

Comparison of Simple EPBD Calculation Tool for Solar Combisystems with TRNSYS

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Abstract

An excel based calculation tool has been developed within the EU project Combisol. It implements the standard calculation method EN 15316-4-3 for solar combisystems, as defined for the Energy Performance of Buildings Directive (EPBD). A base case system and building were defined and a number of parametric studies were performed with this EPBD tool as well as TRNSYS for the same systems and boundary conditions. For all the simulations in this study, the EPBD tool predicted a greater solar contribution than detailed TRNSYS simulations predicted. The difference was greater for Stockholm (high latitude) and Madrid (high solar fraction). Other studies showed that the EPBD predicted changes in solar contribution due to changes in system size, orientation and azimuth as well as store size in the same way that TRNSYS does.

1. Introduction

This paper compares the simulation results of two very different calculation tools for the same boundary conditions and solar combisystems: TRNSYS [1], the well known dynamic simulation software used mostly for research purposes; and a simple excel tool [2] based on the EU standard EN 15316-4-3 [3] for the Energy Performance of Buildings Directive (EPBD) [4]. This tool has been developed within the European project Combisol [5].

1.1. Background

The European Energy Performance of Buildings Directive was introduced in 2002 in order, amongst other things, to set minimum standards on energy performance for new buildings and existing buildings that are substantially renovated as well as to specify a common methodology for calculating the energy performance of buildings. As part of this work a number of standards were introduced to define these calculation methods. One of them was EN 15316-4-3, which is for the determination of useful heat contribution from solar thermal systems. This methodology should calculate the contribution for solar hot water systems as well as solar combisystems that supply space heat as well as hot water. As part of the directive, the energy performance of buildings has to be calculated and a certificate stating this performance is issued.

The European project Combisol, which is supported by Intelligent Energy Europe program, should encourage an accelerated market deployment of solar combisystems – and thus, a higher share of heat produced by solar energy. The project has tasks on promoting best practice for solar combisystems, promoting standardised system concepts, recommendations for manufacturers, training of installers

and measurements of systems in the lab and in the field. In general, approved consultants perform the energy performance calculations for the EPBD certificate and make suggestions for improved energy efficiency. Many, however, lack the tools and for calculating the savings potential of solar thermal systems and especially solar combisystems. This is why the Combsol project has developed a tool based on the calculation method specified within the EPBD framework, with the idea that the tool would be easy to use and easily distributable and thus easy for consultants to use in practice.

2.1. Aim and Method

The main aim of the study was to compare the results from the Combsol EPBD tool with a well known and validated simulation tool. The study was limited to the solar contribution from the systems studied and did not include comparisons of energy savings due to different types of auxiliary heater.

The first stage was to define performance figures for use for the comparison of the tools. These were based on those calculated by the Combsol EPBD tool, as this was the limiting factor. The second stage was to define a base case system and boundary conditions, based on previous work in a national project, for which a detailed TRNSYS model was already available. This base case system was then implemented into the Combsol EPBD tool. The space heating load calculated by TRNSYS was used as input to the EPBD tool that requires the annual load as input. However, the distribution over the year is decided by the user, so initial simulations were carried out to determine how the in-built distributions compared with those calculated by TRNSYS and to choose one of them for further studies. Thereafter, a number of parametric studies were performed that varied climate, collector azimuth and orientation, system size (collector and store), collector type as well as volume in the store. The solar fraction for TRNSYS simulations has been calculated in the same manner as in the tool using equ. 1.

$$SF = \frac{Q_{sol,contr}}{Q_{load}} \quad (1)$$

Where Q_{load} is the total heat load for the system and $Q_{sol,contr}$ is the solar contribution, which is the useful output from the solar part of the tank(s). This is calculated according to EN 15316-4-3 in the EPBD tool, but for TRNSYS it is calculated according to equ. 2.

$$Q_{sol,contr} = Q_{sol,store} - Q_{loss} \left(\frac{Q_{sol,store}}{Q_{sol,store} + Q_{aux}} \right) \quad (2)$$

Where $Q_{sol,store}$ is the solar energy delivered to the store, Q_{loss} the heat losses from the store and Q_{aux} the heat delivered by the auxiliary.

