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Deliverable report

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Deliverable name	Guidelines for the integration of renewables in district heating networks with a focus on solar thermal
Authors The authors bear the entire responsibility for the content of this report and for the conclusions drawn therefrom.	Florian Ruesch, OST-SPF, **florian.ruesch@ost.ch** David Theiler, OST-SPF, **david.theiler@ost.ch** Andreas Bohren, OST-SPF, **Andreas.bohren@ost.ch**
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sweet swiss energy research for the energy transition

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Summary

Swiss district heating networks are largely supplied by renewable energy sources, which can be divided into three categories: wood-based networks, networks with high-temperature waste heat, and networks with low-temperature sources and heat pumps. However, about 5% of historical networks are still heated exclusively by fossil fuels, and about one-third of the “renewable networks” depend on fossil peak or part-load burners. In addition to the obvious possibility of replacing the main source of fossil-only networks, it is particularly important to replace fossil peak and part-load coverage in networks with renewable heat sources to decarbonize district heating. This report identifies and summarizes different pathways and options for the three main energy sources. Fossil fuels can be directly replaced by renewable fuels such as wood, but large storage facilities also play an important role in transferring excess renewable band load from summer to winter. In the case of wood-fired heating networks, solar thermal or heat pumps can also be used. Swiss guidelines and manuals already exist for the well-established renewable energy sources wood, waste heat, and heat pumps. In this deliverable, existing examples and publications on solar thermal district heating from the international community are transferred to the Swiss context. Guidelines for the integration of solar energy into the Swiss district heating system will be provided in the form of factsheets, complementing existing factsheets on the integration of large thermal energy storage.

1 Introduction

The development and expansion of heating grids is considered to be of great importance for achieving the set climate targets. According to the Swiss Energy Perspectives 2050+[1], heating grids play an important role in all four ZERO scenarios. Already in the base case, the amount of heat provided via heating grids is doubled from 22 PJ (2019) to 41 PJ (2050). The scenarios assume that in the future, 26% of the heat demand of buildings will be provided with district heating, when only considering regions with elevated demand resulting in low distribution cost. Taking into account the potential that can be tapped at medium and high distribution costs, this percentage increases to 56% and 65%, respectively. However, this is only desirable if the heat is supplied using renewable energies or waste heat and not by fossil fuels. In the White Paper on District Heating [2], the potential of renewable district heating in Switzerland is analyzed. The study shows that up to 38% of Switzerland's total heat demand for space heating and hot water could be covered economically with renewable district heating. This means that the potential of renewable district heating is higher than the expected needs according to the ZERO basis scenario of the Swiss Energy Perspectives 2050+

On the other hand, the survey conducted by the Swiss District Heating Association [3] shows that the heat production mix of its members is based on fossil energies (oil/natural gas) for about 23%. Fossil energy sources are thus still among the most important primary energy sources in the covered heating networks in Switzerland, along with waste heat (36%) and wood (32%). However, only 5% (energy weighting) of the district heating networks use fossil energies as the main source. The most significant part of the fossil energy consumption in Swiss district heating comes from secondary sources for peak or part loads in mainly renewable grids.

2 Renewables in Swiss district heating systems

2.1 Status of renewable in Swiss district heating

In the list of thermal networks [4], a distinction is made between 19 different energy sources, whereby the main energy source is always specified and then in some cases several additional energy sources. Figure 2 shows the number of heating networks with a respective main energy source, whereby the energy sources were divided into four classes:

- Shades of gray: Fossil energy sources

- Shades of green: biomass-based heat carriers

- Shades of blue: Environmental heat required by a heat pump to generate useful energy

- Shades of orange: Waste heat from various processes

It can be seen that approx. 2/3 of all heating networks in Switzerland are mainly based on biomass, with wood chips clearly being the most frequently used energy source.

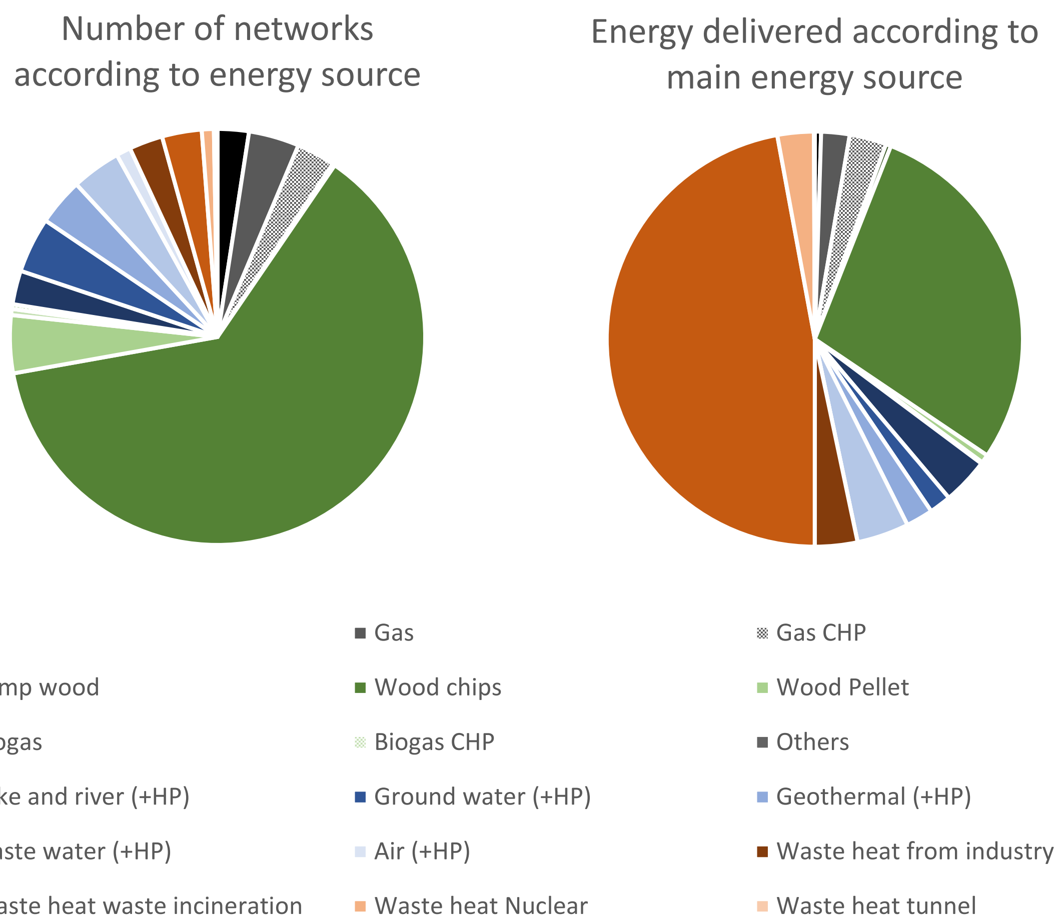

Figure 1: Number of networks and energy delivered by Swiss district heating networks according to their main energy source. The contributions of secondary sources are not considered in these graphics.

However, because networks based on biomass are typically rather small, the classification by number of networks gives an impression that does not do justice to their importance for the heat supply. For example, a few large networks that use waste heat from waste incineration plants as their main energy source generate almost half of the heat produced by district heating in Switzerland. Figure 3 therefore classifies the grids from the list of thermal grids by main energy source, weighted by the total heat quantity of the corresponding grid. However, because the secondary energy sources are not taken into account, this classification does not correspond exactly to the quantity of heat generation with different energy sources. Even if there are only a few, rather smaller grids with fossil fuels as the main energy source, many grids have fossil peak and off-peak load coverage. As a result, the proportion of fossil energy in the heating grids is greater than suggested by Figure 3. The shares of different energy sources (for main and auxiliary generation) are given by “Thermische Netze Schweiz” for 2021 as: 23% fossil, 32% wood and 36% waste heat [5]. Figure 3 therefore does not show the share of the respective energy source in the district heating mix in Switzerland, but rather the importance of networks with the respective energy source as the main energy source in the Swiss district heating landscape. This means that large networks with waste heat from waste incineration plants or nuclear power plants as the main energy source are responsible for half of the district heating generated in Switzerland. However, these are usually supplemented with other energy sources, mainly fossil or biomass pants for elevated demands in winter.

2.2 Integration of renewables in Swiss district heating

The integration of renewables in general has been treated in the EU Project RES-DC and general guidelines and examples are provided and distributed by the Swiss district heating association (www.thermische-netze-schweiz.ch). Based on the analysis of the Swiss district heating networks done in DeCarbCH and its partner projects (summarized in 2.1) and the findings of RES-DC [6], replacing fossil energy in Swiss DH networks by renewables can therefore be divided into three main categories described in the following subchapters. An overview of the main possibilities and pathways is given in Figure 2.

