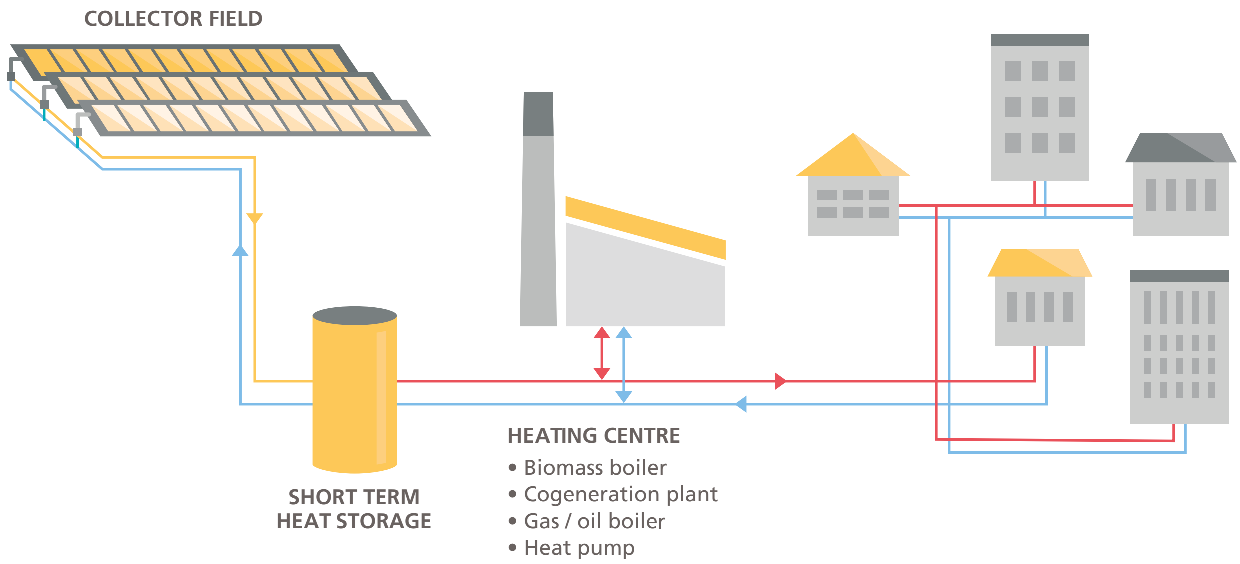
solar heat for cities

the sustainable solution for district heating

What is Solar District **Heating (SDH)?**



SDH is a large field of solar thermal collectors supplying solar energy to the heat network of a neighbourhood, a village or a town. This field is supplemented by a heating centre, which provides additional energy to meet all the heating needs of connected residential, public or office buildings. The heat network can likewise be supplied with surplus energy of collectors installed on the roofs of those buildings.

Fourth-generation heat networks...

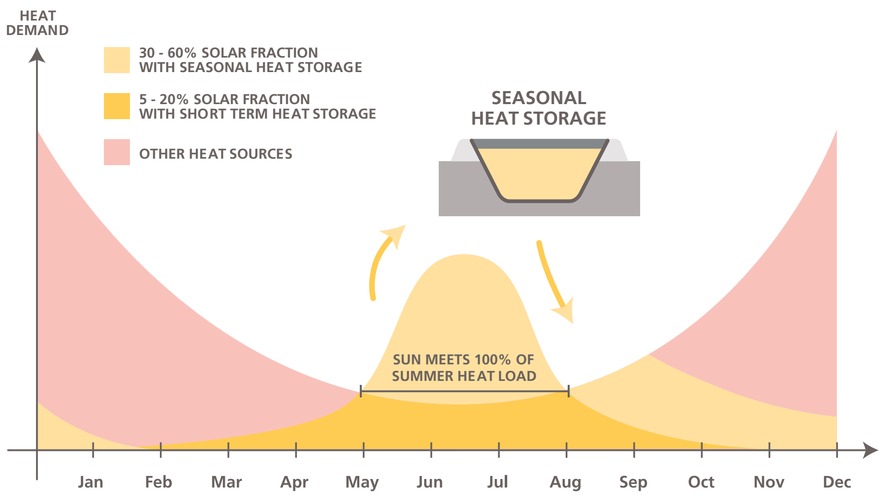
- **run** at lower temperatures, reducing heat losses.
- **improve** supply chain management.
- **serve** areas with many low-energy buildings.
- **make use of** several energy sources, including solar and waste heat.
- **allow** connected heat consumers to supply heat as well.

Source: UNEP [1]

How high can the solar fraction be?

In most cases, solar energy contributes up to 20 % to annual heat demand. Using seasonal storage can increase this solar fraction to 60 % or more.

How does seasonal storage work?



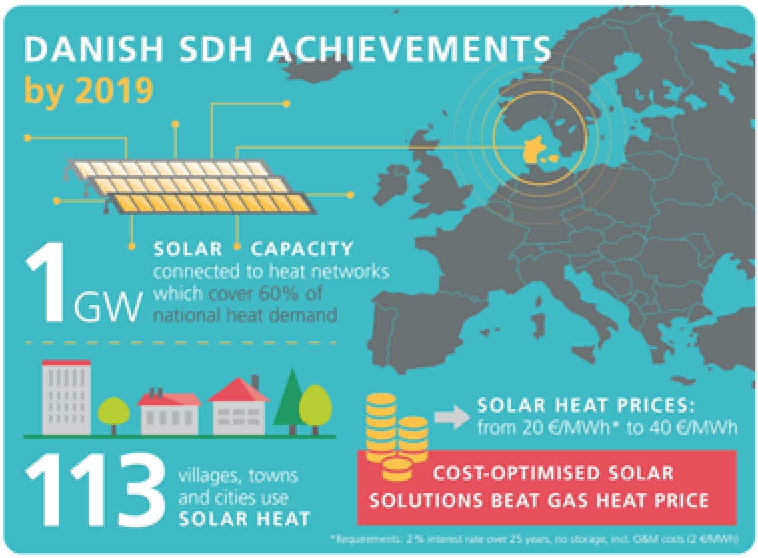
- In Europe, demand for heat is usually around 10 times larger in winter than in summer, when solar irradiation reaches its peak.
- Between May and August, a solar field can meet all hot water needs, so that the district heating company running the field can shut down boilers to significantly extend their useful lifetime (see case study Taars on pp 6/7).
- Seasonal storage can store surplus energy from summer for use in winter.
- Photos of the construction of a 15,000 m³ pit heat storage system can be found on p. 9.

Denmark sets **world records**

In Denmark, 113 villages, towns and cities use solar heat, even though northern Europe is not known to be a sunshine spot. The town of Silkeborg, for example, holds the record for the world's largest solar heat system, a 110 MW (156,694 m²) installation that was commissioned in December 2016 and took just seven months to be built (see photo). In August, Denmark set a new benchmark for other countries in Europe, as SDH capacity topped 1 GW.

