POLICY DEVELOPMENT FOR SOLAR WATER HEATERS IN THE MEDITERRANEAN; A CASE STUDY

Olusola Bamisile, School of Mechanical and Electrical Engineering, University of Electronic Science and Technology of China, Chengdu, Sichuan P.R. China. boomfem@gmail.com
Lucille Aba Abruquah, School of Management and Economics, University of Electronic Science and Technology of China, Chengdu, Sichuan P.R. China. Labruquah@yahoo.com
Sandra C. Obiora, School of Management and Economics, University of Electronic Science and Technology of China, Chengdu, Sichuan P.R. China. Sandra_ora@hotmail.com
Tamas Csordas, School of Management and Economics, University of Electronic Science and Technology of China, Chengdu, Sichuan P.R. China. tcsorda@uestc.edu.cn
Mustafa Dagbasi, Energy Systems Engineering Department, Cyprus International University, Haspolat-Lefkosa, Mersin 10, Turkey. Mdagbasi@ciu.edu.tr

Abstract

In this research, the willingness to support a policy that enforces the installation of solar water heaters on every building in Cyprus is analyzed. The current status of solar water heating (SWH) systems in Cyprus is also evaluated in terms of utility and installation. The binary logit regression model, descriptive statistics, and chi-square crosstab analysis are used to analyze the data collected from 1000 residences across the Island. Cyprus has dropped from first to third in the world's ranking of solar water heaters per capita installation. Out of the 1000 resident sample residence, 778 respondents have solar water heaters installed and 222 had not installed solar water heating systems at the time the data was collected. Findings from this study indicate that respondents support solar water heating installation policy enforcement when their pipes are insulated. They also perceive solar water heating systems to be important and worth the investment. Respondents who would recommend solar water heating to others were more likely to support the enforcement of solar water heating installation policies. On the other hand, respondents who installed solar water heating because their neighbors had done so tended not to support its enforcement. Therefore, it is recommended that the government consider some of the aforementioned factors in order to maximize the benefits of SWH systems on the island.

Keywords: *Cyprus, Energy, Policy, Regression Analysis, Solar Water Heaters.*

1. <u>Introduction</u>

Cyprus is the third largest island in the Mediterranean in terms of landmass and the third largest island in the eastern part of the Mediterranean in terms of the population [1]. It has a great source of solar energy to produce extreme heat but this solar energy is underutilized [1], [2]. With no natural oil reserves, Cyprus has a great potential to domesticate solar energy because of its climatic advantages and geographic positioning [3]. The island is very sunny with an average daily solar radiation of 5.4 kWh/m^2 on the horizontal surface. The mean daily solar radiation varies from 2.3 kWh/m^2 in the cloudiest months of the year (December and January) to 7.2 kWh/m^2 in the sunniest month (July) [4], [5]. The annual global horizontal solar irradiation varies between 1600 kWh/m^2 and 2000 kWh/m^2 as shown in Fig. 1 [6]. The island has two republics (Turkish Republic of North Cyprus and Republic of Cyprus) with a population of about 1.2 million people [5].

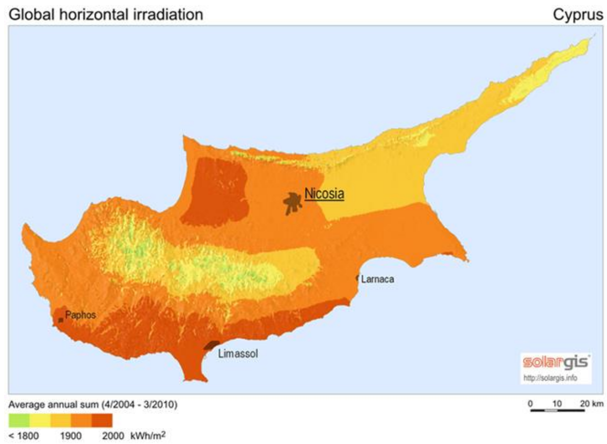

Figure 1: Cyprus Solar Radiation Map [6].

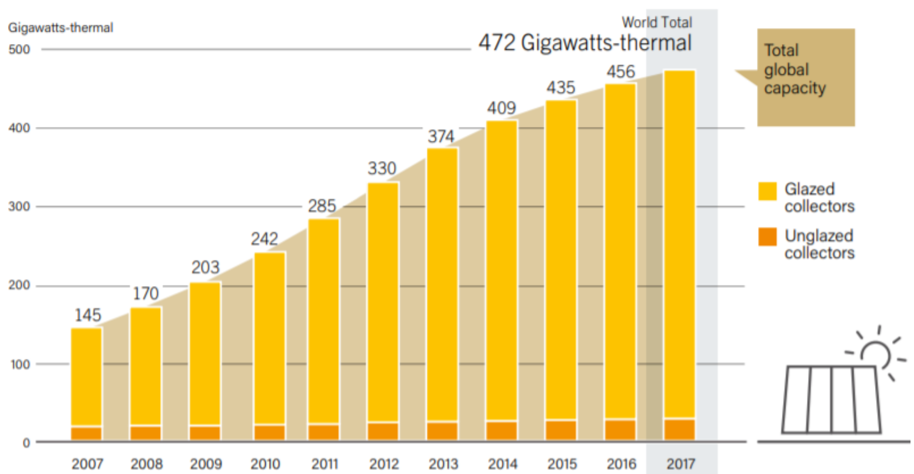

Figure 2: Global solar water heating system installed capacity [7].

Solar water heating (SWH) technology is one of the most mature solar energy application technologies. The commercial application of this technology has been available in the market for over 40 years [8]. The global installed capacity of SWH systems tripled between 2007 and 2017 (Fig. 2). About 34,927 MW_{th} worth of SWH systems was added in 2017 increasing the total global capacity to 472 GW_{th} at the end of 2017. Also, 71% of global solar water heaters are installed in China and the country is ranked first for SWH installation. Cyprus dropped from the first position (in 2004) to third (in 2017) in terms of global per capita SWH systems installation with Barbados and Austria overtaking it to claim first and second positions respectively recently [7], [9]. The manufacture of SWH systems started in the early sixties in Cyprus and the number of installed solar water heaters at the moment exceeds 140,000 units [10].

In literature, different forms of research have been presented on SWH systems. Wu et al. [11], did an experimental study on the performance of a novel SWH system with and without phase change materials (PCM). A full year measurement in Nanjing city in China for couple of consecutive years was done considering different environmental conditions. It was recorded that collector efficiency with PCM is over 30% less than without PCM. A techno-economic feasibility study of SWH systems was presented in another research [12]. The paper gave an overview of existing techno-economic analyses of SWH systems and used meta-analyses to check the effects of technology level, policy support, natural conditions, and supplementary energy type on the payback period of SWH systems. Their result showed nine negative effects and seven positive effects for the areas considered [12]. Shafieian et al. [13], studied the thermal performance of an evacuated tube heat pipe SWH system in the cold season. A mathematical model was developed and used to determine the optimum number of glass tubes of heat pipe solar collectors. Their results showed that hot water extraction had a significant impact on the thermal performance of SWH systems [13].

Research about the application of SWH systems for different countries such as Ethiopia [14], Serbia [15], Algeria [16], Spain [17], and New Zealand [18], [19] were presented in literature. These studies considered the policies, economic and technological feasibility of SWH systems in various countries. The hybrid application of SWH systems [20]–[22] and the market share feasibility of SWH systems [23], [24] were also studied. Ghorab et al. [25], did an inclusive analysis and performance evaluation of solar domestic hot water systems. Their study presented a SWH system with a recirculation loop for domestic application. The system was tested with Canada's weather condition and it was found that the SWH systems performance depends on the flow rate, recirculation loop control strategy, draw time and duration, city weather, and system layout. Also, Daniels et al. [26], researched a SWH system with heat-pipe evacuated tube collectors and found that the system provides adequate thermal energy to maintain two 3.05m x 1.22m x 0.13m concrete slab surface above freezing temperature.

