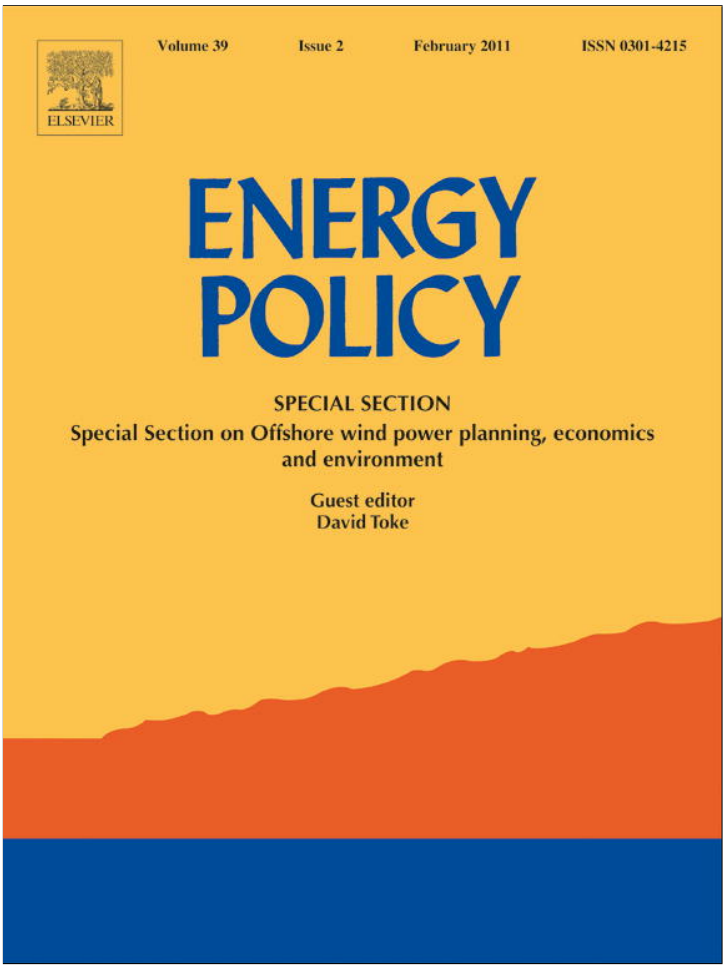

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Subsidy programs on diffusion of solar water heaters: Taiwan's experience

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ABSTRACT

Financial incentives are essentially one of the key factors influencing diffusion of solar water heaters in many countries. Two subsidy programs were initiated by the government of Taiwan in 1986 (1986–1991) and 2000 (2000–present), respectively. Those long-term national programs are considered to be the driving force on local market expansion. In 2008, the regional subsidy programs for solar water heaters were announced by Kaohsiung city and Kiemen county, which resulted in the growth in sales. A revised subsidy was also initiated by the government of Taiwan in 2009. The subsidy is 50% more. However, the tremendous enlargement of market size with a high-level ratio of subsidy over total installation cost might result in a negative impact on a sustainable SWH industry and long-term development of the local market, which is associated with system design and post-installation service. This paper aims to address the relative efficiency and pitfalls of those national and regional programs.

1. Introduction

Global climate change and depletion of fossil fuels are raising public concerns around the world. In particular, the level of CO_2 emission is staggering and unprecedented. Renewable energy has gained increasing support due to its benefits to the environment, and solar thermal applications have also been widely adopted among the leading alternative solutions. With a relatively mature solar thermal technology, solar water heaters (SWHs) have been used in residential sector. Incident radiation is converted to heat and transmitted through a transfer medium such as water. Large-scale systems have also been installed for industrial heating process. Flat-plate and evacuated tube collectors are the most commonly used types of collector (Kalogirou, 2003).

