ENERGY SAVINGS FROM SOLAR HEATED WATER IN BULGARIA

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Abstract
At the present work are presented the monthly results of the work of three thermal solar installations during March 2004- March 2006.
Rows of the following observations are received:

-The amount of the converted solar radiation in the primary circuit by the collector's field in kWh.
-The quantity of the consumed heat energy in the secondary circuit in kWh.

The total solar radiation incident on horizontal surface in the country is calculated based on Anström's formula and the definite monthly coefficients for the Bulgarian climate conditions. The solar collectors are mounted under 40° inclination to SSW direction. Liu-Jordan methodology is used for the calculation of the total solar radiation on tilted surfaces on the square meter of the Netto absorber area of the collectors. So the rows of total solar radiation received on the collector's surface, converted part of this radiation and the consumed part of the received solar energy are presented. The course of the sunshine duration and cloudiness is also shown.

Key words: *thermal solar installation, solar radiation, received and consumed solar energy, hot water production, sunshine duration*

1. Introduction

The European Commission's White Paper for a Community Strategy sets out a strategy to double the share of renewable energies in gross domestic energy consumption in the European Union by 2010 from the present 6% to 12%. One of the mainly renewable energy source is the solar radiation. Utilization of environmental friendly solar systems for hot water and energy production has significantly mitigated the climate change and will be one of the most valuable tools for improving the quality of air, preservation and restoration of the natural resources.

2. The solar thermal installations in Europe

A new record for panel installation was established in 2004 (1 693 004 m^2 vs. 1 537 070 m^2 in 2003). This level is possible in particular through participation of the 10 new EU countries. While they may appear to be very high, these figures nevertheless represent a modest share of the world market (approximately 10%), China alone represents a market of more than 10 000 000 m^2 per year (more than 7 000 MWth) according to the ESTIF (European Solar Thermal Industry Federation).
The objective was finally reached a year later than planned, with a 25 member EU installed capacity of 15 361 824 m2. The ten new member countries contributed to this result by bringing an additional 820 267 m2. The European Union cumulated figure includes both glazed technologies (flat glazed collectors and vacuum collectors) as well as unglazed collectors. This total expresses the number of collectors actually in operation, that is to say after delisting of the oldest installations.
At the individual country level, Germany continues to have the biggest capacity of the European Union with a cumulated installed surface of 6 199 000 m2 (table 1). Greece remained second in the EU in 2004 with 2 826 700 m2 in front of Austria with a total solar thermal surface of 2 399 791 m2. These three leaders represent three quarters (74.4%) of European solar thermal surface.

Table 1. Cumulated capacity of thermal solar collectors installed in the European Union in 2004 *by* EurObserv'ER 2005

	In 2004 in m^2	in MWth
Germany	6 199 000	4 339.3
Greece	2 826 700	1 978.7
Austria	2 399 791	1 679.9
France	792 500	554.8
Netherlands	503 829	352.7
Italy	457 711	320.4
Cyprus	450 200	315.1
Spain	440 151	308.1
Denmark	328 380	229.9
Sweden	224 774	157.3
United Kingdom	176 160	123.3
Portugal	109 200	76.4
Slovenia	101 500	71.1
Poland	94 587	66.2
Slovak Rep.	56 750	39.7
Belgium	52 015	36.4
Czech Rep.	50 000	35.0
Hungary	48 000	33.6
Malta	15 360	10.8
Finland	12 250	8.6
Luxemburg	11 500	8.1
Ireland	7 596	5.3
Latvia	1 650	1.2
Lithuania	1 650	1.2
Estonia	570	0.4
E.U. 25	15 361 824	10 753.5

2.1. The influence of the regional climate on the usage of the solar collectors

The solar radiation reaching earth surface is a main source of renewable energy (solar energy, wind energy, biomass) (e.g. *Leggett, 2005*). The influence of regional climate on the usage of the solar collectors is considerable. Bulgaria receives vast amount of solar energy because of its southern lay and comparatively small amount of cloudiness (*Lingova, 1995*). Sunshine duration in the country is significant even in the spring and autumn.
Bulgaria lays on Balkan peninsula - one of the three south peninsulas. The average annual amount of its south areas reaches more that 1450kWh/m^2 over horizontal surface.

