SOLAR WATER HEATERS IN CYPRUS
MANUFACTURING, PERFORMANCE AND APPLICATIONS

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ABSTRACT

This paper reviews the application of solar water heating in Cyprus. The full reliance of Cyprus on imported oil to meet its energy demand, together with the abundance of solar radiation and a good technological base, created favourable conditions for the exploitation of solar energy in the island. Initially the Cyprus energy scene is presented and analysed with emphasis on the contribution of solar energy to the total energy consumption. From this analysis it is shown that 4.5% of the annual energy demand of Cyprus is provided from solar energy. This energy is used mainly in the domestic sector (93.5%) for hot water production. Additionally, 80% of the hotel apartments and 44% of the hotels are equipped with central solar water heating systems. One of the most widely used systems for domestic water heating is the solar thermosyphon unit. A description of the characteristics and manufacture of thermosyphon units is presented followed by a study on the performance characteristics and environmental protection offered by the systems. Such a system is modeled with TRNSYS and the results show that the system can provide 7225 MJ of energy per year and the solar contribution is 85%. The financial characteristics of the system investigated give life cycle savings, representing the money saved because of the use of the system throughout its life instead of using electricity, equal to 1120 Euro and pay-back time equal to 4 years. Life cycle analysis shows that by using solar energy considerable amounts of greenhouse polluting gasses are avoided. The saving, compared to a conventional system with electricity backup, is about 80% and the pollution created for the production of the system is recouped in about 1.2 years. It can therefore be concluded that solar energy systems offer significant protection to the environment and cost savings and should be employed whenever possible in order to achieve a sustainable future.

1. INTRODUCTION

Two periods characterise the solar age, the 70's when after the oil crisis of 1974 people started thinking ways to reduce their oil dependence and the 90's with the discovery of the depletion of the ozone layer. The latter urged scientists and Governments to consider sources of energy like solar energy and wind, which are friendly to the environment.

Cyprus has no natural oil resources and relies entirely on imported fuel for its energy demands. The only natural energy resource available is solar energy. The climatic conditions of Cyprus are predominantly very sunny with daily average solar radiation of about 5.4 kWh/m^2 on a horizontal surface. Mean daily global solar radiation varies from about 2.3 kWh/m^2 in the cloudiest months of the year, December and January, to about 7.2 kWh/m^2 in July (Meteorological service, 1985). Statistical analysis shows that all parts of Cyprus enjoy a very sunny climate. The amount of global radiation falling on a horizontal surface with average weather conditions is 1727 kWh/m^2 per year. Of this amount 69.4% reaches the surface as direct radiation (1199 kWh/m^2) and the rest 30.6% as diffuse radiation (528 kWh/m^2).

Visitors coming to Cyprus for the first time are amazed by the solar water heaters, which, as it is a habit to produce hot water with solar energy, are present practically on the roof of every house (see Fig. 1). The majority of these systems is used predominantly for hot water production in residential applications and is of the traditional thermosyphonic type. In this paper, after an analysis of the Cyprus energy scene, the present status of solar water heating industry is presented.

Furthermore, the environmental benefits of utilising solar energy are evaluated. The paper concludes with an analysis of the prospects of the solar water heating industry.

Fig. 1. Photo of a neighbourhood in Cyprus showing all houses equipped with a solar water heater

2. THE CYPRUS ENERGY SCENE

With the exception of solar energy, Cyprus has no other resources of its own and has to rely heavily on fossil fuel imports. The energy consumption is predominantly oil based. The only other form of commercial energy used is coal, which is used at times for cement production, when its price is competitive to that of heavy oil. Due to the developmental nature of the economy of Cyprus, energy consumption during the last ten years is increasing at an average annual rate of about 6.9%, which is approximately equal to the rate of increase of the Gross National Product.

The Electricity Authority of Cyprus (EAC) which is a non-profit semi-governmental organization, is responsible for the generation, transmission and distribution of electricity in Cyprus. The Cyprus power system operates in isolation and at present consists of three thermal power stations with a total installed capacity of 988 MWe. Moni power station consists of 6 x 30 MWe steam turbines and 4 x 37.5 MWe gas turbines and is located on the south coast of Cyprus, to the east of Limassol. Dhekelia power station consists of 6 x 60 MWe steam turbines and is located on the southeast coast of Cyprus, to the east of Larnaca. Vasilikos power station consists of 2 x 130 MWe steam turbines and one 38 MWe gas turbine. The steam units at Vasilikos are used for base load generation, while the steam units at Dhekelia are used for base load and intermediate load generation. The steam units at Moni and the gas turbines are mostly used for peak lopping. All stations use heavy fuel oil (HFO) for the steam plant and gasoil for the gas turbine plant. The second phase of Vasilikos power station, which is under way, will comprise a third steam unit using HFO with capacity of approximately 120 MWe. This is expected to be in operation in 2006.

