SDHp2m

… from policy to market

Advanced policies and market support measures for mobilizing solar district heating investments in European target regions and countries

IMPLEMENTATION OF SOLAR DISTRICT HEATING INTEGRATED IN EXISTING DISTRICT HEATING SYSTEMS IN CITIES

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1. INTRODUCTION

In the SDHp2m (Solar District Heating, policy to market) project, the purpose is to rollout Solar District Heating in three “A-regions” (Thuringia in Germany, Styria in Austria and Auvergne-Rhône-Alpes in France) and six “B-regions” (Hamburg in Germany, Mazovia in Poland, Varna in Bulgaria, Västra Götaland in Sweden, Aosta and Veneto in Italy) in Europe.

The boundary conditions for such a rollout differ from region to region. Nevertheless, we have found three standard solutions, that can be utilized in nearly all regions. The solutions are the following:

- Solar district heating combined with biomass in villages without district heating.
- Solar district heating combined with existing district heating using biomass as primary fuel.
- Solar district heating integrated in existing district heating systems in cities.

This manual describes the integration of **solar district heating in existing district heating systems in cities.**

When starting a SDH project in cities with existing district heating there are two main problems. The first is that the summer load is normally already “occupied” because the DH utility uses heat from power production or other sources of excess heat. The second is that it is difficult and expensive to find areas where to place the solar panels.

This does not mean it is impossible to integrate SDH in cities, because more and more cities want to change their heat supply from fossil fuels to renewable energy sources (RES). To do that, for instance, thermal storages often have to be a part of the DH system. In that case large SDH can have a role, as they are one of the cheapest heating technologies.

The manual is divided into steps following the decision-making process. After each step, a decision has to be made by the process stakeholders whether or not to continue the process.

The manual is a “living” document, meaning that new experiences and ideas are always welcome and can be integrated.

2. INITIAL REQUIREMENTS

The reasons for implementing SDH in existing DH systems in cities can be:

- To avoid emissions from burning fuels in the summer period.
- To reach a high level of RES (and a low level of CO_2 emissions), due to the city’s ambitious climate target.
- To supply areas where the transmission capacity is limited, causing the connection of new buildings to be very expensive unless decentralized (S)DH capacity including accumulation is set up.
- To replace natural gas in systems where CHP production in longer summer periods is not feasible.

If a city has enough excess heat in the summer period, integration of SDH will not be the first priority. Nonetheless, this does not have to be a permanent situation since **feed in tariffs for electricity from CHP plants might change**. An example is the Danish gas fired CHP plants, where the feed-in tariffs for electricity were changed to market prices more than 10 years ago. This has reduced the average amount of operation hours/year from 4000 to 500 on average. Over long periods the heat is therefore produced by natural gas boilers, thereby making SDH feasible.

Many large cities have excess heat from several sources (waste incineration, refineries, metal melting industries, etc.), so that the summer load can easily be covered by these sources and there will still be a surplus. If the city has ambitious climate change targets, and there is a surplus of heat in the summer period, some of this heat can be stored and displace fossil fuel heat production in the winter. SDH can be an extra source for filling the thermal storage for the winter, making it possible for a full (or larger) coverage of the heat demand by RES. The plants in these cases will often be very large, but for such plants longer transmission pipes will be feasible and the heat price can be quite low.

Before starting a process for implementation of new DH with solar thermal panels, some additional conditions need to be in place.

Ownership and financing

The solar collector field can be owned and financed by the existing district heating utility or by an external supplier. For the communication in the decision-making process, it is important to know the model of ownership and financing from the beginning of the project.

Read more about:

- Utility as an owner
- Private ownership of roof mounted collectors (for distributed fed-in)
- Private ownership and third-party financing
- Solar collectors in cooperative ownership

In [1], Fact sheet 2.5 “Ownership and financing”.

Positive stakeholders

Whether the SDH plant will be owned and financed by the existing DH utility or some third-party, the **utility** has to be willing to implement the project/ buy the heat if their conditions for taking part in the project are met. For instance, if the DH price would not be higher than in the reference situation (or not more than X % higher). In this case the price calculation model has to be confirmed by the partners.

