QUESTIONS AND ANSWERS ON SMALL SOLAR DOMESTIC HOT WATER SYSTEMS AND THEIR OPERATION

European Commission
Directorate General for Energy and Transport

ENERGIE PROGRAMME

ENERGIE PROGRAMME

Questions and Answers on Small Solar Domestic Hot Water Systems and Their Operation

exergia

Editor: EXERGIA S.A.
Athens, 2003-2004

This publication was produced by EXERGIA S.A. in the context of a project supported by the Directorate General for Energy and Transport. Its content has not been adopted or in any way approved by the Commission and should not be relied upon as a statement of the Commission's or the Directorate-General's view.

Please note that whilst EXERGIA works with all due care and attention, it cannot be liable for any decision made by a client or any reader based on our analysis or any other advice supplied.

Any comments and questions on this publication may be sent to: **n.komioti@exergia.gr**

Table of Contents

Foreword

This document is intended to be used as a guide for the preparation of informative / training material related to Solar Domestic Hot Water Systems, by **Manufacturers, Promoters, Importers,** etc.

This informative material is addressed to **Retailers and Installers** of domestic hot water systems and who come in directed contact with the End Users (i.e. the Customers). They have to face many **questions from prospective buyers** and they should have to be trained to answer all of them in a correct way.

The document includes five different categories of questions, regarding domestic hot water systems, and related to:

- Materials used in solar domestic hot water systems
- Installation of solar domestic hot water systems
- General issues regarding solar domestic hot water systems
- Performance of solar domestic hot water systems
- Meteorological data

The specific manufacturer, or importer, or promoter may select the part of the text, that fits his products, and expand it as he considers appropriately.

He may introduce additional questions, either related to his specific products, or even related to the products of his main competitors stressing the advantages of his products.

1. Materials used in solar domestic hot water systems

1.1 Transparent front cover of the collector

Why is 4mm tempered glass, with a low content in iron oxides, used for manufacturing solar collectors?

Tempered glass, with 4mm thickness, has a 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 very small harmless bits of glass (as happens with car windows), so it offers safety against accidents.

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

1.2 Selective coating of absorbers

What does selective coating offer the absorber?

The main components of a solar collector are the frame, the insulation, the transparent cover and the absorber. The absorber is the part inside the collector, which consists of the black absorbing plate (fins) and the copper tubes, which are very well bonded to the fins.

When a solar collector is exposed to the sun, solar irradiance, which falls on the collector penetrates the glass and is absorbed by the black plate of the fin, which is then 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.

When there is sunlight and the solar collector is in operation, the black absorbing plate (fins) is hot. As with every hot black surface, the absorber emits thermal radiation to the surrounding environment causing heat loss from the front transparent cover of the solar collector and therefore reducing its performance.

The selective coating, which is used on the absorber, considerably reduces such thermal radiation losses and increases the efficiency of the solar collector, because it has much lower emittance of thermal radiation in comparison to a common hot black absorber. It is emphasized that the selective coating absorbs solar irradiation the same way as a black surface.

Solar collectors with selective coating in the absorber operate with higher efficiency in areas with rather low solar irradiance (Northern Europe). They are more efficient for heating water at temperatures of over 60 oC -70 oC, used mainly in industry.

Selective coating is applied to the absorber surface through a chemical process (it is not a paint). The cost of an absorber with selective coating is higher than the one with black paint.

1.3 Insulation materials for solar collectors

Why are two types of thermal insulation (mineral wool and polyurethane) employed in collectors?

Solar collectors are part of solar domestic hot water systems. When the water in the system is not used (vacation periods etc), the water in the storage tank reaches a high temperature. The temperature of the absorber of the collector, during the day, is higher than that of the water in the tank. Under these circumstances, absorbers with black paint can reach temperatures of the order of 150 oC (in an absorber with selective coating the temperature can reach 200 oC). The high temperature ("stagnation" temperature), which a collector can reach, is taken into account for the selection of the appropriate insulation.

The use of polyurethane and mineral wool is considered the best combination for insulation.

- **Polyurethane** is a strong insulating material and offers equivalent insulation at smaller thickness. Furthermore, it is not affected by moisture and it is light. Temperature endurance of polyurethane depends on its type, but it is lower than 150 oC.
- **Mineral wool** is an insulating material, which stands up well to very high temperatures. It is inserted between the absorber and the polyurethane to reduce the temperature which the polyurethane is exposed to.

As a result, the combination of polyurethane and mineral wool creates strong thermal insulation, which contributes to higher collector efficiency and also ensures long life expectancy.

1.4 Use of copper for the absorber

Why is copper employed for the manufacturing of the absorber of a solar collector?

The absorber of a solar collector may be made from a wide range of materials. Absorbers of the sandwich type are made from steel sheets. In other cases, copper or steel tubes are used with fins made of copper, aluminium or steel.

