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Article

Sustainable Development for Solar Heating Systems in Taiwan

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Abstract: In response to the impact of the United Nations Framework Convention on Climate Change, developing and using renewable energy sources and technologies have become vital for managing energy supply and demand in Taiwan. The long-term subsidy programs (1986–1991, 2000–present) for solar water heaters (SWHs) launched by the Taiwanese government constitute the main driving force for market expansion. By the end of 2013, the cumulative area of installed solar collectors was 2.27 million m^2. Approximately 0.3 million systems (or 1.545 million m^2) are in operation. This corresponds to an annual collector yield of 0.92 TWh, which is equivalent to savings of 98.7 thousand tons of oil and 319 thousand tons of $CO_{2,eq}$. The market-driven mechanism is associated with cost-to-benefit ratios, construction businesses, types of building architecture, degree of urbanization and household composition. The strong wind load of typhoons is another major concern. For sustaining the solar thermal industry in Taiwan, the dominant factor for disseminating SWHs in metropolitan areas involves developing building-integrated solar thermal systems. Alternative financial incentives are required for industrial heating processes in the commercial sector.

Keywords: renewable energy; solar heating system; subsidy; economic feasibility

1. Introduction

Global warming and climate change caused by carbon (greenhouse gas) emissions into the atmosphere are raising worldwide concern. Some previous studies have discussed an approach for transforming the energy system to renewable energies [1–4]. Mauthner and Wiss [5] reported in 2013 that the annual energy generated by wind power, solar thermal heat, and photovoltaic sources were 662, 281 and 160 TWh, respectively. In addition, the net energy saving, using renewable energy sources is also of practical importance for a country's socio-economic development. Thus, renewable energy has received increasing support because of its benefits to the environment. Taiwan is a densely populated island with limited natural resources, and it relies mainly on imported fuel for satisfying its energy demands. A substantial increase in energy consumption has caused primary concern for its economic development. As shown in Table 1, the total energy supply increased from 58,329 × 10^3 kL of oil equivalent (kLOE) in 1991 to 106,383 × 10^3 and 138,236 × 10^3 kLOE in 2001 and 2011, respectively. The average annual growth rate was approximately 4.4% during the past two decades [6]. For indigenous energy, as shown in Table 2, biomass and waste corresponded to the major energy resources, and hydropower accounted for 13.35%–23.38% of these resources. In 2011, solar thermal and wind power constituted 3.95% and 5.21%, respectively [6]. The ratio of indigenous energy to total energy supply in Taiwan, which was 2.07% in 2011, has been gradually declining. Taiwan must inevitably face energy crisis in the near future. Thus, National Energy Conferences were convened in 1998, 2005 and 2009 for formulating strategies and measures in response to the impact of the United Nations Framework Convention on Climate Change and seeking a balance among economic development, energy supply, and environmental protection. During the past two decades, the Bureau of Energy under the Ministry of Economic Affairs (BEMOEA) has particularly promoted the research and development of renewable energies, which include (1) wind power generation; (2) photovoltalic energy (solar-PV); (3) solar thermal energy; (4) geothermal energy; (5) ocean energy; and (6) biomass energy. In addition, the Renewable Energy Development Bill was enacted for prompting the research and development of renewable energy in April 2010. Renewable energy is projected to reach 3% of the total energy supply by the year 2020. Furthermore, Taiwan has a subtropical climate (latitude 22° to 25° North), in which the average daily global solar insolation ranges from 1200 to 1700 kWh/m^2/year. The duration of sunshine per year is 2000–2500 h in southwestern regions and 1000–1500 h in northeastern regions. This climate is favorable for installing solar water heaters (SWHs) for producing hot water in both domestic and commercial sectors. This paper presents the status of SWH use in Taiwan, and addressed the effectiveness of the subsidy programs of the government as well as the barriers to market expansion.

Table 1. Energy supply in Taiwan.

