Technology Position Paper

Integration of Large-Scale Solar Heating and Cooling Systems into District Heating and Cooling Networks

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Contents

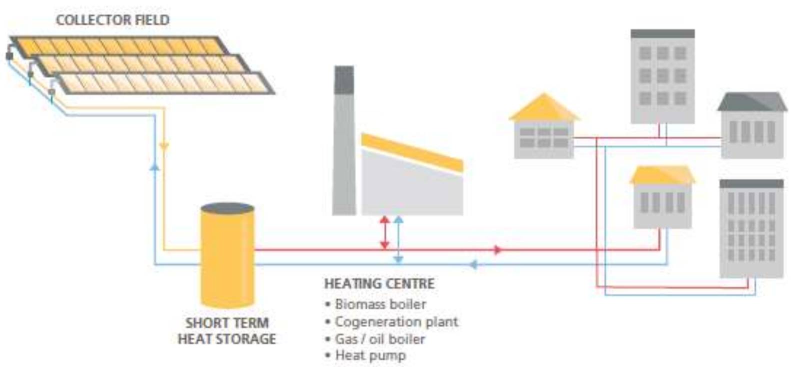
This document was prepared by Sabine Putz, SOLID Solar Energy Systems, Austria and Operating Agent of *IEA SHC Task 55: Towards the Integration of Large-Scale Solar Heating and Cooling Systems into District Heating and Cooling Networks o*f the Solar Heating and Cooling Technology Collaboration Programme with inputs from Task 55 Experts.

This position paper explains the relevance, potential and current status of large-scale solar thermal heating and cooling systems, including large-scale heat pumps and seasonal storages, leading to actions needed to further and best exploit their integration in district heating and cooling networks. It addresses policy and decision-makers as well as influencers and aims to present high-level information as a basis for uptake and further development.

1 Introduction and Relevance

Renewable sources represent a main component of a sustainable energy supply in the urban environment. Nowadays, traditional supply technologies and infrastructures are experiencing big challenges, which are introducing significant changes in how energy is stored and distributed. In this evolution, new, economically attractive, and technologically innovating possibilities for solar thermal energy are emerging in European towns and beyond. Large solar thermal plants offer a significant potential to reduce the usage of fossil fuels and save CO2 emissions.

In terms of the large market potential and reachable heat generation costs, the competition of large solar thermal plants against conventional and other renewable energy sources is a barrier. If solar thermal district heating and cooling is to seize the opportunity of this increasing market potential, then an optimized integration and design of complex systems, targeted transformation strategies, and new financing models are necessary.



Example of a simple large-scale solar thermal system integration into district heating.

An important innovation in the IEA SHC's recent work on the topic, Task 55: Integrating Large Solar Heating and Cooling Systems into District Heating and Cooling Networks, was the analysis of solar thermal systems supplying heating and cooling networks with high thermal shares. Contrarily to previous studies, in which solar thermal covered low network shares, a holistic approach was necessary for successful large-scale integration. This approach resulted in extensive information material for district heating suppliers, investors, urban planners, and various other stakeholders. It also aimed to evaluate economically optimized transformation strategies for the entire heating net – reduction in grid operating temperatures, development of efficient algorithms for operation optimization and control, integration of seasonal thermal energy storage, and analysis of the impact of decentralized supply on the net hydraulics.

2 Current Status

First Solar District Heating Installations

The first large-scale solar heat networks were deployed in the USA and Europe around the 1970s.

In Europe, the first solar heat networks were installed in Sweden. In 1979 and 1980, solar heating plants were connected to newly built residential areas in Ingelstad, outside the city of Växjö, and in Lambohov, outside the city of Linköping.

The first solar heat network in Denmark was put into operation in the spring/summer of 1985 in Vester Nebel. It consisted of 296 m^2 of flat plate collectors installed on the field in front of the district heating substation (straw and oil) and supplied approximately 100 houses with solar heat.

