Barriers and opportunities to maximize the share of solar thermal energy in district heating networks – approaches within the IEA SHC Task 55, Subtask A and selected preliminary results

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Abstract

The integration of large and very large solar thermal plants in district heating (DH) networks gained increasing attention in recent years. However, the integration poses some challenges, especially for large shares of solar heat. This contribution gives an overview of the approach chosen within Subtask A of the IEA SHC Task 55 for assessing the impact of high shares solar thermal energy on the overall district heating and cooling network and different integration aspects in order to maximize the share of solar thermal energy. This includes:

- Collection and analyses of case studies for assessing the technical requirements of large shares
- Economic analyses of overall DHC networks, their supply strategies, transition strategies, heat demand and energy price scenarios
- Analyses of DHC network hydraulics, evaluation of hybrid technologies and possible supply points for large solar thermal installations
- Overall DHC network control strategies and other measures for increasing solar thermal fractions

This contribution describes the used approach and selected preliminary results

Keywords: solar district heating; case studies; integration aspects; transition strategies; network performance; hydraulics; control strategies; return temperature reduction.

1. Introduction

In recent years, megawatt-scale solar thermal (ST) supply to district heating (DH) or district heating & cooling (DHC) systems have gained increasing attention. This alternative energy is available almost everywhere (unlike e.g. deep geothermal energy or industrial waste heat) and thus it can contribute to satisfy the increasing energy demands of districts and cities. Further on, the use of solar thermal supported DHC networks has benefits on an environmental (reduced emissions and air pollution) and systemic level (e.g. DHC infrastructure and local economy). It can make use of synergies in the urban context (suitable integration into urban environment) and can increase energy supply security (reduced fuel imports, diversification of the energy mix).

A breakdown of fuel use in DHC systems worldwide shows that 43.2% are fueled by natural gas, 43% are based on coal and its products, followed by oil (4.3%), biofuel and waste (6.5%), or nuclear energy (0.2%). Solar based energy supply accounts for far less than 0.01% globally. Still, the share of energy based on renewable sources has been growing (IRENA, 2017). The presence of solar thermal supported DHC networks is highly diverse across countries. E.g. Denmark is well known for its integration of large solar thermal plants into local DH networks. Other countries, such as Austria, are about to implement even bigger solar thermal district heating systems.

In a simulation study[1] for Austria, Denmark, Germany and Italy, a technical potential between 3% and 12% solar share in 2050 has been estimated (*solar share = heat supplied by solar thermal collectors / overall heat supply to*

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[1] http://www.sunwindenergy.com/solar-thermal/solar-thermals-role-2050-energy-mix

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the end customers). However, the integration of large solar thermal systems into existing and new DH networks faces several challenges, especially the high network temperatures and the seasonal mismatch between supply and demand, e.g. (BDEW 2017). This is especially relevant as soon as the solar share reaches a level, where the operation of the network and the other supply units are influenced significantly.

The solar heating and cooling (SHC) technology cooperation programm (TCP) of the international energy agency (IEA) was established in 1977 to promote the use of all aspects of solar thermal energy by international collaborative effort of experts from various countries[1]. Its primary activity is to develop research projects (Tasks) to study various aspects of solar heating and cooling. Task 55 of the SHC TCP provides a platform for practitioners and scientists to elaborate the benefits and challenges of solar district heating (SDH) and solar district cooling (SDC) systems[2]. Hence, SHC Task 55 elaborates options and measures to realize sophisticated SDH and SDC plants.

2. Methodology

The activities in IEA SHC Task 55 are funded through a task-sharing approach, where each participant contributes resources in-kind (for example personnel or materials)[3]. The task-sharing approach allows to connect existing national and international projects via the international platform and thus benefit from international experience and exchange. More than 25 international experts share their expertise on SDH and SDC systems, requirements and integrational challenges, existing district energy systems face when integrating large amounts of solar thermal energies. Task 55 is separated into the following 4 Subtasks: **A**: Network Analyses and Integration, **B**: Components Testing, System Monitoring and Quality Assurance, **C**: Design of the Solar Thermal System and of Hybrid Components and **D**: Promotion and dissemination of SDH/SDC and hybrid technologies in new markets.

This contribution describes the approach and selected preliminary results within Subtask A. It focusses on the assessment of the impact of solar thermal technologies on the overall district heating and cooling network and integration aspects in order to analyze barriers and opportunities for maximizing the share of solar thermal energy.

