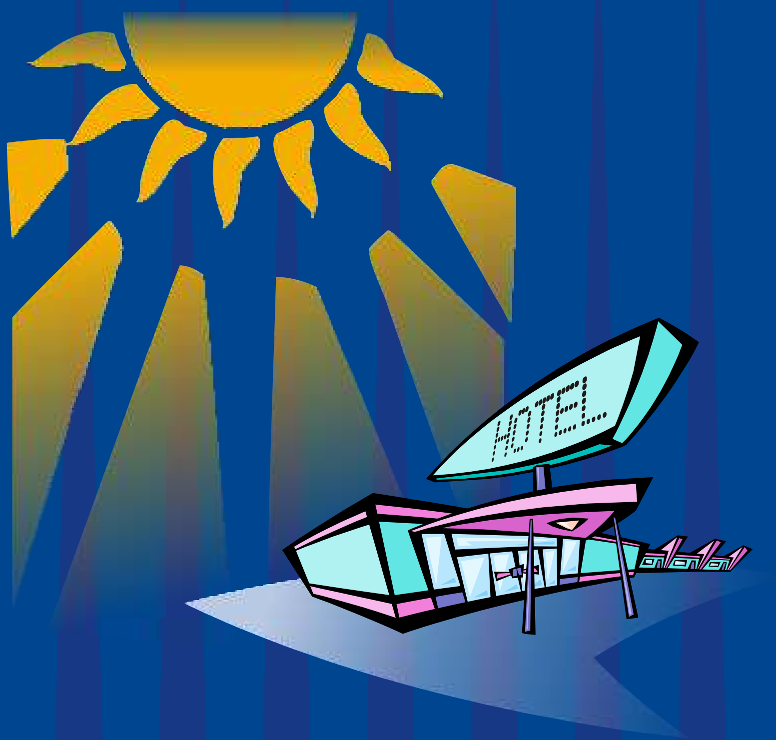

HOT WATER FROM THE SUN FOR HOTELS

Basic facts for the management

European Commission
Directorate General for Energy and Transport

ENERGIE PROGRAMME

Hot Water From the Sun for Hotels

Basic facts for the management

Editor: EXERGIA S.A.
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Foreword

This document is intended to be used as a guide for the preparation of promotion material for

Solar Systems for the Production of Hot Water for Hotels, by **Manufacturers, Retailers, Promoters**, etc. It may be used also by **Regional and Local Authorities** for the same purpose.

The final promotion material is addressed to the **End Users i.e. hotel owners or management.**

It contains short description of the solar systems for the production of hot water for hotels, as well as their components, i.e. the solar collectors, the hot water storage tanks, the control systems, etc.

The specific manufacturer, or retailer, or promoter should select the part of the text that fits his products and expand them as he considers appropriately. He may introduce

- the map with the solar radiation for the country or the region of his interest (Figures 2.1, 2.2, 2.3)
- the cross section(s) of his collector(s), (Figure 4.1)
- the performance i.e. the energy production of a typical system (Figures 6.1, 6.2, 6.3)
- the meteorological data of his region (Figures 10.1 and 10.2)

or other material related to his specific products.

1. Introduction

Sunlight, or solar energy, has served humanity since the origin of mankind, but only in the last decades, the sun is being adopted to supply thermal and electrical energy. Solar energy, which is free, and abundantly available throughout most of the world, is being converted into:

- thermal energy, with the use of numerous variations of solar collectors (liquid or air heating);
- electrical energy, with the use of solar cells, which convert sunlight directly into electricity, through a phenomenon of solid-state physics termed photovoltaics.

Solar thermal systems, are used extensively for the heating water for domestic and other applications in southern European countries, as well as in northern European countries (Germany, Austria, Denmark, etc).

After some decades of technical development, the solar thermal market has reached maturity. High quality products are available in the market. The solar systems are reliable and their efficient operation can be guaranteed.

Solar systems for heating water for hotels have some important advantages:

- They save money to the user, as there is no cost involved in their operation.
- They offer pollution-free energy from the sun and contribute to the reduction of carbon dioxide (CO2) emissions. Carbon dioxide has a greenhouse effect and the potential of global warming.

This document provides to the consumer (hotel owner or management) information about the use of solar energy to heat water for hotels.

- It can help the consumer to decide what kind of system to buy, from whom to buy, where to install it and other similar matters.
- Furthermore, it can guide him on how to obtain information about performance characteristics of the solar systems in order to evaluate their cost effectiveness.

2. Solar Potential

The performance of a large solar system for heating water for hotels depends a lot on the available solar energy in the location where it is installed. The more solar energy is available, the more thermal energy is obtained in the form of hot water.

Figures 2.1, 2.2 and 2.3 present the solar radiation in Greece, in Cyprus and in the Iberian peninsula (from Reference [1]). All figures show the average daily solar energy on a horizontal plane. This is the average value for a whole year. The energy is given in kWh per square meter per day.

The solar collectors of a large solar water heating system are installed on a tilted plane (30° - 45° with respect to the horizontal plane). They are always facing south. Solar energy on tilted surfaces is available.

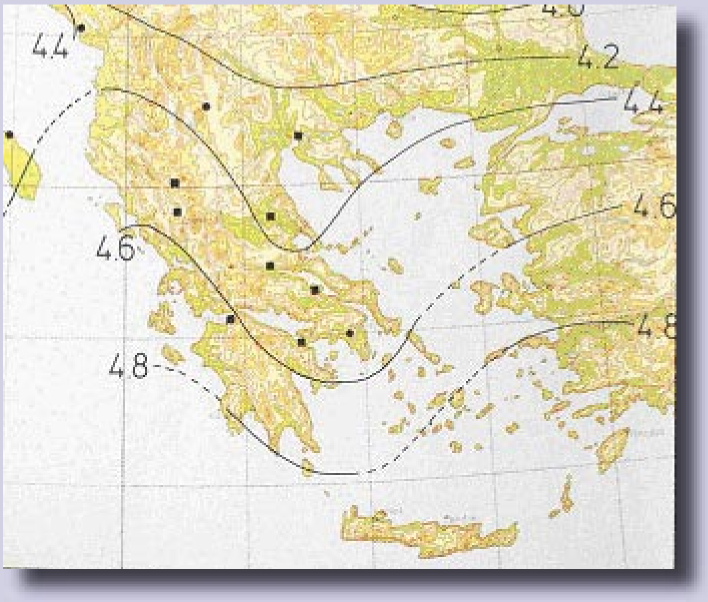


Figure 2.1 Solar energy in Greece (daily average values in kWh per square meter)

