The Central Solar Heating Plant with Aquifer Thermal Energy Store in Rostock, Germany

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KEY-WORDS

Aquifer Thermal Energy Store (ATES), Central Solar Heating Plant with Seasonal Storage (CSHPSS)

Abstract

The first central solar heating plant with an aquifer thermal energy store (ATES) for seasonal heat storage in Germany has been built in Rostock in 1999. The heating system supplies a multifamily house with a living area of 7000 m² in 108 apartments. On the roof of the building solar collectors (Solar Roof) are mounted with an area of 980 m². The ATES operates with one doublet of wells and is located in a depth of 15 to 30 m.

The Paper gives information about the heating system and the investigations that have been performed during the design phase. Furthermore the resulting design values and information about the monitoring program are presented.

Introduction

Stopping global warming of the atmosphere caused by burning of fossil fuels requires a substantial reduction of the fossil fuel consumption. In Germany, 30 % of the energy consumption is used for heat supply of residential buildings. Besides, this field offers the highest potential for energy savings.

Central solar heating plants are the most economic opportunity for the use of solar energy in housing estates to support domestic hot water (DHW) preparation and room heating. In connection with a seasonal heat store more than 50 % of the fossil fuel demand of an ordinary district heating plant can be replaced by solar energy.

The first pilot plants with seasonal heat stores in Germany show good performance and energy savings in the expected range (HAHNE et al. 1999). Although there have been several problems with the initial operation of the plants, mainly concerning the interconnection between the solar and the conventional heat supply system, the technical part of large solar systems is fully understood.

From the economical point of view, solar produced heat can not yet compete with fossil heat production. A substantial part of the investment cost of a central solar heating plant with seasonal storage (CSHPSS) is caused by the seasonal heat store. Formerly built pilot-plants in Germany are equipped with hot-water tanks, gravel-water stores or duct stores. However, the aquifer thermal energy store in Rostock is expected to achieve a decisive reduction of the cost for this component.

Description of the heat supply system

The aquifer store is integrated in the heat supply system for a multifamily house in Rostock-Brinckmansdorf, North-Germany. The building has 108 apartments with a total living area of 7 000 m² in eleven terraced houses. Figure 1 shows a simplified hydraulic scheme of the heat supply system.

