Solar-Collector Industry in Cyprus: Technico-Economic Analysis and Future Perspectives

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This paper deals with the industry of solar water heaters in Cyprus. We first introduce a brief review of the historical development followed by an analysis of the Cypriot solar industrial environment. The role of the Cyprus standards and of the energy department is examined. The basic characteristics of the market of the solar industry including details regarding price inputs; suppliers and technology are presented. An investigation concerning the habits and preferences of the Cypriots towards solar products is described together with a detailed analysis of the production and economic cycle of the solar industry. Finally the impact of solar collectors on the Cyprus energy balance will be considered. The main sources of information were derived from surveys of the department of statistics and interviews with the managers of the largest factories of the island.

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I. HISTORICAL PERSPECTIVES

Cyprus is situated at 35° north of the equator and 33° east of Greenwich. Due to its geographical position Cyprus enjoys an average solar radiation of about 5.4 kWh/m^2/day [1-4] on a horizontal surface. This great advantage has been exploited since 1956 when the first solar water heater (SWH) was imported from Israel for heating water for domestic purposes.

The device had dimensions of 1850 cm x 940 cm, and its anticipated durable lifetime was estimated between 20 and 25 years, given the use of galvanised pipes to minimise corrosion. This design was largely used until 1974. Throughout this period the industry utilised an empirical approach to optimise the SWH characteristics.

As with every economic activity in Cyprus, the SWH industry was greatly affected by the Turkish invasion of the island in July 1974. With one third of the population becoming refugees in their own country, the necessity for new and temporary buildings, primarily housing projects, resulted in a dramatic evolution of the construction industry. This directly affected the demand for SWHs. We emphasise the fact that the government constructed the majority of the temporary houses and this was one of the main reasons for the widespread installation of solar water heaters because the government policy dictated that every house should have such a system. This sudden upsurge in demand encouraged the industry to improve the old designs offering more efficient SWH systems.

1980 is a year characterised by the beginning of more research and development. The 1980's SWH was considerably improved in comparison with the first imported design; the galvanised pipes were now made of copper, the casing was made of aluminium and the dimensions were standardised (1m x 1.5m). Additionally, the absorber plate was painted with special selective paint increasing its durability from between 30-50 years, with no servicing required whilst also improving its appearance. Despite the above improvements, some producers maintained the older technology in order to sell less expensively while ignoring the benefits of the technologically advanced solar collectors and forcing a two-tier pricing policy. It is noted that the above characteristics are still valid for most of the industries.

Since the adoption of SWHs in 1956 they have become necessary additions to almost all new houses. The most significant factor of this phenomenon is the patient and vigorous efforts of the first factories, steadily pushing and improving the technological level of their products. In fact, a SWH is a basic investment affordable by all Cypriot consumers that provides a return on the initial costs by proving to be less expensive than either oil or electrical heating. The SWH involves one-time set-up costs that are depreciated through time, while electricity involves variable costs that are paid with time used. The total cost of a SWH system is approximately 500 Cyprus pounds (including installation); an amount easily affordable by every household.

II. STANDARDS AND TESTING OF SOLAR COLLECTORS

The existence of standards and testing procedures ensure the high quality of SWH. The standards, a responsibility of the Cyprus Standards Organisation (Ministry of Commerce, Industry and Tourism), are implemented by the Applied Energy Service (Ministry of Commerce, Industry and Tourism).

II.1 History of Cyprus Standards

The Cyprus Standards Organisation (CYS) has initially formulated two standards concerning the efficiency of solar water heater.

Firstly the CYS100:1984 examined the testing of Solar Water Heaters intended for domestic use. This standard defined the requirements for the materials used and the method of SWH construction. Later the CYS119:1989 standard was adopted in order to test the performance of flat-plate solar collectors. This testing was carried-out outdoors in real conditions.

However, by defining all the materials of the standard model the CYS100:1984 standard was actually quite restrictive for any further research and development, especially given the continuing improvements in technology. Therefore, two new standards were established. The first was CYS209:1991, which defines the testing method used for the evaluation of the thermal efficiency of solar systems (flat-plate collector, tank, pipes etc.) intended for domestic use. This method is also used for the prediction of the long-term performance and behaviour of solar systems under all meteorological circumstances. The second standard is CYS 259:1994, in fact the most recent standard being used, and defines the procedures for the evaluation of the thermal efficiency of solar collectors. All testing is either carried-out outdoors with natural solar radiation or in a laboratory using artificial radiation.

The main advantage of the two latest standards is that they examine the performance of any model using one scientific method without defining the materials used, the design and so on. Additionally, these two standards comply with the requirements of the European Union being identical to the ones used by E.U. services. Also, due to their accuracy and scientific level they were announced by ISO (International Organisation for Standardisation) to be International Standards.

II.2 Energy Services

The Energy Service of the Ministry of Commerce, Industry and Tourism carries out the testing of the solar systems. This department was founded in 1978,with the help of the government, and its prime scope is to help manufacturers of solar thermals, providing them with professional advice and evaluation of their models. In addition, the department gives advice to the manufacturers concerning the improvement of the performance, design and marketability of their products. This task is tremendously important for the local industry knowing that imports of solar collectors and of solar systems are increasing. The services of the Department are free to all Cypriot companies in an effort to urge solar thermal industries to consult the department. The evaluation of any model is based on the methods described by the standards mentioned

above, CYS209 and CYS259, in this way all models are tested by a typical procedure. When the evaluation is completed test certificates are issued describing performance characteristics. However, these certificates are not obligatory; consequently many SWHs do not comply with the standards. The situation could be improved if the consumers were informed about the existence of the department and the relevance of the certification. Consumer pressure to see certification (ensuring quality) will ultimately force manufacturers to use the services of the department enhancing the quality of their goods.

III. MARKET OF SOLAR THERMAL COLLECTORS

III. 1 Supply Side

In this section, the basic characteristics of the supply side are analysed. As previously mentioned the first SWH units were imported from Israel in 1956. The value of the investment was soon realised by consumers and local producers started to emerge to meet this demand. The industry was enhanced when in 1978 the government set-up the Energy Service and custom duties on materials used for production were removed. A response to this is that every public building installs a SWH system.

A. TECHNOLOGY

In this part, the solar collector together with the entire system is considered because the technology and problems of the system directly affect the solar collector.

A.1 Production Line

The production line of solar collector plates is semi-automated. First, the casing is constructed using aluminium or zinc, having dimensions of 1m X 1.5m. Then, the absorber plate is manufactured based on two main designs (see Fig. 1). In the case of Fig. 1(b) the absorber plate collects more radiation when the rays fall at an angle and in this way the efficiency of the whole system is improved. At the same time the copper pipes are manufactured. Special care must be taken when the risers are welded to the headers. The risers are bonded to the plate using a variety of techniques that affect the thermal contacts (roll bonding is practised only by one company). If the producer wishes to make his model more efficient, he must fit the risers into previously made corrugations in the plate. The use of soldering or special adhesive can improve the contact. Note that headers must be bigger than risers to ensure quick scaling and quick storage of hot water. When the pipes are ready they are fixed on the absorber plate. Thereafter, the pipes and the plate are painted with a special black paint and at this stage the casing is thermally isolated with special cotton. Finally, the absorber plate is installed in the casing, which is closed using glass. The solar collector is now ready for use. Generally all companies follow this production line.