Copper has the best thermal transfer properties of the materials mentioned. Therefore, a smaller amount of copper is necessary for the construction of one absorber, which means lower absorber weight and reduced cost.

Use of copper for the construction of an absorber gives a product with greater reliability and life expectancy, because copper can withstand the corrosive action of hot water (copper tubes) or other corrosive environments (fins).

A collector with a steel absorber of the sandwich type is heavy. Besides creating problems in transport and handling, due to its weight, it also presents reduced thermal performance of the solar domestic hot water system.

This is due to the way a solar domestic hot water system works. In the morning, solar irradiation heats the absorber first and then the water in the storage tank starts to be heated. Near the end of the day, the mass of the absorber cools and the respective thermal radiation is emitted and lost towards the surrounding environment. Therefore, the larger the mass of the collector, the more solar energy used for heating it, and finally lost to the environment.
The same process takes place during a day with periods of sunshine and clouds.

1.5 Insulation materials for hot water storage tanks

Why is polyurethane employed for the insulation of hot water storage tanks?

Polyurethane is a strong insulating material and offers equivalent insulation at smaller thickness. Furthermore it is not affected by moisture, it is light and it is rigid. Common types of polyurethane can sustain the high temperature on the outside surface of the hot water tank.

It is to be noted that many tanks have a double jacket that acts as heat exchanger. The temperature of the outside surface of the tank, in this case, can be higher than 100^{o}C, during the operation of the solar system.

Exclusively, all manufacturers employ polyurethane for the insulation of the hot water tanks, with thickness ranging between 50mm and 70mm. Thickness of 50mm is considered adequate. The circular form of the tank is very convenient for the construction of the required polyurethane molds at relatively low cost.

1.6 Corrosion protection of hot water storage tanks

How are the hot water storage tanks protected against corrosion?

The hot water storage tanks of solar domestic hot water systems must be made to withstand the pressure of city water and the corrosive action of domestic hot water.

Use of mild steel and glass enamelling

Mild steel is the most commonly used material for the construction of hot water storage tanks, because it has the strength for the pressure requirements (6 bar or more) with a tank wall thickness of 2mm-3mm at reasonable cost.

Corrosion protection in the water side of the tank is achieved by the use of glass enamel coating, provided that:

- the steel is suitable for the glass enamelling
- the welding is appropriate for the enamelling (the welds should be smooth in the water side)
- the manufacturing of the storage tank is adapted for the enamelling process
- the application of the glass enamelling should carefully follow all required procedures
- cathodic protection is provided.

It is noted that enamelling is applied in two coats. The ground coat achieves adhesion with the steel and the cover coat sustains hot water corrosive action.

Many years of established experience has shown that properly constructed and enamelled hot water storage tanks, with a magnesium anode for cathodic protection (it protects areas that might not be covered with enamel) present reliable products with long life (decades). It is only necessary to regularly inspect the function of the anode (especially in the beginning).

Use of stainless steel

The use of stainless steel requires the proper quality of steel and a sophisticated welding process, otherwise there is danger of stress cracking failure. Cracking in the storage tank is due to two factors

- pressure inside the tank from the city water network, which creates strain on stainless steel
- the existence of different corrosive elements in the water, which are only active when the tank is under pressure.

Thus, the argument that "storage tanks made of stainless steel do not fail, just as sauce pans do not fail" is refutable, because saucepans are not under the influence of pressure.

Use of mild steel and an internal tank from corrosion resistant material

Corrosion protection of hot water storage tanks, made of mild steel, can be achieved also by the use of an internal tank made from corrosion resistant materials. Thin copper sheets (northern Europe) and polymer materials (Europe, U.S.A.) have been used for the construction of the internal tank.

The outside shape of the internal tank is similar to the inside shape of the mild steel tank. The pressure of the hot water inside the internal tank is transferred to the outside steel tank. The steel tank does not in contact with the hot water and so it is protected from its corrosive action.

The material of the inner tank should withstand the expected high temperatures of the hot water and should be physiological inert and be approved for direct contact with food.

Special measures should be taken in order to avoid the development of vacuum inside the internal tank when hot water is used. Installation of a vacuum breaker in the cold water supply line is one of them.

Use of copper

The use of copper is an expensive alternative for storage tanks, which must withstand city network pressure. Copper of 1mm thickness has been used, mainly in Cyprus, in cases where the solar domestic hot water system is supplied with water from an open-air tank, which is located a bit higher than the solar domestic hot water system, causing aesthetic problems.

2. Installation of solar domestic hot water systems

2.1 Solar systems for users in lower apartments in buildings

Is it possible for a solar domestic hot water system to be used by the occupant of an apartment on the low floors of an apartment building?