	1991		**2001**		**2011**	
	10^3 kLOE	**%**	**10^3 kLOE**	**%**	**10^3 kLOE**	**%**
Total	58,329		106,383		138,236	
Indigenous	1646	2.31	2462	4.1	2864	2.07
Imported	56,683	97.18	103,921	97.69	135,372	97.93

Table 2. Indigenous energy supply.

	1991		2001		2011	
	10^3 kLOE	%	10^3 kLOE	%	10^3 kLOE	%
hydropower	368.4	22.38	487.5	19.80	382.4	13.35
biomass and waste	-	-	1096.0	44.52	1914.0	66.83
PV and wind power	1.7	0.10	0.1	0.00	149.2	5.21
solar thermal	24.9	1.51	81.1	3.29	113.2	3.95

2. SWHs in Taiwan

Water heating constitutes one of the major types of household energy consumption [7]. It is important to optimize the operational energy consumption of hot water systems, including system type and size, system efficiency, hot water consumption patterns, and auxiliary fuel source. SWHs have been proven to be reliable and economical for producing hot water. Crawford and Treloar [8] also indicated that SWHs can pay back their embodied energy investment within four years, comparing with the equivalent conventional hot water systems. In the subsidy programs (1986–1991, 2000–present) offered by the BEMOEA, the cumulative area of solar collectors installed by the end of 2013 was 2.27 million m^2. This is the most successful account of renewable energy application in Taiwan. The daily hot water consumption for each person generally corresponds to the hot water production, according to the area of solar collector installed (A_{SC}) of approximately 1 m^2. According to the household structure, a system with an $A_{SC} \leq 10$ m^2 can be considered a residential system, whereas an SWH with an $A_{SC} \geq 10$ m^2 is mainly ideal for rooming houses and industrial heating processes. A general survey of SWH users indicated that more than 98% of the SWHs were used for producing hot water in the domestic sector. This survey also indicated that the public attitude towards SWHs is critical for motivating first time users. Energy conservation (68%) and safety (26%) pose major concerns. Recommendation by local installers (6%) or other SWH users (9%) is another key factor. Therefore, the mass media should be used more aggressively for enhancing public awareness and promote the use of SWHs.

2.1. National and Regional Subsidy Programs

A national renewable energy policy is a vital prerequisite for translating customer choice into a larger market share for non-conventional energy technologies [9]. Apart from a relatively mature solar thermal technology, it is widely recognized that economic instruments play a key role in disseminating SWHs worldwide [10–14]. In particular, the subsidy associated with the A_{SC} or thermal performance of an SWH has positive effects on economic viability. In Taiwan, the subsidy programs offered by the BEMOEA and regional governments constituted the major driving force for market expansion. As shown in Table 3, a subsidy calculated according to the A_{SC} (NTD 2000 per m^2 for glazed flat-plate and evacuated-tube solar collectors; NTD 1000 per m^2 for unglazed flat-plate solar collectors) was granted with the purchase of an SWH, which met the 1986–1989 national standards regarding thermal performance. The amount of subsidy was halved from 1990 to 1991.

In 2000, the BEMOEA initiated another subsidy program (July 2000–present) for fostering the application of solar thermal energy. The National Cheng Kung University Research and Development

Foundation is also authorized to organize an operation unit for performing the tasks, which include filing and auditing applications, allocating funds, and handling appeals. An SWH user is required to fill an application form, and a subsidy is granted according to the A_{SC} and type of solar collectors installed (NTD 1500 per m^2 for glazed flat-plate and evacuated tube solar collectors; NTD 1000 per m^2 for unglazed flat-plate solar collectors). On remote islands, the amount of subsidy is doubled. For a large-scale system, a layout of the system and its design criteria are also required. A review committee then evaluates the proposal according to certain criteria including local weather conditions (sunshine hours, insolation and local average temperature) and field piping. The comments provided by the reviewers assist the installer in revising the system design. However, Chang *et al.* [15] indicated that this subsidy program is critical for promoting SWHs only at its initial stage, after which it loses momentum. For expanding the market, the BEMOEA introduced a revised subsidy program in 2009. The subsidy to the end users increased 50% (NTD 2250 per m^2 for glazed flat-plate and evacuated tube solar collectors; NTD 1500 per m^2 for unglazed flat-plate solar collectors). Furthermore, Kinmen County (January 2008), Kaohsiung City (October 2008), and Penghu County (January 2012) announced regional subsidy programs for SWHs. An additional subsidy was offered to local households when an SWH is purchased, thus leading to a tremendous increase in sales. However, a high ratio of subsidy to capital cost (approximately 89%) may distort net energy savings and negatively affect the long-term development of local markets [16]. Thus, a revised subsidy program was implemented in Kinmen County in April 2010.