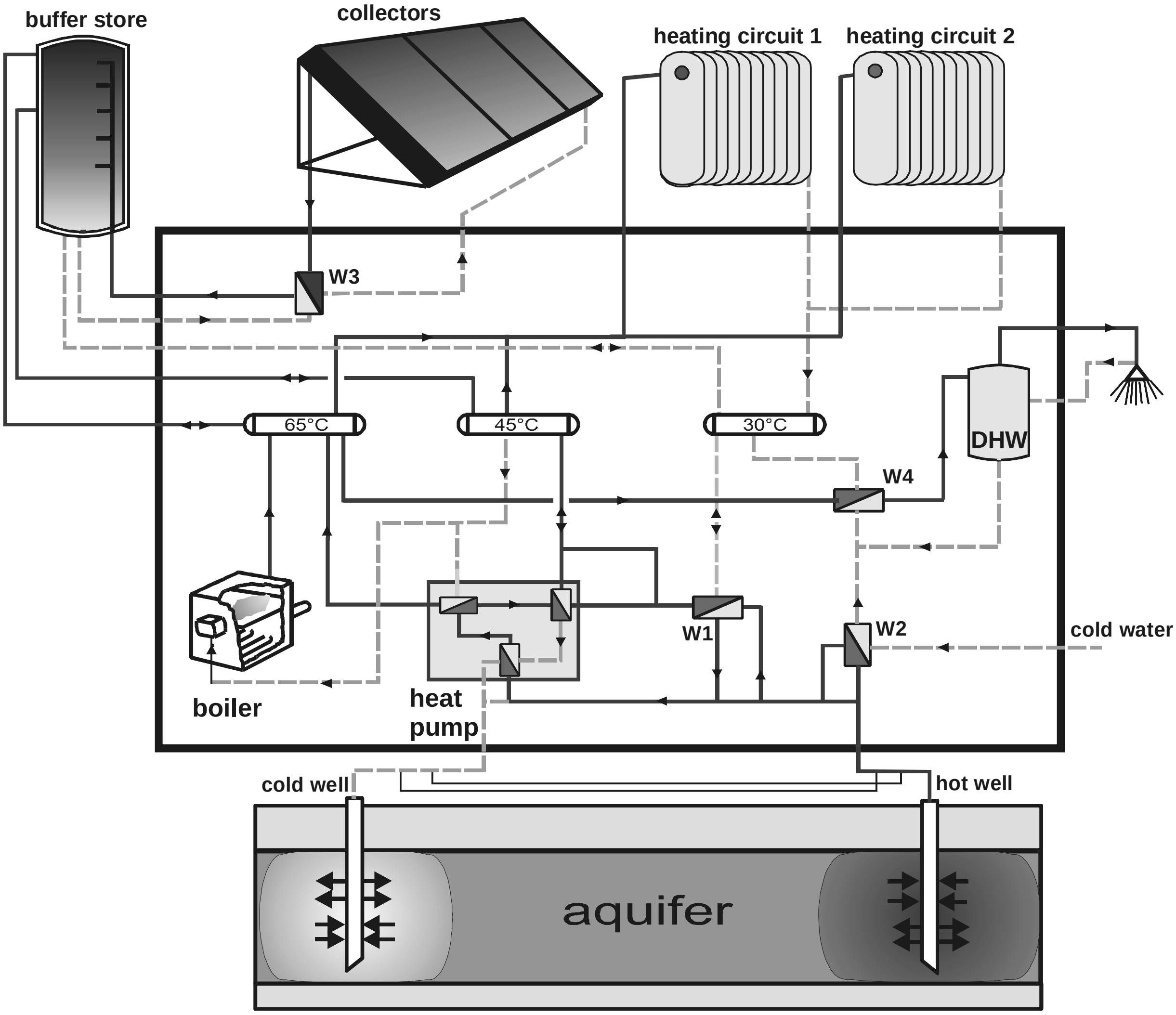

Figure 1: Scheme of the heat supply system (W1-W4: heat exchangers; DHW: domestic hot water)

The heat is produced by a solar system with a collector area of 980 m² that is mounted on the building as a Solar Roof, a heat pump that uses the ATES as heat source and a gas condensing boiler. To overcome the discrepancy between the large amount of solar energy in summer and the heat demand for space heating in winter, the aquifer works as a seasonal store that is heated up in the summer-period by the solar system and unloaded in autumn and winter directly or by way of the heat pump.

To increase the amount of directly usable solar heat (not by way of the ATES), a buffer store with 30 m³ is integrated as well.

To reduce heat losses and to prevent scale formation from the ground water, the store operates at low temperatures with a maximum of 50 °C. For this reason a heat pump is integrated in the system to reach a high usability of the aquifer store. The heat pump delivers heat at two temperature levels, a low one (45 °C) for the floor heating system and a higher one (65 °C) for the domestic hot water. Finally, a gas condensing boiler with a capacity of 250 kW covers the remaining heat load.

The ATES is equipped with one doublet of wells and is located in a depth of 15 to 30 m. During charging-periods cold groundwater is produced by a cold well (production well), heated up by the solar system and injected in a hot well (injection well). In discharging-periods the flow direction turns back. Because of the different flow-directions both wells are equipped with pumps and injection-pipes (see figure 2).

The connection of the ATES to the hydraulic system of the heating system is made by three heat exchangers: the first one (W1) for charging and direct discharging, a second one for discharging via the heat pump and a third one (W2) for preheating of the domestic hot water at low temperatures.

