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Assessment of Solar Water Heating In Cyprus: Utility, Development and Policy

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Abstract- The main objective of this study is to assess solar water heaters' utility, development and policy in Cyprus. The study reviews the relevance of solar water heaters in Cyprus from users' perspective. Cyprus has the highest per capital SWH system ratio in the world without SWH systems policy in place currently. Data were collected from some local manufacturer/sellers of the SWH. Residents of one thousand (1,000) housing units in Cyprus were interviewed on the usefulness and viability in the long and short term of their SWH. SPSS is deployed in analyzing the data collected and a policy that will further enhance the development of solar water heaters is proposed. In Cyprus, solar water heaters are of the thermo-syphon type and consist of two flat-plate solar collectors having an absorber area between 160 x 80 cm for locally manufactured products and 190 x 90 cm for imported ones. It is estimated that the number of systems installed in Cyprus exceeds 80,000 units for residential buildings. From the results, eight out of every ten houses has SWH systems heaters installed and about 50% of houses without solar water heating systems have plans of installing the system soon. Most of the hot water produced by the system are used for bathing and it is noteworthy to mention that over 80% of the respondents interviewed agrees that the system is worth investing in. A comprehensive report of all the findings from this study is properly presented in the paper.

Keywords Solar water heaters, Cyprus, Assessment, Utility, Renewable Energy, Polıcy.

1. Introduction

Energy is an indispensable commodity in this 21st century [1]. Electrical energy is regarded as the bedrock of different energy sources as it can be converted easily into other forms of energy. A larger share (78.3%) of world's energy consumption is still from fossil fuels while the fast developing renewables now accounts for 19.1% of world's energy consumption. Biomass/geothermal/solar heating (including solar water collector for heating) account for 4.1% of the world's energy consumption [2]. According to [3], 77.2% of the world's (electric) power generation is still from fossil fuels. GHG emission in the process of extracting, exploiting, exploring and utilizing fossil fuels still pose a great threat to human race. About 160,000 to 250,000 people die yearly due to direct and indirect effect of climate change (carbon emission) and this may double by 2020 according to WHO [4] [5].

Cyprus has the highest solar water collector (heating) per capita (installation) ratio in the world [6] [7]. It's location on the Eastern Mediterranean region gives it a typical Mediterranean climate with over 300 days of sunshine yearly [8]. Solar energy radiation is very high in areas with dry summer. These area witness over 5 hours of sunshine in winter and about 12 hours of sunshine in summer. Cyprus has a mean solar radiation of about 2.3kWh/m^2 in the cloudiest month (December to January) and about 7.2 kWh/m^2 in peak summer. On the average, 1,727 kWh/m^2 worth of radiation falls on areas with average weather conditions yearly [7] [8].

Energy is an important aspect of Cyprus economy with most of its energy (electricity) generated from the use of imported fossil fuels [9]. The largest consumer of energy in Cyprus is the transport sector while solar energy contributes only 4% to the total energy consumption [10]. According to [3], about 10MW capacity of solar installations has been done in Cyprus with a larger percent of this installation coming from solar water collectors. Most of the hot water used in summer for domestic application are generated from the use of solar water heaters (SWH). About 750,000 m^2 of solar water installation has been made on the island with almost all apartments having a solar water heating system installed. Solar water collector has witnessed about 500% increase in capacity since 2004. Currently, world's solar water collector (heating) capacity is 406 GW_{th} as against 86GW_{th} in 2004 [2]. The main objectives of this research are:

- To assess the utility of solar water collectors from the users' perspective.
- Enumerate the usefulness of the solar water heating system and its input and output ratio financially
- Recommend possible ways of maximizing all installed systems for users under-utilizing the system.
- Finally, a policy to further enhance the development of SWH in Cyprus is proposed based on the responses gotten from the qualitative analysis.

2. Solar Hot Water

SHW technology has grown mature to become a common application in many countries and it is used for domestic hot water production. The technology has been commercially available in many countries for over 30 years [11]. In North America and Northern Europe such as Germany, SWH systems used for single-family homes have hot water storage with volumes of approximately 300 liters, a collector area between 4-6 m^2 and can supply 60-90% of the annual hot water demand depending on the type of collector and local solar radiation conditions [11]. In hotter climates, thermo-syphon systems are often used with a smaller collector area of around 2-4 m^2 and a 100-300 liter storage tank [12]. Thermo-syphon used in China has a hot water storage tank of around 120-200 liters and a collector area of around 2 m^2 [13].

