Evaluation of Solar Combisystems – Overview and Methodology

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Abstract

Increasing market development of solar combisystems can help to reduce primary energy demand of buildings and hence emission of green house gases. To support this market development it is important to strengthen the consumer confidence in solar combisystems. An important aspect for achieving this goal is to ensure the performance and quality of the systems under real operating conditions. In the three year project "CombiSol – Standardisation & Promotion of Solar Combisystems" which is supported by Intelligent Energy Europe, 45 solar combisystems installed in 4 European countries (Germany, France, Austria and Sweden) are evaluated in terms of qualitative inspection and in-situ monitoring. The objective is to gather information on the installation quality and the thermal performance of solar combisystems under real operating conditions and to compare them to results from laboratory testing. This paper presents an overview of the different evaluation aspects as well as first evaluation results.

1. Introduction

Solar combisystems (in the following SCS), are thermal solar systems for both domestic hot water preparation and space heating. An increasing market share of these systems will help to achieve the objectives of the energy action plan of the European Union with regard to the reduction of primary energy demand and the emission of green house gases. In order to accomplish this market enhancement of solar combisystems, the European project "CombiSol – Standardisation & Promotion of Solar Combisystems", supported by the European Commission via the program Intelligent Energy Europe (IEE) was set up. Over a period of three years from December 2007 to December 2010, experts from research, test institutes and industry will work on the following aspects:

- Improvement of consumer confidence in SCS by providing information on the energy efficiency of the systems based on laboratory testing and in-situ measurement
- Elaboration of laboratory test procedures for an objective assessment of SCS
- Promotion of improved quality for newly installed systems.

One major work package in the project is hence the holistic evaluation of solar combisystems. This evaluation comprises a qualitative and quantitative evaluation. Within the qualitative evaluation, the installation quality of the SCS is determined by an on-site inspection of an installed SCS. Within the quantitative evaluation, the thermal performance is determined by in-situ measurement of installed SCS over a time period of one year. The quantitative evaluation comprises the laboratory determination of the thermal performance of not installed SCS as well. The correlation between the qualitative evaluation results and in-situ monitoring results will reveal potential failures during installation and provide important information on the influence of the installation quality on the thermal performance of SCS. This will help to establish recommendations for manufactures and installers, to improve the design of SCS and to reduce risks of bad installations.

This paper will give an overview of the evaluation procedures, explain the methodology in detail and introduce first results of the evaluation.

2. Evaluation of solar combisystems

The large variety of SCS offered on the market, the differences in the integration of the SCS in the heating system and the deviation in installation quality make it difficult to predict the energy savings that will be achieved by a SCS under real operating conditions. The degree of prefabrication of the components has improved, but the installation quality is still an important factor influencing the thermal performance of SCS. In this context the term **installation quality** includes all aspects of installation such as the interconnection of different system components, insulation and controller settings. As SCS are often integrated into existing heating systems the quality of installation cannot be determined by laboratory testing but has to be investigated on the basis of data collected from systems installed in real buildings. For the evaluation of the installation quality, guidelines have been elaborated within the CombiSol project [1]. Furthermore guidelines for the collection of thermal performance indicators such as the fractional energy savings [2] were prepared.

The complete evaluation procedure therefore comprises a qualitative and quantitative evaluation (see Fig. 1). The qualitative evaluation gives information on the specific installation characteristics (e.g. the quality of the thermal insulation) and hence enables the correlation between laboratory and operating conditions. The quantitative evaluation provides information on the thermal performance of the combisystems by means of measurement data taken under real operating conditions (In-situ measurements) as well as under laboratory conditions.

This holistic approach of qualitative and quantitative evaluation allows the correlation between the thermal performance of combisystems under laboratory and under real operating conditions by comparing the differences in the thermal performance indicators.

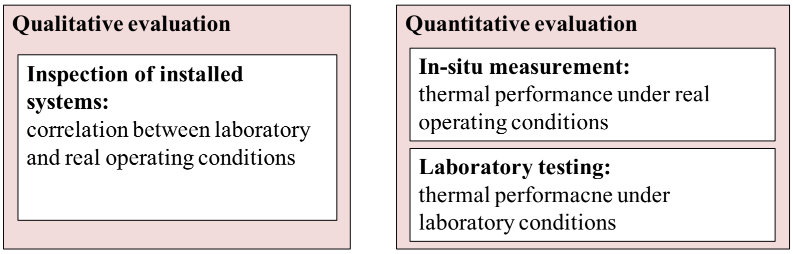

Fig. 1. Qualitative and quantitative evaluation procedures

2.1. Qualitative Evaluation

Despite the fact that the level of prefabrication has developed strongly installers still have to interconnect a lot of different components when installing a SCS at the construction site. The qualitative evaluation of SCS can help to identify key hurdles that may cause lower thermal performance of the system than possible. The results can be used for improving the prefabrication of components for SCS as well as the installation manual and help to avoid mistakes during installation of SCS. The quality of installation is determined during on-site inspections of SCS where the combisystems are examined using standardized checklists.

