Drivers, Data, and Design: A Study of Best-Practice Solar District Heating Installations

IEA SHC TASK 68 | Solar District Heating Systems

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

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This is a report from SHC Task 68: Efficient Solar District Heating Systems, with work done in Subtask D, Activity D1: Use Cases and Dissemination

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1 List of abbreviations

ABBREVATION	MEANING
CAPEX	Capital Expenses
CHP	Combined Heat and Power
DHI	Diffuse Horizontal Irradiance
DNI	Direct Normal Irradiance
DT	Temperature difference (Delta T)
GHG	Greenhouse Gas Emissions
HVFP	High Vacuum Flat Panel
FPC	Flat Plate Collectors
GHI	Global Horizontal Irradiance
PLC	Programmable Logic Controller
PTC	Parabolic Trough Collectors
PTES	Pit Thermal Energy Storage

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3 Executive Summary

This is the final report of Subtask D-1, “Use Cases and Dissemination” of the IEA SHC Task 68: Solar Heating Systems. The work has involved literature studies and data collection from Solar District Heating installations as well as interviews with district heating companies and collector suppliers, with the goal of proving the performance of operational Solar District Heating installations to the industry and public. In addition, emphasis has been placed on drivers and challenges for each installation to give a better understanding of the current challenges related to implementation of solar thermal in district heating networks. In this study, Solar District Heating installations with different characteristics such as heat storage concepts, collector technologies and heat production synergies are investigated.

The study was conducted during spring 2024 and involved the completion of a survey questionnaire sent to district heating companies and collector suppliers. The questionnaire included four sections covering technical parameters, economy, drivers/challenges and an example day of measurement data. Where mail contact with the respondents was unsuccessful, phone interviews were conducted with site managers and engineers enabling completion of the survey.

Each chapter presents information on an operational Solar District Heating installation and starts with an overview of the facility and the listing of basic technical parameters such as solar fraction, collector area, global horizontal irradiation and supply/return temperatures in the district heating network. This is followed by a brief overview of economic data where e.g. capital cost and operational expenses are shown. The design of each plant is then described together with, where possible, a hydraulic scheme of the installation.

To give an indication of solar heat production, one day of measurement data is shown during the solar solstice in the northern hemisphere (21st of June) where irradiation, solar heat production, ambient temperature as well as in/outlet temperature of the collector field is plotted. Being an important part of the report, drivers and challenges as reported by the installation operator are presented and discussed. Each chapter is concluded by noteworthy info regarding e.g. outlook of the installation, operating benefits/challenges or considered future additions.

The study shows operational Solar District Heating installations in combination with heat storages are effective in increasing annual solar fraction and the use of renewables in district heat production. Depending on heat demand coverage and substituted fuels, the use of Solar District Heating results in substantial CO_2 reductions and can cover up to 100% of the heat demand during summer. In most cases, existing subsidies and favourable business models have been instrumental for the realization of each project, where solar thermal in some cases has been the only competitive alternative to a reduced heat price and lowered CO_2 emissions. As reported by the installation owners, cost savings, reduced greenhouse gas emissions and increased use of renewables have been important drivers for each installation.

As reported by the owners of respective installations, a successful implementation of Solar District Heating is dependent on favourable business models and the environmental policies and goals of respective district heating utility. Additionally, the fuel mix currently used for heat production and the price for combustibles play an important part in the decision process for solar thermal. Common factors, as reported by the installation operators, for a successful operation of a Solar District Heating installation include quality of installation work and hardware (collectors, piping, control systems).

4 Introduction

Currently, thermal energy constitutes half of the total end-use of energy in the world and is therefore regarded as an important target for CO_2 reduction and energy efficient measures. Solar thermal (ST) heat production for industrial applications and for district heating (DH) enhances the reduction of greenhouse gas emissions, contributes to fuel flexibility and reduces the dependency on combustible fuels (Renaldi & Friedrich, 2019). The use of ST in DH production also contributes to European goals on climate neutrality and energy efficiency (Swedish Energy Agency, 2023).

As reported by Weiss and Spörk-Dür (2023), the world-wide annual ST energy yield reached 442 TWh by the end of 2022 corresponding to approximately 153 million tons of CO_2-reduction, if assumed to replace oil. During the same year, 41 new large-scale (>350 kW_{th}) solar heating plants for DH, residential, commercial and public buildings were commissioned. The number of operational ST installations have steadily increased since 2000, but it has not been until the last ten years that the concept of Solar District Heating (SDH) has become well-known to the public. Among the first countries to embrace the concept of SDH were Denmark and Germany, with SDH installations still operating after more than 20-years.

In some European countries, the price of biomass has more than doubled over the last few years (*Trädbränsle-, torv- och avfallspriser*, 2024). The increased cost has led heat producers to increase their efforts in finding more sustainable, less price dependant ways for heat production. Combined with greater awareness of concepts like carbon neutrality, producer responsibility and life cycle assessments has enhanced the interest for large scale applications of ST in DH applications.

An increased use of solar thermal in the energy mix can be seen as contributing to the 2050 Paris agreement. The *IEA Net Zero Emissions Outlook* predicts solar thermal power to be the main source for hot water production and constitute up to 35% of total hot water production 2050. Expected market growth is predicted in countries with high solar irradiation, but the technology is also viable in the northern hemisphere due to use of different heat storage technologies.

As stated in *Solar Heat Worldwide* (2023), flat plate collectors (FPC) are dominating the European market while evacuated tube collectors are predominant in Asian countries. As a rule of thumb, other collector technologies such as parabolic trough collectors (PTC) can provide heat in a wider temperature range, making them more viable for high-temperature DH networks frequently occurring throughout Europe. In some cases, supply temperatures between 80-120 °C is needed, putting demands on collector performance an efficiency.

The implementation of solar thermal power in the DH network is highly dependent on the current technical and non-technical (legislations, emission-related taxes, subsidies etc.) conditions in the country. As a reference, Denmark is regarded as one of the leading countries with the highest number of SDH plants per capita due to favourable taxes on fossil fuels, support policies and a low relative heat price.

In this report, an overview of European commissioned SDH installations with varying characteristics is given with the goal of promoting the use of SDH to the industry and the public. Each chapter contains information on technical parameters, economy, design and drivers/challenges for the respective installation. The data presented in the report is derived from literature, interviews and data collection templates sent out to solar thermal installers and DH utilities.

5 Solar District Heating installations

5.1 Silkeborg, Denmark

5.1.1 Overview

The installation in Silkeborg currently holds the position as the world's largest SDH installation in operation. The plant is situated in the middle of Denmark and consists of 12 535 large flat plate collectors occupying a total land area of 156 694m^2. The installation is supported by four 16 000m^3 thermal storage tanks and has a nominal power of 110 MW. Technical data for the installation is shown in Table 1.

Table 1. Technical parameters for the installation.

TECHNICAL PARAMETERS	VALUE	UNIT
COLLECTOR AREA	156 694	m^2
TOTAL AREA OF INSTALLATION	534 000	m^2
NO. OF COLLECTORS	12 535	Pcs.
NO. COLLECTORS IN SERIES	20	Pcs.
COLLECTOR TYPE	FPC Arcon-Sunmark HEATstore (70%) Arcon-Sunmark HEATboost (30%)	Type
COLLECTOR EFFICIENCY	70% (ΔT = 40 K)[1]	%
HEAT CARRIER FLUID	30% propylene glycol/70% DH water	Type
INSTALLED THERMAL POWER	110	MW
HEAT PRODUCTION (YEAR)	72 000	MWh/y
SOLAR FRACTION	17-20	%
SPECIFIC PRODUCTION (YEAR)	640	kWh/kW/y
GLOBAL HORIZONTAL IRRADIATION	976,9	kWh/m^2/y
HEAT STORAGE TYPE	Tank	Type
HEAT STORAGE VOLUME	4 × 16 000	m^3
CO_2 SAVING (YEAR)	15 000	Ton/y
SYSTEM LIFETIME	25	Year
COMMISSIONING DATE	2016-12-31	Date
ADDITIONAL HEATING SOURCES	Gas, electricity, oil, surplus heat	Type
AVG. OPERATIONAL TEMPERATURE	60-95	˚C
DISTRICT HEATING SUPPLY TEMPERATURE	63-80	˚C
DISTRICT HEATING RETURN TEMPERATURE	35-45	˚C
PIPING: SOLAR FIELD-HEX CENTRAL (TYPE, LENGTH)	Standard Logstor DH piping, 21 km.	Type, Length
CONTROL SYSTEM	ABB 800xA	Type
PUMPS	Grundfos NBG	Type
FREQUENCY CONVERTERS	Danfoss VLT	Type

The 2016 commissioning of the plant achieved the municipality's goal of reducing emissions by 45% by 2020. The plant is operated and owned by the municipal utility of Silkeborg Supply and covers the yearly heat demand of 4 400 of the 22 000 households connected to the system. The plant had a capital cost of 33 000 000 euro. Table 2 shows economical parameters over the installation.

5.1.1.1 Economy

The installation was funded by bank loan and had a capital cost of 33 000 000 euro. Economic parameters over the installation are shown in Table 2.

[1] $\Delta T = T_m - T_a$ (T_m … mean heat carrier temperature, T_a … ambient temperature)

Table 2. Economical parameters over the installation.

PARAMETER	VALUE	UNIT
CAPITAL COST	33 000 000	Euro
OPERATION COST		Euro/year
SUBSIDIES	Energy saving subsidy: First year’s production	
BUSINESS MODEL/FUNDING	Bank loan	

5.1.2 Design

The installation is connected to other heat production facilities in the area like biomass and electric boilers. Low temperature heat from the collectors is utilized by combining heat production from the different heat sources. A project with an electric driven heat pump is under development where the heat pump will increase heat output from the PTES in the wintertime. An overview over the installation is shown in Figure 1. The installation is divided into 13 sections A-M, each section including 3100-3200 collectors each.