Moreover, the **local authorities** need to back the project up and support the process by for instance:

- Elaborating strategic energy planning and a heat plan for the city. In the European projects Hotmaps http://www.hotmaps-project.eu/ and Planheat http://planheat.eu/ tools for heat planning are under development.
- Making a “one stop” contact with the municipality for obtaining permissions and support with expertise.
- Keeping the DH grid owned by a municipal or consumer-owned company, so that access for SDH can be public controlled.

Landscape integration:

Figure 1: “Collector Island” (SUNMARK), Almere, Holland. [1], Fact sheet 2.2

Double utilization:

Figure 2: On a slope (Schüco), Crailsheim, Germany (by Stadtwerke Crailsheim GMBH). Notice the size compared to the car on top and the man in the background. [1], Fact sheet 2.2

Landscape integration:

Figure 3: Alternative placement of solar collectors, Example from Brædstrup, Horsens Municipality [5]

Possible areas for placement of the solar thermal panels

Lack of sufficient area appears to be a major obstacle around Europe when placing a SDH plant. Hence, the possibilities for placing solar thermal panels must be investigated at an early stage. The solar collectors can be placed on buildings (rooftops) or on the ground. Placing solar collectors on rooftops is more expensive[1], and is often competing for space with PV systems. Therefore, ground-mounted collectors are the most common solution used for SDH.

The simplest solution is to place the solar collectors on farmland. As an example, Denmark has a target of replacing 10% of existing DH production with solar by 2030. The latter would present the necessity for establishment of ca. 8 mio. m^2 solar collectors. If each collector takes 2-4 m^2 of farmland, and we calculate with 3.5 m^2/m^2 collector area, they will cover a total of 2,800 ha. The total amount of farmland in Denmark is approx. 2.65 mio. ha. Hence, the solar collectors would cover approx. 0.1% of the farmland. In comparison, golf courses in Denmark cover more than 10,000 ha. Moreover, if an area of the same size, as the one to be used for establishing solar collectors, is used for growing crops, the energy yield would be much lower. See Table 1.

	Solar thermal	**Photovoltaics**	**Biomass/ bioethanol**
Annual yield range	133 to 167 kWh_{th}/m^2	50 to 69 kWh_{el}/m^2	2 to 5 kWh_{th}/m^2
Average annual yield	150 kWh_{th}/m^2	59.5 kWh_{el}/m^2	3.5 kWh_{th}/m^2
Increase over solar thermal (multiplying factor)		3	43

Table 1: Annual energy yield per square meter for different renewable energy Sources in Northern Europe: Fraunhofer ISE, PlanEnergi and Chalmers University, [3]

Table 1 is for Northern Europe, but the multiplying factor is similar in Southern Europe. But even if farmland should not be a limiting factor, it sometimes is, and that will have its reflection on the price. Thus, double utilization of areas and utilization of e.g. polluted or wet areas can be a solution. There will also arise a demand for integration in the landscape and visualization of the solutions during the planning process. Examples of collector placement can be seen in [1], [3] and [4], as well as in Figure 1, Figure 2 and Figure 3 on page 4.

Areas for solar collectors can be bought, leased or rented. It is important to keep in mind that there almost always has to be more than one alternative area, in order to avoid having the price decided by a monopolist, and that the solar thermal system can be established as distributed systems as an alternative.

[1] See for instance [1], fact sheet 2.3, Fig 2.3.6 and 2.3.7

Solar heating systems can be centralized or distributed systems.