A national renewable energy policy is a vital prerequisite to translate customer choice into a larger market share for non-conventional energy technologies such as SWHs (Srinivasan, 2009). Government intervention in the form of financial incentives, legislative measures, institutional measures as well as marketing and awareness promotion has a profound effect on market expansion (Chen et al., 2008; Kaldellis et al., 2005; Sidiras and Kouhios, 2004; Wu and Huang, 2006). In particular, one of the most critical factors in the dissemination of SWHs is their financial viability. In general, a typical SWH comprises solar collectors, a circulating pump, a water storage tank and auxiliary equipment (hardware costs) and its installation cost includes field piping, thermal insulation and labor cost. An economic figure of merit such as cost-to-benefit analysis or subsidy ratio (SR, subsidy over total installation cost for a SWH) cannot be over emphasized. Indeed, the subsidization would be an essential factor for penetration of SWHs in residential sector for hot water production.

Financial incentives have been adopted for SWHs in many countries. In Taiwan, the incentive programs launched by the Bureau of Energy, Ministry of Economic Affairs (BEMOEA) and regional governments are regarded as the major driving force for market expansion over the last two decades. However, it is necessary to take a look at the relative efficiency of the long-term incentive programs used. The purpose of this paper is to examine the effect of SR on local market and its possible pitfalls.

2. Solar water heaters in Taiwan

Taiwan has limited natural resources and relies mainly on imported fuel for its energy demands. Energy security has also become one of most important issues faced by the government (Tsai, 2005). In 2009, the total energy supply was 138.06 million kiloliters of oil equivalent (MKLOE). However, indigenous energy contributed only 876 KLOE (0.63% of total energy supply), which was highly dependent on hydropower (40.9%) and natural gas (35.6%). For renewable energy, photovoltaic and wind energy accounted for 8.8% of the indigenous energy supply; and solar thermal energy was 12.9%. The contribution of renewables to total energy supply in Taiwan was less than 0.14%. This is far behind many European countries, such as Sweden and Spain.

Further, water heating is one of the major energy consumption for households in Taiwan. It is strongly demanded to use energy-efficient

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water heaters. Indeed, Taiwan lies between latitude 22° and 25° North. The average daily global solar insolation is about 3.25 kWh/m^2 in the north and 4.64 kWh/m^2 in the south (such as Kaohisung city). It is quite favorable for installation of SWHs. However, the area of solar collectors installed was less than 10,000 m^2 per annum from 1981 to 1985, as shown in Fig. 1. This low level of growth was attributed to the low average family income and high total installation cost of SWHs in comparison with that of conventional water heaters (Chang et al., 2006). Thus, a six-year national incentive program (1986–1991) was activated by the government of Taiwan to encourage utilization of SWHs. By the end of the program, the area of solar collectors installed (A_{SC}) per annum approached 60,000 m^2. In the early 1990s, both average family disposal income and consumption expenditures increased significantly. This would be the key factors behind market expansion (Chang et al., 2008). Further, the government of Taiwan initiated another national incentive program for SWHs in 2000 to promote the application of solar thermal energy. A_{SC} has exceeded over 100,000 m^2 per annum since 2004 (Chang et al., 2009). Then in terms of service life of 15 years, the operating residential SWHs are estimated to be 0.28 million systems by the end of 2009. According to the data of the Directorate General of Budget Accounting and Statistics (DGBAS), the number of households in Taiwan was about 7.8 million in 2009. This indicates 3.6% coverage of all households or 1.22 systems per 100 people. In many countries (such as Cyprus, Israel and Austria), the penetration of SWHs is much higher (Weiss et al., 2008). There still exists much room for further promotion of SWHs within the domestic sector in Taiwan.

A comprehensive market survey was conducted by Chang et al. (2009) to identify key factors for the successful diffusion of SWHs in Taiwan. Other than the economic factors, the architecture of residence (or degree of urbanization) and household composition also play major roles. The survey showed that three- and four-story houses accounted for nearly 75% of SWHs installed while the market share of houses with one-story or six-story more was less than 4%. However, apartments and community housing constitute the major types (over 75%) of residence in Taiwan metropolitan areas. A significant issue is the need for revising current architectural legislations on safety, fitting and field piping of architectures that inhibit the installation of SWHs. Further, the survey indicated that the four-person to six-person households are more positive toward installing a SWH. Although one-person households constitute the highest percentage (28.2% in 2009) among total households in Taiwan, few have SWHs installed. Thus, household composition would be another critical factor for long-term SWH diffusion in Taiwan.