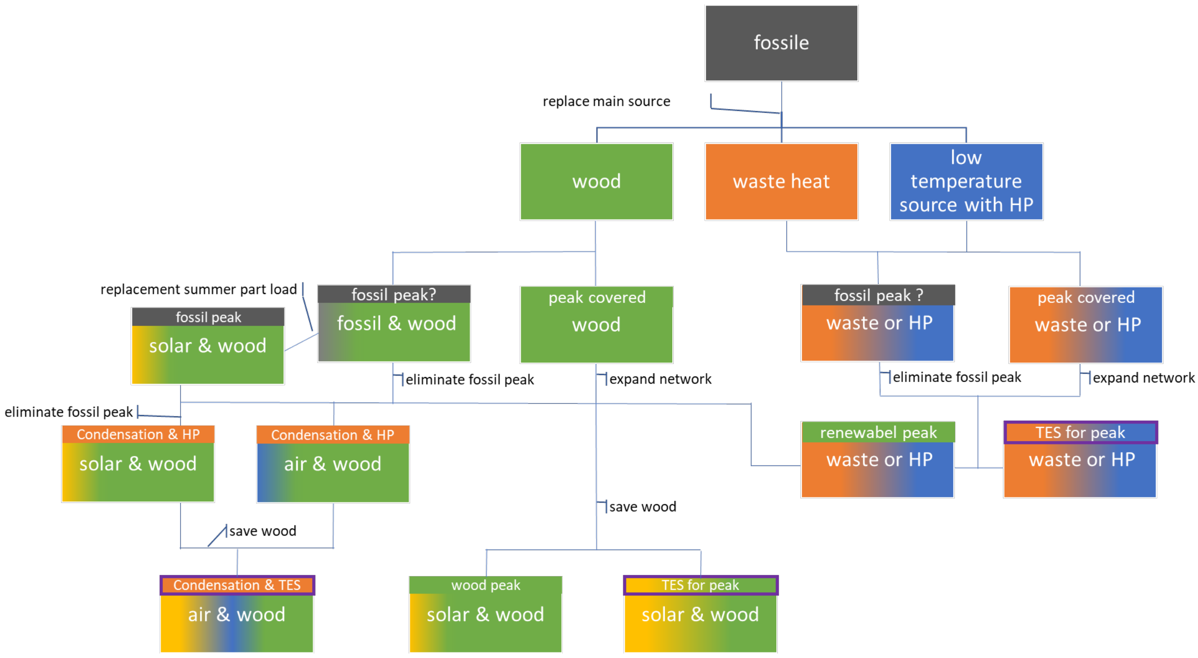

Figure 2: Different pathways for the decarbonization of Swiss district heating systems.

2.2.1 Replacement of the source of the remaining pure fossil networks.

Some district heating networks in Switzerland still rely solely on fossil fuels for heat production, particularly those that are historical. The priority for these networks is to replace the main source of heat with a renewable energy source. Depending on the grid temperature and the availability of renewable sources, it must be decided which main renewable source can be chosen. As these networks are mainly older and sometimes operate at elevated temperatures, the possibilities of integrating renewables are related to the question of how much the network temperatures can be lowered, which is discussed in DeCarbCH deliverable 7.1.1. The availability of high-temperature waste heat, such as from waste incineration, is geographically limited but is one of the remaining options if elevated temperatures are needed. If no high-temperature waste heat is available, wood/biomass is the remaining renewable source with no temperature restrictions and is able to replace the main source in historical, fossil, high-temperature networks. However, the availability of wood/biomass is limited, and there is a large competition with other high-temperature demand for this flexible renewable source (see also DeCarbCH deliverable 1.4.1). Connecting high-temperature waste heat or wood/biomass to district heating systems is well known and described, for example, in the standard handbooks [7] and documents of QM Holzheizwerke [8].

2.2.2 Replacement of fossil peaks

About one-third of the district heating systems with renewable main sources use fossil secondary sources, mainly for providing heating peaks. Fossil peak burners are present in all categories of networks with high renewable main sources, i.e., in wood-based, waste heat-based, and heat pump-based networks. In the case of wood-based networks, fossil secondary sources are sometimes also used to cover summer part loads.

Replacing fossil peak burners directly with renewable fuel burners (mainly wood) is possible in most cases. However, the competition with other high-temperature applications for the sparse wood resources is similar to that described in section 2.2.1. Guidelines for the integration of wood-based burners are given by QM Holzheizwerke [8] (see several documents on www.qmholzheizwerke.ch).

Large wood-based heating centers provide elevated investment costs and are therefore not well-suited for peak coverage from an economic perspective when they have to be newly built only for peak coverage. An ideal combination can be found when existing wood-based networks are largely expanded or connected to other networks with remaining fossil peak coverage. In these cases, the existing wood burner can be used to cover winter peaks and other renewable sources as base load.

Both high-temperature waste heat and heat pump-based grids have access to sources that are more or less constant over the year and therefore, in most cases, provide an energy surplus in summer. Therefore, the integration of large thermal energy stores is another possibility to replace fossil peaks with renewable energy. Surplus summer energy can be stored seasonally and then used to replace fossil winter peaks. This possibility is treated in the DeCharbCH partner project BigStoreDH, and guidelines on the integration, cost, and different storage technologies are given in the form of factsheets [9].

In wood-based networks with fossil part-load coverage, solar thermal collectors or air-source heat pumps provide a possibility to replace fossil energy. Heat pumps can also use the flue gas condensation of wood burners as a source for efficient winter operation and therefore can also cover at least parts of the winter peaks. This option is described in a RES-DC report [6]. Replacing fossil part loads is the most attractive implementation case for solar thermal energy. However, solar energy does not provide the possibility to replace fully fossil winter peaks. Nevertheless, the integration of solar thermal systems in biomass networks can help to save this valuable resource.

2.2.3 Substituion of Biomass

From the perspective of the Swiss energy system, also replacing biomass can be seen as an indirect manner of reducing fossil fuels. Biomass is sparse and provides one of the most cost-effective options to generate high temperature peak energy in winter. If wood/biomass can be saved in DH applications, it will be available for other applications with little renewable alternatives. One suitable way of saving wood in existing heating networks is to integrate solar heat. If a substantial proportion of the biomass required in winter is also to be saved, such systems require large thermal energy storage tanks. These are then also able to cover high peak loads in winter. The integration of solar heat in the Swiss context is discussed in greater detail in the following chapter.

3 Integration of solar thermal in Swiss district heating systems

Seven factsheets have been generated in the framework of this delivery. The first five introduce different types for solar thermal collectors and describe their suitability for the use in combination with district heating networks. Factsheet number six describes the cost and funding schemes of a solar thermal plant for district heating, while factsheet seven covers the topic of integration of solar thermal fields in district heating networks.

3.1 Collector Factsheets

In these five factsheets, the collector types *flat plate, evacuated tube, parabolic trough, vacuum flat plate* and *photovoltaic-thermal* are presented. Their advantages and disadvantages are shown, and typical yields (monthly and annual) for the locations *Rapperswil*, *Davos* and *Lugano* are shown. Existing examples of solar thermal fields combined with district heating are listed and a few renowned collector manufacturers are linked. The factsheets conclude with links to further information as well as a contact to SPF-OST, to which interested parties may refer.

The described information is gathered from several sources. The factsheets are generally inspired by factsheets of Solar Heat Europe [10] and of Solar District Heating [11] and adapted to the situation in Switzerland. The collector information is taken from SolarKeymark [12] and from SPF Testing results. The collector schemes and main parameters/materialization are own work based on these sources.

The monthly yield information is gathered for the three locations using PolySun v2023.8 and Meteonorm 7.2 data [13] [14]using each a high-efficiency and a low-efficiency collector each. They were simulated at south-facing direction with 30° tilt and 50°C collector temperature for the upper efficiency value and with 45° tilt and 80°C collector temperature for the lower efficiency value. The specific gain displayed is the one regarding the gross collector area. As Polysun uses the aperture area specific gain, this value had to be adjusted by the ratio of aperture and gross collector area. The following collectors have been used:

Table 1: Used collectors for the "typical collector output" graphs and their respective Polysun-catalogue numbers.

	FPC	VTC	PTC	VFPC	PVTC
High Efficiency	SF100-03 DE	XL 19/49	PolyTrough1800	MT Power v4	Soblue 72C
Cat. Nr	16340	15086	1549	16617	1107
Low Efficiency	AV 23 light	LaZer2	X10-14	MT Power v3.11	HM1095
Cat. Nr	527	697	13531	12959	1102

The annual yield data was generated using the "high efficiency" monthly data and shown for both 50°C and 80°C collector temperature in a tabular form. Furthermore, monthly values are given in a graphical form for three typical locations Rapperswil (midlads) Davos (alpine) and Lugano (southern Switzerland). In Figure 3 these graphics are shown for flat plate collectors and photovoltaic thermal collectors. As monthly yields depend among others on the quality of the used collector as well as the operation temperature and the local mounting situation. Therefore, no exact limits are given, but the range of achievable yields is faded out.

A selection of national and international examples was selected from the national project SoList and the international plant database of solar district heating [5]. A focus was set to national plants, plants in the neighbouring countries, new or especially impressive/large examples.