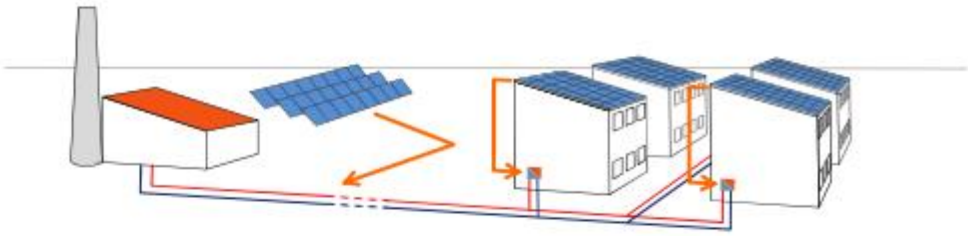

Figure 4: Distributed solar district heating system. [1]

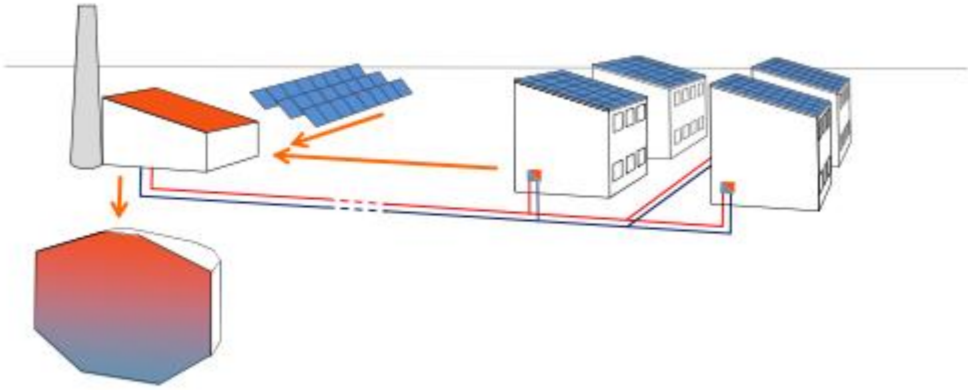

Figure 5: Centralized solar district heating system [1]

<u>Resources needed</u>

Before starting the implementation of new DH with solar panels, one must be aware of the resources needed in the process to:

- Coordinate all activities
- Arrange and participate in meetings
- Elaborate basis for decisions
- Inform about the project and take care of contracts
- Create information in local media

The DH utility can take care of this, however if the supplier is external it has to be done in cooperation.

3. BASIS FOR DECISIONS

To convince investors, municipalities and future consumers, a "Basis for decisions" i.e. a business plan needs to be set up.

Content for investors could be:

- Description of possible heating solutions (different future DH solutions)
- Why integration of solar heat in the present DH system
- Where to place the solar plant
- How to organise and finance the solar plant

- Economic consequences for reference and project (Net Present Value, Internal Rate of Return, yearly costs for consumers). Sensibility analyses.
- Environmental consequences (emissions to soil, water and air)
- Time schedule
- Discussion on possible barriers for realisation of the project
- Draft contract between the utility and external investors (if the investor is external)
- Draft contract between the utility and the supplier of the SDH plant (if the utility invests)

Content for the municipality could be:

- Economic consequences for the municipality as an "island"
- Consequences for employment in the municipality
- Environmental consequences (emissions)
- Consequences for the municipal planning (effect on environmental protected landscape, effect on neighbours to the production plant)
- Social economy

Content for the consumers could be:

- Consumer price for district heating with and without SDH

3.1. Comments to "Basis for decisions"

Description of possible heating solutions

If there is local access to cheaper heat than the one from solar collectors (e.g. excess heat from industrial processes or unused heat from a biogas engine, industrial processes, waste incineration and heat pumps utilizing cheap electricity and producing power-to-heat), SDH will be less feasible and probably not attractive. These possibilities/obstacles have to be described when considering a SDH implementation process. See also [1], Fact sheet 2.1 "Solar heat combined with other fuels".

Why integration of solar heat in the present DH system

The choice of solar thermal and the plant design have to be justified. Moreover, the SDH coverage of the annual heat demand has to be stated, to clarify if it will be possible to turn the boilers off over longer periods and to determine if the SDH plant(s) is central or decentral connected to the existing DH grid.

Where to place the solar plant

A map showing the possible placement of solar collectors and connection to the district heating utility or pipe grid must be a part of the basis for decisions.

How to organize and finance DH

The ownership is important for investors and consumers. For the investors, the business case (security of investment) is important. For the consumer, some of the important factors are the price, confidence in the utility owner and transparency and security of supply.