Table 1: Design values of the heating system

No. of apartments	-	108
living area	m²	7 000
heat demand:		
room heating	MWh/a	319
domestic hot water	MWh/a	144
distribution losses	MWh/a	34
total	MWh/a	**497**
max. heat power	kW	250
collector area (absorber)	m²	980
volume of ATES	m³	20 000
efficiency of ATES	%	63
thermal capacity of heat pump	kW	100
thermal capacity of gas condensing boiler	kW	250
design of floor heating system		45/30
collector heat generation	MWh/a	400
direct use	MWh/a	159
in ATES	MWh/a	234
from ATES	MWh/a	148
direct	MWh/a	2
via heat pump	MWh/a	146
geothermal energy from ATES	MWh/a	74
heat from gas condensing boiler	MWh/a	61
driving power of heat pump	MWh_{el}/a	55
solar fraction	%	**62**

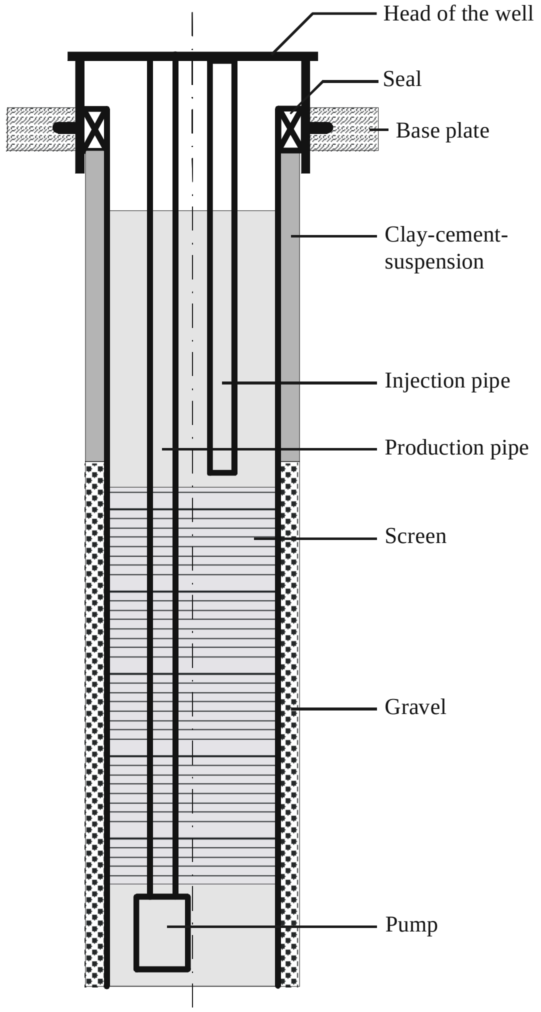

Figure 2: Construction of the wells

Table 1 shows the important data and the design-values of the system. The building´s heat demand for space heating is 30 % lower than required by the 1995 German building code. The total heat demand of the building (for room heating and domestic hot water) amounts to 497 MWh/a. According to the design calculations (GTN 1998) the solar collectors will deliver a usable heat input of 307 MWh/a; 159 MWh/a can be used directly, 148 MWh/a are provided by way of the ATES which has an estimated energy return-ratio of 63 %.

The remaining fossil energy demand is 229 MWh/a, including the generation of the electrical demand of the heat pump and circulation pumps. Compared to a reference system with only a gas condensing boiler (fossil energy demand: 523 MWh/a) the system saves 56 % of the energy demand. Figure 3 shows the relative contributions of the different heat producers.

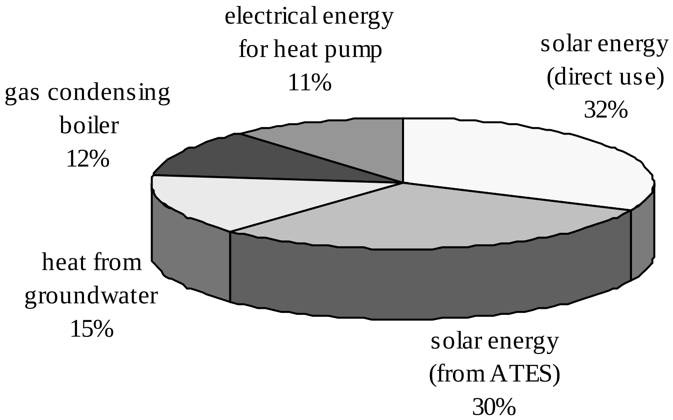

Figure 3: Relative contributions of the heat producers in the heat supply system

Experimental and theoretical investigations for the ATES

In advance of the design-phase for the ATES, several investigations have been performed at the intended location. In addition to the geological structure of the ground, pumping and circulation tests performed at the wells and between the wells and data from three piezometers showed very promising hydraulic and thermal parameters of the ground and made the calibration of a thermo-hydraulic numerical model (FEFLOW 1996) possible. The numerical model allows two- and three-dimensional simulations of geological systems.