The qualitative evaluation comprises the collection of data specific for the locations like the number of persons living in the house, or the heated floor area and the specific data of the combisystems. The specific data of the combisystems include the main components as the solar collector, solar circuit including solar heat exchanger, heat store, auxiliary boiler, domestic hot water preparation and space heating as well as the piping, the thermal insulation and controller settings.

2.2. In-Situ Monitoring

In the project CombiSol 45 installed combisystems are assessed by in-situ measurements over a time span of one year. The aim is to get information on the thermal performance of the complete heating systems under real dynamic operating conditions. One important aspect to be kept in mind concerning the analysis of the measurement data is the fact, that SCS are only one part of the whole heat distribution system in a building. It is therefore important to take the complete heat distribution system of a building into account for the assessment of the data. Hence corresponding guidelines were elaborated for in-situ measurements and data assessment of SCS within the framework of the CombiSol project. Fig. 2 depicts the principle hydraulic scheme of a combisystem with the elaborated measurement points included.

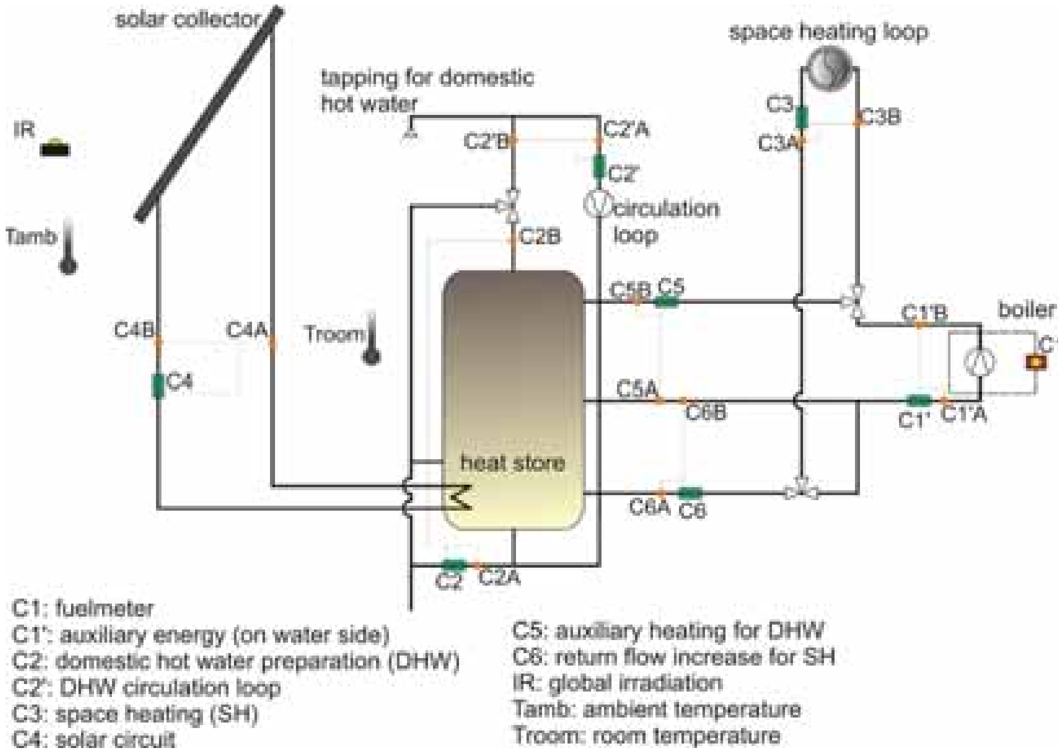

Fig. 2. Principle scheme of combisystems hydraulics including measurement points and corresponding locations

The measurement of all heat fluxes depicted in Fig. 2 enable the determination of the systems performance (e.g. the fractional energy savings) and the performance of the different components. Due to the fact that measurement data are collected every minute, potentials for improvement can be derived not only from the overall energy balances but also from the investigation of the system behaviour in detail.

2.3. Laboratory Testing

As the reliable prediction of the thermal performance of solar combisystems is one of the major aspects concerning the market development, the further development of test methods for SCS is one of the major workpackages of the CombiSol project. In order to determine the influence of the installation quality, combisystem concepts are evaluated both by in-situ measurement and laboratory testing. The qualitative evaluation will give indications for differences in thermal performances. Two different test methods are applied during the CombiSol project in order to predict the thermal performance of different solar combisystem concepts. The parameters of performance assessment are e.g. the fractional energy savings (f_{sav}).