Subtask A is separated as follows:

1. Assessment of technical requirements of existing and newly integrated large scale Solar DHC networks. Aim is to understand the boundary conditions and parameters (technical, economical etc.) enabling high shares of solar thermal supply to DHC networks.
2. Economic analyses of overall DHC networks, their supply strategies, transition strategies, heat demand and energy price scenarios. Aim is to understand possible pathways from zero (or very little) solar shares to high or very high shares (e.g. 20-70%). Here, especially economic parameters should be analyzed.
3. Analyses of DHC network hydraulics, evaluation of hybrid technologies and possible supply points for large solar thermal installations. This part focusses on technical aspects of the integration, building upon existing analyses and case studies on solar thermal integration measures.
4. Assessment of overall DHC network control strategies and other measures that can support the integration of solar thermal energy and thus increase the solar thermal share.

Due to its interdisciplinary scope, activities in Subtask A will be performed in collaboration with other SHC Tasks (e.g. Task 52 on “Solar Heat and Energy Economics in Urban Environments”[4]) and the IEA TCPs on District Heating and Cooling (DHC) and Combined Heat and Power (CHP)[5]. For the later, one main cooperation will be established to the new Annex TS2 on “Implementation of Low Temperature District Heating Systems”[6].

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[1] https://www.iea-shc.org/

[2] http://task55.iea-shc.org/

[3] https://www.iea.org/media/impag/FAQs_new.pdf

[4] http://task52.iea-shc.org/

[5] http://www.iea-dhc.org

[6] http://www.iea-dhc.org/the-research/annexes/2017-2020-annex-ts2-draft.html

3. Selected preliminary results

The runtime of Task 55 is from September 2016 to End August 2020. During the first year, the work in Subtask A focuses mainly on the set-up of the overall structure including a detailed work plan as well as analyzing and consolidating the international activities and projects from the Task 55 participants. Within this contribution, some selected preliminary results can be presented.

3.1. Assessment of technical requirements of existing and newly integrated large scale SDH/SDC – collection and analyses of case studies

Initially, best practice examples and case studies of existing, newly integrated and planned SDH and SDC systems with large (>5%) solar fractions (typically of > 0,5MWth up to GWth) will be collected. The case studies are collected via supporting projects from the IEA SHC Task 55 partners as well as through a dedicated internet research. A template for the data collection was set up with focus on:

- temperature and pressure ranges of both networks and solar systems
- solar thermal share
- storage size
- efficiency of the solar systems
- economic parameters (which will be used in the section 3.2)
- demand structure and possible additional summer demand (e.g. from adsorption chillers) .

Analyzing and comparing the existing case studies, potentials, challenges and barriers for the integration of solar thermal systems will be analyzed. The following aspects should be handled:

- What overall supply mix is the most economic/ ecologic for covering the heat demand in a given network?
- How to transform the DH network towards a maximum share of ST (and other low carbon sources?)
- What is the impact of different boundary conditions (energy prices, demand development …)?
- Evaluation of the system`s performance (e.g. Primary energy consumption and Socio-economic benefits)

3.2 Economic analyses of overall DHC networks, their supply strategies, transition strategies, heat demand and energy price scenarios

Based on the results of 3.1 and other case studies, possible transition strategies supporting a maximum share of solar thermal supply will be derived.

One very prominent example is the transformation strategy developed for the city of Graz (Austria). Fig. 1, left illustrates that current energy generation for district heating (DH) in Graz, Austria, is primarily based on waste heat from fossil-fired combined heat and power (CHP) plants. Due to low prices on the European electricity market, the operation of the CHP plants became increasingly uneconomic. Hence, the operator of the main CHP plant in Graz recently announced its closure in 2020. As a result, almost 80% of the overall heat production in the Graz DH network has to be replaced by new energy sources.

For developing future supply options, the city of Graz initiated a wide stakeholder process (Götzhaber et al 2017). This process resulted in a bunch of measures including the project “BIG Solar Graz” which is supposed to have a share of about 20% on the overall DH supply in Graz – see Fig. 1 right.