Let us consider the case of a five-floor apartment building and a consumer who lives on the second floor. When the consumer turns on a hot water tap, depending on the total length of piping, there will first be an amount of approximately 3-6 litres of water, before hot water reaches the consumer (on the second floor). This amount of water is relatively small compared to water consumption for use in the bathroom, clothes washing or dish washing.

Of course, for other water use of smaller quantity, 3-6 litres may seem like a lot. The problem is reduced with well-insulated pipes for supply of hot water. In the case of apartments on even lower floors, the initial amount of water is a bit larger.

Therefore, it is possible to use a solar domestic hot water system on the lower floors of apartment buildings. However, it is the obligation of the salesperson to inform the consumer about the initial consumption of water before hot water reaches the apartment.

2.2 Domestic hot water re-circulation

What is hot water re-circulation and is it recommended?
There are solar domestic hot water systems (thermosiphon type), which are mounted (both the collectors and the hot water storage tank) on roofs (usually flat) of houses or apartment buildings. In this case, the hot water is obtained from the tank directly.

There are also solar domestic hot water systems which have collectors mounted on the roof, but have the hot water storage tank on a lower level, such as on the ground floor or in the basement. In this case, a pump is required to transfer energy from the collector to the storage tank, while a differential thermostat (control system) controls the operation of the pump. Usually such a domestic hot water system has more capacity (larger collector area, larger tank) than a simple thermosiphon system.

It is common in the case, that the tank is installed in the basement, to use triple energy tanks (boilers), which can be connected to

- solar collectors
- the domestic space heating system (auxiliary heater when the space heating system is in operation)
- electric current (auxiliary heater when the space heating system is in operation).

With these triple energy tanks, it is possible to use another pump, which sends hot water (used for domestic purposes) to the points of consumption in the house and then takes it back to the tank with a suitable piping system. Thus, the consumer has immediately available hot water and is not required to wait. This system (pump, piping) of hot water distribution, also known as re-circulation system, is used in hotels and other similar large facilities.

The constant circulation of domestic 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.

In cases where a hot water distribution system with a re-circulation pump is used or is going to be installed, 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.

It is the obligation of the "designer" or the installer/salesperson to inform the consumer about the considerable losses in the hot water distribution network, so that he (the consumer) can decide for or against the installation of a re-circulation system.

2.3 Solar collector orientation

It is well known that the collectors of a solar domestic hot water system must face south (northern hemisphere). What happens when this is not possible? How much can be the divergence from southern orientation without having low efficiency levels?

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

2.4 Solar collector tilt

The majority of solar domestic hot water systems have collectors at an angle of 45o to the horizontal plane. If we want to mount collectors on a roof with smaller or higher slope (usually systems with a pump) will there be functional problems or reduced efficiency?

When the slope is in the area of 25° to 50°, there is a change in the annual energy gain, which, however, does not exceed 5%. Thus, it is possible to mount collectors on roofs with usual slopes of 25° to 50° without actually having problems of efficiency or malfunctioning.

2.5 Summer vacation

During the summer, the occupants of a household will be away on vacation for some period. Is it necessary to cover the collector of a solar domestic hot water system?

When the water in a solar domestic hot water system is not used during summer, the temperature of the water in the storage tank reaches high levels (of the order of 90°C - 95°C). Solar domestic hot water systems are designed to withstand such high temperatures.

Therefore, the consumer is not obliged to cover the collector of a solar domestic hot water system when he is away. However, covering the collector would prevent water temperature from reaching such high levels in the storage tank.

2.6 Freezing conditions

The weather forecast predicts freezing weather conditions in my area. What must I do to protect my solar domestic hot water system?

The consumer is not required to do anything, during freezing weather conditions in his area, in the case that he has a closed-loop type system. The installer has used a solution of water and antifreeze liquid in the correct proportion (for the specific area) inside the closed loop, during the installation or during the regular maintenance services.

In areas where freezing weather conditions are rare, it is possible for an open-loop solar domestic hot water system to have been installed. If a draining provision has been made, the consumer should go on to drain the solar domestic hot water system according to the installer’s instructions. If such a draining system does not exist, then the consumer should contact the local representative of the solar system supplier and ask for his assistance.

2.7 Potential problems with closed loop systems (leaks to hot water)

A solution of water and antifreeze is used inside the closed loop. What happens if the closed loop develops a leak to the hot water? Does this pose a health threat for the water user?

A solution of water and antifreeze is used inside the closed loop. The content of the antifreeze depends on the minimum ambient temperature during winter in the area, where the solar domestic hot water system is installed.

The pressure inside the closed loop of collectors is, as a rule, always lower than the pressure inside the hot water storage tank (city network pressure). Thus, if the closed loop cracks, the solution will not infiltrate the water for domestic use. In contrast, the opposite will happen. Even if city network pressure decreases and the solution of water and antifreeze does infiltrate the piping network, that will not pose a problem, since the antifreeze liquid which is used is not toxic.