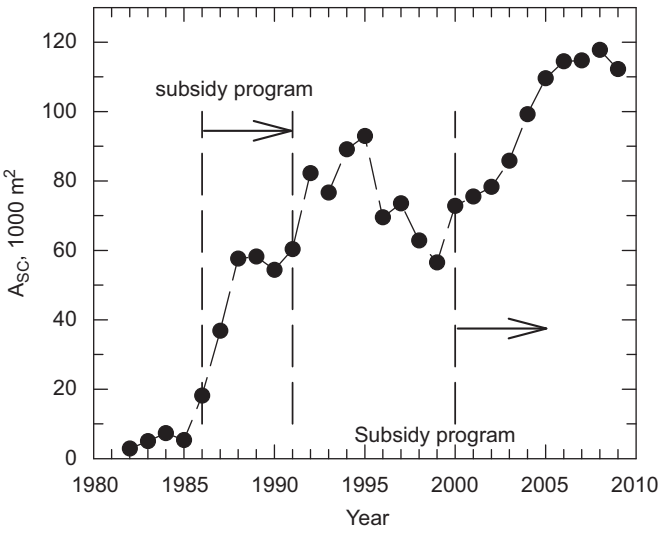

Fig. 1. Area of solar collector installed.

3. Subsidy policies on SWHs

It is well known that subsidy, which is related to either A_{SC} or thermal performance, has positive effects on economic viability of SWHs. For example, Cyprus is the third largest island in the Mediterranean. There are no natural oil resources for its energy demands. Financial incentives in the form of governmental grant for investments in the field of energy conservation and for substitution of fossil energy and conventional fuels with renewable energy sources were provided. The amount of grant was set at 30% of the total investment cost (Kalogirou, 2003). The installation density of glazed flat-plate and evacuated tube collectors in Cyprus ranked the top in the world (Weiss et al., 2008). A review of other international subsidy policies regarding SWHs was given by Roulleau and Lloyd (2008) in terms of their success or failure for selected countries. In Germany and Austria, the direct subsidy was up to 50% of the total installation cost and the long-term policies were considered to be successful with regards to number of SWHs installed. Some other countries adopted the performance-based subsidy programs. The case in Sweden was disappointing due to lower cost efficiency while the installation rate was directly tied to the subsidy in Holland. Further, tax credits and tax deduction have been used as policy tools by some governments. In France, tax credits were up to 50% of the total installation cost of SWHs. The Greek government allowed households to deduct 75% of their investment costs from their taxable income (or 30% of the total installation cost). Those programs are critical for sustaining the SWH diffusion in both countries. In general, most subsidy programs created a positive impulse on penetration of SWHs.

In Taiwan, two national incentive programs (1986–1991, 2000–present) were initiated by the government of Taiwan to promote utilization of SWHs. From 1986 to 1989, a subsidy (2000 NTD/m^2 for glazed flat-plate solar collectors and 1000 NTD/m^2 for unglazed flat-plate solar collectors, 1 USD ≈ 31 NTD) was granted for purchase of a SWH, which meet the criteria with regard to thermal performance. The amount of subsidy is halved from 1990 to 1991. More than 58,000 SWHs (or A_{SC}=320,000 m^2) were installed. The key result of this national incentive program was also the establishment of a standard for SWHs with greater efficiency (more useful energy collected from a solar collector and lower heat loss), which also played a key role in developing consumer confidence in SWHs. Further, Fig. 2 shows the average cost of SWHs in terms of A_{SC}. As can be seen, the unit price decreased significantly (about 35% off) during this national incentive program. It could be attributed to economies of scale (sales increase). With SR taking into account, price reduction ranged from 23% to 28% between 1986 and 1989 and decreased to lower than 20% over the next two years as shown in Fig. 3. This might result in a frozen market during 1990–1991, Fig. 1. In general, this subsidy program was considered quite successful and had a drastic effect on popularization of SWHs in Taiwan. Both end users and solar industry were motivated.