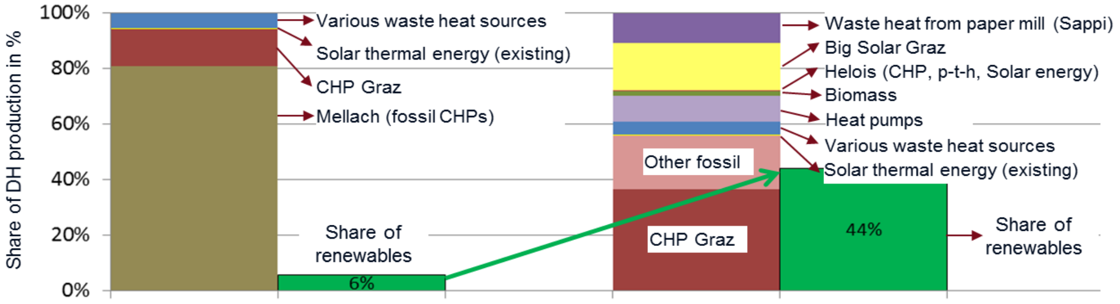

Fig. 1: Transformation strategies, example: Graz, left: current situation of the DH network in Graz, right: possible future supply mix (Prutsch 2017, translated, p-t-h = power-to-heat)

Current energy used for heating and domestic hot water in residential and service buildings in Graz is estimated at 2,400 gigawatt hours per year (GWh/a). In total, 1,100 GWh/a (2013) are provided by DH. While Graz receives 935 GWh per year, corresponding to 39% of the cities heat demand, the remaining 165 GWh/a are distributed beneath the southern communities around Graz, which are obtaining heat from DH mainly in winter. It is planned to further increase the share of DH up to 56% until 2030. Operating temperatures vary seasonally. The system is operated with flow temperatures up to 120°C in winter and up to 75°C in summer. The return flow temperature is on average 60°C. The DH network is operating all seasons throughout the year in Graz, whereas the southern communities are not supplied in summer.

The concept to integrate high solar thermal fractions into the DH network named "BIG Solar" aimed to investigate a maximum solar fraction applicable (e.g. (Poier 2017)). It is limited to the basic condition of having a competitive heat price compared to other sources of heat generation, such as from gas boilers for DH in Graz. Therefore, the size and capacities of key components, namely the collector field, the pit storage, and the absorption heat pumps (AHPs) were simulated in a certain range. Simulations aimed at identifying a system optimum for dimensioning each component and ultimately for the whole system.

First, for estimating the overall potential of the concept the heat load profile of DH in Graz was divided into two shares. A low temperature share for the basic heat load, provided either from solar and the storage directly and from the storage via the AHPs indirectly and a high temperature share, which is mainly for peak load especially in winter, provided by high temperature sources such as gas or biomass boilers. According to the calculation, the BIG solar share may be roughly at 55% of DH in Graz with 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 AHPs from an auxiliary heating source, the pure solar output would be 33%. Therefore, detailed investigations of the concept were performed up to a solar fraction of 30%. TRNSYS, the transient system simulation software tool was applied to run multiple up to a maximum solar fraction of 30% in order to identify the technical and economic optimum. A series of simulations for collector field sizes between 20,000 m² up to 1 Million m², pit storage sizes between 100,000 m³ up to 2 Million m³ and 3 different sizes of AHPs (0, 50 and 100 MW heat output) were performed and evaluated. The multiple simulations with different parameter resulted in a techno-economic optimum of 450,000 m² collector field area, a seasonal heat storage capacity of 1,800,000 m³ and AHPs with a total heat capacity of 100 MW for the DH network of the city of Graz.

The use of AHPs is a key element in the system. On the one hand, AHPs are used to raise the temperature from the seasonal storage, when the storage is already partly emptied and temperature is lower than the minimum necessary 80 to 90°C for DH. On the other hand, AHPs accelerate the cooling down process of the seasonal pit storage, which means higher collector-efficiency at lower temperatures and therefore they lead to an essential yield improvement of the specific net solar heat production. The solar thermal concept also foresees an auxiliary heating component, which serves to power the generator of the AHPs and raises the temperature from the BIG Solar system up to the required 120°C for DH in winter.

Technical limitations such as the maximum capacity of the DH transport line, current heat and temperature loads, or future loads of waste heat from industries, were taken into account. Furthermore, a comprehensive cost evaluation was performed by using capital budgeting. The most important economic key performance indicators (KPIs) such as net present value (NPV), internal rate of return (IRR), discounted payback period (DPB) and levelized cost of energy (LCOE) were calculated and evaluated for different financing scenarios.

To sum up, simulations show that the BIG Solar concept is technically and economically feasible. The economic analysis shows that a heat price is comparable to other heating sources for DH in Graz. Although such a system has high upfront investment costs, the payback-time is moderate and economically reasonable, even in the light of neglected environmental benefits. Moreover, the project has flexible parameters. Given the boundary conditions in Graz such as land availability, the size of the solar thermal system can vary between 150,000 and 650,000 m² respecting the adaptation of sizes of the pit storage and the AHPs by feasible and economic sound price ranges (Reiter, Poier, et al. 2017).