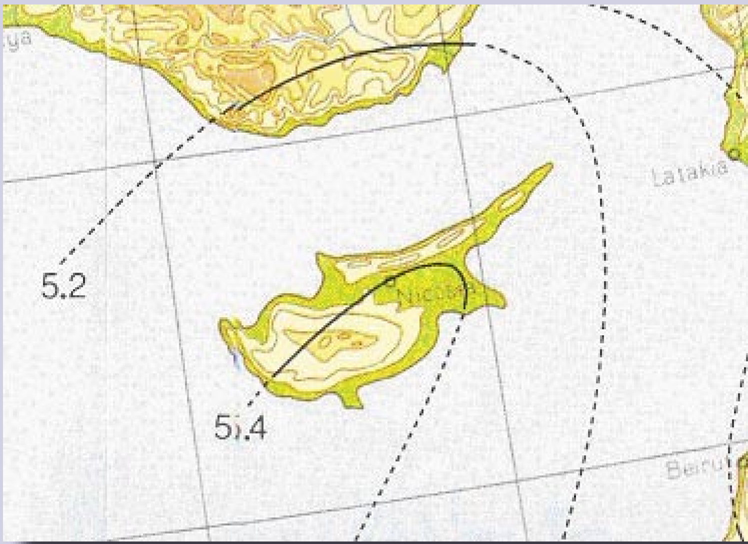


Figure 2.2 Solar energy in Cyprus (daily average values in kWh per square meter)

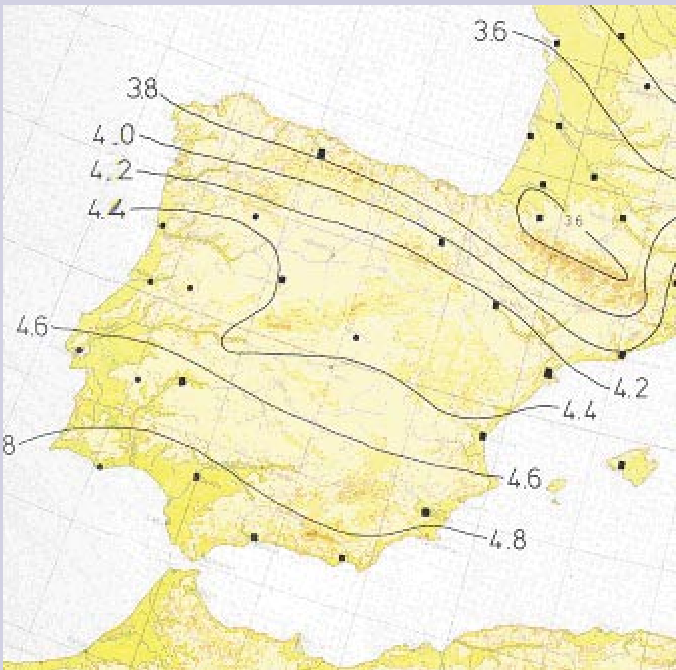


Figure 2.3 Solar energy in the Iberian peninsula (Spain and Portugal), (daily average values in kWh per square meter)

3. Basic Components of Large Solar Systems For Production Of Hot Water

The basic components of a solar system, for the production of hot water in a hotel, are shown schematically in Figure 3.1 and they are:

- the solar collectors and their supporting structure
- the hot water storage tank, usually with internal heat exchanger,
- the solar pump and control equipment
- the piping connecting the various components and
- finally the back up heating system for providing energy during days when the sun can not fully cover the needs for hot water.

The **solar collectors** can be installed on the roof (usually in the case when it is flat), or directly on the ground. They are grouped in rows with enough distance between them in order to avoid shading. They are mounted on a supporting structure.

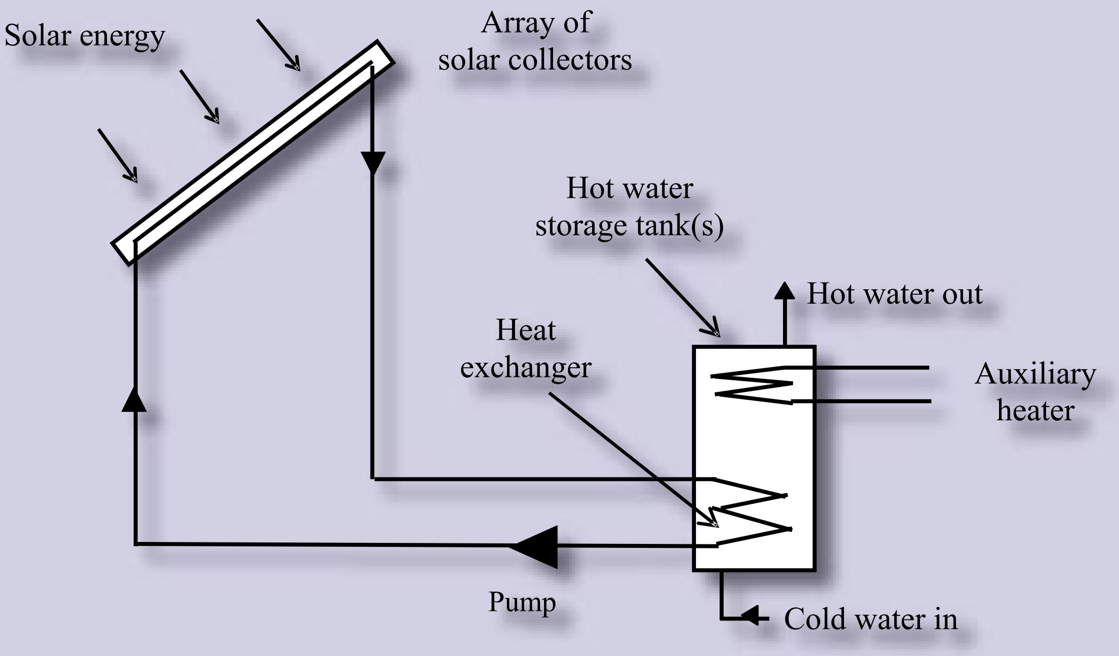


Figure 3.1 Typical solar system for the production of hot water in a hotel (schematically)

A solar system may have more than one hot water **storage tanks**. Some of them are connected to the solar collector loop as shown in Figure 3.2, achieving this way stratification of the temperature of the water in the tanks (Tank 1 has higher temperature than Tank 3). The auxiliary heating is achieved through a separate tank which can be the existing hot system of the hotel.

