A NEW CONCEPT FOR COMBISYSTEMS CHARACTERISATION: THE FSC METHOD

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Abstract – Solar Combisystems are relatively complex systems with many different components and operational parameters. Before the beginning of IEA-SHC Task 26 ("Solar Combisystems"), no method was available with which they could be compared. The well known "f-chart" method was introduced by Duffie and Beckman already in the seventies, but was only useful for dimensioning generic combisystems, with a defined hydraulic scheme. It didn't give a method to compare different designs.
The objective of this work was to develop a simple tool for characterizing the performance of these systems. The method used was to analyse the comprehensive simulation results of Task 26 and to look for relationships between the key external factors of climate and load, and the system performance. The result is a new and simple methodology for characterization of solar combisystems, called the Fractional Solar Consumption (FSC) method. FSC is a dimensionless quantity, which takes simultaneously into account the climate, the space heating and domestic hot water loads, the collector size, its orientation and tilt angle, but which does not depend on the studied system design.
The study shows that fractional energy savings, with and without parasitic energy included, can be expressed as a quadratic function of FSC. The relationship was shown to be valid for a wide range of conditions, but to be limited for certain parameters such as collector orientation and hot water load. The method has been used to create a nomogram and the computer design tool CombiSun.

Keywords – Solar Combisystems, Solar Thermal, Characterization.

1. INTRODUCTION

Characterization of solar combisystems with proper evaluation of performance is difficult, because of the various parameters that have to be taken into account:

- Hydraulic schemes and control strategies
- Meteorological data
- Space heating and Domestic Hot Water loads
- Size of the main technical parameters (collector area, storage volume, …)

A number of questions arise:

- Are some solar combisystems better adapted to particular climates or to particular loads?
- What is the influence of the collector size?
- How can a solar combisystem with a collector range between 5 and 12 m² in a Nordic climate be compared with a solar combisystem with a collector range between 10 and 30 m² in a continental climate?
- Is it possible to develop a method which removes all external parameters (climate, load, collector size) and makes it possible to characterize a solar combisystem in an intrinsic way?

In the past, several simplified methods based on nomograms have been proposed, but many are restricted to solar hot water systems. One of the most widely used is the "f-chart" method [Duffie J. A. , Beckman W. A. (1991)], where dimensionless quantities related to the losses and absorbed solar radiation are used in a characteristic equation to calculate the monthly solar fraction. Correction factors are included in the method to account for heat exchangers, cold water temperature, storage size amongst other things.

In the framework of Task 26 of the International Energy Agency's Solar Heating and Cooling Programme (IEA-SHC), a new method has been developed to characterize solar combisystems in a simple way that answers the above questions.

2. PERFORMANCE INDICATORS

The basic concept is to compare the fractional energy savings of the system with the maximum theoretical fractional energy savings. The method has been shown to be applicable to two main performance indicators:

- the fractional thermal energy savings ($f_{sav,therm}$), that only takes into account the saved fuel input of the solar combisystem compared to a reference heating system (equation 1).
- the extended fractional energy savings ($f_{sav,ext}$), that also takes into account the parasitic electricity W_{par} used by both the solar and reference systems (equation 2).

$$f_{sav,therm} = 1 - \frac{\frac{Q_{boiler}}{\eta_{boiler}} + \frac{Q_{el.heater}}{\eta_{el.heater}}}{\frac{Q_{boiler,ref}}{\eta_{boiler,ref}}} = 1 - \frac{E_{aux}}{E_{ref}} \quad (1)$$

$$f_{sav,ext} = 1 - \frac{\frac{Q_{boiler}}{\eta_{boiler}} + \frac{Q_{el.hetaer}}{\eta_{el.heater}} + \frac{W_{par}}{\eta_{el}}}{\frac{Q_{boiler,ref}}{\eta_{boiler,ref}} + \frac{W_{par,ref}}{\eta_{el}}} = 1 - \frac{E_{total}}{E_{total,ref}} \quad (2)$$

where:

Q_{boiler} thermal energy load of auxiliary boiler
η_{boiler} mean annual efficiency of auxiliary boiler
$Q_{el.heater}$ thermal energy load of electrical heating element
W_{par} parasitic energy consumption of solar combisystem

$\ldots_{,ref}$ values for the reference, non-solar heating system with which the solar combisystem is compared

In IEA-SHC Task 26 the efficiency for production of electricity has been defined as below, and these values are used in this paper.

$\eta_{el.heater}$ 40% for systems that do **not** apply solely renewable energy sources

$\eta_{el.heater}$ 90% for systems that apply solely renewable electrical energy sources

η_{el} 40% for all systems

The system numbers referred to later in the paper are those used within IEA-SHC Task 26, and which have been described in detail by Suter et al. (2000) and Weiss (Ed.) (2003).

3. DEFINITION OF FRACTIONAL SOLAR CONSUMPTION (FSC)

3.1 Reference consumption

The annual consumption for the reference heating system, Eref, is defined according to equation 3, and the monthly consumption by equation 4.

$$E_{ref} = \sum_{1}^{12} E_{ref,month} \tag{3}$$

$$E_{ref,month} = \frac{(Q_{SH} + Q_{DHW} + Q_{loss,ref})}{\eta_{boiler,ref}} \tag{4}$$

where:

Q_{SH} monthly space heating load

Q_{DHW} monthly domestic hot water load

$Q_{loss,ref}$ monthly storage tank losses

$\eta_{boiler,ref}$ boiler efficiency for the reference heating system (constant 85% over the whole year)

For the reference system, no heat-store for space heating is assumed. The monthly heat loss of the DHW-store of the reference system $Q_{loss,ref}$ is given by :

$$Q_{loss,ref} = (UA)_{S,ref} \cdot (T_S - T_{amb}) \cdot \Delta t_m \quad [kWh] \tag{5}$$

where:

$(UA)_{S,ref}$ heat loss coefficient of the store [W/K]

T_S reference store temperature [52.5 °C]

T_{amb} reference room temperature [15 °C]

Δt_m number or hours in the month

The size of the store, $V_{S,ref}$, is defined as 0.75 times the daily DHW-discharge volume (in litres). In Task 26 a nominal daily discharge 200 litres was used.

The heat loss rate coefficient is calculated as:

$$(UA)_{S,ref} = 0.16\sqrt{V_{S,ref}} \tag{6}$$

This is essentially an extension of the definition for reference energy consumption defined in the European standard ENV 12977-2 (CEN, 1997).

3.2 Calculation of FSC

The solar irradiation on the collector area is calculated by multiplying the solar collector area **A** [m²] by the monthly hemispherical irradiation on the collector plane **H** [kWh/m²]. The monthly reference consumption and the solar irradiation are shown on Figure 1, where they define three zones:

①: Final energy consumption of the building, which exceeds the solar potential.

②: Final energy consumption of the building that could be saved by solar energy. This is called 'usable solar energy' ($\mathbf{Q_{solar,usable}}$).

③: Solar energy in excess. This energy can be used for other applications, like a swimming pool for example.