Table 3. Subsidy programs in Taiwan.

Funding Agency	Period	Collector-Area-Based Subsidies
BEMOEA	July 2000–December 2008	Direct subsidy, 1500 NTD/m^2 for glazed flat-plate SC and evacuated tube SC; 1000 NTD/m^2 for unglazed flat-plate SC
BEMOEA	January 2009–present	Direct subsidy, 2250 NTD/m^2 for glazed flat-plate SC and evacuated tube SC; 1500 NTD/m^2 for unglazed flat-plate SC
Government of Kinmen county	March 2008–present	Direct subsidy, the same amount as BEMOEA Subsidizing up to A_{SC} = 6 m^2 after 1 April 2010
Government of Kaohisung city	September 2008–December 2010	Direct subsidy, the same amount as BEMOEA Subsidizing up to 70% of total cost
Government of Penghu county	January 2012–present	Direct subsidy, 3000 NTD/m^2

SC: solar collector; 1 USD ≈ 30 NTD (New Taiwan Dollar).

2.2. National Standards for Solar Collectors and SWHs

Advanced technology is not required in manufacturing SWHs. Thus, the marketability of an SWH product cannot be solely based on word-of-mouth and previous experiences with the product rather than its efficiency and thermal properties [17]. Nevertheless, the quality of SWH installation and after-sale service may affect the reliable operation of an SWH. All products (flat-plate type or evacuated-tube type solar collectors, SWHs), installers/dealers, and manufacturers must possess a certification or license issued by the BEMOEA for them to be eligible for the subsidy programs. The experience of technicians also has a considerable effect on the selection of brands and respective manufacturers. Furthermore, one of the major objectives in the long-term subsidy programs launched by the BEMOEA is to enforce the standards of SWH application. Thermal performance tests of a solar collector (the Chinese National Standards, CNS 15165-1-K8031-1) or SWH (CNS 12558-B7277) are required when filing for a rebate. These standards specify outdoor test methods, conditions, and apparatus for determining the steady-state and quasi-steady-state thermal performance. Table 4 lists the standard of a solar collector in the subsidy programs (1986–1991, 2000–present). $F_R(\tau\alpha)$ and F_RU_L are the slope and intercept of the collector efficiency curve, respectively. The standards require high useful energy collected from a collector (High $F_R(\tau\alpha)$) and low heat loss (low F_RU_L). In 2013, 140 solar collectors, in which the metallic glazed and unglazed flat-plate type solar collectors constituted 90.7%, were certified. Furthermore, the utilization efficiency of an SWH, which should be greater than 50%, is evaluated as the ratio of useful heat absorbed by an SWH to incoming solar energy on solar collectors. The list of certified products comprised 74 SWHs, including metallic flat-plate type (three systems), storage type (five systems), and evacuated-tube type (66 systems).

Table 4. Standard of flat-plate or evacuated-tube solar collectors (1986–1991; 2000–present).

