ENERGY SAVINGS FOR A SOLAR HEATING SYSTEM IN PRACTICE

Simon Furbo & Jørgen M. Schultz
Department of Civil Engineering
Technical University of Denmark
Brovej, Building 118
DK-2800 Kgs Lyngby, Denmark
sf@byg.dtu.dk & js@byg.dtu.dk

Alexander Thür
AEE INTEC
Feldgasse 19
A-8200 Gleisdorf, Austria
a.thuer@aee.at

ABSTRACT

In July 2006 a new developed high efficient solar heating/natural gas heating system was installed in an old one family house in Denmark. The new system was based on 6.75 m² solar collectors and a condensing natural gas boiler. Before the installation of the solar heating system, the house was heated by a non condensing natural gas boiler.

The heat demand, the electricity consumption for the energy and heating system as well as the natural gas consumption were measured before and after installation of the solar heating system. Based on the measurements the energy savings of the solar heating system were estimated to 4200 kWh per year, corresponding to 620 kWh/m² collector per year. The energy savings will vary from year to year. In years with a high heat demand the energy savings will be high. In years with a low heat demand the energy savings will be low.

Keywords: solar combi systems, energy savings, measurements

1. INTRODUCTION

Only few investigations on energy savings for solar heating systems in practice have been carried out. This is really remarkable since most solar heating systems are installed with the aim to save energy. The reason for the few investigations is that it is extremely difficult to measure/document the energy savings for solar heating systems in practice.

In order to determine the energy savings, seven energy quantities/efficiencies must be considered.

Before installation of the solar heating system:

- Utilization of energy for the energy system.
- Electricity consumption for the energy system.

After installation of the solar heating system:

- Net utilized solar energy of the solar heating system.
- Saved energy by turning off the auxiliary energy supply system during the summer.
- Utilization of energy for the auxiliary energy supply system.
- Electricity consumption for the auxiliary energy supply system.
- Electricity consumption for the solar heating system.

Further, to make the determination even more difficult, the energy savings are influenced by the heat demand and hot water consumption, which will vary from year to year due to weather variations, variations of user habits and due to changes of the hydraulics of the energy system.

A Swedish investigation of solar heating systems, based on questionnaires filled in by home owners, showed unexpectedly high energy savings for solar heating systems in practice [1]. Also unexpectedly large variations of the energy savings were reported. Solar heating systems with collector areas between 4 m² and 25 m² were included in the investigations. The reported energy savings ranged from 0 kWh per m² to 2750 kWh per m². The average collector area of the investigated systems was 11 m², and typical energy savings ranged from 650 kWh per m² collector to 900 kWh per m².

A theoretical investigation showed that the energy savings of solar heating systems are strongly influenced by the efficiency of the energy system prior to installation of the solar heating systems [2]. Especially the efficiency during the summer period is of great importance.

An investigation of new natural gas boilers and oil fired burners installed in one family houses without solar heating

systems showed unexpectedly low utilizations of natural gas and oil in the summer and in periods with low heat demands [3]. This is of great interest in countries, such as Denmark, where oil and natural gas are often used as primary energy sources in houses, where solar heating systems are installed. A condensing and a non condensing natural gas boiler as well as a non condensing oil fired burner were included in the investigations. In spite of high yearly utilizations of natural gas and oil between 80% and 95%, the utilization of natural gas/oil decreased to values between 50% and 80% for the boilers/burner in the summer months. In the 5 summer months May-September the energy loss defined as the oil/natural gas consumption minus the space heating demand minus the hot water consumption was about 1000 kWh for the oil fired burner and the non condensing natural gas boiler and about 500 kWh for the condensing natural gas boiler. These energy quantities can easily be saved by well performing solar heating systems.

2. DEMONSTRATION SYSTEM IN A ONE FAMILY HOUSE

A new developed solar heating/natural gas heating system was installed in a one family house with three inhabitants in Helsinge, Denmark, latitude 56°N, in July 2006. The house, which is shown in figure 1 before the installation of the solar heating system, has three floors: A basement including a bedroom and bathroom, a first floor including a kitchen and a second floor including two bedrooms and a bathroom.

Fig. 1. Demonstration house from the south before installation of the solar heating system.

Before the installation of the solar heating system the house was supplied with heat from a Vaillant non condensing natural gas boiler from 1990 with a nominal power of 22 kW. For domestic hot water preparation the natural gas boiler heated a 50 l hot water tank, see figure 2.