Source: IEA SHC [5]

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

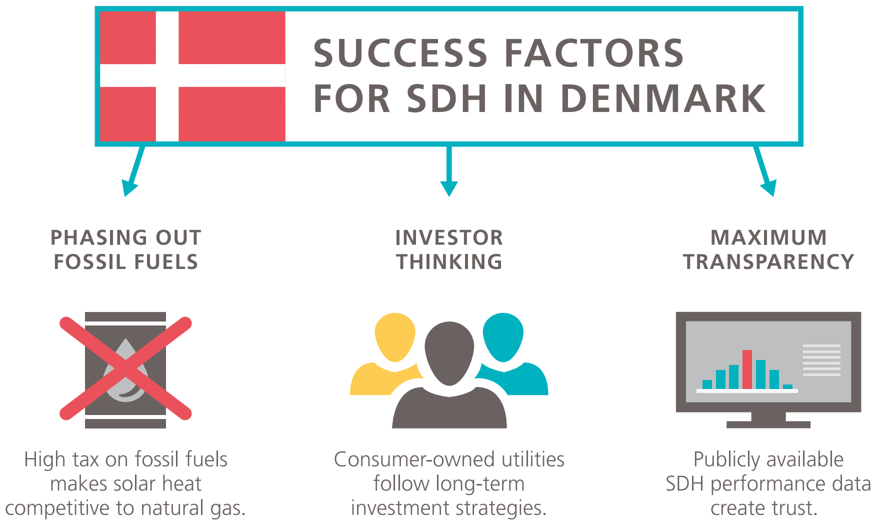


What are the success factors in Denmark?

340 user-run cooperatives…

- **benefit** from smart financing based on loans which are fully guaranteed by the municipality.
- **take** a non-profit approach, so that there is no need to keep good ideas under wraps.
- **exchange** information on the latest technologies, cost-saving methods and efficiency improvements.
- **aim** to avoid gas taxes, which double the price of a kilowatt-hour of produced heat.
- **sign** energy saving agreements with the Danish energy ministry that can be fulfilled with solar district heating.

Source: IEA SHC [5]



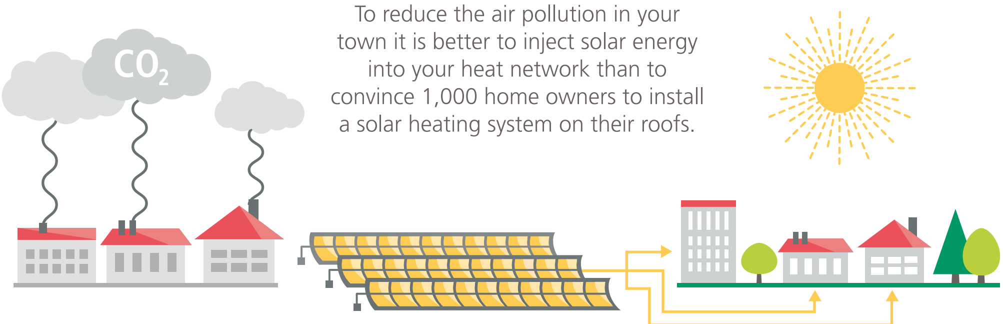
Transparency on solar yields and costs creates the trust that leads to new SDH customers

Daily and monthly yield estimates based on measurements at 66 Danish SDH plants can be found at *http://www.solarheatdata.eu/* Visitors to the website can also view the key technical specifications and economics of each system.

SDH: the smart way to cleaner air and **stable heat prices**

More than 340 SDH systems are up and running around the world and 10 (2017) to 20 (2018) more are added each year. In many towns and cities, district energy plays a key role in supporting climate action and cutting emissions.

SDH is the most cost-effective path to cleaner air



SDH achievements around the world

- **France** has a subsidy scheme for large solar thermal projects, which resulted in the commissioning of the country's first big SDH plant in December 2017 (case study on pp. 14/15).
- **In Germany,** six villages added solar fields to new or existing, mostly biomass-fired, boiler systems in 2018 (see p. 17 of the related case study).
- **Latvian** public utility Salaspils Siltums invested EUR 4.9 million in a 15 MW solar field and 8,000 m^3 storage tank. Both went online September 2019 (see photo and case study on p. 16).
- **Serbian** town Pancevo is planning to expand its SDH system. The plant has performed well since it was commissioned in December 2017 (see case study on p. 10).
- **South Africa** saw its first SDH installation being started up in May 2019. It has a 600 m^2 solar field, which supplies heat to student accommodation in Johannesburg.
- **Inner Mongolia,** an autonomous region in China, is home to the world's biggest district heating plant with concentrating collectors. The system was built in 2016 and has a capacity of 56 MW (93,000 m^2).

Source: solarthermalworld.org [6]

Huge opportunities for SDH in Europe

Of all the small towns in Europe, 2,375 across 22 countries are connected to district heating networks and, at the same time, have enough land on which to build solar fields to meet 20 % of their heat demand. A total of 33.9 GW solar thermal power (48 million m^2) could be installed.

Source: IEA SHC [5]

SMART CITIES USE SOLAR HEAT

MEET YOUR CLIMATE TARGETS

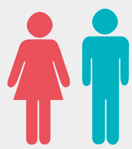
Solar heat is emission-free and 100% renewable.

INCREASE ENERGY SECURITY

Solar heat is an unlimited resource of your municipality.

KEEP HEAT AFFORDABLE

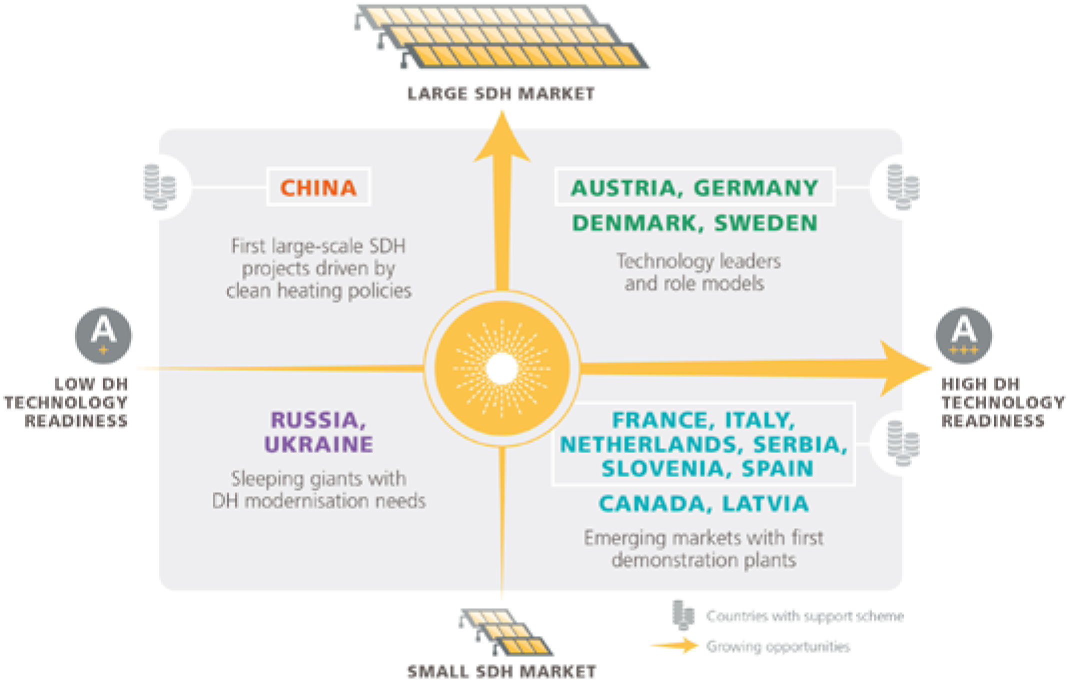
Price of solar heat will remain stable for at least 20 years.



CREATE LOCAL JOBS

Solar heat replaces imported fuels and provides new jobs.

