Advanced Storage Concepts for Solar Combisystems

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Using a typical single family house in Germany as an example, the influence of the solar collector area and the store volume on the energy savings is determined by means of numerical system simulations. Based on these results it is outlined how the system performance can be increased by using advanced storage concepts. In particular the following storage concepts are investigated:

- **hot water stores with improved thermal insulation (e. g. with vacuum insulation)**
- **stores using phase change materials (latent heat stores)**
- **thermochemical energy stores (e. g. based on sorption)**

In addition to the primary energy savings that can be achieved with the different heat storage technologies and system concepts, the resulting solar thermal heat prices and the energy payback times are discussed.

1 Introduction

Thermal solar systems for domestic hot water preparation and space heating, so-called solar combisystems, are already introduced to the market, and their market share is increasing continuously. Today standardised solar combisystems consist of a solar collector with an area between 10 m^2 to 20 m^2 and a hot water storage tank with a volume in the range of 0.7 – 1.5 m^3. If such systems are installed in a „typical“ middle European single family house, they can save approximately 20 - 30 % of the primary energy required for domestic hot water preparation and space heating. In order to increase the energy savings, larger collector areas and/or store volumes are required.

2 Reference conditions

The simulation study is based on a single family house located at Würzburg, Germany with a heated living area of 128 m^2. The roof on which the collectors are mounted is facing south and is inclined by 45°. The building fulfils the requirements according to the German Energy Saving Directive (Energieeinsparverordung: EnEV) resulting in a space heating demand of 9090 kWh or 71 kWh/m^2 respectively. The space heating loop is controlled according to the outdoor temperature and the maximum forward / return temperatures are 50/30 °C.
The heat demand for a hot water production of 200 litres per day at 45 °C equals 28 kWh/(m^2a) or 3590 kWh/a respectively including the heat losses of a “typical” conventional domestic hot water store. Based on these assumptions the total heat demand for domestic hot water preparation and space heating comes up to 12680 kWh/a.
If an oil or gas boiler with an average boiler efficiency of 85% is used, this results in an annual total energy demand of approximately 14900 kWh. The performance of the different systems is assessed on the basis of the fractional energy savings f_{sav}. This quantity describes the percentage of energy that is saved by using a thermal solar system instead of a conventional, none solar heat generation system.

3 Results

By means of a simulation study the influence of different design parameters and store concepts on the fractional energy savings was determined for the reference conditions described above. The results for the so-called advanced storage concepts are shown in figure 1. Additionally two curves for a hot water store with a conventional thermal insulation are plotted as a reference in figure 1. An extensive simulation study about the influence of the hot water store volumes and different collector areas as well as collector types was already published in /1/.

Figure 1 shows, that by using latent or sorption heat stores with an effective store volume of approximately 1 m^3 (plus 750 litres for the “conventional” combistore) and collector areas in the range of 45 m^2 (flat plate collector) it is already possible to cover more than one half of the heat demand by solar energy. Due to the fact that the simulations were based on idealised assumptions, the store volumes may be twice as large in reality. One main reason for this is the volume of the necessary heat exchanger or condensate tank respectively.

At present latent and sorption heat stores for this kind of application are still in the scientific and industrial development phase. Therefore such stores are only offered by a few companies. However, regarding the long-term developments these technologies should not be ignored.

