Comparison Test of Thermal Solar Systems for Domestic Hot Water Preparation and Space Heating

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This paper presents the results on the latest comparison tests of thermal solar systems for domestic hot water preparation and space heating carried out for the German consumers' magazine "test". The systems were tested with regard to thermal performance, durability and reliability, environmental aspects as well as safety aspects. The test procedures as well as the results obtained are described and discussed. Possible future trends e. g. with regard to the development of the technology and the system costs will be shown.

1 Introduction

Following the last comparison test of solar thermal systems performed in 1998 a new series of test results was published by "Stiftung Warentest" in the German consumers' magazine "test" in 2002 and 2003. The results of the test of 16 solar domestic hot water systems were published in /1/. A report on the test of 11 thermal solar systems for combined domestic hot water production and space heating, so-called combisystems, can be found in /2/.

In addition to the customer-oriented and product related results already published in the consumers' magazine "test", this paper provides further background information. The test procedure is described in detail. Furthermore, the ranking of the results, especially with regard to the assessment of the thermal performance, is presented. Finally the long-term development of thermal solar system technology, e. g. with regard to the cost development is discussed.

2 Systems tested

The systems had to be dimensioned by the supplier or manufacturer respectively for a single-family house located at Würzburg, Germany. The house is equipped with a 45 ° inclined, south facing roof. The daily hot water load is 200 litres (at 45 °C) and the heat insulation standard of the building with a heated living area of approx. 130 m^2 fulfils the requirements according to the German Energy Saving Directive (Energieeinspar-verordung: EnEV) which is the present German directive concerning the primary energy demand of buildings. Based on this the yearly heat demand for space heating reaches 9090 kWh or 71 kWh/m^2 respectively.

With regard to the 16 thermal solar systems for domestic hot water preparation (DHW) the effective collector area varied between 3.2 m^2 (system H13, H15,H16) and 5.7 m^2 (system H12). 12 systems are equipped with flat plate collectors and four with vacuum tube collectors (systems H13, H14, H15, H16). The effective usable storage volume of the domestic hot water stores is in the range of 268 litres (system H10) up to 419 litres (system H14). The amount of hot water that is available if only the auxiliary heated part of the store is in operation varies between 100 litres for system H6 and a maximum of 200 litres for system H11.

Concerning the system and storage concepts most of the systems are designed as the typical German „standard systems“ shown in fig 1.

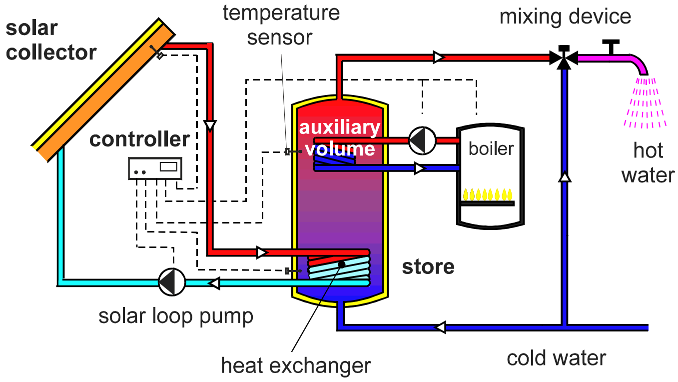

Figure 1: Schematic setup of standard German solar domestic hot water system

For all 16 systems the solar energy is transferred to the domestic hot water via a plain tube heat exchanger. The store of system H1 is the only one that is additionally equipped with a device for stratified charging. Additionally the store of system H11 is charged in a stratified way by using two solar loop heat exchangers: One located in the upper and one located in the lower part of the store. In the case of high temperatures delivered by the solar collector the flow is directed additionally via the upper heat exchanger following a special control strategy.