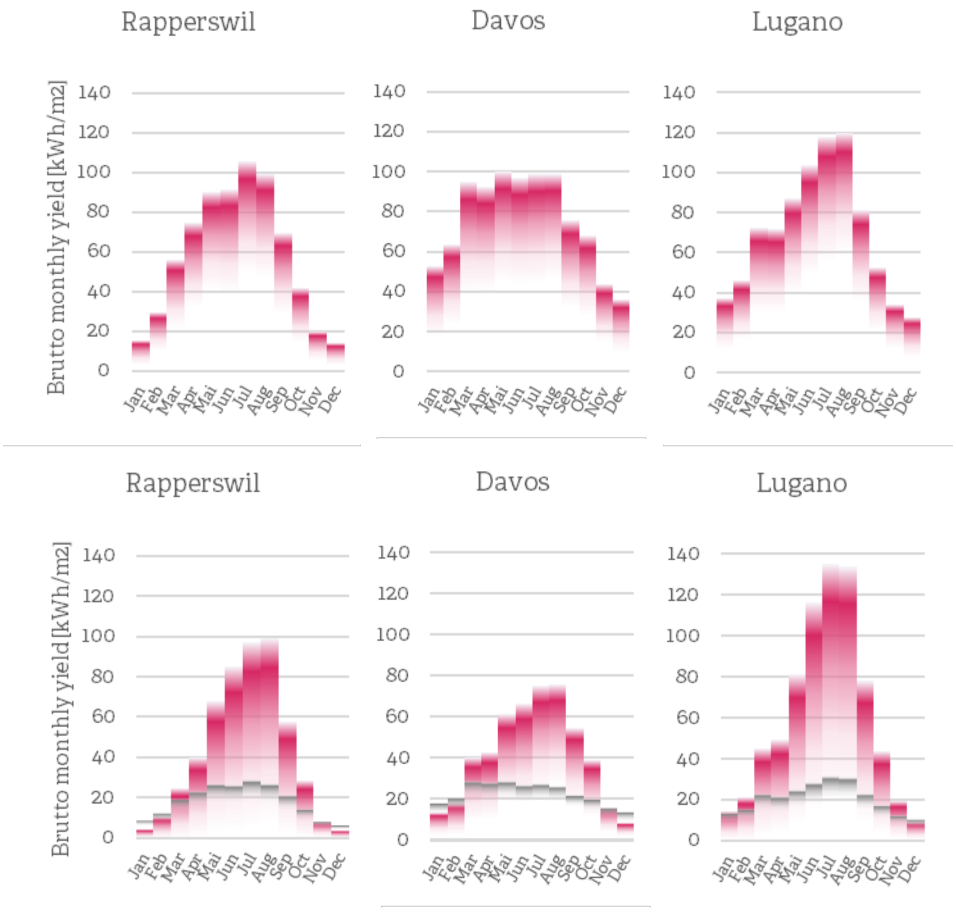

Figure 3: Summary of typical performance date for flat plate solar collectors (top) and photovoltaic thermal collectors (bottom) in Swiss district heating systems.

3.2 Cost and Economics Factsheet

This factsheet summarizes the most important information on the costs of solar thermal systems to transfer it from the international context to the Swiss framework conditions. Data and information from national projects as well as from international cooperation in IEA SHC Task 68 were used for this purpose. Due to a lack of implemented large-scale national projects with solar thermal collectors, data from international projects was used to estimate possible costs in Switzerland. It is particularly important to show scaling effects when constructing systems with a collector area of several thousand square meters, for which no national data is available. Thanks to the collaboration in Task 68, raw data from the International Renewable Energy Agency report [15] could be used for this analysis. Both the current exchange rate at the time of publication of the international data and the higher labor cost index in Switzerland (+ 83% compared to the mean EU index [16]) were taken into account for the conversion, wherefore only labor-intensive cost components such as installation and planning were increased. As the raw data did not include a breakdown by cost share, typical values with 34% wage-intensive shares were used. The breakdown of costs was also based on the example WLS in Schüpfen Switzerland [17].

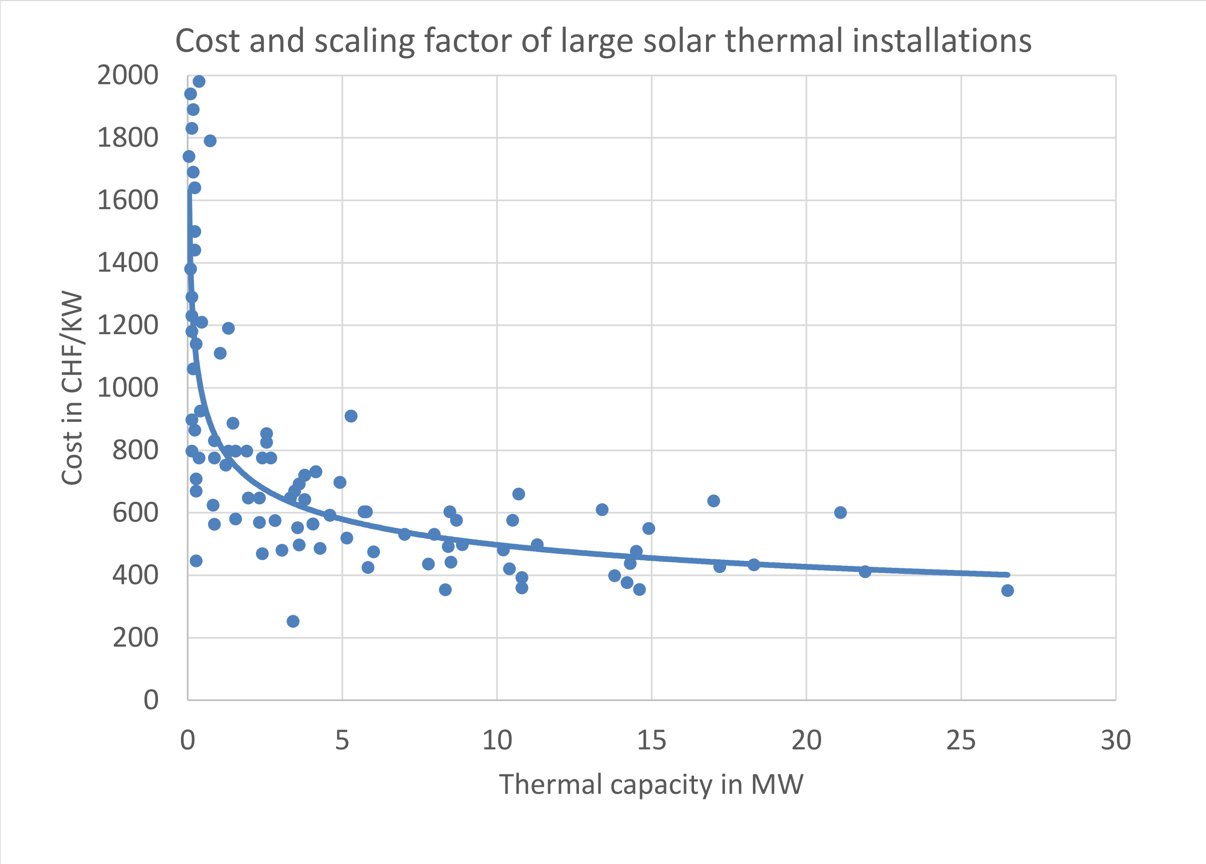

Figure 4: Scaling of the cost of large-scale solar district heating from European examples adapted for Switzerland.

Furthermore, a summary of possible financing schemes and their advantages and disadvantages is given. Such financing schemes can be interesting for heating network operators to reduce risks and to transfer the planning and operation of large solar thermal systems to highly specialized companies. The factsheet also lists examples and companies that have specialized in the field of contracting or financing large solar thermal systems.

The factsheet concludes with the Swiss framework conditions relating to subsidies and the legal situation for large-scale solar thermal plants.

3.3 Integration Factsheet

This factsheet summarizes different integration options and explains their advantages and disadvantages. It discusses centralized and decentralized integration as well as schemes for flow-return, return-return and flow-flow integration. Suitable control strategies are explained in a separate section.

An important point is the combination with thermal energy storage, for which reference can be made to the separate storage factsheets. Two other important aspects, namely the choice of heat transfer fluid and dealing with stagnation, are also addressed. Information in these sections is based on findings from the national projects SOLCAD [18] and BioSolFer [17], but above all from international recommendations [10,11,19].

In addition, the factsheet concludes with an overview of the situation in Switzerland, where there is little experience with very large conventional solar thermal systems, but which is a leader in the integration of PV collectors into low-temperature networks.

4 Conclusions and next steps

Swiss district heating networks are largely supplied by renewable energy sources, which can be divided into three categories: wood-based networks, networks with high-temperature waste heat, and networks with low-temperature sources and heat pumps. However, there are also historical networks that are heated exclusively by fossil fuels. General recommendations for the decarbonization of heating networks in Switzerland were presented by the Swiss partners of the EU project RES-DC [6].

In addition to the obvious possibility of supplying these fossil networks with renewable heat sources, it is particularly important to replace fossil boilers and part-load boilers in networks with renewable heat sources to decarbonize district heating. This report identifies and summarizes different paths and options for the three main energy sources in Swiss district heating networks.

In addition to the obvious option of using renewable fuels such as wood instead of fossil fuels, large storage facilities play an important role in transferring excess renewable band load from summer to winter. In the case of wood-fired heating networks, solar heat or heat pumps can also be used in addition to an expansion of the wood output. The guidelines for the integration of solar energy in heating networks in the form of factsheets developed here supplement the factsheets already published about large storage systems in heating networks.

It is planned to publish and disseminate these factsheets and an explanatory document in cooperation with Swissolar using the resources of the national association. This will ensure that the relevant stakeholders in Switzerland are reached.