A.2 General Technological Features

The majority of SWH systems installed on individual dwellings are of the thermosyphonic type. Such a system is comprised of two solar collectors (total glazing area of $3m^2$) connected in series to a hot water tank that is placed above the top of collectors and a cold water storage tank. The hot water tank is made of copper and it is insulated with glass wool or polyurethane. The capacity of the tank is 180 litres. Originally all hot water tanks were installed with their axis being vertical to the roof whereas recently some have a vertical axis. The vertical axis design is becoming very popular due to its improved appearance, in spite of the fact that it suffers from increased reverse flow and lack of stratification, which results in lower system efficiency. Another feature of the hot water tank is that it is equipped with an auxiliary electric 3 kW heater operated either manually or automatically when sunlight exposure is not sufficient to heat the water.

A.3 Maintenance of SWH

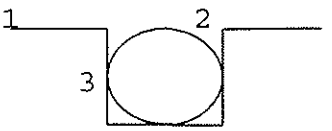
In Cyprus there are now many factories and craftsmen producing SWHs, therefore the availability of maintenance is very good. The quality of service is also satisfactory due to the extensive experience of the manufactures. Certainly consumers can have their SWHs repaired quickly and efficiently.

A.4 Efficiency

The efficiency of SWH systems is measured by the "Applied Energy Department" in accordance to the Cyprus Standard 119:1980. The evaluation process provides curves for the dependence of thermal efficiency n, on $\Delta T/G$ (ΔT is the difference between the mean temperature of the fluid in the

Figure 1(a)

Type (a) absorber plate



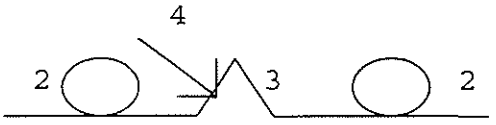
1: absorber plate

2: pipes

3: special canals for the pipes

Figure 1(b)

Type (b) absorber plate



1: absorber plate

2: pipes

3: special peaks

4: sun-rays

collectors and the ambient temperature in °C; G is the solar insulation in W/m^2). The distribution of the efficiency n*, for $\Delta T/G = 0.03 m^{2o}C/W$ for a group of locally produced collectors, tested recently at the facilities of the department, is:

Range:	Number:
40-44%	2
45-54%	17
55-60%	17
Over 60%	4

So, the average efficiency for $\Delta T/G = 0.03$ is approximately 54%.

A.5 Technological Problems

There are a variety of technological problems that have been encountered, of which the effect of scaling (lime scale build-up) is one of the most problematic. In thermosiphon systems the water from the storage tank enters the collectors and gets directly recirculated before use. Therefore, in areas where the water is hard, scaling reduces the performance with time. Another problem is the type of the absorber plate, because corrosion may occur if the fluid and the metal used are incompatible. The plate may also corrode at the point where it is joined to the tubes if dissimilar metals (i.e. copper and aluminium) are used. In addition, the black surface may flake off or deteriorate under exposure to thermal ceiling, humidity and radiation. Finally, the tubes and their welding may distort or fracture due to high temperature, pressure, and scaling or if improper welding methods are used.

B. INPUTS

For the industry under consideration the inputs are labour, machinery and raw materials. Specifically galvanised iron sheets, fibreglass and aluminium are used for the casing; copper is used for the risers and headers and copper, aluminium and U.I. sheet are used for the plate. Furthermore, clear glass, window glass, and non-solar-selective paints are used for the glazing area, with rubber used for the gaskets. Finally, for painting the absorber plate one may use selective or non-selective black paints.

An important issue is the availability of the above inputs. If the access to them is restricted then the producer cannot instantaneously respond to excess demand. In this situation, he must organise his production in advance based on past experience and prediction. This is however a very complex task and if predictions are incorrect this can lead to over or under stocking. The former is not as damaging to the producer as is the latter. Given that the change in technology is relatively slow, he is unlikely to be left with unusable stock. All the above materials are quite general and a surplus will be useful when repairs or servicing is required.

According to the managers of the most important industries, on average, a company can easily employ new workers. Non-specialised workers are in abundance, but specialised craftsmen are not so easily found. However, according to the managers, the basic problem is the high labour costs that cannot be transferred to the consumer through the retail price, due to high price competition. At the same time, it is expressed that the productivity of labour (output produced per unit of labour) decreases intermittently.

The rest of the materials can be provided (according to the managers) with relative ease. However, when the demand for copper is high its provision is difficult. The costs of materials are reasonably low, with prices kept low by the competition between the large number of merchants, who have increased in number as the industry has increased in size. Furthermore, that there are no custom duties on imported materials (a form of government relief) for use in the manufacturing of solar water heaters further contributes to the low costs.

C. TYPES OF SWH SUPPLIERS

In order to understand the structure of the supply side one must investigate the types of suppliers. These types determine the motives of the supplier for the product. If SWHs are the main product of a company then the company will behave differently in comparison to the case where the SWHs are complementary to a set of products. Following this reasoning, suppliers of SWH can be divided into three categories. Firstly, one encounters industries that locally produce solar collectors, whilst also offering the rest of the parts to a SWH system. They also take the responsibility of plumbing the SWH system into the customers' houses. Generally, they do not offer or sell other

products and most of these businesses are family owned and managed. The second category is of importing companies that mainly deal with generic plumbing equipment, bathroom equipment, etc. In order to offer a complete set of products, they import solar collectors and solar water systems, knowing that every new house buys one. Furthermore, customers prefer to buy their home equipment from one source, saving time and money (the homeowners also tend to buy many products, so they can bargain the total retail price). Finally, the third category classifies companies that import and produce solar collectors. These companies are basically the big factories of the island.

The companies that produce SWH can be further classified, based on the technology applied. Again, one encounters three categories. The first category consists of only a few factories that apply advanced technology and charge higher prices accordingly. The second group, which includes the majority of the local factories, utilises very little modern technology. The third category represents factories that apply almost no technology, their numbers lie between those of the other two categories. Although there are many differing degrees of technology, there is still great competition between these categories, with the big factories arguing that they offer better quality, charging higher prices. In contrast the smaller factories support that they also offer the necessary quality but at lower prices. It is often difficult to explain to consumers the subtleties of technical details (why one model is better than another) and because consumers tend to look for less expensive bargains, small, technologically immature enterprises survive. In this competitive situation one must not forget imported products. "Imports" suggest quality and Cypriots have traditionally preferred imported goods, believing them to be superior to local produce even though in this case this is largely unfounded. Therefore, because of their relative low prices, imports pose the biggest threat to the local industry.

D. NUMBER OF SUPPLIERS

Table 1 presents the number of local industries in the years 1988 and 1994, but does not represent the size of these industries, i.e. whether workshops or factories. In general, a significant increase in the number of local industries is observed between these years. In Nicosia and Larnaca districts the industries doubled, in Limassol district they remained constant, while in Paphos and Famagusta districts two and seven industries closed, respectively. The two industries in the Famagusta district still functioning are small workshops since the needs of the district are covered by the production of other industries located elsewhere. As was expected, Nicosia, being the largest of all districts, has the largest number of factories, following high demand. Limassol, (the 2nd in size district) has only 8 units. However, these units are big factories with large production that can offer both improved quality and lower prices than any workshop. Generally, out of these 58 companies only a small fraction imports SWH. The main importers, estimated to be about 10-15, have not been recorded since SWH are only a small part of their activities.

A common issue, connected with the number of suppliers, is the type of market in question. The two extreme situations are perfect competition, i.e. a completely open market and a closed monopoly. However, the number of industries in Cyprus suggests an oligopolistic market, offering differentiated products. Nevertheless, producers consider the sector to be highly competitive due to the small size of the country and high demand, the good transportation system together with a well-organised information network. The market price of SWH from 1992 to 1995 remained almost unchanged (see III.2.c) suggesting that during this period there was tough competition amongst the companies.

III. 2 Demand Side

The other driving force of the economic system is demand. One must bear in mind that at the end of the day what matters is who purchases the product. Therefore, the suppliers must understand the preference and needs of the different types of consumers adopting their products accordingly. In this way, they can increase their sales and profits.