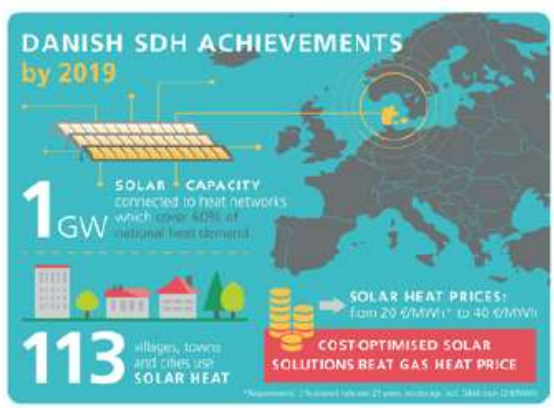
First solar thermal district heating plant at Northview Junior High School (USA) designed and installed by Honeywell in 1974.

First solar district heating plan in Saltum, Denmark, installed by Saltum Varmevaerk.

Solar District Heating Today

Denmark is the leading country in solar thermal district heating and recently set a world record.

Silkeborg: Harnessed solar energy meets 20 % of annual heat demand from 21,000 households.
PHOTO: ARCON-SUNMARK



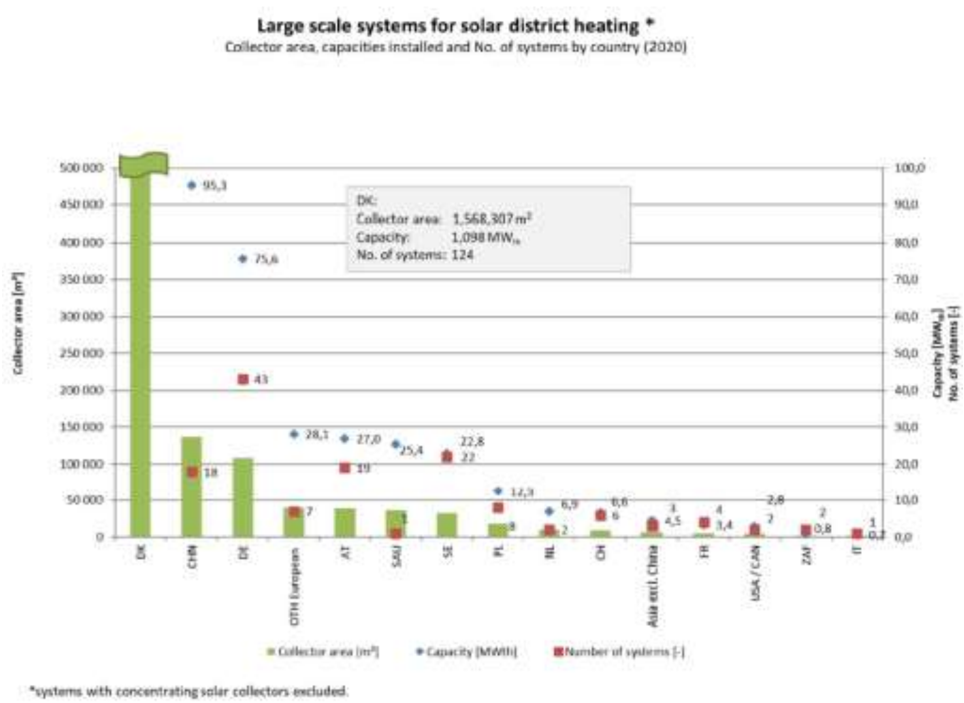
Denmark's largest solar district heating installation (left).
Danish solar district heating achievements – 1GW by 2019 (right).

Denmark aspires to transition to a low-emission society and an energy system independent of fossil fuels by 2050. Presently, the share of renewable energy in total primary energy consumption is 37%, indicating that fossil fuels still contribute substantially to Danish energy consumption. For the electricity consumption, 61% is supplied by renewable energy, mainly due to large wind power production, delivering 46% of the total electricity demand.

