ENVIRONMENTAL FRIENDLY ENERGY SOURCES IN CYPRUS

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ABSTRACT

Cyprus has a small isolated energy system, almost totally dependent on imported fuels to meet its energy demand. 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. Cyprus began manufacturing solar water heaters in the early sixties. The number of units in operation today corresponds to one heater for every 3.7 people in the island, which is a world record. Simulation studies and economic analysis of domestic systems show that 80% of the annual hot water needs of a house of four are covered while the life cycle savings of such system for the current rate of electricity are £740 (€1260) and the pay back time is 4 years. Additionally, such a system, saves 80% of the greenhouse gasses emissions compared to a conventional system. The prospects of the solar water heating industry 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 process heat in industry is a further challenge for the Cyprus water heating industry. The use of other forms of renewable energy systems like PV and wind is very limited. This however is expected to change in the near future due to the incentives given by the Government with the new subsidisation scheme, which is in action since last year.

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 (Hadjioannou, 1987). 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 flat-plate collectors, which 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.

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.

Fig. 1 Practically every house in Cyprus is equipped with a solar water heater.

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. Dhekelia power station consists of 6 x 60 MWe steam turbines. 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.

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 (risers and headers). 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. A number of applications of this type of system in various houses are shown in Figures below. Figure 2 shows the most typical system installed on a flat roof house whereas Fig. 3 shows various applications of systems installed on inclined concrete roofs. These are used nowadays in Cyprus, as an imitation of the old wooden roofs, because they are more aesthetically appealing. 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. 4. 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 Applications of tower-type solar water heaters installed on inclined concrete roofs.

Fig. 4 Pressurised solar water heater installed on an inclined roof.

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 characteristics of a typical system modelled

in this paper are given in Table 1. The results shown that such a system provide 7250 MJ per year. The monthly contribution is shown in Fig. 5. The annual solar fraction obtained is 80% and the system could cover all the hot water needs of a house of four people in the four summer months. The solar fraction determines the percentage of hot water load covered by solar energy. The maximum auxiliary energy needed was during the month of January as shown in Fig. 6 (about 270 MJ).

The scenario used in the economic analysis is that all the 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 £740 (€1260).

Table 1 System specifications.

Description	Value/Type
Total aperture area	2.7m^2
Storage tank capacity	150 litres
Riser tubes material	copper
Number of riser tubes	12
Absorber surface	painted mat black
Glass type	4mm low iron glass
Collector insulation	fiberglass 30mm sides fiberglass 50mm back
Auxiliary heater	3kW electric element

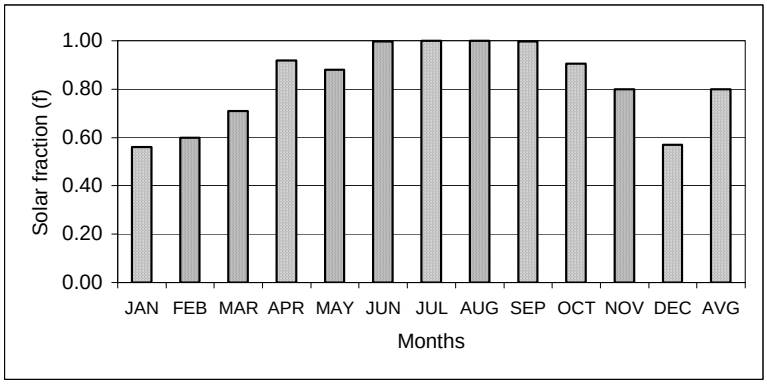

Fig. 5 Predicted monthly and yearly solar contribution of the thermosyphon solar water heater.

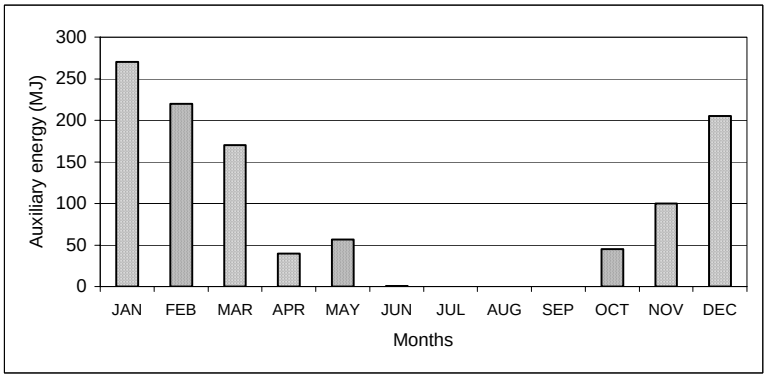

Fig. 6 Predicted monthly auxiliary energy needed by the system.

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. 7. 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 of proper inclination (b) Installation detached from the house.

Fig. 7 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 (this was at a much lower fuel price than today's 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. 8).