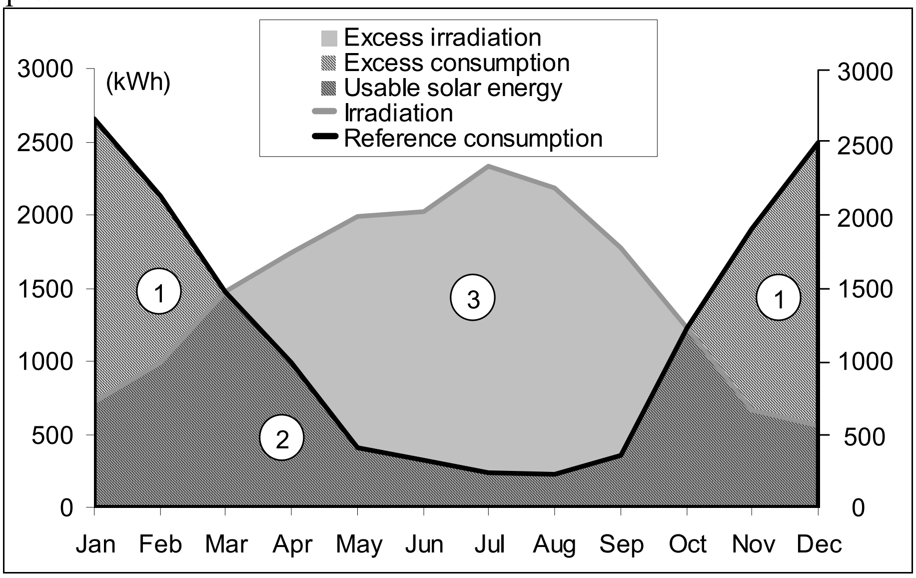

Fig. 1: Monthly plot of final energy consumption for a reference system and solar radiation on a specific collector area, azimuth and slope

$Q_{solar,usable}$ is calculated on a monthly basis in a simple way, using the solar collector area **A** [m²], the monthly solar irradiation on the collector area **H** [kWh/m²] and the monthly reference consumption $\mathbf{E_{ref,month}}$ [kWh]. The minimum of this reference consumption and the available irradiation is taken for each month and then summed over the year:

$$Q_{solar,\,usable} = \sum_{1}^{12} \min(E_{ref,\,month}\,, A \cdot H) \tag{7}$$

Dividing the usable solar energy $Q_{solar,usable}$ (②) by the reference consumption of the house $\mathbf{E_{ref}}$ (① + ②), a new parameter, called **Fractional Solar Consumption (FSC)** is defined (equation 8).

$$FSC = \frac{Q_{solar,usable}}{E_{ref}} \tag{8}$$

FSC can be considered as the <u>maximum theoretical fractional energy savings</u>, which could be reached if the solar combisystem had no losses. Comparing the real fractional energy savings to

FSC gives a good indication of the "effectiveness" of a solar combisystem ; the closer f_{sav} is to FSC, the better the solar combisystem converts the usable solar energy into real auxiliary energy savings.

FSC is a dimensionless quantity, using data for a whole year, which takes simultaneously into account the climate, the building (space heating and domestic hot water loads), the size of the collector area, and its orientation and tilt angle, but which does not depend on the choice of any particular solar combisystem. It must be remembered however, that this quantity is dependent also on the defined boiler efficiency in the reference system ($\eta_{boiler,ref}$), in this case a constant 85% over the whole year. Systems with a better boiler efficiency and smaller store losses can have f_{sav} greater than the absolute value of FSC.

Table 1 gives an example of a FSC calculation, with a resulting FSC value of 0.57 (equation 8):

[kWh]	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Reference consumption (E_{ref})	2659	2131	1477	989	412	320	237	226	359	1230	1905	2494	14415
Solar irradiation available (A.H)	716	991	1477	1740	1989	2017	2335	2183	1769	1230	663	558	17668
Usable solar energy ($Q_{solar,usable}$)	716	991	1477	989	412	320	237	226	359	1230	663	558	7943
												FSC	0.57

Table 1: Example calculation of FSC value

4. PERFORMANCE CHARACTERISATION

4.1 Basic FSC characteristic

Figure 2 is an example of the relation between $f_{sav,therm}$ and FSC, for a typical French combisystem called "Direct Solar Floor", system n°3a in the Task 26 booklet (Suter *et al.*, 2000)). Points have been calculated for the 3 reference climates and the 3 reference houses defined by Task 26 and for several collector sizes (6 to 20 m²). For this diagram, a French design tool, called PSD-MI (CSTB, 1998), has been used to provide the results for calculating both FSC and f_{sav}..

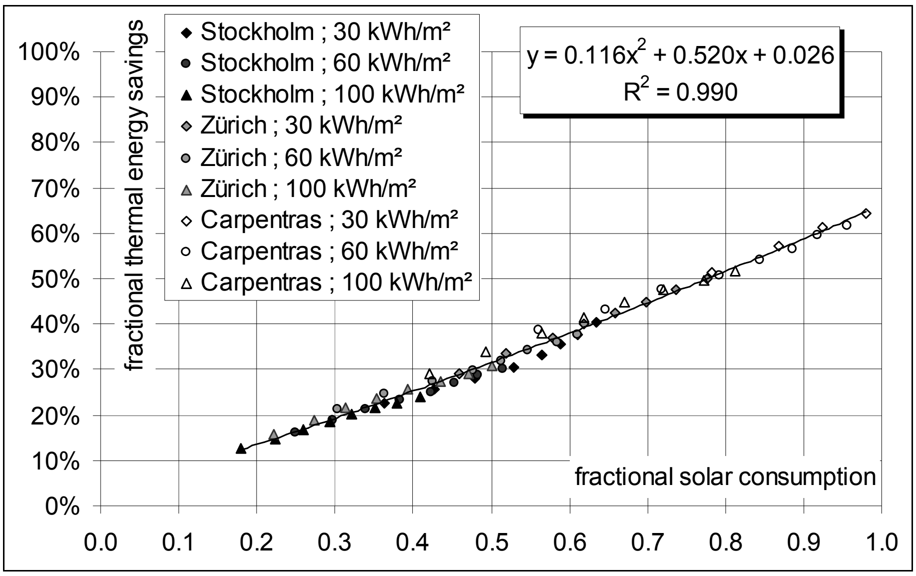

Fig. 2: Fractional thermal energy savings versus fractional solar consumption for System n°3a, calculated with the design program PSD-MI

It can be seen that the points are close to a mean parabola. The target functions can be expressed by a very simple parabolic equation in FSC, and the coefficients for it can be identified with a very good regression coefficient (close to 1).

$$f_{sav} = a \, . \, FSC^2 + b \, . \, FSC + c \qquad (9)$$

a, **b** and **c** are 3 coefficients of the solar combisystem and form the **FSC characteristic** of the solar combisystem.

Analysis of simulations made in the framework of Task 26 has shown that this diagram could be validly used for both performance indicators: thermal or extended fractional energy savings.

However, as the FSC method is a simplified method, it is important to have in mind the main assumptions. These are summarised in Table 2.