Attractiveness of **SDH markets**



This brochure showcases nine SDH systems built in Austria, China, Denmark, France, Germany, Latvia and Serbia. The chart above classifies several countries according to their attractiveness for SDH. The appeal of a national market is based on the technological readiness of its DH sector. The colours used in the chart can also be found in the project presentations from p. 6 to p. 17.

Chinese DH market grows rapidly

Heat networks supply thermal energy to half of all major cities in China – 200,000 km of pipes serve close to 9 billion m² of building space. Rapid urbanisation led to 25 % growth between 2009 and 2013. Initially, the construction of SDH systems was subsidised by the national government, for example, in Tibet (see pp. 8/9) and in Inner Mongolia.

Source: solarthermalworld.org [6]

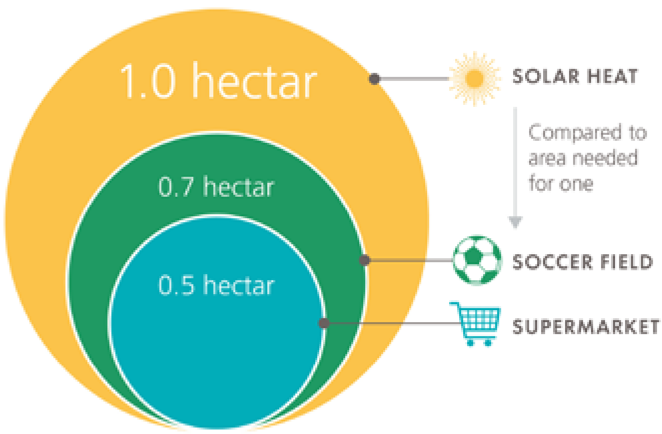
National support schemes

Austria: Climate and Energy Fund, https://www.klimafonds.gv.at/call/solarthermie-solare-grossanlagen-2019/
Germany: Heat Networks 4.0, https://www.bafa.de/DE/Energie/Energieeffizienz/Waermenetze/waermenetze_node.html
France: AAPST 2019, https://appelsaprojets.ademe.fr/aap/AAPST2019-119#resultats
Italy: Conto Termico 2.0, https://www.gse.it/servizi-per-te/efficienza-energetica/conto-termico
Netherlands: SDH+, https://english.rvo.nl/subsidies-programmes/sde
Serbia: Renewable District Energy in the Western Balkans (ReDEWeB) programme, https://www.ebrd.com/work-with-us/projects/tcpsd/renewable-district-energy-in-the-western-balkans-redeweb-programme.html
Slovenia: RES DH tender 2017 to 2020, https://www.energetika-portal.si//javne-objave/objava/r/javni-razpis-za-sofinanciranje-daljinskega-ogrevanja-na-obnovljive-vire-energije-1137/
Spain: PAREER-CRECE, https://www.idae.es/ayudas-y-financiacion/para-rehabilitacion-de-edificios-programa-pareer/programa-de-ayudas-para-la

How much area for SDH do you need ...

... to meet 20 % of the total annual heat demand from 1,000 households living in old buildings?

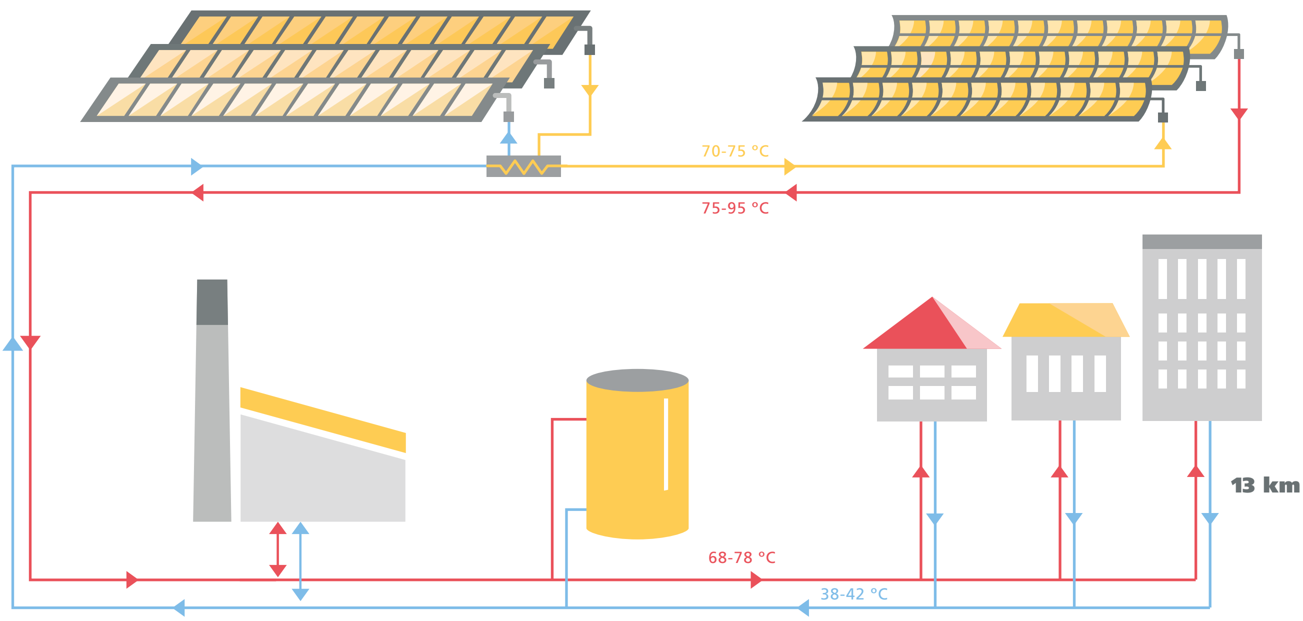
Assumptions for area calculation:
- A typical household has 90 m² of floor space and requires 100 kWh heat per square metre and year.
- The solar field supplies an average of 450 kWh of usable heat per square metre.
- An area of 2.5 m² is needed for 1 m² of collector to avoid shading the following row.



Danish town combines **strengths of multiple collector types**

Optimised solution for heat networks with 70 °C to 95 °C

The return line of the network in Taars, Denmark, with 38 °C to 42 °C heated up in two steps: The flat plate collectors raise the temperature to nearly 70 °C to 75 °C before a field of parabolic trough collectors increases it to between 75 °C and 95 °C.



Economics

Capital costs	Annual solar heat production
2.4 million EUR; 240 EUR / m² excl. VAT	6,082 MWh / year for both collector types
Average heat costs from gas boilers	**Solar heat generation costs**
461 DKK / MWh; 62 EUR / MWh	225 DKK / MWh; 30 EUR / MWh
O&M costs	**Solar fraction over the year**
n/a (cannot be separated between solar and gas)	Approx. 30 % (depending on solar irradiation)

"When compared to conventional gas boilers, systems made up of flat plate and concentrating collectors are both technically feasible and economically attractive in Denmark."

ZHIYONG TIAN, *FORMER RESEARCHER FROM THE TECHNICAL UNIVERSITY OF DENMARK*

PHOTO: AALBORG CSP

Advantages of combining different collectors

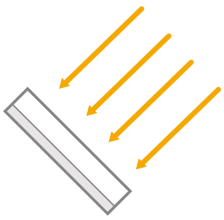
• Flat plate collectors are more effective when run at lower temperatures, while concentrating collectors equipped with evacuated absorbers work efficiently even if the temperatures are higher.