3. General issues related to solar domestic hot water systems

3.1 Performance and reliability standards on solar products

Are there norms or standards for the performance, reliability and manufacturing of solar products?

There are international and European standards concerning the performance, reliability and manufacturing of solar collectors and solar domestic hot water systems.

The standard (ISO 9459-2 or EN 12976-2), regarding the performance of solar domestic hot water systems, provides for a series of tests, measurements and calculations. In addition, it requires the publication of a Test Report, which includes data such as

- the energy gained by the consumer,
- the available volume of hot water of specific temperature (35^{o}C and 40^{o}C),
- the maximum temperature of hot water,

that the solar domestic hot water system supplies during all the months of the year.

The Test Report also includes useful information for the manufacturer (and not only) regarding the performance of the solar domestic system (draw-off water-temperature profiles, tank night thermal losses, existence of conditions for reverse flow).

Two other standards (ISO 9806-1 and EN 12975-2) cover the efficiency of the collectors used in domestic hot water systems. The relevant methods for determining the steady-state thermal performance of the solar collectors (tests outdoors under natural irradiance or indoors under simulated irradiance) are almost the same in the two standards.

The standard (ISO 9806-2 or EN 12975-2), regarding reliability tests, provides for the solar collectors to be subjected to a series of tests (rain penetration, exposure to the sun for some rather long period, other). Its reliability can be examined under the harsh outdoor weather conditions it is usually exposed to.

Furthermore, there are a number of standards regarding the design of the hot water storage tank, methods for protection against corrosion and other materials used in components of solar domestic hot water systems.

3.2 Use of hot water in a household including dishwashing and clothes washing

Where can hot water, from a domestic hot water system, be used in a household?

Hot water is used in the residential sector in order to cover the needs

- in the kitchen, mainly through a dishwasher (20%-25% of the total hot water needs).
- for clothes washing, mainly through a washing machine (30%-35% of the total hot water needs).
- for bathing / showering

The use of solar hot water, from a solar domestic hot water system, presents some difficulties in dishwashing and clothes washing. These difficulties are discussed next, together with recommendations for overcoming them.

Dishwashing

Hot water from a solar domestic system **can not** be used directly in a dishwasher. The reason is that the manufacturer of the dishwasher specifies a maximum temperature for the feeding water, usually of the order of 60°C. A domestic solar system can develop, during summer, water temperature higher than 60°C (it can be up to 90°C) under some conditions (limited use of the hot water).

A mixing device installed at the hot water output of the domestic solar system can control the hot water temperature so that it does not exceed 60°C. Under these conditions, solar hot water can be used in a dishwasher. At the same time the user of hot water is protected from water temperatures higher than 60°C, which may cause burns to him.

Mixing devices are used in many hot water applications in large installations, but they are rather expensive. Low cost, simple mixing devices exist that can be used in a domestic solar system. Their cost is lower than 50 Euro.

Clothes Washing

Hot water from a solar domestic water heater can be used in a washing machine in the case that it (the washing machine) has **two feeding pipes**, one for hot water and one for cold water. Such washing machines exist and their cost is not higher than the cost of a washing machine with one feeding pipe (cold water). Their washing cycle is faster, because it does not require time for water heating.

The promotion of the use of washing machines with two feeding pipes (hot water, cold water) can increase the energy delivery from a solar domestic system. The faster washing cycle is an additional benefit.

3.3 Hot water use per person

How much hot water does a person use each day?

It has been established (measurements), in consumer households with solar domestic hot water systems, that the average hot water consumption per person and per day is of the order of 40 litres. This quantity of 40 litres per day and per person refers to hot water, which the consumer uses directly from the storage tank of the solar domestic hot water system, before mixing with cold water. It includes dishwashing and clothes washing with hot water from the solar domestic system.

This data assists to determine the size of a solar domestic hot water system. For instance, the full needs (including dishwashing and clothes washing) of a 4-member family can be covered by a 160-litre solar domestic hot water system. The individual needs of the family should be considered and in case that they are reduced, the use of a 120-litre solar domestic hot water system should be examined.

The following table offers an initial choice of solar DHW system, according to the number of family members.

Family members	Tank volume (litres)	Collector area (m^2)
2 - 4	120	2.0
4 - 6	160	2.5
6 - 7	200	3.5

3.4 Direct (open loop) and indirect (closed loop) solar domestic hot water systems

There are direct (open loop) and indirect (closed loop) solar DHW systems. What are they and what kind do you recommend in using in my household?

Indirect (closed loop) solar domestic hot water systems.