Cyprus has no natural energy sources except solar energy, which at present covers about 4.5% of the total annual energy requirements. This energy is used mainly in the domestic sector (93.5%) for hot water production. Given Cyprus strong dependence on imported energy, the future energy policies involve further promotion of modern energy technologies and equipment for rational use of energy, maximum exploitation of renewable energy sources and probable use of clean coal technologies.

3. SOLAR WATER HEATING

The low population, the almost exclusive reliance on oil for energy needs, the relatively high cost of electricity, the reasonable high level of technology and the population acceptance of solar energy make the renewable energy options extremely viable from a technical, social and economic point of view.

The first solar water heating systems were imported from Israel in 1956. Cyprus began the manufacture of Solar Water Heaters (SWH) in the early sixties, initially by importing the absorber plates and other accessories from Israel. The progress in the first six years was rather slow. This is attributed to the rather faulty design (leakages, low efficiency etc.) and to their rather high cost.

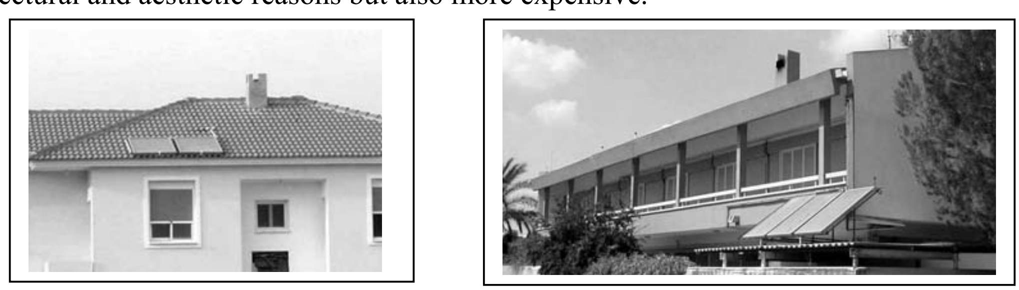
With further developments in the construction of collectors, most technical problems were solved and with the rationalisation of production, the cost was decreased or remained constant and thus a lot more units were installed. The industry of solar water heaters expanded very quickly and today reaches an annual production of about 30,000 m^2 of collectors (about 30 manufacturers).

Typical solar water heaters in Cyprus are of the thermosyphon type and consists of two flat-plate solar collectors having an absorber area between 3 to 4 m^2, a storage tank with capacity between 150 to 180 litres and a cold water storage tank, all installed on a suitable frame. The solar collectors are of the flat plate type, made of copper absorber and copper tubes. The risers are usually bonded to the absorber plate using various techniques. In most cases the risers fit in corrugations made on the absorber plate, while in few cases soldering is used to improve the contact. An auxiliary 3 kW electric immersion heater is used in winter during periods of low solar insolation. In buildings which are equipped with oil fired central heating systems the boiler is used as auxiliary through a heat exchanger fitted in the storage tank of the unit. Figure 2 shows the most typical system installed on a flat roof house. The combination of a pressure unit allows the relocation of the cold-water tank at a lower level. This improves the aesthetic attractiveness of the installation as shown in Fig. 3. In multi-residential buildings a number of units are installed one next to the other.

Fig. 2 Typical application of tower-type solar water heater installed on flat roof

Fig. 3 Pressurised solar water heater installed on an inclined roof.

Another important type of solar waters heaters is the force circulation type. In this system only the solar panels are visible on the roof, the hot water storage tank is located indoors in a plantroom and the system is completed with piping, pump and a differential thermostat. Typical applications are shown in Fig. 4. Obviously this type of system is more appealing mainly due to architectural and aesthetic reasons but also more expensive.



(a) Installation on an inclined roof (b) Installation detached from the house

Fig. 4 Applications of force circulation type solar water heaters.

Hotels, hotel apartments, hospitals and clinics are using either thermosyphon systems in array of several units or active systems equipped with central storage systems, which employ pumps, heat exchangers and oil-fired boilers as back-up source of energy. A study conducted in the past showed that central solar hot water systems for hotels and hotel apartments are technically and economically feasible (Sema-Metra *et al.*, 1985). In particular a payback time of 7 years for a solar hot water system for a 4-star hotel in Cyprus was obtained from this study (at a much lower fuel price than the present value).