With regard to the solar combisystems, systems for combined domestic hot water preparation and space heating, the spectrum of investigated system concepts is much broader. Concerning space heating, for 7 of the 11 systems tested the space-heating loop is operated in the pre-heating mode. This means, that the return line of the space heating loop is only directed through the store if the temperature at the store’s space heating outlet connection is above the return temperature of the space heating loop. The energy delivered by the external auxiliary heater is only transferred to the combistore in order to heat the auxiliary part required for domestic hot water preparation. Auxiliary energy required for space heating is fed directly into the space heating loop (see figure 2a).
The other 4 systems (system C4, C5, C10, C11) use the combistore as a buffer store. This means that the auxiliary energy is always transferred to the store and that the space heating loop is continuously supplied from the combistore (see figure 2b).

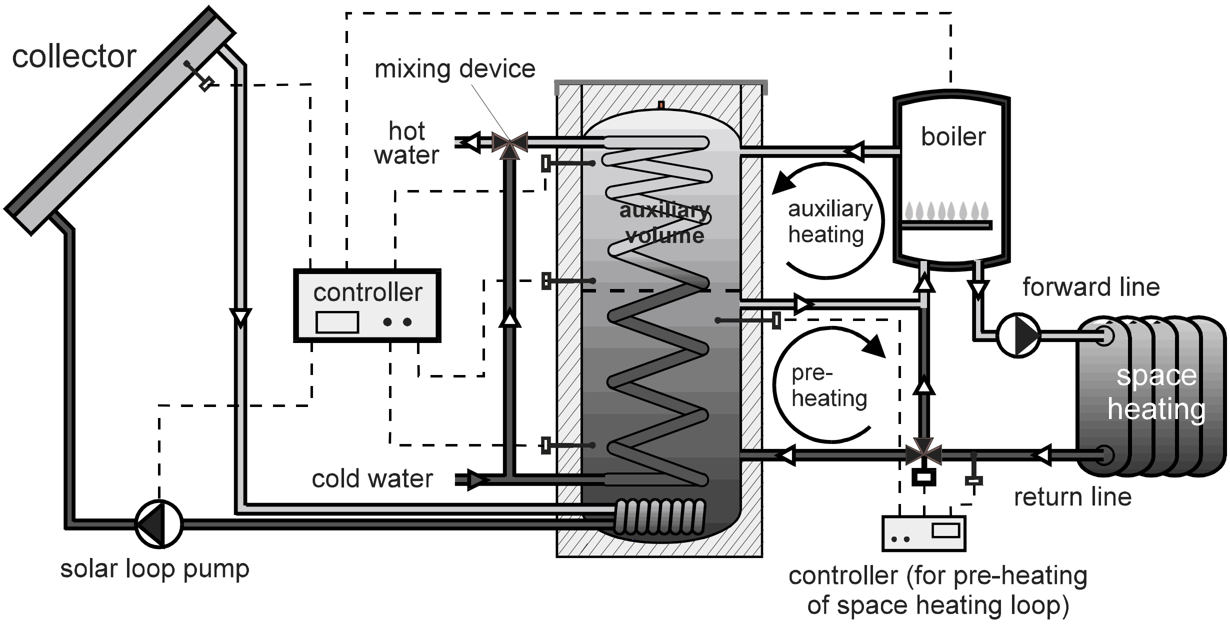

Figure 2a: Schematic design of a combisystem with space heating loop operated in pre-heating mode