	Metal Type		**Non-Metal Type**		**Unglazed Type**	
	$F_R(\tau\alpha)$	F_RU_L	$F_R(\tau\alpha)$	F_RU_L	$F_R(\tau\alpha)$	F_RU_L
1986	≥0.65	≤12.0				
1987	≥0.68	≤10.0	≥0.50	≤10.0	≥0.75	≤25
1988	≥0.72	≤8.0	≥0.60	≤8.0	≥0.80	≤22
1989–1991	≥0.75	≤7.0	≥0.65	≤7.5	≥0.85	≤20
2000–present	≥0.75	≤7.0	≥0.65	≤7.5	≥0.85	≤20

In 2000–2013, the top 10 SWH brands constituted 90% of the local market. The market share of the glazed flat-plate type SWHs was more than 97% in 2001 (Figure 1). The total area of solar collector installed per annum (ΣA_{SC}) increased approximately 50% over the subsequent three years and peaked in 2006, followed by a decrease in 2007–2008. For the revised subsidy program in 2009, the ΣA_{SC} increased gradually. The market share of the glazed flat-plate type, however, has been in a gradual decline since 2003. Nevertheless, the annual sales of evacuated-tube type SWHs increased considerably. Since 2007, the area of solar collector installed per annum is more than 10,000 m^2, in which the market share approached 10%, implying that the role of international competition has been increasing and may become stronger in the near future. Furthermore, the average A_{SC} installed for flat-plate type and evacuated-tube type SWHs are approximately 5 and 3 m^2, respectively.

2.3. Historical Development of the SWH Market

In the 1970s, the major industrial countries of the world faced substantial petroleum shortages. This energy crisis also triggered SWHs manufacturing in Taiwan. As shown in Figure 2, the ΣA_{SC} before 1985 was less than 10,000 m^2. The limited number of installed SWHs was attributed to their high capital cost compared with that of gas or electric water heaters. In the first subsidy program initiated by the BEMOEA, the SWH industry expanded rapidly (1986–1988) and the ΣA_{SC} was approximately 60,000 m^2. In the domestic sector, thermosyphon SWHs with glazed or unglazed flat-plate solar collectors were mainly used for producing hot water. From 1989 to 1991, the local SWH market varied slightly. By the end of the first subsidy program (1991), more than 58,000 SWHs were installed. In 1992–1995, the local SWH market continuously grew with a peak ΣA_{SC} of 90,000 m^2 in 1995. The accumulated A_{SC} was greater than 340,000 m^2. The mature solar thermal technology and rapid economic growth were the key factors that led to the market expansion. The increase in current receipts and disposable income of each household rendered SWHs highly affordable; in addition, while quality control and cumulative experience of certified technicians were also attributed to the increased annual sales. Furthermore, the annual installation of SWHs slowed down in 1995–1999. The faltering economy and decline in new buildings were the major reasons [18].

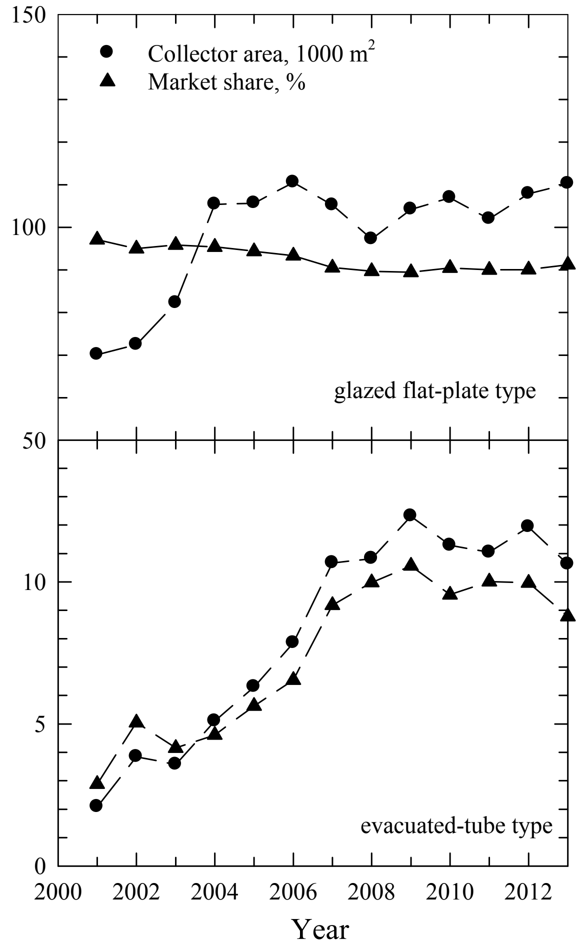

Figure 1. Annual sales of solar water heaters (SWHs) in terms of type of solar collector.