Figure 1. Overview over the installation in Silkeborg (left) and schematic showing the different sections and piping of the installation. (right). Source: Silkeborg Forsyning AB

5.1.3 Measurement data

Measurement data (2023-06-21) from the installation in Silkeborg is presented in Figure 2.

The figure shows solar production is active between approximately 13.00-20.00, with the heat production profile mainly correlating with the irradiation data. The outlet temperature reaches 80˚C around 17.00, with the inlet temperature being relative stable at 45˚C.

5.1.4 Drivers and challenges

5.1.4.1 Drivers

The municipality of Silkeborg has the goal to make DH CO_2-neutral before 2030. Reduced price dependency on other fuels and cheaper heat production have been important factors prior the construction of the plant. A subsidy was given by the state corresponding to first year’s estimated heat production. Drivers for the installation, as reported by the owner, are shown in Table 3.

5.1.4.2 Challenges

With Denmark having had beneficial subsidies promoting solar thermal power in the past, distinctive factors inhibiting further development of SDH plants is the lack of subsidies and tax incentives. Other factors, as reported by the owner of the site, inhibiting the construction of SDH plants are presented in Table 4.

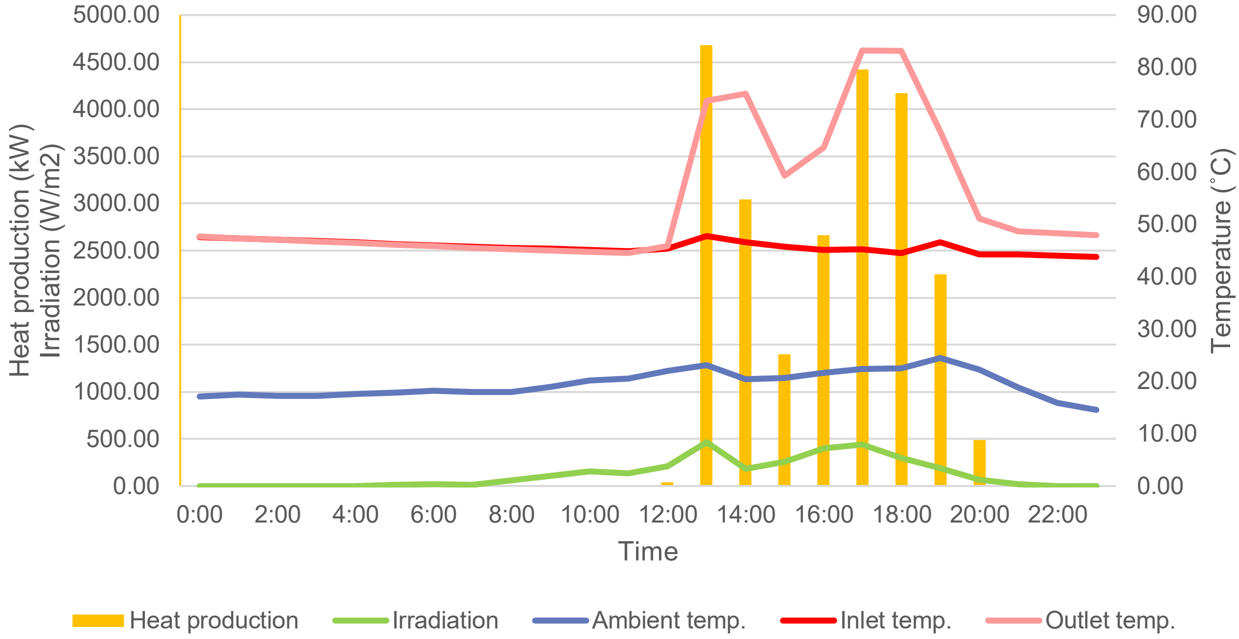

Figure 2. Measurement data[2] from the installation in Silkeborg (2023-06-21).

Table 3. Drivers for the installation of Silkeborg.

FACTOR	DESCRIPTION
REDUCING CO_2 EMISSIONS	The Silkeborg municipality have a goal to make DH CO_2 neutral by 2030.
HEAT PRICE REDUCTION	Reducing fuel price dependency and heat prices.
ENERGY SAVING SUBSIDY (NO LONGER IN EFFECT)	An energy saving subsidy for first year's estimated production was given by the state of Denmark.
FUEL DIVERSITY	Diversity in heat production bringing resilience to the sector.
REVISION ENHANCEMENT	The high heat production during summer enhances and extends revision and service on existing plants and facilities.
PUBLICITY	Renewable energy sources bring good publicity to the municipality.
LIMITED OPTIONS	Regulatory bonds made Solar Thermal one of the only feasible options for the municipality.

Table 4. Challenges for the installation of Silkeborg.

FACTOR	DESCRIPTION
HIGH TEMPERATURES	Solar thermal power is dependent on effective DH networks. Many large networks in Europe are running on high temperatures (>110˚C), making the integration of solar thermal power difficult (FPC temperature range = 30-80˚C).
LOBBYING	Lobbying from competing technologies may influence political agendas.
POLITICAL DECISIONS ON TAXES	In Denmark, taxes on electricity to heat has been removed, resulting in construction of several electrical-powered plants.
SURFACE AREA REQUIREMENT	SDH installations require a substantial amount of surface area that may be a scarce and expensive commodity in urban areas.

5.1.5 Noteworthy

At present, no current plans on expanding the plant are present. Future expansion of the plant would demand further development of the pit storage, which at present is deemed too expensive compared to alternatives.

[2] The time resolution on received data from installations vary.

5.2 St. Ruprecht, Austria

5.2.1 Overview

The installation of St. Ruprecht was commissioned in 2020 and later complimented with a second installation in 2023 due to increased heat demand in the DH network. Both installations feature a 247m^3 storage tank and together constitute an aperture area of 1 800m^2 with a nominal power of 1,4MW. Highly efficient powerSol collectors and optimised system planning result in high solar yields and very low DH return temperatures. Technical data for the installation is shown in Table 5.

Table 5. Technical parameters for the installation.

TECHNICAL PARAMETERS	VALUE	UNIT
APERTURE AREA	1 800	m^2
TOTAL AREA OF INSTALLATION	4 350	m^2
NO. OF COLLECTORS	144	Pcs.
COLLECTOR TYPE	FPC powerSol 136	Type
COLLECTOR EFFICIENCY	62	%
HEAT CARRIER FLUID	corroStar (additives for frost and corrosion protection)	Type
INSTALLED THERMAL POWER	1.4	MW
HEAT PRODUCTION (YEAR)	1 125	MWh/y
SOLAR FRACTION	15	%
SPECIFIC PRODUCTION (YEAR)	804	kWh/(kW y)
GLOBAL HORIZONTAL IRRADIATION	1 216	kWh/(m^2 y)
HEAT STORAGE TYPE	Tank	Type
HEAT STORAGE VOLUME	2 × 247	m^3
CO_2 SAVING (YEAR)	<25	Ton/y
SYSTEM LIFETIME	30	Year
COMMISSIONING DATE	1st=2020, 2nd=2023	Date
ADDITIONAL HEATING SOURCES	Biomass	Type
AVG. OPERATIONAL TEMPERATURE	88	˚C
DISTRICT HEATING SUPPLY TEMPERATURE	80	˚C
DISTRICT HEATING RETURN TEMPERATURE	45	˚C
PLANT PIPING (TYPE, LENGTH)	Logstor, 290 m	Type, Length

The installation is considered an important and sustainable step in supporting the DH system in St. Ruprecht.

5.2.1.1 Economy

The capital cost of the first and second installation was 750 000 (1 587m^2 gross area, 1 080kW$_p$) and 310 000 (366 m^2 gross area, 320 kW$_p$) euro, respectively. 45% of the capital costs were funded by the Climate and Energy Fund and were carried out under the program “Large Solar Plants”. Economic parameters over the installation are shown in Table 6.

Table 6. Economical parameters over the installation.

PARAMETER	VALUE	UNIT
CAPITAL COST	I: 750 000, II: 310 000	Euro
OPERATION COST[3]	1 700	Euro/y
SUBSIDIES	-	Euro
BUSINESS MODEL/FUNDING	45% funding from Climate and Energy Fund[4]	

5.2.2 Design

The installation consists of 16 parallel connected rows featuring nine series connected collectors respectively. An overview of the installation is given in Figure 3.

Figure 3. Overview over the installation (left) and overview over the collector field and biomass boiler (right). Source: Nah Wärme St. Ruprecht

Design parameters for the installation are shown in Table 7.

Table 7. Design parameters for the installation.

PARAMETER	VALUE	UNIT/TYPE
CONTROL SYSTEM	Schneid Ges. m.b.H.	
NO. COLLECTORS IN SERIES/ROW	9	Pcs.
NO. ROWS	16	Pcs.

5.2.3 Measurement data

Measurement data (2023-09-15) from the installation in St. Ruprecht is presented in Figure 4.

The figure shows an active solar production between approximately 09.00-18.00, with the heat production profile mainly correlating with the irradiation data. The outlet temperature reaches its peak of 84˚C at approximately 15:20. The inlet temperature varies between approximately 30 and 60˚C and follows the outlet temperatures time profile.