5 References

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6 Appendix: Factsheets 1-7: Integration of solar energy in district heating

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Flat Plate Collectors

Factsheet 1: Integration of solar energy in district heating

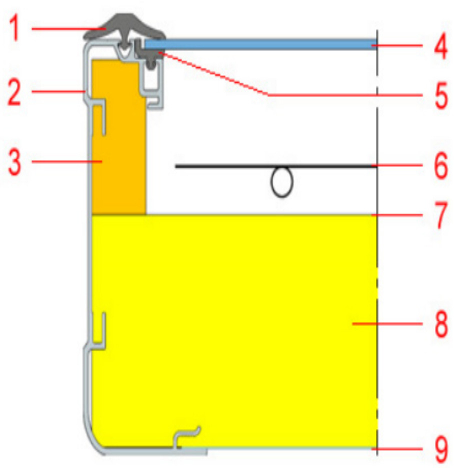
General Information

World's largest collector field in Silkeborg DK with 157'000 m² of flat plate collectors generating 20 % of the district heating energy demand.

General

Flat-plate solar collectors are probably the most fundamental and most studied technology for solar-powered domestic hot water systems. The idea behind it is simple. The sun heats a dark flat surface that collects as much energy as possible. The heat is transferred to a working fluid, (usually an anti-freeze mixture) and transferred to the district heating system via plate heat exchangers. Flat-plate systems typically operate within a temperature range of 30 - 80 °C. With the introduction of selective coatings, the stagnant fluid temperature in flat-plate collectors can reach more than 200 C. Several manufacturers have produced large collectors specifically designed for large scale solar district heating (DH) systems. These collectors reach aperture areas of up to 25 m² each and facilitate the installation and connection of large fields, lowering the cost of open field installations. With typical operating temperatures between 50 °C and 80°C, flat-plate solar collectors can achieve efficiencies of 60-70% and a typical power of 0.7 kW/m² can be applied. In Switzerland, 500-700 kWh/m² per year can be reached depending on the operating temperature.

Construction



1	Sealing
2	Casing
3	Side insulation
4	Front glass
5	Sealing
6	Absorber
7	Back sheet
8	Back insulation
9	Back cover

The heart of a flat-plate collector is the absorber, which is an aluminum or copper sheet with a selective coating. This coating absorbs as much sunlight as possible, but has minimized radiative losses similar to modern window coatings. The fluid-carrying pipes are welded to the absorber sheet to transfer the absorbed energy to the transport fluid. Thermal losses are reduced by mineral wool insulation at the rear and a transparent glass cover at the front. For higher operating temperatures, a second transparent layer is sometimes introduced to further reduce thermal losses. A steel or aluminum casing is used to provide stability and protect the internal components from environmetal influences.

OST
SPF Institut für Solartechnik

Area	1 - 25 m²
Investment cost [a]	220 - 400 CHF/m²
Temperature range	30 - 80 °C
Life expectancy	>30 years

[a] without cost for planning and permits

Materials

Absorber	Glass or	1.6-2.2 mm
	Alu/Copper	0.15-0.4 mm
Piping	Alu/Copper	12 - 40 mm
Cover	Borosilicat glass	1.6 - 4 mm
Insulation	Vacuum	
Casing	Metal (header: plastic)	
Reflector opt.	Aluminum sheet	

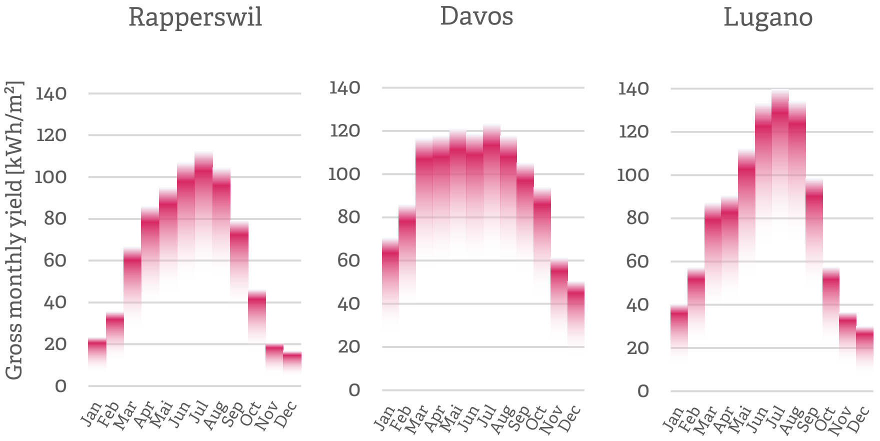
Advantages

- large scale collectors available
- several manufacturers with standard products and production in Europe
- low cost
- established/ long lasting experience with large collector fields
- elevated efficiency at medium temperatures
- elevated recycling rates

Disadvantages

- elevated losses at high temperatures
- stagnation concept needed
- not suitable for the operation with water

Typical collector output



Annual yield* [kWh/m²]

	50 °C	80 °C
Rapperswil	670	414
Davos	1000	656
Lugano	859	550

* Yield of a good product at a constant average operating temperature for a 30° tilted collector facing south. Values refer to gross collector area.

Situation in Switzerland and worldwide

Flat-plate collectors are the most commonly used collector type in district heating (DH). Approximately 1'500'000 m² of collectors are is in operation in DH systems worldwide. The solar thermal district heating market was dominated by Denmark in the period from 2010 to 2020. However, large systems have recently been installed in the rest of Europe and China.

Examples:

Name	Country	Area	Year
Marstal	DK	157'000 m²	2016
Vojens	DK	70'000 m²	2018
Zhongba	CN	35'000 m²	2019
Crailsheim	D	7'500 m²	2003
Dailly Lavey	CH	850 m²	2009

Collector manufacturers

- Meriaura Energy (Finnland, former Savo Solar)
- GREENoneTEC (Austria, former Arcon Sunmark)
- Micoe (China)
- Winkler (Austria)
- Soltop Energie (Switzerland, small scale)
- Ernst Schweizer (Switzerland, small scale)

(not exhaustive list)

Relevant sources & further information

- Webpage *on solar district heating*
- IEA-SHC Task68: *Efficient Solar District Heating Systems*
- SolCAD: *Potentiel du solaire thermique dans les chauffages à distance en Suisse*
- BioSolFer: *Integration von Solarwärme in Biomasse Fernwärmenetze*

Contact
Florian Ruesch
OST – Ostschweizer Fachhochschule
+41 58 257 48 31, florian.ruesch@ost.ch

Generated in the framework of the Project DeCarbCH

DeCarbCH

Evacuated Tube Solar Collectors

Factsheet 2: Integration of solar energy in district heating

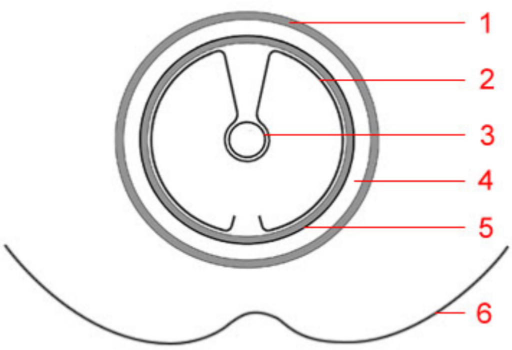
General Information

Evacuated tube collectors provide heat for the network of WLS in Schüpfen CH.

General

Evacuated tube solar collectors (ETC) consist of a series of glass tubes that are evacuated to create a vacuum, with a metal absorber tube located inside the glass tube. The selective coating on the absorber tube enhances the absorption of solar radiation and minimizes the amount of heat that is lost through thermal radiation. A vacuum insulation minimizes heat loss and allows the collector to maintain high temperatures even in adverse weather conditions. ETC are used to generate temperatures up to 150 °C, but can reach stagnation temperatures over 300 °C. When connected to district heating systems, they achieve annual energy outputs in the range of 500-800 kWh/m² (gross) under Swiss conditions.
The low thermal losses allow direct integration into a water-bearing network. To prevent freezing during cold winter nights, some energy is used to keep the collector field temperature above zero degrees. For district heating systems, special large scale collectors with a surface area of up to 15 m² are available.

Construction



1 Cover glass
2 Conductive sheet
3 Heat carrier
4 Vacuum
5 Absorber coating
6 CPC reflector

Vacuum tube solar collectors use vacuum inside a glass tube to reduce thermal losses. The most common collectors are based on the so-called Dewar principle, where a high vacuum exists between an inner and an outer glass tube. A selective layer, which absorbs the sunlight but emits little heat radiation, is usually applied to the inner glass wall. An aluminum sheet, which is no longer in the vacuum, touches the inner glass wall and conducts the heat to a fluid-carrying tube, usually made of copper. There are also vacuum tube collectors in which a metal absorber fin is placed directly in the high vacuum. Optionally, compound parabolic collectors are fitted with specially shaped reflective plates that reflect the radiation passing between the vacuum tubes back to the absorbers.