4. An experiment

At the present work are presented the monthly results of the work of three thermal solar installations during years March 2004 -March 2006. Two of the installations -selective type- are at the National Institute of Meteorology and Hydrology in Sofia and the third –non-selective is mounted in Ahtopol at the Black see region.

4.1. Used Data

Monthly measurements of converted and consumed radiation by solar installations are done. For the estimation of the solar radiation reaching the earth surface data of the sunshine duration are used. Data for sunshine duration and cloudiness in Sofia and Rezovo are taken from the NIMH's network.

4.2. Used methodology for estimation of the solar radiation

Information for the solar radiation received on horizontal and differently oriented tilted surfaces in different places is important for practical aims. There are several methods for its estimation, but theoretical and experimental ones are the basis. Few numbers of meteorological stations measuring the total solar radiation are available on the earth surface. That is why it is necessary oblique methods for its estimation to be used.

The total solar radiation incident on horizontal surface in the country is calculated based on the formula of Anström *(1924)* which lately was further developed by *Prescott (1940).*

$$\frac{Q}{Q_0} = a + b.\frac{s_d}{s_{0d}}$$

where:

Q -daily sum of the total solar radiation received on the horizontal surface.

Q_0 - daily sum of the solar radiation on the upper atmosphere

$\frac{Q}{Q_0}$ - clearness index

s_d - daily sunshine duration,

s_{0d} - maximum possible daily hours of sunshine (day length).

The value of these constants depends on latitude, elevation above sea level, relative air humidity, maximum air temperature, relative sunshine duration, and so on. There are definite the monthly coefficients for the Bulgarian climate conditions using a method of Akpabio and Etuk (2003) based on the least squares method.

Liu-Jordan methodology is used for the calculation of the total solar radiation on tilted surfaces of the solar collectors which are south- westsouth oriented. This methodology, used by Slavov *et. al* (1988), is based on the astronomical parameters and trigonometrically relations and allows the radiation in a given location to be calculated as a function only of sunshine duration and the latitude of the place.

$$\overline{Q_s} = \overline{R} \cdot \overline{Q} = \overline{R} \cdot \overline{K_T} \cdot \overline{Q_0} ,$$

where:

Q_s – the daily total solar radiation on tilt surface over the earth surface

$\overline{Q}$ - the daily total solar radiation on horizontal surface over the earth surface

Q_0 - the daily total solar radiation on horizontal surface on the upper atmosphere.

K_T is definite as a ratio $\overline{K_T} = \frac{\overline{Q}}{\overline{Q_o}}$

$\overline{R}$ is a ratio of the daily total solar radiation on tilt surface over the earth surface and the radiation on the horizontal surface. $\overline{R}$ is:

$$\overline{R} = \frac{\overline{Q_s}}{\overline{Q}} = \left(1 - \frac{\overline{Q_d}}{\overline{Q}}\right)\overline{R_B} + \left(\frac{1+\cos S}{2}\right)\frac{\overline{Q_d}}{\overline{Q}} + a\left(\frac{1-\cos S}{2}\right)$$

where:

$\overline{Q_d}$ e the daily total diffuse solar radiation on horizontal surface over the earth surface.

So the rows of total solar radiation received on the collector's surface, converted part of this radiation and the consumed part of the received solar energy are presented. The course of the sunshine duration and cloudiness is also shown.

4.3. A graphical description of the experiment

On the Figures 1-3 below is presented the work of the three solar installations.
The measured parameters are:

-Converted solar energy- the quantity of converted solar energy (in kWh) in primary circuit by the collector's field (dark grey columns).

-Consumed HW energy – consumed heat energy in the secondary circuit in kWh (light gray) columns).