Ownership of the SDH plant can be the utility or an external investor. The ownership model has to be described and the choice of ownership justified. See also [1], Fact sheet 2.5 “Ownership and financing”.

Economic and environmental consequences for the reference and the project

To calculate the economic consequences of the project, the plant has to be designed, and it is necessary to know:

- Investment, operation and maintenance costs for connection pipes.
- Investment, operation and maintenance costs for the solar panels. Prices can be found in [7]. Nonetheless, suppliers are often willing to give estimates on prices.
- Efficiency curve for solar collectors and grid temperatures over the year.
- The annual production from the SDH plant
- Saved costs in the existing DH system
- Financing conditions

From the above stated conditions, total cost for investment, annual costs of heat production and heat losses can be calculated. Afterwards, annual costs for heating a standard house can be calculated and compared to the costs for the existing DH system.

Environmental consequences (emissions) for boilers can be found in [6] and [7].

Possible calculation tools for solar yield calculation are energyPRO (https://www.emd.dk/energypro/), Polysun (http://www.velasolaris.com/english/home.html), T*Sol (http://valentin.de/calculation/thermal/start/en), TRNSYS (http://www.trnsys.com/), etc.

Guidelines for detailed design can be found in [1], Chapters 6,7 and 8.

An example of a calculation of economic consequences for an utility-owned and financed SDH plant can be found in Appendix 1.

Draft contract between utility and external plant owner/supplier of the SDH plant

If a SDH plant is owned by others than the utility, a contract has to be agreed upon between the parties. In [1], Fact sheet 2.5 “Ownership and financing”, there is a list of important issues that need to be included in the contract:

1. Subject of the contract

Fixes the basics of the solar energy supply:

- Who is the plant owner, who is the utility?
- General information on the system integration of the solar thermal plant
- Start of the energy supply, usually fixed within a certain period of time or with a latest starting date.

2. Duration of the contract

Fixes the beginning and the end of the energy supply, and additionally:

- Exit clauses and exit terms for contracting out of the agreement for both contractual parties. This can be a tricky paragraph, and it is important to negotiate conditions which assure long-term stability for selling the solar energy!

3. Installation of the solar plant, property line

- Who is responsible for the installation of the technical equipment?
- Describes in all detail where the limits of performance are drawn, in particular the utilities responsibilities are defined. Moreover, the energy delivery point (usually position and integration of heat exchanger) is specified.
- Certifications requested
- Who pays the electrical energy for pumps and other equipment?
- Who cares for the ongoing service and maintenance of the solar plant?
- Property structure of the areas which are going to be affected by the solar plant in some way (tech room, roof, space for piping, …)

4. Details on the energy supply and the operation of the plant

Fixes all details between the plant owner and the utility that are related to the solar energy supply service:

- For the plant owner, is there a right to deliver the system's energy output to the utility? Required forward temperature, pressure and max flow? Obligation of backup?
- For the utility, is there an obligation or a right to buy the solar energy? How about required return temperature?
- All the risks concerning damage of the solar plant and damages or consequential damages that are due to some improper operation of the plant are for the plant owners' account.
- Date for earliest and / or latest begin of the energy delivery to the utility.

5. Solar energy price

This part specifies all questions related to the tariff model of the solar energy. It is completely arbitrary for both contract parties to agree upon a model which serves both sides' interests.

- Same price for the whole year or difference between summertime and wintertime?
- Price reduction for lower temperatures than required?
- Solar energy indexed to consumer price index / some other energy (be careful with risk of fluctuating prices) / any other reasonable factor?
  What's the effective date that serves as a basis for the indexing calculations?
- What happens if one of these factors changes drastically? New definition of this part of the contract?
- What happens if solar energy prices are related to other fossil fuel prices?

6. Metering and charging of the solar energy

- How is the solar energy metered?
- Any prerequisite for the metering facilities or the metering system in general?
- How is the solar energy going to be metered and charged to the customer?
- Who calibrates the metering equipment?

- Term of payment for the solar energy invoices

7. Other contract clauses

- How are withdrawals from the energy supply contract handled? States all circumstances under which one of the contract parties could exit the contract without legal consequences.