Figure 3.2 presents also the components of the **control system** which are:

- two temperature sensors, one in the collectors and one in Tank 3 (the colder of the three tanks) and
- a differential temperature controller

When the temperature of the heat transfer fluid in the collector is higher than the water temperature in the tank (the colder part in the tanks), then the pump operates.

The location of the two sensors and the differential controller itself are very important for the efficient operation of the solar system.

Figure 3.2 shows also schematically the hot water distribution system to the consumption points (rooms, etc) and the **re-circulation pump**. The re-circulation pump provides hot water to the points of consumption in the hotel and then takes it back to the tank with the auxiliary heating. Thus, the consumer has immediately available hot water and is not required to wait.

The constant circulation of hot water in the distribution network produces heat losses. From calculations that have been made in small and big hotels, it has been concluded that approximately 20% - 30% of the total energy, which is consumed for water heating, is lost in the distribution network. In addition, in many cases when the hotel was only partly occupied, the losses in the distribution network reached up to 50% of the total energy.

For the reduction of the heat losses in the hot water distribution system with a re-circulation pump there must be

- good insulation of the hot water distribution piping
- limitation in the time of use of the re-circulation pump (use of a time switch or other method) as much as conditions allow.

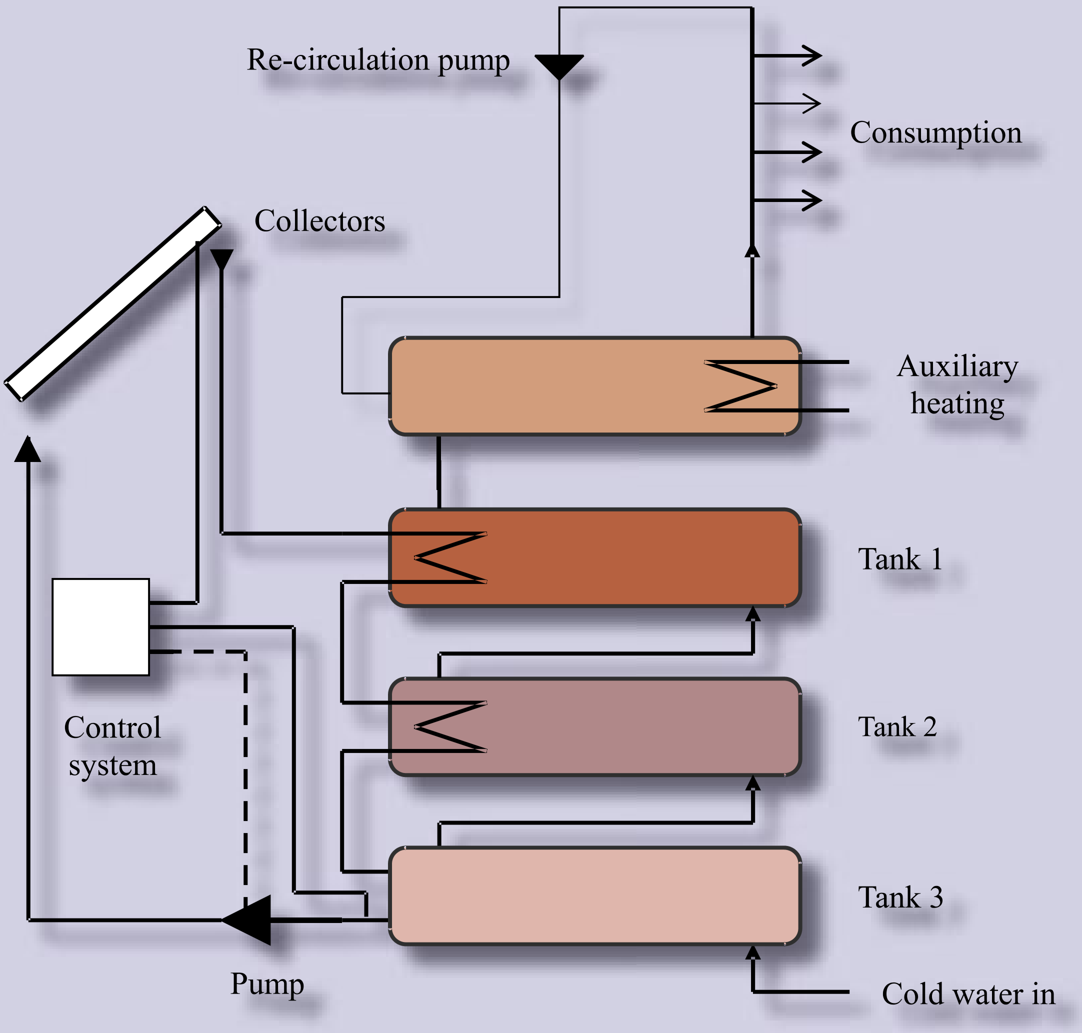


Figure 3.2 Connection of the solar hot water tanks for better temperature stratification of the produced hot water, auxiliary heating and hot water re-circulation

4. The Solar Collector

The main components of the solar collector are the frame, the insulation, the transparent cover (glazing) and the absorber. The absorber is the part inside the collector, which consists of a black metallic surface (usually copper or aluminium fins) and metallic tubes (usually from copper). Absorber surface and tubes are well bonded. Schematically these components are shown in Figure 4.1

When a solar collector is exposed to the sun, the solar irradiation, which falls on the collector penetrates the glass and is absorbed by the black surface, which is heated. Next, the heat transfer fluid (water, or water and antifreeze etc), that is in the absorber tubes, is also heated and it transfers the energy to the water in the storage tank(s).