Some researchers have studied SWH systems application in Cyprus. Kalogirou used TRNSYS for the modeling and simulation of a hybrid PV-thermal solar system for Cyprus. A heat exchanger with fins is placed at the back of a normal PV panel. This regulates the PV operating temperature thereby giving a higher efficiency. Hot water is produced from the heat exchanger and the results from their simulation show that the optimum water flow rate of the system is 25 liters/hr. [27]. Another research by Maxoulis et al. [9], considered the economic opportunities attached to SWH systems in Cyprus. The paper reviews the competitiveness, economic performance, and evolution of the SWH industry using the cluster theory of Michael Porter. Details about the SWH system production industry in relation to the local market were also investigated. In a similar study [28], the hot-water production of hotels in Cyprus was considered in terms of energy and environment. Air-source heat pumps with flat plate solar collectors were identified to have the lowest primary energy consumption. It was concluded that the tourism sector of Cyprus needs to phase out the use of boiler systems and promote the use of solar thermal systems to reduce energy consumption and make the environment more sustainable.

Despite the huge amount of SWH systems installed in Cyprus, it is quite intriguing to know that there has never been a policy that mandates the installation of solar water heaters. The only SWH policy available in Cyprus is a subsidy policy for SWH [29] and this is still at the planning stage. According to International Energy Agency (IEA), the scheme will support the replacement and establishment of SWH for residential applications with a grant of 350 Euros for the entire system and 175 Euros for solar panels only [30]. Out of all the literature considered, there was no in-depth research into the current status, utilization, and policy of SWH systems in Cyprus. The closest was the research by Bamisile et al. [8], in which descriptive analysis was used to check the utility and development of SWH systems in Cyprus. Therefore, there exists a gap in literature regarding the utilization and policy of SWH on this Island. In this research, the Binary logit regression model will be used to check the willingness of Cypriots to accept a policy that enforces SWH for each building. Chi-square crosstab analysis will be employed to analyze the current status of SWHs. Determinants to the acceptance of this policy will also be identified and the prospects of the policy in the nearest future will be considered. Primary data from 1000 residences in Cyprus is collected and used for the analysis in this research. The main contribution of this paper is the determination of factors that encourages SWH policy based a primary data. The rest of the paper provides details about the materials and methods, statistical analysis, results, and conclusions from the survey.

2. Materials and Methods

2.1. Data collection

A standardized quantitative survey was used to collect data on 1000 housing units in Cyprus through a random sampling method. The types of housing units were classified under studio apartments/dormitories (55%), 2 or 3 bedroom apartments (28%), duplex (12%), and others (5%). Respondents in these housing units were asked questions about the use of SWH systems, willingness to recommend SWH systems to neighbors, and support for SWH policy enforcement throughout Cyprus. In relation to the use of SWH systems, respondents were asked about the number of years they have used SWH systems, the functionality of the system, the sufficiency of hot water produced daily, and knowledge regarding SWH insulation pipes. Further details of these aforementioned variables are shown in Table 1.

Table 1: Description of variables and summary statistics of survey questions

Variables	Description	Proportion
SWH Policy	1 if respondent supports policy that enforces SWH installation; 0 otherwise	0(.1825) 1 (.8175)
Location	Residence location of respondent classified into 4 categories: (1) Lefkosa, (2) Girne, (3) Magusa (4) Others	1(.5463) 2(.2827) 3 (.1170) 4 (.0540)
Apartment Type	Type of apartment respondent lives in, classified into 4 categories: (1) Studio apartment/Dormitory (2) 2/3 Bedroom apartment (3) Duplex (4) Others	1(.1195) 2(.5476) 3(.2931) 4 (.0398)
No_Years	Number of years SWH has been installed in respondent's house/apartment classified into 5 categories: (1) Less than a year (2) 1-5 years ago (3) 5-10 years ago (4) Over 10 years ago (5) I don't know	1 (.0810) 2(.3201) 3 (.3265) 4(.2648) 5(.0077)
Working	1 if the respondent's SWH system is not currently working; 2 if SWH is still working till date.	1(.1054) 2(.8946)
Water_Provision	1 denotes SWH system does not provide enough hot water during hours needed; 2 denotes SWH provides enough hot water.	1(.4370) 2(.5630)
Insullated_Pipes	Knowledge of whether SWH pipes installed in an apartment are insulated: (1) No (2) Yes (3) Don't know	1(.4383) 2(.4781) 3(.0835)
Daily_Production	Quantity of hot water SWH system produces daily: (1) Exactly what is needed (2) More than enough (3) Not enough (4) Can not tell	1(.3985) 2(.1247) 3(.2789) 4(.1979)
Worth_INV	Perception of whether SWH system is worth the investment with 1 representing not worth the investment and 2 representing the affirmative	1(.1568) 2(.8432)
Importance	1 represents perception that SWH is not an important part of the respondent's building; 2 represents the perception that SWH is an important part of building	1(.1735) 2(.8265)
Recommend_SWH	1 denotes the respondent does not recommend SWH installation and 2 denote respondent recommends SWH installation.	1(.8740) 2(.1259)

Reason	Respondents' reason for installing a SWH system classified under 4 categories: (1) Produces hot water during summer (2) Reduces electricity bills (3) Everyone in the neighborhood has one installed (4) Other reasons	1(.2198) 2(.5553) 3(.0398) 4(.1851)

2.2. Statistical analysis

One of the objectives of this study is to ascertain the determinants of solar water heating installation policy enforcement in Cyprus. Respondents were asked whether they would support a policy that enforces SWH installation in all houses in Cyprus. As aforementioned, this dependent variable was measured on a binary scale where 1 denotes their support for such a policy and 0 otherwise. The statistical analyses usually adapted for a dichotomous dependent variable are the binary logit or probit, regression models. Since the logit and probit models produce similar partial effects, we adopt the binary logit model based on the assumption that errors adhere to a standard logistic distribution instead of a standard normal distribution in the probit model [31], [32]. The true willingness to support the enforcement of SWH installation in Cyprus denoted by $SWHPolicy_{NC^*}$ is a latent variable which is inconspicuous thus, the reported willingness to support SWH represented by r $(SWHPolicy_{NC^*})$, serves as a good proxy. We use a binary regression model analogous to the one below in determining the effect of selected variables on the respondents' willingness to support SWH policy enforcement in Cyprus.

$$SWHPolicy_{NC^*} = \varphi + \beta_1 Insulated\_Pipes_{NC} + \beta_2 Reason_{\mathrm{NC}} + \beta_3 ImportantSWH_{NC} + \beta_4 Working_{NC} + \beta_5 Worth\_INV_{NC} + \beta_6 Recommend\_SWH_{NC} + \xi$$

Where $SWHPolicy_{NC^*} = \begin{cases} 0 \; if \; SWHPolicy^*_{NC} \leq 0 \\ 1 \; if \; SWHPolicy^*_{NC} > 0 \end{cases}$

In the above binary regression model, φ denotes the level of change in r $(SWHPolicy_{NC^*})$, holding the assumption that all the independent variables are non-existent, $\mathrm{Insulated\_Pipes}_{\mathrm{NC}}$ denotes whether the respondents' SWH system is insulated, $Reason_{\mathrm{NC}}$ represents respondents' reasons for installing SWH system in their apartment, $ImportantSWH_{\mathrm{NC}}$ denotes whether the respondent perceives SWH to be an important part of their building, $Working_{\mathrm{NC}}$ represents whether the respondent's SWH system installed still works as at the time of the survey, $WorthINV_{NC}$ denoted whether it is worth investing in the SWH system, $RecommendSWH_{NC}$ denotes the respondent's intention to encourage people to install SWH systems in their apartments.