Compared to other Mediterranean countries and the European Union, Cyprus is in a very good position with respect to the exploitation of solar energy. The estimated park of solar collectors in working order is 560,000 m^2, which corresponds to approximately 0.86 m^2 per inhabitant as compared to 0.56 and 0.2 for Israel and Greece respectively (see Fig. 5).

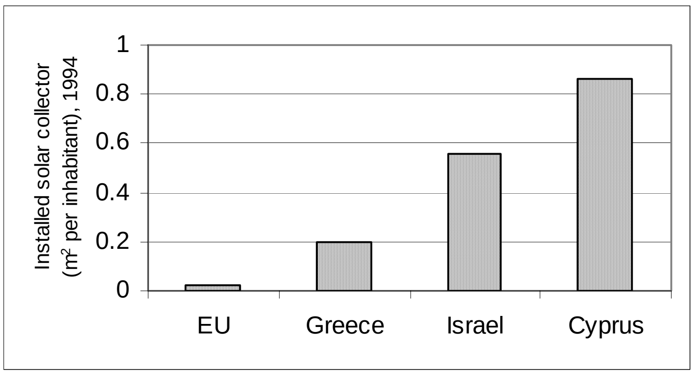


Fig. 5 Installed solar collector area per inhabitant, 1994.

It is estimated that the number of solar water heaters installed in Cyprus exceeds 190,000 units. This corresponds to one solar water heater for every 3.7 persons in the island, which is a world record. The estimated collector area installed up today including central systems in hotels and hotel apartments, is about 560,000 m^2 out of which 540,000 m^2 are installed in houses and flats. In the tourist industry, it is estimated that about 44% of the existing hotels and 80% of the existing hotel apartments are equipped with solar-assisted water heating systems and the contribution of solar energy to the total energy consumption in the hotel industry is about 2%. An important market potential exists for the development of solar water heaters in the commercial and industrial sectors.

Except from very few imported collectors of the vacuum tube type, flat plate collectors are invariably used in all solar water heaters in the country. The average quality is acceptable and the solar water heater in Cyprus enjoys a very good reputation by the public. The average life of the systems is 20 years although systems more than 25 years old are still operational.

Imports of solar water heaters are few made mainly from Greece, Israel and Australia. About 700 systems are imported per year (2000 m^2 of solar collector area per year).

4. THERMOSYPHON SOLAR WATER HEATER

Thermosyphon systems, shown in Fig. 6, heat potable water or a heat transfer fluid and use natural convection to transport it from the collector to storage. The water in the collector expands becoming less dense as the sun heats it and rises through the collector into the top of the storage tank. There it is replaced by the cooler water that has sunk to the bottom of the tank, from which it flows down the collector. Circulation continuous as long as there is sunshine. Since the driving force is only a small density difference larger than normal pipe sizes must be used to minimise pipe friction. Connecting lines must be well insulated to prevent heat losses and sloped to prevent formation of air pockets which would stop circulation. At night, or whenever the collector is cooler than the water in the tank the direction of the thermosyphon flow will reverse, thus cooling the stored water. One way to prevent this is to place the top of the collector well below (about 30cm) the bottom of the storage tank.