8. Legal venue

- Fixes the legal venue for any misconceptions between the contract parties
- Usually, there are appendices to the energy supply contract. Most commonly, the following appendices are included:
  - Hydraulic scheme of the energy delivery station with integration of the solar plant
  - Hydraulic scheme of the solar thermal plant.

If an utility owns the SDH plant, they have to make a contract with the supplier of the SDH plant. If it is a total contractor, a checklist for contract content can be found in [1] Fact sheet 3.2 “Tendering and contracts” p.4. A model for setting up performance guarantees can be found in [1] Fact sheet 3.3 “Performance guarantees”.

<u>Time schedule</u>

A time schedule showing the stages in the planning period (information campaign, authority permissions), detailed design, call for tenders, contracting, building the plant and commissioning has to be a part of the basis for decisions document.

<u>Possible barriers</u>

Possible barriers that need to be considered and complied with when situating the solar thermal field include the effect on environmental protected landscape (e.g. Natura 2000) and integration in the landscape.

Moreover, the economic consequences for the municipality and consequences for employment can be calculated. This is done by estimating the local share of investment, fuel and maintenance costs, and dividing them with the total annual costs of employees, then comparing them to the corresponding figures for the existing heating system. But compared to traditional farming, solar thermal plants will increase biodiversity and plants surrounding the collector field open possibilities of green corridors between for instance forest areas.

Finally, sensitivity calculations showing how robust SDH is to changes in the most volatile preconditions have to be carried out. For instance, financing conditions and calculated lifetime of the SDH plant and biomass boilers, as well as development of biomass prices, are important.

4. PUBLIC ACCEPTANCE AND AUTHORITY PERMISSIONS

If the Basis for decisions is accepted by the stakeholders, information and involvement of the population of the city, along with the process of acquiring public permissions, can start. Usually it is not difficult to get public acceptance of a SDH plant.

However, experience from wind power and biogas planning says that the investor(s) has to be proactive to gain public acceptance. If a strategic energy plan and/or a heat plan is elaborated for the municipality, it can be of great help in gaining public acceptance, as long as people have been involved in the planning process, because lack of information and inclusion gives a feeling of powerlessness and can cause huge frustrations, angry feelings and resistance against projects.

On the Danish island Samsø, several energy projects have been implemented in the period from 1996 until now with public perception and acceptance. One of the experiences from the implementation projects is that careful preparation in the first steps is a must. In the project “Implement” supported by the EU Interreg program, Samsø Energy Academy described the implementation process in “A manual on citizen involvement” [8]. The manual is described for a biogas project but is useful for other projects as well.

The steps in the manual are:

- Elaboration of baseline study including collection of information about local social habits.
- Engagement of people that know local habits and conditions.
- Identify the directly involved project stakeholders.
- Find “what’s in it for me” for the involved stakeholders.
- Define objectives for involvement and a strategy for how to reach the stakeholders.
- Involve the local authorities in the project.

The process (must be carried out from the bottom and controlled from the top)

- Communication must be clear and proactive. Communication channels must be defined.
- Objective of meetings must be clear, and meetings prepared by contacting key stakeholders before the meeting and discuss possible scenarios of what might happen.
- Between the meetings the project can contact key stakeholders, arrange working groups, arrange sightseeing to similar projects.

This method of involvement has created local ownership to all kinds of energy projects on the Island of Samsø. It is also important that there is a master plan for transition to renewable energy for the island and that this masterplan is broadly discussed and politically approved.

5. BUILDING THE PLANT

When authority permissions are obtained, tendering, contracting and building the plant can take place. This work needs to be carried out by professionals, but it is important that the implementation company continuously inform people about the project. If the project includes implementation of DH pipes in the streets, this can cause a lot of troubles with traffic that need to be explained beforehand. See also [1] Fact sheet 3.2 “Tendering and contracts” and Fact sheet 4.1 “Supervision of construction and commissioning”.