With the component based CTSS (Component Testing - System Simulation, according to ENV 12977-2) method, previously developed by ITW (Institute for Thermodynamics and Thermal Engineering) the thermal performance of SCS is predicted on the basis of physical short term tests, performed for the main system components [3]. Based on the parameters determined for the different components from those tests, the annual thermal performance of the complete system is predicted for defined reference conditions (e.g. meteorological data, load profiles) by using a component-based simulation program such as TRNSYS [4].

By the black box approach based on the CCT (concise cycle test) method, which was originally developed by SPF (Solartechnik, Prüfung Forschung), and further developed by INES (Institute National de l´Énergie Solaire) the complete SCS is physically tested (except collector) under laboratory conditions [5]. In order to predict the annual thermal performance of a combisystem without a test sequence lasting one complete year, 12 characteristic test days were defined. The annual thermal performance is extrapolated from the 12 day test results.

3. Evaluation Results

Since the aim of the evaluation is to provide information on the correlation between the thermal performance under real operating conditions and laboratory conditions, in the course of the CombiSol project the same system concepts were evaluated using the qualitative evaluation, in-situ monitoring and laboratory testing. Since the CombiSol project is still ongoing no in-situ measurement data is available for one complete year. Hence in the following the comparison will be based on preliminary results for two system configurations.

Both systems are installed in single family houses within 100 km around Stuttgart, Germany. The first combisystems (SCS1) supplies heat for 3 inhabitants and a heated living area of 100 m^2 with a total collector aperture area of 9 m^2 and a heat store volume of 750 l. The second combisystem (SCS2) supplies heat for 4 inhabitants and a heated living area of 190 m^2 with a total collector aperture area of 13.96 m^2 and a heat store volume of 1000 l.

3.1. Qualitative Evaluation Results

Since the qualitative evaluation should, if existent, indicate reasons for lower thermal performance than possible, the thermal insulation of the complete system is one of the most important aspects during this evaluation part. The components are mostly prefabricated, hence the focus is on the piping and the interconnections between the components. One example from the qualitative evaluation is discussed below.

Fig. 1 shows a well insulated (left) and a not insulated connection at the heat store (right). The not insulated heat store connection is at the top of the heat store where the backup volume for domestic hot water preparation is located. Due to natural convection within the connecting pipe and also due to the high thermal conductivity of copper used as piping material the pipes are in the same temperature range as the set temperature of the backup volume for domestic hot water preparation. This implicates constant high heat losses throughout the whole year, causing a direct increase in energy demand and hence a decrease in thermal performance of the complete system.

Fig. 3. Insulation of the heat store connections, well done (left side) and missing (right side)

3.2. In-situ Monitoring Results

Since the CombiSol project is still ongoing and so far there are no in-situ monitoring results available for one complete year in Germany, some exemplary monitoring results are presented below. Table 1 shows the results of two evaluated combisystems for the one month of April 2010; the measurement points and quantities are indicated in Fig. 1.

Table 1. results of in-situ monitoring for two combisystems (SCS1 and SCS2) for April 2010

Measurement point	SCS1	SCS2
Mean inside air temperature (at heat store) [°C] (T_{room})	20.8	28.6
Mean outside air temperature [°C] (T_{amb})	11.7	11.5
Total space heating demand [kWh] (C3)	883	1871
Domestic hot water demand [kWh] (C2)	154	30

Domestic hot water circulation loop losses [kWh] (C2’)	140	107
Total auxiliary energy at the boiler outlet [kWh] (C1’)[1]	706	1372
Irradiation [kWh/m^2] (IR)	- (not measured)	141
Total collector gain (transferred into store) [kWh] (C4)	560	487[2]

First results show satisfactory performance (fractional energy savings of 41.2 % for SCS1 and 32.4 % for SCS2) of the combisystems as well as some indications for possible improvement. Those indications are drawn from e.g. energy balances or further examination of the measurement results using higher time resolutions. In the following some aspects for improvement are described exemplary.

The high inside air temperatures for SCS2 (see table 1) indicates potential for the reduction of the overall heat losses. This indication was recognised during the qualitative evaluation as well (see Fig. 4 right side). Next to those constant heat losses, further examination of the inside air temperature showed an increasing temperature during times of high space heating demands. Fig. 4 depicts parts of the space heating distribution system (left side) and the room temperature with the corresponding space heating demand (right side). The quick increase in the room temperature during high space heating demands implicates high thermal losses of the space heating distribution system in the room where the store is located. Hence the missing insulation of the piping can be identified as a potential for improvement in the thermal performance of this system. The pulsing of the measured heat demand for space heating (fig. 4 right side) is due to the same flow temperature of the floor and radiator heating circuit. This is due to the both circuits being connected to the boiler without a hydraulic separator including such a device also offers potential for improvement.