2. EPBD Tool

2.1. Calculation Method

The Combisol EPBD tool uses the calculation method specified in EN 15316-4-3, which in turn is based on the well known F-chart method. This is a correlation method where the solar contribution has been correlated against two dimensionless parameters X and Y and a series of coefficients using the results of hundreds of simulations for a variety of systems. X and Y are based on physical parameters such as incident radiation and ambient temperature, incidence angle modifier, area and zero loss coefficient and heat loss coefficient of the collector as well as factors derived for store size and solar loop efficiency. These parameters and factors are input data to the calculation method. Typical values for some of the parameters and factors are given in the standard. The method calculates the solar contribution on a monthly and thereafter annual basis. The method divides the solar contribution into two parts: one for the DHW contribution and one for the space heating contribution.

2.2. Input and Outputs

Fig. 1 shows the input worksheet to the tool (but not including definitions for the auxiliary part of the system). This consists of data for the boundary conditions such as climate (from internal database or user specified data), space heating and DHW load, orientation and azimuth of the collector. In addition data for the system are required, most of which are used for deriving the dimensionless quantities X and Y described in the previous section. For most quantities there are typical and “penalty” (relatively poor) values that can be chosen by the user. Alternatively users can supply their own values.

The screenshot displays the 'INPUT Solar System' worksheet. It is organized into several columns and rows, with some cells containing dropdown menus or checkboxes. The parameters include:

- System location:** Location (Austria, Vienna), G (1230 kWh/m²), T_a (9.5 °C).
- Loads:** Annual space heating load (20 000 kWh), Daily hot water load (0 kWh), Average hot water tap temperature (55 °C), Annual hot hot water load (kWh).
- Thermal losses:** Total annual load, space heating + hot water (incl. DHW) (20 000 kWh), Back-up set point temperature (55 °C).
- Collector details:** Collector type/name (D11 Flat plate collector, typical), Number of collector modules (1), Total collector area (19.50 m²), Collector orientation - tilt (47 °), Collector orientation - compass (E).
- Controller and pump:** Controller power consumption (C. Specify own value), Self-circulation / pumped circulation - pump speed (C. Specify own value), Solar loop efficiency / heat exchanger factor (A. Typical value), Solar loop pipe losses (C. Specify own value).
- Tank specifications:** Location of solar tanks (Intero), System type (One tank / integrated back-up), Separate tanks for hot water and space heating? (One tank for both hot water and space heating), Total volume of tanks (1000 litres), Back-up volume of tanks (200 litres), Total volume, space heating tank (litres), Back-up volume, space heating tanks (litres), Total ABCB store volume (litres).
- Other parameters:** Azimuth (1.00, 2.00, 3.00, 4.00, 5.00, 6.00, 7.00, 8.00, 9.00, 10.00, 11.00, 12.00), Controller usage (0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100), Pump power (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100), Heat (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100), Overall (2.7, 2.7, 2.7).

Fig. 1. Input worksheet for the Combisol EPBD tool.

The tool then calculates the solar contribution and the savings compared to a reference system defined in the input worksheet. The results are presented as values as well as diagrams, see Fig. 2.