Following the decrease in SWH installation between 1995 and 1999, the BEMOEA initiated another national incentive program (July 2000–present) to foster the application of solar energy. By filling an application form, a subsidy was granted to end users according to the area and type of solar collectors installed (1500 NTD/m^2 for glazed flat-plate and evacuated tube solar collectors, and 1000 NTD/m^2 for unglazed flat-plate solar collectors), which should also meet the criteria of thermal performance specified in the first national incentive program. To encourage the installation of SWHs on remote islands (such as Kiemen and Penghu counties), the amount of subsidy was doubled. This national incentive program was obviously critical for the promotion of SWHs at the initial stage. The annual A_{SC} doubled from 1999 to 2006 but lost its significance thereafter (Chang et al., 2009). To further expand the market, the BEMOEA launched a revised

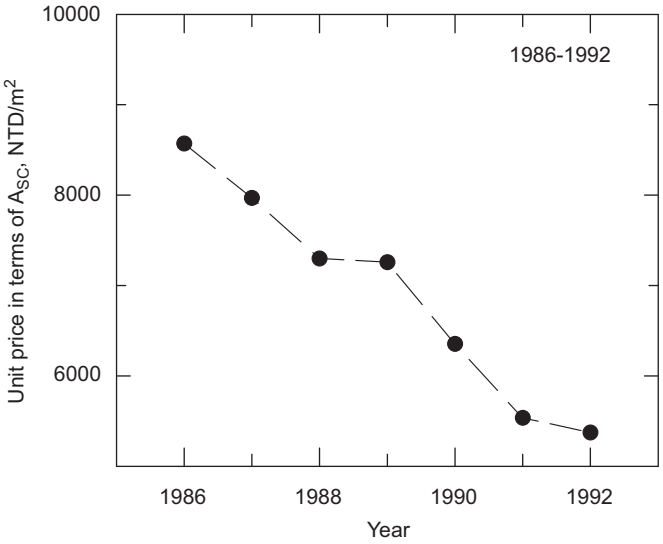

Fig. 2. Unit price of SWHs in terms of A_{SC}, 1986–1992.

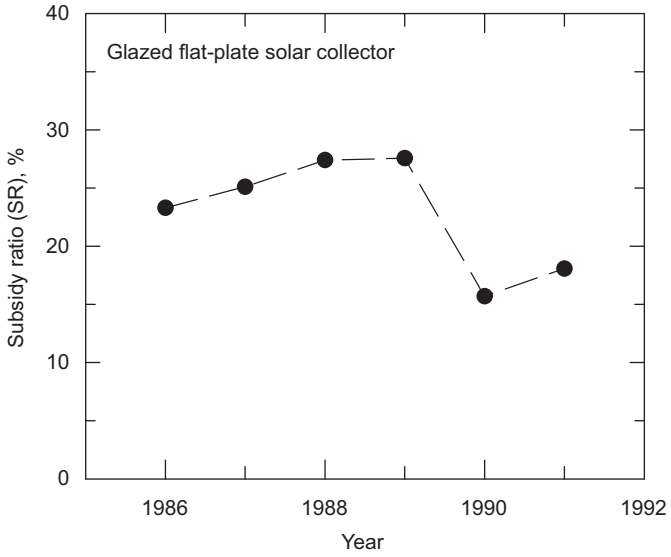

Fig. 3. Subsidy to total installation cost ratio, 1986–1991.

national incentive program in 2009. The subsidy to end users increased by 50%.

Furthermore, Kiemen county and Kaohsiung city government announced regional incentive programs in 2008. An additional subsidy (of the same amount given by the BEMOEA) for purchase of a SWH was granted to households living in the Kiemen county (January 2008) or Kaohsiung city (October 2008). Fig. 4 shows the SWHs installed and annual A_{SC} in Kiemen and Penghu counties. As can be seen, the market size was very limited in both counties between 2000 and 2007, in which less than 30 systems (or $A_{SC} < 100$ m^2) were installed annually, indicating poor effectiveness of the incentive program on remote islands. However, the regional incentive program by Kiemen county in 2008 led to exponential increase in SWH sales. The number of SWHs installed was 113 systems (or $A_{SC}=465$ m^2) and 745 systems (or $A_{SC}=4435$ m^2) in 2008 and 2009, respectively. In Kaohsiung city, the local market expanded steadily between 2001 and 2006. The number of SWHs installed rose from 1250 systems (or $A_{SC}=5464$ m^2) in 2001–2760 systems (or $A_{SC}=11{,}560$ m^2) in 2006, as shown in Fig. 5. A