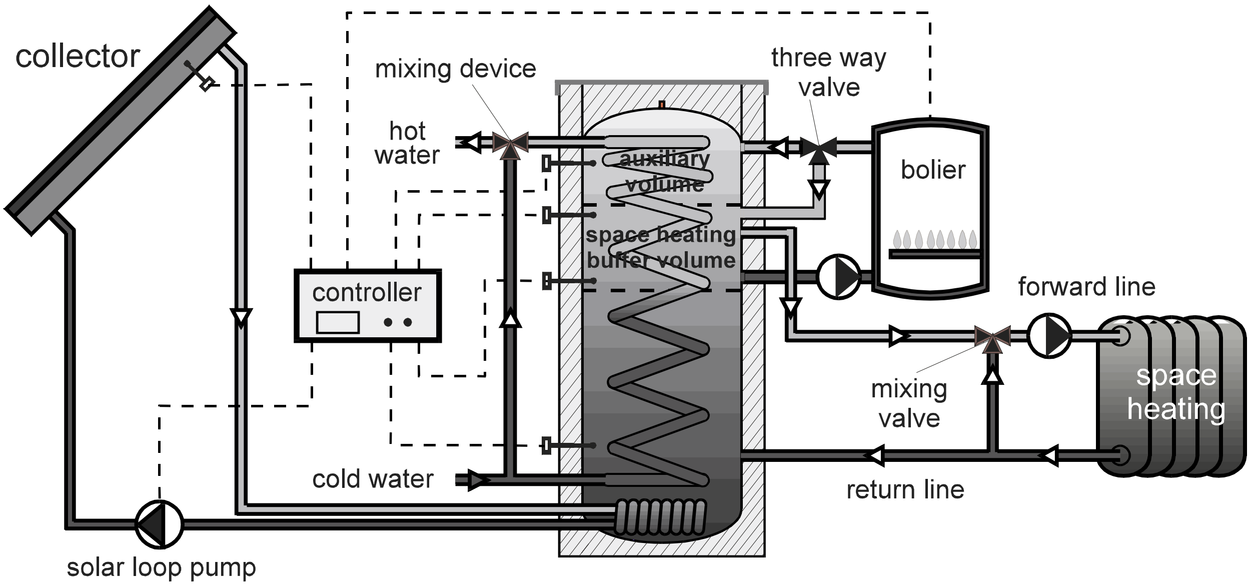

Figure 2b: Schematic design of a combisystem using the combistore as a buffer store

In comparison to a similar investigation of solar combisystems carried out five years ago it is remarkable that the solar combisystem technology has moved towards a higher level of integration. Five years ago when ordering a combisystem, one was supplied with a collection of separate, individual components. Today in many cases the appearance of the components already shows obviously that they belong to the combisystem of a certain manufacturer.
The positive trend towards compact systems was also documented by the fact that the manufacturers did not anymore select so-called two-store-systems for the test. The state of the art concerning maximum compactness are systems were the gas burner is already integrated into the combistore (system C9 and C11) or directly connected at the combistore (system C10).
The effective collector area of the combisystems investigated is in the range of 5.7 m^2 (system C2) to 14.2 m^2 (system C7). 6 systems use flat plate collectors. The other 5 systems are using vacuum tube collectors (system C2, C3, C4, C5, C10). The volume of the combistores varies from 450 litres for system C9 up to nearly 1000 litres for system C7 and C11. The usable hot water volume is in the range from 100 litres (system C2 and C3) up to a maximum of 300 litres for system C4. Concerning the systems using the combistore as a buffer for the auxiliary heater, the buffer volume for the boiler or gas burner, respectively, varies between 80 litres for system C4 and 225 litres for system C10.

3 Test procedure

With exception of the thermal performance, the solar domestic hot water systems and the solar combisystems were tested according to the same procedures.

3.1 Thermal performance

The solar domestic hot water systems were tested on the basis of EN 12976-2 “Thermal solar systems and components – factory made systems - test methods” according to the DST method (Dynamic System Testing). In addition a separate collector test was carried out and the most important parameters of the store were determined from enhanced DST-measurements with sensors in the collector loop in order to enable a component based system simulation with TRNSYS.
The solar combisystems were tested on the basis of EN 12977-2 “Thermal solar systems and components – custom built systems - test methods” according to the CTSS method

(Component Testing – System Simulation). The parameters of the most important components (collector, store, controller) determined in this way and the hydraulic configuration of the individual systems were transferred into the simulation program TRNSYS.
For the determination of the "usable hot water volume" an additional test sequence on the store was performed according to the "DFS hot water comfort test" /3/.