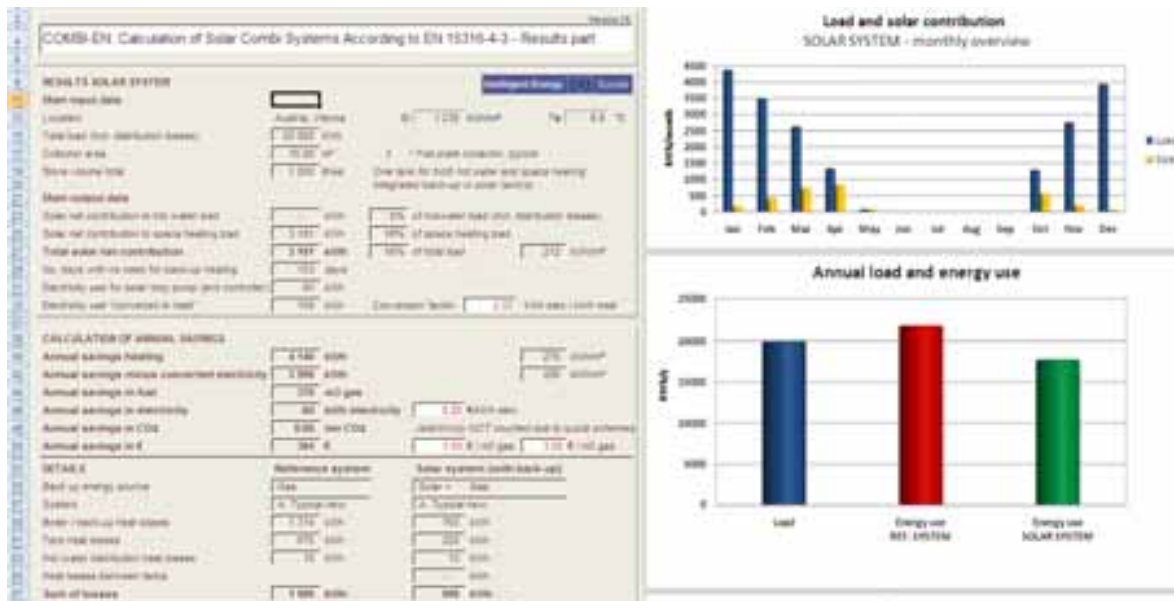


Fig. 2. Results worksheet for the Combisol EPBD tool.

3. Simulated Systems

3.1. Base Case Building and System

A modern single storey, single family house with a gross area of 146 m² and an overall U-value of 0.20 W/m².K, as sold by a company in Sweden, is used as the heat load in this study. The space heat is supplied with floor heating in each of the main rooms. There is no ventilation air heat recovery. It is assumed that four people live in the house, and that they use altogether on average 200 l/day hot water per day. The solar combisystem simulated in this study is of the type #11 as defined in the work of IEA-SHC Task 26 [7]. It has an internal heat exchanger for solar heat and two internal heat exchangers for the preparation of domestic hot water. The auxiliary comes from an electrical heating element in the store. Space heating is taken for two levels in the store, one below and one above the electrical heater, and mixed with the return water to the desired flow temperature using a four-way valve.

3.2. Implementation in TRNSYS

The building and system are modelled in detail in TRNSYS. The building is modelled using Type 56 multizone building model with 6 zones (not including the attic). Each zone has on/off controlled floor heating based on the room temperature and is in standby to deliver heat when necessary all year round. The temperature delivered to the floor heating is decided based on the outdoor temperature together with a temperature curve depending on climate and house type. To avoid too high temperatures in the summer, internal blinds and opening of windows is part of the model. The building also contains internal gains from equipment and persons and can make use of passive solar gains when available. The contact with the ground is modelled with Type 703a “slab on grade” model.

The solar collector subsystem can be divided into three parts; a collector with controls, a tank with backup heating and domestic hot water preparation including a tapping profile. The majority of the system model is based on the IEA-SHC Task 32 template [8], including the standard flat plat collector,

and has been adapted to the more detailed building model used in the study as well as the exact details of the solar combisystem. The store was modeled with Type 340 multiport model, using parameters derived from previous research projects and with the heat loss being coupled back to the building model, more exactly to the relevant zone in the building. The floor heating system from the existing building was connected to the tank using a 4-way valve (Type 221) which was temperature controlled. The DHW load was that of IEA-SHC Task 26 [7] at 200 l/day and seasonal variation of cold water temperature.

3.3. Implementation in EPBD Tool

The EPBD tool has far fewer parameters than TRNSYS and so the input data was “translated” into the tool to be as similar as possible. The annual heat load calculated from TRNSYS was used as input to the EPBD tool. The tool has three choices of monthly distribution of this annual load, and the “no passive utilisation” was used as this best matched the monthly profile from TRNSYS. The DHW load was defined as 200 l/day, the energy being calculated by the tool. The tool has an option for manual input of the load distribution.

The EPBD tool allows the definition of both an auxiliary heater for the solar heating system as well as a reference system. An electrical heater (100% efficient) was used for the solar heating system while the reference system was not defined as it was not part of this study.

4. Simulation Results

The following sections show the results of the parametric studies. A system with 10 m² flat plate collector (as used in IEA-SHC Task 32), 750 litre store for the standard insulated house is used as the base case. Results are for this base case unless otherwise stated.

4.1. Variation of Location

Table 1 shows the key figures for four European climates used in the comparison, while Fig. 3 shows the results for the base case solar combisystem for the four climates, with solar contribution in the left hand figure and solar fraction in the right hand figure. Two other key figures are shown for the TRNSYS simulations: $Q_{sol,store}$ is the solar energy delivered to the store, while $Q_{sol,net}$ is $Q_{sol,store}$ less store losses. The equivalent solar fractions, as calculated by equ. 1 are also shown.

