LOCAL MARKET OF SOLAR WATER HEATERS IN TAIWAN

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ABSTRACT

For promotion of solar water heaters (SWHs) in Taiwan, incentive programs were firstly initiated in the period of 1986 to 1991 and re-initiated from 2000 to the present. These programs create an economic incentive for the end users and have a drastic effect on the popularization of solar water heaters. A general survey of SWHs' users indicated that most solar water heaters were mainly used by the domestic sector for hot water production. There were over 97% SWHs with the area of solar collector less than 10 square meters, which is considered as the residential systems. Limited large scale SWHs, in which the area of solar collector is over 100 square meters, were installed each year. To analyze the behavior of the major actors in local market, two questionnaires were developed. One was addressed to sales agencies and other distribution agents while the other one were approached through person-to-person interviews with household owners (over 4000 samples). Other than the cost of solar water heaters and energy price, it is found that the type of housing and completion of housing construction are the main factor in market diffusion. The potential market of solar water heaters in Taiwan is also associated with the climatic conditions, population structure and urbanization.

INTRODUCTION

Energy supply and security plays a vital role in the national economical development. In Taiwan, energy consumption increased from 37.73 million kiloliters of oil equivalent in 1986 to 114.66 million kiloliters of oil equivalent in 2007. The average annual energy consumption growth rate during this period was about 5.5%. However, Taiwan is a densely populated island with limited land-based energy resources. The ratio of indigenous energy to total energy supply decreased from 10% in 1986 to 1.7% in 2007. In addition, the increasing levels of greenhouse gas CO_2 by burning fossil fuels is creating global warming. To establish a reliable and clean energy supply and demand system, two National Energy Conferences were convened in 1998 and 2005 for the purposes of formulating strategies and measures in response to the impact of the United Nations Framework Convention on Climate Change and to seek a balance among economic development, energy supply, and environmental protection.

Although the intermitted nature of renewable energy resources, they are a sustainable and clean energy asset derived from nature. Other than the net energy saving, the environmental benefits are reduction in the production of air pollutants and release of greenhouse gas into the atmosphere. The major sources include solar energy, wind energy, geothermal energy, ocean energy, biomass, and energy from waste. For the development of indigenous alternative and renewable energy resources, the Taiwanese

government initiated the subsidy programs on solar water heaters (SWHs), solar photovoltaic systems, resource exploration of geothermal power demonstration systems and energy crop green bus projects. A Renewable Energy Development Bill has also been submitted for ratification to establish a legal environment for renewable energy (Wu & Huang 2006). It is expected that renewable energy will share 3% of primary energy supply by 2020 in Taiwan

Taiwan is ideally located to take advantage of solar thermal energy technologies, which has been proved to be reliable and economical in cases of hot water production. The accumulated area of solar collectors installed in 2007 reached 1.53 million square meters. This is the 12th largest installment base in the world. However, there should be some SWHs out of service as a result of ageing. In this context, Taiwan has a great experience in the SWHs market. On the other hand, the Taiwan market has been growing at a slower pace during the last few years. Thus the present study is devoted to an extensive evaluation of the local SWHs market. The time variation of the local market is initially presented. Several questionnaires were evaluated to discuss the perspectives for its further development. This information would be useful for all parties related to this market, manufacturers, potential users and policy makers.

HISTORICAL SWHs MARKET IN TAIWAN (1978-2007)

Taiwan began the manufacture of SWHs in 1978, Fig. 1. In the next seven years, the SWHs penetration in the local market was gradually rising. The area of solar collectors installed was less than 10,000 m^2 per annum. This is attributed to lower average family income in the early eighties and higher capital cost of SWHs compared with conventional hot water heaters. In order to encourage the utilization of SWHs, the Taiwanese government initiated a six-year subsidy program (1986-1991). This subsidy program built up the standard of application for SWHs. More useful energy collected from a solar collector and lower heat loss were required. The manufacturers of SWHs were also motivated by this financial incentive. As a result, the local market expanded dramatically (1986-1988), approaching 60,000 m^2 per annum. In the next three years (1989-1991), the local market was roughly constant. Furthermore, more than 340,000 m^2 of solar collectors were installed through 1992-1995. This would be due to the mature solar thermal technology. The rapid economic growth and a subsequent increase in the current receipts and disposable income of each household in this period would be the other key factors. More households can afford to purchase SWHs. In addition, Chang et al. (2008) indicated that popularity of SWHs in Taiwan is strongly coupled with the status of new construction. According to the Construction and Planning Agency of the Ministry of the Interior (CPA, MOI), the construction of new buildings reached a peak in 1994. This corresponds to the peak area of solar collectors installed as shown in Fig. 1. Since 1996 the local market decreased significantly. The annual area of solar collectors installed in 1999 was less than that at the end of the first subsidy program (1991). The faltering economy and declined rate of construction of new buildings would play the major role.