[3] Operational costs include maintenance, electricity costs and grassland maintenance costs.
[4] https://www.klimafonds.gv.at/solare-grossanlagen/

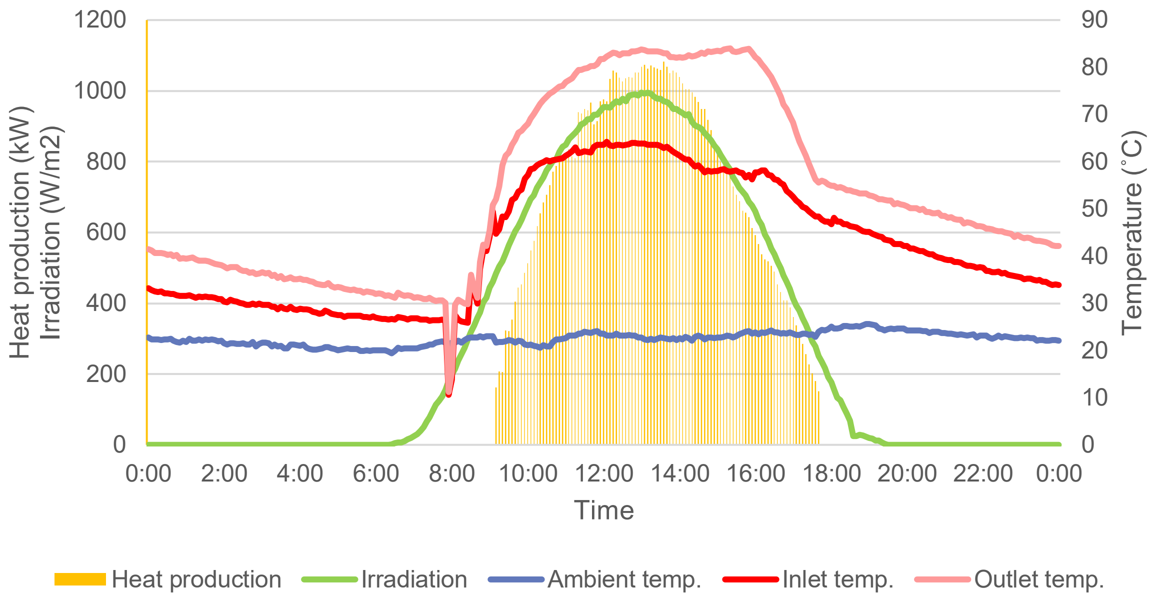

Figure 4. Measurement data from the installation in St. Ruprecht (2023-09-05).

5.2.4 Drivers and challenges

5.2.4.1 Drivers

The decisive factor for the integration of solar thermal energy in the DH network in St. Ruprecht was the sustainability aspect and the reduced fuel price. Drivers for the installation are shown in Table 8.

Table 8. Drivers for the installation of Silkeborg (site-owners perspective).

FACTOR	DESCRIPTION
SUSTAINABILITY	The SDH installation help reduce greenhouse gas emissions from the total DH production. Most of the components in a solar thermal system can be recycled.
REDUCED FUEL PRICES	The installation is designed to cover over 70% of the heat demand during June-August. This help reduce fuel prices for the DH production in St. Ruprecht.
NO NOICE POLLUTION	Solar thermal power is produced without any noise pollution.
LOW MAINTENANCE	Compared to other heat production sources, solar thermal power can be regarded as low maintenance.
DURABLE	Older installations have proven solar thermal power to be durable and reliable.
SURFACE AVAILABILITY	An incentive to construct the installation was patches of unused land not being cultivated by neighbouring farmers.
FUNDING	45% of the capital cost were covered by the Climate and Energy fund.

5.2.4.2 Challenges

The main challenge prior the construction of the installation was the capital cost. Nah Wärme St. Ruprecht is emphasizing on the continuation of subsidies for solar thermal power systems to develop the sector further.

5.2.5 Noteworthy

The second installation was commissioned in 2023 to maximize summer heat demand coverage.

5.3 Geneva, Switzerland

5.3.1 Overview

The installation of Geneva was constructed to support Services Industriels de la Ville de Geneve (SIG) in the energy transition by replacing an older PV installation with a solar thermal system. The project was initiated in 2019 under the name "SOLARCADII" with TVP as chosen supplier. Technical data for the installation is shown in Table 9.

Table 9. Technical parameters for the installation.

TECHNICAL PARAMETERS	VALUE	UNIT
APERTURE AREA	784	m^2
TOTAL AREA OF INSTALLATION	1 700	m^2
NO. OF COLLECTORS	400	Pcs.
COLLECTOR TYPE	HVFP TVP MT-Power	Type
COLLECTOR EFFICIENCY	67,3% (peak)	%
HEAT CARRIER FLUID	Water/glycol mix	Type
INSTALLED THERMAL POWER	0,546	MW
HEAT PRODUCTION (YEAR)	539	MWh/y
SOLAR FRACTION	< 0,5%	%
SPECIFIC PRODUCTION (YEAR)	650	kWh/(kW y)
GLOBAL HORIZONTAL IRRADIATION	1 206	kWh/(m^2 y)
HEAT STORAGE TYPE	-	Tank
HEAT STORAGE VOLUME	-	4 ×16 000 m^3
CO_2 SAVING (YEAR)	130	Ton/y
SYSTEM LIFETIME	25	Year
COMMISSIONING DATE	2020-12	Date
ADDITIONAL HEATING SOURCES	Biomass	Type
OPERATIONAL TEMPERATURE	75-85	˚C
DISTRICT HEATING SUPPLY TEMPERATURE	90 (summer)-115 (winter)	˚C
DISTRICT HEATING RETURN TEMPERATURE	72	˚C
PLANT PIPING (TYPE, LENGTH)	-	Type, Length

With the relatively low solar fraction, heat storages were considered not relevant during the construction of the installation. The DH network operates under high temperatures between 90-115 ˚C, where yearly heat losses in the DH network is estimated to 10%.

5.3.1.1 Economy

The total capital cost for the installation was estimated to 2 120 000 euro, of which the solar field constituted merely 850 000 euro. Additional costs were constituted by i.e. architects, civil engineering and painting. Economic parameters over the installation are shown in Table 10.

Table 10. Economical parameters over the installation.

PARAMETER	VALUE	UNIT
CAPITAL COST	2 120 000	Euro
OPERATION COST[5]	5,30-8,50	Euro/(m^2 y)
SUBSIDIES	130 000 subsidy from Swiss climate foundation	Euro
BUSINESS MODEL/FUNDING	2/3 CAPEX paid by end-user of the installation. 1/3 paid over 20 y based on performance.	

[5] Operational costs include maintenance, electricity costs and grassland maintenance costs.

5.3.2 Design

The installation features a field of collectors constructed on a 1 700 m^2 metallic structure situated close to the DH network. The collectors are arranged in 50 rows with 8 collectors in series in each row. The collector field is constructed with an azimuth angle of 4˚ and a collector tilt of 17,5˚. Figure 5 shows an overview of the installation.

Figure 5. Overview over the installation (left) and the heat transfer station (right) located under the metallic structure.
Source: TVP Solar

The installation features two circulation pumps with flow rates varying between 5-23 m^3/h with a 500 kW plate heat exchanger in the heat transfer station. Extensive weather monitoring is used featuring measurements on DNI/DHI/GHI, ambient temperature, wind speed/direction and relative humidity. PLC loops regulating the solar loop and heat transfer to the district heating network are used in combination with PLC communication via Modbus. Recorded data is collected from a TVP PLC and sent to a SIG server for monitoring. A simplified flow chart over the installation is shown in Figure 6.

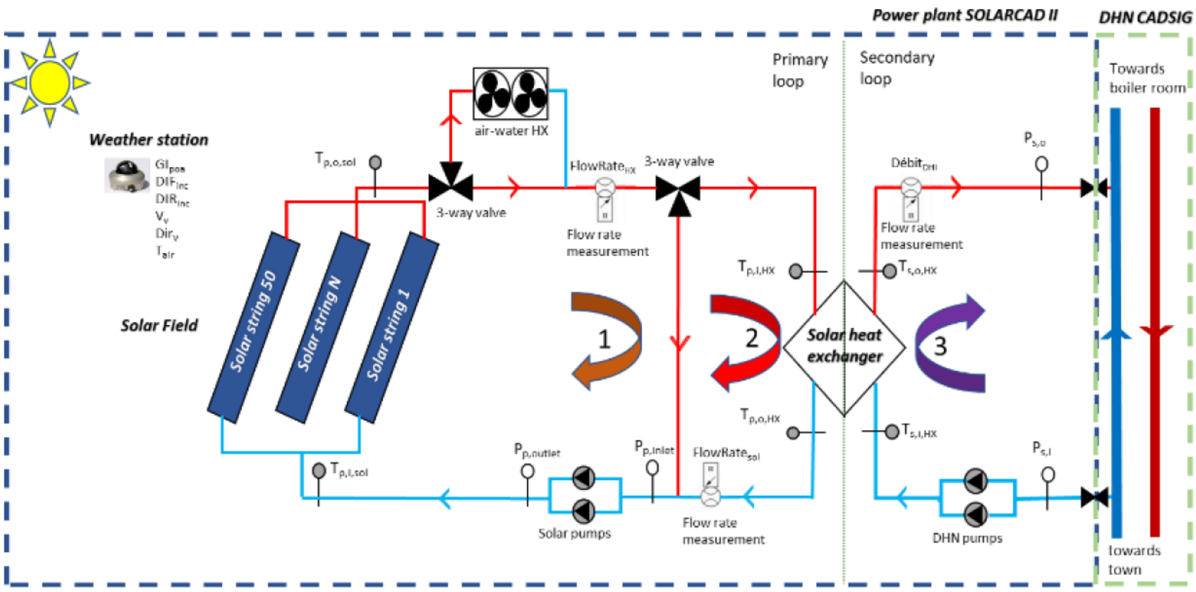

Figure 6. Principle sketch showing essential components and working principle of the installation.
Source: TVP Solar

5.3.3 Measurement data

Measurement data (2021-09-15) from the installation in Geneva is presented in Figures 7-8.