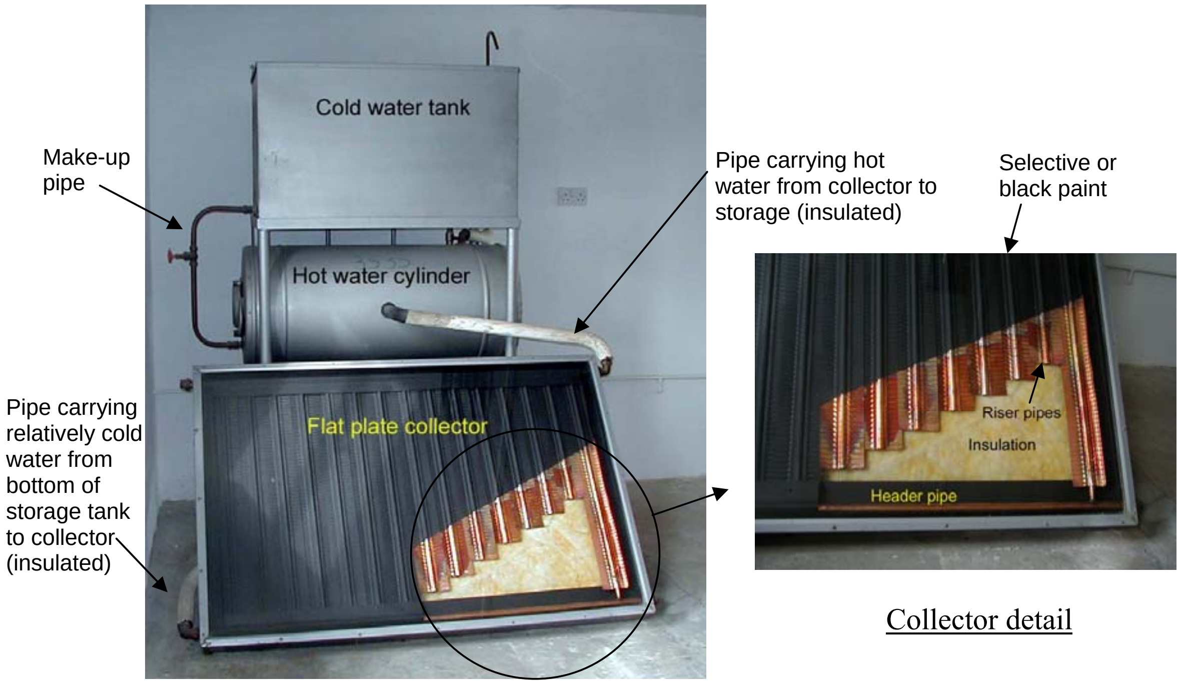


Fig. 6 Photo of a laboratory model thermosyphon solar water heater

The main disadvantage of thermosyphon systems is the fact that they are comparatively tall units, which makes them not very attractive aesthetically. Usually, a cold water storage tank is installed on top of the solar collector, supplying both the hot water cylinder and the cold water needs of the house, thus making the collector unit taller and even less attractive. For direct systems, pressure-reducing valves are required when the city water is used directly (no cold water storage tank) and pressure is greater than the working pressure of the collectors. The storage tanks are made of copper sheet insulated with glass wool or polyurethane. The casing is usually made of galvanised steel sheet. The supports are mainly made of galvanised pipe of angle iron.

Since in open loop thermosyphon systems the water from the storage tank enters the collectors and gets directly recirculated before use, scaling is a serious problem especially in areas where the water is hard; scaling tends to reduce performance with time.

The usual type of collector employed in thermosyphon units is the flat-plate. A typical flat-plate solar collector is shown in Fig. 7. When solar radiation passes through a transparent cover and impinges on the blackened absorber surface of high absorptivity, a large portion of this energy is absorbed by the plate and then transferred to the transport medium (water) in the fluid tubes to be carried away for storage or use. The underside of the absorber plate and the side of casing are well insulated to reduce conduction losses. The liquid tubes can be welded to the absorbing plate, or they can be an integral part of the plate. The liquid tubes are connected at both ends by large diameter header tubes (Kalogirou, 2004b).

The transparent cover is used to reduce convection losses from the absorber plate through the restraint of the stagnant air layer between the absorber plate and the glass. It also reduces radiation losses from the collector as the glass is transparent to the short wave radiation received by the sun but it is nearly opaque to long-wave thermal radiation emitted by the absorber plate (greenhouse effect).

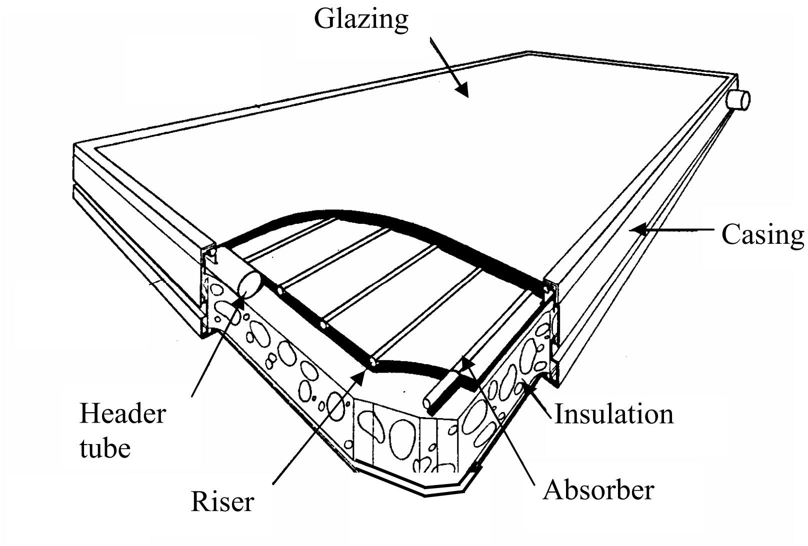


Fig. 7 Pictorial view of a flat-plate collector

Flat plate collectors are usually permanently fixed in position and require no tracking of the sun. The collectors should be oriented directly towards the equator, facing south in the northern hemisphere and north in the southern. The optimum tilt angle of the collector is equal to the latitude of the location with angle variations of 10° to 15° more or less depending on the application (Kalogirou, 2003).