A. TYPES OF CONSUMERS

Thus far we have concentrated on the home consumer, because it was this market that spawned

Table 1: Number of local industries in Cyprus in the year 1988 and 1992

TOWNS	1988	1994
Nicosia	15	30
Famagusta	9	2
Larnaka	7	14
Limassol	8	8
Paphos	6	4
Kerynia	–	–
TOTAL	45	58

Table 2: Total Preference Percentages for SHW for 1988-1994

Year	Percentage Total	Percentage Urban	Percentages Rural
1988	88	88	90
1989	87	86	88
1990	93	93	93
1991	92	95	85
1992	92	91	94
1993	93	93	93
1994	95	95	95

Table 3: Preference Percentages of Houses and Apartments per District for 1994.

District	Preference % of Houses	Preference % of Dwellings (Houses & Apratments)	% of Ap. out of new deal
Nicosia	99	95	25
Famagusta	100	95	77
Larnaka	99	93	40
Limassol	97	97	19
Paphos	100	94	53

the SWH market in the first place. Now in a mature SWH market the consumers of the industry can be classified according to the construction on which the SWH is installed. Therefore, one may define three basic categories, dwellings (private and public), hotel apartments and hotels. The latter two categories are a consequence of the now flourishing Cypriot tourist industry that has seen remarkable growth since the Turkish invasion of 1974 and constitutes a significant portion of the overall market.

Dwellings remain the most significant market sector with an average of 95% of all new private dwellings in 1994 and all public dwellings installing a SWH. Hotel apartments are in second place with an installation percentage of 80% and finally hotels with a percentage of 44%. The difference in these percentages is due to the distinct needs and characteristics of each category. On average, four or five people in Cyprus live in a house. Therefore, a SWH with a glazing area of $3m^2$ is enough to cover most of their hot water needs in the winter. In the extreme case where there is little sunshine, they can supplement the heating mechanism with electricity. It is cheaper for them to use a combination of SWH and electricity than to use electricity alone. Hence, their installation percentage is higher than hotel apartments and hotels. Hotel apartments are small houses let to visitors in the summer season. Therefore, the investors knowing that there is little need for hot water in the summer prefer not to use SWH extensively, since it is less expensive to install elements in tanks than to have a SWH for each apartment. Hotels also share this reason for the lack of SWH installations. Bear in mind that Cyprus is a summer tourist resort and in winter (when hot water is needed) the number of visitors is drastically reduced. Those who do holiday in Cyprus usually take hotel rooms as part of a package deal; therefore, the hotel apartments remain empty. Furthermore, hotels must have hot water all the time to meet customer demand and electricity is a more reliable heating source, especially during winter. Unlike hotel apartments, hotels are busy in winter, businessmen stay there, wedding receptions are held, conferences are organised and so forth. Therefore, in winter they not only need to have hot water as part of the facilities offered but also they need plenty of it for their activities. Moreover, there are technical reasons that make SWH impractical for hotels. Hotel roofs are used for all kinds of equipment such as air-conditioning units and there is no room for a big SWH system required for the extensive needs of a hotel.

Saving energy is imperative nowadays and therefore the government has established financial incentives for all the aforementioned consumers. This has resulted in SWH being installed on all residential public buildings (mainly for refugees). Also, every commercial bank is obliged to provide loans (at 8% interest rate) to all house-owning applicants for the purchase of a SWH. Finally, all new hotels can borrow money from the Cyprus Tourist Organisation (at 5-6% interest rate) or from the Cyprus Development Bank (at 8% interest rate) for the installation of a SWH system. These incentives are a form of government relief.

B. PREFERENCES OF PRIVATE SECTOR.

The preference of the consumer market is the driving force of any economic system. It determines what will be produced; with what quantities and for whom it will be produced. Hence, in this section we will consider in depth the preferences of private consumers towards SWHs used for hot water domestic purposes (category: dwellings private sectors). This choice was made based on the fact that private dwellings are the most important industry customers.

The most evident and clear observation one makes, without the use of sophisticated statistics, is the increasing preference percentage of this sector. Specifically, from Table 2 it is observed that in 1994 the total installation percentage reached 95% dictating that the Cypriot consumer does install a SWH on his dwellings. From the same table it is seen that Limassol and Larnaca end in 1994 with a relatively low percentage compared to the previous year because in Table 3 we included apartments (77.5% of New dwelling in Limassol and 40% in Larnaca are apartments, see Table 3). Even though in Paphos 52.8% of new dwelling are apartments, Paphos still present a high preference percentage (93.5%) because the preference percentage of new houses is 100%. We now consider a more formal statistical analysis.

Specifically, it was investigated whether there is a difference in preferences towards solar collectors between the rural and the urban areas of the country, and between rural and urban areas of each district in Cyprus. The data for this analysis has been taken from the Construction Surveys of 1988 up to 1994 of the Department of Statistics. These figures represent percentages of private new dwellings (blocks of flats

and houses) with solar heaters.

B.1 Testing Hypothesis.

In order to statistically investigate the subject, it was assumed that the percentages are influenced by (a) the geographical position, being the district (Nicosia, Larnaca, etc.) or the urban area and the rural area; and by (b) the year at which they were observed. Therefore, the randomised block design has been applied. Due to lack of numerical data it was impossible to prove and find the appropriate distribution to be used and therefore, the Friedman's non-parametric test was used [6,7]. This test is the equivalent of the variance analysis for parametric distributions.

B.2 Format of Testing

Each test investigates the similarity of each population, which can be the districts and the rural or urban areas of each district, and the similarity of each block (years). The null hypothesis of the tests is: H_0 : similar populations or blocks (years) and the alternative hypothesis is: H_1 : dissimilar populations or blocks (years). The level of significance (a) is 5%. To test the above hypothesis, one must compute two different test-statistics, one for the population, F_k, and one for the blocks (years), F_b. The tests are divided in three categories, type A, B, C, and their results are presented in Table 4.

B.3 Analysis of Results

(a) A-Tests

Firstly, we investigated the possible differences among districts (populations are all the districts and blocks from the years 1988 to 1994).

Regarding the population tests, they all showed that the preferences evolved in the same way in all districts. The results are logical due to the small size of Cyprus and the advanced transportation system resulting in population homogeneity.

In addition the tests showed that the preferences of the inhabitants of rural areas did not change intertemporally, nor did those of the urban areas and when the two areas were combined the distribution of the percentages changed over time.

(b) B-Tests

Secondly, we compared the urban and rural area s of each district for the period 1988-1994. These tests showed that the rural and urban area of each individual district and all districts together represent the same distribution of percentages.

It was also found that the distribution of the percentages of the each year is the same. This outcome implies that each rural and urban area of each district has a particular level of preference for SWH that remained almost the same from 1988 to 1994. Furthermore, the B5 year test (total urban, total rural) also showed that the percentages of the years did not change.

(c) C-Tests

Finally, we investigated the preferences of the districts for the periods 1988-89 and 1990-94. This division was made in order to examine whether there are differences between the preferences of the two decades in terms of total percentage, and percentages for rural and urban areas.

On the one hand, it was found that the urban areas differ from district to district. Carefully studying Fig. 2, one observes that in the 80's Nicosia (SWH installation 91%) and Larnaca (SWH installation 91.5%) exhibited the highest percentages followed by Limassol (SWH installation 83.6%) and Paphos (SWH installation 74.6%). However, in the 90's Larnaca was the first (SWH installation 97.2%), Limasol the second (SWH installation 95.2%), Paphos the third (SWH installation 92.4%) and Nicosia the forth (91.1%). This completely different pattern is the reason for the statistical results. The preferences of the coastal towns rose, overwhelming the island's capital since in Nicosia more blocks of flat are built that have technical and space problems for installing SWH. Note that in Nicosia in 1994 when the 25.3% of new dwellings were apartments (a low percentage), the preference percentage was as much as 95% implying a negative correlation between apartments and installation percentages. Additionally, coastal towns enjoy more radiation during winter, so that dwellings located there acquire more hot water than those in the capital. On the other hand, the percentages increased from one decade to another; the mean percentage for the 80's is 85.145 and for 90's is 93.99 (see Fig. 2).