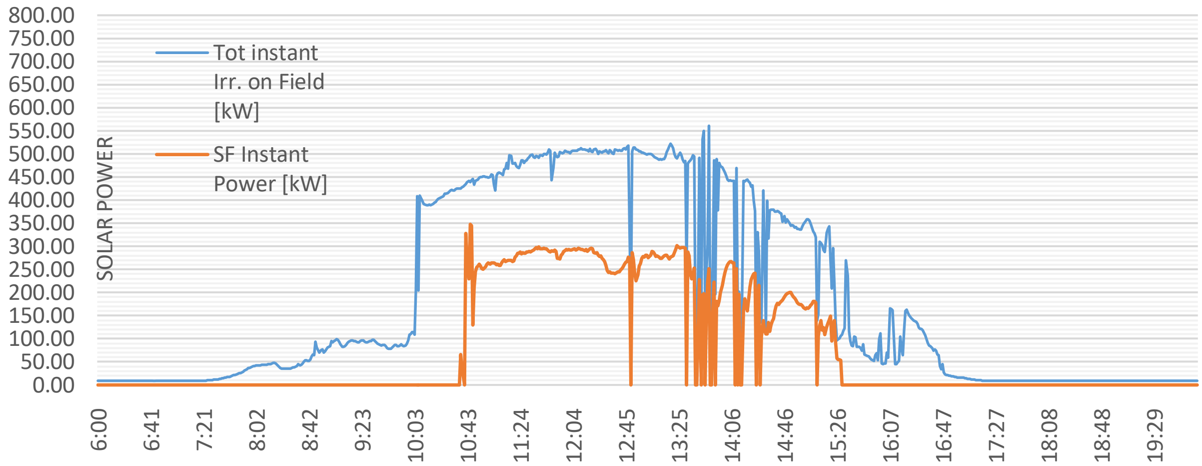

Figure 7. Heat production and irradiation (2021-09-15) from the installation in Geneva. Source: TVP Solar

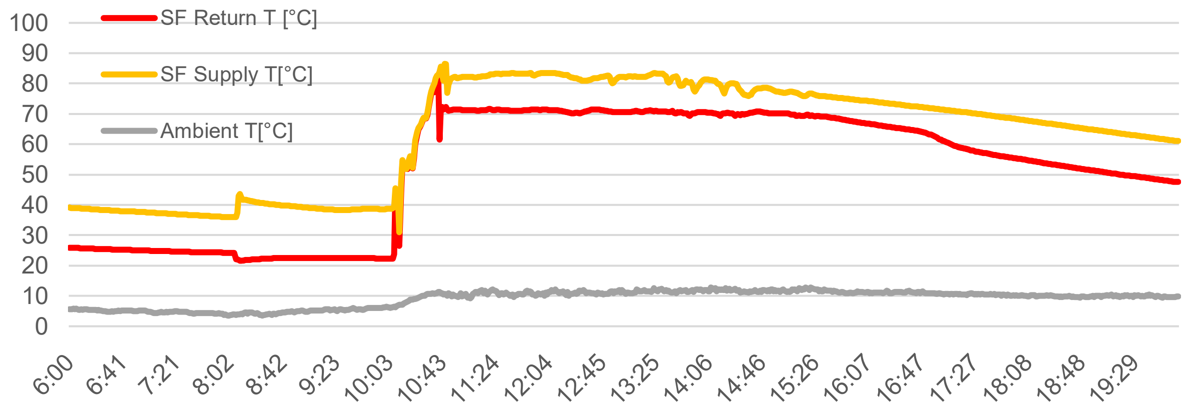

Figure 8. Supply/return temperatures (2021-09-15) from the installation in Geneva. Source: TVP Solar

The figures show heat production mainly correlates with the irradiation data with a peak power production of approximately 350 kW at 10:50. Heat production is active between approximately 10:45-15:30, with the outlet temperature (Supply T) reaching its peak 85 ˚C at 11:00.

5.3.4 Drivers and challenges

5.3.4.1 Drivers

The project was initiated to enable a renewable heat supply in the DH network of SIG. Additionally, separate goals of plant monitoring and optimisation were decided on:

1. Optimisation of usable solar heat production
2. Validation of theoretical performance of the installation
3. Stabilise solar heat production over time
4. Assess the potential for SDH in Switzerland

Drivers for the installation, as reported by the owner, are shown in Table 11.

Table 11. Drivers for the installation of Silkeborg.

FACTOR	DESCRIPTION
SUSTAINABLE HEAT PRODUCTION	SIG's goal of sustainable heat production and energy transition motivated use of solar thermal power in the DH network.
REPLACEMENT OF OLDER POWER GENERATION	With the abolishment of an older PV installation, surface area was made available and used to replace old sustainable power production with new.

5.3.4.2 Challenges

Factors inhibiting the construction of SDH plants, as reported by the site manager, are presented in Table 12.

Table 12. Challenges for the installation of Silkeborg.

FACTOR	DESCRIPTION
SPACE AVAILABILITY	SDH installations take up a lot of space and is commonly constructed close to the original DH facility where land availability could be scarce.
BOILER DECREASED EFFICIENCY	Adding solar thermal to DH networks already operating on biomass boilers may result in decreased boiler efficiency.

5.3.5 Noteworthy

Currently, a feasibility study for a second project on an additional connection point in the DH network is ongoing. Regarding the development of SDH, TVP emphasizes on using unused land for collector fields to save biomass for winter by replacing it with solar thermal power during summer.

5.4 Mürzzuschlag, Austria

5.4.1 Overview

The installation of Mürzzuschlag consists of collectors from multiple manufacturers and is connected to 7 accumulator tanks à 60 m^2, respectively. Additional heat production sources in the DH network consists of gas and biomass boilers. The installation was commissioned in 2020 to maximise solar fraction during summer months and minimise combustion of natural gas. The installation features an aperture area 7 000 m^2 with an installed power of 5 MW. Technical data for the installation is shown in Table 13.

Table 13. Technical parameters for the installation.

TECHNICAL PARAMETERS	VALUE	UNIT
APERTURE AREA	6 850	m^2
TOTAL AREA OF INSTALLATION	17 000	m^2
NO. OF COLLECTORS	426 KBB K5Giga+ 60 Gasokol GigaSol 136 48 Ensol DIS 150	Pcs.
COLLECTOR TYPE	FPC	Type
COLLECTOR EFFICIENCY	-	%
HEAT CARRIER FLUID	Propylene glycol 40%	Type
INSTALLED THERMAL POWER	4,8	MW
HEAT PRODUCTION (YEAR)	3 014	MWh/y
SOLAR FRACTION	11	%
SPECIFIC PRODUCTION (YEAR)	628	kWh/(kW y)
GLOBAL HORIZONTAL IRRADIATION	1 176	kWh/(m^2 y)
HEAT STORAGE TYPE	7 tanks	Tank
HEAT STORAGE VOLUME	7 x 60	m^3
CO_2 SAVING (YEAR)	663	Ton/y
SYSTEM LIFETIME	20	Year
COMMISSIONING DATE	2020, extension of plant completed 2023	Date
ADDITIONAL HEATING SOURCES	Biomass, natural gas	Type
OPERATIONAL TEMPERATURE	90	˚C
DISTRICT HEATING SUPPLY TEMPERATURE	80	˚C
DISTRICT HEATING RETURN TEMPERATURE	60	˚C
PLANT PIPING (TYPE, LENGTH)	-	Type, Length

The installation was awarded the Energy Globe of Styria for exemplary function and took part in large-scale research project ThermaFLEX, was awarded the Energy Globe Austria in June 2023. It is constructed close to the DH network on a former ski slope.

5.4.1.1 Economy

The installation is financed through a heat purchase agreement and received funds from the Climate and Energy fund, the Province of Styria and Land Steiermark. To ensure stable operation and minimize risk for customers, an ESCo contract was established between the supplier SOLID and the customers.

5.4.2 Design

The collector field consists of collectors from different manufacturers and feeds into to storage tanks providing heat to the DH systems om Mürzzuschlag. A control system ensures optimal operation together with the biomass and gas boilers in the DH network. An overview of the installation is shown in Figure 9.

Figure 9. Overview of the installation in Mürzzuschlag.
Source: SOLID Solar Energy Systems

5.4.3 Measurement data

Measurement data (2023-08-12) from the installation in Mürzzuschlag is presented in Figure 10.