A flat-plate collector generally consists of the following components as shown in Fig. 8:

Glazing. Glass or other diathermanous (radiation-transmitting) material.
Tubes, fins, or passages. To conduct or direct the heat transfer fluid from the inlet to the outlet.
Absorber plates. Flat, corrugated, or grooved plates, to which the tubes, fins, or passages are attached. The plate may be integral with the tubes.
Headers or manifolds. To admit and discharge the fluid.
Insulation. To minimise the heat loss from the back and sides of the collector.
Container or casing. To surround the aforementioned components and keep them free from dust, moisture, etc.

Flat-plate collectors have been built in a wide variety of designs and from many different materials. They have been used to heat fluids such as water, water plus antifreeze additive, or air. Their major purpose is to collect as much solar energy as possible at the lower possible total cost. The collector should also have a long effective life, despite the adverse effects of the sun's ultraviolet radiation, corrosion and clogging because of acidity, alkalinity or hardness of the water, freezing of water, or deposition of dust or moisture on the glazing, and breakage of the glazing because of thermal expansion, hail, vandalism or other causes. These causes can be minimised by the use of tempered glass.

For fluid-heating collectors, passages must be integral with or firmly bonded to the absorber plate. A major problem is obtaining a good thermal bond between tubes and absorber plates without incurring excessive costs for labour or materials. Material most frequently used for collector plates are copper, aluminium, and stainless steel.

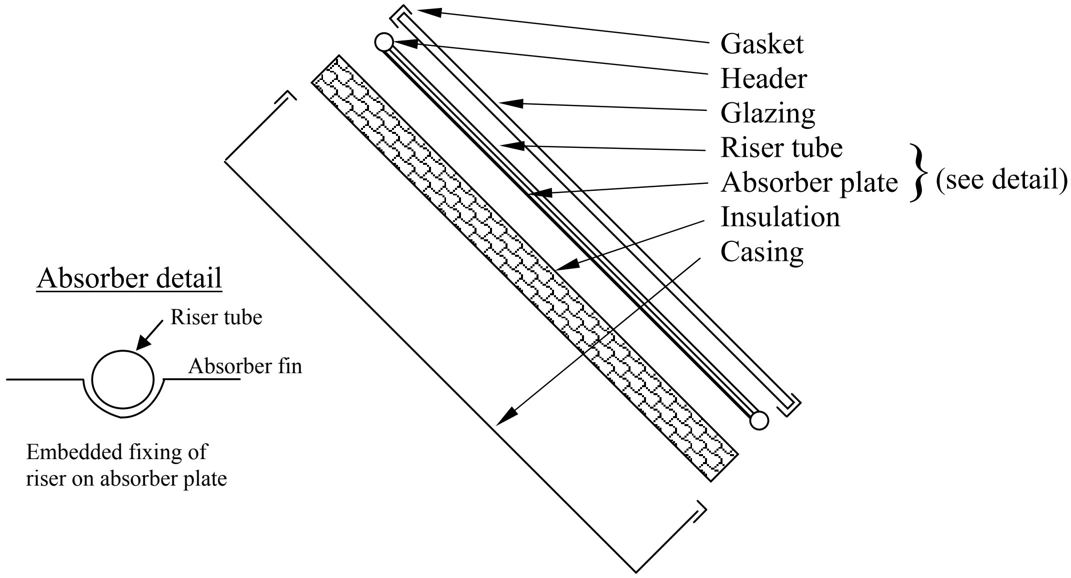


Fig. 8 Exploded view of a flat-plate collector and absorber detail

Flat plate collectors are by far the most used type of collector. Flat–plate collectors are usually employed for low temperature applications up to 100°C, although some new types of collectors employing vacuum insulation and/or transparent insulation (TI) can achieve slightly higher values. The characteristics of the flat plate collector considered in this study are shown in Table 1 whereas the characteristics of the thermosyphon system are shown in Table 2.