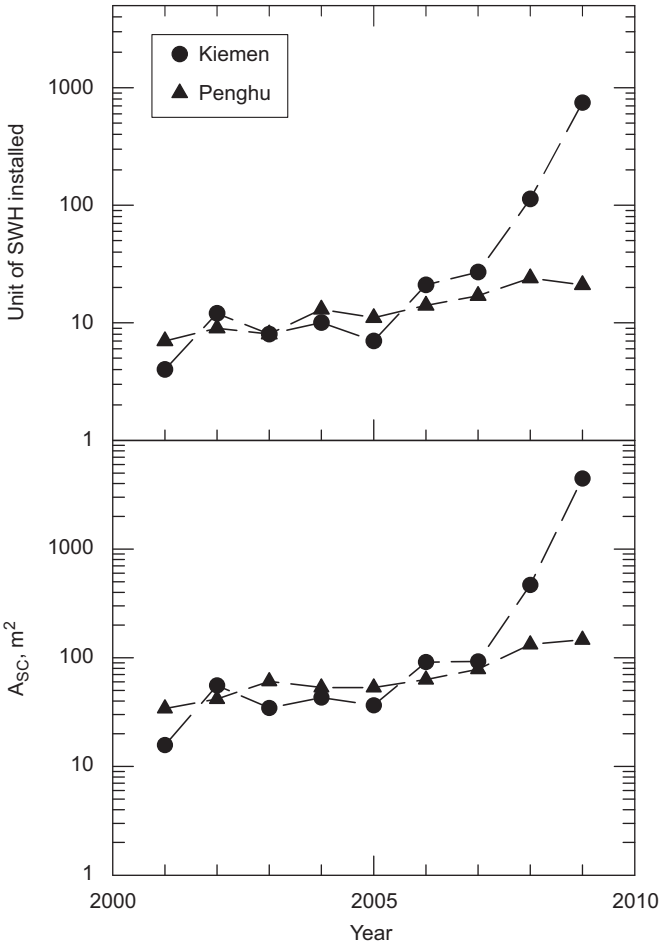

Fig. 4. SWHs on remote islands (Penghu and Kiemen).

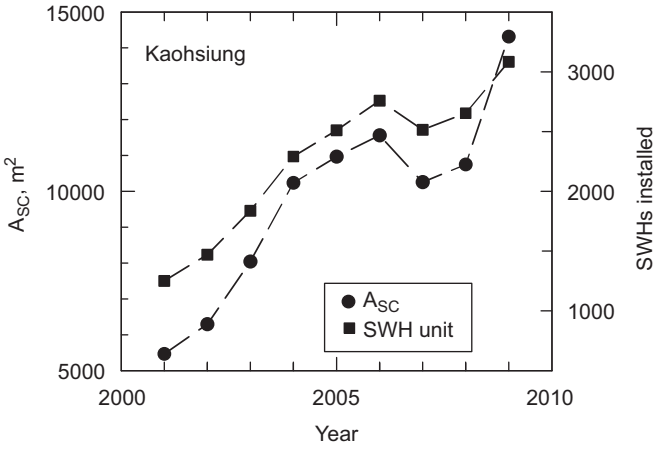

Fig. 5. SWHs in Kaohisung city.

drop in 2007 corresponded to an increase in price of raw materials (copper and stainless steel), which resulted in much higher total installation cost for a SWH. Thus households are less motivated to install SWHs purely because of financial considerations (family disposal income and consumption expenditures). The regional incentive program provided another driving force for market expansion. There were over 3,000 SWHs installed ($A_{SC}=14{,}312$ m^2) in 2009. In terms of A_{SC}, there was about 23% increase in comparison with that in 2006.