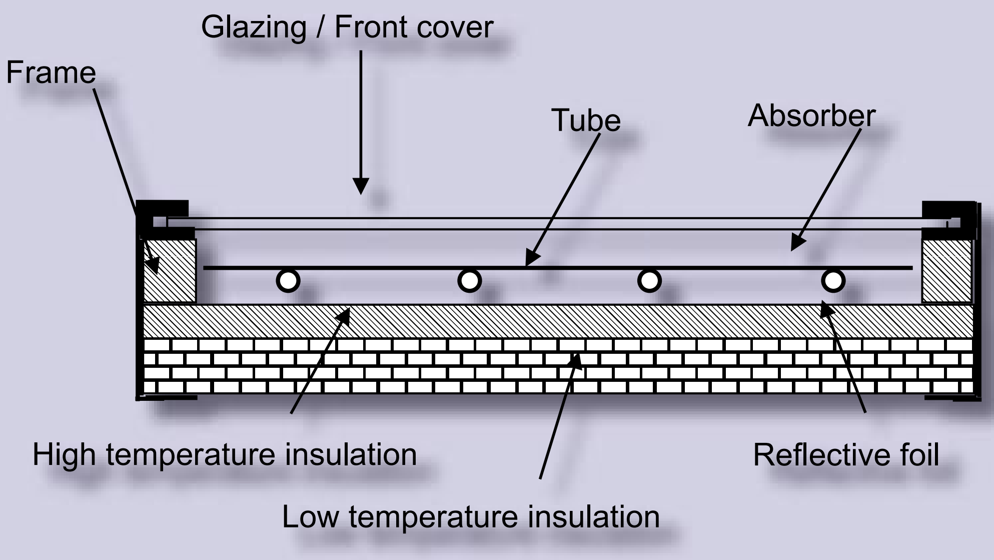


Figure 4.1 Typical cross section of a glazed liquid heating solar collector.

Under certain conditions, like in summer and when the pump of the solar system is not operating, the absorber surface can develop high temperatures (stagnation temperature), which can reach 150°C or even 200°C in some collectors. This is the reason that close to the absorber the insulation should sustain high temperatures.

Matt black paint is used for the absorber surface in the common collectors, which can operate efficiently to temperatures up to 50°C.

Selective coatings, used on the absorber surface, result to efficient operation of the collector

- at higher temperatures of 50°C - 70°C and
- in places with rather low solar radiation (Northern Europe)

Common glass is used for the front cover of the collectors. It is noted that the green appearance of the common glass (as seen from the side) is due to the existence of iron oxides. They reduce its transmittance to the solar radiation.

Tempered glass, with low content in iron oxides, has higher transmittance to solar radiation compared to common glass, therefore it gives higher performance to the solar collectors.

Tempered glass has also much greater durability than common glass and therefore the possibility of breakage is almost eliminated. In addition, in the rare case of breakage, it shatters into small harmless bits of glass (as happens with car windows), so it offers safety against accidents.

The frame provides the structural stiffness in a collector. It holds together the transparent cover, the absorber and the insulation.

The integrity and long term durability of a collector depends strongly on the design and the quality of the sealing assembly around the cover and around the fluid inlet and outlet pipes.

Water-tightness between the frame and the transparent cover is very important for the collector reliability.

Because of the risks of water penetration in solar collectors with aging (and not only), it may be considered preferable that the casing is designed with **drain holes** and possibly with adequate **ventilation**. At the same time provision should be taken to prevent insects from entering the collector.

A solar collector is required to absorb solar irradiance and to transfer the absorbed energy into a heat transfer fluid with a minimum of heat losses. The **thermal efficiency** of the collector is defined as the ratio of the energy transferred to the fluid to the corresponding solar energy.

The thermal efficiency of a solar collector is high when its operating temperature is low. In contrast, its efficiency is low when the operating temperature is high. In the latter case, a collector at a high temperature loses energy towards the surrounding environment from all sides, especially through the transparent cover.

5. Basic Requirement For The Installation

A solar system for the production of hot water system should be installed in a location so that plenty of sunshine falls onto its collectors. The solar collectors accept the maximum amount of solar energy during a day when

- They face true south (collector orientation);
- The sun rays fall perpendicular (as much as possible) on the collector surface (the collectors should have a tilt to the horizontal plane);
- Their view to the sun is unobstructed especially when the sun's rays are most intense (shading)

Collector orientation

The solar collectors should face true south in order to have as much solar energy falling on them as possible, during a day.

In many cases, a slight westerly orientation is preferable to true south, in order to take advantage of the afternoon's higher outdoor temperatures, which leads to better collector performance.

Divergence of up to 20º from southern orientation creates a very small reduction of the amount of solar irradiation on the collector plane. For greater divergence of up to 45º, the reduction is in the order of 15% during winter months and relatively small (approximately 5%) during summer months.

Collector tilt

A tilt of the collector plane to the horizontal plane equal to the local latitude (at the equator the latitude is 0º, at the north pole is 90º) makes possible for the collectors to catch the most solar energy during the year.

The majority of solar water heating systems in the Mediterranean countries have collectors at a tilt angle of 30º - 45º to the horizontal plane

When the tilt is in the range of 25º to 50º, there is a change in the annual energy gain, which, however, does not exceed 5%.

Shading

Large obstructs should be avoided in front of the solar collectors, because their shadow during the period 09:30 to15:30 will reduce their performance. Small shadows early and late in the day make no difference in the collector performance.

6. Performance Of a Large Solar System For Hot Water

Design methods for large solar systems, that fit standard configurations, are available. They are easy to use and provide adequate estimates of long term thermal performance. Such estimates are provided in the next paragraphs for two types of hotel:

- one that operates the whole year and
- one that operates only during the period April - October (Mediterranean region)

In both hotels, a large solar system is considered with 300m^2 of collector area, installed at a tilt of 30^o with respect to the horizontal plane. The collectors are with selective coating and are suitable for operating with high efficiency at temperature 50^{o}C - 70^{o}C. Collectors with black paint are also considered in paragraph 6.1 for comparison purposes.