-The temperature of the hot water produced from the installations

-Sunshine duration

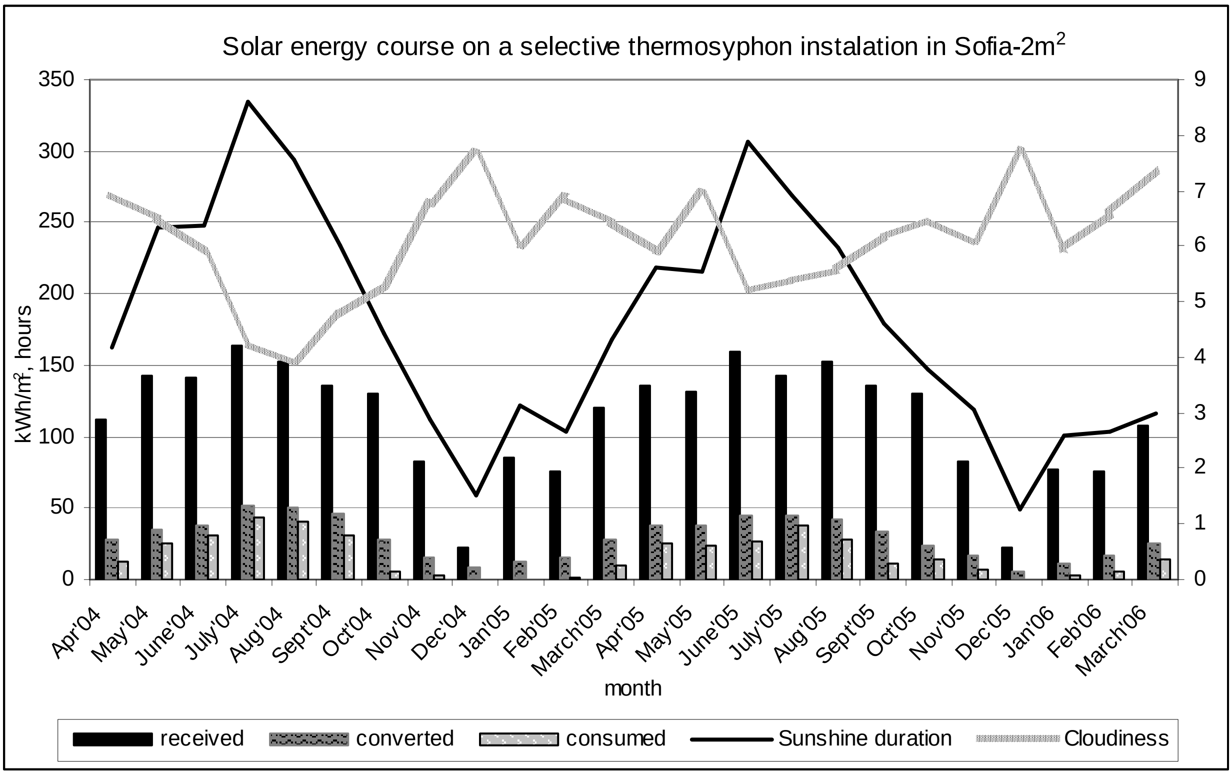

Figure 1. The solar energy course on a selective thermosyphon installation in Sofia.

On Figure 1 is shown the work of a thermosiphon installation in Sofia with absorber area of the collector 2 m^2. The collector's surface is tilted on 40° and oriented on SSW. The incident radiation on it is calculated by the methods of Anström and Liu-Jordan described above and also in (*Todorova and Ivanov, in the press*). The joint courses of the radiation-received on squared meter of the collector's area, converted and consumed; the monthly sum of the sunshine duration and the mean monthly cloudiness are presented. As it could be seen from the figure the installation doesn't work well in the winter. Nevertheless, the total consumed energy for hot water heating with the thermosyphon installation for the whole period of the experiment-two years (Apri 2004-March 2006) per square meter is 402 kWh. The total received energy in Sofia for the period per square meter is 2721,5 kWh. And the total consumed energy of the thermosyphon installation for the same period for the whole installation is 804 kWh.

