

CENTRAL SOLAR HEATING PLANTS WITH SEASONAL HEAT STORAGE

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ABSTRACT

Solar assisted district heating systems contribute to the reduction of CO₂ emissions and global warming. The combination with long-term heat storage makes high solar fractions of approximately 50 % possible. Several pilot central solar heating plants with seasonal thermal energy stores built in Germany since 1996 have proven the suitable operation of these systems. These pilot plants have also confirmed the achievement of high solar fraction up to 50 %. Long-term operational experiences concerning, for example, the slope of the collector fields, the influence of net return temperatures and insulating materials were gained.

Four different store types for seasonal heat storage have been developed and tested under realistic operation conditions: Hot-water thermal energy store (e.g. in Friedrichshafen), gravel-water thermal energy store (e.g. in Steinfurt-Borghorst), borehole thermal energy store (in Neckarsulm) and aquifer thermal energy store (in Rostock).

Further central solar heating plants with seasonal heat storage are currently under construction. One of it supplies a district heating net in Crailsheim with thermal energy for space heating and hot water preparation. This system consists of two sections, of which the first one was taken into operation in 2004. The second section of the plant will be completed in 2007. The seasonal thermal energy storage will be realised as a borehole thermal energy store.

INTRODUCTION

Since 1996 several pilot central solar heating plants with seasonal thermal energy store (CSHPSS) were realised within the frame of the research and demonstration program "Solarthermie 2000". All these plants are tested under realistic operation conditions and are scientifically accompanied and analysed in detail by - among others - the Institute of Thermodynamics and Thermal Engineering (ITW). The continuation of this research program under the name "Solarthermie2000plus" [1], funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) makes the construction of further pilot plants possible, e.g. the solar assisted district heating system in Crailsheim.

SOLAR ASSISTED DISTRICT HEATING SYSTEMS

System concepts

Solar assisted district heating systems with short-term heat storage are designed for a solar fraction, based on the total heat demand for space heating and hot water preparation, of approx. 15 to 20 %. Usage of solar heat in solar assisted district heating systems allows the

installation of large collector fields which are considerably less expensive than small collector systems. The solar fraction is the proportion of usable solar heat to the total thermal energy used (hot water and space heating).

Solar assisted district heating systems with long-term heat storage are designed for a solar fraction of approx. 50 %. These systems usually supply more than 100 flats. The seasonal mismatch between high solar irradiance in summer and high heat demand in winter is balanced by seasonal heat storage. Figure 1 shows schematically different possibilities to integrate the district heating net into the buildings.

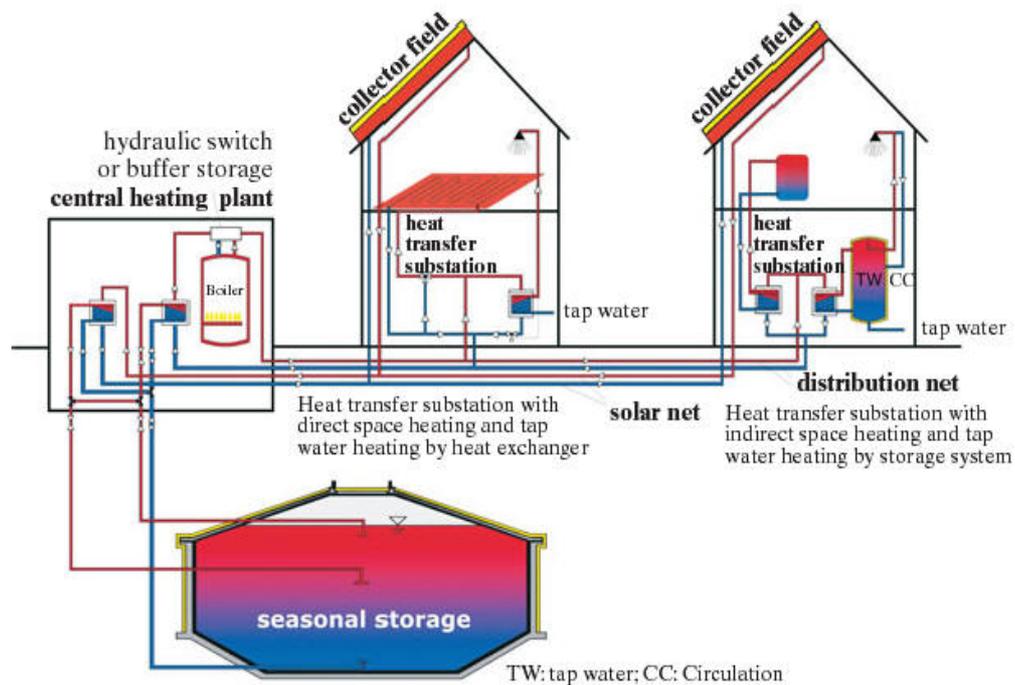


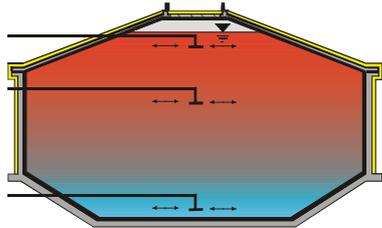
Figure 1: Solar assisted district heating systems with long-term heat storage