On the other hand the evolution of the percentages of the rural and urban areas of the two decades were the same.

Figure 2

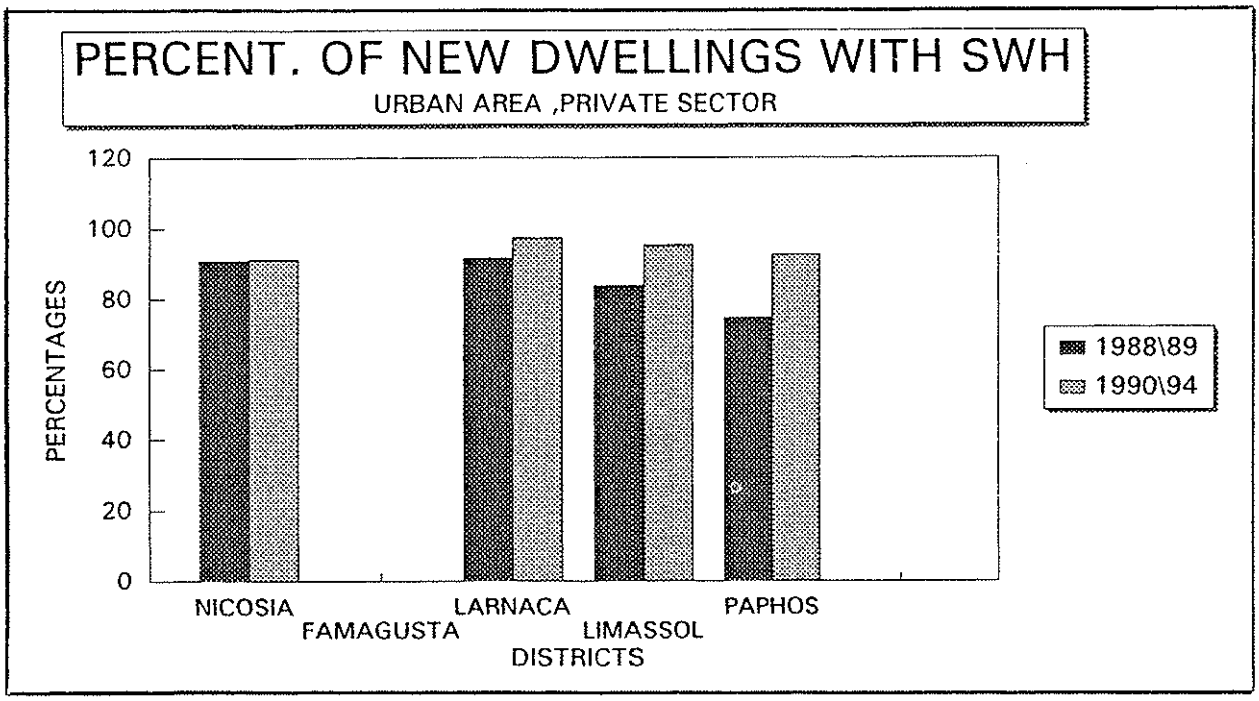


Figure 3

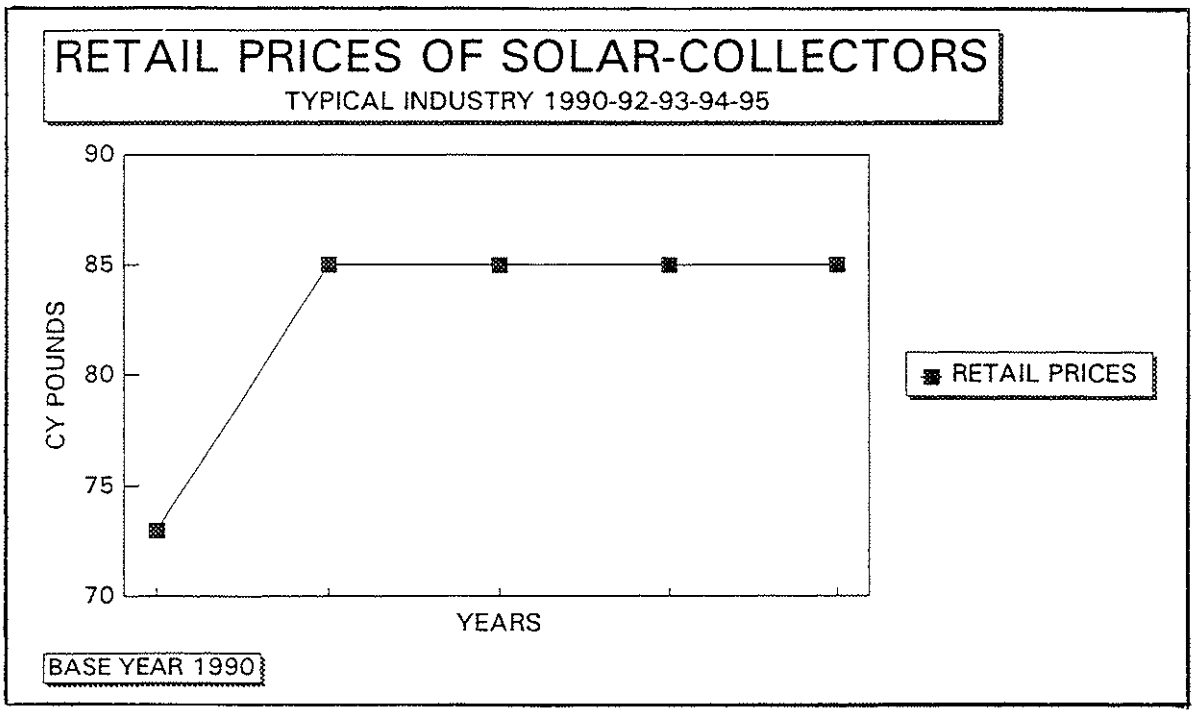


Table 4: Friedmans Tests, α=5%

No of tests (a)	Population or block (b)	Value of the test-statistic (c)	Critical Region (d)	Results Inferences (e)
A1	Population: districts (urban & rural) K=5	Fk=7.31	Fk>9.49	All districts have the same percentages. Ho accepted.
	blocks: years 1988...1994 b=7	Fb=12.86	Fb>12.59	Years not similar, percentages changed each year. Hi accepted
A2	Population: districts (urban only) K=4	Fk=7.63	Fk>7.81	The percentages of urban areas of each district are the same. Ho accepted
	blocks: years 1988...1994 b=7	Fb=11.49	Fb>12.59	The distribution of percentage of each year are the same. Ho accepted.
A3	Population: districts (rural only) K=5	Fk=1.49	Fk>9.49	The percentages of urban areas of each district are the same. Ho accepted.
	blocks: years 1988...1994 b=7	Fb=7.95	Fb>12.59	The percentages each year remained the same. Ho accepted.
B1	Lamaca District Population: urban rural K=2	Fk=1.28	Fk>3.84	Urban and Rural areas of Lamaca district are the same. Ho accepted.
	blocks: years 1998...1994 b=7	Fb=7.45	Fb>12.59	The percentages remained the same throughout the period 1988/94. Ho accepted.
B2	Nicosia District Population: urban rural K=2	Fk=1.28	Fk>3.84	Urban and Rural areas of Nicosia district are similar. Ho accepted.
	blocks years 1988...1994 b=7	Fb=5.95	Fb>12.59	Years do not differ. Ho accepted.