The study on solar thermal large-scale installations integrated into the DH network of the city of Graz was one of the first analyses undertaken. Next to the study, a range of analyses named ´BSX-BigSolarX´ have been performed. Results indicated flexible parameters and techno-economically feasible collector field sizes similar to parameters identified in Graz. A number of study results will be available in upcoming Task 55 expert meetings.

3.3 Analyses of DHC network hydraulics, evaluation of hybrid technologies and possible supply points for large solar thermal installations

The technical integration options of the solar thermal energy will be evaluated from a hydraulic point of view. This is including the differentiation between central and decentral supply into existing networks as well as different local hydraulic connections and supply options. Also, the related challenges in the network performance will be evaluated considering the interaction with other supply technologies. Fig. 2 shows possible supply points for solar collectors in a DH network.

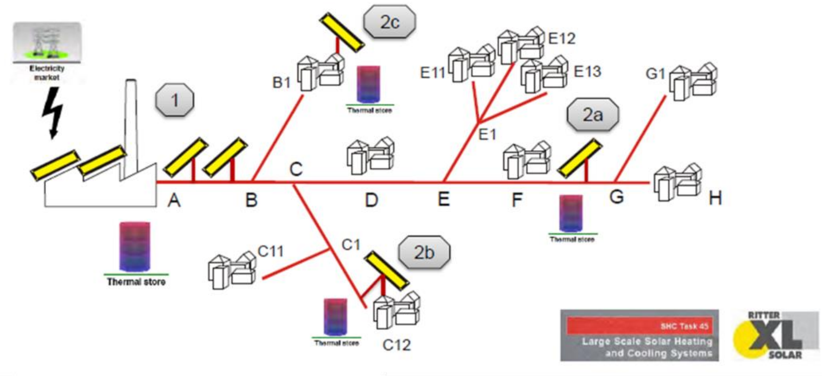

Fig. 2: Possible supply points for solar collectors in a DH network (from IEA SHC Task 45)

The *central* solar thermal systems are typically installed in combination with other heat-only or CHP plants and provided with a thermal storage unit, e.g. (SDH Guidelines 2012). As contribution to IEA SHC Task 55, the project partner PlanEnergi described the possible supply schemes of central solar systems; the most efficient solutions have to be identified in each case according to more parameters, among others:

- network supply and return temperature
- Solar system supply temperature
- Storage charge level and location of the possible storage charging/discharging points
- Boiler operational flexibility to return temperature fluctuations

The connection of *decentral* solar thermal systems is investigated in detail by (Schäfer et al. 2015), who analyzed the state of the art identifying 31 case studies in Austria, Denmark, Germany, and Sweden, and evaluated the potential and barriers for optimizing the integration. In the most cases (29), the connection is return-to-supply, in one case return-to-return, and in one case both options are possible. Contrarily to central collectors, the storage unit is not necessarily present in the decentral plants. Simulations allowed identifying the size of the existing users' connections as a possible hydraulic bottleneck limiting the solar share: in one case study, the solar collectors cannot entirely integrated into the network if the aperture exceeds 25% of the available roof area. Such issues can be faced adding new appropriate connections or/and storage units. As expected, the best solutions are highly case-sensitive.

However, while the network parameters considered in the existing studies are essentially the supply and return temperatures and the thermal load, a more complete investigation should take into account further aspects playing as well an important role in the integration of solar thermal systems. In particular, a solution-oriented approach to hydraulics cannot exclude the topology of the entire network and the (possible) supply points: the effects and the potential of the integration of decentral solar systems are in fact expected not to be the same in a linear, a ring, or a mash network, as well as they will vary according to the location of the supply point [Köfinger et al 2016]. For supply points outside the city center, hydraulic limitations might apply due to small pipe diameters in outskirt network branches. In some cases, the possibilities for bidirectional flows in line networks should be also investigated.

3.4 Overall DHC network control strategies and other measures for increasing solar thermal fractions

Another focus of Subtask A is on the assessment of measures for increasing the solar fraction. In doing so, the following measures should be considered:

Short term flexibility measures: In district heating networks, normally two distinct customer side heating load peaks occur at almost the same time of the day typically as morning and evening peaks (see Fig 3, right). This requires the intervention of additional peak boilers, usually operated with fossil fuels at high costs. Solar thermal energy has its supply peak usually directly in-between the morning and evening peak and therefore can only partly be used for covering the heating load, especially in summer times, when the solar thermal supply surpasses the heat demand. Short term flexibility measures for overcoming this mismatch include centralized and customer side storages, the utilization of the network as storage and customer side load shifting, with all measures mentioned being state-of-the art.