Worldwide, Denmark is a good example of a mature and commercial solar district heating market, but other markets are catching up, especially China. In several other countries, smaller niche markets exist, such as in Austria, where 28 systems >500 m² feed into district heating networks, smaller microgrids in urban areas, and local biomass heating networks and supply energy to large residential, commercial, and public buildings. Other countries to note are Germany with 43 large-scale systems (some of these with seasonal storage), Sweden (22 systems), France (17 systems), Poland (14 systems), Greece (13 systems), and Switzerland (10 systems). Although Germany is currently considered a niche market relative to Denmark, accelerated market growth is observable. In some countries (for example, the Netherlands, Poland or UK), new incentive programs for large-scale solar heating are currently coming up. And, Canada's Drake Landing Solar Community, operating since 2007, is proof that solar district heating can maintain very high solar fraction renewable energy systems, over 90%, even in locations like Alberta, Canada, where temperatures range from -33°C to 28.3°C.

Solar District Heating Systems by 2020

By the end of 2020, 262 large-scale solar district heating systems (>350 kWth; 500 m²) with an installed capacity of 1.410 MWth (2.01 million m²) were in operation. As can be clearly seen in the following figure, Denmark leads this market segment in terms of both the number of systems and the installed area. In addition to Denmark (124 systems) and China (18 systems), a number of other countries are showing an increasing interest in this type of plant, as they offer an excellent opportunity for decarbonizing the heat sector in neighborhoods and entire cities. Several countries, such as Saudi Arabia, Asia (excluding China), Japan, Kyrgyzstan, Russia, USA, Canada, and South Africa, have already started to decarbonize their district heating sector by using large-scale solar thermal systems.



Large-scale systems for solar district heating– capacities and collector area installed and number of systems in 2020 (concentrating systems and PVT collectors add up to 162,784 m²). *Source: Solar Heat Worldwide Report 2021*

3 Potential

Solar thermal systems used in residential buildings, hotels, hospitals, and district heating systems and for renewable and storable heat can significantly contribute to rapidly moving closer to a net-zero greenhouse gas emissions economy.

Solar district heating is steadily growing. This can be seen in the number of megawatt-scale systems for district heating and industrial applications. Twenty-three large-scale solar thermal systems with about 228,900 m² (160 MW_{th}) were installed in Europe in 2019. Of these installations, 15 were in Denmark (191,300 m²), including five extensions of existing systems, six in Germany (14,700 m²), one in Latvia (21,700 m²), and one in Austria (1,200 m²). Due to the new systems installed in Denmark, their market grew at a remarkable 170% in 2019.