B3	Limassol District Population: urban rural K=2	Fk=1.29	Fk>3.84	Urban and Rural areas have the same distribution or percentages. Ho accepted.
	blocks: years 1988...1994 b=7	Fb=7.93	Fb>12.59	Percentages for the years are the same. Ho accepted.
B4	Paphos District Population: urban rural K=2	Fk=1.28	Fk>3.84	Urban and Rural areas are the same. Ho accepted.
	blocks: years 1988...1994 b=7	Fb=6.86	Fb>12.59	The percentages remained the same from 1988 up to 1994. Ho accepted.
B5	Total, all districts Population: urban rural K=2	Fk=1.29	Fk>3.84	The distributions of the percentages of urban and rural area for all Cyprus are the same. Ho accepted.
	blocks: years 1988...1994 b=7	Fb=4.98	Fb>12.59	The percentages for each year varied in the same way. Ho accepted
C1	Urban aread population: all districts K=4	Fk=13.2	Fk>7.81	Districts' percentages for the urban. Hi accepted.
	blocks: years 1988..89 1990..94 b=2	Fb=4	Fb>3.84	Percentages varied from one period to other. Hi accepted.
C2	Rural Area population: all districts K=5	Fk=6.4	Fk>9.49	The shape of the distributions of the two areas are the same. Ho accepted.
	blocks: years 1998...89 1990...94 b=2	Fb=1.8	Fb>3.84	The distributions of the percentages of the years are not different. Ho accepted.
C3	Total, urban and rural areas population: districts K=2	Fk=6.8	Fk>9.49	Percentage of each district are the same. Ho accepted.
	blocks: years 1988...1994 b=7	Fb=5	Fb>3.84	The distribution of the percentages changed from one period to another. Hi accepted.

Figure 4

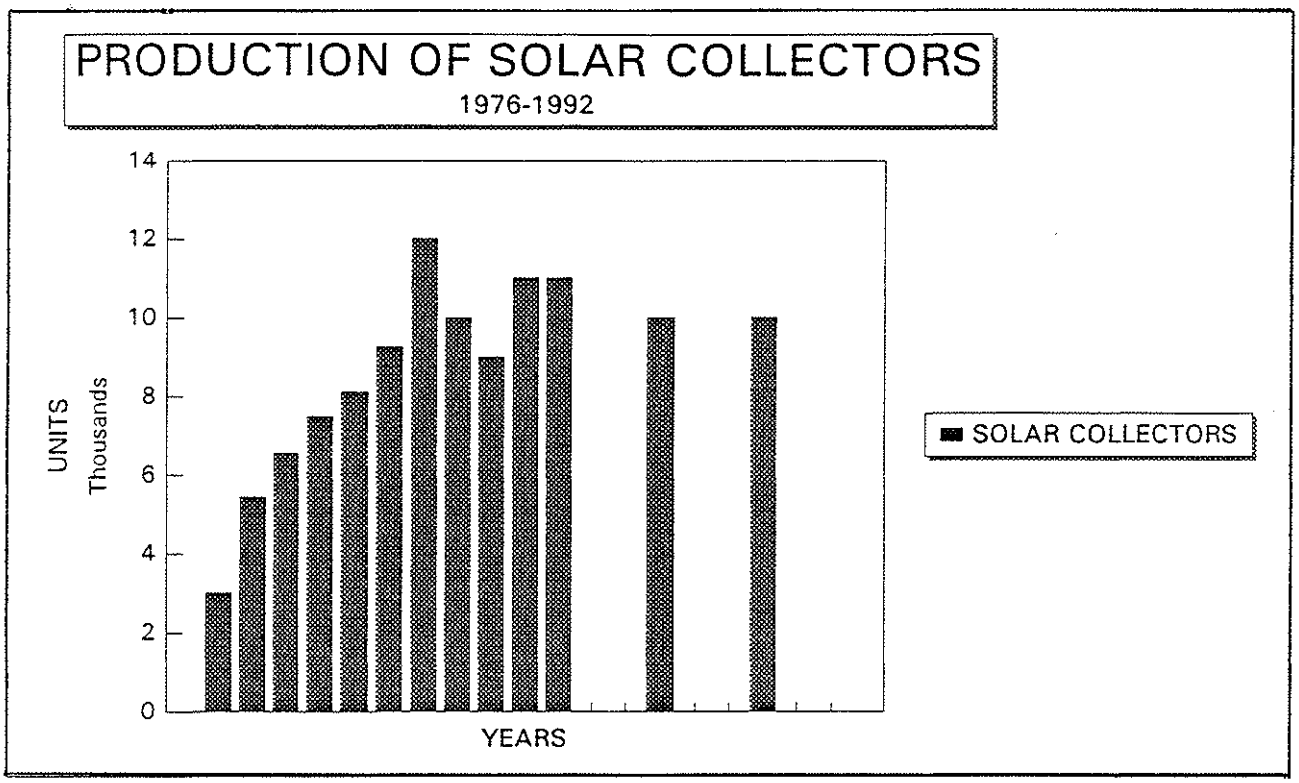
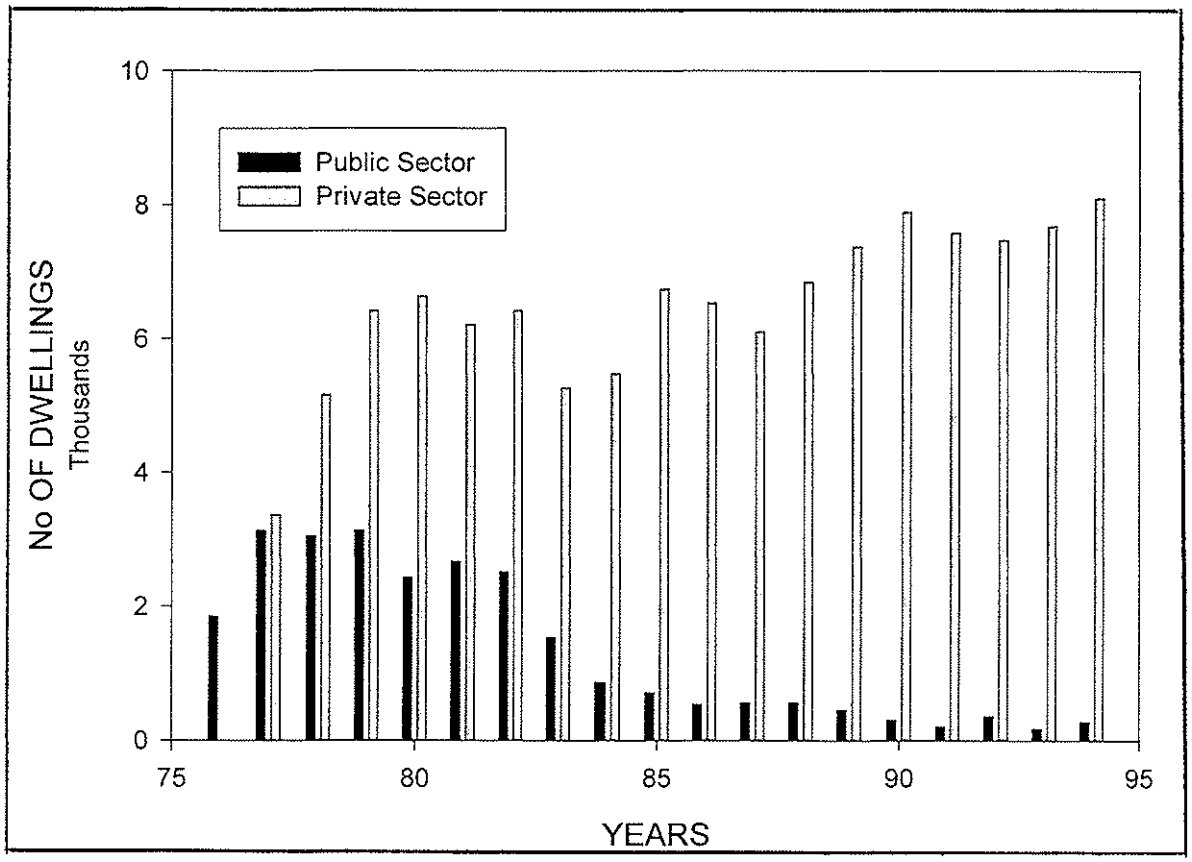