Table 1 Characteristics of a the flat plate collector considered here

Parameter	Characteristics
Riser pipe diameter	15mm
Riser tubes material	copper
Number of riser tubes	12
Header pipe diameter	28mm
Absorber plate thickness	0.5mm
Glass type	4mm low iron glass
Collector insulation	fiberglass 30mm sides fiberglass 50mm back
Fixing of risers on the absorber plate	Embedded
Absorber coating	Black mat paint
Glazing	Low-iron glass
External casing material	Galvanized sheet

Simulation studies of this kind of system were conducted with TRNSYS and the typical meteorological year (TMY) values for Nicosia-Cyprus. Details of the model are given in Kalogirou and Papamarcou (2000) and may not be repeated here, although it should be noted that in the aforementioned reference a system with poorly insulated storage tank was modelled. The results shown that such a system provide 7225 MJ useful energy (Q_u) per year. The energy flows of the system and the monthly contribution (F_{solar}) are shown in Fig. 9. The annual solar contribution obtained is 85% and the system could cover all the hot water needs of a house of four people in the four summer months. Solar contribution represents the amount of hot water load covered with solar energy. The maximum auxiliary energy (Q_{aux}) needed was during the month of January as shown in Fig. 9 (206 MJ). The division of Q_u and the incident energy falling of the collector (Q_{ins}) gives the collector efficiency. On an annual basis this is equal to 28%.

Table 2 System specifications.

Description	Value/Type
Total aperture area	$3.8m^2$
Storage tank capacity	160 litres
Auxiliary heater	3kW electric element
Efficiency mode	$n\ v_s\ (T_i - T_a)/G$
G_{test} – flow rate per unit area at test conditions ($kg/s\text{-}m^2$)	0.015
I – intercept efficiency	0.79
S – negative slope of the first-order coefficient of the efficiency ($W/m^{2\ \circ}C$)	6.67
b_o – incidence angle modifier constant	0.1
Collector slope angle	40°

The scenario used in the economic analysis is that the total cost of the solar system is paid from the beginning (i.e., no credit payments are assumed). The thermal performance degradation of the system is assumed to be 1% per year, the period of economic analysis is taken as 20 years (average life of locally produced systems), whereas all the other percentage figures (inflation rates and market discount rate) are mean values of the last 10 years. Electricity is assumed to be used for the auxiliary heating element. The results obtained show that the pay-back time is 4 years and the present worth of life cycle savings is equal to €1120.

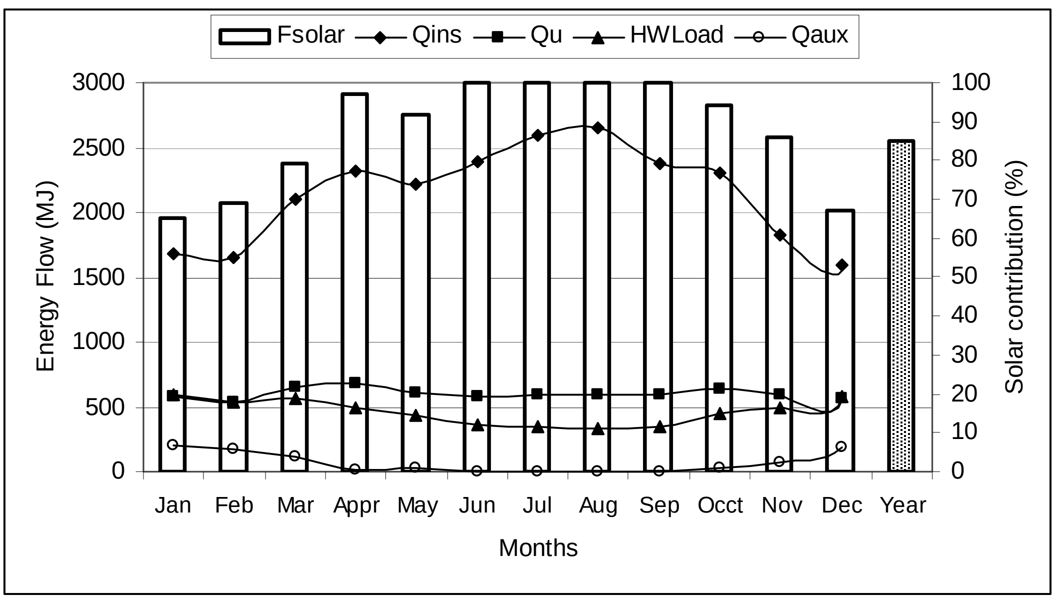


Fig. 9 Predicted energy flows of the system and solar contribution of the thermosyphon solar water heater

5. LIFE CYCLE ANALYSIS

Sometimes people argue about the real environmental benefit of this kind of systems. Therefore a study was undertaken by the author recently to evaluate the environmental benefits resulting on the use of the system and the return of the energy required to manufacture the systems (Kalogirou, 2004a).

Several potential solutions to the current environmental problems associated with the harmful pollutant emissions from the burning of fossil fuels have evolved, including renewable energy and energy conservation technologies. Many countries consider today solar, wind and other renewable energy sources as the key to a clean energy future. Renewable energy systems can have a beneficial impact on the environmental, economic, and political issues of the world. The energy saving and environmental benefits derive from the reduction in consumption of electricity and/or diesel which are used conventionally to provide energy.