The meteorological data used are those of the Mediterranean region. The hot water temperature is considered at the level of 50^{o}C.

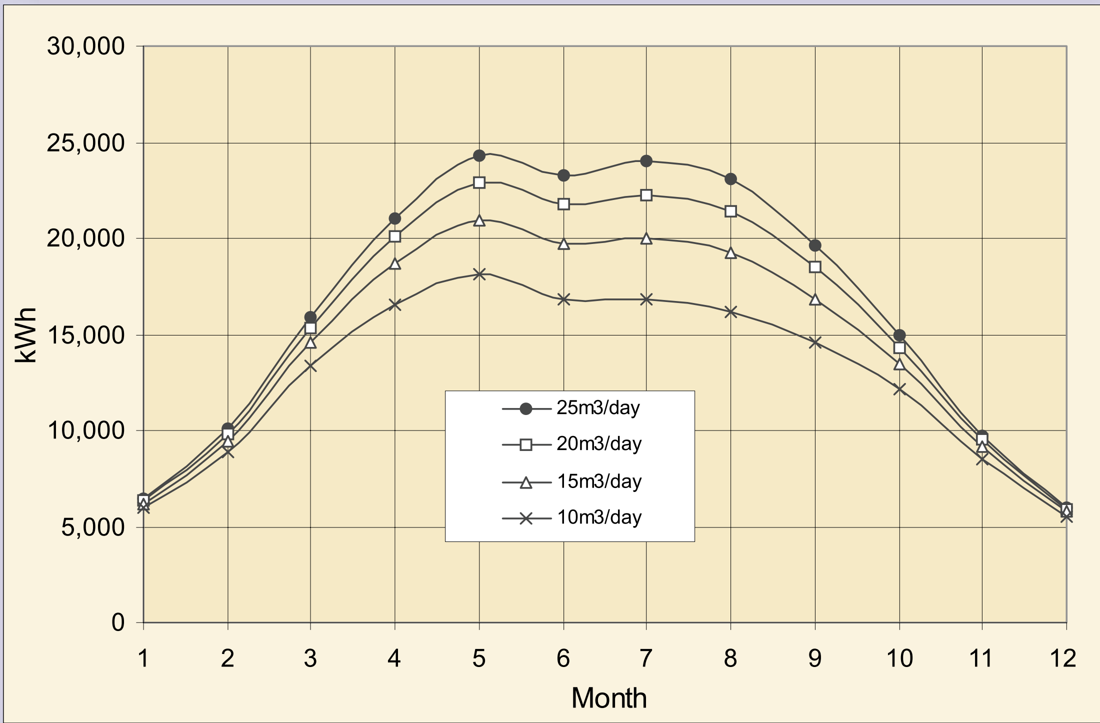
The energy delivered by a solar system depends on the water consumption. So the performance of the two systems is provided for various water consumption rates. The water consumption in a hotel depends on its occupancy, which does not remain the same during the year.

6.1 Hotel Operating During the Whole Year

Figure 6.1 presents the monthly and the annual performance of a large solar system for the production of hot water to cover the needs of a hotel operating during the whole year.

Under conditions of water consumption of 25 m^3/day (assuming a daily consumption of 80 litres to 100 litres per guest, it corresponds to approximately 300 hotel guests), the solar system cover 46.1% of the annual needs for hot water (solar fraction) of the hotel. The annual energy delivery is 661.1 kWh per square meter of collector area (selective collectors).

Reduction of the water consumption reduces the energy delivery by the solar system as it is shown in the diagram and in the table included in Figure 6.1, but it covers bigger part of the needs.

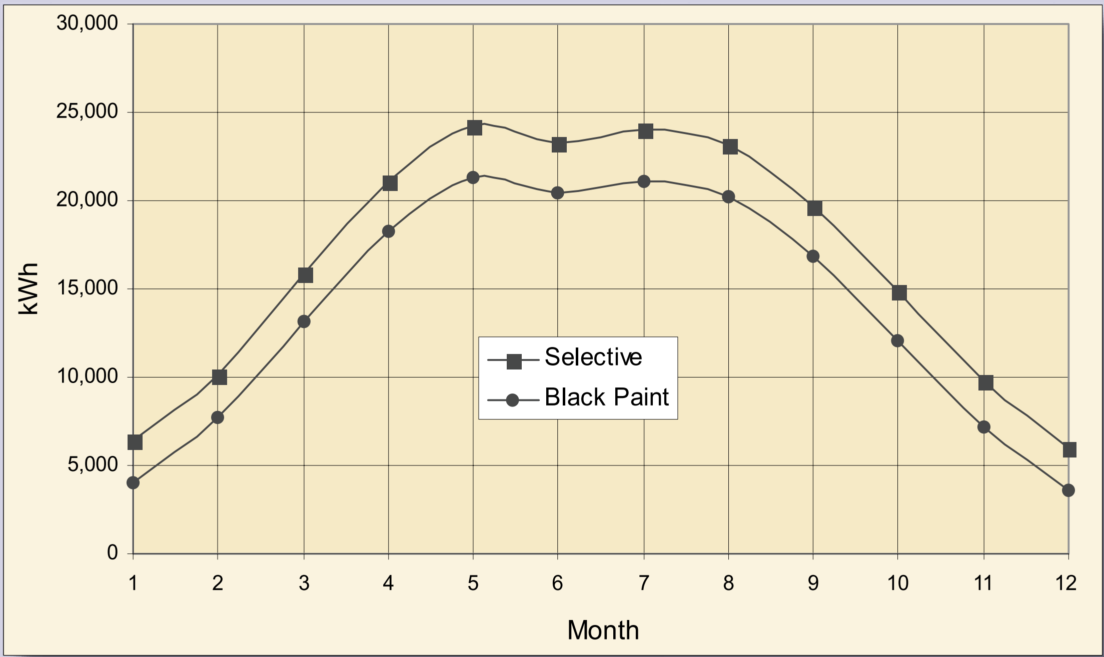


Consumption m^3/day	Annual Solar		
	Fraction (%)	Energy (kWh)	Energy (kWh/m^2)
25	46.1	198,337	661.1
20	52.8	188,046	626.8
15	60.4	173,947	579.8
10	69.9	153,652	512.2

Figure 6.1. Energy performance of a large solar system operating during the whole year for various water consumption rates (selective collectors, 300m^2, tilt 30^o water at 50^{o}C)

Figure 6.2 provides data related to the use of collectors with black paint. It shows the energy delivery by the same solar system employing two types of collectors, i.e. with selective coating and with black paint. Usually collectors with selective coating area more expensive than collectors with black paint. They have also tempered low iron cover for increased efficiency, which adds cost to the collector.