Simulations with the calibrated model gave, among other results, answers to the following questions:

- What is the necessary distance between the wells to make sure that there is no thermal breakthrough?
- What is the optimum disposal of the wells to minimise the thermal drift of the hot bulb resulting from the modest groundwater movement?
- How big is the influence on the environment (in horizontal and vertical direction)?

The resulting disposal has a distance of 55 m between the wells and an alignment of the wells along the flow direction of the groundwater with the hot well in flow direction. In this way, the slightly drifting warm bulb can be 'sucked back'

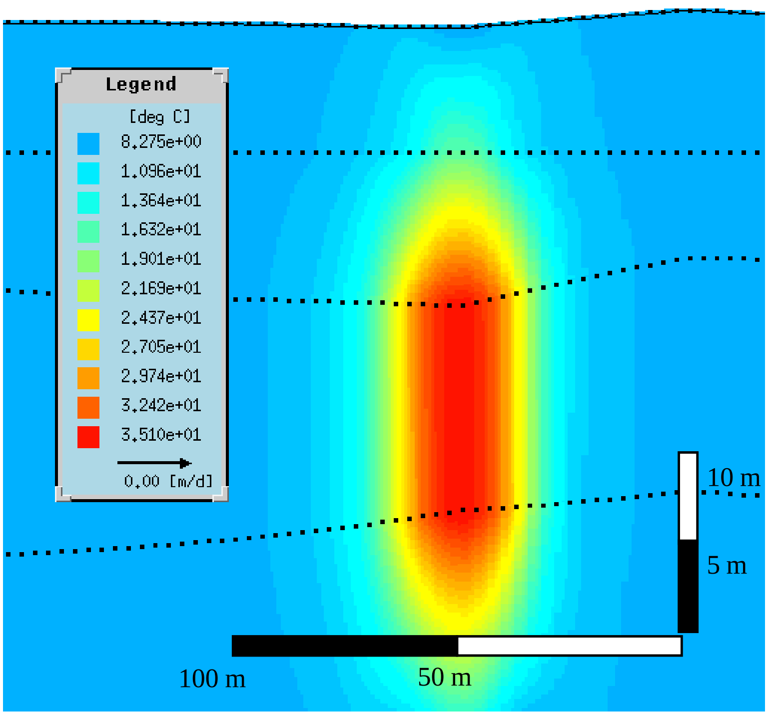

Figure 4: Temperatures in the warm bulb in the first year (vertical section)

at discharging periods and the heat losses can be minimised.

The temperatures in the warm bulb in the first year according to the simulations are shown in figure 4. The maximum horizontal expansion is approximately 50 m.

Assuming that equal amounts of ground water are produced at charging and discharging, the ratio of charged to discharged heat of the store is 56 % in the first year of operation and 79 % in the third year. Actually, the amount of water at discharging will be more than four times higher than at charging. Hence, the ground will be cooled down by the heat pump below the initial temperature. The heat delivered at temperatures below 10 °C is considered as geothermal heat.

Figure 5 shows the monthly charged and discharged heat.