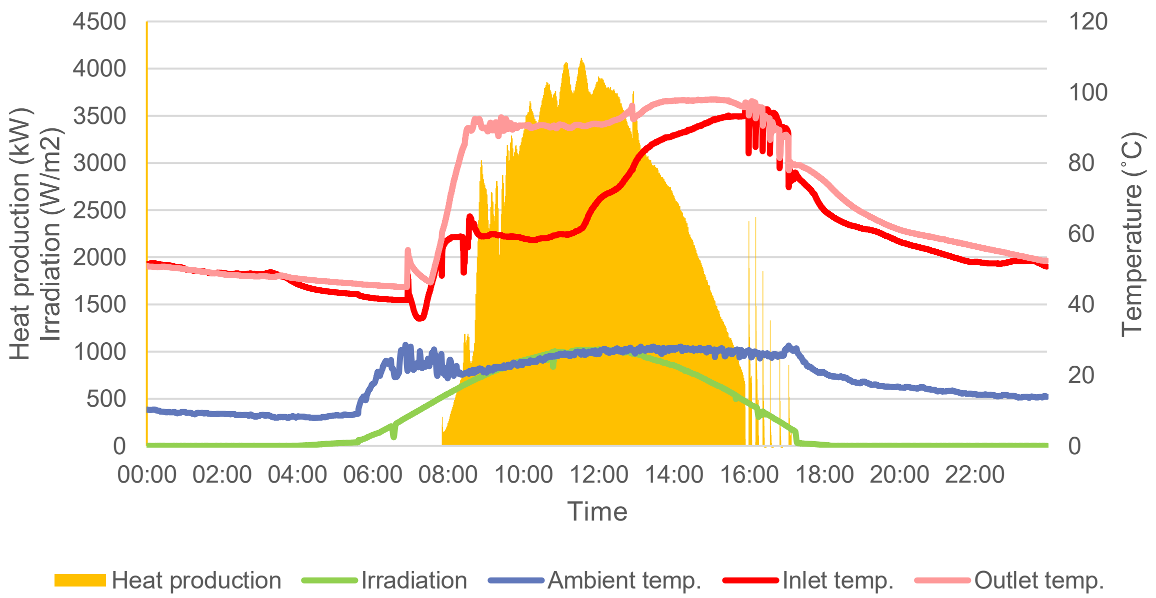

Figure 10. Measurement data from the installation in Murzzüschlag (2023-08-12).

The figure shows an active solar production between approximately 08.00-17.00, with the heat production profile correlating with the irradiation data. The outlet temperature peak is approximately 90 ˚C at 13.00. The inlet temperature varies between approximately 40 ˚C and 90 ˚C and coincides with the outlet temperature at approximately 16.00. The figure shows a consistent solar irradiation throughout the day.

5.4.4 Drivers and challenges

5.4.4.1 Drivers

Solar thermal power was implemented in the DH network of Mürzzuschlag to increase the share of renewable fuel sources and to reduce greenhouse gas emissions. With part of the heat production consisting of biomass and natural gas, increased independence of fuel prices served as an additional driver. Drivers for the installation, as reported by the owner of the installation, are shown in Table 14.

Table 14. Drivers for the installation of Mürzzuschlag.

FACTOR	DESCRIPTION
INCREASED SHARE OF RENEWABLES	The operator of the DH network has a goal of a 100% renewable energy share in the DH production. The SDH system result in a solar fraction up to 100% during summer.
REDUCE GHG EMISSIONS	The total GHG emissions from DH production is reduced due to reduction in biomass and natural gas combustion.
INDEPENDENCE OF FUEL PRICES	Reduced use of natural gas and biomass reduce dependency on fuel prices.
SURFACE AREA AVAILABILITY	The large open area (ski slope) close to the DH network enabled the supplier and DH operator to quickly come to agreement.
FUNDINGS	The installation received fundings from Land Steiermark and the Climate and Energy fund.

5.4.4.2 Challenges

The optimisation of heat supply from the solar installation and biomass boiler required development and investment of a high-end control system to enable the solar fraction to reach up to 100% during summer.

5.4.5 Noteworthy

The owner of the installation, Stadtwerke Mürzzuschlag, encourages all local DH companies to combine biomass and SDH with sufficient heat storages. The SDH installation has enabled Stadtwerke Mürzzuschlag to reach high shares of renewable energy and ensure a flexible heat supply. The operator encourages targeted funding operations to support feasibility studies and construction of installations throughout Europe.

5.5 Tåårs, Denmark

5.5.1 Overview

The hybrid solar DH installation of Tåårs features flat plate and parabolic trough collectors in series. Two storage tanks are used with a total volume of 2 430 m^3. Its construction is thanks to the 2014 Taars Varmeverk board decision to substitute a large share of natural gas with solar thermal power. The installation was commissioned in 2015 and provides a solar fraction of 22% in the DH network supplying 850 households during 2016. Technical data for the installation is shown in Table 15.

Table 15. Technical parameters for the installation.

TECHNICAL PARAMETERS	VALUE	UNIT
APERTURE AREA	10 000	m^2
NO. OF COLLECTORS	FPC: 473 PTC: 60	Pcs.
COLLECTOR TYPE	FPC, PTC	Type
HEAT TRANSFER FLUID	FPC: Glycol/water (35%) PTC: Water	
HEAT PRODUCTION (YEAR)	4 060	MWh/y
SOLAR FRACTION	22	%
SPECIFIC PRODUCTION (YEAR)	406	kWh/(kW y)
GLOBAL HORIZONTAL IRRADIATION	1 017	kWh/(m^2 y)
HEAT STORAGE TYPE	2 tanks	Type
HEAT STORAGE VOLUME	2 430	m^3
COMMISSIONING DATE	2015-08	Date
ADDITIONAL HEATING SOURCES	Gas boilers	Type
AVG. OPERATIONAL TEMPERATURE	60-95	˚C
DISTRICT HEATING SUPPLY TEMPERATURE	68-78	˚C
DISTRICT HEATING RETURN TEMPERATURE	38	˚C

The installation in Taars was world-first in combining FPC and PTC collectors, with the idea of utilizing the full capacity of both collector types.

5.5.1.1 Economy

The total capital cost for the installation was calculated to 3.5 million euro (excl. VAT). The project received a total funding of 0.4 million euro (excl. VAT). Economic parameters over the installation are shown in Table 16.

Table 16. Economical parameters over the installation.

PARAMETER	VALUE	UNIT
CAPITAL COST	3 500 000	Euro
SUBSIDIES	400 000	Euro

The main entrepreneur for the installation was Aalborg CSP, with Arcon Solar and Aalborg CSP supplying the FPCs and PTCs respectively. The installation was sold as a turn-key system with the offer of a long-term reduced customer heat price. The distribution of the project cost is shown in Figure 11.

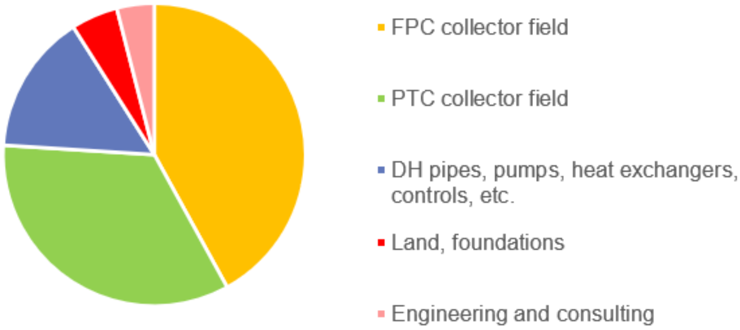

Figure 11. Distribution of the project cost for the installation in Taars.

The installation was sold as a turn-key solution to Taars Varmeverk with the purpose of reducing the customer heat price.

5.5.2 Design

The collector fields are constructed side by side close to a monitoring station supplying weather data. With the PTC field being constructed in an east-west tracking orientation and the FPC field in south orientation, the total heat production curve is evened out throughout the day. The combination of different collector technologies also enables each collector type to be operated in respective a highest-efficiency span, with FPC's reaching highest efficiencies at lower temperatures. With the PTC field constituting approximately 40% of total aperture area, the installation also features a 'fail-safe' mode prohibiting overheating due to the PTC's ability of defocus from direct irradiation. An overview and schematic over the installation of Taars are shown in Figure 12.

Figure 12. Overview over the installation in Tåårs (left) and schematic showing the different sections of the installation (right).
Source: Task 52 Solar Heat and Energy Economics in Urban Environments: Technology and Demonstrators

The working principle of the installation is based on a continuous flow of preheated water entering the parabolic trough collectors, enabling full utilisation of each collector field before entering the storage tanks and DH network. With the heat carrier fluid varying in the PTC and FPC loop respectively, a heat exchanger is used to transfer heat from the PTC to the FPS loop as shown in Figure 13.

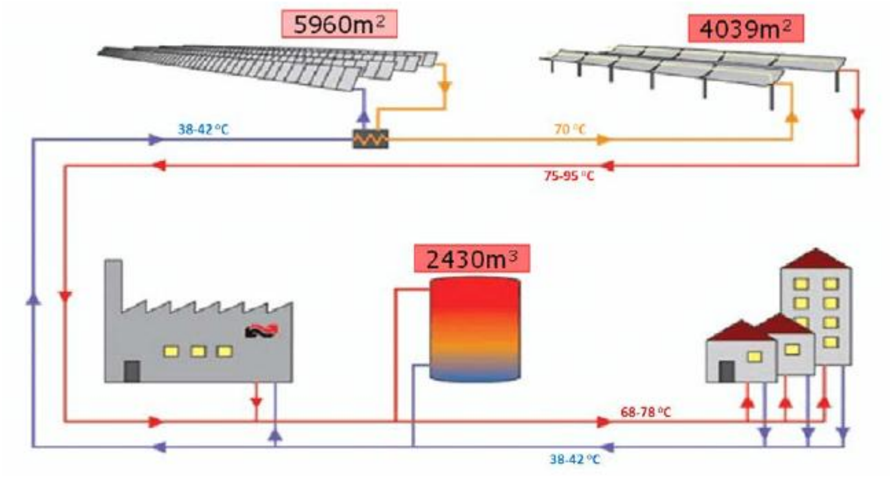

Figure 13. Working principle of the installation in Taars.
Source: Aalborg CSP

The FPC field is mounted in a 50˚ tilt angle with a row spacing of 5,67m. Design parameters over the installation are presented in Table 17.

Table 17. Design parameters for the installation.

PARAMETER	DESCRIPTION
APERTURE AREA	FPC: 5 960m^2 PTC: 4 039m^2
NO. COLLECTORS PER ROW	FPC: varying PTC: 10
ROW SPACING	FPC: 5,67m PTC: 12,60m
BACK-UP SYSTEM	2 natural gas boilers

5.5.3 Drivers and challenges

5.5.3.1 Drivers

Due too low electricity prices during summer and an increase in fuel prices, the installation was initiated with the board of Taars DH utility recognizing the need to reduce natural gas consumption to increase feasibility of the DH plant. Drivers for the installation, as reported be the owner of the installation, are shown in Table 18.