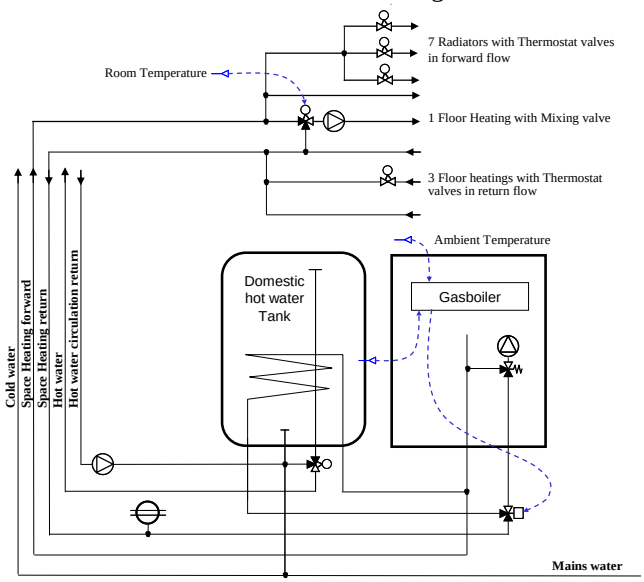

Figure 2. Schematic sketch of the energy system before installation of the solar heating system.

The solar heating system installed in the house has 5 Velux solar collectors, type S08 with a total collector area of 6.75 m². The collect orientation is 15° towards east from south and the collector tilt is 45°. The collectors have a start efficiency of 0.79, a first order heat loss coefficient of 3.76 W/m²K, a second order heat loss coefficient of 0.0073 W/m²K² and an incidence angle modifier of $1-\tan^{3.9}(\theta/2)$, where θ is the incidence angle.

The solar heating system is based on a technical unit and a heat storage unit produced by METRO THERM A/S. The technical unit includes a modulating condensing natural gas boiler from Milton A/S, type Milton Smart Line HR24, with a nominal power for space heating of 5.7-23 kW and a nominal power for hot water preparation of 5.7-28.5 kW, a heat exchanger producing domestic hot water, and all equipment needed to operate the solar collectors, the natural gas boiler and the heating system. The heat storage unit includes a 360 l solar tank which can be charged by means of the solar collectors and the natural gas boiler [4]. The tank insulation is partly PUR foam, partly vacuum panels.

Both the technical unit and the heat storage unit are built into 60 x 60 cm units by METRO THERM A/S. Due to this prefabrication, the installation of the system is easy and the risk of installation mistakes is reduced. The design of the units provides good operation conditions for the condensing natural gas boiler and for the solar collectors and high energy savings for the system.

Figure 3 shows a schematical sketch of the two units as well as the solar collector loop and space heating system.

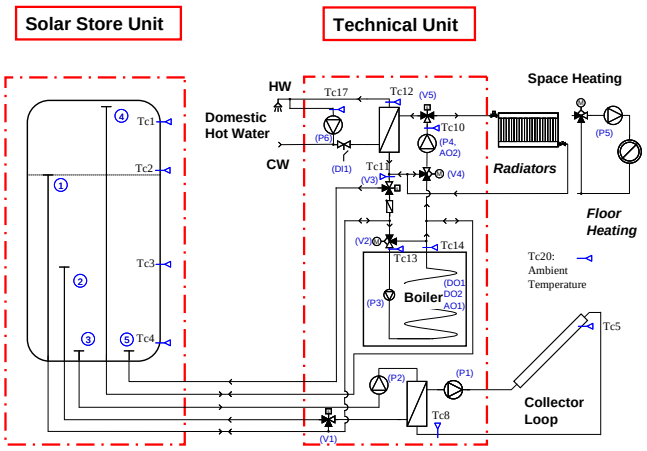

Fig. 3. Schematic sketch of the solar/natural gas heating system.

Figures 4 shows the house after installation of the solar heating system.

Fig. 4. Demonstration house with collectors on the roof and the solar tank and technical unit in the basement.

3. ENERGY MEASUREMENTS

3.1 Monitoring systems

The space heating demand, the hot water consumption, the heat loss of the circulation pipe, the natural gas consumption and the electricity consumption of the natural gas boiler and the heating system were measured in periods before and after installation of the solar heating system. Further, the heat transferred from the natural gas boiler to the hot water tank was measured before installation of the solar heating system. Furthermore, the heat produced by the solar collectors, the heat produced by the boiler as well as the electricity consumption of the solar heating system were measured in the period after installation of the solar heating system.

Based on the measurements it is possible to estimate the energy savings of the solar heating system.

3.2 Measured energy quantities

The measurements started in August 2004 and will be continued until December 2007. Not all the energy quantities mentioned in section 3.1 were measured during the whole measuring period. A constant energy quantity of 10.67 kWh per m^3 natural gas is assumed.