Assumptions
Exactly the same reference conditions must be used for the solar combisystems and the reference system
$E_{ref,month}$ depends on the definition of the reference system and specifically its heat source ; in Task 26, a gas boiler was used with constant efficiency of 85%
Simulations have to be done in the same way ; for comparison of curves coming from different programs, it has to be assumed that the programs deliver identical (or very similar) results.
No large spread in the values ; the regression coefficient R^2 has to be close to 1
The reference and the solar combisystem deliver the same thermal comfort to the occupier of the house
There are some limitations to the use of the method: ▪ orientation only up to ± 45 ° from south ▪ for the hot water load must be in the range 150 - 300 litres/day ▪ not valid for FSC = 1

Table 2: Major assumptions of the FSC method

4.2 Calculation of auxiliary energy consumption

The fractional energy savings estimated by the FSC characteristic can then be used to estimate the auxiliary energy consumption of the combisystem using equation 10a and 10b.

$$E_{aux} = E_{ref} \, (1 - f_{sav,\, therm}) \qquad (10a)$$

$$E_{total} = E_{total,\, ref} \, (1 - f_{sav,\, ext}) \qquad (10b)$$

4.3 Storage Capacity Correction Factor

A scattering of points around the parabolic curve can be noticed. In order to investigate this, points have been sorted according to the storage size / collector area ratio. A deeper analysis of the data revealed the need for a storage capacity correction factor SC, which has been introduced in the same way as in the f-chart method (Duffie and Beckman, 1991). Equation 9 has to be slightly modified and becomes equation 11 with characteristic coefficients a_{SC}, b_{SC} and c_{SC} instead of a, b and c.

$$f_{sav} = SC \, . \, (a_{sc} \, . \, FSC^2 + b_{sc} \, . \, FSC + c_{sc}) \qquad (11)$$

An equation for SC has been derived so that SC has a maximum value of 1 for a specific storage size / collector area ratio.

$$SC = \left(\frac{V}{\alpha \, . \, A} + \beta\right)^{\gamma} - \gamma \left(1+\beta\right)^{(\gamma-1)} \left(\frac{V}{\alpha \, . \, A} + \beta\right) + 1 - \left(1-\gamma\right)\left(1+\beta\right)^{\gamma} \qquad (12)$$

where:

V	storage volume	[l]
A	collector area	[m²]

α, β and γ have been calculated in order to get the highest regression coefficient for the parabolic curve representing f_{sav}/SC versus FSC. The following values have been obtained:

$$\alpha = 160 \text{ l/m}^2 \quad \beta = 0.1 \qquad \gamma = 0.25$$

With these numerical values, equation 12 becomes:

$$SC = \left(\frac{V}{160 \, . \, A} + 0.1\right)^{0.25} - 0.001455 \frac{V}{A} + 0.20864 \qquad (13)$$

In figure 3, the storage size correction factor has been plotted against the storage size / collector area ratio.

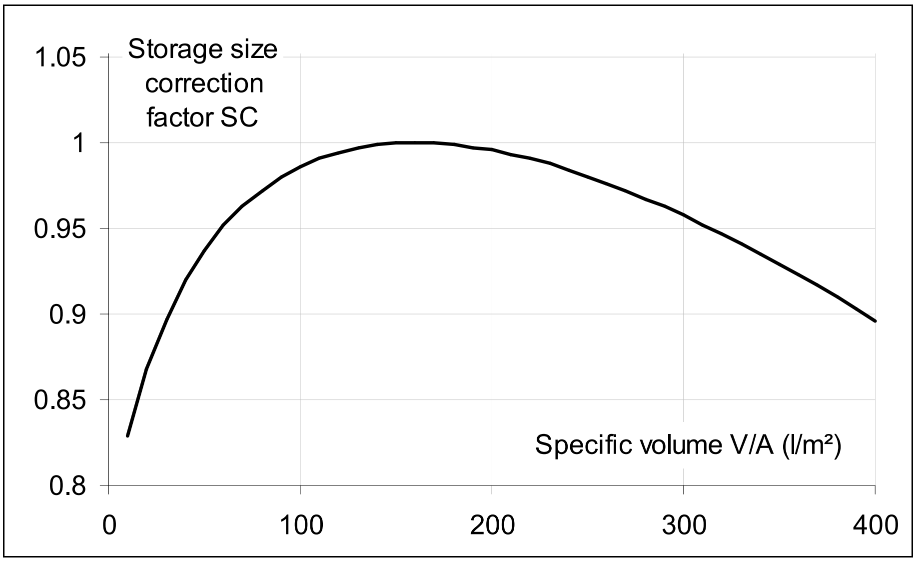

Fig. 3: Storage size correction factor

Using this more accurate method, the regression coefficients of the parabolic curve are improved for most systems (figure 4) and just kept identical for some others, as for example system n°4, which has a constant storage size / collector area ratio.

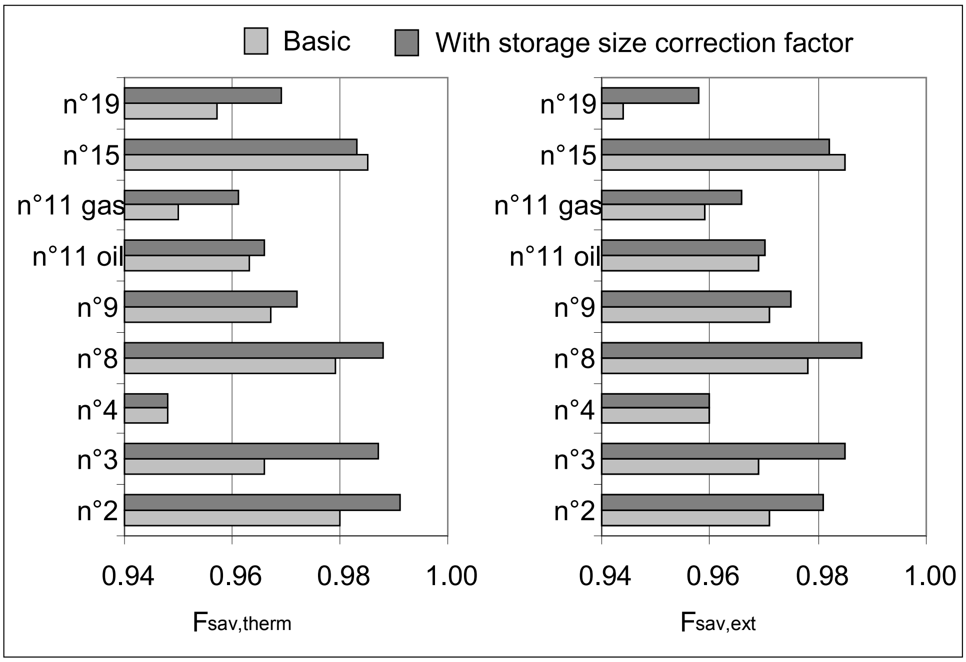

Fig 4: R^2 values for identification of the parameter values for the FSC characteristic of different SCS (identified by their number), without and with the storage size correction factor

4.4 Calculation of FSC on a daily basis

The choice of time period, used for summing the energies in the calculation of FSC, was also studied. Daily, weekly and monthly values of FSC were calculated.

For a daily or weekly approach, equations 3, 4, 6 and 7 have to be adapted using daily or weekly values instead of monthly values when required.

The analysis shows that even if the daily approach seems to be a little more accurate for the fractional thermal energy savings, both methods lead to a characterization with similar regression factors (figure 5).