Table 1. Key figures for the base case system for different climates.

	Stockholm	Malmö	Zurich	Madrid
Space heating load [kWh]	12 891	9 090	8 317	5 865
DHW load [kWh]	3 117	3 117	3 031	2 715
Global radiation [kWh/year]	980	976	1 105	1 662
Average temperature [°C]	5.3	7.7	9.1	13.9
Store losses [kWh]: TRNSYS / EPBD	984 / 1134	942 / 1204	1049 / 1237	1406 / 1605

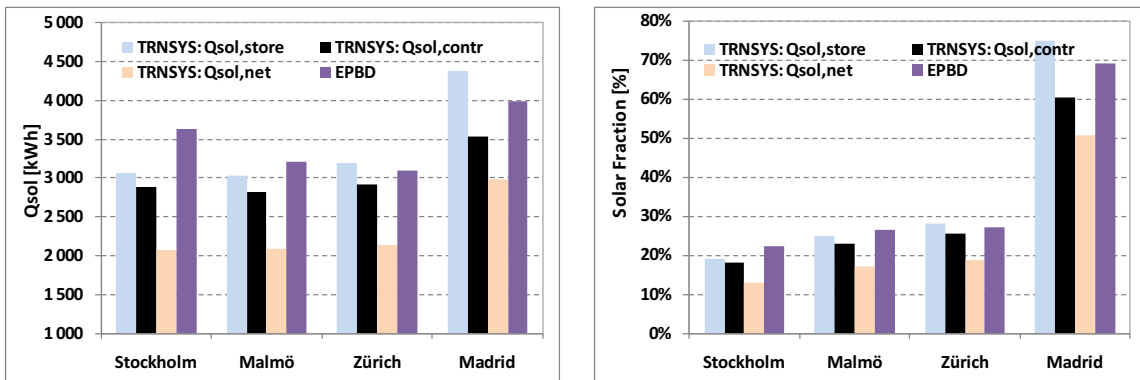


Fig. 3. Solar contribution (left) and solar fraction (right) for four different climates for the same base case system.

The results show that the solar contribution calculated by TRNSYS is always less than that calculated by the EPBD tool, ranging from 6% (Zurich) to 26% (Stockholm).

4.2. Variation of System Size

Fig. 4 shows the key figures of solar contribution (Q_{sol}), auxiliary heat (Q_{aux}) and store losses (Q_{loss}) for the TRNSYS and EPBD calculations for both Stockholm (left) and Madrid (right). Both the solar contribution and store losses increase more with system size for the EPBD tool compared to TRNSYS. In addition, the value for Q_{aux} is roughly 1000 kWh higher for TRNSYS than for EPBD for the Stockholm climate. This is partly explained by the difference in solar contribution. In TRNSYS the heat losses are gains in a small room, and the heat transfer to the rest of the building is limited, resulting in only a small amount of the store losses being used to reduce space heating load. This is treated differently in the EPBD tool and these differences could contribute to the difference in values for Q_{aux} . For the Madrid climate the calculated Q_{aux} values are quite similar, except for the largest system size. The system with 20 m² in Madrid is a special, as the EPBD tool gives a 100% solar fraction and for TRNSYS the solar energy to the store is greater than the total load, also resulting in a 100% solar fraction according to the definition of solar fraction using equ. 1.

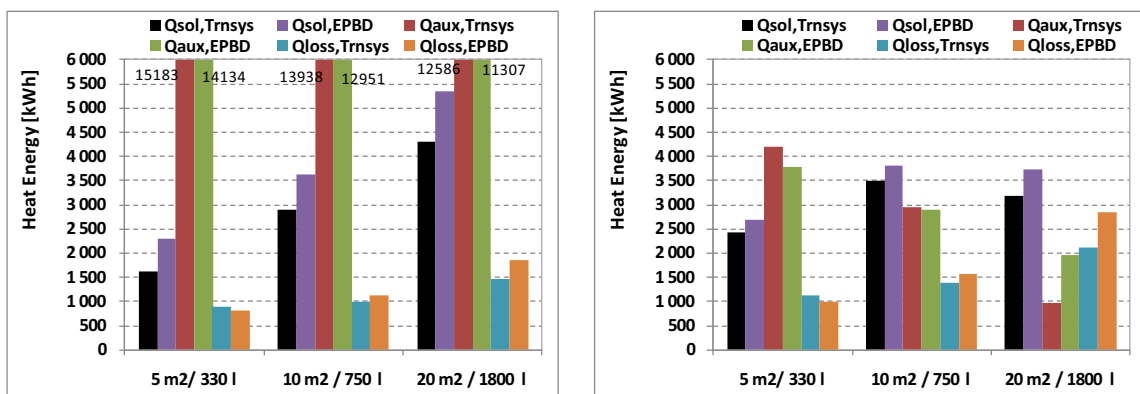


Fig. 4. Key figures for solar combisystems of different sizes for in Stockholm (left) and Madrid (right).

