to continue to inform about the project. In the second phase was held "open house" day with 100 visitors despite bad weather.
The establishment of the first phase of Gram in 2009 was the first solar district heating project in the

municipality. Gram District Heating focused on the involvement of representatives from the municipality - both officials and politicians – already from 2007. Gram District had visited Marstal District Heating to learn from their experiences.

The intension was that also the people in the municipality administration benefited from the experience from their Marstal colleagues in relation to the local plan, building application and environmental conditions. Especially environmental issues related with glycol was a topic.

In the second phase – now including a of pit heat storage - encountered new challenges in relation to environmental issues, including the handling of the desalinated water. Through a good dialogue with the municipality we found a good pragmatic solution that includes control measurements after 2 and 5 years.

3.5.1 The planning process - regulatory procedures

The processes with the municipality include project proposals, after approval of this a building permit is applied for. One may however, apply for building permission before the final approval of the project proposal. EIA screening (environment) is made in parallel with the proposed project, and the conclusion here is included in the proposed project.

It must be decided whether the project can be implemented within the existing local plan, if the local plan should be adapted - or if a totally new local plan has to be made. In urgent cases the local plan (and EIA screening) and project proposal can be dealt with in parallel, i.e. it can all be treated in the same city council meeting - or the month after. However, this is not preferable since there is a risk that local area plan process is eroded. Normal procedure is first local plan and EIA screening, which typically takes 9-12 months, then 6-7 months to preparation and approval of project proposals. Building permit does not take much time and can usually be handled afterwards.

Haderslev municipalitys present heat and energy plan was prepared in cooperation between the municipality, the district heating plants and DONG Energy. The focus is on the reduction of CO_2 emissions and converting from gas. Two of the three district heating plants in the municipality now have solar heating, the third uses wood chips.

With respect to the solar heating system location in the landscape, both Gram and Vojens are located unproblematic in the outskirts of the city and pit heat storage is placed in an old gravel pit in an industrial area.

With regard to environment, glycol is an issue related to groundwater. The municipality has assessed the risks, including precautions for any leaks, which involves a plan at the waterworks. A solar district heating system should not be placed too close to a ground water source, but glycol is degraded relatively quickly, so limited risk. The municipality's experience is mediated in several forums, including guests from Germany.

In the first plant of 10,000 m^2, Gram District Heating was itself the developer, since it was a relatively simple project. But even though it was relatively simple, it required a lot of time and resources, including budget control to the board and management of suppliers. In the second phase, which included the pit heat storage Gram District selected a consultant. The second stage had a size that made it mandatory for EU tender, so there were in general bigger requirements for the project.

These two approaches had both advantages and disadvantages. If the district heating company has the possibility to involve itself a lot, part enterprises can be chosen, providing a more flexible installation, with fast decisions and more direct contact with the suppliers. This is time consuming, and if the project is very large, as in the case with the second phase of including the pit heat storage it is recommended to choose a turnkey solution, although it means a longer decision time.

The good collaboration between the many parties, involved in a construction project of this size is important. In order to create good conditions for cooperation, Gram District Heating organized once in the first phase - and twice in the second phase - social events to bring people close together.

For the second phase was also asked different offers of financing. The project is divided into different parts that are depreciated with a different time horizon; lid (10 years), electronics and machinery (15 years), pit heat storage (20 years), solar collector field (25 years) and buildings (30 years). The depreciation profile adapted so that consumers pay the same per year for 30 years.

Gram District had foreseen the possibility of the second phase before the first phase was established. Likewise is the possibility of a wood chip plant being considered, so there is room for that too. The establishment of the pit heat storage has, in addition to greater coverage with solar, made possible the exploitation of excess heat from a nearby industry.

3.6 Dronninglund

By operating manager of Dronninglund District, Johan Frey
http://www.dronninglundfjernvarme.dk/

The solar district heating system in Dronninglund was commissioned in 2014 - the world's largest at that time, meeting about 40 % of the heat demand.