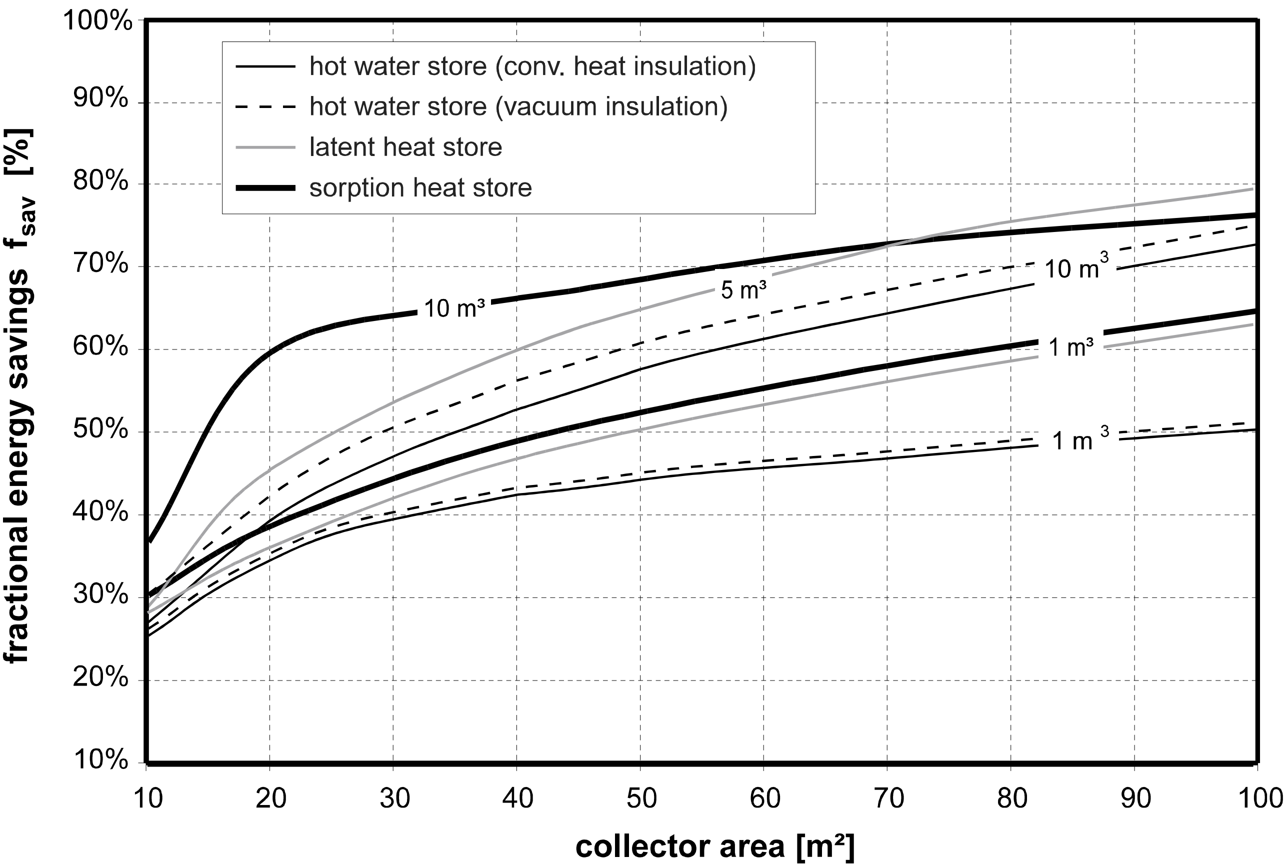

Figure 1: Fractional energy savings for different store technologies and store volumes (plus 750 litres for the “conventional” combistore) as a function of the collector area (flat plate collector)

Compared with latent and sorption stores, hot water stores require larger store volumes. However, the main advantage of hot water stores is that they are based on a well known technology that is already introduced to the market. Due to this they also show at present the largest potential for cost reduction. With further improvements such as vacuum heat insulation an increase in thermal performance is still possible.

4 Solar heat price

The assessment of thermal solar systems based on economic aspects is difficult, since the cost effectiveness of this type of systems strongly depends on the development of the fossil fuel prices.
An additional aspect complicating an economic assessment is that the advanced storage technologies are not introduced to the market up to now. But only when a technology is established on the marked and is produced in large quantities the results of an economic analysis are reliable /2/.

Due to this the following cost considerations are limited to system concepts that can be realised with today’s system technology and with the use of water as heat storage medium.