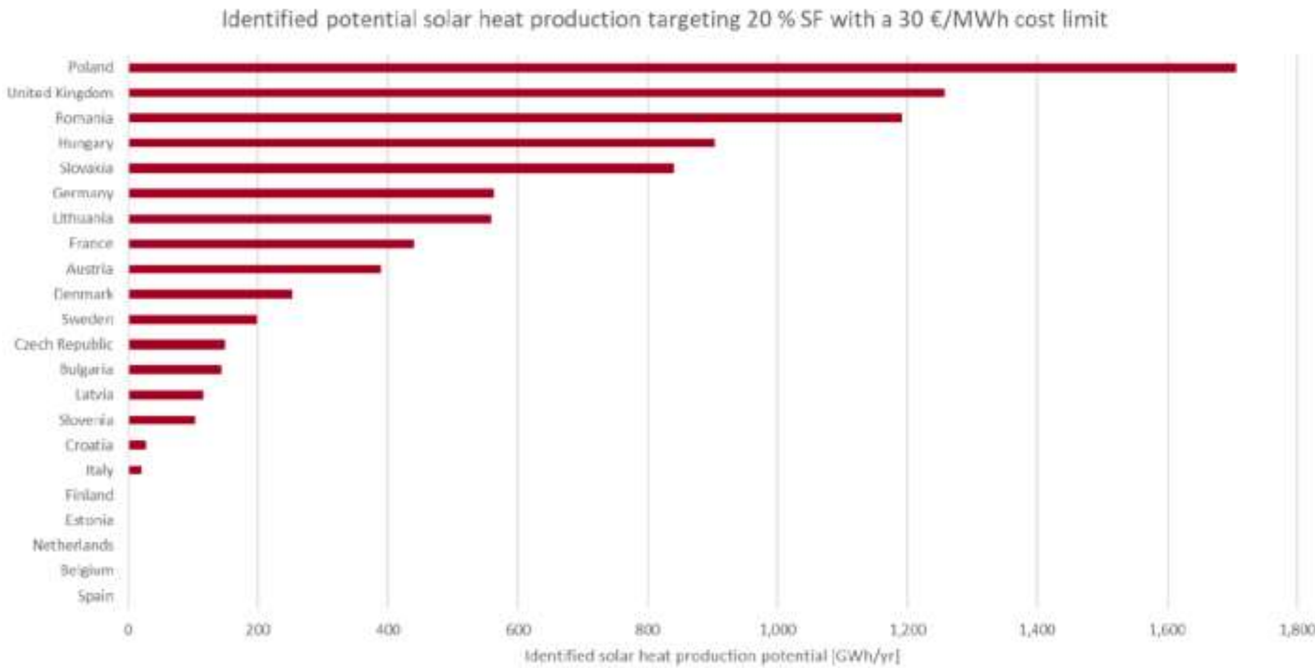
In recent years, the size of the newly installed collector areas has increased significantly. In 2016, the world's largest SDH (solar district heating) collector area was built in Denmark (157,000 m²), followed by projects in Tibetan regions (22,000 m²) in China with high solar fractions of up to 100% of the space heating demand, and the largest German plant with 14,800 m². It is expected that the trend of large-scale SDH systems will continue in the coming years and that these systems will become increasingly important for the decarbonization of the heat supply.

The EU aims to have a net-zero greenhouse gas emissions economy by 2050, as envisioned in the European Commission's 2050 long-term strategy, to meet the EU's commitment under the Paris Agreement. While renewables have made an important contribution in this area, there is still a long way to go, particularly in the heating and cooling sector.

Experts of IEA SHC Task 55 estimated the solar heat potential in Europe, assuming 20% solar fraction and solar heat cost limits between 25 and 60 €/MWh.

The figure below shows the potential solar heat production for a 30 €/MWh cost limit for countries in Europe. Poland has significant potential for solar heat as they have huge district heating networks, which can be supplied by renewable. The biggest challenge for implementing large-scale solar thermal installations is the use of land for anything other than agriculture. Currently, incentive programs for large-scale solar thermal installations are coming up in Poland.

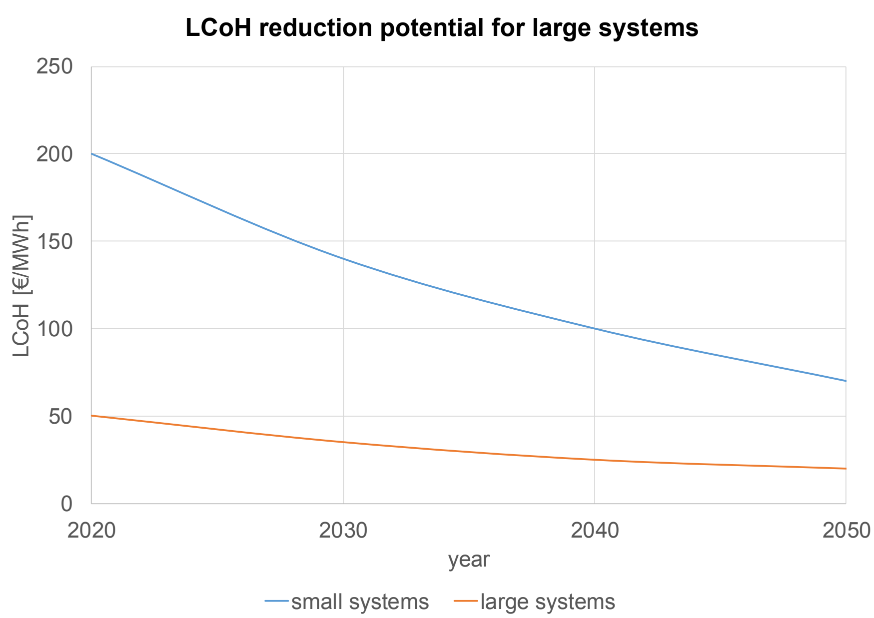
To summarize, the potential analysis indicates that a roll-out of large-scale SDH is possible and economically feasible in most countries. Solar thermal and seasonal storages in intelligent combination with other generating options can improve the feasibility of fully decarbonized DH systems.