Figure 5



C. Retail Price

According to the managers the retail price in Cyprus pounds (CY £1.00 = US $ 2.15) without VAT is on average CY£ 60.0 per m^2. This price complies with the typical industry price of the solar collector given by the Department of Statistics. Between 1992 to 1995, the typical industry retail price of solar collectors, as well as the consumer price index of SWH systems, remained constant (see Table 5 and Fig. 3). As we know high competition ensures a uniform price and since many factories are functioning on the island it is difficult to deviate from the average market price charged.

IV. PRODUCTION AND BUSINESS CYCLES

IV.1 Business Cycle of the Local Industry of SWH

The aggregate production of the industry for periods 1976-1992 was found in the Metal Industry Surveys of the Department of Statistics and Research. Two kinds of numerical figures were available: (a) units produced; and (b) quantity in money units, current prices. The current prices were standardised using a consumer price index with 1980 being the base year (the data for the years 1987, 1988, 1990, 1991 were not kept by the Department). Figure 4 graphically presents the production of SWH which is divided into four different regimes starting with a tremendous increase from 1976 to 1982, followed by a decline from 1983 to 1984 and an increase in the period 1985 and 1986 and finally a levelling off from 1990 to 1992. This pattern is justified by the fact that, after 1974 there was a tremendous development in the construction industry (re-building Cyprus after the Turkish invasion); a favourable effect that abated in the beginning of 1987.

Is the local industry moving to a recession? The fall in production may be a precursor, however the subject is not that simple. The local industry is monitored and influenced by many different forces originating from internal and external factors. These forces interact in the market defining supply and demand and at this stage a survey of these forces will be given.

A. Construction Industry

Generally speaking, the solar-collector industry is mostly controlled by the construction industry. The construction industry is showing negative real growth rates from 1992, adversely affecting SWH production and sales (Department of Statistics and Research (1993)). According to the construction survey of 1993 the negative rates are justified by the completion of projects designed for tourist purposes (hotels, hotel apartments) and by the decrease in the number of new dwellings.

Specifically, the construction of new dwellings is of paramount importance, since SWHs are a complementary product of the industry. During the research a variety of events in the construction industry were found to influence SWH production. Firstly, the number of dwellings completed by the public sector, that by law must have a SWH system, is constantly decreasing (see Fig. 5). Secondly, the number of dwellings constructed by the private sector with SWH is also showing very low growth rates (see Fig. 5). Hence, the high percentages of new houses with SWH is offset on the one hand by this low growth rate and on the other hand by the preference of Cypriot consumer towards imported goods (see Fig. 4). The low rate growth of new dwellings is basically justified by the high building costs (Table 6). Despite the high construction costs, expensive houses are being built. A simple investigation of the new rooms constructed by the private sector, the area (m^2) of new dwellings as well as the mean area (m^2) of new dwellings, justifies that the newer the houses the more expensive they are [Table 7]. Therefore, consumers spend more, and consequently the solar collectors that are being ordered are the expensive models. This is why even though the quantity for 1989 and 1992 remained the same (10,000 units) the constant money value of these units increased by CY 95,622 (see Fig. 6).

B. Installation of Solar Water Systems on Old Houses

As SWH became popular in Cyprus, they were retrofitted to old houses and this situation further helped the production of solar collectors. However, the above process began in the period 1977-1979 when SWH became very popular and most of the old houses have probably installed a solar water system by now.

C. Replacement of Old Solar-Collectors

Solar-collectors as a means for heating water for domestic purposes became popular in 1975. As the

Table 5: Price measurements for SWH for the years 1990-1995

Year	Prices of Solar-Collectors CY	Consumer Price Index of SWH Systems (Base Year 1990)
1990	73	100.00
1992	85	112.50
1993	85	112.49
1994	85	112.11
1995	85	112.89

Table 6: Index of Cost of Construction of New Dwellings for 1976-1994

Year	Dwelling Index of cost of construction
1976	38.81
1977	41.4
1978	48
1979	55.81
1980	66.07
1981	75.98
1982	82.43
1983	86.22
1984	92.99
1985	100
1986	101.69
1987	103.78
1988	110.85
1989	118.4
1990	125.33
1991	132.4
1992	139.79
1993	148.84
1994	152.34

Table 7:Characteristics of new dwellings constructed by the private sector

Year	# of new rooms constructed (thousands) -Private Sector	Area of new dwellings (m^2)	Average area of new dwellings (m^2 per dwelling) -Private Sector
1985	34.86	-	-
1986	34.05	-	-
1987	29.19	-	-
1988	35.67	1025.30	151.60
1989	37.30	1050.60	145.16
1990	39.73	1240.50	158.10
1991	38.92	1202.50	159.70
1992	38.11	1189.90	161.30
1993	40.54	1278.50	167.70

average durability of those collectors was defined to be 20 to 25 years, one would expect that the replacement period has already begun. The majority of SWH industry managers support this. However, since the SWH is not directly observed by the inhabitants of a house (the SWH systems are installed on the roof), old SWH are replaced when they are completely useless. Consequently, the "durability" of the SWH may be lengthened by more than the 25-year period. Additionally, climate conditions on the island do not harm the system (e.g. damaging hail in the winter is a rare phenomenon). These reasons contribute to the slow replacement process. Nevertheless, the replacement of old SWHs is a positive force for the industry that will increase production in the years to come.

D. Imports

Generally, Cypriot consumers have always preferred foreign to local products. This attitude, as well as the increasing sales of the solar collectors in 1978-1982, urged many companies to import solar water systems. The total numbers in Table 8 show a clear increasing trend with the 5906 imported units being more than half of the 10,000 units (Table 9) locally produced in 1992. The reaction to this by the local industry owners is retail price stabilisation of the solar-collector and of the solar system (Fig. 3 and Table 5). Therefore, in 1993 and 1994 the imports decreased but were still significant. As it is shown on Table 8 the foreign solar collectors are mostly imported from Greece, Italy, United Kingdom, Australia, Japan, and Spain. Of these countries, only the imports from Greece and Spain show a clear upward trend, in particular the imports from Spain increased by 1282 units from 1993 to 1994. Spain and Greece are members of the European Union, so there are no import duties and the retail price of the imported units is very competitive. It is clear that if the Cypriot industries want to compete with the Europeans a number of corrective measures focussing on quality and price must be taken in the years to come (see Section V). Predicting whether the industry is heading towards recession or expansion is not easy, as there are many parameters that are based on human decisions. However, based on the evidence of this section we conclude that the local industry faces problems in contrast to the market of SWH in general preference rate in 1994 was 95%).

IV.2 Econometric Analysis

In the previous part of this section, the various components that affect the SWH industry were analysed. In this part, the effects that can be quantitatively measured are investigated.