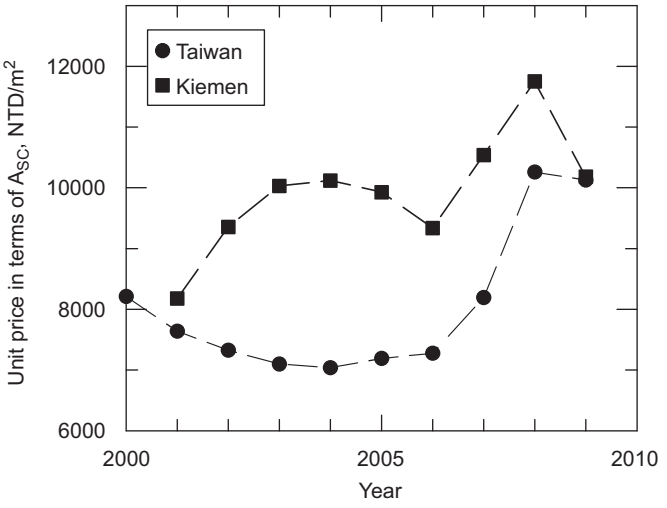

Fig. 6. Unit price of SWHs in terms of A_{SC}, 2000–2009.

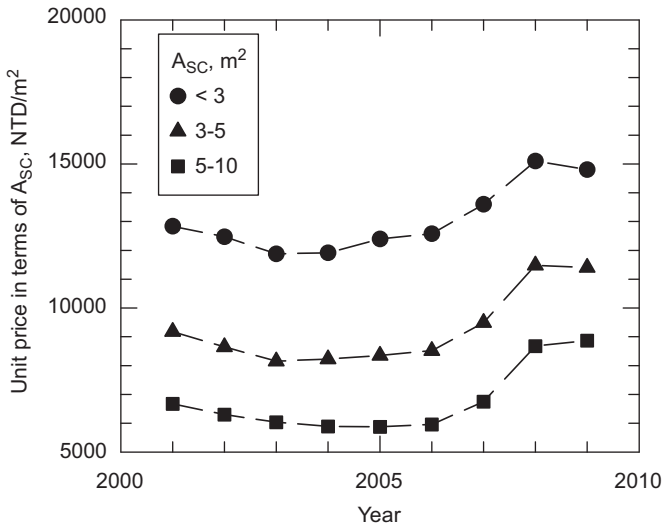

Fig. 7. Unit price in terms A_{SC}.

Similar to international experiences with regard to effect of economic feasibility on market expansion of SWHs, the annual A_{SC} in Taiwan is also associated with the total installation cost. As shown in Fig. 6, the unit price of a SWH in terms of A_{SC} decreased steadily between 2000 and 2004 and increased slightly over the next two years. Note that the unit price reduction in the first four years within the present national incentive program is related to technical change and a systematic effort to reduce costs through economies of scale (or sales increase) (Chang et al., 2009). In Kaohsiung city, the variation of unit price followed a similar trend. However, the price of SWHs increased over 39% between 2006 and 2008. As mentioned above, an increase in price of raw materials played the major role in this cost increase. In Kiemen county, an opposite trend was observed between 2000 and 2004, during which the unit price increased over 23%. The increase in unit price between 2006 and 2008 exceeded 58%. The number of local qualified installers/dealers could partly explain the peak unit price in 2008. The big drop in 2009 could be attributed to sales increase (almost 10 times in terms of A_{SC}) and more local qualified installers/dealers.