In addition to reduction of carbon footprint and provision of hot water, one of the major advantages of installing solar water heater in residential buildings is the monthly savings on expenses. However, despite its huge monthly savings, SWH has high upfront cost of installation as a disadvantage. The effect of the high upfront cost can be minimized when payback period for SWH is taken into account. Studies have shown that the general trend of increasing and volatile energy prices in addition to a rise in environmental responsibility will continue to drive the market in immediate and long time [14]. Global SWH capacity according to REN21 Global Status Report is depicted in Figure 1.

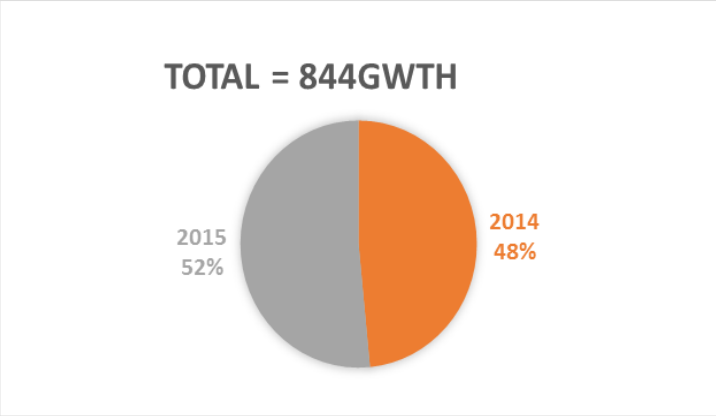

Fig 1: Solar hot water heating: existing capacity [15]

The history of SWH is dated back to 1767 when a prototype was built by Swiss naturalist De Saussure; he built an insulated box painted black at its bottom with two panes of glass covering at the top. He called it *Hot Box*, as the invention was capable of applications in cooking, heating, and producing hot water [13]. The first commercial SWH, named Climax, was produced by Clarence M. Kemp in 1891 [16]. Researchers gave attention to improving the design of the SWH system to make it durable and efficient in 1900. Thermo-syphon principle was first introduced by William Bailey to assist the movement of water in the collector and storage tank. He tailored the Kemp's SWH system, by segregating it into two major parts; the solar thermal collector for collecting solar radiation and storage tank for storing the produced hot water in 1909. He also introduced insulation to the storage tank to prevent heat losses [17]. In 1950, Japan's first commercial SWH was designed by Yamamoto by paying attention to a large bath tub, filled with water that was kept outside in the sunshine for a longer period of time. Later, SWH units based on the closed-pipe system were introduced [13]. SWH became a commercial product in the early 1960s. A typical SWH is of a thermos-syphon kind that uses an absorber area of 3–4m^2 flat-plate type solar collectors to energize a capacity of 150–180 liters storage tank [18].

3. SWH Basic Operational Principle

Based on heat transfer fluid (HTF) circulation mode, Solar Water Heating systems can be classified into active and passive categories [19]. Active systems use a mechanical system or circulating pump while passive systems use gravitational forces to circulate the HTF. SWH depends on the performance of collector's efficiency in capturing the incident solar radiation and effectively delivering it to the water. Water can be heated to about 60-80^{o}C temperatures. The heated water is confided or collected in a well-insulated tank to avoid heat loss to the surrounding environment. Thermo-syphon principle ensures that water is automatically circulated from the tank through the collectors and back to the tank continuously [14]. A simple operational principle of a SWH system is shown in Figure 2.