To further promote the application of solar thermal energy, the Taiwanese government initiated another subsidy program for SWHs (July 2000-present). This created an economic incentive for the end users. In Fig. 1, it is clear that this subsidy program has a strong impact on the popularization of SWHs. The growth rate was about 29% in 2000. Since 2004 the area of solar collectors installed was over 100,000 m^2 per annum. The

annual area of solar collectors installed was doubled from 1999 to 2006. It is clear that the financial incentives for SWHs offered by the government during the last two decades have boosted the domestic market. Furthermore, the local market is almost constant in the 2006-2007 period. This might imply that the current subsidy program has lost momentum in expanding the market for SWHs. However, the population of residual SWHs today in Taiwan still covers a small percentage of households. The potential market should be far from saturation point. Particularly, Taiwan has to face the uncontrollable oil price variations. With the recent fossil fuel market situation, the high oil price is expected to be another driving force to affect the market demand for SWHs.

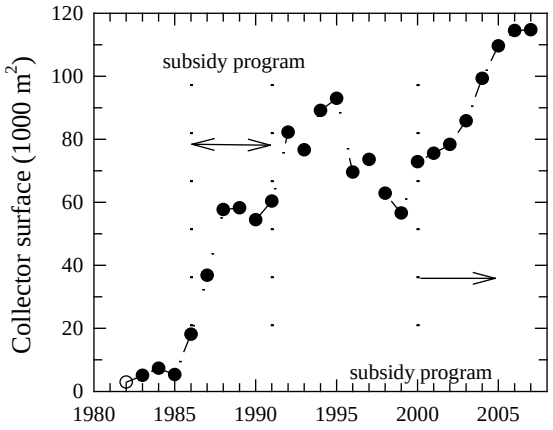

Fig. 1 Annual sales of SWHs in Taiwan

SUMMARY OF SWHs INSTALLED (2000-2007)

In the second subsidy program, the Taiwanese government provides the financial incentive to the end users based on the area of solar collectors installed (1,500 NTD/m^2). The amount of subsidy in the remote islands is double, in which the subsidy is up to 25% of the installed cost of a SWH. In addition, the performance of SWHs (e.g. design, installation and after-sale service) is critical to improve SWHs acceptability by the end uses. To be eligible for this subsidy program, all technicians (installers, dealers and manufacturers) must take some training courses in order to possess a license. With the guideline of system design (tilt angle of solar collector, thermal insulation, shading by neighboring buildings and pipe routing), reliable operation of SWHs has been reported. In addition, certification of SWHs was also a prerequisite. There is only one laboratory (Industrial Technology and Research Institute), which was accredited by Bureau of Energy, Ministry of Economic Affairs, for SWHs' performance testing. From 2000 to present, there were 344 qualified products, 295 qualified installers/dealers, and 40 qualified manufacturers. It is noted that 95 % of qualified installers/dealers are located in the western Taiwan.

The National Cheng Kung University Research and Development Foundation has been authorized to organize an operation unit to carry the tasks of the present subsidy program, which include filing and auditing of applications, allocation of the funding, and appealing process. For each new SWH installed, the end users should provide address and SWH specifications/price. This essential information about the system was then statistically analyzed to generate the regional distribution of SWHs in Taiwan. Furthermore, two approaches were applied to investigate the key factors in the local

market of SWHs in this work. The desk research is mainly on the collection of the related data from official and other sources, and the field research based on the use of a number of questionnaires has been conducted. A number of 500 SWHs owners each year were approached through person-to-person interviews. These questionnaires consisted of questions on (a) the attitude towards SWHs; (b) main technical problems; (c) installation location; (d) year of completion of housing construction; (e) household structure.