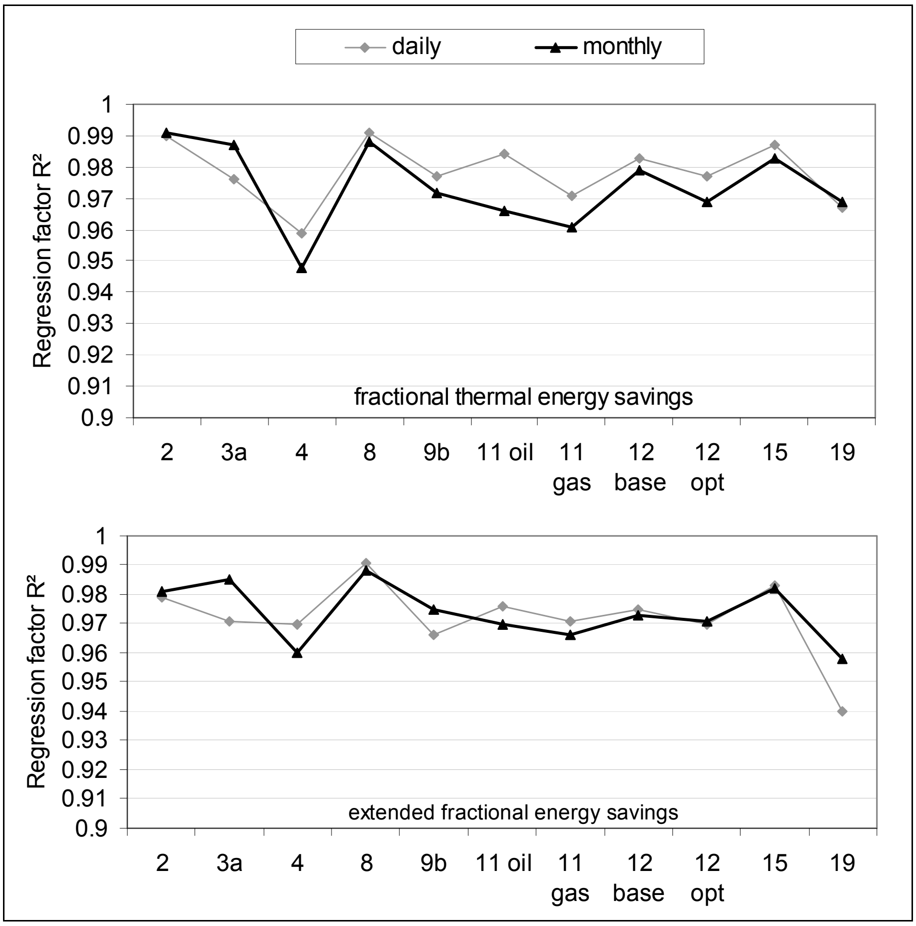

Fig. 5: Comparison between monthly and daily approach for the fractional solar consumption

Due to the fact that a monthly calculation is much easier and faster than a daily one, and also to the fact that the monthly approach is better adapted to the presentation of monitoring results, the monthly approach should be adopted.

5. VALIDATION OF THE FSC METHOD

Comparing the fractional energy savings and auxiliary energies calculated by the detailed simulations, i.e. those used to derive the FSC characteristics, with the simplified estimate given by equations 9 and 10 gives a measure of the predicting accuracy of the FSC method. For this, the regression coefficient for the plot of the estimated against the simulated values, as shown in figures 6 and 7 is used as a measure (calculations made without use of the storage size correction factor).

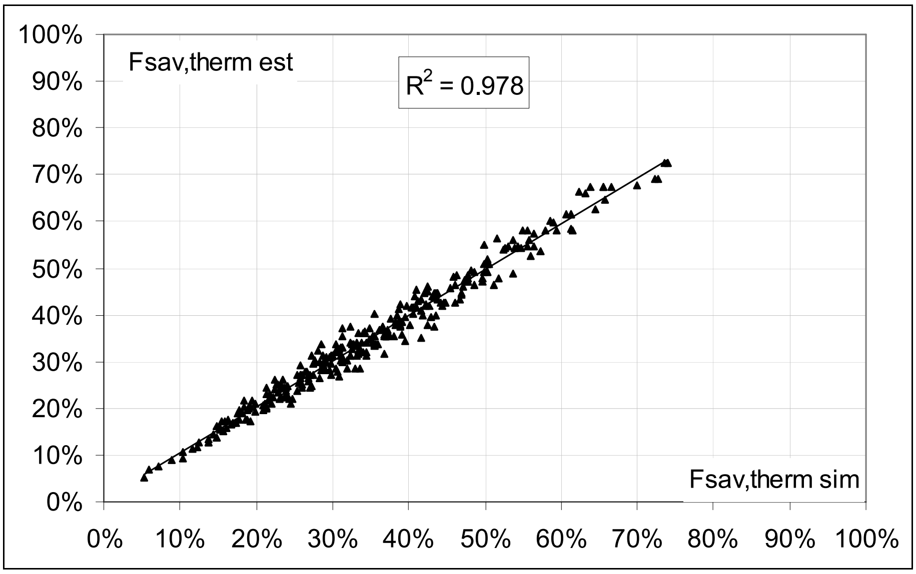

Fig 6: Accuracy of the FSC method for fractional thermal energy savings estimation

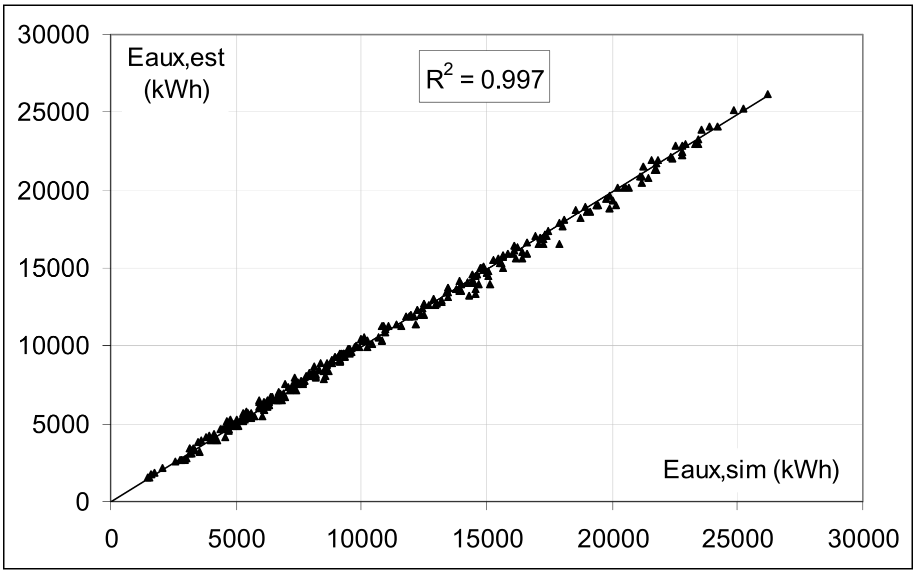

Fig 7: Accuracy of the FSC method for auxiliary energy consumption estimation

Similar regression coefficients have also been calculated taking into account the parasitic electricity needed (extended fractional energy savings and total auxiliary energy consumption), and using either the basic method (equation 9) or the storage size correction factor (equation 11). Table 3 shows the regression coefficients for the primary energy used only for heating purposes (lines 1 and 3) whereas lines 2 and 4 include the primary parasitic energy consumption.

	basic	with SC
$F_{sav,therm}$	0.978	0.982
$F_{sav,ext}$	0.983	0.986
E_{aux}	0.997	0.998
E_{total}	0.998	0.998

Table 3: Regression coefficients of auxiliary energy calculations

These comparisons have been made with 292 results coming out of simulations for single-family houses. However, for the multi-family house (system n°19), the points are a little more scattered because of a wider range of collector areas and storage tanks than used for solar combisystems in single-family houses.