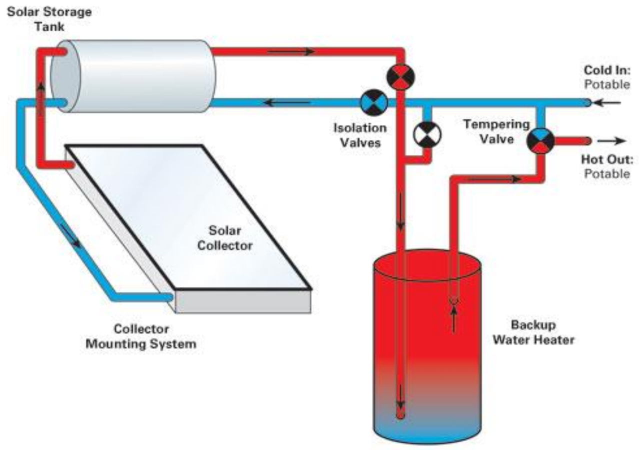

Fig. 2: SWH operational principle

4. SWH Applications

Several factors influence SWH market in residential buildings. Such factors include demand for hot water, type of house, utility supply conditions, SWH awareness, household income, and policies [14]. When hot water is generated, it can find applications in domestic, commercial and industrial sectors. In North Cyprus, these applications can further be sub-divided into Hotels, Hospitals, Hostels and Dormitories. Software tools such as Homer, PVGIS, and PVSyst have been deployed in simulating and estimating solar energy performance in North Cyprus [20]. TRNSYS software and a mechanical model was used to analyze the energetic performance and economic viability of an existing SWH system. The result was compared to a similar system that was experimentally simulated [21]. An experimental study was also carried in Chile to maximize the production of a SWH using floating photovoltaic to reduce water evaporation. This system is a hybrid system and was tested on a pond. The pond with the hybrid system design is 90% better than the controlled pond [22] . A simulation was also done by [] to evaluate the optimum criteria for selecting SWH for domestic use in Saudi Arabia [23]. Solar Advisor Model (SAM) was also deployed in a large scale installation of PV systems in Cyprus for energy predictions [24]. However, apart from the simulations of [25] where SWH system system were predicted to cover 82% of the annual hot water requirements with pay-back times of the order of 8.3 years., there has not been a recent documentation or research on the use of software tools to estimate and forecast SWH performance.

5. SWH Applications

Problem Statement of the Study

The aim of this study is to evaluate the utility/usefulness of SWH systems in Cyprus and check if citizens support a policy that enforces installation of solar water heating system on all buildings in Cyprus. The study will propose a SWH Policy based on citizen's response.

Research Design and Study Sample

The universe of this study includes all houses in Cyprus and the study sample consist of 1000 different housing units (12.1% Studio/Dormitory (n=121), 54% two or three Bedroom Apartment (n=540), 29.1% Duplex (n=291), 4.8% other housing units (n=48)). This housing units were selected at random in different location within Cyprus with emphasis on three main locations. The data was collected by interviewing the occupants of each apartment and some personal data that may affect SWH system's installation (e.g. Monthly salary, Number of Occupants per room etc.) were collected. A summary of the demographic characteristics is given in Table 1.

Table 1: Demographic characteristics of housing units

	Independent Variables	n	%
Type of apartment/house	Studio/Dormitory	121	12.1
	2/3 Bedroom Apartment	540	54.0
	Duplex	291	29.1
	Others	48	4.8
	Total	1000	100.0
Location	Nicosia	568	56.8
	Kyrenia	264	26.4
	Famagusta	116	11.6
	Others	52	5.2
	Total	1000	100.0
Total number of occupants per apartment/housing unit	1-3	181	18.1
	4-6	233	23.3
	7-9	318	31.8
	above 9	268	26.8
	Total	1000	100.0
Average number of hours spent at home daily	Less than 5 hours	211	21.1
	5 – 10 hours	453	45.3
	11 – 15 hours	275	27.5
	Above 15 hours	61	6.1
	Total	1000	100.0
Average monthly income of respondents	Less than 1000TL	184	18.4
	1000Tl – 3000TL	428	42.8
	3001TL – 5000TL	215	21.5
	above 5000TL	173	17.3
	Total	1000	100.0

Research Instrument

Four item categories were used in the research model to collect the data about Respondents' demographic characteristics. The first category was used to know if each respondent has a SWH system. In the second category, two items were prepared to check the willingness to install SWH system for those without one. The third category features seven items used to collect data about each respondent's utility scale and Fourth category has five items that check each respondents support for SWH policy. It should be noted that only respondent's with an installed SWH were questioned about utility scale and support for SWH policy. Statistical package for social analysis (SPSS) was used to analyse the data collected from all respondents. Findings and results generated from this study were presented. A crosstab analysis was used to check the relationship between each respondent's demographic data and support for a SWH system policy in Cyprus.