Area	1 - 15 m²
Investment cost [a]	280 - 450 CHF/m²
Temperature range	60 - 120 °C
Life expectancy	>30 years

[a] without cost for planning and permits

Materials

Absorber	Alu/Copper	0.2 - 0.4 mm
Piping	Alu/Copper	12 - 40 mm
Cover	Low iron glass	3 - 4 mm
Insulation	Mineral wool	5 -10 cm
Casing	Metal (Alu/Steel)	

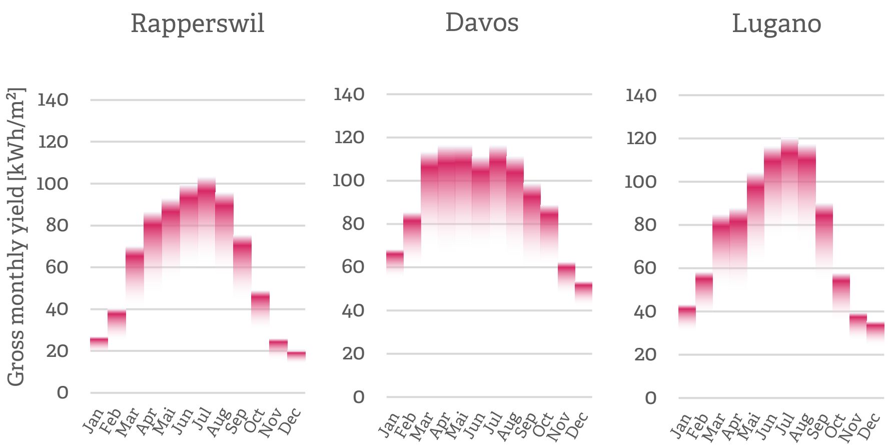
Advantages

- Low heat losses
- Elevated temperatures reachable
- Good harvesting of direct an diffuse radiation
- Elevated efficiency at flat incidence angles
- Horizontal installation on flat surface possible

Disadvantages

- Solar inactive header needed
- Glass tube production in far east

Typical collector output



Annual yield* [kWh/m²]

	50 °C	80 °C
Rapperswil	714	608
Davos	1038	905
Lugano	868	752

* Yield of a good product at a constant average operating temperature for a 30° tilted collector facing south. Values refer to gross collector area.

Situation in Switzerland and worldwide

Vacuum tube collectors dominate the global solar thermal market due to the Asian market for domestic hot water. Several lage installations exist in Europe, including Germany's largest solar thermal field in Greifswald. Switzerland also has some large VTC istal-lations in district heating networks, lage building complexes or for process heat generation.

Examples:

Name	Country	Area	Year
Greifswald	D	18'800 m²	2022
Lemgo	D	9'200 m²	2022
TicTricTrac Zürich	CH	1'000 m²	2020
HUG Geneva	CH	510 m²	2023
Wärmeverbund Lyssbach	CH	460 m²	2012

Collector manufacturers

- Ritter XL
- Viessmann
- SUNDA
- Micoe

(not exhaustive list)

Relevant sources & further information

- Webpage *on solar district heating*
- IEA-SHC Task68: *Efficient Solar District Heating Systems*
- SolCAD: *Potentiel du solaire thermique dans les chauffages à distance en Suisse*
- BioSolFer: *Integration von Solarwärme in Biomasse Fernwärmenetze*

Contact
Florian Ruesch
OST – Ostschweizer Fachhochschule,
+41 58 257 48 31, florian.ruesch@ost.ch

Generated in the framework of the Project DeCarbCH

Parabolic Trough Collectors

Factsheet 3: Integration of solar energy in district heating

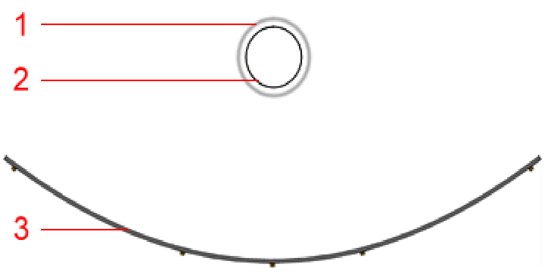
General Information

Two collector rows of the parabolic trough collector field in Brønderslev, DK. The 16.6MW$_{th}$-Plant has an aperture area of 29'929 m² and is combined with a biomass-organic rankine cycle for combined heat and power generation. Foto: Brønderslev Forsyning.

General

Parabolic trough collectors (PTC) consist of long, curved mirrors arranged in a parabolic shape to focus sunlight onto a receiver tube located at the focal line of the parabola. Therefore they reach elevated temperatures and provide extemely low heat loss in the collectors. In large concentrated solar power systems, they can reach up to 500°C. Smaller (e.g. rooftop) models can still reach 300°C, although the temperature used for district heating systems is much lower. To keep the focus on the absorber tube, a sun-tracking support system, which moves the collector throughout the day is needed. PTC collectors are therefore able to follow the sun and reache better efficiencies at flat incidene angles in the beginning and the end or the day. Because of the focussing mirror, diffuse sunlight is not harvested and PTC collectors are therefor suitable for Regions with an elevated fraction of direct sunlight. furthermore, they have the advantage of being able to tilt the collectors downwards for cleaning, snow or hail protection, and can be de-focused when there is no energy demand.

Construction



1 Glazing
2 Absorber
3 Mirror

The mirrors of a PTC are coated with a highly reflective material to collect and focus the sunlight onto the absorber tube. Absorber tubes are protected from environmental influences and heat loss with a glass layer. Depending on the required temperatures, the gap between the glass and the absorber can be filled with gas or vacuum for a further minimization of heat losses. The temperature inside of the receiver tubes can reach values higher than 500°C; but are usually operated at lower temperatures of up to 150°C for district heating networks. The collectors are typically mounted along the north-south axis on a sun-tracking support structure. This structure changes the tilt of the collector throughout the day, ensuring that the mirrors are always focused on the receiver.

Area	0.5-5 m width, 4-12 m length
Investment cost [a]	220 - 400 CHF/m²
Temperature range	100 - 500 °C
Life expectancy	>30 years

[a] without planning and heat exchanger cost

Materials

Absorber	Metal	Ø 2-8 cm
Reciefer Cover	Glass	1.6-3mm
Insulation	Air or Vacuum	
Reflector	Aluminum or Coated Glass	

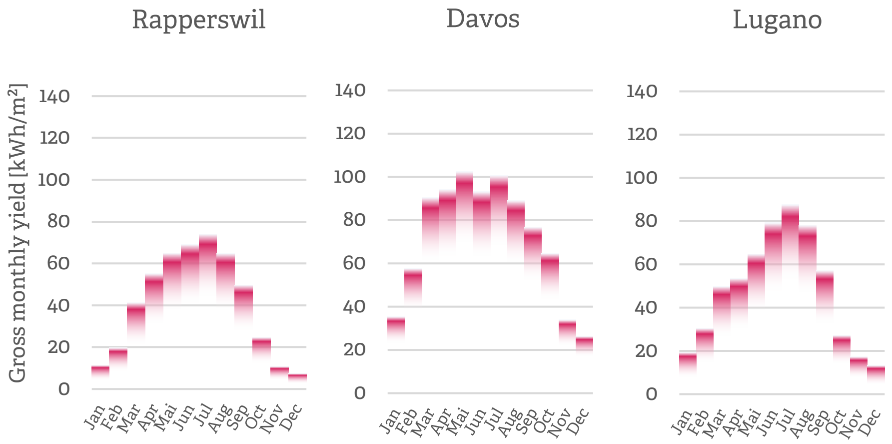
Advantages

- High temperatures possible
- Easy switch off by tracking system
- Outbut distributed over the whole day due to the tracking system

Disadvantages

- Mecanical trackung system needed
- Diffuse radiation not used
- Difficult roof integration
- Sensitive to soiling and dust

Typical collector output



Annual yield* [kWh/m²]

	50 °C	80 °C
Rapperswil	449	418
Davos	786	745
Lugano	525	489

* Yield of a good product at a constant average operating temperature for a tracked system with north-south orientation. Values refer to gross

Situation in Switzerland and worldwide

The main application of parabolic trough collectors is the generation of industrial process heat above 100 °C, for which there are many successful examples worldwide. parabolic trough collectors are also used in the food industry in Switzerland, e.g. at CREMO in Fribourg. In recent years, some very large systems have been built to support district heating networks with high flow temperatures, with parabolic troughs sometimes being connected in series with flat-plate collectors.