Product and Application

For hot water production in the domestic sector, most SWHs use natural circulation. A horizontal storage tank was positioned above the solar collectors, and more than 95% of the SWHs had an electrical booster element installed as a backup heating system. The solar collectors used are flat-plate type and evacuated-tube type. Almost all metallic (stainless or copper) flat-plate type solar collectors were produced domestically while the collectors of evacuated-tube type were imported, in which the average area of solar collector installed of SWHs is 5 m^2 and 3 m^2, respectively. The ratio of volume of storage tank to solar collector area ranges from 50 to 80 litres/m^2. The annual sales of SWHs with both types of solar collectors are shown in Fig. 2. The glazed flat-plate type with metal absorbers and glass cover are widely used to transform solar energy into heat. The market share was over 97% in 2001. The area of solar collectors installed per annum increased almost 50% in the next three years. Since 2004 the yearly installation appeared to reach the saturation point, and the market share declined gradually. On the other hand, the annual sales of evacuated-tube type expanded greatly. In 2007 the area of solar collector installed was more than 10,000 m^2, in which the market share approached 10%. The role of international competition might be more important in the future.

It will be very difficult to promote SWHs without governmental support. The Taiwanese government enforces the improved performance or standards (energy collected and heat loss) on SWHs since the first subsidy program. Thus the product marketability is not solely based on word of mouth and previous experiences with the product rather than actual performance. However, the manufacturing procedure of SWHs does not require advanced technology. Other than the cost, technical guarantee/support would be one of the major factors affecting the brand selection. Thus the quality control and cumulative experience of certified technicians are considered to be related to the annual sales of individual manufacturer. In the period of 2001-present, the area of solar collectors installed in Taiwan is about 657,000 m^2 and the market share of top ten brands is shown in Fig. 3. Although there are 40 qualified manufacturers, the top ten brands occupy 90% of the local market, particularly for the top three ones (50%). It is also noted that the price reduction was observed in the first four years of the present subsidy program. This is not only related to technical change but also to a systematic effort to reduce costs through economies of scale (or sales increase).