Heat gained from solar collectors is transported via the solar net to the central heating plant and, if required, distributed to the buildings, see Figure 1. Solar collectors are installed preferably on large roofs and the seasonal heat store is built to the ground. Heat supplied via the heat distribution net is used for space heating and hot water preparation. If neither the solar collectors nor the seasonal heat store can cover the heat demand on the heat distribution net, a conventional gas condensing boiler for example supplies additional heat. The design of solar assisted district heating systems is described in detail in [2] (in German).

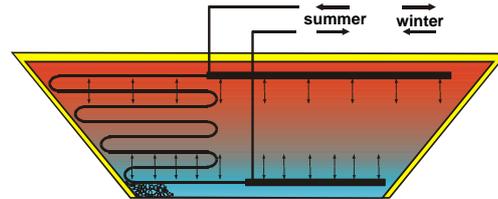
Seasonal heat storage

Four different store types for seasonal heat storage have been developed and tested under realistic operation conditions since 1984, Figure 2 [3]. The selection of a specific store type depends on the geological and hydro geological situation in the ground below the respective construction site. A preliminary geological examination of the store site is necessary especially for aquifer and borehole thermal energy stores. If different store types are possible, an economic optimisation should be carried out taking the construction costs for the different types of stores into account.

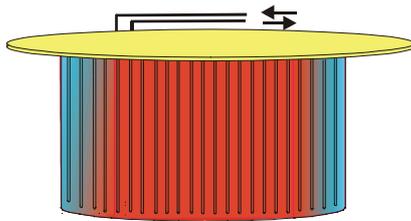
Hot-water thermal energy store



Gravel-water thermal energy store



Borehole thermal energy store



Aquifer thermal energy store

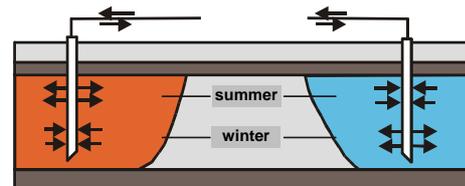


Figure 2: Different store types suitable for long-term heat storage

Realised solar assisted district heating systems with long-term heat storage

At present seven pilot plants for solar assisted district heating systems with long-term heat storage are in operation in Germany. Three more plants are under construction. The first pilot-plants were taken into operation in autumn 1996. In the following four selected plants with different store types will be depicted.

Friedrichshafen

Start-up in 1996

Approx. 390 flats

4.050 m² solar collector area (2.835 kW_{th})

Hot-water heat store (12.000 m³)



Figure 3: Hot-water heat store in Friedrichshafen during construction

Neckarsulm

Start-up in 1998

Approx. 300 flats

5.469 m² solar collector area (3.828 kW_{th})

Borehole thermal energy store (63.360 m³)



Figure 4: Solar collectors installed on the roof of a school in Neckarsulm

Rostock

Start-up in 2000

108 flats in one apartment building

1.000 m² solar collector area (700 kW_{th})

Aquifer thermal energy store (20.000 m³)



Figure 5: Apartment buildings with solar-roof in Rostock

Steinfurt-Borghorst

Start-up in 1999

42 flats

510 m² solar collector area (357 kW_{th})

Gravel-water heat store (1.500 m³)



Figure 6: Solar assisted district heating system in Steinfurt-Borghorst

Source: em. Prof. Gockell, University of Braunschweig

Operational experiences

For operation in Germany and high solar fraction, collector fields must be tilted about 35 to 45° against horizontal. This increases solar gains in winter compared to smaller slopes and hence reduces the required storage capacity. Low net return temperatures of the district heating system are essential for high collector efficiency and allow the seasonal heat store to be discharged to low temperatures in winter. This reduces storage heat losses significantly and

increases the usable storage capacity. The insulation effectiveness of mineral fibrous insulating material used for the insulation of the first generation of seasonal thermal energy stores is very sensitive to moisture from the surrounding soil. Today, insulating materials based on glass which can resist the strong influences of high temperature and humidity are utilised.