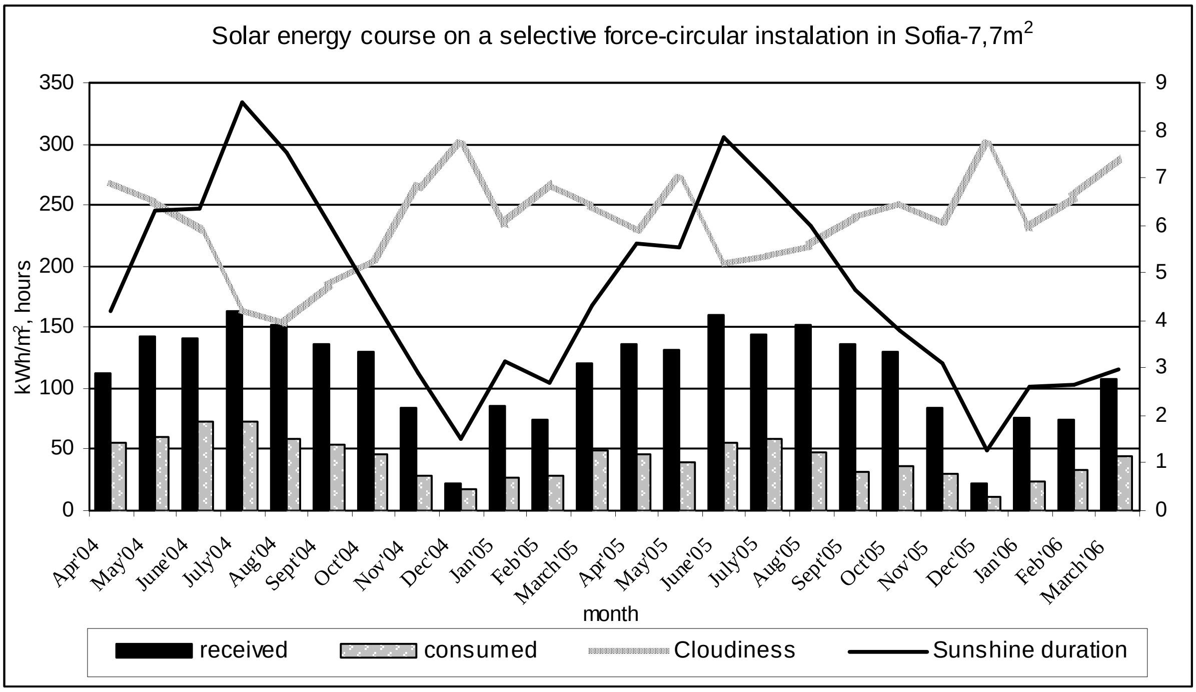

Figure 2. The solar energy course on a selective force-circulation installation in Sofia.

The work of a force-circular installation in Sofia with absorber area of the collector 7,7 m^2 is shown on the Figure 2. The collector's surface is also tilted on 40° and oriented on SSW. The joint courses of the radiation-received and consumed on squared meter of the collector's area; the monthly sum of the sunshine duration and the mean monthly cloudiness are presented. During the whole year the amount of consumed hot water from this installation is much bigger, then this of the thermosiphon installation. This installation works very well even in the cold, but sunny winter months. The total received energy in Sofia for the period April 2004-March 2006 per square meter is 2721,5 kWh. For the two years the consumed energy per square meter of the selective forced-circulation system is 1026,9kWh. The consumed energy of the installation for the two years is 7906,8kWh.