The energy yield of the thermal solar systems was determined by means of system simulations for the boundary conditions described in chapter 2 on the basis of the system or component parameters, respectively, that were determined during the test.
For the calculation of the fractional energy savings, the energy saved by the thermal solar system was compared with the energy demand of a conventional (none solar) system.
The system efficiency is determined by relating the energy saving of the solar thermal system to the available solar radiation. Hence the system efficiency is an indicator how effective the solar energy is used.

For the assessment of the thermal performance, the fractional energy savings, the system efficiency, the usable hot water volume, and for combisystems additionally the space heating buffer volume, are taken into consideration. The assessment concept was intentionally designed in a way that the typical design parameters such as collector area, store volume, usable hot water volume and, if existing, the space heating buffer volume did not affect the results as long as they are varied within sensible limits. Due to this approach the thermal performance of the system is primarily affected by the performance of the different components and their interaction within the complete system.

3.2 Behaviour during operation, durability and reliability
The behaviour of the whole thermal solar system or its subsystems, respectively, was observed during different operating conditions (e. g. stagnation). In order to assess the durability and reliability, the quality and the suitability of the materials used as well as the way how they were processed was considered. Additionally the period of warranty for the most important components (collector, store and controller) was assessed.

3.3 Environmental aspects
The energy payback time was determined and the used materials as well as the packaging was assessed.

3.4 Safety aspects
The most important components as well as the whole system was investigated with respect to electrical safety and the risk of injury due to sharp edges, burning and scald. The documentation was checked with regard to notes dealing with safety aspects during the installation of the system. For systems with an integrated gas burner safety aspects related to gas and fire were considered additionally.

3.5 Handling
The way how the system has to be mounted, maintained and operated was assessed. Criteria of this assessment were e. g. the time required for the system installation as well as ergonomic aspects. Additionally it was examined if the corresponding work steps were described understandably, detailed and correctly in the documentation supplied with the system.

4 Results

Two of the **solar domestic hot water systems** (SDHW) were assessed “very good” as the overall mark (system H3 and H11). With regard to the assessment of the thermal performance in total four SDHW systems obtained “very good” (system H3, H11, H13, H14). Two of these systems were equipped with flat plate collectors and two with vacuum tube collectors. This result shows that it is not necessary to use vacuum tube collectors in order to be assessed as “very good”.
Only for one system (H6) the thermal performance - and therefore also the overall mark - was rated with “fair”. The reasons for the relatively low thermal performance of this system were related to performance deficits of the solar collector and a disadvantageous control strategy. It is by chance that this system shows with 100 litres usable hot water volume also the lowest value in this category. Due to the assessment scheme used (see chapter 3.1) this fact is not the reason that the thermal performance of this system was only reacted with “fair”.

The **solar combisystems** C7 and C11 received „very good“ as the overall mark. In addition to these two systems, also system C5 shows a „very good“ thermal performance. It is encouraging that also in this category only one system (C9) was marked with „fair“. In this case the reason is predominantly related to a store concept that is designed disadvantageously with regard to thermodynamic aspects.

5 Financial aspects

It is already well known that thermal solar systems provide benefits for the environment. Nevertheless in the present investigation this was confirmed once more by the short energy payback times. The minimal values for the solar domestic hot water systems were 1.3 years (system H13) and 2.0 years for the solar combisystems (system C2).

In addition the development of the system costs is quite positive. Figure 3 shows average values of the system costs (including VAT and installation) for solar domestic hot water systems (SDHW) and solar combisystems (COMBI).