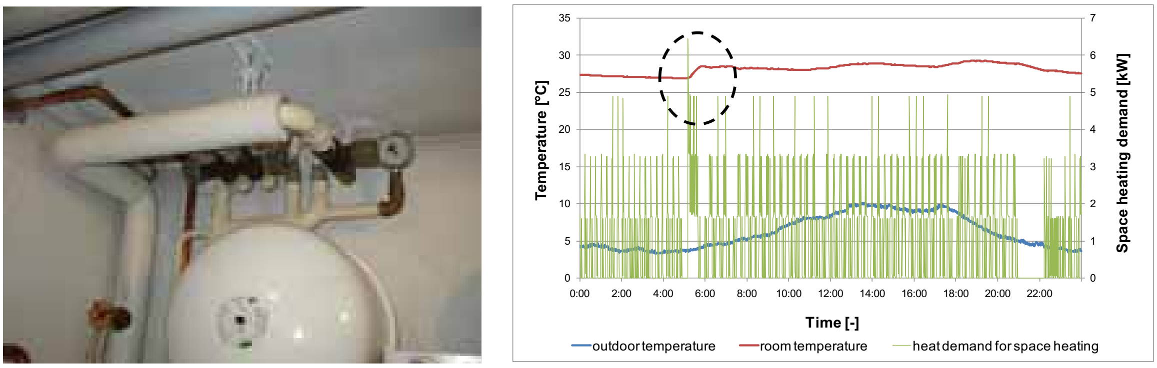

Fig. 4. Space heating distribution system (left side) and space heating demand with corresponding room temperature (right side)

3.3. Laboratory Testing Results

For the comparison of the two different test methods, the same combisystem concepts as represented by SCS1 and SCS2 was used. Their thermal performance was determined by applying the CTSS and the CCT test method using the same boundary conditions for both methods. Those boundary

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[1] Value calculated from C3, C5 and C6

[2] Measured data not reliable due to problems with flowmeter (values are too low)

conditions include e.g. the total collector area, the total heat store volume as well as the same set temperature for the backup volume for domestic hot water preparation. The component parameters (for the CTSS method) were determined according to EN 12975 (collector), ENV 12977-3 (heat store) and CEN/TS 12977-5 (controller). The system simulation for the CTSS method was performed according to ENV 12977-2 [4].

Since the system tests according to both test methods are still ongoing there are no final results available at the moment. However, first exemplary results determined with the CTSS method are shown below for SCS2. In order to assess the quality of the system simulations being an integral part of the CTSS method, the results of the system simulations (according to the CTSS method) are compared to the corresponding measurement data. For this comparison, the system setup of SCS2 was implemented in the transient simulation program TRNSYS. The system simulations were performed using the boundary conditions of the in-situ monitored system as a basis. These include not only the main component parameters resulting from the individual tests of the components but also the real load and weather conditions (e.g. the measured space heating load or the irradiance).

The results from the measurements and from the system simulation of SCS2 for April 2010 are depicted in table 2. The total auxiliary energy demand determined by the system simulation shows with a deviation of –1,75 % a very good agreement with the measured data. The deviation concerning the collector gain is based on the unreliable measurement data due to problems with the flow meter in the collector circuit (see also table 1).

Table 2. Measurement data and simulation results of SCS2 for April 2010

Measurement point	Measurement	Simulation	Deviation [%]
Total auxiliary energy at the boiler outlet [kWh] (C1')	1372	1348	-1,75
Total collector gain (into storage tank) [kWh] (C4)	487[3]	726	(49,18)

Apart from the deviations based on problems with the measurement equipment in the collector loop, the simulation of the system shows good agreement with the system at installation site. Hence the simulation model in combination with the specific component parameters used for the CTSS method is very applicable for the prediction of the thermal performance of combisystems.

Annual system simulations according to the CTSS method for this combisystem applying reference boundary for weather (Würzburg) and load profiles as specified in CEN/TS 12977-1 result in fractional energy savings of 25.7 % .

4. Conclusion

During the course of the CombiSol project several solar combisystems are evaluated applying the holistic evaluation procedure described above. First evaluation data indicate a satisfactory performance of the evaluated combisystems. But also some potential for improvements could be detected based on first in-situ measurement results. Starting points in this context are the solar thermal systems itself such as e.g. the thermal insulation of the heat store, but also the heat distribution system of the building e.g.

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[3] Measured data not reliable due to problems with flowmeter (values are too low), see table 1

with regard to the temperature level. First results from the laboratory test method CTSS show good accordance with the behaviour of the systems under real operating conditions. This implicates a good capability of the test method to predict the thermal performance of solar combisystems for specific boundary conditions in a realistic way. The holistic evaluation methodology presented hence enables the correlation between thermal performances of combisystems under laboratory and real operating conditions. This correlation will help to determine the impact of the installation quality on the thermal performance of SCS.

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Further information to the Project "CombisSol" is available in the Internet via: www.combisol.eu

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