The total heat demand of the house, that is: Space heating demand + domestic hot water consumption + heat loss from circulation pipe, and the natural gas consumption month by month appear from figure 5. It is clear that both the heat demand and the natural gas consumption is much lower after the installation of the solar heating system than before. The reasons for the reduced natural gas consumption are the decreased heat demand due to warm weather in the autumn of 2006 and in the start of 2007 and the new energy system with solar collectors and an improved natural gas boiler. Further, it is noticed that the difference between the natural gas consumption and the total heat demand in the winter months is lower after installation of the solar heating system than before. In the spring, summer and autumn the natural gas consumption is lower than the total heating demand after installation of the solar heating system. Before installation of the solar heating system the natural gas consumption is for all months higher than the total heat demand.

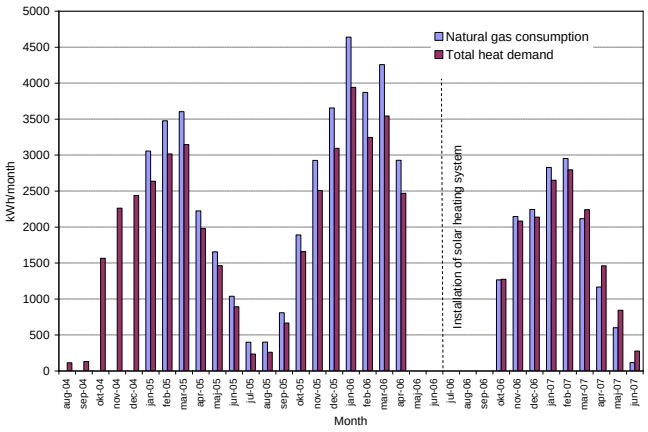

Fig. 5. Total heat demand and natural gas consumption for the house during the measuring period.

Figure 6 shows the measured utilization of the natural gas as a function of the total heat demand month by month. The utilization of the natural gas is defined as: (space heating demand + hot water consumption + heat loss from circulation pipe)/natural gas consumption. The utilization of natural gas is strongly increased by the solar heating system, especially for low heat demands. Further, the utilization of natural gas after installation of the solar heating system is much higher in the sunny spring than in the less sunny autumn.

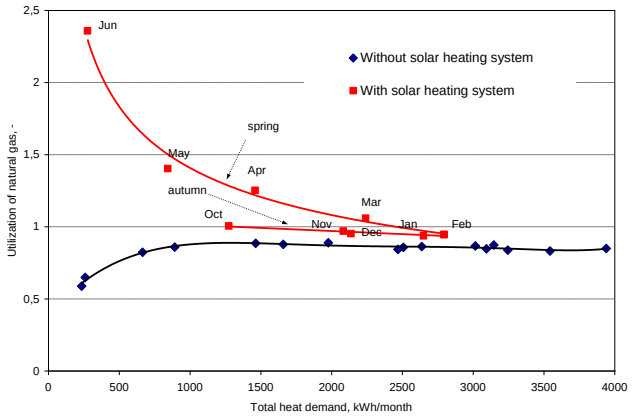

Fig. 6. Utilization of the natural gas as a function of the total heat demand.

Based on the total monthly measured heat demand and the curves of figure 6 it is possible to estimate the natural gas consumption for the house for all months without and with the solar heating system, if only the heat demands are measured. Consequently, the energy savings for the house achieved by the solar heating system can be determined for all months, where the total heat demand is measured. However, so far the utilization curve for the solar heating system is not covering July, August and September due to a lack of measurements in these months. Therefore energy savings for the summer months are not estimated with a good accuracy.

The yearly natural gas savings for the solar heating system is for the period May'05-April'06 estimated to 4100 kWh. This corresponds to a reduction of the natural gas consumption of 14.4%. Additional electricity savings of 60 kWh are estimated. The total estimated yearly energy savings are 4200 kWh, corresponding to about 620 kWh per m² collector. For other periods with durations of one year the energy savings will be different. For increasing heat demand the energy savings will increase.

The measurements will be continued. Therefore the accuracy of the estimates of the energy savings will be improved, and the variations of energy savings from one year to another caused by weather variations and variations of user habits can be determined.

4. CONCLUSION

Measurements of the heat demand and energy consumption in a demonstration house before and after installation of a new developed solar heating/natural gas heating system based on a condensing natural gas boiler and 6.75 m² solar collectors have been carried out.

Based on the measurements the energy savings by the solar heating system were estimated to 4200 kWh per year, corresponding to 620 kWh/m² collector per year. The energy savings will vary from year to year. In years with a high heat demand the energy savings will be high. In years with a low heat demand the energy savings will be lower.

5. REFERENCES

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