6. Results, Discussion and Policy

This section presents the result gotten from a study carried out in 1,000 housing in Cyprus. Review of solar water heater policy, utility and development in Cyprus is the main objective of this study. Some of the data collected and the result discussed in this section are collected from SWH local manufacturers/sellers in Cyprus. This section is divided into two paragraphs. The first paragraph discuss the SWH design in Cyprus based on data collected from local manufacturers/sellers and some literatures. Paragraph two presents the results of the analysis done on the data collected on 1,000 housing units. The paragraph discuss SWH from the users' perspective.

It is estimated that the number of SWH installed in Cyprus exceeds 80,000 units for residential buildings. Cyprus began the manufacture of SWH in the early sixties [18]. SWH industry grew rapidly and today it approaches an annual production of about 30,000m^2 of collectors of over 20 manufacturers. More of the SWH systems installed in Cyrpus are locally made although the imported SWH are more durable. In Cyprus, SWH are of the thermo-syphon type and consist of two flat-plate solar collectors having an absorber area between 160 x 80 cm for locally manufactured products and 190 x 90 cm for imported ones. İt has a storage tank with a capacity of between 150 1iters and a cold water storage tank, all installed on an accompanying frame. During the winter season, an auxiliary electric immersion heater are used in periods of low solar insolation. Another important type of SWH in Cyprus is the force circulation type. This forced circulation system is designed such that only solar panels are visible on the roof, the hot water storage tank is located indoors and the system is completed with piping, pump and a thermostat. Architectural and aesthetic reasons make the forced circulation type more appealing; they are however more expensive. The approximate estimation of collector area currently installed in Cyrpus is about 560,000 m^2 [18], of which 540,000 m^2 are installed in homes. Over 50 % of the existing hotels are equipped with solar-assisted water heating systems and the contribution of solar energy to the total energy consumption in the hotel industry is quite high. A typical SWH installation for domestic applications in Cyprus would cost about 550 Euros and 1350 Euros for locally made and imported system respectively. This cost of SWH varies from region to region. The important aspects to consider when estimating the installation cost include; Collector, hot water storage tank, cold water storage tank, insulations and pipes and labor/engineering cost. In a typical SWH system in Cyprus, the cold water tank is typically 2m high and the maximum shading is 2m which means the next installation must be two meters away. For tall buildings (more than 6 or 7 floors) the roof area is not enough to fit the installation of SWH system sufficient for the whole building. In such a case, a centralized system is used instead of individual installation.

Consistent with literature, SWH is installed in a majority of households surveyed in TRNC. 77.8% of the houses surveyed have installed SWH systems. Amongst the homes without SWH, one out of every two homes do not have SWH installed either because of its high cost of installation or they have insufficient income to support the installation of SWH systems in their homes. This represents about 50.6% of the respondents. Also, 13.1% of TRNC residents claim they do not have access to installation materials or experts. Less than 48 percent of the SWH installed for household residence have their pipes insulated. Figure 3 shows the reasons residents do not SWH in their homes and the percentage of residents representing those reasons. From the results, it is important policy recommendations should include volume size of heated water going to be produced. It will also be important to take note of the peak use hours and the most significant primary use which happens to be for bathing. Policy, should also consider cost and work on both making SWH cheaper to install and make available loans and grants to help low income earner have SWH installed.

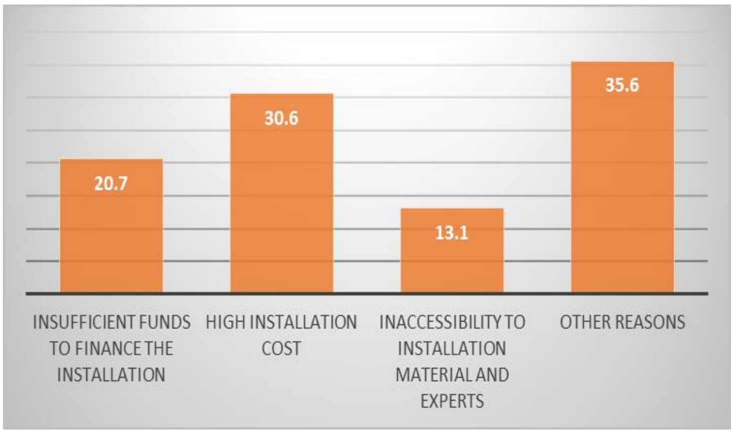

Fig. 3: Why residents don't have SWH system installed in their apartments?