The solar system with the black paint collectors covers 39.0% of the annual hotel needs for hot water and the annual energy delivery is 552.3 kWh per square meter of collector area.



	Annual Solar		
Type	Fraction	Energy (kWh)	Energy (kWh/m^2)
Selective	46.1	198,337	661.1
Black Paint	39.0	165689	552.3
Water consumption: 25m^3/day			

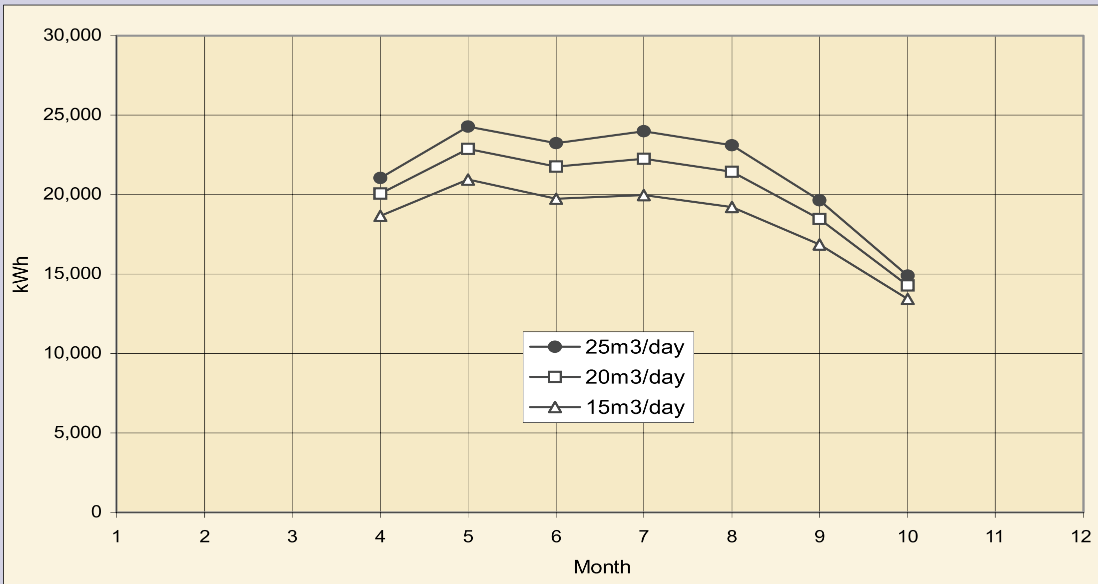
Figure 6.2. Energy performance of a large solar system operating during the whole year (collectors 300m^2, tilt 30^o water at 50oC, 25m^3/day). Collectors with selective coating and black paint are considered.

6.2 Hotel operating during the period April - October

There are hotels in the Mediterranean area that operate during the tourist period i.e. the period from April to October. The conditions are very attractive for the use of solar systems, as there is demand for hot water during a period with plenty of sunshine.
Figure 6.3 presents the monthly and the annual performance of a large solar system for the production of hot water to cover the needs of such a hotel.

Under conditions of water consumption of 25 m^3/day (assuming a daily consumption of 80 litres to 100 litres per guest, it corresponds to approximately 300 hotel guests), the solar system cover 66.1% of the annual needs for hot water (solar fraction) of the hotel. The annual energy delivery is 500.7 kWh per square meter of collector area (selective collectors).

Reduction of the water consumption reduces the energy delivery by the solar system, as it is shown in the diagram and in the table included in Figure 6.3, but it covers bigger part of the needs.



Consumption	Annual Solar		
m^3/day	Fraction (%)	Energy (kWh)	Energy (kWh/m^2)
25	66.1	150,216	500.7
20	73.7	141,153	470.5
15	82.7	128,834	429.4

Figure 6.3. Energy performance of a large solar system operating during the period April - October for various water consumption rates (selective collectors, 300m^2, tilt 30° water at 50°C)

6.3 Solar energy as percentage of the total needs (Solar fraction)

Figure 6.1 presents the energy delivered by the sun in a solar system with 300 m^2 of collector area and for various water consumption rates. For a constant water consumption of 25 m^3/day, the sun covers the 46.1% of the total needs during the period of a whole year.

During summer, the temperature of the cold water supply is higher than the one in the winter and also more solar radiation is available (see paragraph 10 of this document). Under these conditions the solar contribution to the total needs is higher in summer than the one in winter.

Figure 6.4 presents, for each month, the solar energy delivered by the solar system as a percentage of the total needs. The solar energy covers a percentage of 70% - 80% of the total needs during summer months.