Table 18. Drivers for the installation of Taars.

FACTOR	DESCRIPTION
LOWER CUSTOMER HEAT PRICE	A lower customer heat price (DKK/kWh) compared to the existing solution was a major deciding factor for the installation.
SECURITY OF OPERATION	The PTC field's ability of automated stagnation management avoiding boiling of the system due to defocusing of the parabolic trough collectors constituted an important incentive for the installation.
MATURE TECHNOLOGY	Solar thermal power was regarded as a top alternative with the technology being proven in Denmark regarding reliability, lifetime and performance.
REDUCED N-G CONSUMPTION	The use of natural gas is reduced (especially during summer) with solar heat production covering a large part of the heat demand.

5.5.3.2 Challenges

Challenges for the installation involved both technical and economic factors and are shown, as reported by the owner of the installation, in Table 19.

Table 19. Challenges for the installation of Taars.

FACTOR	DESCRIPTION
NEW TECHNOLOGY	At the time, there was a lack of experience regarding PTC technology and the synergy between PTC and FPC.
BANKABILITY	To receive loans for the funding of the installation, the economic performance and feasibility had to be proven with calculations and simulations.
CONTROL STRATEGY	With different collector technologies connected in series featuring differences in orientation, hydraulic design and heat production, the new design concept presented challenges during the construction of the installation. Further challenges were met with design of optimal charging strategy for the heat storage.
INADEQUATE IRRADIATION DATA	During the time of installation, there was a lack of measured DNI data in Denmark resulting in challenges in system design and operational strategies.

5.5.4 Noteworthy

As reported by the owner, factors contributing to the successful operation and construction of the installation involved professional planning and design. Other factors mentioned contributing to the success of the installation was the high competence in the solar field among parties involved during the construction. With a consumer-based cooperative regulating the DH market in Taars, the investment in SDH was made by the DH consumers themselves.

Corresponding challenges prior and during the construction of the installation was the occurrence of extreme weather conditions and the use of two turn-key solar thermal companies, being competitors in the Danish market.

Evaluation of up-to-date operational data shows operational advantages such as a more daily evenly heat production with PTC producing more heat early and late in the day and FPC reaching its production peak during midday, enabling a more even operation of boilers. During the first year of operation, the installation reached a solar fraction of 26%, being close to the design target of 30%.

5.6 Härnösand, Sweden

5.6.1 Overview

The installation of Högslätten, Härnösand was commissioned during the summer of 2021 and consists of 192 PTC collectors. The installation is located on an elevated land area overlooking the small city Härnösand close to the collector manufacturer Absolicon Solar Collectors AB. Currently, there is no heat storage installed, and the installation is put in standby mode from November to March due low solar angles and intensities. Högslätten was constructed to serve as a SDH demonstration plant for Absolicon while the local energy company, Härnösand Energi och Miljö, was eager to reduce their CO_2 emissions. Technical data for the installation is shown in Table 20.

Table 20. Technical parameters for the installation.

TECHNICAL PARAMETERS	VALUE	UNIT
APERTURE AREA	1 056	m^2
TOTAL AREA OF INSTALLATION	2 940	m^2
NO. OF COLLECTORS	192	Pcs.
COLLECTOR TYPE	PTC T160	Type
COLLECTOR EFFICIENCY	76,4	%
HEAT CARRIER FLUID	Water with glycol	Type
INSTALLED THERMAL POWER	0,74	MW
HEAT PRODUCTION (YEAR)	329	MWh/y
SOLAR FRACTION	0,21	%
SPECIFIC PRODUCTION (YEAR)	445	kWh/(kW y)
GLOBAL HORIZONTAL IRRADIATION	889,4	kWh/(m^2 y)
HEAT STORAGE TYPE	-	Type
HEAT STORAGE VOLUME	-	m^3
CO_2 SAVING (YEAR)	65-189	Ton/y
SYSTEM LIFETIME	25	Year
COMMISSIONING DATE	2021 summer	Date
ADDITIONAL HEATING SOURCES	Wood chips/pellets, oil, industrial waste	Type
AVG. OPERATIONAL TEMPERATURE	73-120	˚C
DISTRICT HEATING SUPPLY TEMPERATURE	80	˚C
DISTRICT HEATING RETURN TEMPERATURE	45	˚C
PLANT PIPING (TYPE, LENGTH)	Underground pre-insulated DH pipes	Type, Length

The installation is planned to be extended to a total aperture area of 3 000m^2.

5.6.1.1 Economy

The capital cost of the installation was calculated to 341 088 euro, of which a 45% subsidy was given from the Swedish Energy Agency. Economic parameters over the installation are shown in Table 21.

Table 21. Economical parameters over the installation.

PARAMETER	VALUE	UNIT
CAPITAL COST	341 088	Euro
OPERATION COST	3 500 (approx. 1% of capital cost)	Euro/y
SUBSIDIES	45% R&D grant	Type
BUSINESS MODEL/FUNDING	Heat purchase agreement	Type

5.6.2 Design

The installation consists of 8 sub-circuits of 12 collectors each. The collectors are mounted on a 1-axis mounting system and gathered in sections containing 12 collectors each. The installation features 4 rows with 4 sections in each row. Figure 13 shows an overview of the installation.

Figure 14. Overview over the installation at Högslätten.
Source: Absolicon Solar Collector AB

Heat from the collector field is transferred to the DH network through a solar central constructed next to the collector field. A principal sketch over the installation is shown in Figure 15.

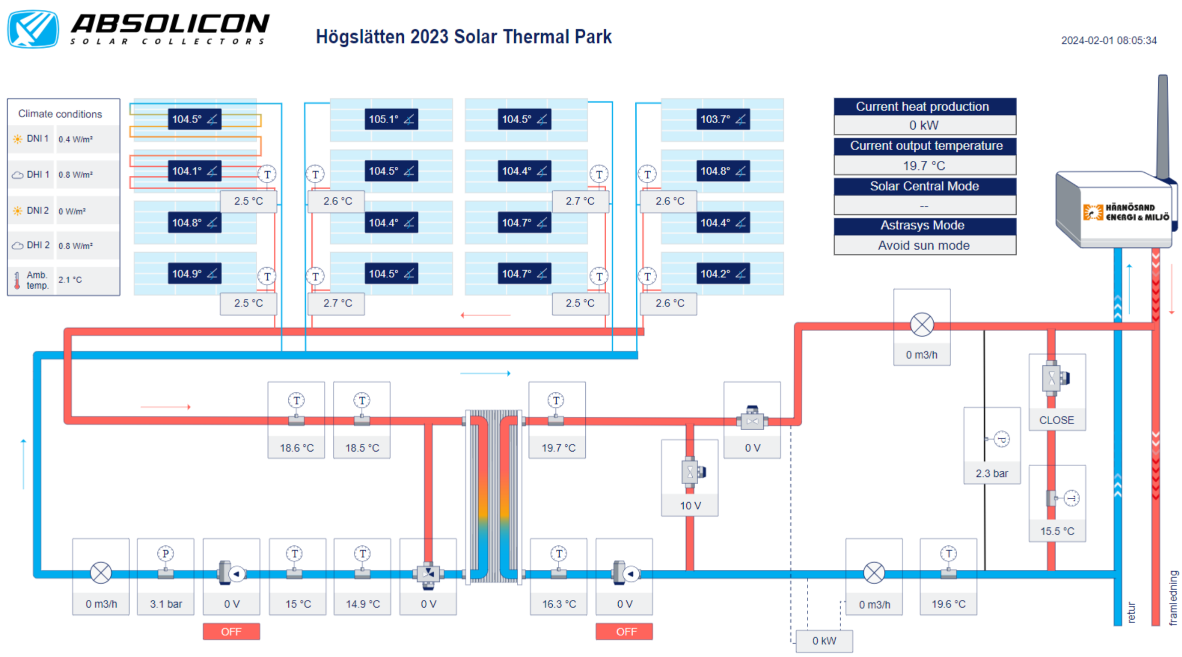

Figure 15. Principle sketch over the installation at Högslätten.
Source: Absolicon Solar Collector AB

The installation is regulated to control the temperatures on both the collector and DH side with the help of sensors and valves.

5.6.3 Measurement data

Measurement data (2023-06-21) from the installation in Härnösand is presented in Figure 16.