6. SYSTEM COMPARISON

Nine systems have been simulated in the framework of Task 26. All use the same reference collector. This was necessary to be able to compare system concepts, including hydraulic design and control strategies. The results cannot be used directly for intercomparison of the commercial systems, as the solar collectors in commercial systems have different characteristics from those of the Task 26 collector.

Figure 8 gives the results for the fractional thermal energy savings, for all systems simulated in Task 26 using definitions such that the systems designs can be compared. It can readily be seen that there is a significant spread in characteristics. However, the slopes are fairly similar for most systems, the major difference being the absolute level. This level is principally determined by the efficiency of the auxiliary heater and of the store losses, compared to those for the reference system. In the systems shown here, the annual average boiler efficiency ranged from 80% to 105%, compared to that of the reference system of 85% (Weiss, 2003).

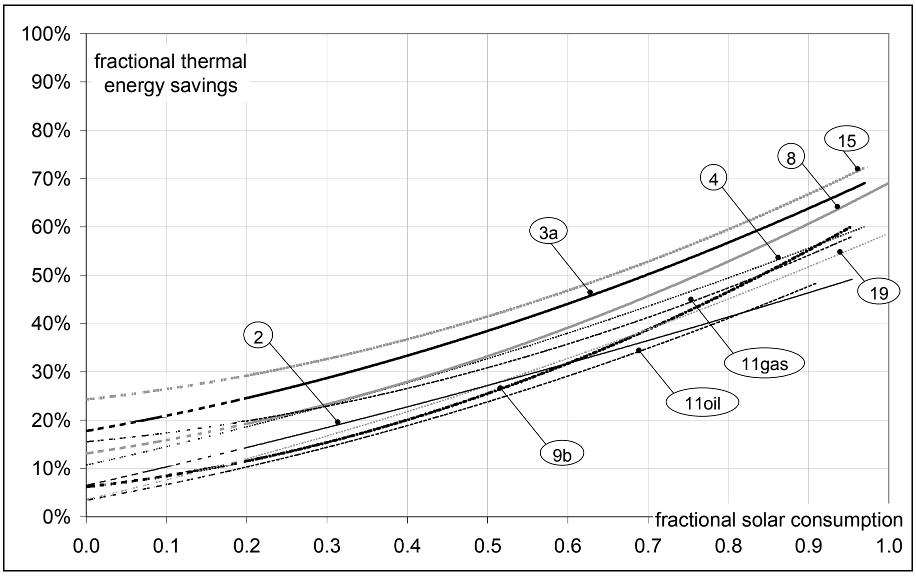

Fig. 8: Fractional thermal energy savings versus fractional solar consumption for systems simulated in Task 26

Characteristics have also been plotted for the extended fractional energy savings (Figure 9), revealing similar sets of curves.

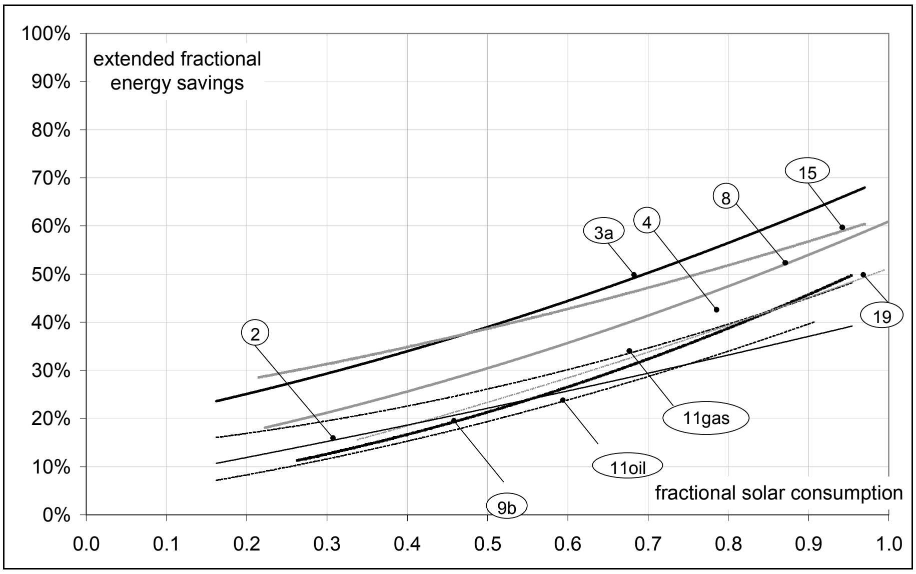

Fig. 9: Extended fractional energy savings versus FSC for systems simulated in Task 26.

7. PLANNING AND DESIGN TOOLS BASED ON THE FSC METHOD

The FSC method provides a powerful and easy way to elaborated simple tools for designers or architects. Two developments have been carried on in the framework of Task 26 (Weiss, 2003).

7.1 The Task 26 Nomogram

The Task 26 nomogram is based on the FSC method described above and can be used for sizing a given system or comparing different systems. It is limited to the systems and climates used in Task 26 but the load can be chosen arbitrarily. A view of the nomogram is given in Figure 10. More details and the way to use the nomogram can be found in Weiss (Ed.) (2003). This manual tool can be used with profit for educational purposes.

The FSC nomogram is to be used for quick estimation of the energy savings, after having chosen 4 parameters:

- a) a system,
- b) a climate,
- c) a collector area,
- d) a reference consumption.

The nomogram is built with 4 diagrams:

	X - axis		**Y - axis**		**Diagonal axis or parameter**	
		Unit		Unit		Unit
①	Collector area	m²	Specific collector area	10^{-3} m²/kWh	Annual reference consumption	kWh
②	Specific collector area	10^{-3} m²/kWh	Fractional Solar Consumption	-	Climate	-
③	Fractional Solar Consumption	-	Fractional Energy savings	%	System	-
④	Specific collector area	10^{-3} m²/kWh	Specific energy savings	kWh/m².y		