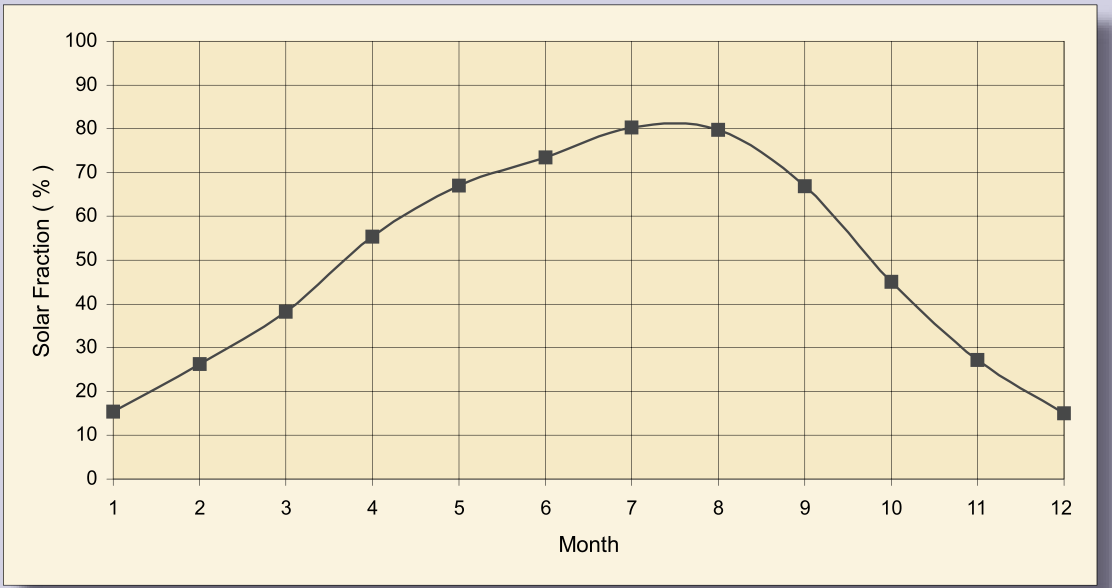


Figure 6.4. Solar fraction of a large solar system operating during the whole year (selective collectors 300m², tilt 30o water at 50°C, 25m³/day)

The size of a solar installation is designed to cover the majority of the needs in summer. A larger system may cover more needs, but the extra cost is justified up to a certain point.

7. Monitoring The Performance Of A Large Solar System

The proper operation of a large solar system is not easy to follow, because the auxiliary system covers, if necessary, the needs, and so there are no complaints from the customers of the hotel (as it happens with other services in a hotel).

For this reason, it is necessary to include, during the installation of a large solar system, some kind of limited monitoring equipment, in order to follow its performance.

- A flow meter, to monitor the quantity of the cold water entering the solar tanks, provides a good indication of the energy needs.
- The temperature of the water leaving the solar tanks provides indication about the proper operation of the solar system.
- Monitoring the auxiliary energy (heating oil, natural gas, electricity) will also reveal possible problems.

Values from those devices have to be compared with those during the initial operation of the system immediately after the installation and delivery.

Sophisticated monitoring systems exist at a higher cost. Such systems are employed when the "solar results guaranteed" approach is applied (see paragraph 8 below).

8. Solar Results Guaranteed (SRG)

In solar systems, guarantees commonly affect collectors, pumps, hot water storage tanks, control systems, etc. for a period ranging from one to five years. However, the perfect condition of the components in a facility does not guarantee the proper operation of the system.

Large solar system for hotels have an auxiliary heating facility (operating on gas, heating oil, electricity) to provide supplementary energy and thus ensure constant availability of water at the requested temperature.

Under these conditions, an inadequate operation of the solar system may remain permanently unknown, as hot water generation is constantly guaranteed by the conventional system and the only consequence for clients in an increase on their energy bill.

Solar results guaranteed has been applied in many countries and the development of the method has been funded by the European Commission. It requires monitoring of the operation of the solar facilities (usually tele-monitoring).

The manufacturer or the promoter of the large solar system considers the specific application and offers not only the installation of the system but also its performance (energy delivery), which he also guarantees.

The application of solar results guaranteed clearly contributes with advantages to the solar thermal market. The following are the most important of them:

Stronger awareness for the service rendered

With the application of solar results guaranteed, operations are not only limited to the sale of a solar facility, that is, to the material elements, but they also focus on rendering a specific service, which corresponds to a minimum yearly energy production.

This change is crucial and it makes sales offers closer to the real demands of potential clients, who must be rather more concerned about the energy generated or the annual economic savings reached than the number of collectors installed in their building.

Increasing users' confidence

Some solar facilities made in the past never reached the features expected by the user, either due to real operational problems or because expectations were too optimistic. Such failures built a bad sector image in some geographical areas, which still has negative repercussions in the market today.

Solar results guaranteed makes it easier to overcome such problem as the conditions on the service rendered are clearly stated in the offer (and they are specified in generated kWh). They are guaranteed by contract and these are supervised during a period of time.

Minimising users' risk

The economic profitability of the investment is guaranteed by SRG since in the case that solar generation (and therefore, savings) is lower to the one guaranteed, the user is compensated with an amount that makes up for the cost of traditional energy consumed in excess. Under such conditions, potential clients find it easier to solve the problem of funding the start-up investment.

Increasing facility reliability

The need to reach specific energy results makes it necessary for participating companies to increase the quality of their facilities since such companies would also be affected in case of malfunctions. On the other hand, potential breakdowns are more easily spotted and solved thanks to follow-up processes and thus avoid penalisation on energy production.

Finally, SRG discourages the temptation to deliberately make optimistic energy calculations aiming at an easier marketing of facilities.

Familiarity of the user with the solar facility

With solar results guaranteed, users are sharply updated on facility operation and the level of guarantee fulfillment and this provides the means to support the investment made.

On the other hand, updating users with malfunctions will improve their knowledge on the facility and will encourage them to enhance exploitation and maintenance. Sometimes, after an initial period of somewhat indifference, the maintenance personnel of hotel have acquired big interest to improve the features of solar facilities. In some occasions, the actual clients have called the company in charge of following-up the facility to enquire about some malfunctions that they believed they had alerted (which normally end up in false alarms) or they have carried out solar collector cleaning operations with unnecessary regularity.

Such positive evolution will be possible when the facility follow-up is not limited to simply reporting malfunctions and operations made but it also includes an attempt to train users by telling them the reasons for occasional malfunctions and the steps to follow to prevent the problem from arising again. It must not be forgotten that after the period of measurements planned and checking that the guarantee has been fulfilled, it is the actual user who must continue with the exploitation of the solar system.

The evolution of the SRG and the solar market

The SRG, combined with financial instruments such as Third Party Financing, leasing, low interest loans, etc should be the new trends for the next years of the solar energy sector in southern Europe.

Solar Monitoring Services provide continuous measurements of production and consumption figures obtained by solar energy systems. There are different technological possibilities of energy metering with remote reading. Always one of them can cover specific needs within the available budget.

9. Financial and Environmental Evaluation

The cost of the installed system, its energy delivery and the operating expenses can be used for the financial evaluation of a solar system.