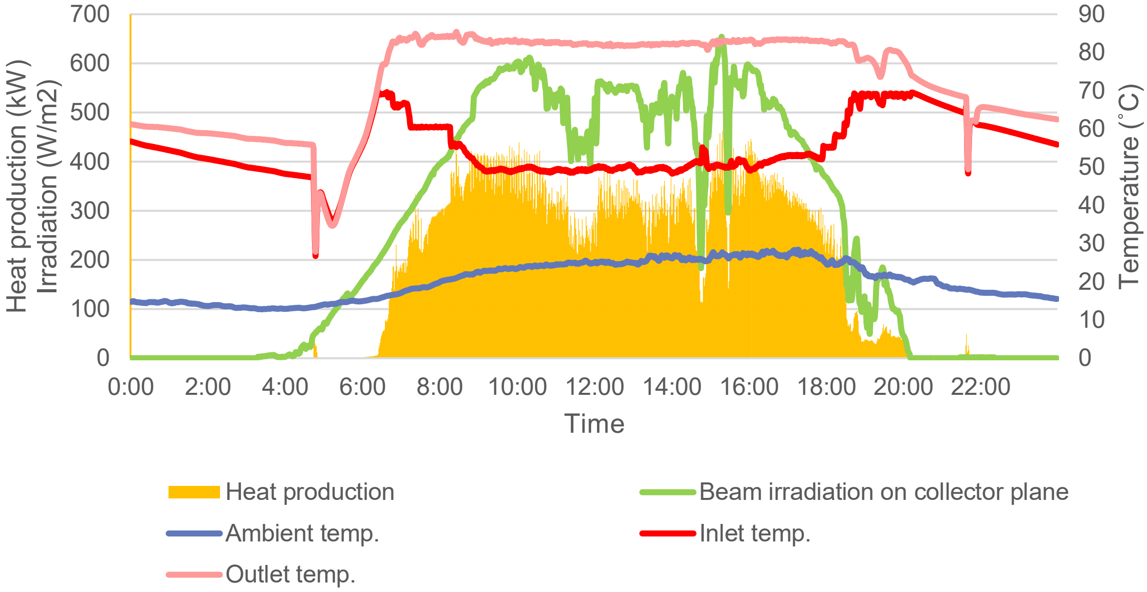

Figure 16. Measurement data (2023-06-21) from the installation in Härnösand.

The figure shows an active solar production between approximately 06.30-20.00 with the heat production profile mainly correlating with the irradiation data. The outlet temperature reaches its peak of approximately 85˚C at 07.00 and is relatively constant until the end of the heat production at 20.00. The inlet temperature is kept relatively constant between 08.00-18-00.

5.6.4 Drivers and challenges

5.6.4.1 Drivers

The installation was constructed due to Absolicon's need for a demonstration site for their T160 PTC collectors. After the subsidy was granted from the Swedish Energy Agency, the local government accommodated a hectare of land close to the DH network for the installation. In addition, there were wishes from the local DH company to reduce their CO_2 impact, relying heavily on industrial waste, forest residues and oil during peak loads. Drivers for the installation is shown in Table 22.

Table 22. Drivers for the installation of Härnösand (as reported by the site-owner).

FACTOR	DESCRIPTION
DEMONSTRATION SITE	Absolicon was in need for a demonstration site for their PTC collectors.
CO_2 REDUCTION IN DISTRICT HEATING PRODUCTION	The local DH company relied heavily on biomass and wanted to reduce the use of forest residues.
FUNDING	The project was granted a substantial subsidy from the Swedish Energy Agency covering 45% of the capital cost for the project.

5.6.4.2 Challenges

As reported by the site-owner, the biggest challenge is the misconception that burning biomass does not result in CO_2-emissions. In Sweden, there is no subsidies to replace biomass with other energy sources. A technical challenge associated to the installation was the drilling of the foundations due to unfavourable ground properties.

5.6.5 Noteworthy

As reported by the plant management, the seasonality of the heat production is important due to long sunny days during summer and lower solar intensities and angles during winter. The collectors are being put out of commission between November-March and set into “storm setting” that tilts the aperture area downwards facing the ground prohibiting damage and leakage from snow accumulation. A seasonal heat storage is not required since the heat load is higher than the heat production throughout the whole season. Still, the implementation of a seasonal thermal heat storage is being considered in the case of future extensions of the collector field.

After finishing the project, the installation was granted the award “good environmental choice” by the Swedish nature conservation association. A short-term goal is expanding the total aperture area of the installation to 3 000 m^2. A long-term goal is replacing the entire biofuel consumption of the local DH company- requiring an aperture area of up to 50 000m^2. The current operation of the plant has proved to Swedish authorities that it is entirely possible to replace biofuels with solar thermal power during summer.

5.7 Dronninglund, Denmark

5.7.1 Overview

The initiative for the installation in Dronninglund started in 2005 when the board of Dronninglund Fjernvarme established a long-term plan to phase out natural gas from the fuel mix. The installation was commissioned in 2014 with the end-goal of covering 50% of the annual heat demand with solar thermal. To enable the high solar fraction, a large pit storage[6] was constructed adjacent to the collector field. The special geological conditions enabling such constructions were at the time hard to find, with high ground water levels and unfitting soil types in the surrounding area. The only available area in the Dronninglund vicinity was in an abandoned gravel pit where both the collector field and pit storage finally were constructed. The solar thermal installation consists of 2 982 FPC collectors from the manufacturer Arcon Solar. The collectors are mounted on galvanized steel profiles processed into the ground. Technical data for the installation is shown in Table 23.

Table 23. Technical parameters for the installation.

TECHNICAL PARAMETERS	VALUE	UNIT
APERTURE AREA	37 573	m^2
TOTAL AREA OF INSTALLATION	92 473	m^2
NO. OF COLLECTORS	2 982	Pcs.
COLLECTOR TYPE	Arcon Solar, FPC	Type
COLLECTOR EFFICIENCY	43	%
HEAT CARRIER FLUID	Water with glycol	Type
INSTALLED THERMAL POWER	26	MW
HEAT PRODUCTION (YEAR)	19 217	MWh/y
SOLAR FRACTION	40	%
SPECIFIC PRODUCTION (YEAR)	739	kWh/(kW y)
GLOBAL HORIZONTAL IRRADIATION	1 265	kWh/(m^2 y)
HEAT STORAGE TYPE	Pit storage	Type
HEAT STORAGE VOLUME	60 000	m^3
CO_2 SAVING (YEAR)	967	Ton/y
SYSTEM LIFETIME	25 (collectors), 20 (PTES)	Year
COMMISSIONING DATE	2014	Date
ADDITIONAL HEATING SOURCES	Bio oil, natural gas	Type
AVG. OPERATIONAL TEMPERATURE	72	˚C
DISTRICT HEATING SUPPLY TEMPERATURE	75	˚C
DISTRICT HEATING RETURN TEMPERATURE	40	˚C
PLANT PIPING (TYPE, LENGTH)	Pre-insulated DH pipes	Type

An absorption heat pump uses the storage water as heat source and produces DH at flow temperature. The heat pump is driven by heat from a bio-oil boiler that heats the water to 160˚C. The collector field fully covers the heat demand during summer with the excessive surplus heat being stored in the pit storage.

5.7.1.1 Economy

The total cost for the installation was calculated to 14 130 000 Euro. A 20-year bank loan with a 3% interest rate was used to cover the capital cost of the installation. Economic parameters over the installation are shown in Table 24.

[6] Detailed explanation of design and operation of the pit storage is concluded in a paper and can be accessed at https://www.sciencedirect.com/science/article/pii/S0038092X22009252

Table 24. Economical parameters over the installation.

PARAMETER	VALUE	UNIT
CAPITAL COST	14 130 000	Euro
SOLAR COLLECTORS	5 856 000	-
DH PIPES	985 000	-
TRANSMISSION PIPE, EXCAVATION AND MOUNTING	344 00	-
SOLAR FIELD, MOUNTING OF PIPES	144 000	-
SOLAR FIELD, EXCAVATION FOR PIPES	177 000	-
SOLAR CENTRAL WITH PIPES, PUMPS HEX AND HP	3 551 000	-
STORAGE EXCVATAION AND LANDSCAPING	673 000	-
STORAGE MEMBRANE	1 263 000	-
ADDITIONAL COSTS	1 137 000	-
OPERATION COST	58 560 (solar field) 39 000 (PTES)	Euro/y
SUBSIDIES	16% demonstration project subsidy	
BUSINESS MODEL/FUNDING	Full ownership by the DH company (non-profit, consumer owned)	-

5.7.2 Design

As shown in Figure 17, the collector field is divided into two main sections. The absorption heat pump is located adjacent the bio-boiler in the CHP plant at Sondervang.

Figure 17. Overview over the collector field in Dronninglund (left) and schematic over the different components (right) where the collector field (1) is constructed next to the pit storage (2) and solar central (3). The DH pipes (4) closely follow the right side of the collector field.
Source: PlanEnergi

A principal sketch over the installation is shown in Figure 18.

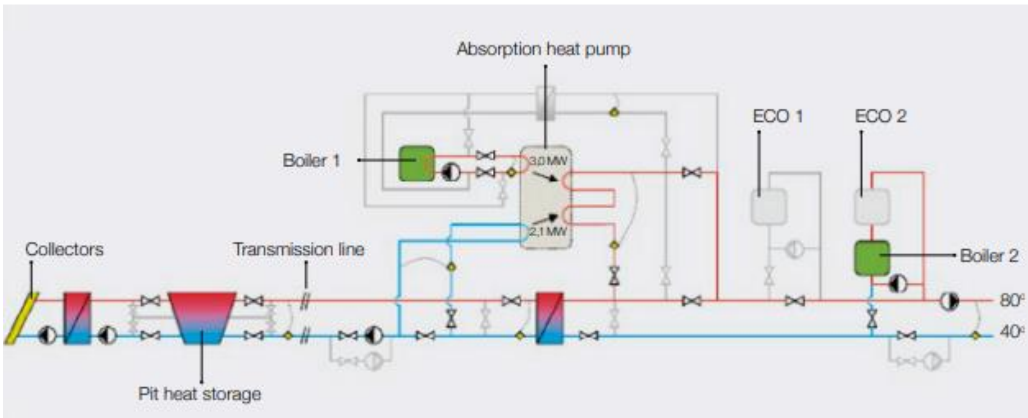

Figure 18. Principle sketch over the installation in Dronninglund.
Source: PlanEnergi

The installation is regulated to control the temperatures on both the collector and DH side with the help of sensors and valves.

5.7.3 Measurement data

Measurement data (2018-06-21) from the installation in Dronninglund is presented in Figure 19.