APPENDIX 1: BIG SOLAR GRAZ

The Challenge

Current heat generation for district heating (DH) in Graz, Austria, is primarily from waste heat of fossil-fired combined heat and power (CHP) plants. Due to low prices on the European electricity market, the operation of CHP plants is not economic sound anymore and may lead to problems for cities, that are highly dependent on the heat of such plants. Thus, the operator of the CHP plants in Mellach near Graz announced their closure in 2020. Almost 80% of the overall heat production has to be replaced.

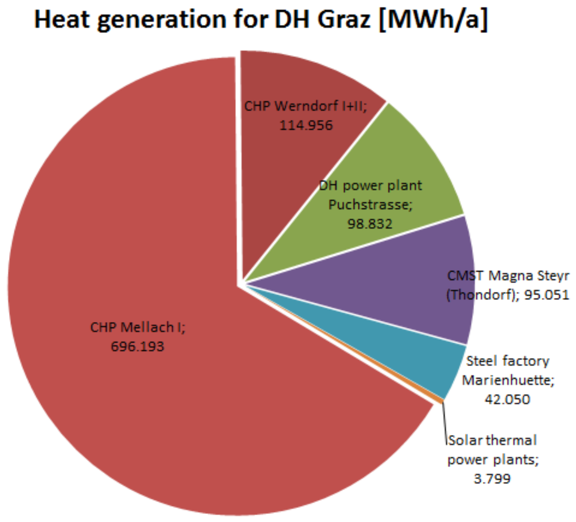

Figure 1: current heat generation for Graz district heating

The Approach

Therefore, in 2014 the Graz city senate constituted a project team to find various options for providing heat for DH in Graz and its surrounding communities for 2020/30. Furthermore, the city senate enacted main objectives, which have to be taken in consideration. These main objectives are: (1) no deterioration of the primary energy factor of DH-generation; (2) no deterioration of specific greenhouse gas emissions (g/kWh); (3) consideration of the current emissions in Graz; (4) no increase of the costs, compared to other types of heating; and (5) security of supply and quality [9].

In different working groups, alternatives like biomass, geothermal, industrial waste heat, big and small CHP, heat pumps and others. The meetings showed that solar thermal with seasonal storage has a huge potential compared to the alternatives and thus In June 2015 the company S.O.L.I.D. was assigned to develop in cooperation with the regional energy provider Energie Steiermark a technical and economic feasibility study for integrating a large-scale solar thermal system into the DH network of Graz. It was realized with the technical assistance of PlanEnergi, a Danish consultant company, which has extensive experience in modeling dynamic simulations for large solar thermal systems and seasonal storages, and the local consultancy Energy Agency Graz.

