Outline of the joint research project of SWT, ZfS, ISFH and FhG-ISE: Analysis and evaluation of large thermal solar „combi-systems“

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In the past German R+D-programme "Solarthermie-2000" large thermal solar systems for tap water heating have been investigated and basic principles for planning and dimensioning developed. In the following programme "Solarthermie2000plus" the same will be done for large thermal solar systems for both tap water and room heating (so called combi-systems) with at least 100 m² collector area. Similar investigations have been done for combi-systems in one-family houses. However, large combi-systems differ from these small systems in respect of construction of the solar collector field, the heat stores, the heat exchangers and the connection to the conventional heating technique. The few existing large thermal solar combi-systems in Germany differ very much from each other which shows a great uncertainty of how to design such systems. Therefore it is necessary to develop guidelines for planning and dimensioning of this system technology as well as to further establish this technology on the market. The project is split up in three tasks shared between four partners. In this paper the partners and their tasks are presented.

1. Aims of the Project

In the past, large thermal solar systems were mainly used for tap water heating. In recent years there is a tendency to use this technique for both tap water and room heating. With these systems higher solar fractions of the total annual heat demand of buildings can be achieved. In the range of small thermal solar systems with collector areas of up to 20 m² combi-systems add up to 20 % of the total thermal solar market. There already is a large range of complete products which can easily be installed and which provide reliable results. However, in small systems the variation of system configurations does not strongly affect the solar fraction and specific solar heat costs [1].

This is different in the range of large thermal solar systems with at least 100 m² of solar collectors. In the German R+D-programme Solarthermie-2000 large thermal solar systems (collector area > 100 m²) for tap water heating were investigated [2]. Finally the technical standard was implemented in technical rules [3]. For solar systems for tap water and room heating no such rules exist. As these systems are mainly built in public buildings (such as hospitals or schools,…) or in housing areas of public building promoters, their profitability is a very important factor. Variation of system configuration leads to very different results. Thus the large solar combi-systems must be designed at optimal cost in respect of investment and operation. The necessary service should be as low as possible.

Figure 1: One of the five multi-family houses of plant C with solar thermal collector field (facade)

Existing large thermal solar combi-systems (about 20 in Germany) are very diverse in design, regarding the solar collector field, the heat stores, the heat exchangers and the connection to the conventional heating technique. There are no sufficiently documented operating results of these systems. That is why no reliable propositions can be given for designing new systems. This research project aims at the implementation of recommendations and technical rules for the design of large thermal solar combi-systems.
Therefore six existing solar combi-systems will be investigated over a period of two years. With the help of simulations in TRNSYS [4] based on the measured data the advantages and disadvantages of the different systems will be identified. Economically advantageous improvements will be carried out. Special studies on the stagnation effects of single collectors and collector fields in the existing systems and on test stands will be done to give recommendations on how to reduce stagnation in solar collectors. The joint research project began in October 2003 and will be running for 2 ½ years.

2. Selection of existing combi-systems

There are two basic differences in the system configuration of solar combi-systems in a way how the boiler and the thermal solar collectors are integrated in the system with a lot of variations. With a serial integration of the thermal solar system as shown in figure 2 only the solar collectors charge the buffer store. If the temperature of the buffer store is too low the boiler delivers the remaining necessary heat.