Examples:

Name	Country	Area	Year
Bronderslev	DK	26'900 m²	2018
Högslätten	SE	3'000 m²	2023
CREMO Freiburg	CH	627 m²	2012

Collector manufacturers

- Absolicon
- Solarlite CSP
- Torresol Energy
- Solitherm
- SBP Solar
- Aalborg CSP

Relevant sources & further information

- Webpage *on solar district heating*
- IEA-SHC Task68: *Efficient Solar District Heating Systems*
- SolCAD: *Potentiel du solaire thermique dans les chauffages à distance en Suisse*
- BioSolFer: *Integration von Solarwärme in Biomasse Fernwärmenetze*

Contact
Florian Ruesch
OST – Ostschweizer Fachhochschule,
+41 58 257 48 31, florian.ruesch@ost.ch

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Vacuum Flat Plate Solar Collector

Factsheet 4: Integration of solar energy in district heating

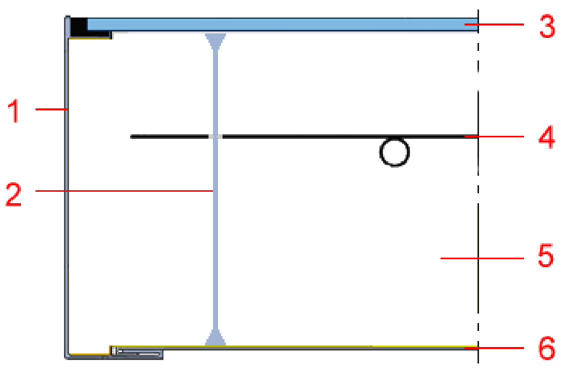
General Information

Vacuum flat plate collectors provide heat for the district heating network of Geneva. Source: TVP Solar

General

Vacuum flat-plate collectors are a further development of the classic flat-plate collectors. A high vacuum inside the collector almost completely prevents losses through heat conduction or convection. The air pressure of approx. 10 t/m² exerts a great load on the front and rear sides, so that the front glass in particular must be supported with regular supports. The manufacture of durable vacuum-tight connections between the front glass and the metal collector housing is the main challenge in the manufacture of flat-plate vacuum collectors. This has been commercialised mainly by spin-off companies from CERN. Evacuated flat-plate collectors have a very good yield of both direct and diffuse solar radiation and can also be used for high temperatures of up to approx. 200 °C.

Construction



1 Casing
2 Internal support
3 Front glass
4 Absorber
5 High vacuum
6 Back sealing

Vacuum flat-plate collectors are similar in design to conventional flat-plate collectors, but use a high vacuum instead of conventional insulating materials to minimise heat loss. The vacuum creates high forces, requiring the frontglass and the rear panels to be supported at regular intervals. A selective absorber plate absorbs around 95 % of the solar radiation, but only radiates a small amount of heat. The solar energy is transferred to a tube with a heat transfer fluid by thermal conduction. A glass solder becomes a vacuum-tight seal between the cover glass and the collector frame. Through heat conduction, the solar energy is transferred to a pipe with heat transfer fluid. A glass solder is used to achieve a vacuum thight sealing between the cover glass and the collector frame.

Area	2 m²
Investment cost [a]	220 - 400 CHF/m²
Temperature range	80 - 180 °C
Life expectancy	20>30 years

[a] without planning and heat exchanger cost

Materialien		
Absorber	Copper	0.2 mm
Piping	Alu/copper	12-40 mm
Cover	Low Iron glass	5 mm
Insulation	High vacuum	10^{-3} mbar
Casing	Metal (Steel)	

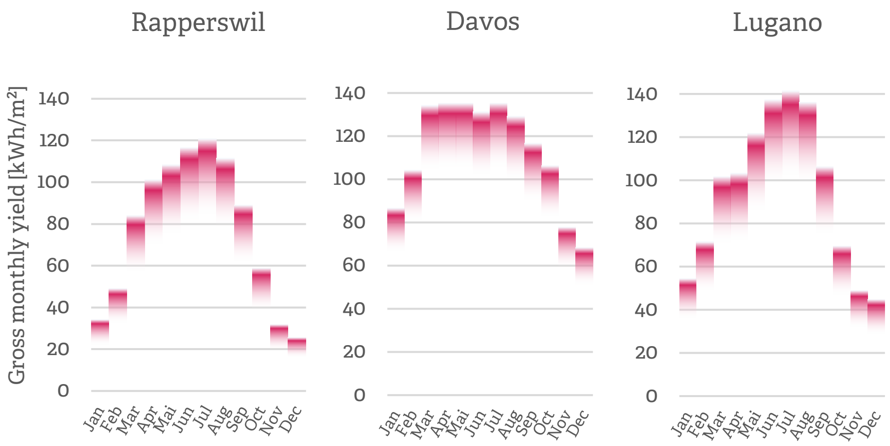
Advantages

- Low heat losses
- Elevated temperatures reachable
- Good harvesting of direct an diffuse radiation

Disadvantages

- Only relatively small units available
- Dominated by one manufacturer
- Experience with several decades of operation not yet available

Typical collector output



Annual yield* [kWh/m²]

	50 °C	80 °C
Rapperswil	848	738
Davos	1238	1106
Lugano	1035	915

* Yield of a good product at a constant average operating temperature for a 30° tilted collector facing south. Values refer to gross collector area.

Situation in Switzerland and worldwide

Vacuum flatplate collectrs are currently only commercialized by a Swiss company which is a spin off of CERN Several Installations are operable since several years in different climatc conditions worldwide. Switzerlands largest solar thermal installation for conventional district heating consists of VFPC and in Groningen (NL) an installation of 48'000 m² of ground mounted VFPC is currently under construction

Examples:

Name	Country	Area	Year
Dorkwerd (Groningen)	NL	48'000 m²	2023
SolCAD II	CH	800 m²	2021
Emmi Burgdorf	CH	160 m²	2022

Collector manufacturers

- TVP Solar

Relevant sources & further information

- Webpage *on solar district heating*
- IEA-SHC Task68: *Efficient Solar District Heating Systems*
- SolCAD: *Potentiel du solaire thermique dans les chauffages à distance en Suisse*
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Contact
Florian Ruesch
OST – Ostschweizer Fachhochschule,
+41 58 257 48 31, florian.ruesch@ost.ch

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Photovoltaic Thermal Collector

Factsheet 5: Integration of solar energy in district heating

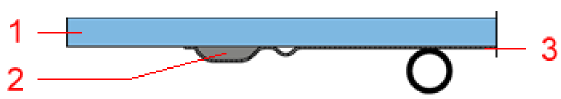
General Information

Switzerland's largest solar themal installation consist of about 3500 m² of PVT collectors regenerating borehole storages of the lowtemperature network for the Suurstoffi blocks.

General

Photovoltaic Thermal (PVT) collectors are a type of solar technology that combines the benefits of solar photovoltaic (PV) panels and solar thermal collectors. PVT collectors are suitable to be integrated in low temperature or "anergy" grids providing energy in the temperature range of 10-40°C. A typical application is to regenerate large borehole fields which serve as low temperature source for anergy networks and the decentralized heat pumps connected to the grid. For this typical application thermal outputs in the range of 300-400 kWh/m² can be expected in Switzerland, however the output of uncovered PVT collectors is strongly dependent on the operation temperature. Covered PVT collectors for higher temperature applications are part of ongoing research and development. PVT collectors generate both electricity and low grade thermal energy, making them an attractive option for use in new settlements with a demand of electricity and low temperature heat.

Construction



1 PV-Module
2 Bonded joint
3 Absorber

Most of the commercially available uncovered photovoltaic thermal collectors consist of a front cover similar to a conventional PV module with a thermal absorber on the backside.
Some products use the absorber also as heat exchanger with the ambient air to source heat pumps. They cannot normally reach temperatures above 70°C because they have no insulation.

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Area	1 - 2 m²
Investment cost [a]	220 - 400 CHF/m²
Temperature range	-5 - 40 °C
Life expectancy	20 - 30 years

[a] without planning and heat exchanger cost

Materialien

Absorber	PV cell	
Piping	Alu/copper	12 - 40 mm
Cover	Low Iron glass	3 - 4 mm
Insulation	Uninsulated	
Casing	Metal (Alu/Steel)	

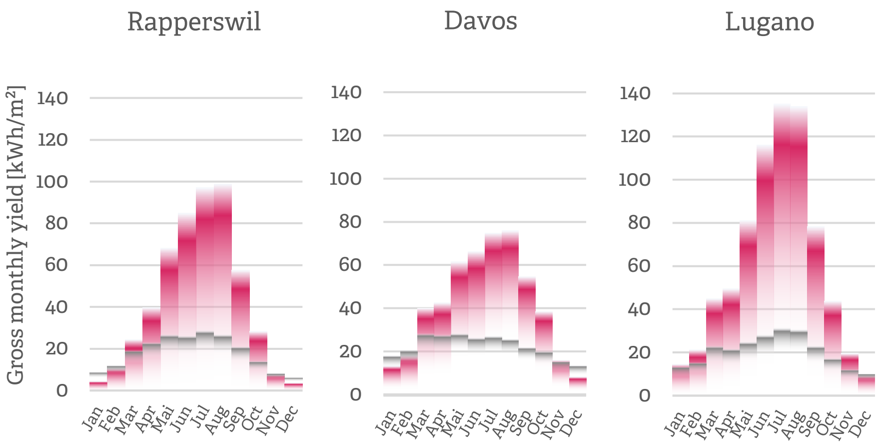
Advantages

- Generate thermal and electrical energy
- Low stagnation temperatures, no overheating protection needed
- Cooling provides slightly higher electrical output ov PV part

Disadvantages

- Only for low temperature applications
- Low thermal output at low outdoor temperatures/in winter

Typical collector output



Annual thermal yield* [kWh/m²]

	20 °C	30 °C
Rapperswil	478	214
Davos	464	233
Lugano	680	345

* Yield of a good product at a constant average operating temperature for a 30° tilted collector facing south. Values refer to gross collector area. The gray bars in the graph show the electric yield.

Situation in Switzerland and worldwide

The main application of PVT collectors is the regeneration of geothermal borehole fields connected to buildings, building complexes or districts supplied by low temperature networks. Switzerland is a pioneer in this technology and therefore the largest solar thermal installation in Switzerland is the 3500 m² PVT field connected to the low temperature network at "Suurstoffi" in Rotkreuz.