In (Schmidt and Basciotti 2014), those measures have been analysed and compered based on a literature review and network simulations of a typical rural heating network in Austria. The results can be summarized as follows:

- Centralized storage tanks are already used in many DH networks for various reasons (as back-up, for decoupling heat and electricity production in CHP and for peak load reductions) and represent a suitable measure for short term flexibility at a high economic viability.
- Smaller distributed storages at the customer side have a high storage capacity and the additional potential to reduce the pumping energy. However, they are very investment cost intensive and difficult to implement.
- The utilization of the network as storage is promising due to the very low investment costs and the resulting fast amortization, however, restrictions on the network side (i.e. the thermal expansion due to the additional temperature changes causes stress in the pipes and other system components) allow only limited number of temperature changes and lead to the risk of piping leakage respectively.
- Implementing load shifting for larger loads (e.g. hotels, swimming pools, shopping centre) is another conceivable measure resulting in a cost effective generation of short term flexibility. However, the practical implementation on a large scale needs further investigation.

In conclusion, for improving the supply of solar thermal energy in DH networks, the penetration of short-term flexibility measures and their cost-effectiveness need to be improved, including the development and integration of new technologies (e.g. storages, controls), services (including customer involvement) and business models. Also measures for forecasting the flexibility of the DH network need to be develop in order to be included in the overall system management.

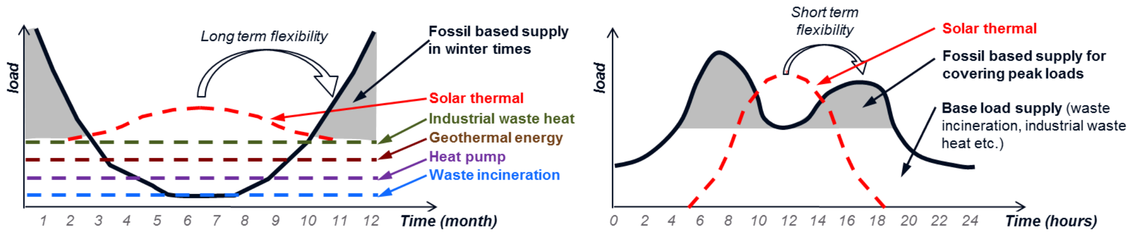

Fig. 3: Mismatch between the DH network demand and seasonal (left) and daily (right) behavior of different heat sources

Long term flexibility measures: Beside the short term mismatch, a major barrier for integrating solar energy and other renewable heat sources (such as geothermal energy and ambient heat) as well as waste heat in DH networks is their seasonal mismatch to the demand profiles (see Fig. 3, left). Here, two cases have to be differentiated: First, DH networks with very low operational costs in summer, i.e. the base load is covered by heat pumps, geothermal energy or industrial waste heat. For economic reasons, those sources should not be turned off or operated on part load for allowing solar energy to be integrated. As a consequence, every notable solar supply in summer times needs to be either cooled to the ambient or stored for transition times or winter. This applies also for a base load supply by waste incineration, having a “must-run” condition.

Second, DH networks where the base load is covered by supply units that consume fuels, e.g. fossil fired CHP plants or biomass plants. Here, the solar energy can actually safe operation costs and could be economically beneficial. However, subsidies and profits on the electricity markets from CHP plants might require those plants to run as well in summer times. Also very large shares of solar energy, i.e. exceeding 20% of the overall heat supplied to the network, need to be stored in a seasonal storage anyways, e.g. (Winterscheid et at 2017).

For this purpose, various seasonal storage systems are available nowadays, including aquifer, borehole, pit, tank storages, e.g. (SDH Guidelines 2012). However, these systems have up to now mainly been integrated in small/rural networks or building clusters in Germany, Denmark and Sweden. For increasing the long term storage capacity of larger, urban DH networks, the disadvantages of seasonal storages, especially the mismatch of the maximum storage temperature to the typical network temperature level, the high space requirements and the high investment costs need to be overcome.