Table 4: Description of the diagrams used in Task 26 FSC nomogram

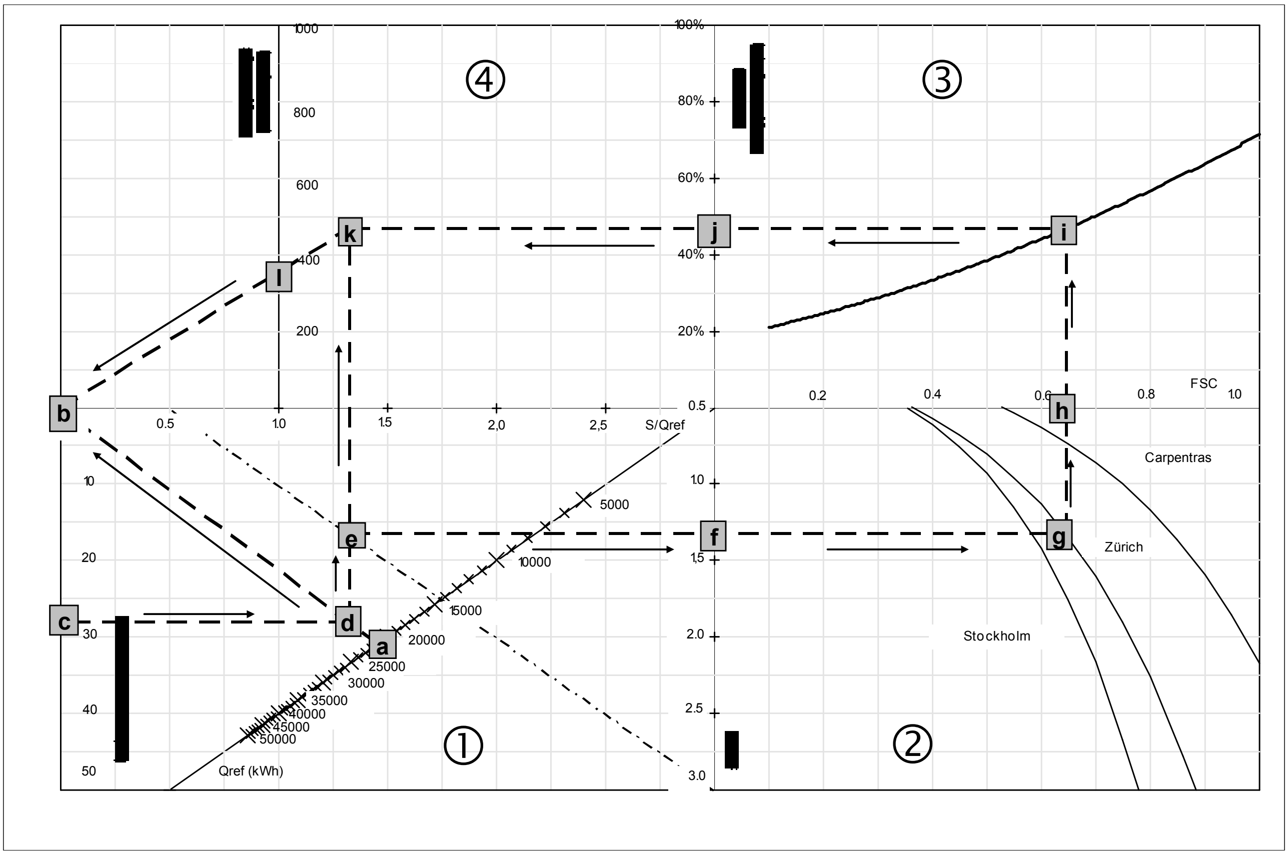

Fig. 10: The Task 26 FSC nomogram

Diagram ① calculates the specific collector area (S/Q_{ref}), according to the chosen **collector area** and the chosen annual **reference consumption**

Diagram ② calculates the Fractional Solar Consumption (FSC), according to the specific collector area and the chosen **climate**

Diagram ③ calculates the thermal fractional energy savings ($F_{sav,th}$), according to the Fractional Solar Consumption and the chosen **system**

Diagram ④ calculates the energy savings (Q_{sav}), according to the specific collector area and the thermal fractional energy savings

Letter	**Unit**	**Meaning**
a	kWh/year	Reference consumption
b	-	Origin of the specific collector area axis
c	m²	Collector area
d		
e		
f	10^{-3} m².year/kWh	Specific collector area
g		
h	-	Fractional Solar Consumption
i		
j	%	Fractional energy savings
k		
l	kWh/m².year	Energy savings

Table 5: Parameters used in Task 26 FSC nomogram

Nomogram can be used with following steps (For each step, the example values are given in brackets).

a) Choose a **reference consumption** (**a** = 22,000 kWh) ;

The reference consumption Q_{ref} is calculated according to task 26 reference conditions:

(space heating load + DHW load + reference store losses)/reference boiler efficiency

The efficiency of the reference boiler is **0.85**. The yearly heat losses of the store (table 6) are calculated according to the daily hot water demand Vd (l/day), in the same way as in ENV12977-2 (CEN standard):

$$Ql,ref = 0{,}16 \sqrt{0.75\ Vd}\ (TS - TS,amb) . 8760 \quad (kWh/year) \qquad (12)$$

with TS = 52.5 °C (Hot Water temperature) and TS,amb = 15 °C (Ambient temperature)

Vd : Daily hot water demand (l/day)	Ql,conv : Reference store losses (kWh/year)
100	455
150	557
200	644
250	720
300	788

Table 6: Yearly reference heat losses of the store

b) Draw a line from point **a** to the origin ;
c) Choose a **collector area** (**c** = 28 m²) ;
d) Draw a horizontal line from point **c** until you meet the segment [**ab**] at **d** ;
e) Draw a vertical line from point **d** until you meet the diagonal line ;
f) Draw a horizontal line from point **e** until you meet the vertical axis at **f** : you get the specific collector area
g) Draw a horizontal line from point **f** until you meet the **climate** curve (**g** on curve for Zürich) ;
h) Draw a vertical line from point **g** until you meet the horizontal axis at **h** : you get the Fractional Solar Consumption (FSC = 0.64) ;
i) Draw a vertical line from point **h** until you meet the **system** curve at **i** ;
j) Draw a horizontal line from point **i** until you meet the vertical axis at **j** : you get the Fractional energy savings ($f_{sav,th}$ = 47 %) ;
k) Draw a horizontal line from point **j** until you meet the vertical line coming from **e** at point **k ;** Draw a line from the origin **b** to point **k**, and extend it if required. Point **l** at the intersection of this line with the energy savings axis gives the Specific Annual Energy Savings compared to the reference system with annual boiler efficiency of 85% (350 kWh/m².year).

7.2 The Task 26 Design Tool COMBISUN

The Task 26 design tool, called CombiSun, is also based on the FSC method. The FSC value is dependent on the size of the collector, its orientation and the total load of the system. It is thus possible to estimate the savings of any system with a known FSC characteristic, if one knows the system load and climate as well as the size and orientation of the collector. In contrast to the nomogram, this tool is not restricted to the three climates used in Task 26, as it comes with a larger database of different climates.

CombiSun (Perers & Bales, 2003) can be downloaded free of charge from the Task 26 website or from http://www.elle-kilde.dk/altener-combi/dwload.html

CombiSun is aimed at a wide range of users and is designed principally to enable users to make a choice of the overall size of the system for the given location and building size. Several of the systems included in the tool are not sold with a specific boiler, rather this is chosen by the buyer or installer. This choice greatly affects the overall savings of the system.

Input	Description
Climate	The climate for the calculation – from a database of climates.
Type of building	The user can choose from the three Task 26 single-family house constructions (insulation thickness)
Size of building	Floor area of the building
Azimuth	The azimuth of the collector field
Slope	The slope of the collector field
DHW load	The DHW load for the calculation

Table 7: The user inputs to CombiSun.

Table 7 shows the user inputs to the program. TRNSYS is used to simulate the building on an hourly basis and to calculate the irradiation on the chosen collector orientation.