The use of a heat exchanger, in the hot water storage tank of a closed loop solar domestic hot water system, allows the use of a "separate" (from the hot water) heat transfer fluid to carry heat from the solar collector to the storage tank. In this case, the hot water for consumer use does not pass through the collector.
In this closed loop system, antifreeze can be used in the heat transfer fluid. Therefore, by using the correct proportion, it is possible to reliably protect the solar domestic hot water system from freezing weather conditions in the area where the system has been installed.
As a rule, a closed loop solar domestic hot water system should be recommended.

Direct (open loop) solar domestic hot water systems.
In open loop solar domestic hot water systems, the water for consumer use passes through the collector. In this case, there are two problems.

- The solar domestic hot water system is not automatically protected from freezing weather conditions. Action must be taken by the consumer to drain it (with the help of suitable valves and air venting, which must be installed when installing the solar domestic hot water system).
- Deposits, in areas with very hard water, might block the copper tubes of the absorber. As a consequence, there is a constant decrease in the efficiency of the solar domestic hot water system.

An open loop solar domestic hot water system could only be used in areas with limited possibilities of freezing weather conditions. In the rare case of such freezing conditions, it is recommended that there be provision for valves and air venting for draining (emptying) the solar domestic hot water system. The problem of deposits in the case of hard water is not easily dealt with.

3.5 Principle of operation of a thermosiphon

How does a simple solar domestic hot water system, which is mounted on the flat roof of a house, work?

A solar domestic hot water system consists of the solar collector (or collectors) and the hot water storage tank, which is mounted above the collector.

The main components of the solar collector (as referred to elsewhere as well) are the frame, the insulation, the transparent cover and the absorber. The absorber is the part inside the collector, which consists of the black fins and the copper tubes (fins and copper tubes are well bonded).

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 fins, which are then heated. Next, the heat transfer fluid (water, or water and antifreeze) that is in the absorber tubes is also heated and it transfers the energy to the water in the storage tank.

The fluid circulates automatically inside the copper tubes of the absorber and the heat exchanger of the storage tank. Its circulation is based on the fact that water, when heated, becomes lighter. This flow of fluid inside solar domestic hot water systems is known as natural or thermosiphonic flow.

For the proper operation of a solar domestic hot water system, it is required that the storage tank is above the collector. If there is not a suitable height difference, it has been observed that the solar domestic hot water system loses its temperature during the night. This is due to a phenomenon called reverse flow, i.e. conditions appear which allow the fluid of the collector to move inside the absorber piping in the opposite direction than that of the normal operation. Thus, warm fluid flows to the collector, where it eventually cools.

3.6 Principle of operation of forced circulation systems

What are solar domestic hot water systems with a pump (forced circulation systems)?

Besides solar domestic hot water systems, which operate with natural circulation, there are also cases, where the solar collectors are mounted on the roof, but the hot water storage tank is situated elsewhere, for example on the ground floor or in the basement of a house. In this case, a pump is required for the circulation of the heating fluid. In addition, a control system (usually a differential thermostat) is required for the operation of the pump only when it is necessary (when there is sunlight, etc).

These systems are known as forced circulation solar water heating systems. They are installed in single family houses, hotels, industries, etc.

3.7 Use of expansion tanks in the closed loop DHW systems

Why is an expansion tank required for closed loop solar domestic hot water system?

In the morning, when a closed loop solar domestic hot water system begins to operate, the heat transfer fluid is gradually heated until, at some point in the afternoon, it reaches its maximum temperature. However, because of the heating, the closed loop fluid expands and its volume increases (the expansion of water-antifreeze mixtures is higher than the one of plain water). The expansion tank "receives" this volumetric increase of the closed loop fluid, without the development of high pressure in the closed loop.

4. Performance of solar domestic hot water systems

4.1 Typical draw-off profile

A solar domestic hot water system is exposed to the sun for a whole day. When we draw off the hot water at the end of the day, how does its temperature vary? What is the seasonal (summer, winter,...) effect on this?

In the afternoon on a sunny day, when the hot water is drawn off from a solar domestic hot water system, it is observed that the temperature of the hot water remains constant in the beginning for some portion of the total volume of the storage tank.

Measurements have shown that the temperature of the domestic hot water, during draw off, of a typical solar domestic hot water system, remains constant for 70 - 80% of the water volume of the storage tank. This percentage depends on the season of the year.

A typical diagram of the hot water temperature of a solar domestic hot water system (draw-off temperature profile) is shown in Figure 4.1. The same Figure 4.1 shows also the temperature of city water with which the solar domestic hot water system is supplied.