There are incentives (national, regional, etc), that may apply under specific conditions, that have also to be considered

The contribution of a solar system in the reduction of the greenhouse emissions (CO_2) is very important. As a first approximation, it can be considered that for each kWh produced by the solar system the emissions reduction is

- 1.1 kg of CO_2, if the replaced energy is electricity produced by lignite
- 0.8 kg of CO_2, if the replaced energy is heating oil
- 0.4 kg of CO_2, if the replaced energy is natural gas

10. Meteorological Data

A large solar system is supplied with water from the city network (or other source) and, with the help of the sun, heats the water so that it can be used for the needs of a hotel.

10.1 Water temperature

The temperature of water from the city network or other source, which feeds a large solar system, does not remain stable during the year. During winter, the temperature is in the order of 10°C, while during summer months water temperature might exceed 25°C.

Figure 10.1 below shows the mean monthly values of the temperature of water from the city network for some area.

Water must be at a temperature in the order of 50°C to be used for the needs of a hotel. Thus, in winter, water temperature must be increased by 30°C - 40°C, while in summer by 20°C -25°C.

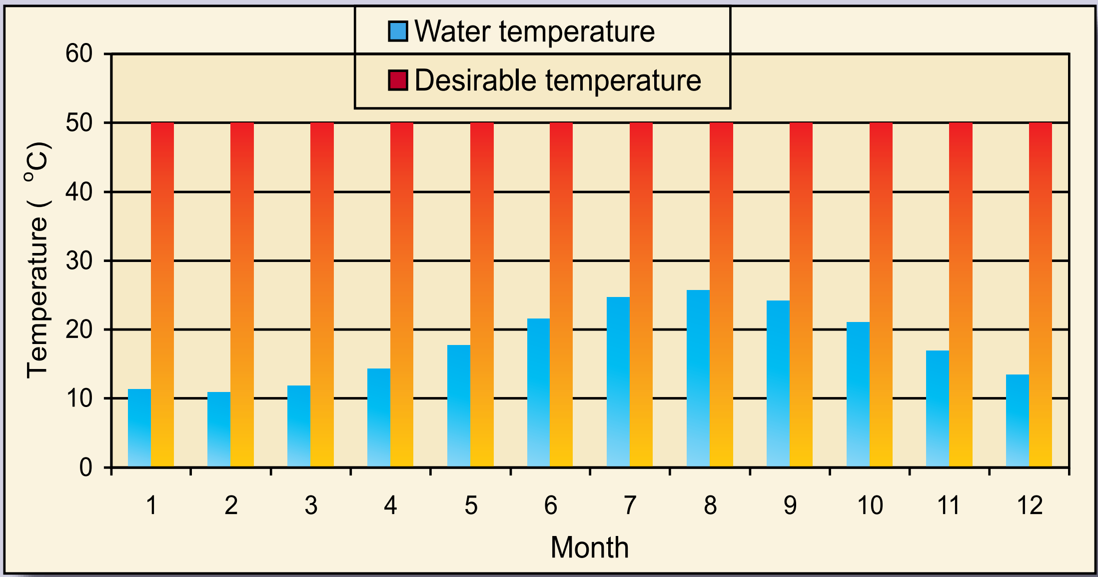


Figure 10.1 Mean monthly values of the temperature of the (city) water of some area.

10.2 Solar energy

A large solar system heats the water with the help of solar energy. The available solar energy varies during the year. It is high in summer, but low in winter, about 1/3 of what is available during summer.

Figure 10.2 shows the mean monthly values of the daily solar energy on the plane of the collector for some city

By observing Figures 10.1 and 10.2, it can be seen that in winter, when water is cold, there is little solar energy available. On the contrary, in summer, when city water is warmer, there is abundant solar energy.

These characteristics of the solar energy is very attractive in hotels, in the Mediterranean area, that operate in the period April - October. The demand for hot water is high during a period that solar radiation is high.

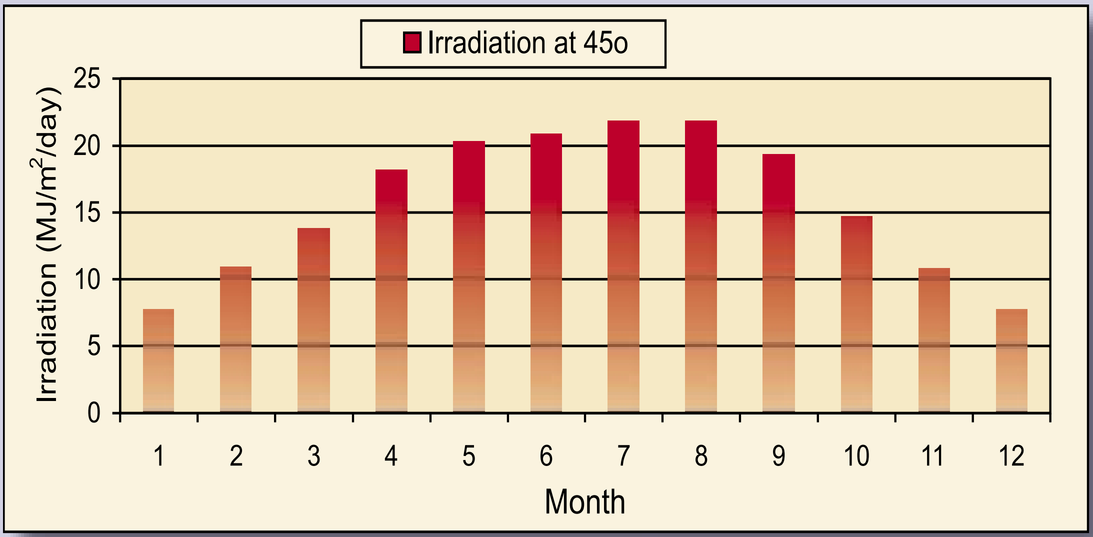


Figure 5.2. Mean monthly values of the daily solar energy (collector tilt 45o) of some city

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[2] Guaranteed Results of Collective Thermal Solar Installations, A Thermie Programme Action, European Commission, D.G. for Energy, 1994 Glazing / Front cover

in the framework of the project:
SOL-MED II
Widening the use of European Solar Thermal Technologies
in Mediterranean Countries following the Successful Model of Greece
PART B: Italy, France, Romania, Bulgaria, and Turkey
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