• Overheat protection: Parabolic troughs can be defocused to prevent stagnation. This allows higher solar fractions of up to 30 % without additional storage.

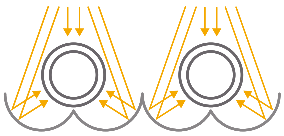
Collector types

Stationary
Fixed tilt or seasonally adjusted

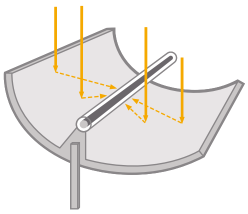
Tracking
Linear or two-axis tracking



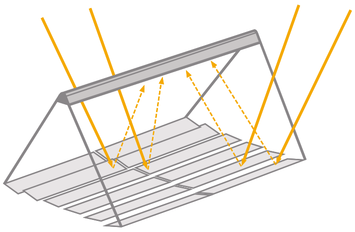
Flat plate collector



Evacuated tube collector with compound parabolic concentrator (CPC)



Parabolic trough collector



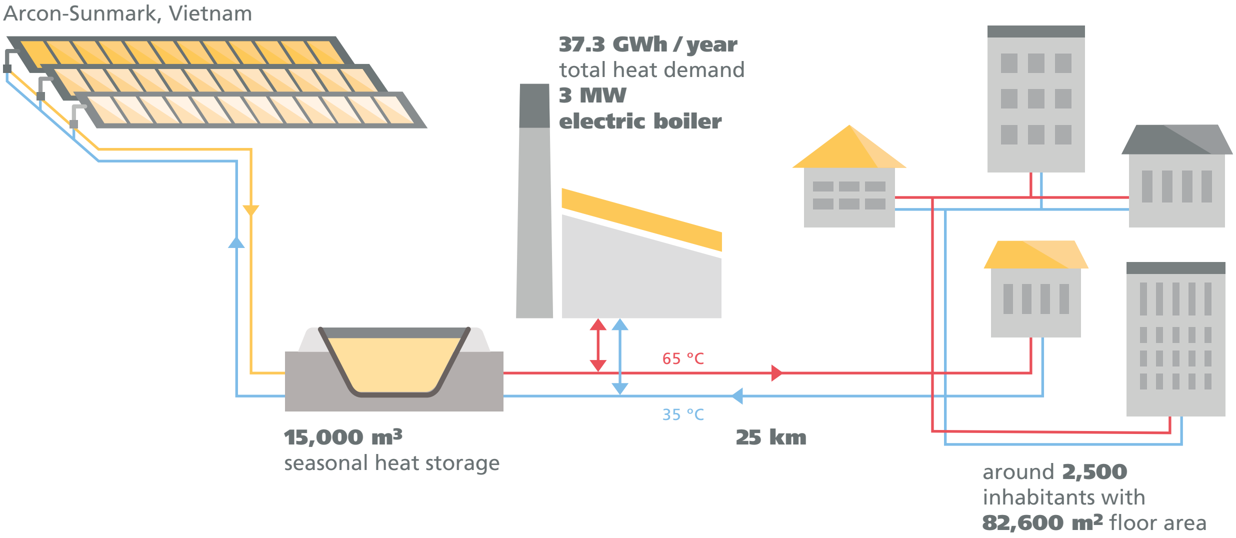
Linear Fresnel collector

Taars **Fjernvarme** - consumer-owned coperation
TAARS, DENMARK

First fully subsidised **SDH system in Tibet**

Sun meets 90 % of space heating demand

Half the households in the Tibetan town of Langkazi have been connected to a new solar district heating plant since December 2018. Its solar fraction is above 90 % because solar heat is used to provide thermal comfort in winter only. Surplus energy produced in summer is directed to a pit storage system. Centralised devices producing hot water for showering are not common in these parts of China.



START OF OPERATION: DECEMBER 2018

PHOTO: ARCON-SUNMARK

Only eight months to project completion was quite an achievement, considering the extreme weather in this part of the world and the logistics of getting personnel, equipment and material to the remote town.

Who is who

Owner of system
Municipality of Langkazi

100 % sponsor of system
Central Chinese Government

Manufacturer of collectors
Arcon-Sunmark, Vietnam

Turnkey SDH supplier and operator
Solareast Arcon-Sunmark Large-Scale Solar Systems Integration, China

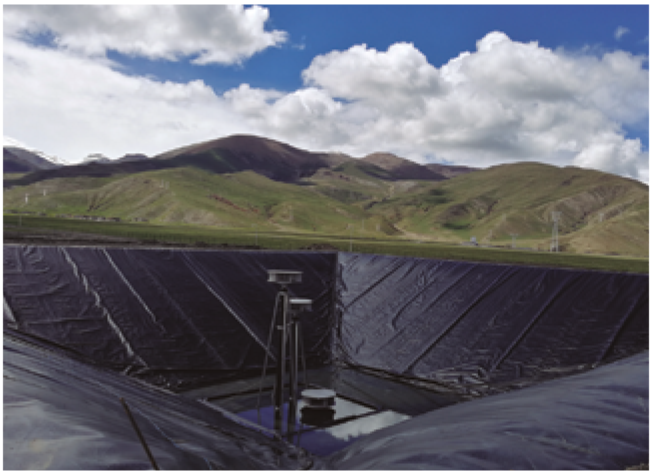
"Between December 2018 and May 2019, the SDH plant has reached a solar fraction of 100 %, so that room temperatures in the connected buildings have remained at 16 °C or above."

AARON FENG GAO, *MANAGING DIRECTOR*

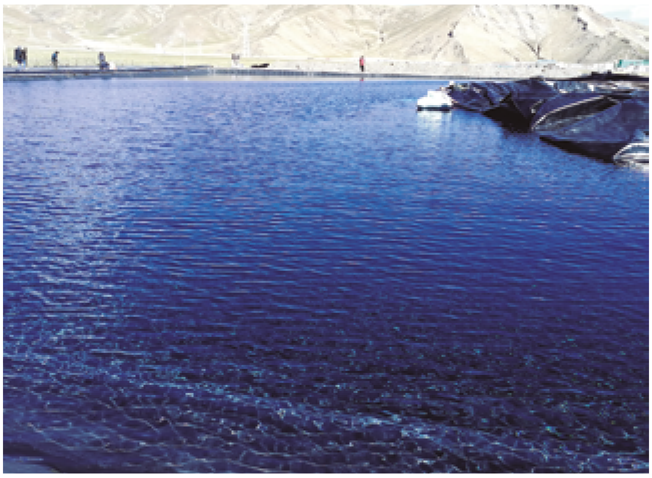
Construction of a pit heat storage at Langkazi, Tibet, China

1. Dig a hole in the ground and put the soil around the edges.

2. Add a watertight liner at the bottom of the pit.



3. Fill the pit with water.



4. Put an insulating and floating cover on top.

PHOTOS: ARCON-SUNMARK

Seasonal pit heat storage: successful cost learning curve in Denmark

Denmark has long-term experiences in pit heat storage construction. Five systems above 60,000 m³ are in operation. An increase in the size of these systems has brought down costs considerably. Denmark´s first big pit storage demonstration system with 10,000 m³ built in Marstal 2003 came to 67 EUR / m³. This made it nearly three times as expensive as today's biggest seasonal storage (210,000 m³), which was put up in 2015 in Vojens and costs only 24 EUR / m³. Danish engineers suggest using a benchmark of around 30 EUR / m³ when calculating the cost of pit heat storage with a capacity of 100,000 m³ or more. The first-ever pit heat storage outside Europe is the one in Langkazi (see photos above).