One example for the integration of seasonal storages is the urban DH network Linz (Austria). Here, available industrial waste heat from a steel mill cannot be fed directly into the network during summer times since a waste incineration plant already covers the whole summer load and has a must-run condition (Pauli 2016). As a consequence, the integration of a seasonal storage was investigated for shifting the summer surplus waste heat into the transition time. Within a pre-study (Muser et al 2015) possible locations, geometries and costs of a seasonal storage for the Linz DH network have been analysed. Based on this study, two different operational scenarios for the integration of this seasonal storage have been analysed (Köfinger et al 2017): First, a “simple” operation strategy of the seasonal storage, where the storage is mainly charged in the summer and discharged in autumn/winter. Further on, a “strategic” operation strategy has been developed, allowing also short term charging/discharging and as a consequence also to enhance the operation of the existing CHP plants and reduce the use of the peak load boiler. Whereas the “simple” charging strategy the 1.8-fold storage capacity can be used, for the strategic charging strategy, this value goes up to 4.4 and therefore increases its economic feasibility. As a consequence, in a best case scenario a payback period of ~20 years could be achieved, although various uncertainties (especially electricity prices) apply. Together with high investment costs of about 100 mil. Euros, the investment risk for the storage is unacceptable high in the particular case. However, smaller DH networks with lower network temperatures and lower investment costs have already proven to be realizable.

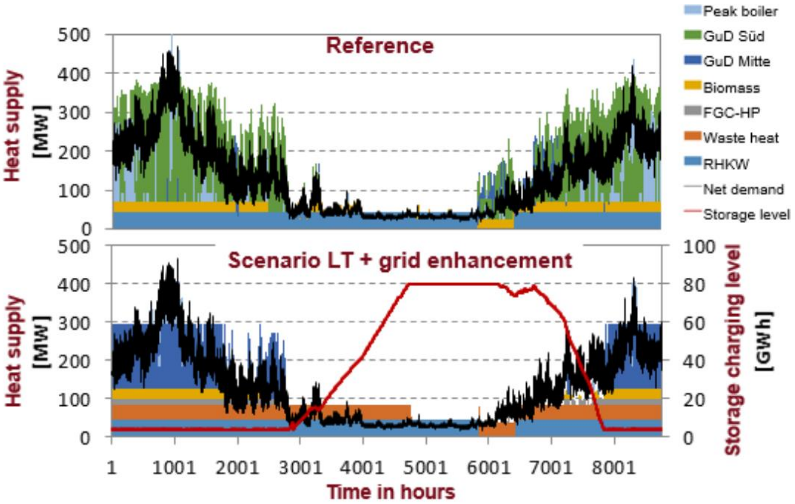

Fig. 4: Simulation based evaluation of the integration of a seasonal thermal storage in the DH network of Linz (Austria) for improved waste heat utilization, top: reference scenario without seasonal storage, bottom: integration of the seasonal storage in a low temperature scenario with enhancement of the network (Köfinger et al 2017)

Control strategies for an efficient integration of solar thermal plants into district heating networks: The operation of a district heating network incorporating different producers with at least one being a solar thermal plant and different consumers in any case goes along with several control problems to be considered.

At *first*, the scheduling (load respectively energy management) of the different producers and possibly also consumers has to be managed properly, i.e. a strategy which is able to plan ahead the use of the different components is necessary. This is especially important when slowly reacting and/or weather dependent heat producers, such as solar thermal plants, or relevant energy storages, as it is the case in both the short and long term flexibility measures previously mentioned, have to be considered. Thus a high-level control has to decide the general mode of operation and adjust the reference values for different process variables, such as for example the required outlet temperature of the collector field. In most practical applications this high-level control is specifically adjusted to the particular heating network and bases on various standard controllers and additional expert rules. Within the last years it got increasingly popular to incorporate weather forecasts, however, with the control algorithms still basing on specific expert rules.

A very promising alternative approach is the application of a model predictive controller (MPC). MPC bases on mathematical models used to predict the future behaviour of the system for different courses of the manipulated variables. This allows to determine the optimal future course of the manipulated variables, thus in the specific case of a district heating network with different producers and consumers the optimal future operational strategy. This prediction is periodically repeated always using updated values for the state of the different components. The different approaches for MPCs for (bidirectional) heating networks mostly base on mixed-integer linear programs (MILP), since not only continuous states but also discrete states, e.g. for the activation and deactivation of specific producers, have to be considered, e.g. (Moser et al 2017). The resulting optimization problem of the MPC, formulated as mixed-integer linear program (MILP), has to be solved by appropriate MILP solvers. In order to provide the MPC with the future heat demand of the consumers or for example the future solar yield to be expected additional forecast methods have to be applied. Within the Task both control approaches, control strategies based on expert rules as and different MPC approaches, as well as forecast methods for the future heat demand or the solar yield to be expected are considered.