3. Results and Discussion

This section presents the result from analyzing the data collected from residences in Cyprus about SWH. The primary data used in the research are collected from 1000 different respondents and analyzed with STATA and SPSS analyzing programs. The descriptive statistics from the data collected are given in Table 1. The results are presented in two sub-section. The first subsection checks the application of the SWH system and the perspective of the respondents as regards the worth of investment, quantity of hot water produced, insulation of pipes, and other parameters. The second subsection discusses the willingness of the Cypriots to accept a policy that enforces SWH installation on every building.

Out of all the 1000 residents interviewed, 778 have SWH installed with their buildings and 222 do not have this system. Of the 222 residents without SWH systems, 51.5% attributed their inability to install a system to economic reasons (high installation and insufficient funds to finance the installation). While 13.1% said they do not have access to installation materials, the remaining 35.6% gave other reasons. The residents without SWH systems were further asked about their willingness to install a system soon, 56% have plans to install this system in the nearest future. The analysis about the current status and policy enforcement of SWH are based only on data collected from respondents with SWH installed in their residence.

3.1. Application

Chi-Square Crosstab Analysis

Several key variables were cross-tabulated, and the Chi-square tests, as well as symmetric measures using Pearson's R and Spearman Correlation, were run on each pair of variables. Setting our Monte Carlo significance at a 95% confidence interval on both tests, we investigate the relationship between the variables and whether the combinations are significant to the introduction of the SWH policy in Northern Cyprus.

Table 2A: SWH installation time and Worth Investment

			Worth Investment		
			Yes	No	Total
SWH Install time	Less than a year ago	Count	43	20	63
		% within SWH Install time	68.3%	31.7%	100.0%
		% within Worth Investment	6.6%	16.4%	8.1%
		% of Total	5.5%	2.6%	8.1%
	1 – 5 years ago	Count	198	51	249
		% within SWH Install time	79.5%	20.5%	100.0%
		% within Worth Investment	30.2%	41.8%	32.0%
		% of Total	25.4%	6.6%	32.0%
	6 – 10 years ago	Count	226	28	254
		% within SWH Install time	89.0%	11.0%	100.0%
		% within Worth Investment	34.5%	23.0%	32.6%
		% of Total	29.0%	3.6%	32.6%
	Over 10 years ago	Count	183	23	206
		% within SWH Install time	88.8%	11.2%	100.0%
		% within Worth Investment	27.9%	18.9%	26.5%
		% of Total	23.5%	3.0%	26.5%
	I don't know	Count	6	0	6
		% within SWH Install time	100.0%	0.0%	100.0%
		% within Worth Investment	0.9%	0.0%	0.8%
		% of Total	0.8%	0.0%	0.8%
Total		Count	656	122	778
		% within SWH Install time	84.3%	15.7%	100.0%
		% within Worth Investment	100.0%	100.0%	100.0%
		% of Total	84.3%	15.7%	100.0%

The time the SWH system was installed and whether the respondents think SWH systems were worth the investment were cross-tabulated. According to the chi-square test result, there exists a positive trend between the length of time the SWH system is installed and the percentage of those who agree that the SWH system is worth the investment (Table 2B). At less than a year of installation time, 5.5% of the 8.1% of respondents in this category considered SWH systems worth the investment while 29% of the 32% with SWH system installation of 6-10 years consider it a good investment (Table 2A). Although the time frame of installation of SWH systems differs for the respondents, a larger percentage (84.3%) indicated that the investment is worth it (Table 3). Also, a chi-square cross-tabulation test is used to inquire whether their SWH system still works and whether they consider the SWH system to be a good investment. At 100% confidence on both the upper and lower bounds (Table 3B), we note that those whose SWH systems continue to work till date were more likely to consider it a good investment at a rate of 77% of the 89.5% whose SWH systems continued to work till date (Table 3A). A larger percentage of those who have a working system till date (91.3%) think the SWH system is a good investment. It should be noted that out of all the respondents interviewed 89.5% indicated that their systems are still working till the time the data was collected (Table 1).

Table 2B: Chi-Square Tests SWH installation time and Worth Investment

	Value	df	Asymp. Sig. (2-sided)	Monte Carlo Sig. (2-sided) Sig.	Monte Carlo Sig. (2-sided) 95% Confidence Interval Lower Bound	Monte Carlo Sig. (2-sided) 95% Confidence Interval Upper Bound	Monte Carlo Sig. (1-sided) Sig.	Monte Carlo Sig. (1-sided) 95% Confidence Interval Lower Bound	Monte Carlo Sig. (1-sided) 95% Confidence Interval Upper Bound
Pearson Chi-Square	25.098[a]	4	.000	.001[b]	.000	.003			
Likelihood Ratio	24.147	4	.000	.001[b]	.000	.003			
Fisher's Exact Test	22.682			.001[b]	.000	.003			
Linear-by-Linear Association	20.326[c]	1	.000	.000[b]	.000	.003	.000[b]	.000	.003
N of Valid Cases	778								

a. 1 cells (10.0%) have expected count less than 5. The minimum expected count is .94.
b. Based on 1000 sampled tables with starting seed 1507486128.
c. The standardized statistic is -4.508.

Table 3A: Crosstab Still Working and Worth investment

			Worth Investment Yes	Worth Investment No	Total
Still Working	Yes	Count	599	97	696
		% within Still Working	86.1%	13.9%	100.0%
		% within Worth Investment	91.3%	79.5%	89.5%
		% of Total	77.0%	12.5%	89.5%
	No	Count	57	25	82
		% within Still Working	69.5%	30.5%	100.0%
		% within Worth Investment	8.7%	20.5%	10.5%
		% of Total	7.3%	3.2%	10.5%
Total		Count	656	122	778
		% within Still Working	84.3%	15.7%	100.0%
		% within Worth Investment	100.0%	100.0%	100.0%
		% of Total	84.3%	15.7%	100.0%

Table 3B: Chi-square test for Still Working * Worth investment

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	15.198[a]	1	.000	.000	.000	
Continuity Correction[b]	13.972	1	.000			
Likelihood Ratio	12.883	1	.000	.001	.000	
Fisher's Exact Test				.000	.000	
Linear-by-Linear Association	15.179[d]	1	.000	.000	.000	.000
N of Valid Cases	778					

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 12.86.
b. Computed only for a 2x2 table
c. For 2x2 cross-tabulation, exact results Insulated Pipes provided instead of Monte Carlo results.
d. The standardized statistic is 3.896.

In Table 4A, the crosstab results of the relationship between SWH pipe insulation and whether SWH systems are considered a good investment are presented. The chi-square test at 98% confidence (Table 4B) shows a positive relationship. We note that 86.8% of the 47.8% of respondents whose pipes were insulated considered it a good investment compared to 83.9% of the 43.8% whose pipes were not insulated. When the quantity of hot water produced as indicated by the respondents was checked against the investment perception, the result showed that there is a positive relationship (between quantity produced and worth of investment). At a 97% confidence (table 5B), we see that the quantity produced did not negatively affect the overall consideration of SWH being a good investment. 84.3% of all respondents in the category consider the SWH system a good investment. We also note that the largest percentage of the 15.7% who did not consider SWH as a good investment, a majority of 7.1% came from the category of those who did not consider the quantity of hot water produced daily to be enough for them (Table 5A). Table 6A cross-tabulation considers the relationship between the quantity of hot water produced and whether their SWH pipes are insulated. At 100% confidence on the lower bound, and 97% significance on the upper bound (Table 6B), it is notable that the largest percentage of 51.6% of the 47.8% who indicated that their pipes were insulated produced the exact quantity of hot water. Also, most of those who don't get enough hot water from their SWH system do not have their pipes insulated. Insulated piped reduces losses within a SWH system and the result from this study shows that the more insulated the pipes are the more the quantity of hot water produced.