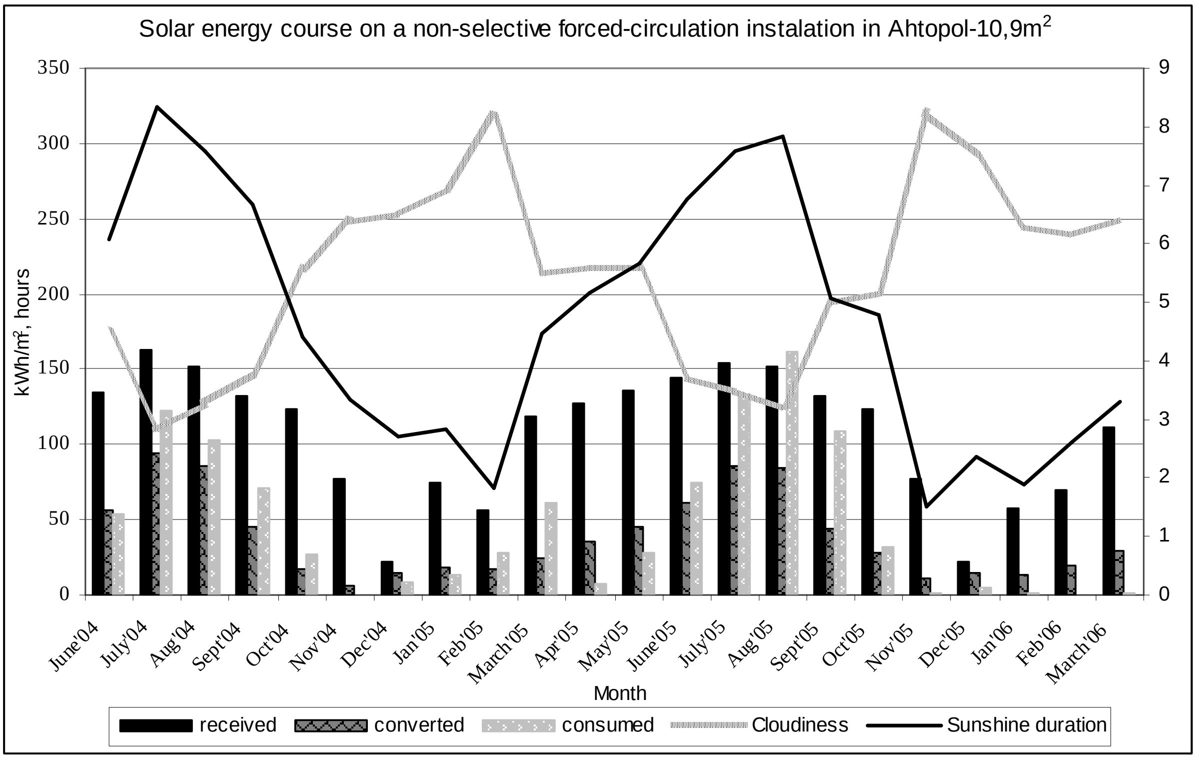

Figure 3. The solar energy course on a non-selective force-circulation installation in Ahtopol.

The work of the non-selective forced-circulation system in Ahtopol (on the Black sea) is presented on the Figures 3. The collector's surface here is tilted on 35° and oriented on SSW. The joint courses of the radiation-received, converted and consumed on squared meter of the collector's area; the monthly sum of the sunshine duration and the mean monthly cloudiness are also presented. The measured data for this installation are for two months less. They start in June 2004. For this period received total solar energy per square meter in Ahtopol is 2358,9 kWh. The consumed energy per square meter is 1042,2kWh and for the heating of hot water for the whole installation is 11 359,4kWh.

The total saved energy of the three solar installations for almost two years is 20,1MWh. This saves not only resources, but also from throwing the emissions CO_2 in the atmosphere. This is one of the ways to preserve the nature.

5. Conclusion

The hot water solar installations works effectively from the middle of March to the end of October. During this period they save the energy for heating of the water and produce hot water with comfortable temperature. However, the EU has very ambitious targets for collector installations, with a target of 100 million square meters by 2010. Solar thermal systems will then play an important role in the struggle against global warming.

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