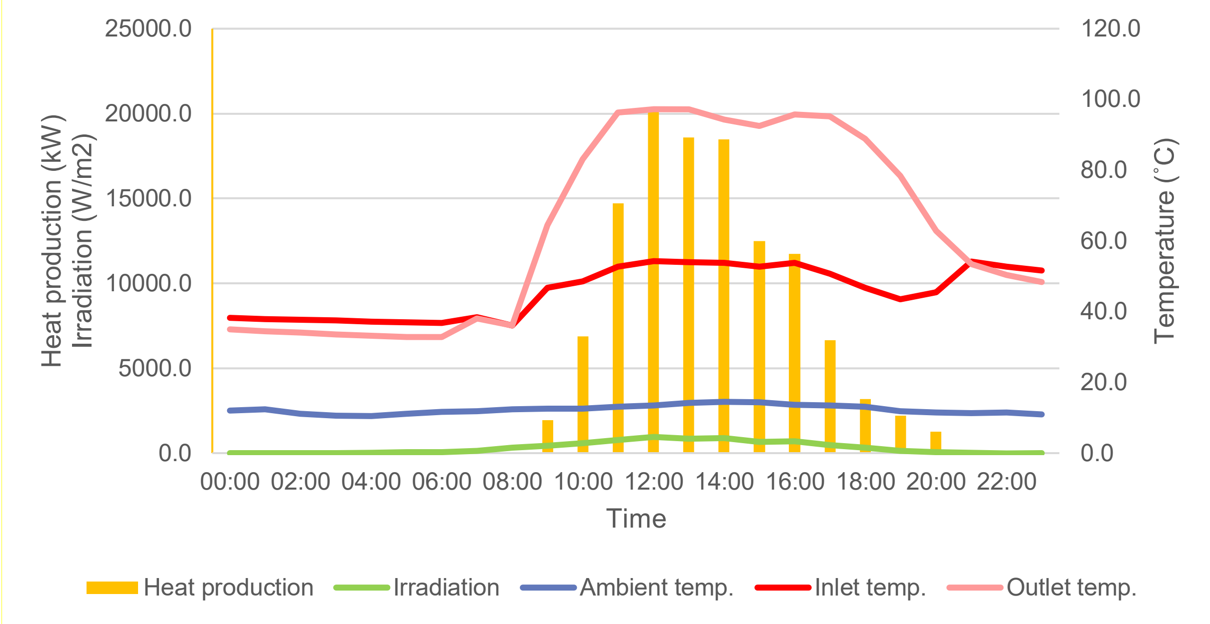

Figure 19. Measurement data (2018-06-21) from the installation in Dronninglund.

The figure shows an active solar production between approximately 07.00-20.00 with the heat production profile mainly correlating with the irradiation data. The heat production reaches its peek at noon and is held relatively constant to 14:00. The outlet temperature reaches its peak of approximately 100˚C at 12.00 and is relatively constant between 11:00-17:00.

32 temperature sensors are distributed at different heights inside the storage volume of the pit storage. The measured data from the sensors in addition to complementary data from the collector field and DH network enable calculation of storage efficiency and heat capacity. During 2014, the storage efficiency was calculated to 78% with two full storage cycles and a total storage heat capacity of 5 100MWh. The monitoring results from the pit storage are shown in Figure 20.

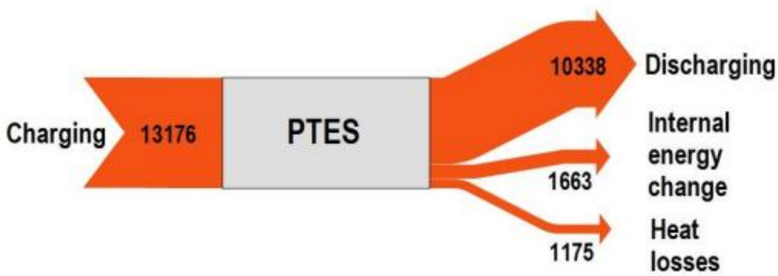

Figure 20. Monitoring results (2014) from the pit storage.
Source: PlanEnergi

5.7.4 Drivers and challenges

5.7.4.1 Drivers

The installation in Dronninglund was constructed to demonstrate the function of a pit thermal energy storage in combination with solar thermal. The installation was initially designed to cover 50% of the heat demand. The goal of a 50% solar fraction was not reached since an electrical driven heat pump was part of the original design concept. Drivers for the installation in Dronninglund are shown in Table 25.

Table 25. Drivers for the installation of Dronninglund (as reported by the site-owner).

FACTOR	DESCRIPTION
DEMONSTRATION SITE	To demonstrate a full-scale pit storage in combination with solar thermal.
HEAT DEMAND COVERAGE	Goal to cover 50% of the heat demand in Dronninglund with solar thermal.
NEW PIT STORAGE COVER SOLUTION	To demonstrate a new cover solution for the pit storage where problems (air pockets under the cover, water pits near the edges, moisture in insulation) from the pit storage in Marstal are solved.
IMPLEMENTATION OF MULTI-PURPOSE ENERGY STORAGE	Implement an energy storage that has a natural place in the 5th generation DH network where excess heat from e.g. industries and CHP plants can be stored in addition to electricity-to-heat solutions such as wind power and PV.
REDUCE THE PRICE FOR HEAT PRODUCTION AND STORAGE	The heat production price was predicted to be reduced to 400 DKK/MWh and the cost for storing excess heat to 200-250 DKK/MWh.
REDUCED CO_2 EMISSIONS	Contribution to Danish energy policy objectives with a "carbon-free" asset in the DH network.
SUBSIDY	A 10% subsidy scheme for energy efficiency was in effect during the construction of the installation for which the project was eligible due to solar thermal counting as reduction in energy consumption.

5.7.4.2 Challenges

The main challenge associated with the installation was the high upfront payment and interest rate following the completion of the collector field and heat storage. The availability of municipality-guaranteed loans enabling low interest rates were not present during the commissioning of the installation.

5.7.5 Noteworthy

During the commissioning phase, an electrical driven heat pump was used to utilize heat from the storage. This resulted in bad economic performance for of the installation due extra costs related to Danish electricity taxes. As a result, Dronninglund Fjernvarme booked meetings with the Danish minister of taxation trying to change the rules for taxation on electricity used for heat pumps. The minister promised to change the rules but unfortunately, they were still in effect during the commissioning of the installation. The heat pump was later changed to the current absorption heat pump.

The aperture area of the collector field was originally intended to 35 000m^2 instead of the current 37 573m^2. The extra collectors were implemented because calculations showed feasibility in an increased aperture area with the possibility for the local CHP plant to join the open electricity market reducing its operation during summer to only a few hours.

During the first year of commissioning, Marstal District Heating found corrosion in the storage resulting in the construction of a facility for reverse osmosis removing salts and raising the pH in the storage water. This investment added to the capital cost of the system.

As reported by the installer, SDH currently has a hard time competing with other heat production technologies in Denmark. The market for solar DH has been growing very fast during the last decade due to the 10% subsidy scheme for energy efficiency. In recent years, the regulation changed in favour for heat pumps challenging the role of solar thermal in Denmark. SDH is otherwise a competitive low-carbon solution that can cover 10-60% of the heat demand of any rural area cover by DH. To spread the use of SDH, one challenge is therefore to expand the use of DH. Support programs for solar thermal technologies and sharpened requirements for fossil-free heat production or increased taxes on fossil fuels are reported to be important factors to promote SDH. In addition, proof-of-concepts from commissioned installations play are vital for decision makers prior implementation of SDH in a new country.

6 Conclusion

This study presents an overview of commissioned European SDH installations with different collector technologies, types of heat storage, solar fractions and primary heat source(s). Most of the studied installations use biomass or gas as main heat source(s) and utilise solar heat to cover the heat load during summer to a varying extent. In smaller DH systems, site managers' report a 100% heat demand coverage by using solar.

The number of collectors in each installation varies between 150-12 500pcs., where FPC collectors together with a glycol/water working fluid constitute the most common setup. Accordingly, the supply DH temperature mainly varies between 75-90 ˚C and the return temperature between 35-45˚C. Heat storages are used to a varying extent with a SF between 10-20% for non-experimental/pilot installations without the possibility for cross-seasonal heat storage. With the installations being situated at varying latitudes, the GHI is in the range of 890-1 265kWh/(m^2/y) and the specific production accordingly between 406- 804kWh/(kW y).

A common case prior the construction of collector fields is the abolishment of existing heat production technologies or the release of large land areas. These circumstances have proven to work as natural incentives for ST integration in addition to environmental agendas at the DH supplier. Additional recurring drivers and challenges prior SDH constructions concluded during the study can be summarised below

Drivers	Challenges
Necessity for demo/pilot installations	Capital cost
Heat storage co-construction synergy	High DH supply temperature
Fuel diversity	Lobbying of competing technologies
Sustainability trademark	Industrial uncertainty for emerging technologies
Revision enhancement	Decreased boiler efficiency
Reduced noise pollution	Deficit of production data from operational installations
Technical readiness	Necessity of high-end control systems
Low maintenance	

DH utilities throughout Europe place an increased emphasis on reducing GHG emissions and inexhaustible heat production. In some cases, ST has been regarded as the only competitive alternative to a reduced heat price. Heat storage is regarded as a prerequisite for an increased SF at higher latitudes and is utilised in different forms connected to the installations in the study.

In summary, DH utilities and site managers emphasise on the reliability of ST technology and mention reduced GHG emissions and fuel price dependencies as important drivers for SDH projects. In addition, all installations covered in the report have received funding or subsidies prior the construction which, as reported by site managers, arguably serves as the most important factors for finalizing SDH projects throughout Europe. Consequently, the most prominent obstacles prior SDH constructions are associated with, in addition to area availability and competing heat sources, lack of subsidies and funding.

7 References

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