Solareast Arcon-Sunmark Large-Scale Solar Systems Integration

LANGKAZI ,TIBET, CHINA

Serbian mayor impressed with **SDH demonstration plant**

"Community feedback and system performance have motivated us to strive for more."

Key factors in the decision to install a demonstration SDH plant were the trust public utility company JKP Grejanje put in solar heating technology and the commitment by the mayor of Pancevo to improve quality of life in the city. Based on the expertise gained in two years of running the demonstration plant the city began planning a follow-on project to mount 198 collectors on the roof of the Kotež heating plant. United States Agency for International Development (USAID) will cover about 60 % of the project costs (total contract value of about EUR 150,000).

SASA PAVLOV
MAYOR OF PANCEVO

Sep-Nov 2011 Exploring innovative solar solutions

Dec 2011 Preliminary approval for funding

Jan 2012 Application on waiting list for funding

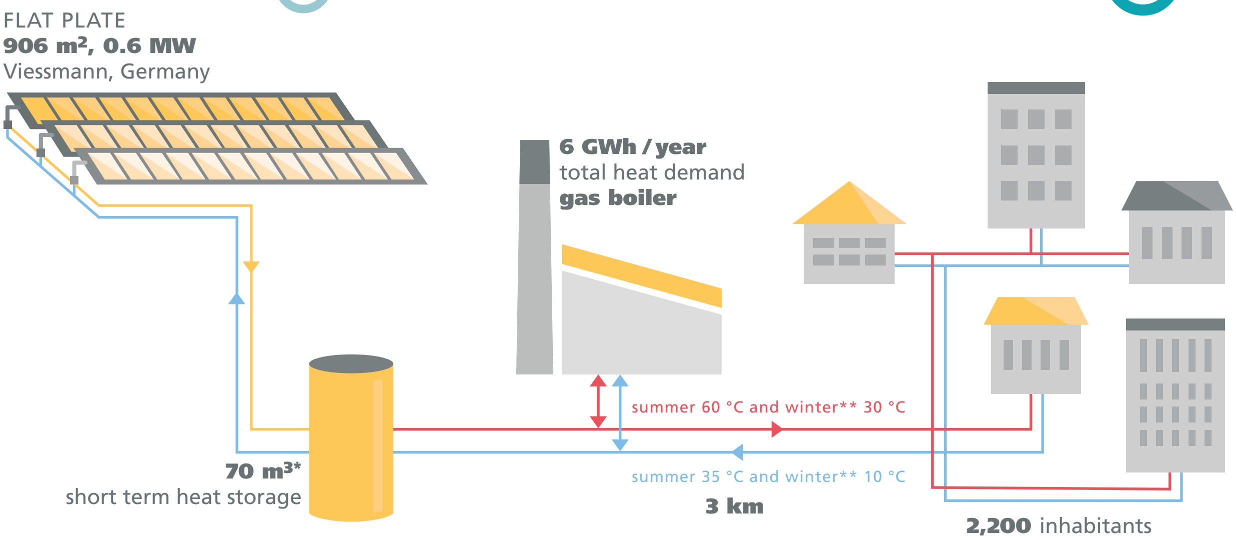
Oct 2015 Scheduling completion for the end of December 2016

Feb 2016 Starting procurement process

Aug 2016 Receiving building approval

Nov-Dec 2016 Installation of system

Jan 2017 **JKP started up the plant**



* plus decentralised 100 m³ storage at substations, with 4 m³ at each.

**In winter, solar energy preheats ambient air for being used in natural gas combustion in the heating centre.

SOLAR HEAT OUTPUT:	SOLAR SHARE:	KIND OF INSTALLATION:	ENERGY SAVINGS:
667 kWh / m²	10 %	three-metre steel structure	75,000 m³ natural gas per year

JKP **Grejanje**
PANCEVO, SERBIA

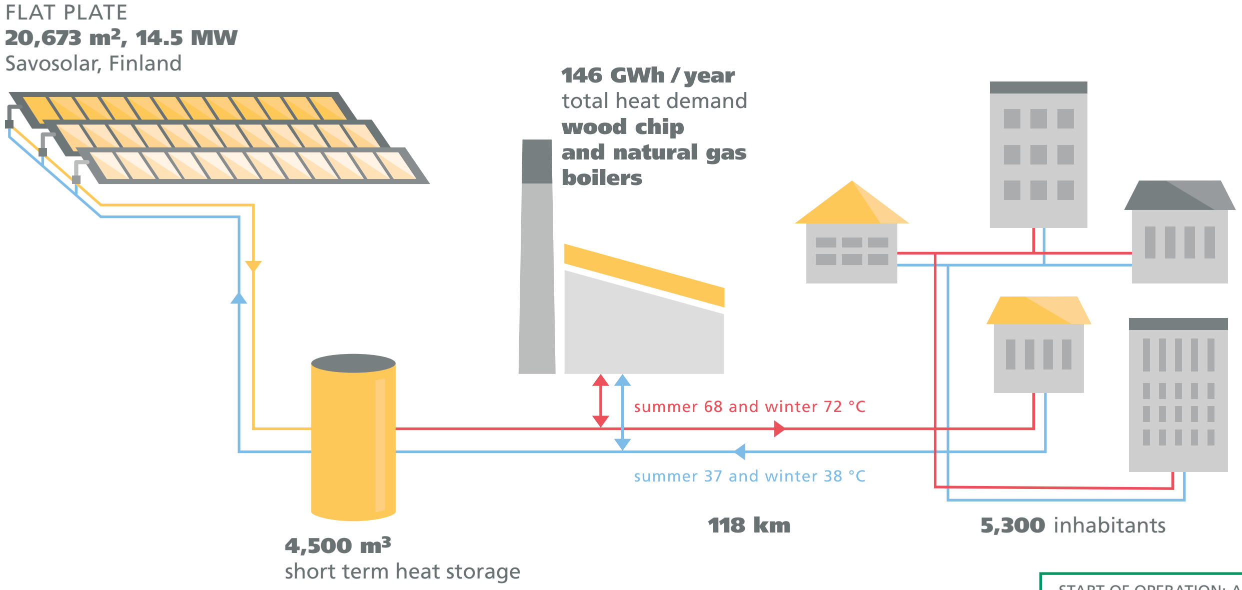
"SDH improves the quality of life in Pancevo by providing cleaner air and a sustainable, less expensive solution for supplying hot water and space heating."

SASA PAVLOV, *MAYOR OF PANCEVO*

Danish utility adds **14.5 MW of thermal power**

5,300 co-owners benefit from competitive pricing structure

The staff at utility cooperative Grenaa Varmeværk has been satisfied with the performance of the 8.5 MW solar plant that the business started up in 2014. It has not only managed to cut the price of heat in the past two years, but it is also one of the cheapest DH operators in the country. Since the start of this year, Grenaa has nearly tripled its solar heat capacity with the new 14.5 MW system.



START OF OPERATION: APRIL 2019

Economics of 14.5 MW plant

Capital costs
4.7 million EUR ; 227 EUR / m² excl. VAT

O&M costs
12,500 EUR / year

Specific annual solar heat production
419 kWh / m² gross collector area

Solar heat generation costs
21 EUR / MWh

Savings of biomass
3,800 tons per year

Solar fraction over the year
6.5 %

Upcoming investment in smart heat

Grenaa Varmeværk is currently installing two large heat pumps, which will later be supplied with solar energy from the short term storage tanks. The utility aims to shut down the second on-site biomass boiler in summer to significantly extend its lifetime.