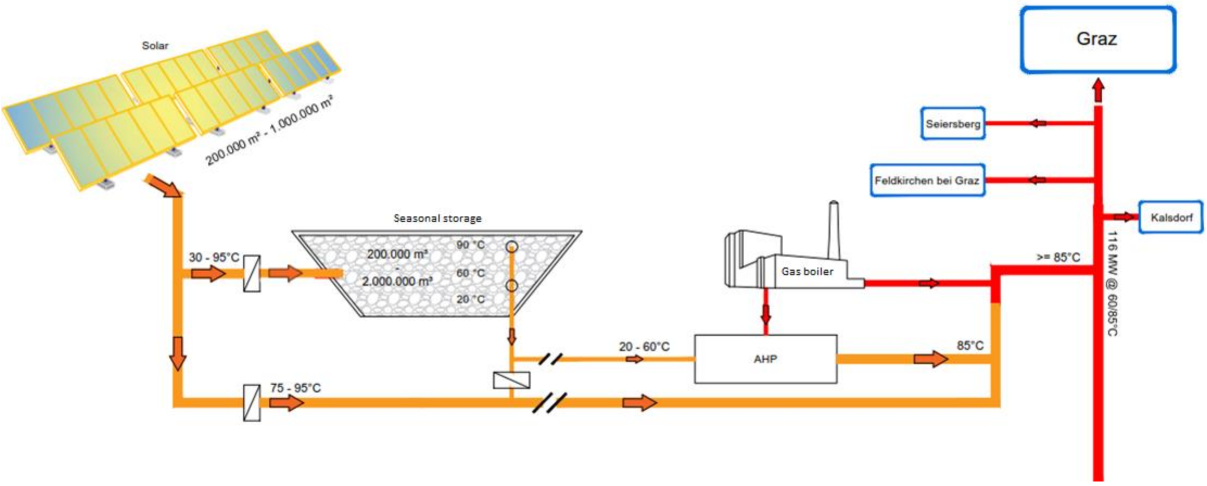

Figure 2: Concept of BIG Solar Graz

The BIG Solar Graz concept foresees a maximum solar fraction with a competitive heat price compared to heat from gas boilers for the DH network of Graz. Figure 2 gives an overview about how the concept looks like. However, it has to be noted, that the size of the collector field, the pit storage and the absorption heat pumps (AHPs) are simulated between a certain range, to find a system optimum for dimensioning each component. AHPs play a key role in this concept, leading to an essential yield improvement of the specific net solar heat production.

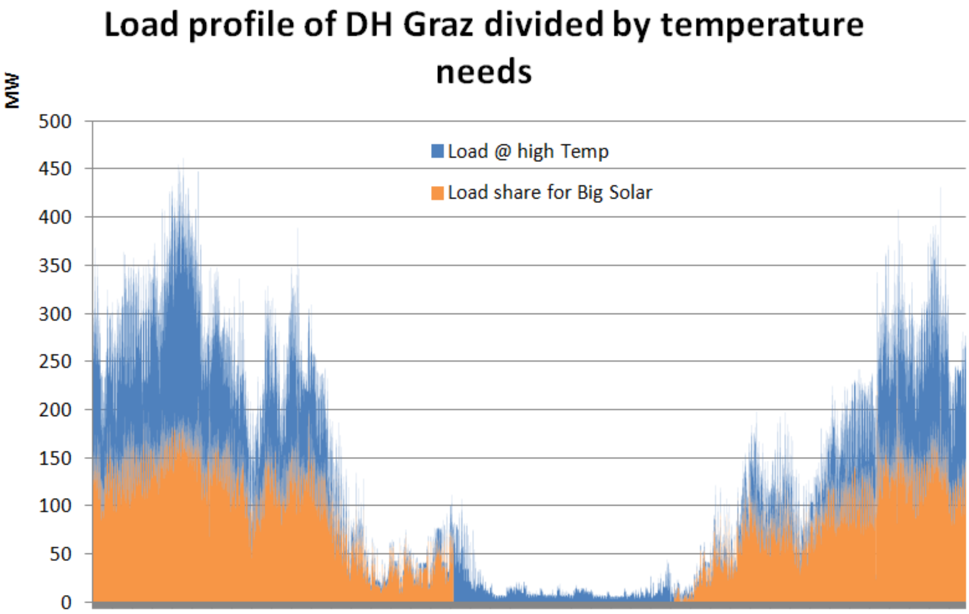

Figure 3: Load profile of DH in Graz divided by temperature needs over the year

For having a first estimation of the potential for the concept the load profile of the DH net was divided in two shares. A low temperature share provided either from solar or the storage directly or via AHPs and a high temperature share, which needs to be provided from high temperature sources such as gas boilers. Figure 3 illustrates these two shares. In summer the city of Graz already has enough heat from existing solar thermal plants and waste heat from industry, thus the long distance pipe from Big Solar plant is shut off for three months in summer. Orange is the Big Solar share and blue the share of the gas boilers. By taking this calculation into account the Big Solar share may be 55% of DH in Graz within the current boundary conditions. Moreover, by taking into account that only one part of the energy is supplied by solar and the other part is supplied by the driving energy for the thermal heat pump which might be gas, but also could be biomass the pure solar output would be 33%. Therefore detailed investigations of the concept were performed up to a solar fraction of 30% (Figure 4). The simulations showed that a setup and dimensioning as in Figure 5 is most feasible.