Table 4A: Crosstab on Insulated Pipes and Worth Investment

			Worth Investment		
			Yes	No	Total
Insulated Pipes	Yes	Count	323	49	372
		% within Insulated Pipes	86.8%	13.2%	100.0%
		% within Worth Investment	49.2%	40.2%	47.8%
		% of Total	41.5%	6.3%	47.8%
	No	Count	286	55	341
		% within Insulated Pipes	83.9%	16.1%	100.0%
		% within Worth Investment	43.6%	45.1%	43.8%
		% of Total	36.8%	7.1%	43.8%
	I don't know	Count	47	18	65
		% within Insulated Pipes	72.3%	27.7%	100.0%
		% within Worth Investment	7.2%	14.8%	8.4%
		% of Total	6.0%	2.3%	8.4%
Total		Count	656	122	778
		% within Insulated Pipes	84.3%	15.7%	100.0%
		% within Worth Investment	100.0%	100.0%	100.0%
		% of Total	84.3%	15.7%	100.0%

Table 4B: Chi square test on Insulated Pipes and Worth Investment

				Monte Carlo Sig. (2-sided)			Monte Carlo Sig. (1-sided)		
					95% Confidence Interval			95% Confidence Interval	
	Value	df	Asymp. Sig. (2-sided)	Sig.	Lower Bound	Upper Bound	Sig.	Lower Bound	Upper Bound
Pearson Chi-Square	8.915[a]	2	.012	.008[b]	.002	.014			
Likelihood Ratio	7.934	2	.019	.024[b]	.015	.033			
Fisher's Exact Test	8.242			.019[b]	.011	.027			
Linear-by-Linear Association	7.026[c]	1	.008	.007[b]	.002	.012	.005[b]	.001	.009
N of Valid Cases	778								

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 10.19.
b. Based on 1000 sampled tables with starting seed 1507486128.
c. The standardized statistic is 2.651.

Table 5A: Crosstab on Quantity Produced and Worth Investment

			Worth Investment		
			Yes	No	Total
Quantity Produced	Exact quantity needed	Count	280	30	310
		% within Quantity Produced	90.3%	9.7%	100.0%
		% within Worth Investment	42.7%	24.6%	39.8%
		% of Total	36.0%	3.9%	39.8%
	More than enough	Count	84	13	97
		% within Quantity Produced	86.6%	13.4%	100.0%
		% within Worth Investment	12.8%	10.7%	12.5%
		% of Total	10.8%	1.7%	12.5%
	Not enough	Count	162	55	217
		% within Quantity Produced	74.7%	25.3%	100.0%
		% within Worth Investment	24.7%	45.1%	27.9%
		% of Total	20.8%	7.1%	27.9%
	I can't say	Count	130	24	154
		% within Quantity Produced	84.4%	15.6%	100.0%
		% within Worth Investment	19.8%	19.7%	19.8%
		% of Total	16.7%	3.1%	19.8%
Total		Count	656	122	778
		% within Quantity Produced	84.3%	15.7%	100.0%
		% within Worth Investment	100.0%	100.0%	100.0%
		% of Total	84.3%	15.7%	100.0%

Table 5B: Chi Square test on Quantity Produced and Worth Investment

				Monte Carlo Sig. (2-sided)			Monte Carlo Sig. (1-sided)		
					95% Confidence Interval			95% Confidence Interval	
	Value	df	Asymp. Sig. (2-sided)	Sig.	Lower Bound	Upper Bound	Sig.	Lower Bound	Upper Bound
Pearson Chi-Square	24.162[a]	3	.000	.000[b]	.000	.003			
Likelihood Ratio	23.330	3	.000	.000[b]	.000	.003			
Fisher's Exact Test	23.167			.000[b]	.000	.003			
Linear-by-Linear Association	10.758[c]	1	.001	.001[b]	.000	.003	.000[b]	.000	.003
N of Valid Cases	778								

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 15.21.
b. Based on 1000 sampled tables with starting seed 1507486128.
c. The standardized statistic is 3.280.

Table 6A: Crosstab between Quantity Produced and Insulated Pipes

			Insulated Pipes			
			Yes	No	I don't know	Total
Quantity Produced	Exact quantity needed	Count	192	103	15	310
		% within Quantity Produced	61.9%	33.2%	4.8%	100.0%
		% within Insulated Pipes	51.6%	30.2%	23.1%	39.8%
		% of Total	24.7%	13.2%	1.9%	39.8%
	More than enough	Count	56	31	10	97
		% within Quantity Produced	57.7%	32.0%	10.3%	100.0%

		% within Insulated Pipes	15.1%	9.1%	15.4%	12.5%
		% of Total	7.2%	4.0%	1.3%	12.5%
	Not enough	Count	74	129	14	217
		% within Quantity Produced	34.1%	59.4%	6.5%	100.0%
		% within Insulated Pipes	19.9%	37.8%	21.5%	27.9%
		% of Total	9.5%	16.6%	1.8%	27.9%
	I can't say	Count	50	78	26	154
		% within Quantity Produced	32.5%	50.6%	16.9%	100.0%
		% within Insulated Pipes	13.4%	22.9%	40.0%	19.8%
		% of Total	6.4%	10.0%	3.3%	19.8%
Total		Count	372	341	65	778
		% within Quantity Produced	47.8%	43.8%	8.4%	100.0%
		% within Insulated Pipes	100.0%	100.0%	100.0%	100.0%
		% of Total	47.8%	43.8%	8.4%	100.0%

Table 6B: Chi square test on Quantity Produced and Insulated Pipes

	Value	df	Asymp. Sig. (2-sided)	Monte Carlo Sig. (2-sided)			Monte Carlo Sig. (1-sided)		
				Sig.	95% Confidence Interval		Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound		Lower Bound	Upper Bound
Pearson Chi-Square	75.202[a]	6	.000	.000[b]	.000	.003			
Likelihood Ratio	73.439	6	.000	.000[b]	.000	.003			
Fisher's Exact Test	73.185			.000[b]	.000	.003			
Linear-by-Linear Association	53.728[c]	1	.000	.000[b]	.000	.003	.000[b]	.000	.003
N of Valid Cases	778								

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 8.10.
b. Based on 1000 sampled tables with starting seed 307647058.
c. The standardized statistic is 7.330.

Table 7A: Crosstab between Still Working and SWH Install time

			SWH Install time					Total
			Less than a year ago	1 – 5 years ago	6 – 10 years ago	Over 10 years ago	I don't know	
Still Working	Yes	Count	41	224	229	196	6	696
		% within Still Working	5.9%	32.2%	32.9%	28.2%	0.9%	100.0%
		% within SWH Install time	65.1%	90.0%	90.2%	95.1%	100.0%	89.5%
		% of Total	5.3%	28.8%	29.4%	25.2%	0.8%	89.5%
	No	Count	22	25	25	10	0	82
		% within Still Working	26.8%	30.5%	30.5%	12.2%	0.0%	100.0%
		% within SWH Install time	34.9%	10.0%	9.8%	4.9%	0.0%	10.5%
		% of Total	2.8%	3.2%	3.2%	1.3%	0.0%	10.5%
Total		Count	63	249	254	206	6	778
		% within Still Working	8.1%	32.0%	32.6%	26.5%	0.8%	100.0%
		% within SWH Install time	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	8.1%	32.0%	32.6%	26.5%	0.8%	100.0%

Table 7B: Chi square test on Still Working and SWH Install time

	Value	df	Asymp. Sig. (2-sided)	Monte Carlo Sig. (2-sided) Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Monte Carlo Sig. (1-sided) Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Pearson Chi-Square	47.683[a]	4	.000	.000[b]	.000	.003			
Likelihood Ratio	36.802	4	.000	.000[b]	.000	.003			
Fisher's Exact Test	35.633			.000[b]	.000	.003			
Linear-by-Linear Association	27.297[c]	1	.000	.000[b]	.000	.003	.000[b]	.000	.003
N of Valid Cases	778								

a. 1 cells (10.0%) have expected count less than 5. The minimum expected count is .63.
b. Based on 1000 sampled tables with starting seed 205597102.
c. The standardized statistic is -5.225.