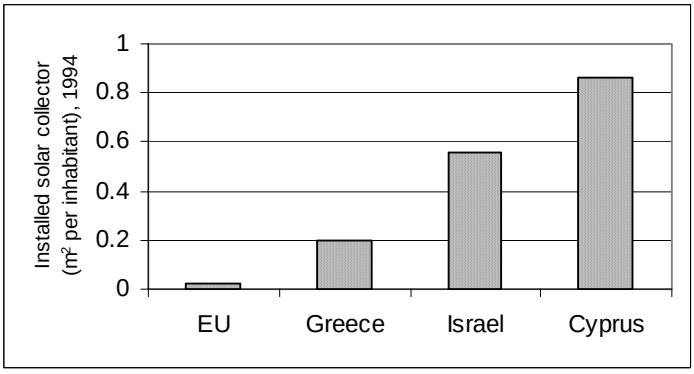

Fig. 8 Installed solar collector area per inhabitant, 1994.

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 are still operational.

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 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.

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

4. 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, 2004).

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 diesel. The results are shown in Table 2.

Table 2 Environmental impact of thermosyphon system with diesel backup

Emissions	Units	Conventional	Solar system	Savings (%)
Carbon dioxide (CO_2)	Tons/year	0.766	0.259	66.3
Carbon monoxide (CO)	g/year	1615	363	77.5
Nitrogen oxides (NO_x)	g/year	1615	324	80.0
Nitrous oxide (N_2O)	g/year	7	1	80.7
Methane (CH_4)	g/year	15	3	82.8
Hydrocarbons	g/year	62	11	82.8
Sulfur dioxide (SO_2)	g/year	775	145	81.3
Dust	g/year	136	52	61.7
Savings in GHG	%	**-**	**-**	**80.0**

As can be seen by using solar energy instead of conventional fuel a very large amount of pollutants is 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.

5. OTHER RENEWABLE ENERGY SYSTEMS

Despite the good penetration of solar water heaters no other significant application of renewable energy systems exists on the island. The systems that can be considered are photovoltaics, wind turbines, industrial process heat, solar desalination and solar thermal electricity generation.

Applications of photovoltaics in Cyprus are very limited. These are mainly used in television transmission stations at the mountains and for the lighting of public telephone booths (Fig. 9). There are also some very limited applications of PVs in private houses and in agriculture for water pumping. The installed capacity of photovoltaics up today is estimated at 2.2 MW. The new Electricity Authority building headquarters includes a 2 MW PV shading system (Fig. 10). This is the largest PV system on the island.

Fig. 9 Telephone booth powered by PV

Fig. 10 EAC Headquarters PV shading system

A PV manufacturing facility is set-up a few years ago in Cyprus. It produces standard PV panels with a capacity of 160 W_e with PV cells imported from Germany. The produced panels are used both at the local market and for exports.

Given the good solar potential of the country, the opportunities for PVs and solar thermal applications, like industrial process heat, solar desalination and solar thermal electricity generation, are enormous. These could now be easily carried out with the help of the Government through the new subsidization scheme.

Despite the extended use of wind turbines for water pumping, which were used all over Cyprus during the last decade, no wind power plants are installed today. The wind potential of Cyprus is rather limited but there are certain locations on the island where small wind parks can be installed. One of these is the area near the Kourris dam. In this area the very first wind park will be installed by the Electricity Authority of Cyprus. The park will be relatively small and will be constructed on a pilot basis, mainly to evaluate the potential of Cyprus in this form of renewable energy.

The new subsidisation scheme is put into operation since the beginning of last year. It includes the subsidisation of the initial cost of newly build systems as well as the replacement of old solar flat plate collectors. The amount of subsidies depends on the type of applicant, household or industry. For an individual owner subsidies of the initial cost are up to 40% for solar thermal systems and 55% for PVs. Furthermore, for grid connected PVs the Electricity Authority is obliged to buy the produced energy at a rate of 0.12 £/kWh (0.20 €/KWh) whereas the current rate is about 0.07 £/kWh (0.12 €/kWh). It is believed that the subsidisation scheme would create a positive boost in the application of solar energy systems, both thermal and PV, in households (for central heating systems) and industry.

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 seem 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 (600 m^2 per year).

There is no commercial application of industrial process heat in Cyprus 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. The same applies for solar desalination and solar thermal electricity generation.

The prospects of PV and wind systems are good especially now that the new subsidisation scheme is in action. Due to the abundance of solar radiation available, PV systems have good prospects of success, however their cost needs to be reduced considerably in order to make them competitive.

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 hot water units in operation today corresponds to one heater for every 3.7 people in the island, which is a world record.

Additionally, in this study the environmental protection offered by the most widely used renewable energy system, i.e., solar water heating 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 diesel backup is considered. Also the system gives positive and very promising financial characteristics.

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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