The sample of the models is given in Table 10 covering the years 1976-86, for which the production for solar collectors was available without any missing values. Furthermore, since the sample is small the models incorporate the least possible number of variables. All models are defined in terms of rates of growth and they fall in the category of Simple Normal Linear Regression (see Spanos, 1986) and they are estimated by ordinary least squares. In addition, a simple significance test was conducted with H_0: $B_i=0$ and H_1: B_i¹0 where B_i is the coefficient of the regressors or the constant terms.

Firstly, the rate of growth in the production of solar collectors (ROGSC) was regressed on the rate of growth of new dwellings in the private sector (ROGNDP). The results of the estimation are as follows:

Model 1:

$$ROGSC = 0.03889 + 0.68642\ ROGNDP + U_t$$
$$[0.048260]\ [0.12915]$$

where U_t is the residual and the numbers in brackets are the standard errors of the coefficients. The student's-t critical values for the significance test of the constant and of the coefficient of ROGNDP is 0.806 and 5.315 respectively. Therefore, the new dwellings private sector is a very important determinant in the production of SWH.

Secondly, a model of the rate of growth of the production of solar collectors (ROGSC) to the rate of growth of new dwellings public sector (ROGNDPB) was estimated giving the following results:

Model 2:

$$ROGSC = 0.21984 + 0.77205\ ROGNDPB + U_t$$
$$[0.03250]\ \ [0.10522]$$

With respect to the student's-t significance test the critical values were 6.612 for the constant term and 7.337 for the coefficient of the ROGNDPB. Therefore, both are important, meaning than even though the ROGNDPB influences ROGSC, it does not fully explain it [6,7].

Table 8: Imports of Solar Collectors, 1991-1994

Year Country	1991	1992	1993	1994
Australia	164	202	472	36
Greece	222	194	396	932
Italy	520	2908	580	408
Japan	126	258	260	184
Spain	-	220	280	1562
U.K.	48	30	264	250
TOTAL	1118	5906	2060	3426

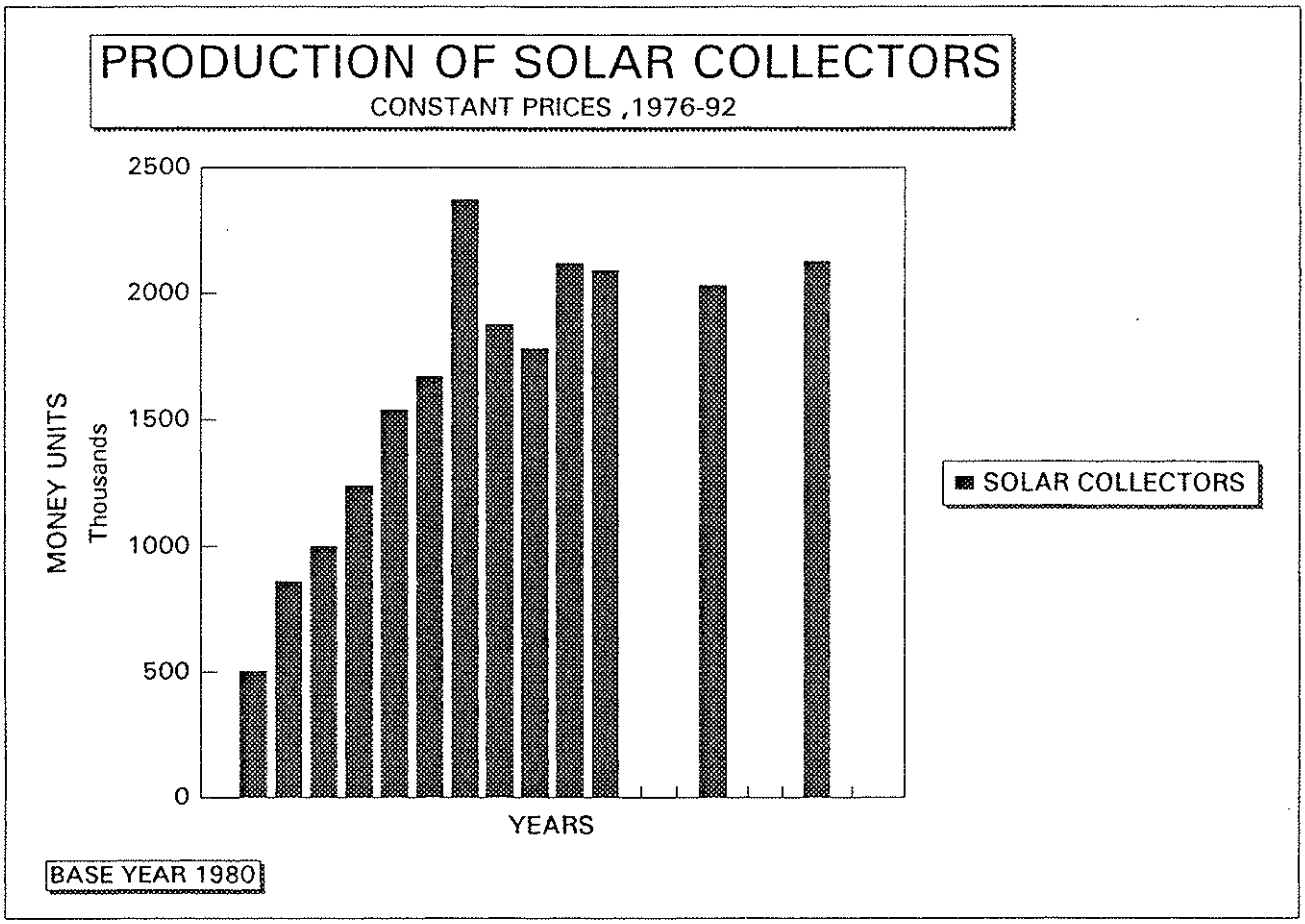
Table 9: Production of Solar Collectors between 1982 and 1992

Year	1983	1984	1985	1986	1989	1992
Units	10,000	9,000	11,000	11,000	10,000	10,000

Table 10: Data used in the Econometric Models

Year	SC	ROGSC	NDP	ROGNDP	NDPB	RPGNDPB	ND	ROGND
1976	3010		1698		1845		3543	
1977	5432	0.804651	3400	1.002356	3145	0.704607	6545	0.847305
1978	6557	0.207106	5102	0.500588	3077	-0.021622	8179	0.249656
1979	7484	0.141376	6345	0.24363	3153	0.0246994	9498	0.161267
1980	8111	0.083779	6586	0.037983	2423	-0.231526	9009	-0.5148
1981	9258	0.141413	6159	-0.06483	2672	0.1027652	8831	-0.01976
1982	12000	0.296176	6436	0.044975	2513	-0.059506	8949	0.013362
1983	10000	-0.16667	5726	-0.11032	1561	-0.37883	7287	-0.18572
1984	9000	-0.1	5447	-0.04873	880	-0.436259	6327	-0.13174
1985	11000	0.222222	6758	0.240683	717	-0.185227	7475	0.181445
1986	11000	0	6500	-0.03818	534	-0.25523	7043	-0.059

Figure 6



In the last model estimated, ROGSC regressed on the rate of growth of new dwellings, public and private (ROGND). The results of the estimation are:

$$\textit{Model 3:}$$
$$ROGSC = 0.0780 + 0.84539\ ROGND + U_t$$
$$[0.032956]\ [0.10998]$$

As was expected, the ROGND was found to be significant (t-statistic = 7.687) since public and private dwellings explain the greatest part of the production of SWH.

When the above estimations were contacted, misspecification testing was used to investigate the statistical adequacy of the model, i.e. whether the residuals were systematic (if this is so, more variables are needed to explain the dependent variable, see ref. 5). The misspecification testing showed that all the models are well specified and therefore their results can be trusted, that is new dwellings of private and public sector are the driving force for the production of solar collectors in the sample period.