Table 8A: Crosstab between Production timing and Insulated Pipes

			Insulated Pipes: Yes	Insulated Pipes: No	Insulated Pipes: I don't know	Total
Production Timing	Yes	Count	251	150	37	438
		% within Production Timing	57.3%	34.2%	8.4%	100.0%
		% within Insulated Pipes	67.5%	44.0%	56.9%	56.3%
		% of Total	32.3%	19.3%	4.8%	56.3%
	No	Count	121	191	28	340
		% within Production Timing	35.6%	56.2%	8.2%	100.0%
		% within Insulated Pipes	32.5%	56.0%	43.1%	43.7%
		% of Total	15.6%	24.6%	3.6%	43.7%
Total		Count	372	341	65	778
		% within Production Timing	47.8%	43.8%	8.4%	100.0%
		% within Insulated Pipes	100.0%	100.0%	100.0%	100.0%
		% of Total	47.8%	43.8%	8.4%	100.0%

Table 7A looks at the relationship between whether their SWH system is working till date and when their SWH heating system was installed. At 100% confidence (Table 7B), it is notable that 95.1% of the 25.2% whose SWH systems were working, installed the system over 10 years ago. Also, 90.2% of the 29.4% whose SWH systems still work till date installed them within six to ten years ago. This further shows how durable the SWH system application in Cyprus is. The average lifespan of a SWH collector is 10 years and with proper maintenance, the system can last up to 25 years. In Table 8A, the cross-tabulation considers the relationship between accurate hot water timing and whether the SWH pipes are insulated. At 100 and 97% confidence on the lower and upper bounds (Table 8B), we note that of the 67.5% who said they got hot water when they wanted it, 57.3% had insulated pipes compared to just 34.2% who did not get enough hot water when they wanted it. Finally, Table 9A shows the relationship between the type of house the respondent lives in and the quantity of hot water they received for SWH. At a 98% confidence (Table 9B), it is notable that the higher percentage of 51.3% of those who felt they got the exact quantity needed were those who resided in 2/3-bedroom apartments. Simultaneously, of the 27.9% of those who feel they do not get enough 59% percent of them reside in 2/3-bedroom apartments (Table 9A). Notably, 54.8% of all respondents are residing in 2/3-bedroom apartment-style houses. The bar chart of all the crosstab analyses is displayed in the appendix section of this paper.

Table 8B: Chi-square test on Production timing and Insulated Pipes

	Value	df	Asymp. Sig. (2-sided)	Monte Carlo Sig. (2-sided)			Monte Carlo Sig. (1-sided)		
				Sig.	95% Confidence Interval		Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound		Lower Bound	Upper Bound
Pearson Chi-Square	39.894[a]	2	.000	.000[b]	.000	.003			
Likelihood Ratio	40.218	2	.000	.000[b]	.000	.003			
Fisher's Exact Test	40.112			.000[b]	.000	.003			
Linear-by-Linear Association	21.777[c]	1	.000	.000[b]	.000	.003	.000[b]	.000	.003
N of Valid Cases	778								

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 28.41.
b. Based on 1000 sampled tables with starting seed 307647058.
c. The standardized statistic is 4.667.

Table 9A: Crosstab between Apartment type and Quantity Produced

			Quantity Produced				Total
			Exact quantity needed	More than enough	Not enough	I can't say	
Apartment type	Studio/Dormitory	Count	26	17	24	26	93
		% within Apartment type	28.0%	18.3%	25.8%	28.0%	100.0%
		% within Quantity Produced	8.4%	17.5%	11.1%	16.9%	12.0%
		% of Total	3.3%	2.2%	3.1%	3.3%	12.0%
	2/3 Bedroom Apartment	Count	159	54	128	85	426
		% within Apartment type	37.3%	12.7%	30.0%	20.0%	100.0%
		% within Quantity Produced	51.3%	55.7%	59.0%	55.2%	54.8%
		% of Total	20.4%	6.9%	16.5%	10.9%	54.8%
	Duplex	Count	113	23	59	33	228
		% within Apartment type	49.6%	10.1%	25.9%	14.5%	100.0%
		% within Quantity Produced	36.5%	23.7%	27.2%	21.4%	29.3%
		% of Total	14.5%	3.0%	7.6%	4.2%	29.3%
	Others	Count	12	3	6	10	31
		% within Apartment type	38.7%	9.7%	19.4%	32.3%	100.0%
		% within Quantity Produced	3.9%	3.1%	2.8%	6.5%	4.0%
		% of Total	1.5%	0.4%	0.8%	1.3%	4.0%
Total		Count	310	97	217	154	778
		% within Apartment type	39.8%	12.5%	27.9%	19.8%	100.0%
		% within Quantity Produced	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	39.8%	12.5%	27.9%	19.8%	100.0%

Table 9B: Chi-square test on Apartment type and Quantity Produced

				Monte Carlo Sig. (2-sided)			Monte Carlo Sig. (1-sided)		
					95% Confidence Interval			95% Confidence Interval	
	Value	df	Asymp. Sig. (2-sided)	Sig.	Lower Bound	Upper Bound	Sig.	Lower Bound	Upper Bound
Pearson Chi-Square	23.980[a]	9	.004	.004[b]	.000	.008			
Likelihood Ratio	23.440	9	.005	.005[b]	.001	.009			
Fisher's Exact Test	23.383			.003[b]	.000	.006			
Linear-by-Linear Association	7.536[c]	1	.006	.009[b]	.003	.015	.007[b]	.002	.012
N of Valid Cases	778								

a. 1 cells (6.3%) have expected count less than 5. The minimum expected count is 3.87.
b. Based on 1000 sampled tables with starting seed 1509375996.
c. The standardized statistic is -2.745.

3.2 Determinants of SWH Policy enforcement in Cyprus

3.2.1 Logistic Regression Analysis

Table 10 shows the binary logit regression results, which provide meaningful indications that act as key determinants to be considered towards the success of widespread SWH installations in Northern Cyprus. From the set of independent variables analyzed, all but one have statistically significant results. Positive coefficients mean that an increase of one unit in these variables further increases the likelihood that a respondent supports the policy to enforce SWH installations on the island.

The P-value estimates indicate a strong positive correlation between having insulated water heater pipes and supporting the policy that enforces SWH installations in all houses on the island at about a 3% level of significance. This indicates that those who can maximize the SWH system through insulated pipes see the benefits of the SWH policy enforcement. Similarly, a respondent’s perception of SWH systems being important aspects of their buildings and the perception that SWH systems installed are functioning till date are both positively correlated to supporting the enforcement of SWH installation policies at a less than 1% level of significance. Thus, respondents who perceive SWH systems to be important, as well as those whose systems are functioning well till date, are highly likely to support the enforcement of SWH installation policies. This is logical considering that if the SWH system fails, there is no reason to support the enforcement of SWH policy across the island. There is also a positive relationship between the perception that SWH systems worth the investment and support for the enforcement of SWH installation policies at a less than 10% level of significance. Hence, respondents who perceive SWH to be worth the investment tend to appreciate the importance of it and are likely to support the enforcement of policies pertaining to its installation throughout the island. On the contrary, respondents who do not consider SWH systems as a reasonable investment do not need to recommend others carry it out as well.