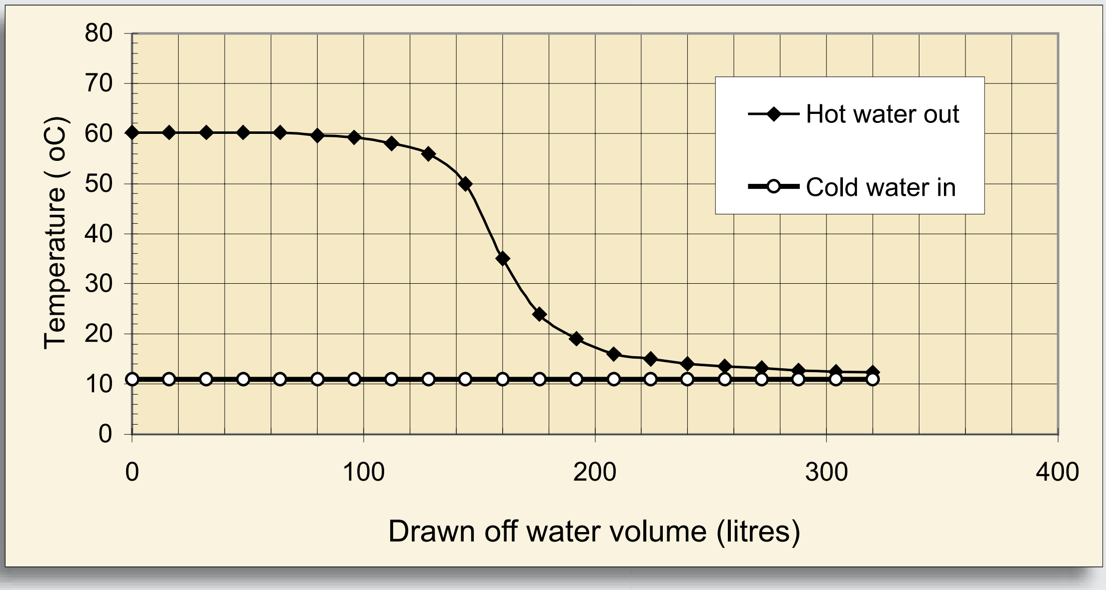

Figure 4.1: Temperature of the hot water of a solar domestic hot water system with a tank of 160 litres

It is obvious from Figure 4.1 that the temperature of hot water remains higher than the cold water temperature up to a volume of 300 litres (the tank volume is 160 litres). This is due to the mixing, during draw off, of the hot water in the tank with the cold water entering the tank.

The maximum temperature of the hot water, which a solar domestic hot water system provides us with on a specific day, depends on

- the available solar energy of that particular day
- the ambient air temperature and
- the temperature of the cold water on the morning of that particular day.

Thus, if the solar DHW system is full of cold water from the city network in the morning, it is expected that the hot water will reach a temperature in the order of

- 55°C - 65°C during sunny spring / summer day and
- 35°C - 40°C during a sunny winter day.

In cases where the storage tank has hot water from the previous day, even higher temperatures are expected.

Diagrams like the one shown in Figure 4.1 are included in the Test Report for a domestic hot water system, tested according to the Standard related to its performance (ISO 9459-2, or EN 12976-2). Please also see paragraph 3.1

4.2 Night losses of a hot water storage tank

How many degrees does the temperature of hot water in the solar DHW system drop during the night?

There are many times when there is hot water in the storage tank of a solar domestic hot water system during the night. This happens either when the hot water is not used, or when an auxiliary electric heater is used (night electricity rates, etc).

It is normal, during the night, when there are low ambient air temperatures, to have heat losses from the storage tank, which cause a decrease in water temperature.

If water at a temperature of 50-60^{o}C is left inside the tank of a typical solar domestic hot water system in the evening, the temperature of the water on the morning of the next day will have dropped by 4-6^{o}C, depending on the season.

Information related to the night thermal losses of a hot water storage tank is included in the Test Report for a domestic hot water system, when it is tested according to the Standard related to its performance (ISO 9459-2, or EN 12976-2).

4.3 Solar collector thermal efficiency

What is solar collector thermal efficiency?

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.

Information related to the thermal efficiency of a solar collector is included in the Test Report according to the Standard related to its performance (ISO 9806-1, or EN 12975-2).

When the hot water of a solar domestic hot water system has been used during any day, the following morning, with the increasing solar irradiance, the solar collector operates at low temperatures (taking into account that the water in the storage tank is rather cold). Therefore, efficiency is high. In contrast, in the afternoon, when the water in the storage tank has been heated, the collector operates at high temperatures and therefore at a lower efficiency rate, but it has already heated the water. If, at some point in between, we draw off hot water, the collector will eventually have a higher energy output at the end of the day.

If the transparent cover of the collector is touched with the hand and it is noticed that it is hot, this means that it is working at a high temperature, therefore not efficiently. In this case, either the water in the storage tank is already hot or the closed loop system does not work properly. As a consequence, the collector does not produce energy.

4.4 Making good use of the sun

How can I use my solar domestic hot water system more efficiently?
A solar collector has a high thermal efficiency when its operating temperature is low. Therefore, the main principle is for the water in the storage tank to be at a low temperature in the morning, when solar irradiation begins to increase.