A variable that appears to be very important of late is the import of solar collectors that negatively affect the ROGSC of the domestic industry. However, the data on imports (Table 11) begins from 1982 and the only period that a comparable sample, with the domestic production of solar collectors, exists is 1982-1986. Therefore, an econometric model could not be estimated with five observations. Nevertheless, in order to get an indication of the importance of imports the percentage of imports to the domestic production of solar collectors was calculated. This percentage was 14.12 in 1982, 24.78 in 1983, 18.27 in 1984, 15.40 in 1986, 22.60 in 1986, 21.28 in 1989 and 59.06 in 1992. These percentages increased through time implying a negative influence for the local industry of SWH.

V.The Impact of Thermal Solar Collectors on the Cyprus Energy Balance.

Cyprus imports all the petroleum used to produce electricity and therefore a large part of its Gross Domestic Product is transferred abroad every year. Thus, a measurement that saves electricity contributes to the Cypriot economy, with less money spent on petroleum and more spent on local investments and consumption. In this way, the solar collectors can be of primal significance. Therefore, in this part the contribution of SWH to the energy balance of Cyprus on 1.1.95 will be estimated. For this, one needs the stock of SWH on 1.1.95, the annual energy saved by a SWH together with the rate of utilisation of the present stock of SWHs in Cyprus.

Firstly, the stock of SWH was retrieved from a paper of the Ministry of Commerce, Industry and Tourism (Solar Energy Utilisation in Cyprus, Ministry of Commerce, Industry and Tourism, Applied Energy Centre, May 1995). The paper reported that the glazing area (m^2) installed at the end of 1994 on dwellings was 643,332m^2, on Hotel Apartments 26,471m^2 and on Hotels 12,209m^2. Therefore the total glazing is 682,012m^2 and the total SWH units are 227,333. Secondly, the annual energy saved by a SWH was calculated. As it is known, in Cyprus, the total glazing area of a collector is 3m^2, the average daily radiation is 5.4 Kwh/m^2/day (inclination 35^0), the SWH average efficiency is 0.3 and the usefulness of the solar hot water is 0.6. Therefore, the useful energy yearly produced is:

3 x 5.4 x 0.3 x 365 = 1,064.34 Kwh per SWH.

Finally, the rate of utilisation of the present stock of SWH in Cyprus is 0.9. This coefficient takes into account that part of the present SWH stock not optimally used: SWHs under repair, oversized SWHs compared to consumer needs, houses and flats unoccupied for various reasons, etc.

Therefore the estimated *electricity saving* is:
227,337 x 0.9 x 1,064.34 = **217.8 Gwh/year**.

This electricity saving represents 10.7% of the electricity consumed and 8.1% of the electricity produced on the island (domestic consumption of electricity in 1994 2,031,800,000 Kwh/year). Furthermore, if one transforms the electricity saving in Cyprus pounds (US$1 = C£0.5), one infers that the consumers on 1.1.95 saved £8,710,699, which represents 0.24% of the gross domestic product for 1994, current prices. Of course this percentage does not indicate the full contribution of the electricity saving to the economy since the multiplier effect is not taken into account. As standard macroeconomics suggests, a one-dollar increase of investment or consumption or public expenditure increases GDP by more than one dollar. Therefore, the electricity saving spent for consumption (private or public) and/or investments increased the GDP by more than 0.24%.

VI. Corrective Measures

If the local industries want to survive the anticipated competition they should improve their products using the facilities and advice of the Applied Energy Service on a regular basis. The retail price of the local units should follow the decrease of the retail price of the imported European units due to decreasing import duties. In addition the appearance of the local products should be improved, as it is their main perceived disadvantage compared with foreign models (e.g. find clever ways of adapting the SWH on inclined roofs since they are very fashionable). Collective advertising campaigns should be held to convince the Cypriot consumer that the local solar collectors do have a sound scientific basis. Another target of advertising should be to urge consumers to replace old SWH, stressing the advantages of the new models. At the same time all Cypriot industries should cooperate merging individual experiences and knowledge to improve their products and their services. As has been mentioned, only 44% of the hotels use SWH; the market of hotels should be the target of the industry. Manufacturers are faced with two options: either cooperation, whilst attempting to increase the use of SWH in hotels, or attempting to hold onto their existing market share. A practical step to cooperation is for small units to merge with each unit concentrating on producing a particular part of the SWH system. In this way, productivity will increase and economies of scale will set in.

Total 11: Total Import of Solar Collectors.

Year	Imports	IMP Rog
1976		
1977		
1978		
1979		
1980		
1981		
1982	847	
1983	1239	0.462809917355
1984	822	-0.33656174334
1985	847	0.030413625304
1986	1243	0.467532467532
1987	811	-0.34754625905
1988	937	0.155363748459
1989	1064	0.135538954109
1990	1086	0.020676691729
1991	559	-.048526703499
1992	2953	4.282647584973
1993	1030	-0.65120216729
1994	1713	0.663106796117
1995	1046	0.38937536486

Table 12: Determinants of the business cycle of the SWH Industry.

	Description of Influence	*Direction of Influence*
1	*Construction Industry*	
	a) New dwellings completed by the public sector	*Negative*
	b) New dwellings completed by the private sector	*Negative*
	c) Percentage of installation of SWH on new dwellings	*Positive*
	d) Construction Costs	*Negative*
	e) The new houses that are being constructed are more expensive than the older ones	*Positive*
2	*Installation of SWH on old houses*	*Positive to neutral*
3	*Replacement of old SWH*	*Positive*
4	*Imports*	*Negative*
5	*Un-coperation of solar water industry owners*	*Negative*

VII. Conclusions

From 1956 the SWH industry has become one of the biggest industries of the island. Presently, 58 industries divided into three categories are functioning-companies that locally produce solar collectors, importing companies, and companies that produce and import solar collectors.The characteristics of the products of these industries can be investigated by the Energy Service of the Ministry of Commerce, Industry and Tourism. The evaluation of the efficiency of the solar collector and of the SWH is carried out according to CYS259:1994 and CYS209:1991 standards, respectively.

Regarding the supply side, the main characteristics of the industry are that the technology is semi-automated, the inputs (raw materials and labour) are readily available, labour costs are high (according to employers) and the current market price without VAT is CY£85 per $1.5m^2$

Furthermore, the preferences towards SHW of the inhabitants of Nicosia, Famagusta, Larnaca, Paphos and Limassol district generally are the same from 1988 to 1994. In the same period the percentages of installation of SWH on new dwellings were increasing.

It was shown that the production for 1994 is about 10,000 units. In 1982 the production was 12,000 units. Is the industry driven to a recession? To answer this question we must study the determinants of the business cycle of the industry (Table 12) and of the individual industries (number of industries and retail price).

The Cypriot industry of SWH has all the necessary impetus to face the future with optimism. The industry owners have the necessary experience, the equipment, the machinery and the premises that can produce technological advanced products. 95% of the new dwellings constructed in 1994 installed a SWH, the Cypriot consumer, despite the area or the district that he lives, prefers solar systems to electric systems for heating water. Nevertheless, this consumer can choose between local or imported products. If the local industries want their solar collectors to be preferred they should cooperate and work hard. The collapse or the future evolution of the Cypriot SWH industry basically depends on the actions of SWH industry owners.

We close by noting some important experiences of Cyprus. The first is the successful exploitation of a natural energy source, offering a relatively cheap and alternative source of electricity that is easily accessible to the consumer. The second is the promotion of SWH technology to the point that every individual considers it a mainstream form of energy production.

Appendix A: Lack of Data

The Kyrenia district, urban and rural area as well as the Famagusta urban area are not included in the testing due to lack of numerical facts. This lack is a result of the Turkish occupation.

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