The likelihood of recommending the SWH system also depicted a highly significant positive correlation with support for the enforcement of the SWH installation policy. In essence, the more the respondent is likely to recommend SWH to others, the more likely they are to support the policy that mandates that all homes install SWH across Northern Cyprus. Not only is the location of Cyprus one of the most suitable environments for the enforcement of a SWH policy, but it is also positively received in general as 81.75% of all 1000 observations supported the enforcement of such a policy as depicted in Figure 3.

Interestingly, when the reasons for why respondent’s installed SWH were inquired into, a significantly negative correlation was found between supporting the SWH policy and installing SWH systems because everyone else had one. This implies that respondents are less willing to support the SWH enforcement policy simply based on the fact that their neighbors have it installed. On the other hand, for other reasons, the null hypothesis could not be rejected such as in terms of the relationship between SWH policy support and the reduction of electricity bills due to installed SWH added value.

Table 10: Binary logit estimation results for the determinants of willingness to support SWH installation policy

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Variables	Coefficient	P value	Odds Ratio
Insulated Pipes	.5284***	0.003 [.1803]	1.6961
ImportanceSWH	1.1248***	0.000 [.2540]	3.0796
Working	.3753***	0.014 [.1526]	1.4555
Reasons			
Reduces electricity bill	.2465	0.351 [.2644]	1.2795
Neighbourhood	-.8071*	0.090 [.47549]	.4462
Other reasons	.1456	0.653 [.3239]	1.1567
Worth_INV	.5157*	0.071 [.2861]	1.6748
Recommend	1.8227***	0.000 [.2785]	6.1884
Constant	-6.2805***	0.000 [.0015]	.00187
Regression Index			
LR chi2(8) = 151.54			
Prob > chi2 = 0.0000			
Pseudo R^2 = 0.2050			
Log likelihood = -293.92765			
Observations = 778			

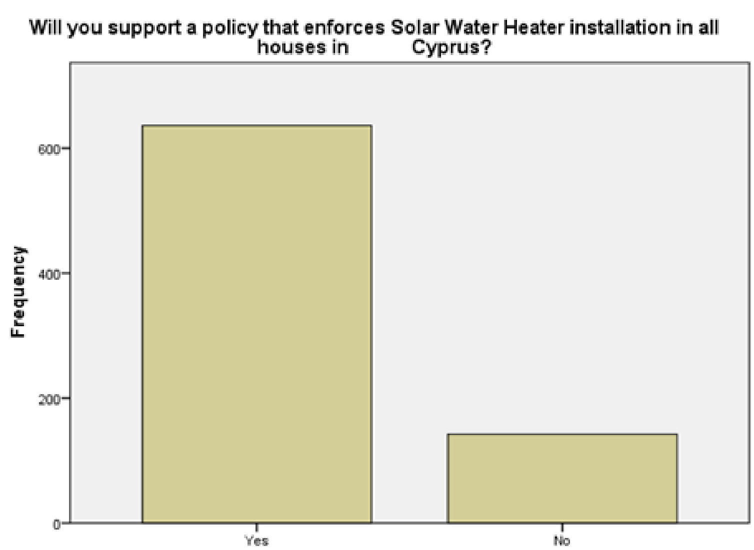

Fig 3: Bar chart of residents' willingness to support a policy that enforces SWH installation.

3.2.2 Odds Ratio Analysis

The Odds ratio column in table 10 provides significant insights into the study. In logistic regression, the odds ratio is basically exponentiations of the coefficients. It represents the way the odds change with a one-unit increase in the variable while holding all other variables constant. In the odds ratio column in table 10, we see that the odds ratio for insulated pipes is 1.69. This indicates that a one-unit increase in insulated pipes installation increases the odds of a respondent supporting the SWH policy in North Cyprus by 69%. In the case of how important respondents feel the SWH system is important to their buildings (ImportanceSWH), the odds ratio is 3.08. This indicates that a one-unit increase in ImportanceSWH perception increases the odds of supporting the SWH policy by about 208%.

Where the working consistency of the installed SWH system is concerned (Working), the odds ratio is 1.455, indicating that a one-unit increase in Working increases the odds of supporting the SWH policy by 45%. Where the reasons for installing SWH is concerned, we see that the odds ratio for conserved electricity bill due to SWH system installation (Electricity bill) is 1.27. Although we do not observe any significant contribution from this reason by just looking at the p-value column, we note however that a one-unit ratio in the perception of conserved electricity bill increases the odds of supporting the policy by 27%. In the case of installing SWH systems due to seeing neighbors install it as well (Neighborhood) the p-value produces a negative correlation to policy support. The odds ratio is less than 1 at 0.44 indicating an exposure that is associated with lower odds of the outcome. In essence, a one-unit increase in Neighborhood as a reason leads to a decrease in the odds of supporting the policy by about 66%.

We observe the odds ratio of WorthINV (Worth the investment) to be 1.67 indicating a 67% increase in the odds of supporting the policy with every one-unit increase of WorthINV. The highest odds ratio value we observe belongs to the Recommendation (Worth recommending to others to install) variable with a 6.19. It implies that a one-unit increase in Recommendation produces a 519% increase in the odds that they will also support the SWH policy in Northern Cyprus. It can be observed that the odds ratio result emphasizes the significant findings from the P values of the binary regression.

4. <u>Conclusions and Recommendations</u>

Cyprus is located in the Mediterranean and has a daily solar radiation rate that averages 5.4kWh/m^2 on the horizontal surface, and peaks to 7.2kWh/m^2 in July. The island's dynamics make it one of the best locations to implement a SWH installation policy. SWH technology is gaining vast popularity now as other sources of energy experience depletion. Today, most countries including Barbados, Austria, and China are seeking out alternative energy sources to replace non-renewable energy sources. This paper takes a sample of 1000 Cypriot housing units and investigates the determinants to the likelihood of supporting a SWH enforcement policy. The application, utility, and durability of currently installed systems were also investigated in this research. In the case where the government mandates the installation of SWH systems, we investigate the factors that affect the respondent's support of such policies. We used a logit regression model where 1 stands for support and 0 otherwise. It was found that having consistently working SWH systems especially with the presence of insulated pipes, the perception of the SWH system being worth the investment, and considering the system as an integral part of their buildings were all positively correlated determinants of supporting the SWH policy enforcement. It is also notable as found from the cross-tabulation that factors such as the stage in years of the installation, whether the installed system still works, whether the pipes installed are insulated in nature, and whether the quantity of hot water finally produced all affect the respondent's perception that the SWH system is worth the investment. Finally, we find that respondents are more likely to support the SWH policy enforcement if they themselves see the benefit of the system, and consider the installation of SWH good enough to recommend to others.

Based on our findings, we have some recommendations to make. If the Cyprus government hopes to mandate the SWH installation policy, they need to consider the following factors. First, people are only willing to install and support such policy's if it indeed works consistently and they are able to maximize its benefits. Secondly, people are more likely to support such a policy if it presents itself as a good enough investment. In essence, the financial benefits of installing a SWH must be well outlined for the citizens to regard the policy as a positive one. Also, they cannot be expected to install SWH systems simply because their neighbors have them installed. Each family must see the value of it, and even find it to be an integral aspect of their building's infrastructure. The installation should also be able to produce enough hot water especially at times when they are most needed. In essence, the design, the cost, and the value of installing a SWH system should be clearly outlined before the citizens can be expected to embrace the enforcement of a SWH policy in Cyprus.