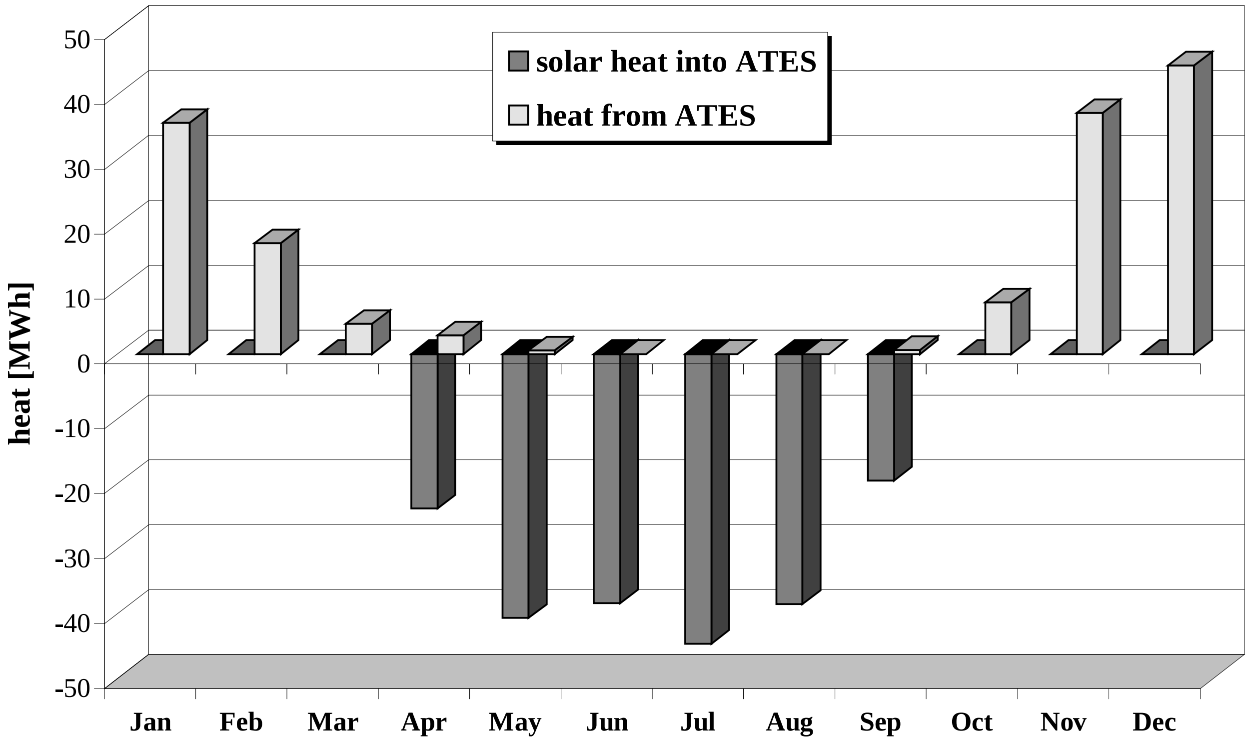

Figure 5: Monthly heat balance for the ATES

Monitoring

Within the framework of the German research program “Solarthermie 2000” the Institute for Thermodynamics and Thermal Engineering (ITW) is responsible for the scientific evaluations. For this purpose the system is extensively instrumented with measurement equipment.

In the heating unit all essential temperatures, flows and heat balances are recorded. Additionally, the weather conditions are monitored.

For the monitoring of the Aquifer store, more than 50 temperature sensors have been installed in the ground to be able to determine the shift of the warm bulb. Furthermore, the temperatures and flows at charging and discharging are recorded.

In addition to the thermodynamical monitoring, a geochemical monitoring program is carried out by Geothermie Neubrandenburg GmbH (GTN). The main targets for this are to supervise the behaviour of the groundwater and to identify variations.

With the acquired data, the operating conditions of the system can be monitored and energy balances can be provided. In comparison to the design values, operational or technical problems can be identified and rectified. Furthermore the data will be used for validation and further development of the design tools.

The involved parties of the project are listed in Table 2.

Table 2: Involved parties

Initiator	WIRO Wohnen in Rostock Wohnungsbaugesellschaft mbH
Architect	AP Architekten Partner Planungsgesellschaft Rostock mbH
Planner of the heat supply system (solar system, aquifer store, heat pump ...) and execution of the geochemical monitoring program	GTN Geothermie Neubrandenburg GmbH
Planner of the house-heating system	Wilfried Hubert Ing.-Büro für Gebäude- und Umwelttechnik
Scientific accompaniment and execution of the thermodynamical monitoring	Institut für Thermodynamik und Wärmetechnik Universität Stuttgart
Financial support	Bundesministerium für Wirtschaft und Technologie

Acknowledgements

This work was financially supported by Bundesministerium für Wirtschaft und Technologie, Project Nr. 0329606S. The authors gratefully acknowledge this support. The authors themselves carry the responsibility for the content of this paper.

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