14.5 MW collector field intalled on a former industrial site PHOTO: SAVOSOLAR

"Our board of directors shares one vision: to use solar to supply consumers with cost-effective heat. And we will save costs when the system produces solar energy in summer because we can shut down one of our two wood chip boilers during that time."

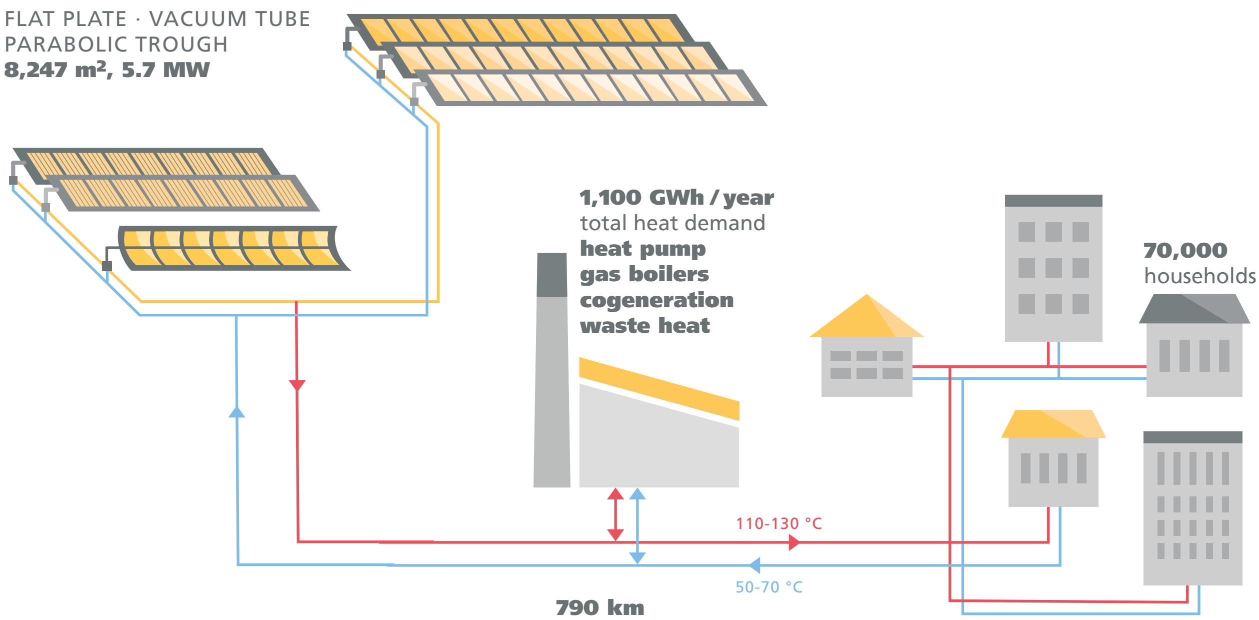
SØREN GERTSEN, *MANAGING DIRECTOR*

Grenaa **Varmeværk**
GRENAA, DENMARK

Large solar collectors show good results on **Austrian test field**

7 solar thermal technologies put to the test under real-life conditions

This project combines a wide variety of technologies, e.g., large flat plate collectors, vacuum tubes and parabolic troughs, which have been integrated at different stages of development. Testing them on site has brought to light their comparatively good performance and moderate maintenance needs. The practical, long-term experience of running these systems in a real-life setting has also proved to be highly efficient.



START OF OPERATION: 2008

Tested collectors

Flat plate

5,725 m²	ökoTech, Austria
1,140 m²	Arcon-Sunmark, Denmark
621 m²	KBB, Germany
254 m²	Savosolar, Finland
211 m²	GREENoneTEC, Austria

Vacuum tube (heat pipe)

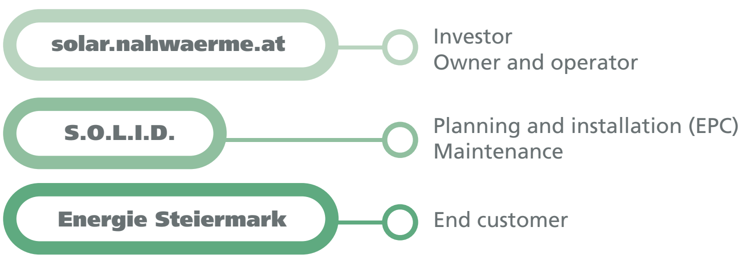
208 m²	AkoTec, Germany

Parabolic trough

88 m²	Absolicon, Sweden

ESCO model

The utility Energie Steiermark profits from a heat purchase agreement signed with solar.nahwaerme.at, an energy service company (ESCO).



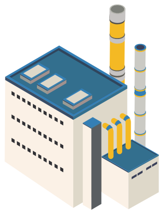
Energie **Steiermark**
GRAZ , AUSTRIA

The following are key features of large collectors

- Run at high temperature
- Come with an improved mounting system
- Require less time and effort to install

Test field with large collectors on the former dump site beside the DH plant in Graz PHOTO: S.O.L.I.D.

Pre-heating with **high efficiency**



COLLECTOR
13 m² flat plate collector with single glass

SIZE
656 m² gross area, **740 kW**

SITE OF INSTALLATION
Roof-mounted on boiler house

INSTALLATION: MAY TILL JULY 2018

COMMISSIONING: AUGUST 2018

MEASURED SOLAR YIELD:
688 kWh / m² in the first year

TURNKEY SUPPLIER:
GREENoneTEC

APPLICATION:
Pre-heating the make-up water for the district heating network of Vienna **(20 °C to 65 °C)**

Installation of large flat plate collectors with 13 m² each on the roof of the boiler house. Due to the low inlet temperature of 20 °C into the solar field, the collectors achieved a high specific annual yield of 688 kWh / m² in the first year of operation.

PHOTO: GREENoneTEC

Wien Energie GmbH
VIENNA, AUSTRA

SDH lowers price of heat **in French town**

Project partners guarantee solar yield over five years

The primary aim of this project has been to lower the heat price for consumers by 2.5 %, even after taking into account a carbon tax increase planned by the French government. Public funding covered 70 % of total project costs, which came to EUR 1.25 million.

Collaborative effort of multiple planning, engineering and manufacturing experts

Tecsol, Eklor, Pasquiet Equipements and Engie Cofely: These are the four companies which signed a contract guaranteeing the municipality a reliable solar yield over five years.

Tecsol
Created feasibility and detailed design study

Girus
Conducted predesign study

Eklor
Delivered solar field

Pasquiet Equipements
Installed SDH plant

Municipality of Châteaubriant
Paid for SDH system (and still owns it)

Engie Cofely
Operates SDH plant, heating centre and DH network, from which heat is sold to households

PHOTO: JEAN-FRANÇOIS MOUSSEAU

"It is really exciting to know that we have broken new ground for SDH in France. We succeeded because we enjoyed broad support from a variety of government agencies."