Table 1 shows the solar heat prices for various collector areas and collector types as well as for different store volumes. For each configuration an average and an inexpensive value are given. The average value is determined without taking into account subsidies or self services (e. g. installation by the owner). For the calculation of the inexpensive value these possibilities for saving were taken into account. Additionally discount prices of the components were used.

store volume [m^3]	collector area [m^2]	f_{sav} [%]	solar heat price average [EURO/kWh]	solar heat price inexpensive [EURO/kWh]
0.45	10 (FC)	25	0.19	0.06
0.45	20 (FC)	32	0.27	0.09
1	10 (VC)	32	0.25	0.09
1	100 (FC)	50	0.69	0.24
	35 (VC)	50	0.38	0.18
10	35 (FC)	50	1.27	0.38
	22 (VC)	50	1.33	0.41
30	28 (FC)	50	1.12	0.35
	18 (VC)	50	1.13	0.38
30	100 (VC)	94	1.05	0.41
100	100 (FC)	93	1.32	0.53

Table 1: *Solar heat prices (including VAT) for different system dimensions with flat plate collector (FC) and vacuum tube collector (VC). Calculated according to the annuity method: interest rate 4 %, lifetime 20 years*

5 Energy payback time

The energy payback time is the period, the system has to be in operation in order to save the amount of primary energy that has been spent for production, operation and maintenance of the system. Based on an overall consideration a system only contributes to the saving of our resources if it is operated longer than its energy payback time.
With regard to the determination of the energy payback time arguments are the same valid as discussed for the cost assessment in the previous section: Concerning the systems with hot water stores the listed energy payback times represent only a rough estimation. For systems based on advanced storage technologies it was not possible to determine reliable values of the energy payback time due to the lack of appropriate data.

The energy payback time of some selected system dimensions is listed in table 2.

store volume [m^3]	Collector area [m^2]	f_{sav} [%]	energy pay-back time [years]
0,45	10 (FC)	25	2.0
1	100 (FC)	50	5.2
10	35 (FC)	50	4.2
30	28 (FC)	50	6.5
100	100 (FC)	93	8.4

Table 2: Energy payback time for different *system dimensions with flat plate collector (FC) and water store*

6 Conclusions

With regard to systems that achieve fractional energy savings of approximately 50 %, the lowest value of the heat price is found for the reference system with 1 m³ store volume and 35 m² vacuum tube collector with 0.18 EURO/kWh. Partly more expensive are system designs that lead to the same fractional energy savings by using larger store volumes and smaller collector areas. At present, it is more cost effective to enlarge the collector area instead of an enlargement of the store volume. The reasons for this are the following: On one hand the subsidies that were accounted for the determination of the inexpensive value of the heat price are related to the size of the collector area and not to the store volume. On the other hand collectors are already today produced in large quantities and therefore offered relatively cheap. A totally different situation arises if the store volume is enlarged: Large hot water stores are only produced in small quantities or sometimes even as a custom made product. A consequence of this fact is that a high potential for cost reduction can be realised by using large standardised stores.

With regard to the solar heat prices the presented results showed that even today it is already possible to cover approximately 50 % of the heat demand by solar energy at moderate costs. Depending on the chosen configuration of store volume and collector area or collector type respectively, the resulting heat prices are similar to the ones of typical combisystems already offered on the market /2/. However, the fractional energy savings of these systems only amounts to 20 – 30 %.
The step over the “50 % fractional energy saving borderline” from the solar supported conventional heating system to a fossil supported solar heating system is quite small. The

potential of the environmental benefits of such advanced solar combisystems is shown by the fact that the energy payback times for all investigated systems were significantly below the expected lifetime of the systems.

The cost-effective, efficient and environmentally friendly storage of heat is one of the key technologies for the further development of solar technology. Looking on the current building situation and the amount of buildings that have to be retrofitted, it is obvious that a very large potential market exists for relatively small thermal solar systems.
Due to this facts the IEA (International Energy Agency) established within their Solar Heating and Cooling Program an corresponding working group named Task 32 „Advanced Storage Concepts for Solar Buildings“. Within this task European manufacturers and research institutes will work together during the next four years in order to bring storage technology, and in this context also solar technology, at least one important step forward.

Literature:

/1/ H. Drück, H. Kerskes, W. Heidemann, H. Müller-Steinhagen: Solare Kombianlagen der nächsten Generation - Advanced Solar Combisystems, Tagungsband zum zwölften Symposium Thermische Solarenergie, Seiten 59 - 63, Otti, Regensburg, 2002, ISBN 3-934681-20-4

/2/ H. Drück, W. Heidemann, H. Müller-Steinhagen: Comparison Test of Thermal Solar Systems for Domestic Hot Water Preparation and Space Heating, proceedings of EuroSun 2004, to be published