Second, it must be ensured that the heat produced by the different producers is properly fed into the district heating network and transported to the corresponding consumers. If there would be only one (central) heat producer in a network, this would be comparatively simple. In this case the pumps supplying the network would aim for setting the differential pressure in such a way that the supply is ensured even for the most distant consumer. However, in the general case, this is more complex, since it has to be ensured that the pumps of the individual producers do not work against each other. At first it has to be distinguished between producers which need to feed into the network immediately, since they cannot store the heat produced locally, and producers coupled with a buffer and consequently able to temporarily store the heat produced. One common approach is to use heat producers with buffer storages for maintaining the differential pressures, while the others regulate the mass flows of the feeds to ensure that their heat is properly transferred to the heating network. In detail, the finally applied approaches strongly depend on the actual heating network and there is also no systematic approach available in literature.

Third, the mode of operation of the collector field chosen by the high-level control (load respectively energy management) has to be realized by the respective low-level control at the solar collector site as efficiently as possible. Strictly speaking the outlet temperature of the collector field respectively the different sub-fields has to be controlled by adjusting the flow rate to the current radiation. This is in general done by varying the pump speed. Additionally, the individual fields are typically equipped with adjustable balancing valves in order to ensure an adequate flow distribution in the individual subfields. These valves can either be adjusted manually for nominal operation or be driven by a servomotor in order to achieve an adequate flow distribution for every operating condition and thus avoid exergy losses by mixing flows with different temperatures. The controllers applied typically are simple linear PID controllers, which in some are enhanced by a static feedforward control signal for the pump speed based on a static model for the heat output of a solar collector representing a static energy balance, where the parameters are determined in a standardized collector test (EN12975-2) and can be found in the datasheet. In research more advanced approaches can be found, e.g. (Camacho et al, 2007), but they have not reached a wide practical distribution up to now. A promising approach, also using mathematical models describing the collector field but explicitly aiming for practically manageable complexity, is presented in another article within this conference proceedings (Unterberger et al, 2017).

Measures for reducing the return temperatures: The potential for the utilization of solar thermal, but also other alternative heat sources such as industrial waste heat, geothermal energy and heat pumps, in DH networks is strongly correlated to the temperature level at which the networks are operated. Currently, many “traditional” existing DH networks are not designed for a significant share of solar thermal energy due to the relatively high network temperatures, often between 60°C (return) and 120°C (supply). Fig. 4 compares “traditional” high temperature DH networks with low temperature systems enabling higher shares of solar thermal energy.

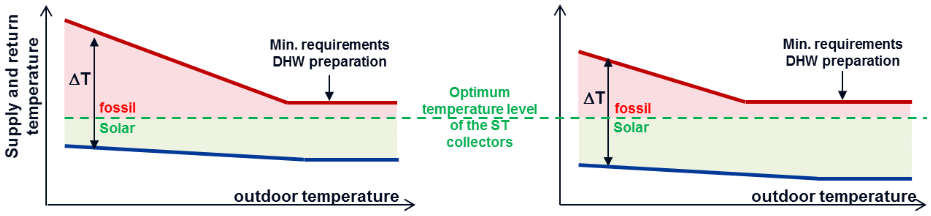

Fig. 5: Schematic description of the influence of the temperature level of the district heating network on the potential for the utilization of solar thermal energy (left: high supply and return temperatures in the DH network result in a limited potential of solar thermal energy, right: decreasing return and supply temperatures enable an increasing share of solar thermal energy)

Most of the technical measures for transforming traditional DH networks towards low temperature systems are well known, mature and in principle straightforward in their implementation. They can be distinguished in following areas:

- building side optimization such as hydraulic balancing and the correct use of thermostatic radiator valves
- Detecting and minimizing errors and faults in substations and domestic hot water preparation
- cascading (using the return flow of high temperature customers as a supply to low temperature customers)

Within Subtask A business models, existing strategies and the impact of different approaches from the participating parties as well as from literature should be analysed in detail within the Task. Here, a strong link to the currently starting IEA DHC Annex TS2 on low temperature district heating systems will be established.