CATHERINE CIRON
MEMBER OF THE DEPARTMENTAL COUNCIL OF LOIRE-ATLANTIQUE
(FORMERLY DEPUTY MAYOR OF CHÂTEAUBRIANT)

2012 Connection to DH grid under discussion by two large heat consumers

May 2013 Feasibility SDH study conducted by Tecsol, France

June 2015 Terms of SDH system management by French utility Engie Cofely included in existing plant operation agreement

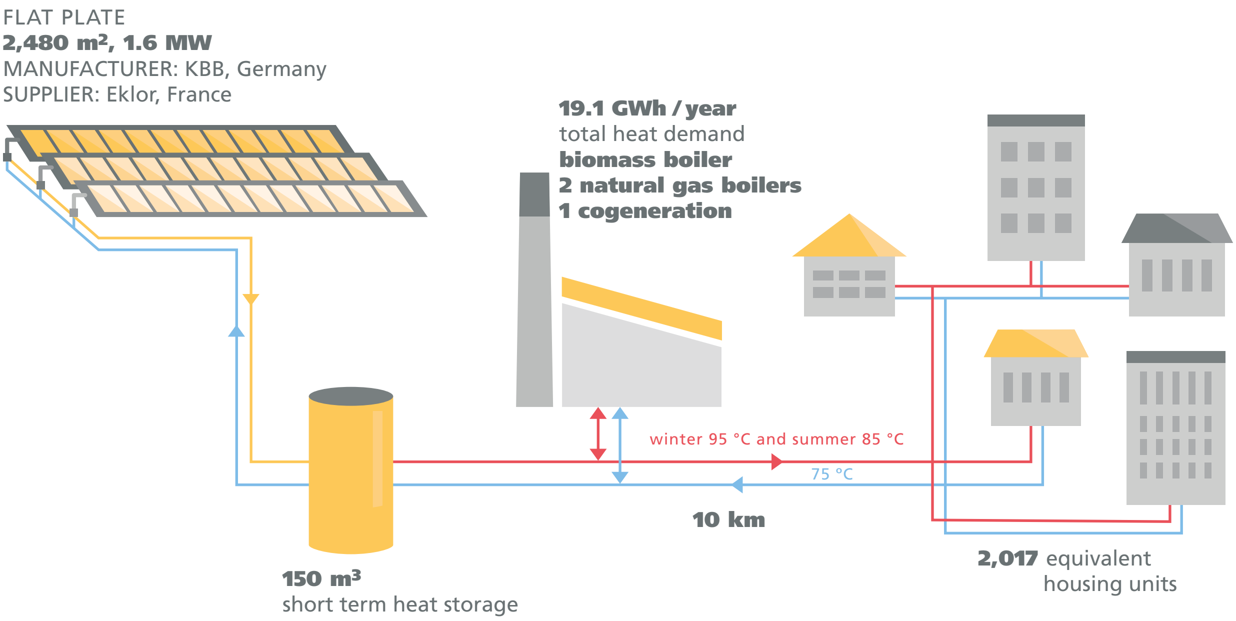
Oct 2015 Predesign study carried out by Girus, France

Nov 2015 Detailed design study carried out by Tecsol, France

Nov 2016 Tenders accepted for construction of 900 MWh-SDH plant (output cap added to prevent overheating in summer)

Jan 2018 Construction started

June 2018 **Plant commissioned**



INSTALLATION PERIOD: JAN TO JUNE 2018 · COMMISSIONING: 5 JUNE 2018

Economics

Capital costs	**Solar heat generation costs**
1.47 million EUR excl. VAT	55.2 EUR / MWh (including 70 % funding)
O&M costs	**Solar fraction over the year**
15,000 EUR / year (1 % of investment costs)	5 %
Specific annual solar heat production	**Solar fraction in summer**
363 kWh / m² gross collector area	70 %

Latvian utility wants to **cut down on fossil fuel use**

"Denmark's big progress in SDH inspired us"

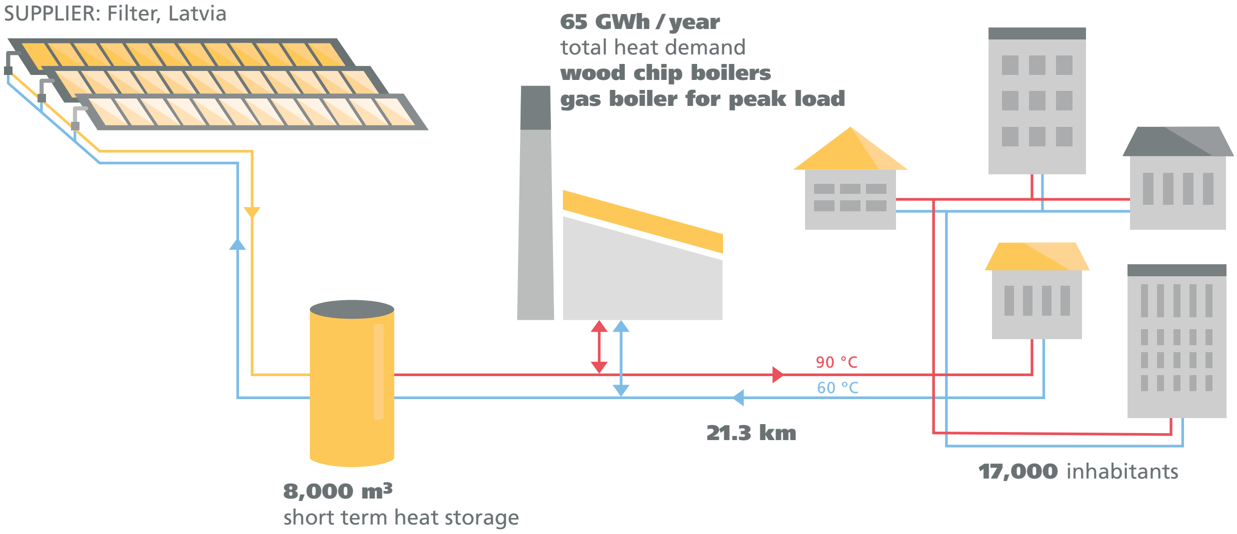
"We've been working on this project since we visited Denmark in 2016 to attend a conference on district heating. The aim is to reduce our carbon footprint and become less reliant on fossil fuels."

The district heating network operator serving the town of Salaspils started the installation of a solar system after a neighbouring cogeneration plant was closed down. The 15 MW solar district heating plant will meet 20 % of the annual heat demand.

INA BERZINA-VEITA
MANAGING DIRECTOR
AT SALASPILS SILTUMS

- **Sep 2016** Participated in SDH conference in Denmark
- **Jan 2017** Conducted feasibility study on SDH
- **Feb 2017** Secured EU funding
- **Dec 2017** Launched public comment period on land use
- **Mar 2018** Invited tenders for SDH system
- **Aug 2018** Signed contract with SDH turnkey system supplier Filter, Latvia
- **Sep 2019** **Increased renewable share in DH output to 90 %**

FLAT PLATE
21,672 m², 15 MW
MANUFACTURER: Arcon-Sunmark, Denmark
SUPPLIER: Filter, Latvia