THE SOLAR ASSISTED DISTRICT HEATING SYSTEM IN CRAILSHEIM

The district heating net

In Crailsheim the development area 'Hirtenwiesen' is arising from a former military compound. About 260 flats in mainly detached houses plus a school and a gymnasium are to be supplied with thermal energy for space heating and hot water preparation via a district heating net. The expected heat demand will add up to 4.100 MWh/a, out of which 50 % will be covered by solar energy.

Functional principle and design data of the solar heating plant

The solar heating plant consists of two sections, of which the first one was taken into operation in 2004:

- The first section consists of collector fields installed on apartment buildings, the school and the gymnasium (so far 1.558 m²), a hot-water buffer store with 100 m³ and a heat transfer station connecting the plant to the district heating net.
- The second, mainly seasonal operating section is currently under construction. It will consist of approximately 5.000 m² collector area mounted on a noise protection wall, a second buffer store and a borehole thermal energy store (BTES).

Figure 7 shows the functional principle of the solar heating plant. All design data were obtained by transient simulations using the software package TRNSYS [4]. Further information on the solar heating plant is given in [5].

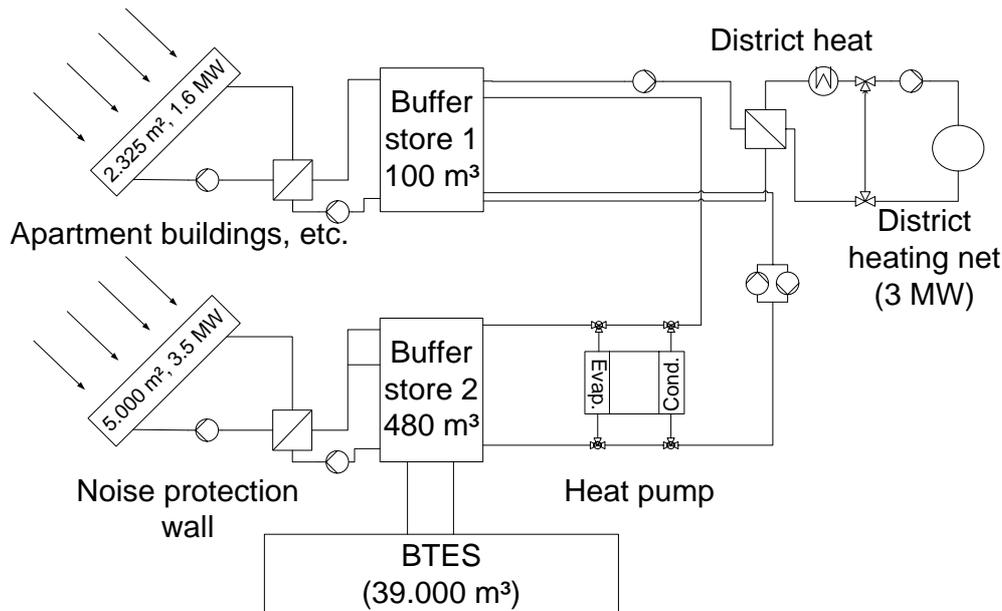


Figure 7: Functional principle of the solar heating plant

Seasonal thermal energy store

The seasonal thermal energy store in Crailsheim will be realised as a borehole thermal energy store [6]. It will consist of 80 double-U-pipes with a depth of 55 m and a spacing of 3 m. The store volume comprises 39.000 m³. The borehole thermal energy store can be discharged by two heat pumps down to 20 °C.

Instrumentation for scientific research and first measurements

The solar heating plant is scientifically accompanied and analysed in detail to obtain new technical know-how and to identify optimisation potential. Altogether 40 temperatures, nine flow rates and several valve settings and pressures of the first part of the heating plant are measured. Table 1 shows the heat balance for the year 2006.

	unit	value
Irradiation on collector plane	kWh/m ²	1.307
Heat gain of collectors	MWh	545
per m ² collector area	kWh/m ²	350
Solar heat into the district heating net	MWh	473
per m ² collector area	kWh/m ²	303
Heat losses of the buffer store and the heat transfer station	MWh	72
Solar fraction (based on total heat demand)	%	20

Table 1: Heat balance 2006 of the solar assisted district heating system in Crailsheim

SUMMARY

Several pilot central solar heating plants with seasonal thermal energy store built in Germany since 1996 have proven the functioning and suitability of long-term heat storage in combination with solar assisted district heating systems. The new plants in Munich, Crailsheim and Eggenstein will further contribute to technical and economical improvement.

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