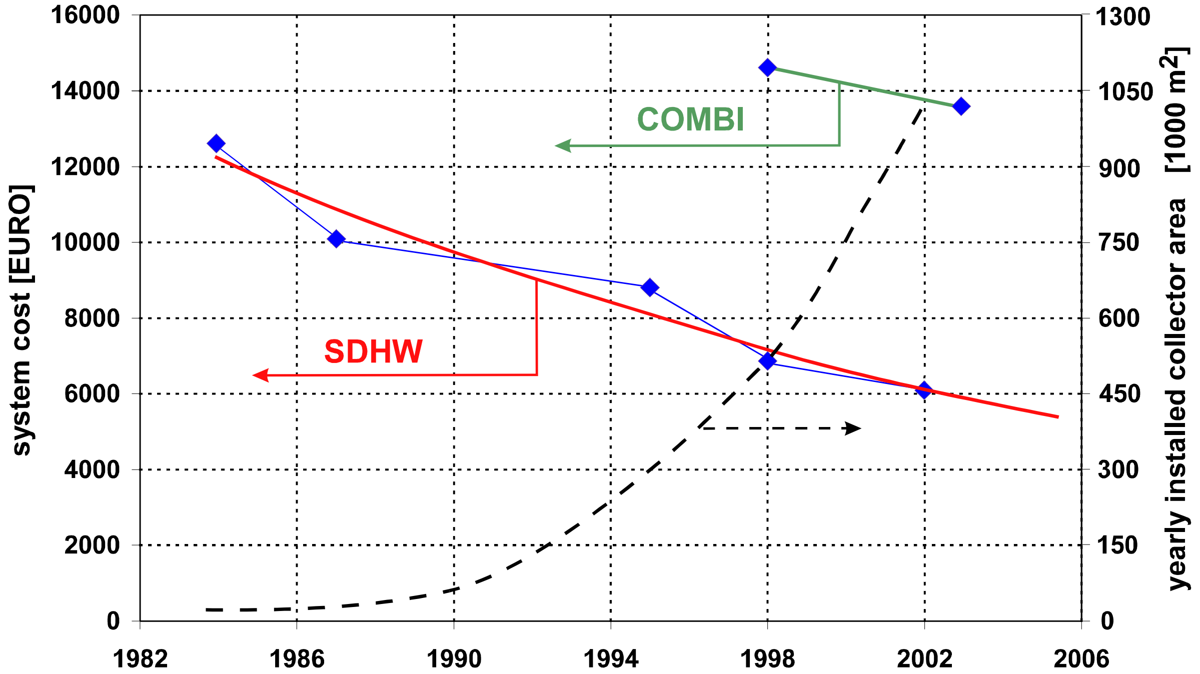

Figure 3: *Development of average costs for thermal solar systems (incl. VAT and installation); Source: Stiftung Warentest*

It is obvious that the price degradation observed in the past for SDHW systems nowadays also appears for solar combisystems.

Although thermal solar systems, especially with regard to single and double family houses, are usually not sold in order to save money it is important to know the price of one kilowatt hour of solar energy. Therefore figure 4 shows the energy savings and the heat prices of the systems investigated.