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Appendix

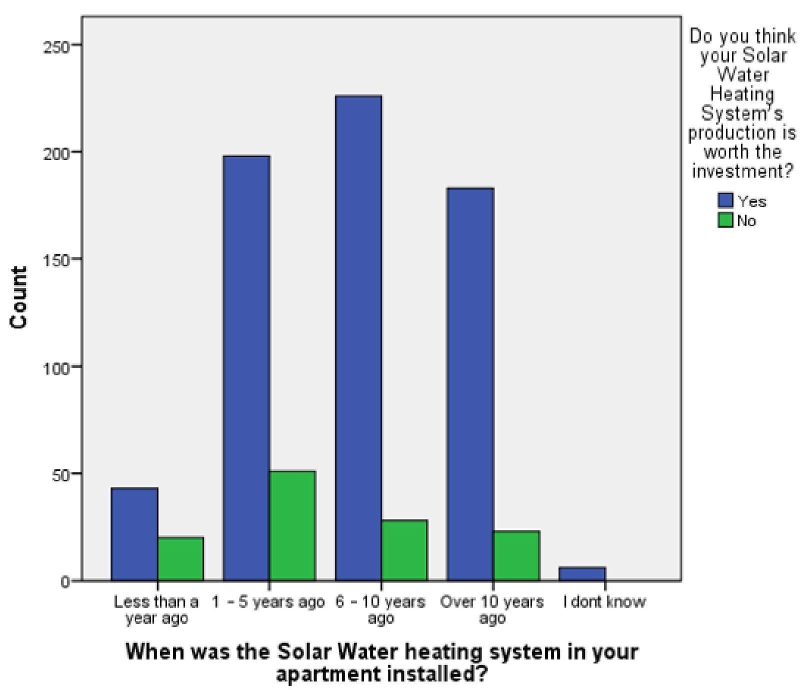

Figure 4. Crosstab bar chat depicting SWH installation time and Worth Investment

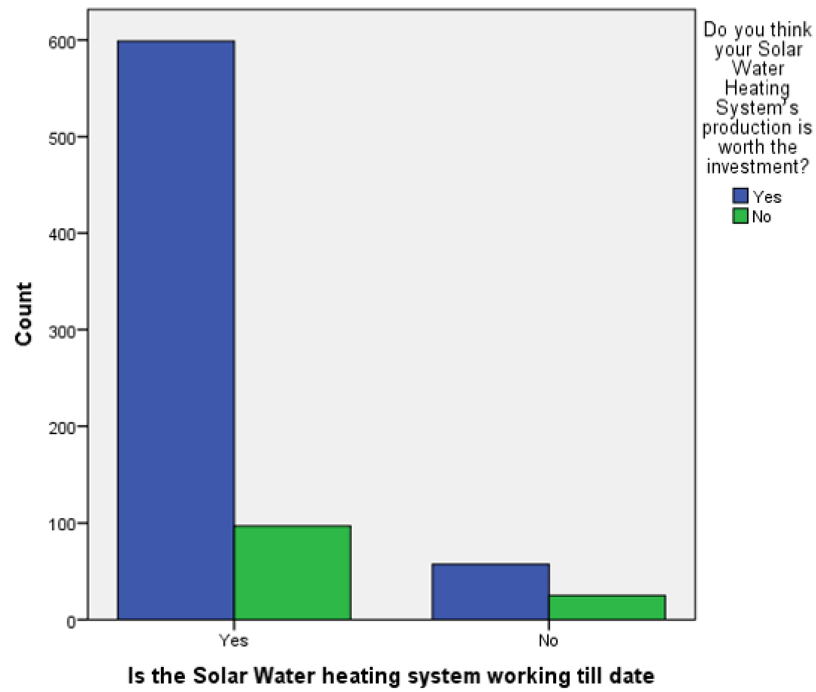

Figure 5: Bar chat depicting Still working and Worth Investment

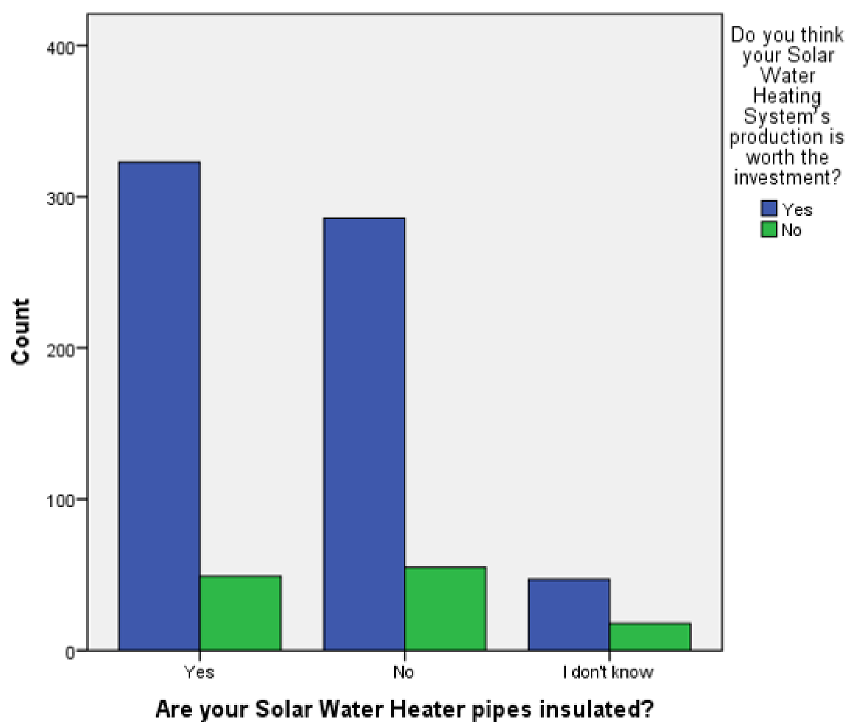

Figure 6: Bar chat depicting Insulated Pipes and Worth Investment

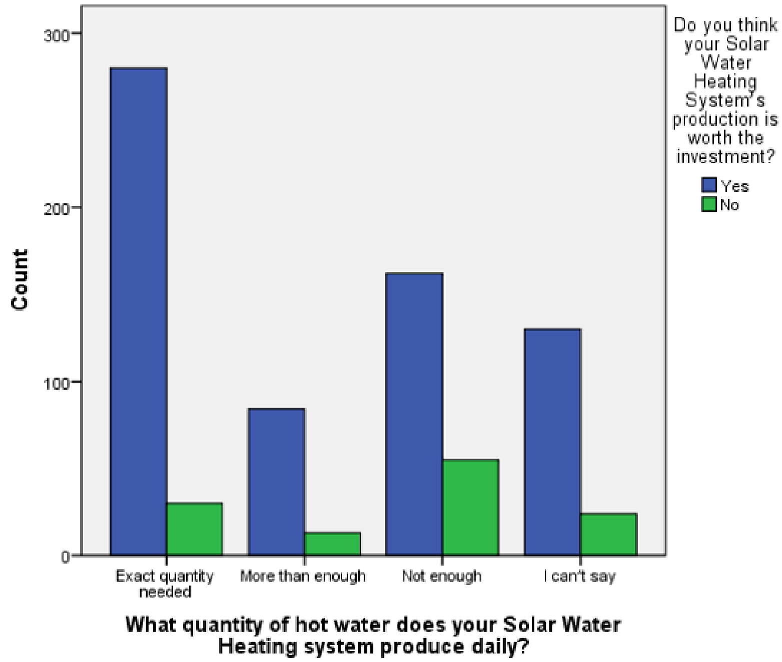