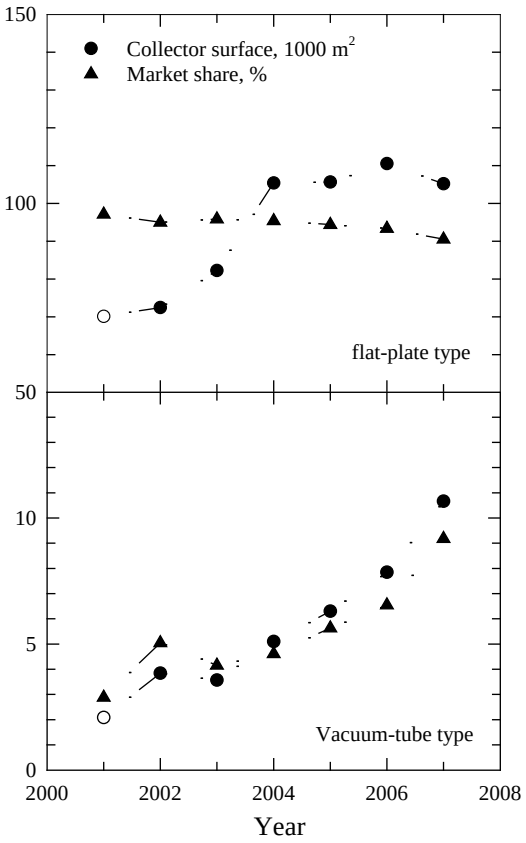

Figure 2 Annual sales of SWHs with flat-plate or evacuated-tube solar collectors

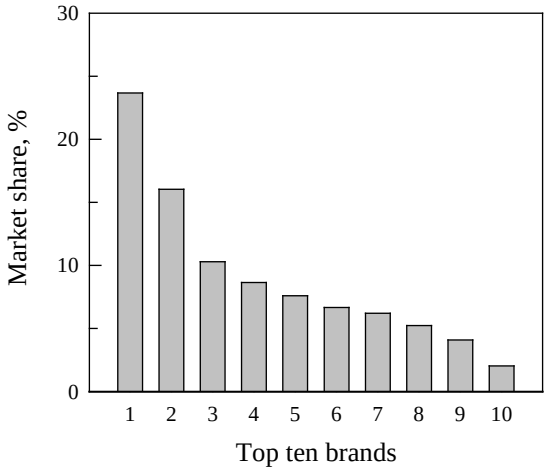

Figure 3 Market share of top ten brands, 2001-2007

Public Attitude towards SWHs

The capital cost of SWHs is considerably higher than that of conventional hot water heaters. Thus the available family income would be a serious factor in the potential number of households who can invest in SWHs. The monetary benefit accrued to the end users is another concern, which would depend on the amount and cost of fuel saved through the use of SWHs (Argiriou & Mirasgedis 2003; Chandrasekar & Kandpal 2004;

Kaldellis et al. 2005). In Taiwan, the area of solar collectors installed increased significantly in the late eighties, which is partially due to the rapid economic growth and a subsequent increase in the current receipts and disposable income of each household. Most households can afford to purchase SWHs (Chang et al. 2006). Moreover, Taiwan has strong potential for harnessing solar energy. The payback period was expected to decrease with the improved system design and performance. Thus with the well-organized and concerted efforts (subsidy programs and research projects) taken by the government, there is increasing public interest in the domestic sector.

Concerning the public attitude towards SWHs applications, a total of 4,900 copies of the questionnaire by the end users were filled in. It was found that there are about 14% households replacing the old systems. The detailed time-evolution of cumulative SWHs in operation could be evaluated with a more comprehensive market survey in the future. The present survey indicated the relative importance of the various factors according to the opinions of households owing SWHs. Households give a greater emphasis to economic factor (energy saving, 56%). This should be attributed to the emergent worldwide energy reserves shortage. On the other hand, hot water heaters using LPG or natural gas are the most popular ones in Taiwan. However, carbon monoxide poisoning was frequently reported in winter. Safety is another concern by the respondents. The opinion of friends and market campaigns (product distribution network) are also appreciated. Finally, households are favorably but not thoroughly influenced by environmental factors, including limitations on greenhouse gas production and sharp environmental deterioration problems. Thus further promotion campaigns are necessary to educate end users on the socio-cultural benefits of SWHs applications.

Residential SWHs

The use of solar thermal collectors is an economic alternative for hot water production in Taiwan. In view of the current governmental-supported financial incentives to end users, there were 138,824 units installed in the period of 2001-2007, Table 1. The yearly installation increases continuously. However, the applications for dormitory and others (swimming pool or manufacturing process) are rather limited. It is also known that the system design and cost of SWHs are related to the composition of the families. According to the historical data of average daily global solar insolation in Taiwan, the daily production of 50^{o}C hot water by solar collectors is estimated to be 75 liters per square meter. On the other hand, the average consumption of 50^{o}C hot water is about 60 liters per person. In Fig. 4, it can be seen that less than 1% of SWH users are one-person households. The family size of 4-6 persons is more positive in installing a SWH (almost two-third of the users). The data of SWH installation in terms of solar collector area is shown in Table 2. It can be seen that most systems (82-88%) had the area of solar collector installed from 3 to 10 m^2. This agrees with the household structure of SWH users. Furthermore, the market survey indicated that the share of evacuated tube type solar collector expanded greatly recently and its average installed area was less than that of flat plate type. This should be attributed to more systems with the installed area less than 3 m^2. However for the economic concerns, larger scale applications would benefit from the effect of scale. The unit price of both types of solar collectors is shown in Table 3. As expected, the unit price decreases with larger area of solar collectors installed of a SWH, particularly with flat-plate type solar collectors. Compared with

smaller SWHs for single-family households (below 3 m^2), the solar heat cost in a larger scale (A_c > 5 m^2) can be cut in half.