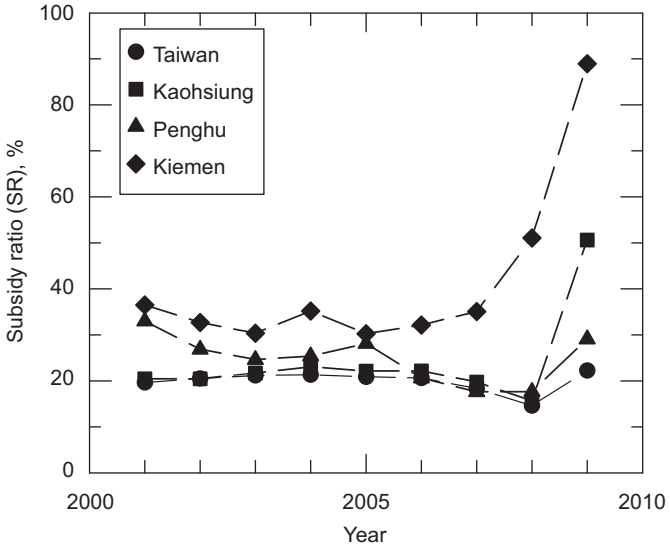

Fig. 8. Subsidy to total installation cost ratio, 2001–2009.

4. Effect of subsidy ratio on market expansion in Taiwan

The average size of households in Taiwan decreased from 3.29 to 2.96 persons from 2001 to 2009. Kaohsiung city and Kiemen county followed a similar trend. Thus, most residential systems installed (82–88%) had A_{SC} ranging from 3 to 10 m^2 (Chang et al., 2009). Note that most residences with SWHs in Taiwan are three- and four-story houses, while those on remote islands are mainly one- and two-story houses. A personal interview with one of the major manufacturers/installers indicated that the installation cost for a SWH with A_{SC}=6 m^2 accounts for between 24% and 16% in Taiwan and on remote islands, respectively, The difference was mainly due to the type of residence, in which the cost of field piping is higher for three- and four-story houses than for one- and two-story houses.

It is also known that SWHs of larger scale could benefit from the effect of scale. Fig. 7 shows the unit price of SWHs in terms of A_{SC} (flat-plate solar collectors). As can be seen, the variations of unit price for SWHs of all three scales of are similar. However, the unit price of a larger SWH (A_c=5–10 m^2) is only about half that of a smaller SWH (below 3 m^2) from 2001 to 2007. The increase in unit price over the next two years slightly reduces the benefit of scale effect. Further, the variation in SR during the second national incentive program is shown in Fig. 8. In Taiwan, the SR ranged from 18.3% to 21.3% from 2001 to 2007. Small variation was also observed for Kaohsiung city. In 2008, the big jump in unit price of a SWH resulted in a much lower SR (~15%). With the revised national incentive programs, the SR became 22.2% and 50.6% in Taiwan and Kaohsiung city, respectively. In consequence, there was 16% increase in the unit of SWHs installed in Kaohisung city from 2008 to 2009. On the remote islands, the SR in Penghu county was lower than that in Kiemen county, particularly in 2006 and 2007. It is not known why the unit price of a SWH was much higher in Penghu county at this moment. Further survey should be conducted. With the revised national incentive program by the BEMOEA, the SR in Penghu county increased to 29% in 2009. In Kiemen county, total financial incentives (from both the BEMOEA and local government) accounted for about 51% and 89% of the total installation cost in 2008 and 2009, respectively. This results in the fast growth of SWH sales, as shown in Fig. 4. Note that the unit of SWHs installed was 27, 113 and 745 in 2007, 2008 and 2009, respectively.

The efficiency of financial incentives can be assessed in terms of their role in reducing the effective total installation cost to end user (Chandrasekar and Kandpal, 2005). However, Srinivasan (2009)

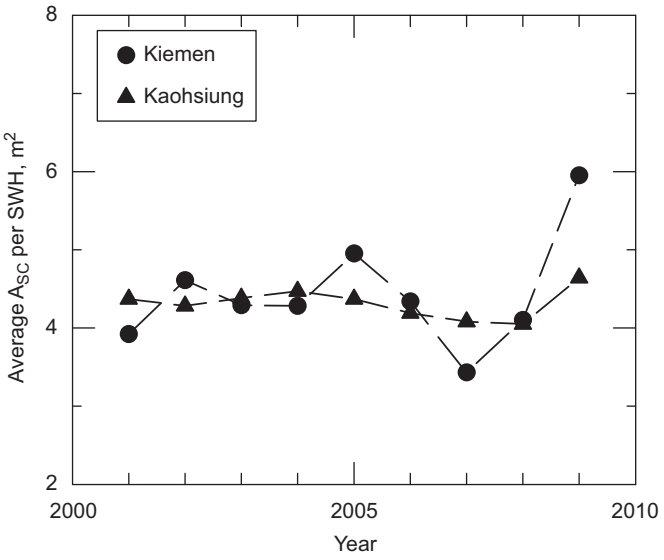

Fig. 9. Average A_{SC} per SWH.