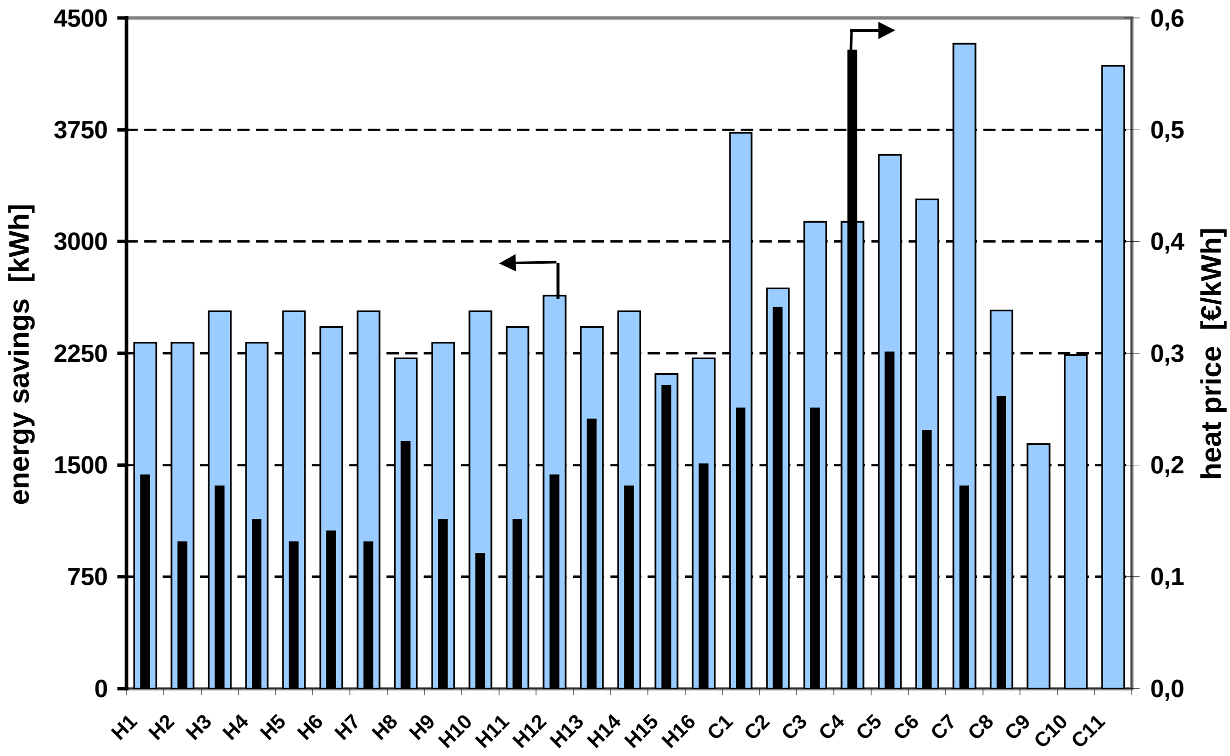

Figure 4: Energy savings and heat price of solar domestic hot water systems (H) and solar combisystems (C)

The cost accounting was performed on the basis of the annuity method (interest rate 4 %, lifetime 20 years) without taking into account subsides. Due to the fact that the systems C9, C10 and C11 were combisystems with an integrated gas burner the heat prices of these systems are not included since they are not direct comparable with the other systems.

On the basis of theoretical considerations it can be expected that the heat prices will increase with increasing (fractional) energy savings, and therefore decreasing system efficiency. This consideration is valid for solar domestic hot water systems as well as for solar combisystems. However figure 4 shows that this effect can (up to now) not be observed. This indicates that heat prices and system costs are primarily determined by other parameters such as the system technology or the individual cost structure of the manufacturers or traders. On the basis of this fact it can in general be concluded that most of the systems are still far away from a cost minimum.

Figure 4 shows also that the minimum heat price is in the range of 0,12 to 0,13 €/kWh. Taking into account the present German subsides of 110 €/m^2 collector area leads to heat prices of approximately 0,10 €/kWh. This value is very close to the current price of heat generated with individual oil or gas boilers.

6 Conclusions

Compared to the previous comparison test carried out in 1998 solar technology made one more step towards professionalism. Most of the investigated products convinced due to good quality and performance. This was indicated e. g. by the fact that during reliability and durability testing only one collector failed with a major failure. Furthermore no significant lacks of safety such as underdimensioned expansion vessels, have been noticed. This comparison test showed that by now thermal solar systems are well introduced to the market and are a serious technology for the generation of heat for domestic hot water and space heating.

Literature:

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/3/ DFS hot water comfort test. Described in: Stryi-Hipp, G., Kerskes, H., Drück, H., Bachmann, S.: Abschlussbericht des Projekts "Testverfahren für Solaranlagen zur kombinierten Brauchwassererwärmung und Raumheizung (Kombianlagen)", Institut für Thermodynamik und Wärmetechnik (ITW), Universität Stuttgart, 2001

Acknowledgement:

The results presented in this paper have been obtained by the engineers of the Test and Research Centre for Thermal Solar Systems (TZS) located at ITW: S. Bachmann, S. Fischer, M. Hampel, H. Kerskes, M. Peter und E. Streicher. This work was partly financed by the Deutsche Bundesstiftung Umwelt. The authors gratefully acknowledge this support.