Identified potential for solar heat production with a 30€/MWh in Europe.
Source: IEA SHC Task 52: Solar Heat and Energy Economics

Levelized Cost of Heat

The graph below shows the current situation and the cost reductions that could be achieved. The Levelized Cost of Heat (solar thermal) LCoH is in the range of 50 €/MWh for district heating systems located in mid-European climates.



The costs of both small and large systems can be significantly reduced under the following boundary conditions:

1. Overheating protection limiting the heat transfer fluid temperature below 100 °C results in lower investment costs in the heat transfer fluid loop and

lower maintenance costs.

2. Performance increase of components and overall systems results in a higher energy yield, thus lowering the LCoH even if the upfront investment for a better performing component and/or system is higher.
3. Standardization of the components, mechanical and hydraulic interfaces, and the overall systems. Standardization reduces the costs all along the value chain from the production of the components up to the installation of the systems and results in well-installed systems with lower maintenance costs and a longer lifetime, leading to a reduced LCoH.
4. Long-lasting components and systems will result in significantly reduced operating and maintenance costs.

4 Actions Needed

To support the rapid decarbonization of district heating, the table below highlights some of the challenges and the actions needed to overcome them.

Challenge	Action needed
Development of system components for solar district heating	• System technology for optimized operation of solar thermal district heating systems with seasonal storage. • Technical concepts and business models for integrating decentralized solar thermal systems into heating grids. • Technical concepts and business models for thermo-electrical smart grids with integrated solar thermal systems. • System design with increased solar thermal fraction in smart heating grids. • Integration of decentralized cooling and air-conditioning systems into solar thermal district heating systems.
Planning and implementation of large solar district heating systems	• Design and 'rule-of-thumb' rules focused on integration points. • Commissioning rules for large-scale systems improved and further tested. • Advanced concepts to support sustainable and healthy land use around cities and industrial areas for solar thermal energy. • Cost reductions in the same order of magnitude seen in the wind and PV industries.
Demonstration of large solar district heating systems	• Feasibility studies on system optimization of large projects. • Development of new low-temperature district heating systems, where

	temperatures less than 60°C-80°C are promoted as the future choice for decarbonization of heating and cooling. • Demonstration sites with medium and high-temperature collectors. • Explore retrofitting existing higher temperature district heating networks with newly developed vacuum PVT systems. Potential to increase energy yield per m^2 by 30%-50% and significantly enable PVT coupled with heat pumps to play a role in distributed and centralized solutions. • LCA and recycling of solar district heating components. • New materials and technologies for collectors, thermal energy storages, and other components to reduce costs and increase performance and reliability. • Innovative control and monitoring concepts with forced integration of new ICT technologies (e.g., new sensors, advanced self-learning, self-adapting control and monitoring strategies, communication of the solar system components, active building components, connection to the internet (e.g., using weather forecast)) and integration in the Smart Home solution to increase performance, reliability, and reduce costs.
Awareness raising	• Targeted information dissemination at the government level. • Classes and simulation tools for engineering education programs. • Better communication with storage and heat pump industry. • Targeted communication on best practices and SDH cost-effectiveness.
Simulations and validations	• Thermal system modeling and yield prediction for solar district heating. • Define KPIs based on testing and simulation solutions to ensure that the evaluation is reliable, relevant and increases sector confidence. • Develop common notations and KPI's for communicating research and field results so that comparisons are possible between different manufacturers and planner offers.