As mentioned above, the questionnaire indicated that there were about 14% households replacing the old systems. The service life ranged from 5 to 15 years. In terms of service life of 15 years, the current operating SWHs are estimated to be 260,000 systems. According to the data of Directorate General of Budget Accounting and Statistics (DGBAS), the number of households in 2007 was about 7.5 millions in Taiwan. This indicates that the population of residual SWHs might be only up to 3.5%. This represents only a small fraction of the potential application of solar thermal technology, and it is far away from the target for the year 2020 with 20% households with a SWH. However, it is known that the potential market of SWHs could be related to the construction of new buildings, household structure and available installation location. Thus to be more realistic, the potential households with a SWH should be estimated based on the above factors. Then policy makers can organize systematic efforts in order to achieve the target in 2020.

Table 1 Application of SWHs (units)

	2001	2002	2003	2004	2005	2006	2007	Total
Homeowner	12,636	14644	16,479	21,569	22,489	24,223	26,171	138,211
Dormitory	50	45	61	83	93	76	161	569
Others	3	4	8	10	5	9	5	44

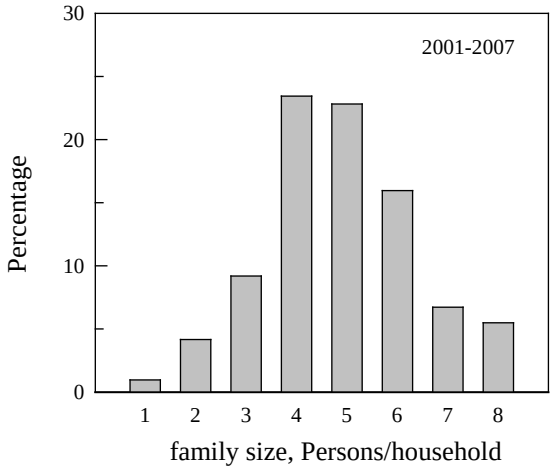

Figure 4 Household structure of SWH users

Table 2 Installation of SWHs in terms of area of solar collector

A_c, m^2	Below 3	3-5	5-10	10-100	Above 100	Total
2001	1,188	5,395	5,780	318	8	12,689
2002	1,970	6,080	6,260	377	6	14,693
2003	2,056	7,004	7,027	457	4	16,548
2004	2,939	8,981	9,300	433	9	21,662
2005	3,205	9,600	9,363	411	8	22,587
2006	3,757	10,354	9,806	379	12	24,308
2007	4,335	11,997	9,523	478	4	26,337

Table 3 Unit price in terms of solar collector area (NT$/$m^2$)

A_c, m^2	Below 3	3-5	5-10	10-100	Above 100

Flat plate	12,527	8,659	6,181	6,870	7,003
Evacuated tube	8,726	7,420	6,932		

Regional distribution of sales

Through the questionnaires used in this work, local climate and degree of urbanization are among the dominant factors on the regional distribution of sales. Taiwan is situated between latitude 22 and 25 degrees North, which measures 377 km long and 142 km wide at its widest point, Fig. 5. About two-thirds of the island is covered with lush forested mountains. In the period of 2004-2007, the average annual duration of sunshine at eight representative locations (five in the western district and three in the eastern district) ranged from 1,450-2,400 hours, as shown in Fig. 6. This corresponds to the average daily global solar insolation of about 3.25 kWh/m^2 in the north and 4.64 kWh/m^2 in the south (Tang 2000). However, it is known that hot water consumption is expected to be the highest in winter and the least in summer. In Taipei, Ilan and Hulien, the winter months received less than 100 hours sunshine. This essentially results in less energy saving and longer payback period of SWHs. The impact of typhoons is another concern for the home owners to install SWHs in the eastern Taiwan (Ilan, Hulien and Taitung) (Chung et al 2008). In addition, almost all SWHs in Taiwan are positioned on the roof of buildings (flat roofs or tilted roofs). Thus the degree of urbanization may not allow easily the implementation of SWHs. According to DGBAS, there are five main urban area (more than one million residents; Taipei, Taoyuan, Taichung, Tainan and Kaohsiung) and two secondary urban area (0.3 to 1 million residents; Hsinchu and Chiayi) in Taiwan. Installation of SWHs would depend on the architectural type in each area.