Thus, if there is a need to use the auxiliary electric heater during the night, it is recommended to use the hot water by the morning of the next day. This way the solar collector will be able to start to operate at a low temperature and therefore efficiently.

Another piece of advice is to use hot water during the day and not collectively at night or the following morning. In this case, increased efficiency rates have been measured in the order of 20-25%.

4.5 Expected yearly performance

What is the energy that it is expected to be delivered by a solar domestic hot water system during one year? What are the relevant assumptions?
The standard (ISO 9459-2 or EN 12976-2), regarding the performance of a solar domestic hot water systems, provides in the relevant Test Report the expected

- energy to be delivered by it
- available quantity of the hot water of specific temperature 35^{o}C - 40^{o}C,
- maximum temperature of hot water,

during all months of the year, usually for three cities in a specific country.

The energy output (each month, year) is determined in the Test Report for only one draw off at the end of the day and for following three load conditions:

- draw off of one tank volume

- draw off until the hot water temperature reaches 35°C;
- draw off until the hot water temperature reaches 40°C.

Under these assumptions, the expected energy delivery is of the order of 500kWh to 800 kWh per year and per square meter of collector area. More information is included in the relevant Test Report available from the manufacturer of the solar domestic hot water system.

5. Meteorological data

A solar DHW system is supplied with water from the city network and, with the help of the sun, heats the water so that it can be used for the needs of a family.

5.1 City water temperature

How does the temperature of the city water vary during the year? How does this influence the operation of my domestic hot water system?

The temperature of water from the city network 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 5.1 below shows the mean monthly values of the temperature of water from the city network for some city

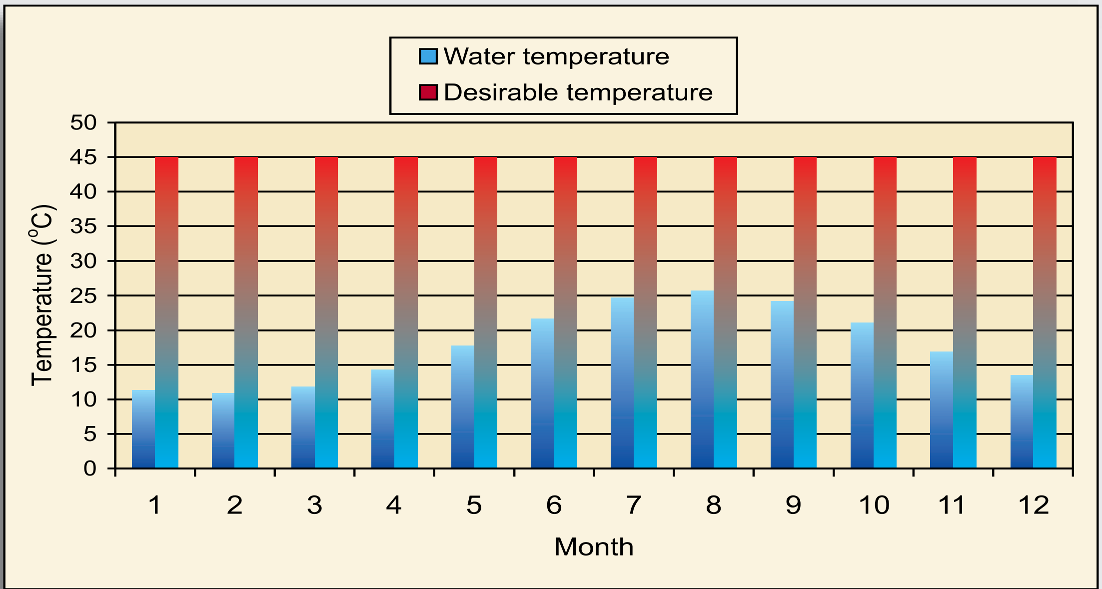

Figure 5.1 Mean monthly values of the temperature of the city water of some city

Water must be at a temperature in the order of 45°C to be used for the needs of a family. Thus, in winter, water temperature must be increased by 30°C -35°C, while in summer by 15°C -20°C, which means half of what is required in winter.

The temperature, which the water in a solar domestic hot water system finally reaches at the end of a sunny day also depends on the temperature of the water in the morning i.e. the city water temperature. The higher the initial water temperature is, the higher the final water temperature will be.

So considering two cities of the same country, one north in the country and one in the south, the city water of the northern city generally will be colder. Under these conditions, the domestic hot water system in the south will produce hotter water and it will seem to be more effective. Both solar domestic systems might provide to the water the same amount of energy from the sun.

5.2 Solar energy

How does solar energy vary during a year?