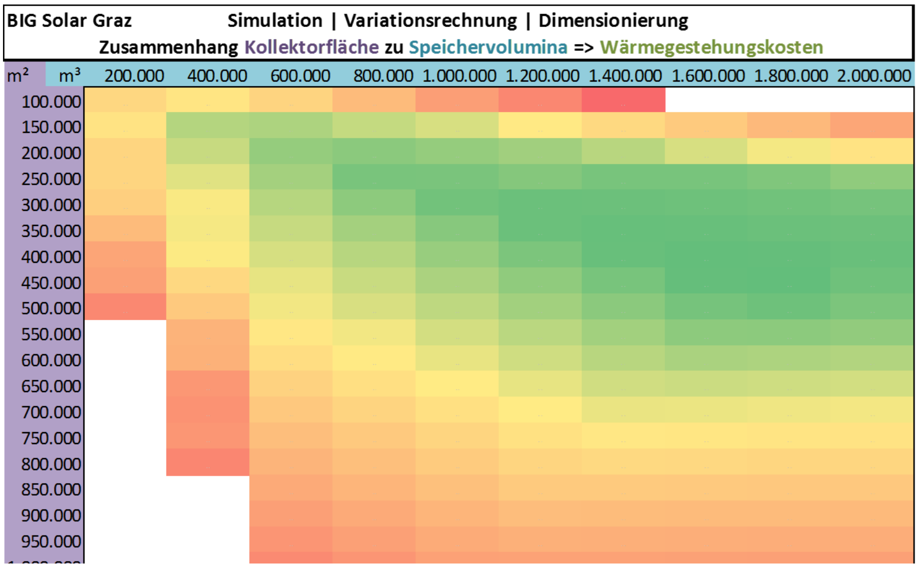

Figure 4: economic calculation of different solar plant sizes (left) and storage sizes (top); dark green means lowest heat generation cost

The current simulations show that it is technical feasible to build such a large-scale solar thermal system including a seasonal pit storage and AHPs as proposed in the BIG Solar Graz concept. Regarding its economic feasibility, it can be said that the heat price is competitive compared to heat from gas boilers for the DH network for Graz. Although such a large-scale solar thermal system has high upfront investments the payback-time is in a moderate range and economically sound. Moreover, it has to be said that on an economic point of view the size of the project is quiet flexible. This means giving the boundary conditions in Graz including land availability, the size of the solar system can vary between 150,000 m² and 650,000 m² including the adaption of the size of the pit storage and the AHPs, the price stays in economic sound range (Figure 4).

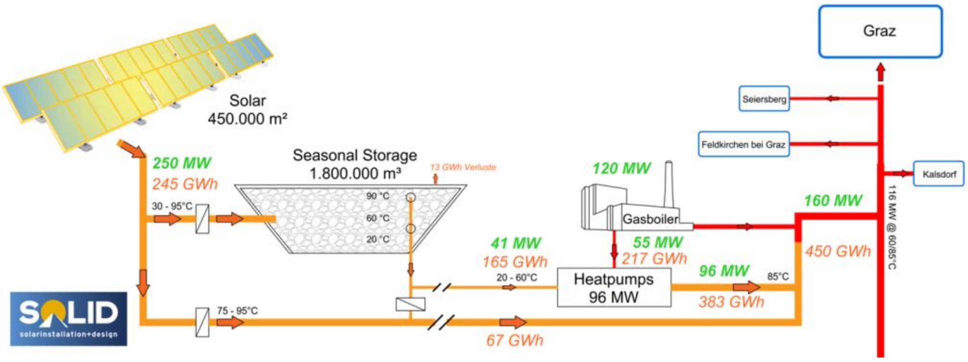

Figure 5: scheme of Big Solar Graz

The big solar system has these advantages for the utility and the DH customers:

- Economic competitiveness (despite high network temperatures in Graz)
- System solution for available heat at anytime
- Security of supply
- Climate-friendly heat supply, no fine dust pollution (very important in Graz)
- Long-term price stability
- refinancing costs are projectable, independent from the development of prices of fossil energy sources

The district heating utility and partner companies decided to build the Big Solar system and, as of end of 2017, are in negotiations for obtaining the needed land area of around 100 ha. Further the development of the system concept is going on and the strategy for operation and control and safety aspects are elaborated. Also preparation of permissions and administrative procedures are going on.

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