Examples:

Name	Country	Area	Year
Suurstoffi	CH	3'500 m²	2014
Oberfeld Ostermundigen	CH	1'320 m²	2013
REKA Blatten	CH	672 m²	2016

Collector manufacturers

- PVT Solar
- Solator
- DualSun
- Abora
- Naked Energy
- AGC Solar
- Solimpeks
- Ensol
- Fath

(not exhaustive list)

Relevant sources & further information

- PVTwrapup *Summary on PVT systems in Switzerland*
- Webpage *on solar district heating*
- IEA-SHC Task68: *Efficient Solar District Heating Systems*

Contact
Florian Ruesch
OST – Ostschweizer Fachhochschule,
+41 58 257 48 31, florian.ruesch@ost.ch

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Cost and Economics

Factsheet 5: Integration of solar energy in district heating

General Information

The development of very large solar thermal systems, especially in Denmark, has led to a decrease in the cost of solar heat with larger and larger solar thermal systems through optimisation of collectors, mounting and piping for large field installations. Production costs of less than 4 Cts/kWh of solar heat can be achieved for large-scale free-standing systems. However, the cost price of heat is highly dependent on various factors, with the lowest costs possible for very large ground-mounted systems. Feasibility studies have shown that solar heat production costs of around 6-7 Rp/kWh are also possible in Switzerland, even with collector areas starting at thousand square meters. Although there are no binding regulations for subsidizing large scale solar thermal systems, financial support can be expected in some cantons. Production costs of less than 5 cents per kWh are possible in Switzerland if subsidies are included.

Cost of Installations

Typical cost and scaling

There is a significant economy of scale in the implementation of solar thermal energy. This is supported by an analysis conducted by IRENA of all large-scale European plants in recent years. The results have been converted to Swiss conditions, taking into account higher labor costs, and are shown in Figure 1. The data show that the target cost for large installations can be reduced by a factor of four to 400 CHF/kW. This means that costs of just over 200 CHF/m² can be achieved under ideal conditions. Roof-integrated systems of less than 1000 m² have already been built in Switzerland at considerably higher costs.

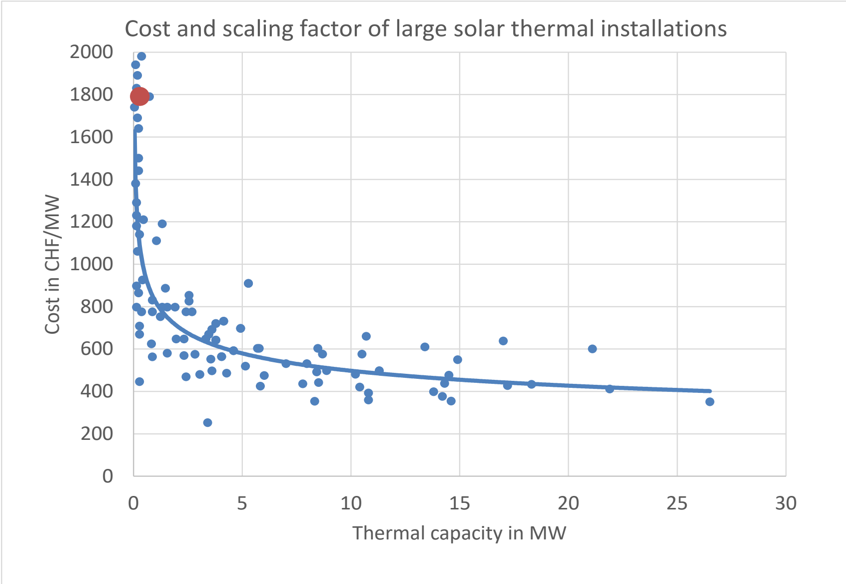

Figure 1: Cost of international large solar thermal installations adapted to Switzerland vs. their respective thermal capacity. The cost of a Swiss example WLS is given in red.

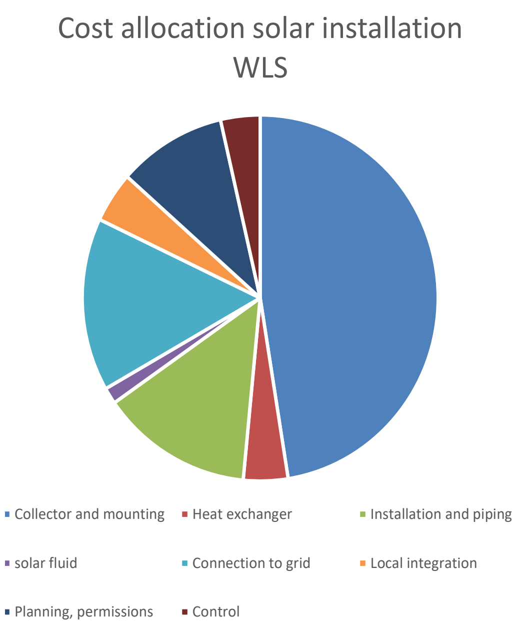

Figure 2: Cost distribution for the system of WLS with about 500 m² in Schüpfen CH. Sorce: WLS from BioSoFer report.

Cost assignment

In large-scale solar thermal systems in the range of tousand squaremeter in Switzerland, about half of the cost is typically spent on the collectors. The other half of the cost is divided between storage, integration, control, planning and installation. The figure 2 on the left shows the cost distribution for the system of WLS with about 500 m² in Schüpfen CH (source: BioSoFer report, see also figure on the left). There, no additional storage tank was required, but a longer connection pipe to the central station and an additional integration for a building at the location of the solar system had to be built. for larger systems the fraction of planning, control and installations gets and pure material cost for collectors, pipping and mountig gets dominat. Systems with a high solar fraction require relatively large storage tanks, and the share of the storage tank in the total cost increases with the targeted solar fraction.

Operating cost

Typical values for operating cost*

Financing cost	5-10%
Maintenance cost	0.27-0.5 %
Electricity/pumping cost	0.14-0.25 %
Land use	1-2 %

*annual cost as a fraction of total investment

Solar energy is free

Since the primary energy, i.e. the solar radiation, is free of charge in solar thermal systems, there are no energy costs and the operating costs are dominated by the capital costs. Only the operation of the circulation pumps requires some electrical energy. Based on international experience, the IEA SHC Task 52 gives a typical value for annual electricity costs of 0.14% of the investment costs. Maintenance costs should be less than half a percent of the investment costs, with a value of 0.27 % for large Danish installations. This shows that the financing costs for large solar thermal systems dominate the operating costs, which are strongly dependent on parameters such as the duration and the interest rate. Even with an optimistic interest rate of 3% and a payback period of 25 years, the financing cost is 5.5%. Shorter terms and higher interest rates result in significantly higher financing costs. Land costs (for lease or land purchase) are also not insignificant; according to the IEA SHC, they amount to 1-2% of the total investment costs per year.

Funding schemes

For large solar thermal plants, there are alternative funding schemes to the well-known bank loans, although some of them have not yet been used in Switzerland. They have their different advantages and disadvantages in terms of cost, liability and ownership.

Energy contracting

In this business model, the plant is financed by a third party, usually an Energy Service Company (ESCO) or specialized contracting companies (e.g. the operator of the district heating system). The plant is owned by this company, which then sells the energy to the heat consuming company. The heat price and the minimum purchase duration are contractually fixed. All aspects regarding financing as well as all operation & maintenance are handled by the contracting company. Some contracts include an option to purchase the plant after a pre-determined period.

Special Purpose Vehicles (SPV)

A special purpose vehicle is a company created solely for one specific purpose. In this case, the SPV is owned by either the user or by an ESCO and pays dividends to them. The SPV owns the solar plant and sells heat to the consuming company. This system reduces the risk for the owning company and provides more contractual flexibility.

Contracting companies:
- local Energy suppliers
- NewHeat, France
- Enertracting, Germany
- Solid, Austria

Third-party investors:
- kyotherm, in France
- TVP Investment

Subsidies and permissions in Switzerland

In Switzerland, financial support for solar thermal energy is part of the building program and is therefore regulated at the cantonal level. This also means that there are only binding rules for financial support for smaller systems integrated into buildings. A harmonised subsidy model defining minimum financial support according to the formula written below is adopted by most cantons. However, this rule often soesn't apply directly to very large grid-integrated systems and special rules usually have to be clarified individually with the relevant authority. The current subsidy situation for each individual canton can be found at www.kollektorliste.ch.

$$S > 1200 + 500/P$$

where P is the installed nomina power in [kW] and the resulting subsidy S in [CHF], from: HFM2015.

Legal situation for field installations

Technical installations in the agricultural zone may be approved if they are "locally bound and serve a higher interest". In the case of large solar thermal installations, both can be claimed, as they must be built close to large consumers such as heating networks and serve the supply of renewable energy. However, since this is a matter of weighing up interests and there are no precedents yet, there is no clarity in Switzerland on the permissibility of large solar thermal plants in the agricultural zone.