A domestic hot water 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 5.2 shows the mean monthly values of the daily solar energy on the plane of the collector for some city

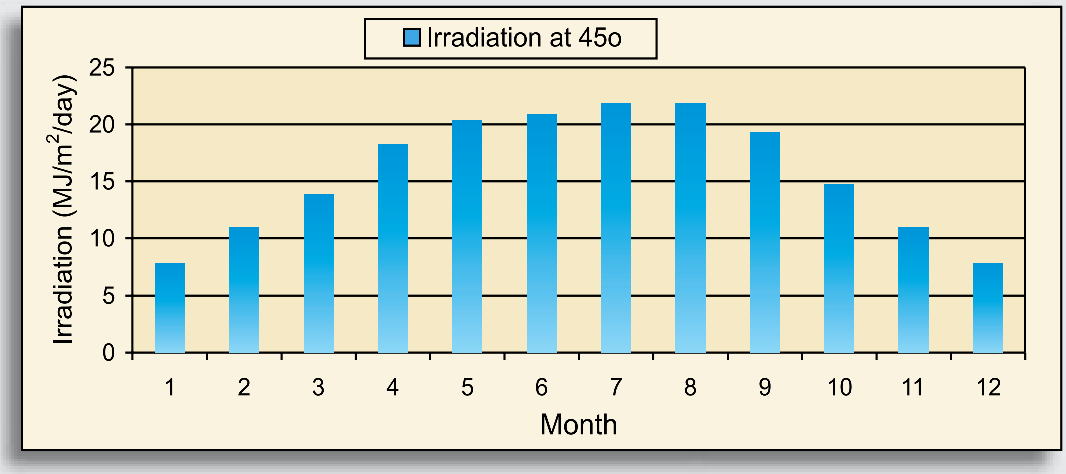

Figure 5.2. Mean monthly values of the daily solar energy (collector tilt 45°) of some city

By observing Figures 5.1 and 5.2, 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.

It is obvious that, in winter, the use of an auxiliary electric heater is necessary, mainly during cloudy weather conditions. On sunny days, there is considerable solar contribution for water heating.

5.3 Ambient temperature

How does the ambient air temperature vary during the year? How does this influence the operation of my domestic hot water system?

Another parameter concerning the operation of a solar domestic hot water system is ambient air temperature. The lower the ambient air temperature is, the higher the heat losses of the solar collector and of the hot water storage tank will be to the surrounding environment. This means that, in winter, low ambient air temperatures contribute to reduced energy output from a solar domestic hot water system.

Figure 5.3 shows the mean monthly values of the daily ambient air temperature during the day for some city.

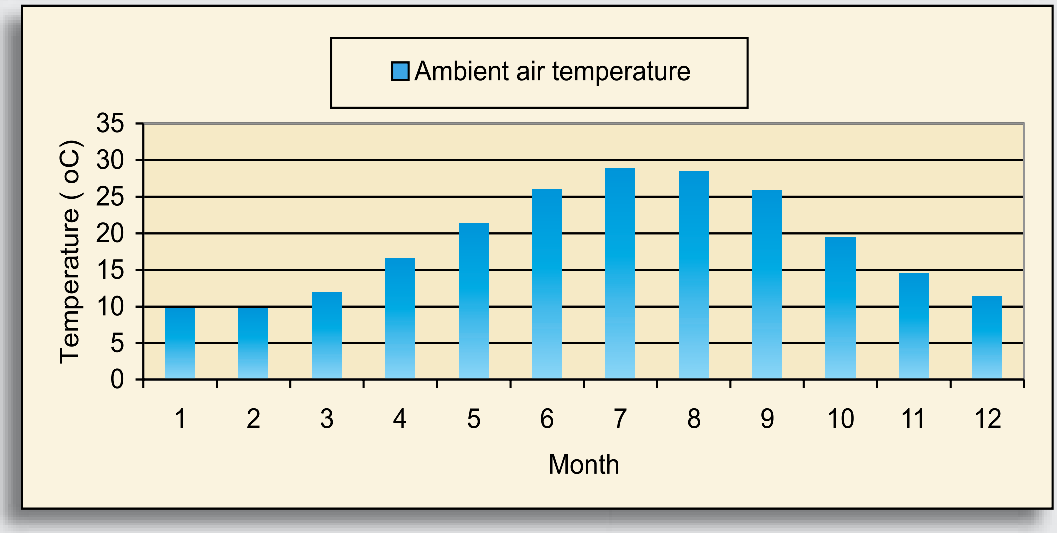

Figure 5.3 Mean monthly values of daily ambient air temperature during the day of some city

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
Contract No.: NNE5/2002/86

Editor:
EXERGIA S.A.
ENERGY & ENVIRONMENT CONSULTANTS
Apollon Tower, 64 Louise Riencourt Str. • 115 23 Athens, Greece
e-mail: office@exergia.gr
http://www.exergia.gr

exergia
ENERGY & ENVIRONMENT CONSULTANTS