4. Discussions

Based on the preliminary results, a literature review and stakeholder discussions, following analyses of the strengths, weaknesses, opportunities and threats (i.e. SWOT analyses) for the integration of solar energy into DH networks can be summarized:

Strengths: Besides being free of any emissions such as CO_2, NO_x or others (including noise), the main asset of solar thermal energy supply to DH networks is the good availability and the very low operation cost in combination with fuel independency and long term stability. Compared to other renewable sources, especially biomass, the required specific land use area is very low, e.g. (Poier 2017). The DH network temperatures in summer times are in general lower, supporting the efficiency of the collectors. Thermal driven adsorption chillers can increase the summer demand and thus absorb a possible surplus heat in summer times. The solar thermal components as well as different centralized and decentralized integration concepts are state-of-the-art and well proven in various DH networks already. Further on, producers of components for solar thermal collectors and system installers are often available regionally, resulting in high local added value.

Weaknesses: Additional to the high specific investment costs of solar thermal energy systems, the main disadvantage is the supply competition to other renewables (e.g. heat pumps, geothermal energy), waste heat (e.g. from industrial processes) and pants with must-run condition (e.g. waste incineration) in summer times. Seasonal storages for shifting the summer surplus heat to transition or winter time are available, but difficult to integrate in urban DH networks. Further on, higher network temperatures in winter times reduce the efficiency of the collectors. Also the integration of thermal driven adsorption chillers require higher network temperatures. For reaching significant solar shares, the systems require large areas that are limited and costly in an urban context. Larger and low-priced areas are likely to be far from the city center and thus additional investment costs for transport pipes and hydraulic limitations for supplying to outskirt network branches might apply.

Opportunities: For different reasons, many DH network operators are working continuously on the reduction of their network temperatures and this will increase the efficiency or solar thermal systems by trend. The utilization of large shares of other renewable or alternative heat sources (such as heat pumps, geothermal energy and waste heat) in DH networks supports the integration of seasonal storages. Finally, for accomplishing the COP21 targets, direct or indirect subsidies (e.g. CO2 taxes) for solar thermal energy are either already in place or are currently discussed in some countries.

Threats: One main threat are the long payback times of the systems, reducing the flexibility in the overall system. Further on, large and exposed collector areas might be damaged due to more frequent extreme weather events due to the climate change, resulting in by trend lower heat energy supplied the network and higher maintenance cost. Finally, the price of the land for installing the collectors might increase, as soon as the land owner get aware of the aim of the intended land use and want to increase their own profit – especially if only limited areas are available.

5. Conclusion & outlook

Solar thermal energy is one of the few renewable heat sources, that is available almost everywhere and can bring multiple benefits to DH networks (on an environmental and systemic level) with very low operation costs and risks. However, the integration of large solar thermal systems into existing and new DH networks faces several challenges, especially the high specific investment costs, the mostly very high network temperatures and the seasonal mismatch between supply and demand.

Task 55 of the IEA Solar heating and cooling technology cooperation program provides a platform for practitioners and scientists to elaborate the benefits and challenges of solar district heating (SDH) and solar district cooling (SDC) systems. As part of Task 55, Subtask A focusses on the assessment of the impact of solar thermal technologies on the overall district heating and cooling network and integration aspects in order to analyze barriers and opportunities for maximizing the share of solar thermal energy.

During the first year, the work in Subtask A focuses mainly on the set-up of the overall structure including a detailed work plan as well as analyzing and consolidating the international activities and projects from the Task 55 participants. However, some preliminary results already show the strengths (especially small running costs), weaknesses (especially the high specific investment costs and a competition to renewable or must-run base load supply), opportunities (especially decreasing temperature levels and possible subsidies) and threats (especially long payback times) for a large scale integration of solar energy into existing and new DH networks. More results from Subtask A can be expected in the next years.

The international cooperation between IEA SHC Task 55, Subtask A and the IEA DHC TCP will lead to a more holistic understanding of integrated systems with a clear focus on achieving a high share of solar thermal supply in DH networks by following up on some best-practice examples from Denmark and the current discussions in Graz. Both TCPs show significant expertise, which in the past had mainly been focused on each system individually. In a future energy system, the different sectors have to be highly integrated to reflect developments not only in Task 55, but also in other IEA TCPs.

Finally, it should be mentioned, that the integration of solar thermal energy can trigger some significant synergies: most of the measures supporting the integration of solar thermal energy also support the integration of other renewable and alternative energy sources such as heat pumps, geothermal energy and industrial waste heat. Although being in competition to each other, especially seasonal storages are a key element for the other sources as well. Additionally, the integration of various heat sources and efficiency measures will require an overall management strategy, supporting also the integration of solar thermal energy.

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