However, as many as 56% of homes without solar heating systems plan to install solar water heater soon. Figure 4 shows that 8.1% of the households that have installed solar water heating systems installed their SWH within the last one year, 40% within the last 5 years and Only 20.6% of households have Solar water heating systems that are 10 years or older. At present, only 10.5% of installed of solar water heating systems are not working.

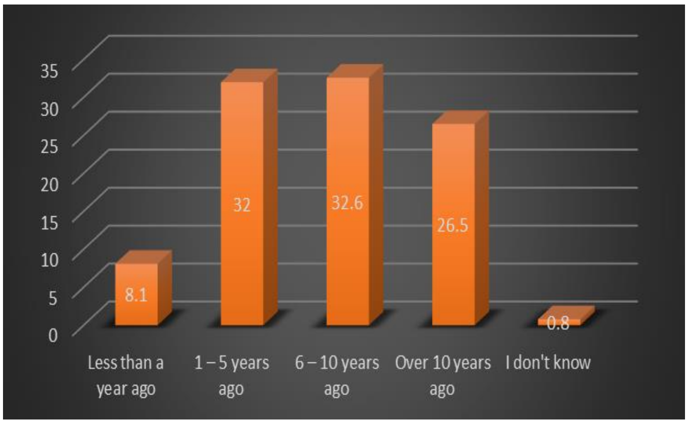

Fig 4: Installation date of SWH in Cyprus

Figure 5 shows that bathing is the most popular use of heated water from solar water heaters. 87.5 percent of households with SWH majorly need heated water to bath. Only 12.5% of households say they used hot water produced by the SWH for domestic uses which include but not limited to washing and cooking. The peak hours for use of heated water from the SWH system is between 17:00hrs and 22:00hrs, six out of every ten respondents claim to use heated water within that period. Only 18% of people with installed SWH used heated water between 05:00hrs and 10:00hrs. The household surveyed shows that about 43% accept that their installed SWH do not provide enough heated water during the hours they need it. However, about 12% of household have more than enough heated water daily.

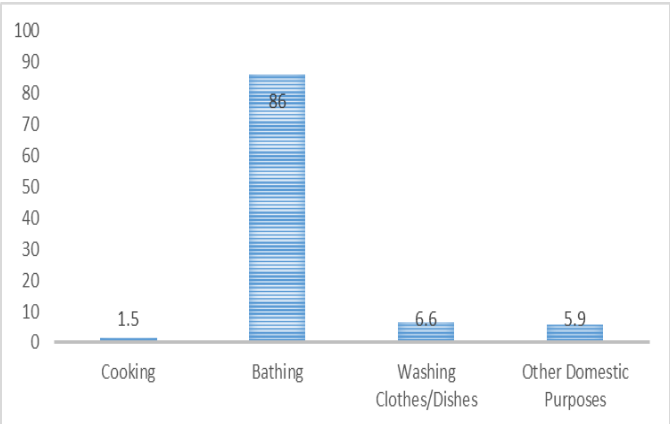

Fig. 5: What Cyprus residents use the hot water produced by their SWH for mostly

At least 5 out of every 10-household installed solar water heating system to reduce the cost of electricity used in their homes. Table 2 represents the percentage of users who are satisfied with their investment in SWH. 84% of households are very satisfied with the economics of the SWH installed in their residence. Also. Over 82% of house consider SWH as an important feature to any building.

Table 2: Value gained for investing in SWH

	Frequency	Percent
Yes	656	84.3
No	122	15.7
Total	778	100.0

Over 80% of people surveyed will actively encourage other people to install solar water heating system and as many as eight out every ten people will support government legislation that requires residences to compulsorily install solar water heating systems in buildings.

7. Conclusion

Use of SWH systems is popular in Cyprus. 7 out of every 10 households have it installed in their homes and 8 out of every 10 will be prepared to support legislation that enforces its installation in homes. However, its biggest single impedance is the initial investment cost, more than half of people without SWH point at cost as the main reason for not having it installed. Furthermore, at least 4 out of 10 say they do not get enough heated water from their systems at the time they need it. Also, more that 40 percent of houses do not have insulated pipes in their systems. Therefore, policy recommendations include volume size of heated water going to be produced. It is also be important to take note of the peak use hours and the most significant primary use which happens to be for bathing. Decisions that allow for reduced installation cost should be considered; loans and grants should be made available to help low income earner have SWH installed.

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