Figure 10 The solar district heating system is 37,573 m ^{2} with a pit heat storage of 60,000 m ^{3} . Dronninglund District heating is described here: http://www.drlund-fjernvarme.dk/ , also a brochure can be found here.

3.6.1 Planning

The board took the initiative to explore strategies for the heat supply. With the assistance from a consultant, various scenarios were studied and on this basis it was decided to build a solar district heating system. A prerequisite was that the heat was not allowed to be more expensive.

At the AGM, there was not full support for the solar thermal system: 124 voted for and 87 against. The resistance was primarily based on the fact that it was a great investment (14 mil. €, almost 10 000 € per house), even though a shareholder is liable only for deposits debt. Other argued for a solution with the biomass (straw).

From the idea in 2006 to the decision in 2011 was thus five years. Experience shows that a good relation to the shareholders/users is essential, i.e. you have create confidence, e.g. by good clear information.

In Dronninglund it is also the experience that early and close dialogue with the municipality is important. In Dronninglund was an environmental official designated to participate in all meetings of the solar district heating project. The municipality's benefit is the fact that the solar system helps to meet the city's climate objectives.

A significant barrier for establishing the solar district heating system in Dronninglund was obtaining a piece of land.

Another barrier was objections to the local plan forwarded to the “Nature and Environmental Appeal Board”. This delayed the project at 1-$1^1/_2$ years.

Building permits was no problem, however, one must be aware of different fees depending on whether it is a building or not. It's only the engineering building which is a "building", the rest are technical systems, which implies a lower fee for processing/approval.

In relation to the pit heat storage, one must be aware that water disposal tax does not apply.

With regard to taxation of land, there are different practices in municipalities. It is a good idea to learn in detail how it works locally.

In relation to the environment it was no big problem with glycol . There has been a leak of 6-7 m^3 due to pipe leakage. Notice shall be given to the authorities and an action plan elaborated. The main thing is that the system is equipped with surveillance. The leakage was treated in the way that soil was removed.

Dronninglund conducted a full environmental impact study for the entire solar system.

At the area of the solar district heating system is sheep fence, but there is access to the public – popular place for dog walkers.

3.6.2 Operation

The experience with respect to the operation is that a solar district heating system is easy to operate - operation can be done by the usual staff.

There are six solar meters. An algorithm excludes the two most unlikely. Experience shows that drifting clouds can affect production. Control-wise, it is advantageous to divide the system into smaller sections. In Dronninglund the 37,573 m^2 are divided into two sections - four would be better.

4 Where to get more information

This chapter provides a short overview of further available information.

4.1 International Energy Agency - Solar Heating and Cooling (IEA SHC):

- Task 7 "Central Solar Heating Plants with Seasonal Storage" - mainly historical interest, since it took place in the period 1979-1988. http://task07.iea-shc.org/
- Task 45 "Large Scale Solar Heating and Cooling Systems" - 2011 to 2014, and contains a number of useful technical "fact sheets" on e.g.: collectors field, seasonal storage, hydraulics, financing, monitoring, etc. . http://task45.iea-shc.org/
- Task 55 "Towards the Integration of Large Systems SHC into District Heating and Cooling" – ongoing task – you may join in. http://task55.iea-shc.org/

4.2 SDH-EU - Solar District Heating Europe

SDH is an acronym for "Solar District Heating" and is a European Union project in three stages ("SDHplus", "SDH take-off" and "SDHp2m") and in total 9 years common European gained experience in solar district heating systems. The project website contains a lot of information e.g. the "SDH Guidelines", a "List of Professionals", a "System database" - and more.

4.3 SolarHeatData.EU

SolarHeatData.EU is a website with information about more 50 than solar district heating systems:

- Description of the system – mostly including investment costs
- Measured performance

So far only Danish systems are listed, but systems from other countries are more than welcome to participate/contribute.