To investigate the environmental benefits of utilising solar energy instead of conventional sources of energy, the different emissions resulting from the solar system operation are estimated and compared to those of a conventional fuel system. The emissions reported are those which are responsible for the most important environmental problems. The environmental pollution is expressed in physical units of the emitted substances per year. The quantities of the emissions depend on the solar collector size and the required auxiliary energy and are compared to a non-solar system which is using electricity (immersion heater). The results are shown in Table 3.

Table 3 Environmental impact of thermosyphon system with electricity backup

Emissions	Units	Conventional	Solar system	Savings (%)
Carbon dioxide (CO_2)	Tons/year	1.982	0.40	79.8
Carbon monoxide (CO)	g/year	496	100	79.8
Nitrogen oxides (NO_x)	g/year	74	15	79.8
Nitrous oxide (N_2O)	g/year	7	2	79.8
Methane (CH_4)	g/year	12	3	79.8
Hydrocarbons	g/year	50	10	79.8
Sulfur dioxide (SO_2)	g/year	743	150	79.8
Dust	g/year	248	50	79.8
Savings in GHG	%	-	-	79.8

As can be seen by using solar energy instead of conventional fuel a very large amount of pollutants are avoided. The percentage saving obtained is about 80%. Therefore for the Cyprus case, if the number of existing solar water heaters (mentioned in section 3) is considered, one can understand the magnitude of the environmental pollution reduction per year, just for water heating.

The negative environmental impact of solar energy systems includes land displacement, and possible air and water pollution resulting from manufacturing, normal maintenance operations and demolition of the systems. However, land use is not a problem when collectors are mounted on the roof of a building, maintenance requirement is minimal and pollution caused by demolition is not greater than the pollution caused from demolishing a conventional system of the same capacity. Additionally, all materials used in the construction of the collector can be recycled.

The pollution created for the manufacture of the solar collectors is estimated by calculating the embodied energy invested in the manufacture and assembly of the collectors and estimating the pollution produced by this energy. The total embodied energy required to produce a solar hot water system is calculated using primary and intermediate production stages. The primary stage is established from an assessment of the various materials used and their corresponding mass. Table 4 summarizes the unit materials used and lists their corresponding mass and embodied energy content for the production of one flat-plate collector panel. As can be seen from Table 4, the total embodied energy content is calculated at 3540 MJ. This comprise the primary embodied energy of materials and the intermediate embodied energy, i.e., the amount of energy used in the production and assembly of the component parts during the construction stage and was determined through a stage-by-stage appraisal of the power sources used. Inherent within this intermediate stage is the fabrication of purchased components like screws, glass and insulation.

Table 4 Embodied energy content of one flat-plate collector 1.9m^2 in area.

Description	Mass (kg)	Embodied energy index (MJ/kg)	Embodied energy content (MJ)
1.9x1x0.05m insulation	6	117	702
1.9x1x0.005m glass	13.4	15.9	213.3
2m, 22mm copper pipe	2.4	70.6	169.5
20m, 15mm copper pipe	12.4	70.6	875.5
2.3x1.3x0.005m galvanized steel sheet	11.7	34.8	408.4
6m rubber sealant	0.6	110	66
Black paint	0.3	44	13.2
Casing paint	0.9	44	39.6
20 No. screws	0.00125	34.8	Ignored
1.9x1x0.003m copper absorber	5	70.6	353
Total			2840.5
Add 10% for contingencies			284.1
Unit manufacture using a net to gross value of conversion rate of 27%			415.4
Grant Total			**3540**

An analysis of the embodied energy content of the complete solar water heating system is shown in Table 5. It should be noted that only the extra components of the solar system are considered in this analysis as the other components are standard and are also present in the conventional system. As can be seen the total embodied energy for the complete system is 8700 MJ.

Table 5 Embodied energy content for the construction and installation of the solar water heating system

Description	Mass (kg)	Embodied energy index (MJ/kg)	Embodied energy content (MJ)
2 No solar panels	-	-	7080
4m, 22mm copper pipe	3.8	70.6	268.3
4m, pipe insulation	1	120	120
Steel frame	30	34.8	1044
Total			8512.3
Installation			187.7
Grant Total			**8700**

The objective of this analysis is to compare the pollution created for the manufacture and installation of the solar systems against its benefits due to the lower emissions realized during the operation of the systems. Therefore, for the life cycle assessment of the systems considered the useful energy supplied by solar energy per year (7225 MJ), is compared with the total embodied energy of the systems shown in Table 5. As can be seen the total energy used in the manufacture and installation of the systems is recouped in about 1.2 years, which is considered as very satisfactory.