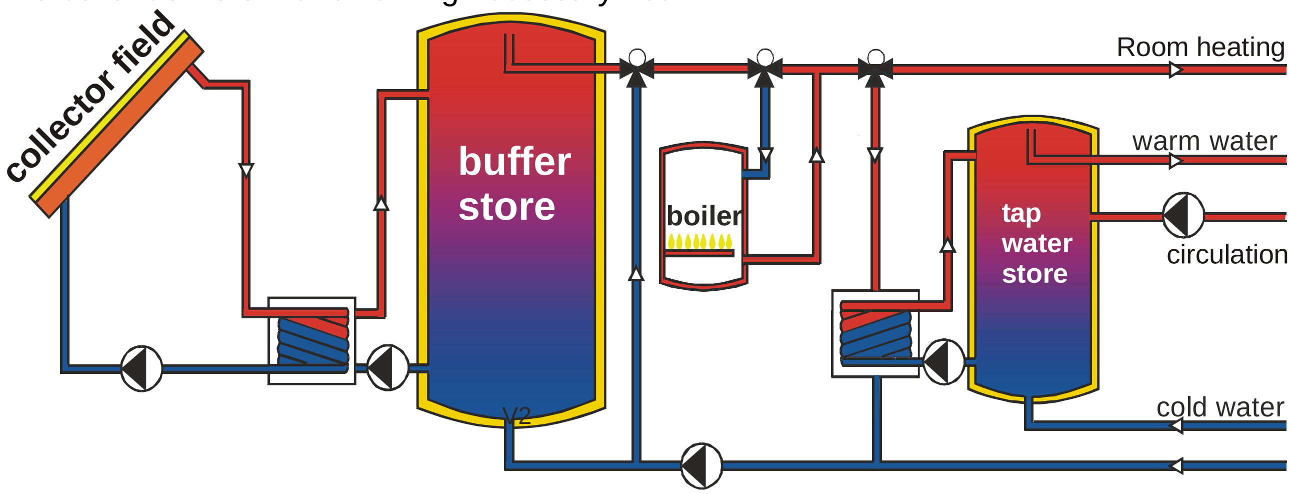

Figure 2: *Serial integration of the thermal solar system*

With a parallel integration (see figure 3) the boiler is charging e.g. the upper third of the buffer store and keeps it on a certain temperature level if the solar collectors do not deliver enough heat. An advantage of the parallel integration is that the boiler does not start as often as in serial integration which improves its efficiency. However the higher temperatures in the buffer store can diminish the solar fraction and lead to higher heat losses of the buffer store.

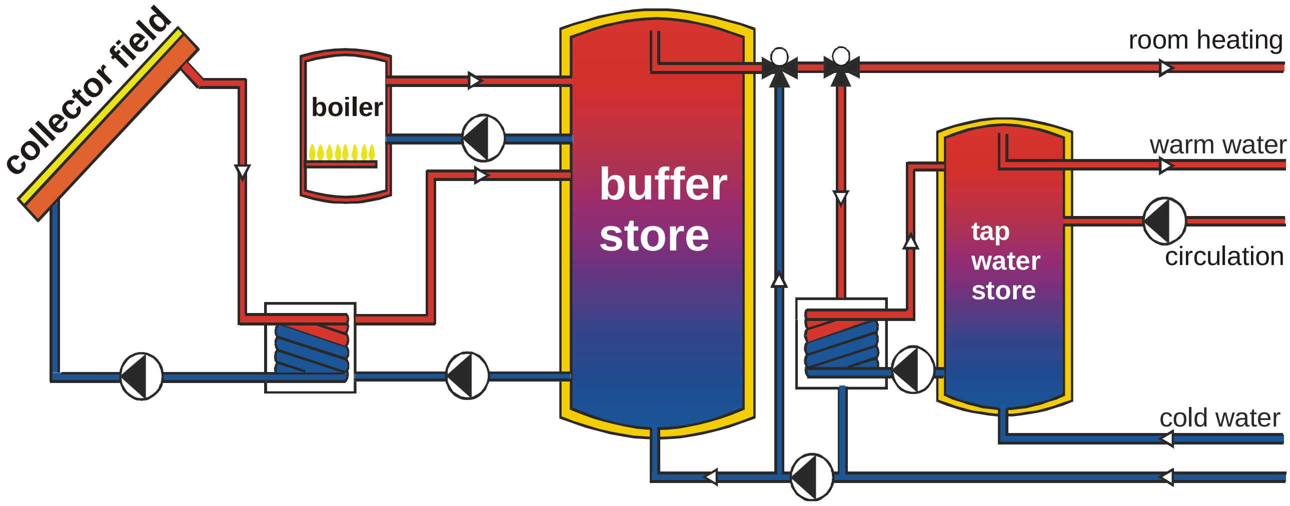

Figure 3: Parallel integration of the thermal solar system

Which of the two systems is better depends on certain criteria, e.g. the heat load of the connected housing area. This will be considered in the project as well. Both serial and parallel integration can be found in the chosen systems. An overview of these systems with the main features is given in table 1.

Table 1: Overview of the selected thermal solar combi-systems

	Collector area	**Buffer store volume**	**Specific buffer store volume**	**Boiler integration**	**number of appartments**	**heating system (besides solar)**
	m²	m³	l/m²			
A	92	2 x 2,5	54.3	serial	28	gas
B	140	3 x 3	64.3	parallel	63	wood pellets
C	140	3 x 2	42.8	parallel	40	gas/borehole heat exchanger with el. heat pump
D	249	38	152.6	parallel	10+1office	gas
E	45	1.5	33.3	parallel	15	gas
F	90	4 x 1	44.4	parallel	36	gas

3. Measurement system

It is planned to install extra sensors for solar radiation, ambient and system temperatures, mass flow measurement and operating hours of pumps. Figure 4 shows the placement of the sensors in a schematic system. In nearly all solar systems that are chosen, an electronic control exists so that it will be tried for some systems to get additional data from the control. In these systems only at those points where there are no sensors of the control, extra sensors will be installed (e.g. mass flow sensor in the solar circuit).