COMMISSIONING : SEPTEMBER 2019

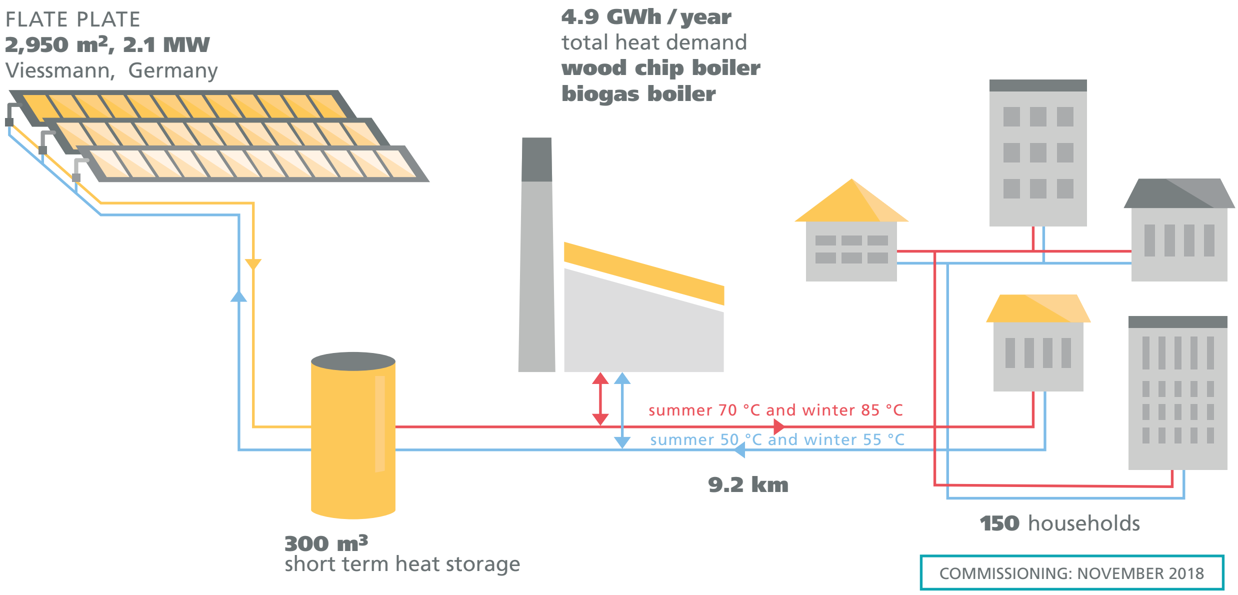
Salaspils **Siltums, Ltd**
SALASPILS, LATVIA

Bioenergy village Mengsberg

wins German solar award

for setting up local renewable heat production and a strong co-operative

Because the village of Mengsberg has many protected historic buildings, energy retrofits are difficult to carry out. Nevertheless, the community was intent on becoming independent of fossil fuels, so it chose to set up a renewable heat supply. In 2018, about 150 households in the village were connected to a heat network that uses solar thermal energy and wood chips to meet heat demand.



Economics

Specific capital costs
350 EUR / m2

O&M costs
0.8 - 1.0 ct/kWh

Specific annual solar heat production
330 kWh / m2 gross collector area

Solar heat generation costs
30 EUR / MWh

Solar fraction over the year
17 %

PHOTO: BIOENERGIEGENOSSENSCHAFT MENGSBERG

Bioenergiegenossenschaft **Mengsberg BEGM eG**
MENGSBERG, GERMANY

References

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Acronyms

IEA	International Energy Agency
DH	District Heating
SDH	Solar District Heating
SHC	Solar Heating and Cooling
ESCO	Energy Service Company
EU	European Union
GW	gigawatt(s)
MWh	megawatt-hour(s)
kWh	kilowatt-hour(s)
O&M	Operation and Maintenance

Glossary

Solar fraction
or solar savings fraction is usable solar energy output divided by total energy delivered from the heat network each year.

ESCO
stands for energy service company, a business model where a technology supplier signs an agreement to provide a district heating company with heat instead of a turnkey solar system. ESCOs finance, operate and maintain SDH installations, while their customers pay instalments based on either cost savings or set rates for the amount of energy they receive. In EU directives, this model is called EPC or Energy Performance Contracting. In the United States, it is known as a third-party energy services agreement.

Collector area
is one way to describe the size of a SDH system. In the context of flat plate and vacuum tube collectors, the reference approach is based on collector gross area, the maximum projected area of the complete collector. In the case of concentrating collectors, the aperture area is used to describe the size of the collector field and it is defined as the projected area of the reflectors/mirrors. With parabolic troughs the supplier refers to the flat, rectangular area specified by the outer perimeter of the mirrors (aperture).

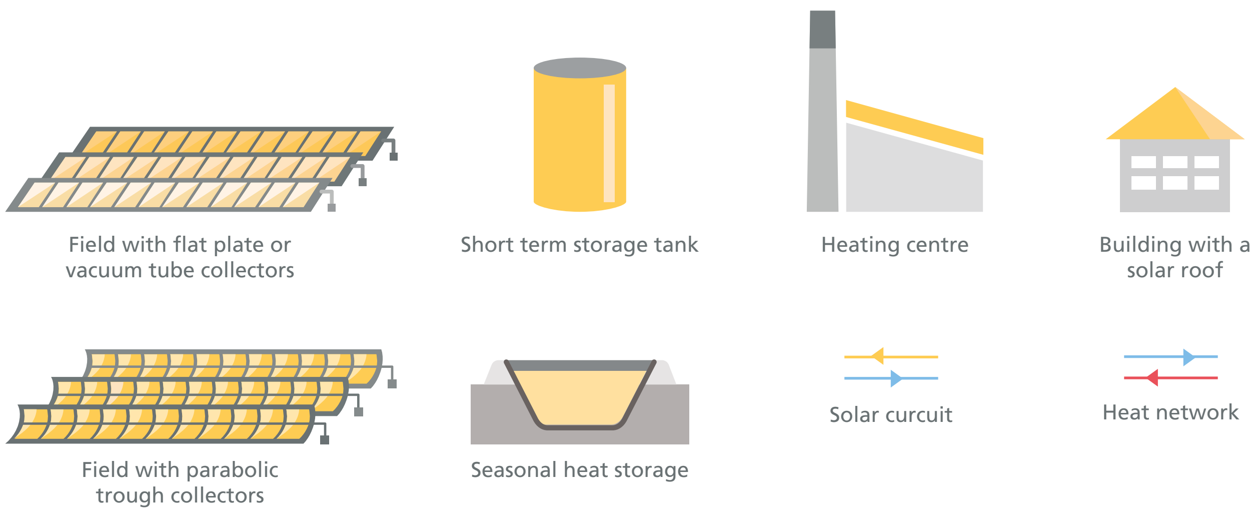
Solar thermal capacity
is calculated based on collector area by using a conversion factor of 0.7 kW_{th} / m^2. The IEA SHC Programme and multiple trade associations jointly created this factor to enable comparisons between solar thermal and other energy generation technologies. Actual capacity may be different depending on local solar radiation levels and the temperatures required for heat delivery.

Renewable heat
is thermal energy sourced from renewables, such as solar, biomass, biofuel and geothermal.

Short term heat storage
stores energy temporarily, for several hours or even a day, when there is more or less demand for heat than can be supplied. For example, it can store energy during the day to meet demand at nighttime.

Seasonal heat storage
holds in heat over longer periods, which could mean several weeks or months. In Europe, about 65 % of the annual solar radiation hits the earth's surface between May and September. However, the residential sector requires the most heat from October to April. Excess solar energy not used in summer must therefore become available in months with low radiation. The purpose of seasonal heat storage is to store thermal energy collected from large solar fields in summer to heat buildings via a distribution network in winter.

Pit heat storage
is a large water reservoir excavated in the ground for storing thermal energy during several months.



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International research and industry stakeholder network that develops technical and economic strategies to increase the number of SDH plants worldwide.

European Copper Institute
www.copperalliance.eu

Institute that supports sustainable energy solutions for buildings and industry by promoting and defending the use of copper.

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