Relevant source & further information

- www.kollektorliste.ch
- Webpage *on solar district heating*
- IEA-SHC Task68: *Efficient Solar District Heating Systems*
- SolCAD: *Potentiel du solaire thermique dans les chauffages à distance en Suisse*
- BioSolFer: *Integration von Solarwärme in Biomasse Fernwärmenetze*

Generated in the framework of the Project DeCarbCH

Kontakt
Florian Ruesch
OST – Ostschweizer Fachhochschule,
+41 58 257 48 31, florian.ruesch@ost.ch

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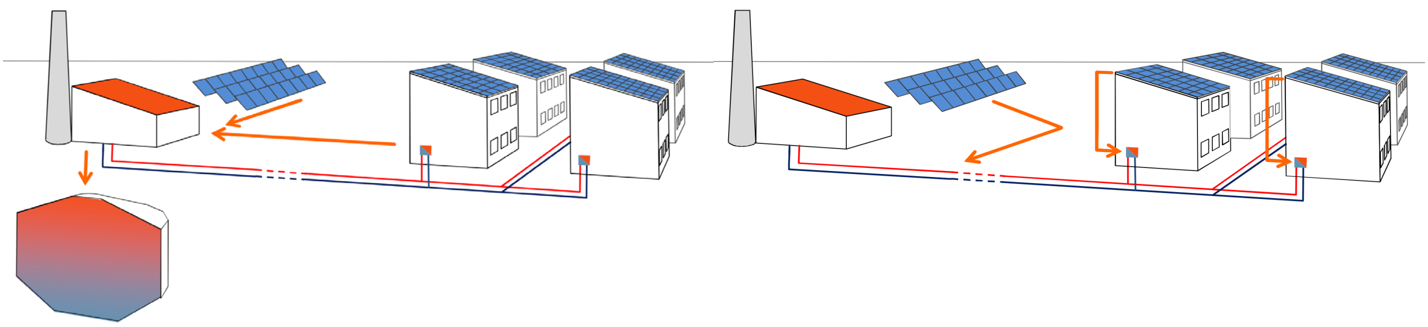
Grid integration of solar heat

Factsheet 7: Integration of solar energy in district heating grids

General Information



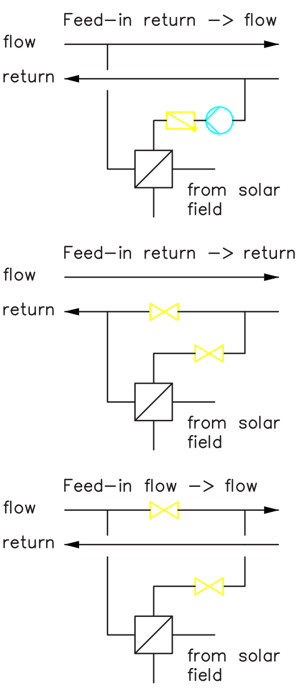
Centralized (left) and decentralized (right) integration of solar heat in district heating networks. *Source: Solites, via solar-district-heating.eu*

General

Solar collectors for district heating (DH) can be mounted on large roofs, carports, on existing structures such as walls or dams, or ground mounted in open fields. This is usually determined by space availability and distance to the DH network. Centrally integrated solar fields raise the temperature of the transfer fluid just upstream of the main heating point. The conventional heater then increases the temperature to the desired network temperature. This integration method requires a large seasonal thermal storage at the integration point if a high solar fraction is to be reached. This type of system is typically owned and operated by the owner of the DH system.

Decentralized solar thermal integration typically uses multiple smaller solar units, e.g. on small fields, carports, or by "prosumers": consumers that are able to feed in heat when the local production exceeds the local consumption. These systems typically do not require heat storage, as the grid is used as a heat store. These solar systems can be owned and operated by homeowners, companies, energy service companies (ESCOs) or the district heating provider.

Integration



Field integration can be accomplished using three feed-in principles. In the return->flow mode, the temperatures and pressure difference are defined by the heating grid and the solar field must be operated at flow rates matched to the required temperature. No valve is required in the grid line, but a pump is needed to overcome the pressure difference between return and flow.

The return->return principle uses the lowest operating temperatures resulting in higher solar yields. An additional valve is required in the grid line. This principle results in fluctuating return temperatures that must be balanced by other heat generators. A combination of return->flow integration in summer and return->return integration in winter can be favorable.

The flow->flow integration method results in the lowest solar yields and fluctuating grid temperatures. It is not normally used.

Control Strategies

The operation of a solar DH network includes the optimization of solar system yield, DH temperature, heat storage, heat consumption, electricity consumption, and so on.
For the solar system, variable flow rates in the range of 10-50 l/h per square meter of solar collector area are typically used to match temperatures to the DH flow temperature. These can be controlled using either the collector field temperature or an irradiance measurement. The latter does not suffer from thermal inertia, but cannot detect partial shading of the solar field.
In the case of a return->return integration a fixed "highflow"-rate around 50-70 l/h per square meter of solar collector area result in elevated efficiency.
Solar systems are usually switched off during the night and only operated when they are warm enough to provide heat to the DH system.

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Heat transfer fluid

Solar thermal systems are usually operated with a mixture of antifreeze and water as heat transfer fluid to prevent freezing during cold winter nights. In these cases, it is necessary to separate the systems, which is typically done using plate heat exchangers. However, there are also manufacturers who propagate a constant flow of water through the collector field to prevent freezing. These systems must be actively maintained at temperatures above 0°C using energy from the heating network. The resulting energy loss can be kept low by using vacuum collectors and good thermal insulation, and accounts for only about 2% of the solar yield.

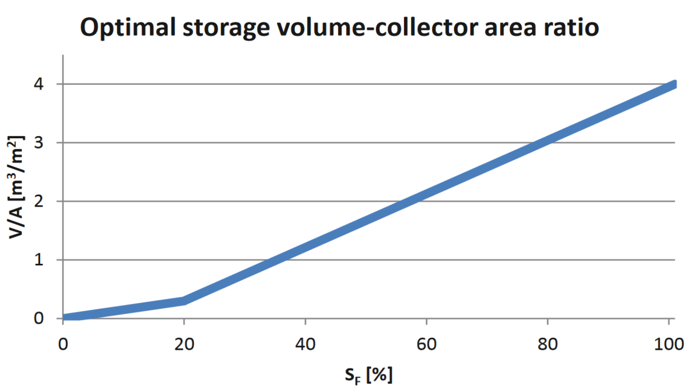
Avoiding stagnation

If the circulation pumps fail, or if the solar energy production exceeds the capacity of the grid and the available storage tanks, solar thermal systems face stagnation. Without a stagnation concept, solar thermal collectors can reach temperatures of more than 200°C during stagnation. In such emergency situations, stagnation is usually managed using stagnation cooling by air chillers.
Nevertheless, an emergency concept is needed to drain the system at high temperatures and pressures in case of failure.

Combiantion with Thermal Energy Stores

Since the yield of a solar thermal system depends mainly on solar radiation and therefore cannot be controlled, in many cases a thermal energy storage (TES) system is needed. A TES can compensate for time differences in production and demand. The size of a storage tank depends largely on the coverage of the solar system. If the maximum solar yield is less than the minimum grid demand, no storage is required. In this case, the solar system can always supply all the energy to the grid and the difference to the demand is generated by an additional energy source. Depending on the summer demand, solar coverage rates of 5-10% can usually be achieved without additional storage.
If the solar system is to cover a higher fraction of the demand, the required storage volume increases disproportionately. The thermal storage then needs to cover increasingly longer periods of bad weather. In typical heating networks, a solar fraction of 15-20% is required to cover the entire summer demand with solar energy. This is particularly interesting in combination with biomass as additional heating source, as these boilers can then be completely switched off during the summer.
Higher solar coverage rates can also be achieved using seasonal storage. In Vojens (DK), for example, a solar system with 70,000 m² of collectors and a pit thermal energy store (PTES) of 200,000 m³ achieves a coverage rate of almost 50% of the heating demand ccvered by the grid. The Drake Landing solar community in Canada even achieves solar fractions of 90-100% using a borehole thermal energy store (BTES).

Pit thermal energy store of Dronninglund (DK), the large solar thermal field installation can be seen in the background. Source: Solites



Proposal from SDH (solar district heating) for the rough dimensioning of the storage tank for different solar coverage ratios.

Situation in Switzerland

In Switzerland, there are some solar thermal plants that feed into thermal grids. However, these have low solar coverage rates of less than 10% and are therefore not dependent on large storage facilities.
On the other hand, Switzerland is a leader in the field of low-temperature or other energy grids, which are sometimes operated with ground storage. These networks can be supported with uncovered or PVT collectors due to the lower temperatures in the grid and the borehole thermal storage of approximately 5-30°C. Ground thermal energy stores that cool down during winter operation can be regenerated during summer using uninsulated collector technologies. For example, the world's largest PVT collector field regenerates the borehole thermal energy store of the low-temperature grid in the Suurstoffi district in Risch-Rotkreuz.
Low-temperature grids require integration concepts that differ from those presented in this fact sheet.

Relevant sources & further information

- Webpage *on solar district heating*
- IEA-SHC Task68: *Efficient Solar District Heating Systems*
- BigStoreDH: *Grosse Wärmespeicher für Wärmenetze inkl. factsheets regarding large storages*
- Solites Rechner: *Rechner für solare Fernwärmeanlagen*

Contact
Florian Ruesch
OST – Ostschweizer Fachhochschule,
+41 58 257 48 31, florian.ruesch@ost.ch

Generated in the framework of the Project DeCarbCH