The emissions created from total embodied energy are presented in Table 6. Additionally, these emissions are compared with the emissions saved because solar energy is used instead of auxiliary energy in order to estimate the payback period for each pollutant. In all cases the emissions are estimated by considering that all embodied energy was produced from electricity. This is not quite correct but electricity is chosen, as is the most polluting fuel, therefore it gives the worst possible results. As can be seen from Table 6, the payback periods for the cases investigated vary from 1.2 to 1.5 years according to the particular pollutant considered.

Table 6 Pollution created for the construction and installation of the solar water heating system and payback times

Emission	Pollution created from solar system embodied energy	Savings and payback of solar system
Carbon dioxide (CO_2)	1.934 Tons	1.582 (1.2)
Carbon monoxide (CO)	483 g	396 (1.2)
Nitrogen oxides (NO_x)	72.5 g	59 (1.2)
Nitrous oxide (N_2O)	7.3 g	5 (1.5)
Methane (CH_4)	12.1 g	9 (1.3)
Hydrocarbons	48.3 g	40 (1.2)
Sulfur dioxide (SO_2)	725 g	593 (1.2)
Notes: 1. Number in parenthesis represent payback in years 2. The units of savings are in g/year except carbon dioxide which is tons/year		

6. PROSPECTS

The prospects of the solar water heating industry are good. The first sector that may be improved is that of the hotel industry. Hotels usually spend a lot of money in decoration and the creation of attractive environment for their customers. In addition to its cost benefits, the use of solar energy for water heating can be advertised as an environmentally friendly feature of the hotel. Terms such as "**Green Hotel**" can be adopted in such a case in order to attract "**green tourists**" who are groups of people sensitive to energy conservation and environmental issues. Hospitals and schools are some other sectors of the economy that can adopt solar energy for water heating.

Additionally the use of solar energy for space heating and cooling and for process heat in industry (**green heat**) is a further challenge for the Cyprus water heating industry. There are a number of experimental buildings equipped with solar active systems in combination with oil-fired central heating systems. The results obtained by monitoring these applications is that solar space heating does not seam to be an economically attractive proposition due to the very high initial investment cost, the short annual duration of optimal use of the system, leading to a long pay-back period. However, such a system can be combined with absorption cooling to cover also the cooling needs of a house provided domestic size absorption units are developed.

Another incentive is to promote the exports of solar water heaters. Today exports are occasional and are estimated to be about 200 units per year (about 600 m^2 per year).

Another area that can be developed is that of solar industrial process heat applications. There is no commercial application of industrial process heat in Cyprus so far due to the "chicken and egg" theory, i.e., no entrepreneur will invest on research and development funds without a sizable market and there is no sizeable market until low-cost, proven technology units are available. Perhaps this impasse can break from the new subsidisation scheme of the Government which is now in effect and provides some financial aid towards the initial cost of the system. The same applies for solar desalination and solar thermal electricity generation.

7. CONCLUSIONS

The abundance of solar radiation together with a good technological base, created favourable conditions for the exploitation of solar energy in the island. The contribution of solar energy to the total energy consumption is 4.5%. This energy is used mainly in the domestic sector (93.5%) for hot water production. The number of solar water heating units in operation today corresponds to one heater for every 3.7 people in the island, which is a world record. The majority of these systems are of the thermosyphon type.

Such a system is modeled with TRNSYS and the results show that the system can provide 7225 MJ of energy per year and the solar contribution is 85%. The financial characteristics of the system investigated give life cycle savings, representing the money saved because of the use of the system throughout its life instead of using electricity, equal to 1120 Euro and pay-back time equal to 4 years.

Additionally, in this study the environmental protection offered by the system is presented. The results show that by using solar energy considerable amounts of greenhouse polluting gasses are avoided. The saving, compared to a conventional system, is about 80% when electricity backup is considered. The energy spent for the manufacture and installation of the solar systems is recouped in about 1.2 years, whereas the payback time with respect to emissions produced from the embodied energy required for the manufacture and installation of the system varies from 1.2 to 1.5 years according to the particular pollutant considered.

The prospects of the solar water heating in industry, solar desalination and solar electricity generation are good. A sector that may be improved is that of the hotel industry. Additionally the use of solar energy for space heating and cooling and for the applications mentioned above is a further challenge for the Cyprus water heating industry.

It can therefore be concluded that solar energy systems are friendlier to the environment and offer significant protection of the environment. The reduction of greenhouse gasses pollution is the main advantage of utilizing solar energy. Therefore solar energy systems should be employed whenever possible in order to achieve a sustainable future. We own it to our children, our grandchildren and the generations to come.

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