Due to the sunlight conditions, the SWHs installed in northern Taiwan (Taipei, Ilan, Taoyuan and Hsinchu) is expected to be lower than those in the western and southern districts. As shown in Table 4, the number of households was about 2.37 millions in Taipei urban area (2007). This corresponded to 31.5% of the total households in Taiwan. However, there were only 588 SWHs installed in the period of 2001-2007, in which the cumulated area of solar collectors was 4,087 m^2 and the units of SWHs installed per thousand households was only 0.25. Additionally, limited SWHs (311 units) were installed in Ilan. In Taoyuan and Hsinchu, the popularization of SWHs (less than 15) was less than that of rural area (over 25, not including the eastern district). In southern Taiwan, the market share was over 55%. The popularization is the highest in Tainan urban area while the area of solar collectors installed was over 150 thousands square meters in Kaohsiung. Furthermore, it should be noted that the average daily global solar insolation in Taitung was roughly the same as that in Taichung. However, the popularization is only about one-fourth. This might be attributed to the income levels of household and typhoon impact.

CONCLUSIONS

SWH is a very reliable and mature technology, and is the most successful story for the development of renewable energy in Taiwan. Public awareness on energy saving and environmental aspects is also very positive. However, the use of SWHs for domestic hot water production represented only a small fraction of the potential applications of this

technology. Through desk and field research, the major diffusion barriers for households are economic nature (disposal income and incentives), population characteristics (household composition), degree of urbanization (available installation location) and climatic conditions (solar insolation, typhoon etc.).

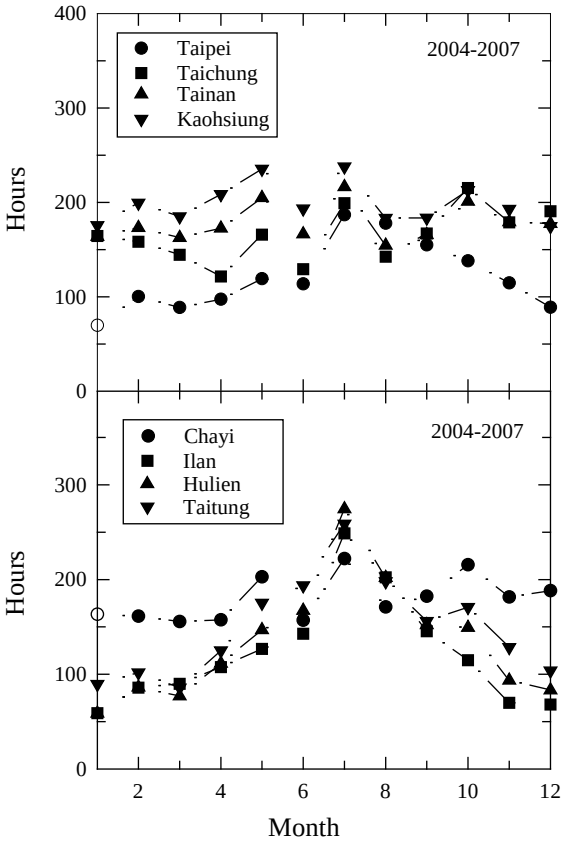

Figure 6 Duration of sunshine

Table 4 Number of households (2007) and SWHs installed (2001-2007)

	Household	SWH Units	Popularization	A_c, m^2	Market share, %
Taipei	2,373,123	588	0.25	4,087	0.62
Taoyuan	617,085	9,245	14.98	56,665	8.63
Taichung	702,400	15,512	22.08	81,198	12.36
Tainan	415,531	19,412	46.72	96,515	14.69
Kaohsiung	981,589	34,884	35.53	151,076	23.00
Hsinchu	226,433	2,285	10.09	15,979	2.43
Chiayi	121,960	3,403	27.90	15,961	2.43
Ilan	146,924	311	2.12	1,463	0.22
Hulien	116,766	729	6.24	5,689	0.87
Taitung	77,892	400	5.13	2,219	0.34
Others	1,732,746	44,204	25.51	225,961	34.40

*Popularization: units of SWHs installed per thousand households

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