Figure 7: Bar chart depicting Quantity Produced and Worth Investment

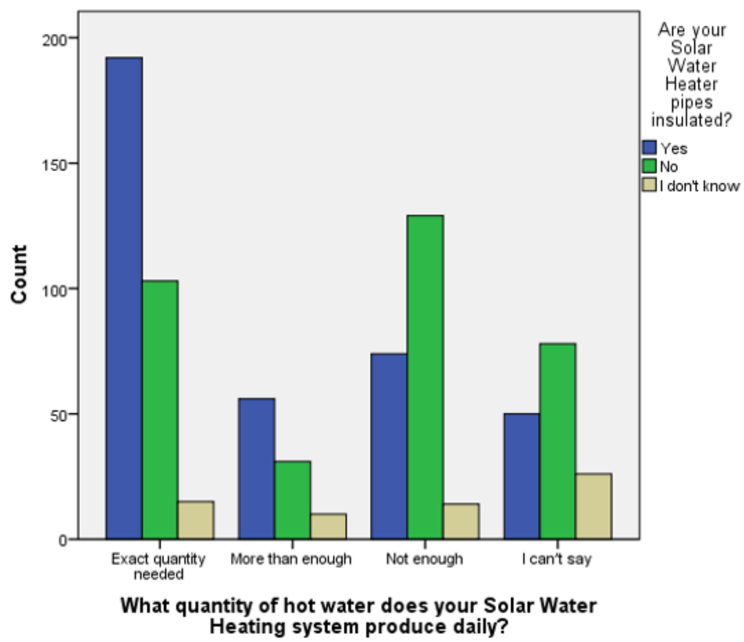

Figure 8: Bar chart depicting Quantity Produced on Insulated Pipes

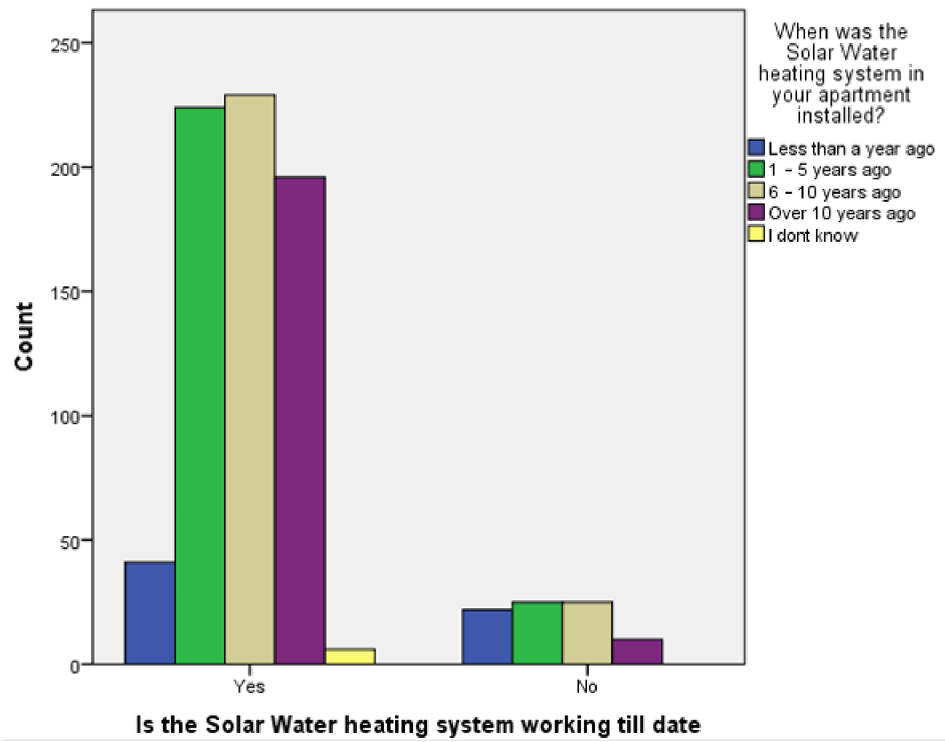

Figure 9: Bar chart depicting Still Working and SWH Install time

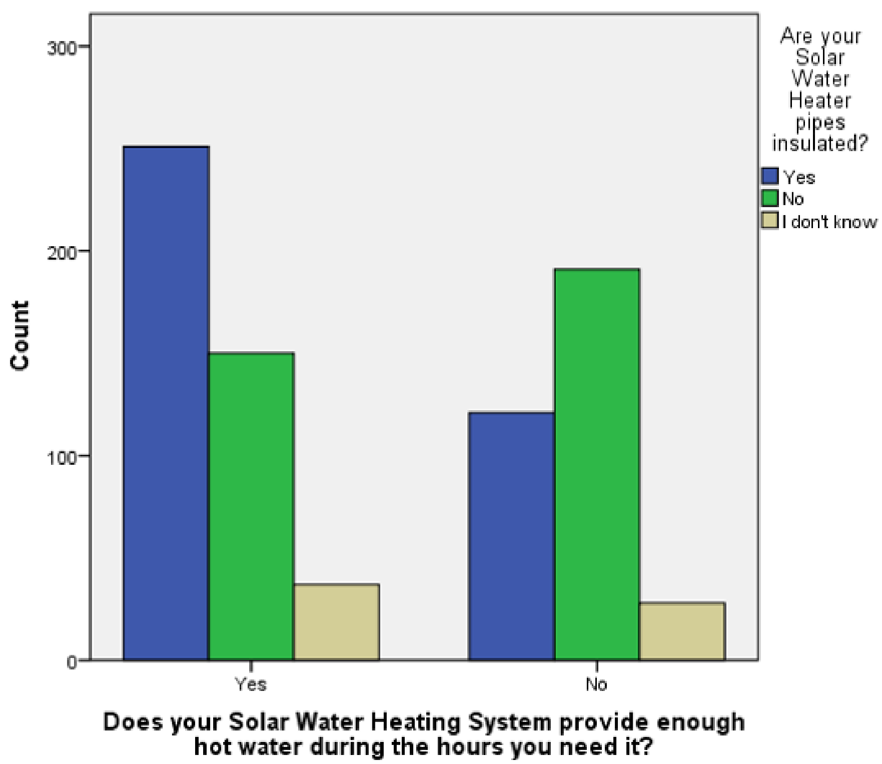

Figure 10: Bar chart depicting Production timing on Insulated Pipes

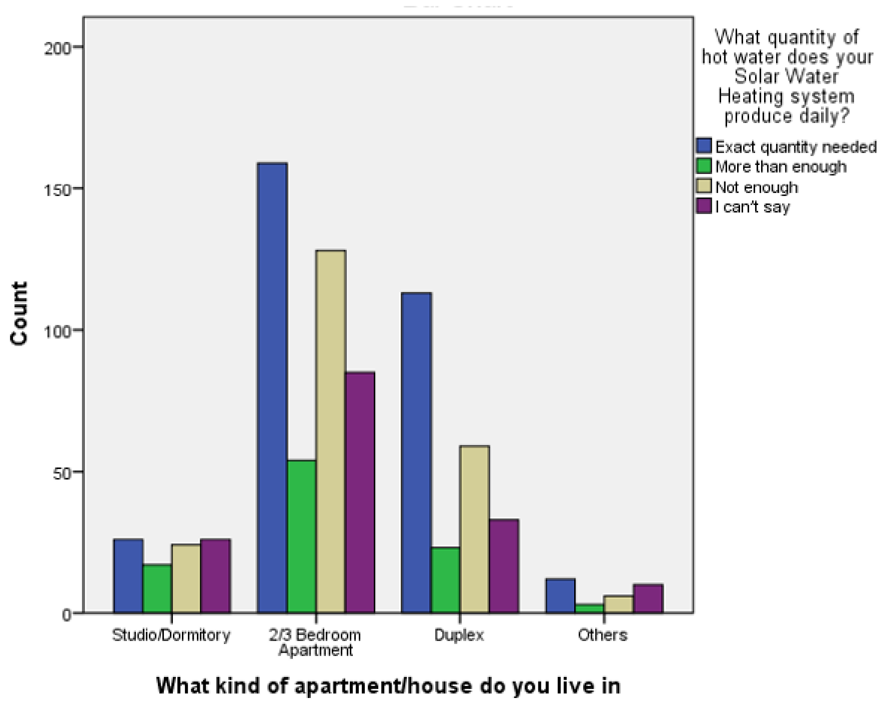

Figure 11: Bar chart depicting Apartment type on Quantity Produced