4.3. Variation of Collector Type, Azimuth and Orientation

Fig. 5 shows the solar contribution's variation with tilt and azimuth. The trends shown for the tools are very similar apart from higher collector tilts, where TRNSYS predicts a greater decrease in solar contribution. In addition to the results shown here, five different collectors were simulated for the base case. These were two flat plate collectors and three evacuated tube collectors with different incident angle and other properties. The differences between the EPBD tool and TRNSYS results were similar for all collectors.

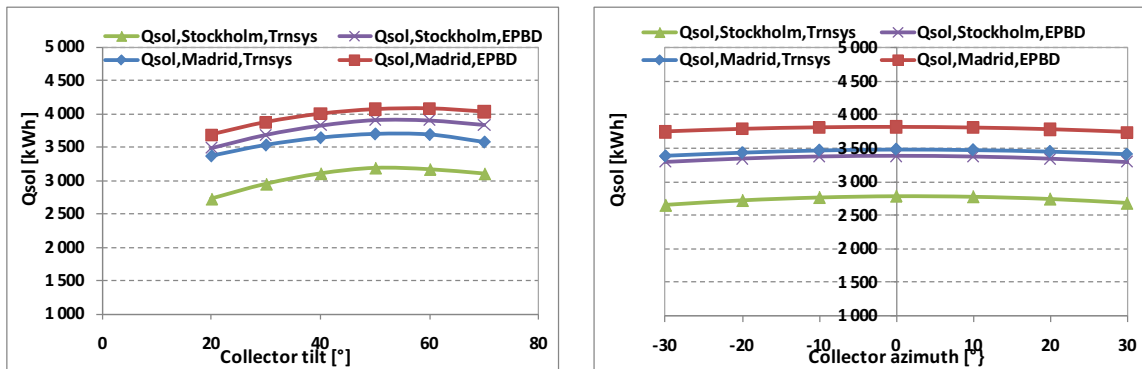


Fig. 5. Solar contribution for collector tilt (left) and azimuth (right).

4.4. Variation of Store Parameters

Fig. 6 shows the variation of solar contribution with the store volume. The EPBD tool gives slightly different trends for low store volumes, overestimating the solar contribution compared to TRNSYS. The storage volume correction factor in the F-chart method is derived for specific volumes between 37.5 and 300 l/m² collector area, whereas the specific area for the smallest store here is only 33 l/m².

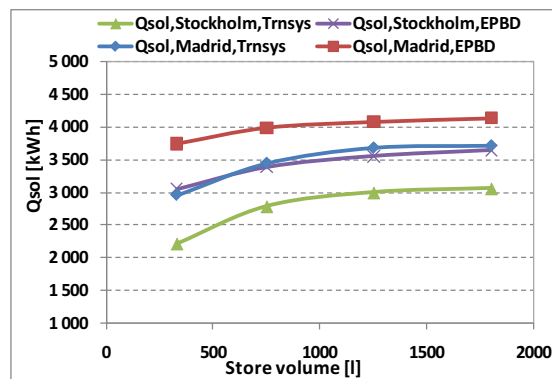


Fig. 6. Solar contribution for store size with constant collector area of 10 m².

5. Discussion and Conclusions

The F-chart method that is the basis of the EPBD tool is derived from correlations from detailed simulation results. The range of simulations was limited, and thus the method is also limited. For example the method should be limited to climates with latitudes below 60°. Stockholm, with 59.3° is very close to this limit. Similarly the specific store volume is limited to the range 37.5 to 300 l/m² collector area. The results presented here show that the EPBD tool always predicted a greater solar contribution than TRNSYS predicted. The difference was greater for Stockholm (high latitude) and Madrid (high solar fraction). Other studies showed that the EPBD predicted changes in solar contribution due to changes in system size, orientation and azimuth as well as store size in the same way that TRNSYS does.

Acknowledgements

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