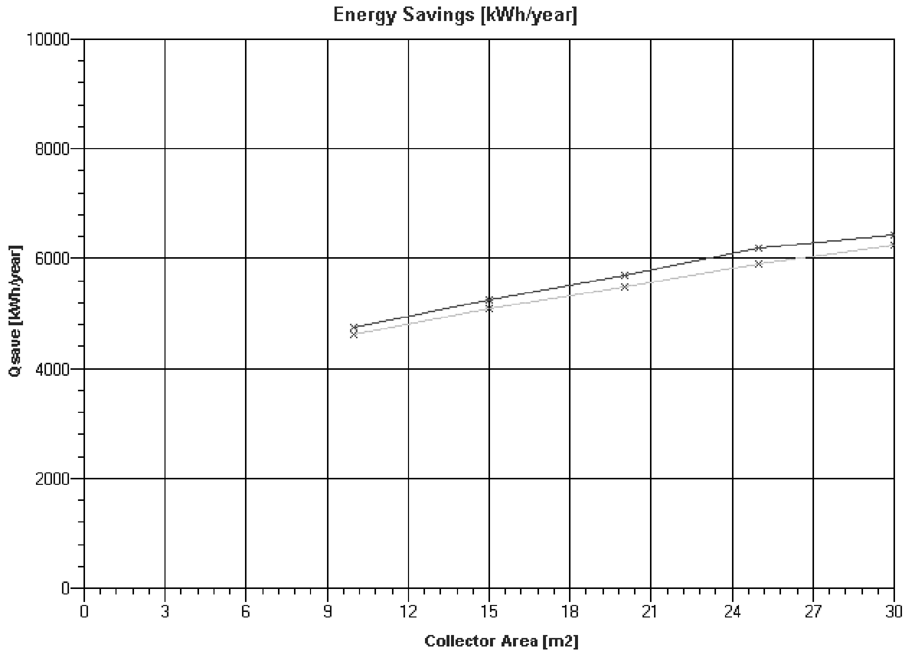

Fig. 11: Example output diagram from CombiSun for the same system with 10 m2 of collector, but two different azimuths (south-east (grey line) and south (black line)).

The output from this TRNSYS simulation is then used by CombiSun to calculate the FSC values for a range of collector sizes. The corresponding energy savings are then calculated for these collector areas and the chosen system, based on the system FSC characteristic. These results are then written out in table form and can be plotted in a diagram such as Figure 11. Several different plots can be made in the same diagram, for different systems or other variations in user input. The diagram can be scaled and exported as a separate file so that it can be incorporated into reports. A standard report can also be created and printed out. It is possible to easily add additional climates and systems to the database.

8. PRESENTATION OF MONITORING RESULTS WITH THE FSC METHOD

8.1 Results of the European Alterner project Solar Combisystems

From April 2001 to March 2003, Austria, Denmark, France, Germany, Italy, Sweden and The Netherlands have carried out the EC Altener programme project: Solar Combisystems.

Within the framework of this project, a monitoring method based on the FSC method has been elaborated (Letz, 2003). It was used to compare results from 13 monitored plants located in five different countries: Austria, Denmark, France, Germany and the Netherlands.

Plants differ by the climate, the space heating and domestic hot water loads (5000 to 55 000 kWh/y) and the collector area installed (3 to 20 m²). However, with the FSC method, all systems can be represented on the same diagram (Figure 12) with one point for each annual result. The results can are then easily visualised, and systems with functioning problems, showing poor fractional energy savings compared to the FSC values, can easily be identified. (Letz and all, 2003).

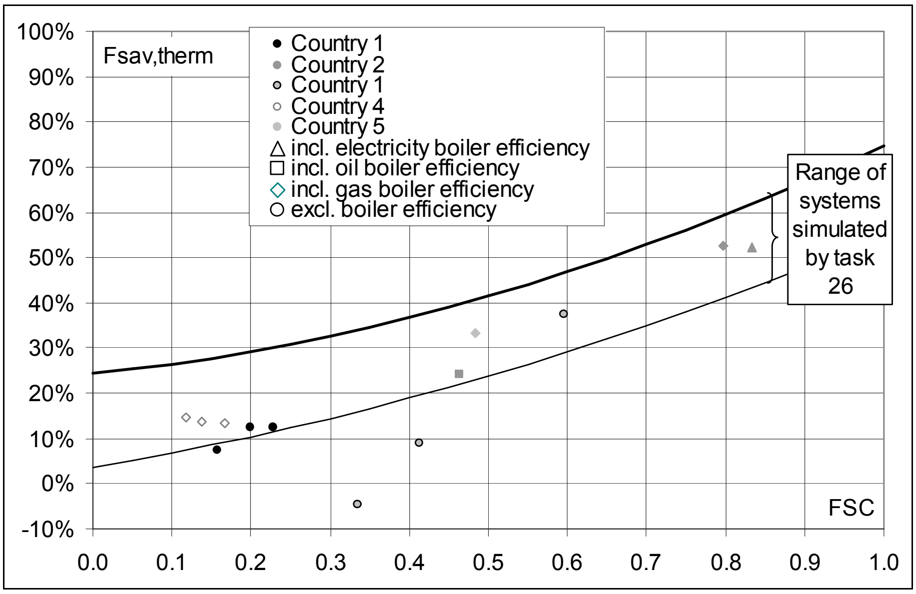

Fig. 12. Monitoring results of 13 combisystems installed in Europe

8.2 Results of the French EvalSSC project

From 2003 to 2006, a monitoring project has been carried on in France, involving 5 different manufacturers. (Letz , 2007).

32 combisystems have been evaluated, using a similar method as the one used in the Altener project, except the values for the calculation of reference consumptions, which have been derived from the French Thermal Regulation RT 2000. These reference values are a little higher than the ones adopted by Task 26.

Results show a good behaviour of the systems for one manufacturer (B), acceptable results for another (D) and poor results for the 3 others (Figure 13). A deeper analysis performed for these 3 manufacturers has shown several possible causes: the system itself is not optimised, mainly with regards to the control strategy; the space heating loops are not well designed (high and low temperature loops connected together); and finally some plants are not well installed, e.g. long uninsulated pipe runs.

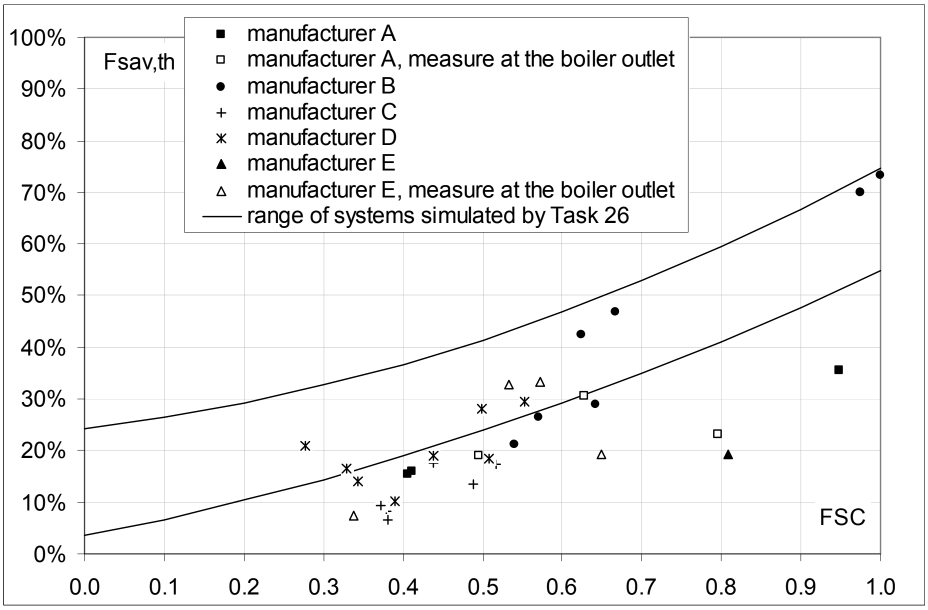

Fig. 13. Monitoring results of 32 combisystems installed in France

9. FUTURE WORK

Another aspect that was studied in more detail was the influence of the hot water load.