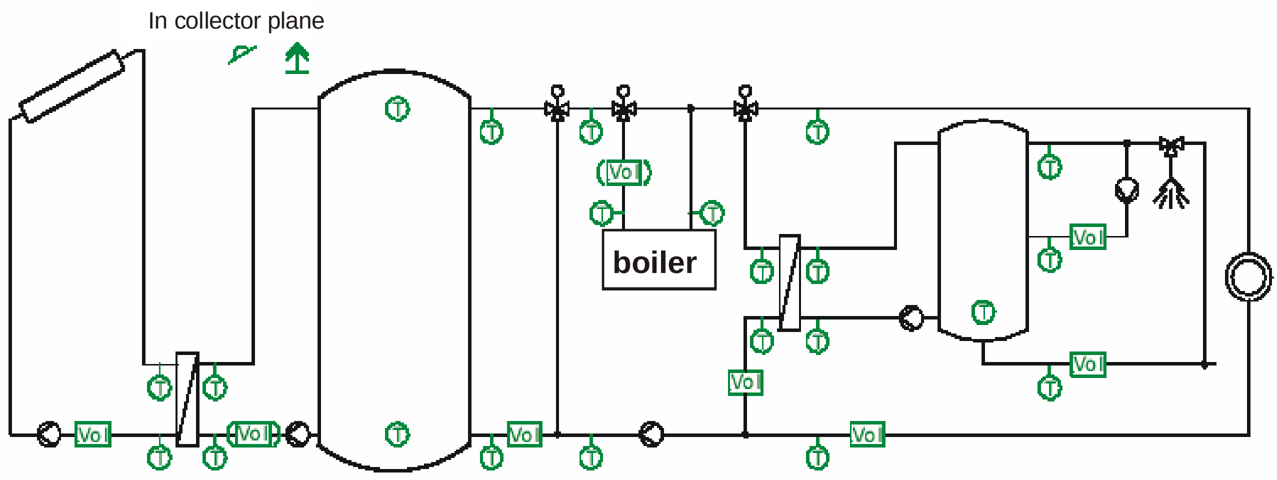

Figure 4: Sensors for measuring in the solar combi-system (schematic) [source: ZfS]

For detailed measurements of the collector field two systems will be equipped with additional sensors at certain points in the collector field.

4. Tasks of the different project partners

Four Institutes will work together on different tasks of the project. The results will be exchanged as often as necessary to get a better overview on certain aspects of large thermal solar combi-systems. The partners and their tasks are listed below.

SWT - Solar & Wärmetechnik Stuttgart together with ZfS – Rationelle Energietechnik GmbH:

1. Selection of six existing combi-systems, equipping them with measurement instrumentation, measuring and analysing them in detail over a period of two years.
2. Check for defects of the system after a short measurement period, which have to be eliminated before further measurements.

3. Analysis of the operating behaviour of the system and single components. Outlining the advantages and disadvantages of the different systems.
4. Building up simulation models of the systems for analysis of the existing technique as well as development of improved systems by variation of parameters.
5. Calculate the economic efficiency of simulated improvements.
6. Implement economically efficient improvements in the existing system, further measurements.
7. Develop a guideline for planning and dimensioning of this system technology

ISFH – Institut für Solarenergieforschung GmbH Hameln/Emmerthal:

1. Analysis of the stagnation effects of three large collector fields on a test bench as well as measurement of the stagnation in one existing system over two summers. Therefore detailed measurement of temperature, pressure and degradation of the solar fluid is planned.
2. Analysis of how the collector fields are deflated and recharged (during/after stagnation).
3. Investigation of two flat-plate and one vacuum-tube collector fields based on the results above.
4. Recommendations on how to reduce stagnation in the system based on the measurements and the results of the partners.
5. Investigation of these recommendations in real operating behaviour.

Fraunhofer-Institut für Solare Energiesysteme, ISE, Freiburg:

1. Evaluation of the stagnation of collector fields by analysing the detailed performance during stagnation of a single collector.
2. Measurement of draining and steam power of single solar collectors under consideration of different absorber pipings.
3. Simulation of the stagnation behaviour of a single collector based on the measurements. Afterwards simulation of large collector field.
4. Simulation of the effect of a fluid-air-heat exchanger to transfer heat to the environment in case of stagnation.
5. Recommendation on how to reduce stagnation in collector fields based on the measurement results and collector simulation.
6. Analysis of the degradation of the solar circuit heat transfer fluid.
7. Publication of the results of all partners on a web page and in a work shop. (http://www.Solarkombianlagen-XL.info)

5. References

[1] Styri-Hipp, G.; Kerskes, H.; Drück, H., Bachmann, S.: Kombianlagen Abschlussbericht des Projektes „Testverfahren für Solaranlagen zur kombinierten Brauchwassererwärmung und Raumheizung (Kombianlagen)", DFS, Freiburg, 12/2001

[2] Peuser, F.A.; Remmers, K.-H.; Schnauss, M.: Langzeiterfahrung Solarthermie – Wegweiser für das erfolgreiche Planen und Bauen von Solaranlagen; Solarpraxis Supernova AG, Berlin, 2001, ISBN 3-934595-07-3 (English version: Solar Thermal Systems, Solarpraxis Berlin 2002, ISBN 1-902916-39-5)

[3] VDI 6002-1: Solar heating for domestic water – General principles, system technology and use in residential buildings (will be published in July 2004)

[4] TRNSYS Version 15.0 – User Manual. Solar Energy Laboratory, University of Wisconsin, Madison und Transsolar, Stuttgart.

6. Acknowledgement

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