pointed out that governments might choose to subsidize certain sectors of consumers as part of their development strategy. The discounted prices could lead to supply-side distortions. Inappropriately designed subsidy programs could end up being counterproductive. As mentioned above, SWHs in Taiwan were mostly installed in residential sector and the average size of households in Taiwan and Kiemen county was also roughly the same. Thus, other than climatic conditions (sunshine hours and solar insolation), the system design in terms of A_{SC} should be roughly the same in order to meet the requirement of hot water production. As shown in Fig. 9, there is slight variation in average A_{SC} ($=4.05-4.37$ m^2) for a SWH in Kaohsiung city between 2001 and 2008 followed by an 8% increase ($A_{SC}=4.64$ m^2). In Kiemen county, there were only 65 systems installed between 2001 and 2006. The average A_{SC} ($=3.92-4.95$ m^2) might not be statistically meaningful. However taking the rise in average A_{SC} from 2007 (27 systems) to 2009 (745 systems) into account, the increase was from 3.43 to 5.95 m^2 (over 70% increase). This phenomenon is of interest. Possible explanation is given as below.

According to the average daily global solar insolation in Taiwan, the daily production of 50 °C hot water by solar collectors is estimated to be 75 liters per square meter. On the other hand, the average consumption of 50 °C hot water is about 60 liters per person (or 180 liters per household). Thus, as a thumb of rule with the system design for a SWH, the ratio of persons of households and A_{SC} is approximately equal to one in common practice. After taking the average household size in Kiemen county into account, it is highly speculated that some SWHs installed could be over designed. Note that the installation costs might remain unchanged for a smaller or larger residential SWH. However, hardware cost was mainly scaled with A_{SC}. When the unit price of solar collectors (NTD/m^2) is less than the total financial incentives (9000 NTD/m^2) offered by the BEMOEA and Kiemen county government, the subsidy could approach the total installation cost. As a consequence, an over-design system might result in mismatch between demand and production of hot water. The net energy saving is also distorted. Furthermore, the tremendous enlargement of market size with such a high-level SR might result in a negative impact on SWH users or a sustainable SWH industry. For example, it is highly possible that some local installer/dealers might go out of business upon termination of these subsidy programs. Then, SWH users could suffer from a lack of post-installation service for the remaining portion of the system's technical lives thereafter (Srinivasan, 2009). Kiemen county government has recently realized this possible negative impact on sustainable development of SWHs. The regional incentive program was temporarily suspended in March 2010. Following the international subsidy policies on SWHs (Roulleau and Lloyd, 2008), an upper limit on SR is proposed. The total subsidy could not exceed half the total installation cost of a residential SWH. This revised regional incentive program was thought to have a more positive impact on local market development.

5. Conclusions

Similar to international experiences with regard to effect of financial incentives for SWHs, the direct subsidy on the users' side has definitely been the driving force on market expansion in Taiwan over the last two decades. In terms of private economic benefits, higher SR would certainly increase the total number of systems installed (the economies of scale). However, only a combination of rational national and regional policies can generate a wealth of service, price and quality options to ensure a sustainable SWH industry. The distribution of capital subsidy could be put to better use. In Kiemen county, the tremendous sales increase due to the hybrid subsidy programs appears to have a negative impact on long-term development of the local market. An over-design system would also result in distortion of net energy saving. The incentive program implemented by the regional government should be revised and more carefully addressed. In particular, the subsidy in most successful international SWH incentive programs is in terms of total installation cost other than the area of solar collector installed in Taiwan. The hybrid subsidy programs and an upper limit on SB in Kiemen county could refer to those international experiences.

Acknowledgement

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