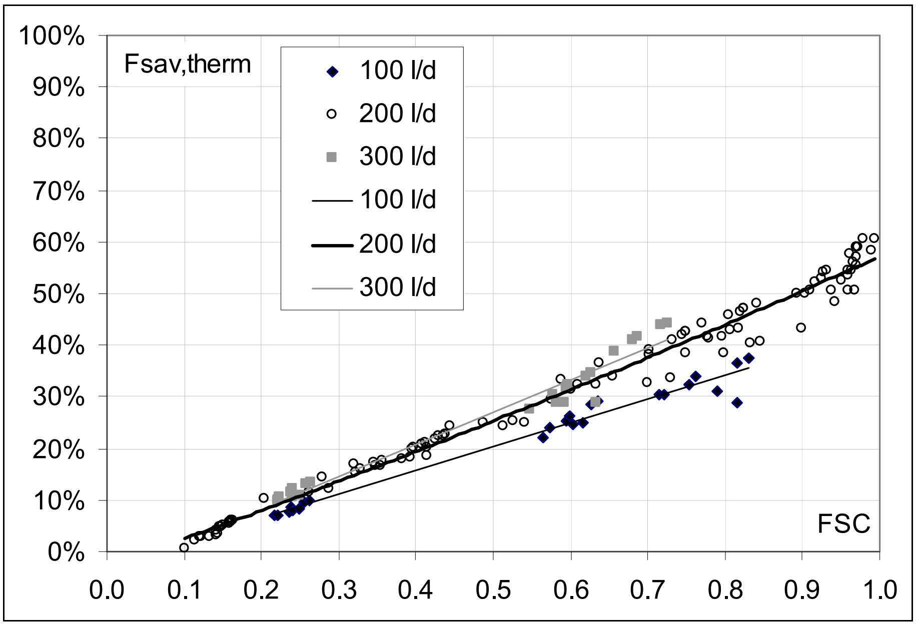

Fig. 14. Simulation results for system n°11 with oil boiler, with varying amounts of hot water load.

Figure 14 shows that the basic FSC characteristic is not suitable for a wide range of hot water loads for system n°11.

The characteristics for results using a nominal daily hot water discharge of 200 and 300 litres/day lie close together and can be represented by a single characteristic.

However, the characteristic for a discharge of 100 litres/day is significantly different from those for 200 and 300 litres/day and should be represented by a separate characteristic.

In contrast, the results for similar simulations for system n°3 (figure 15) show a less marked difference between the characteristics for the three different discharge levels of 100, 200 and 300 litres/day. One characteristic can therefore be used to represent this whole range.

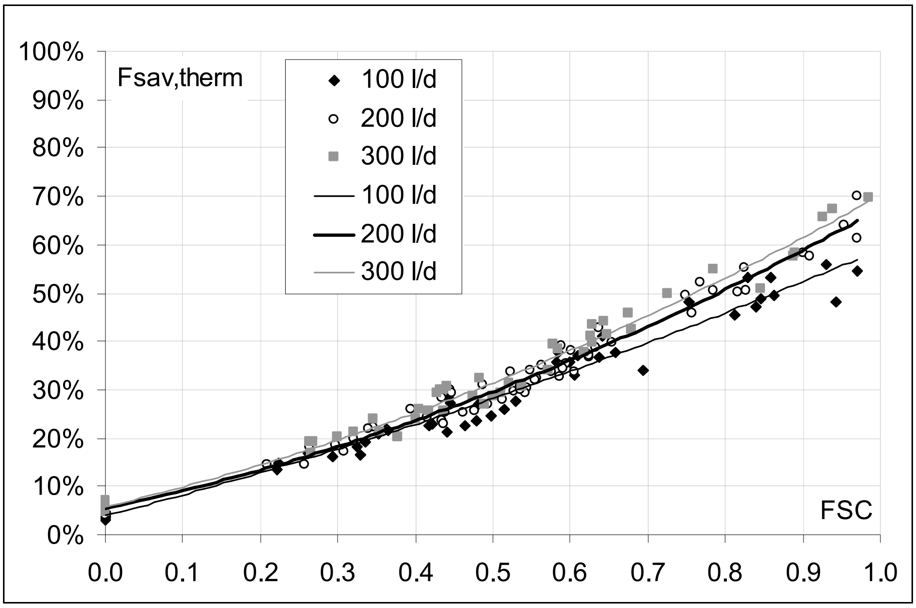

Fig. 15. Simulation results for system n°11 with oil boiler, with varying amounts of hot water load.

The dependence of the hot water load on the FSC characteristic needs to be studied in more detail, and a correction factor needs to be found, if possible. Furthermore, a wider range of simulations needs to be performed using the simulation models used in Task 26 (or others) in order to check whether there are any other limitations to the method, and if so to find further correction factors.

10. CONCLUSION AND RECOMMENDATIONS

The Fractional Solar Consumption (FSC) procedure provides an easy way to characterise and compare combisystems. Different accuracy levels can be adopted, with or without storage size correction factor, depending on the required accuracy level. The method works equally well for two performance indicators defined by Task 26.

10.1 Combisystems characterisation

A generic combisystem can be described by:

- A hydraulic diagram, related to a specific concept
- A control strategy
- Main dimensioning parameters (collector area range, storage volume range)
- Secondary dimensioning parameters, usually dependent on the storage size (heat exchangers size, insulation level (UA-value for the store), volume heated by the auxiliary ….)

With regard to the characteristic coefficients suitable for the FSC procedure, three different situations can be met:

- system installed with a unique storage size (for example n°3a or n°8): the system is described by a single data set for each target function.

- system installed with several storage sizes, that cannot be summarised in a single equation (for example n°11 gas): one data set for each storage size. For rough evaluation, a single data set could be used.
- system installed with several storage sizes, that can be summarised in a single equation (for example n°9): a single data set.

Further work is required in order to determine a hot water load correction factor and to more precisely determine the limits for the method.

10.2 Combisystems comparison

The basic FSC characteristics can be used for a quick and simple comparison of solar combisystem performance, using a single diagram of fractional energy savings or final energy consumption versus FSC. Introducing a correction factor for the store size reduces the regression factor for the characteristic but the resulting diagram is not as easy to interpret directly. However, the correction factor is easy to include in design tools.

10.3 Utilisation of the FSC diagram

The FSC diagram can be used:

- for presentation of results obtained by simulations, laboratory tests or in situ monitoring
- for simplified dimensioning tools, that can be used for example in thermal standards

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