As mentioned previously, the second subsidy program was introduced in 2000, providing financial incentives for the end users and exerting a strong impact on the promotion of SWHs in Taiwan. The growth rate was approximately 29% in 2000, and the ΣA_{SC} exceeded 100,000 m^2 since 2004; the ΣA_{SC} doubled from 1999 to 2006. However, the local market became rather stagnant in 2006–2008. A drop in 2009 corresponded to the global economic crisis, in which households were less motivated to install an SWH because of financial considerations (family disposal income and consumption expenditures). In summary, more than 0.27 million SWHs were installed from 2000 to 2013. Furthermore, a survey conducted by Chang *et al.* [18] indicated that nearly 14% of households replaced their old systems. In terms of a service life of 15 years, approximately 0.3 million systems (or 1.545 million m^2) are in operation. This corresponds to an annual collector yield of 0.92 TWh, which is equivalent to savings of 98.7 thousand tons of oil and 319 thousand tons of $CO_{2,eq}$. According to the data of the Directorate General of Budget Accounting and Statistics [19], the total number of households in Taiwan was nearly 8.286 million in 2013. These statistics indicated that the popularization of residential SWHs was approximately 3.62% or 64 m^2 per 1000 inhabitants, which represented only a small fraction of all households in Taiwan. Great potential still exists for active promotion of SWHs within the domestic sector in Taiwan.

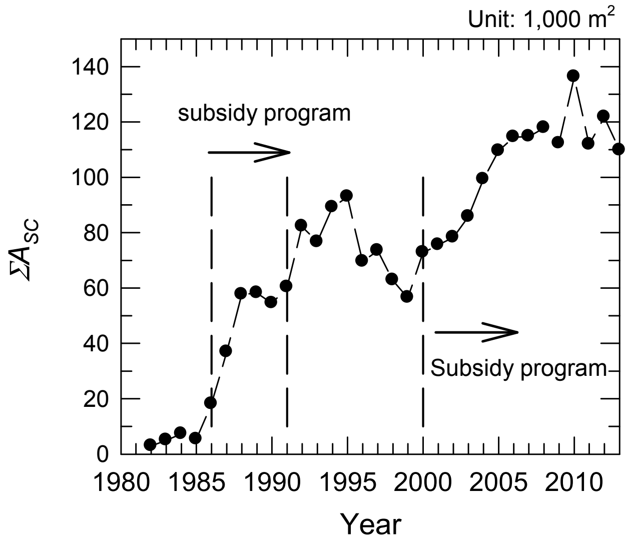

Figure 2. Area of solar collector installed per annum.

3. Barriers to SWH Promotion

Wu and Huang [20] reported that the barriers to the widespread diffusion of renewable energy technologies in Taiwan include technological advancements, the economy, institutions, laws, and public acceptance during the development process. For SWHs, Chang *et al.* [15,18] reported that the major factors were economic/financial considerations, degree of urbanization, and legislative support. Labay and Kinnear [21] indicated that financial considerations are key elements in the decision process of consumer adoption. Because the capital cost of SWHs is considerably higher than that of gas or electric water heaters, average family disposable income is a vital factor in consumer adoption decisions. Another vital factor is the monetary benefit accrued to end users, and this hinges on the cost of fuel saved when using SWHs. In addition, apartments and group housing constitute the major types of residence in Taiwan's metropolitan areas. The degree of urbanization (types of building architecture) may limit the locations available for installing SWHs. Therefore, building-integrated solar thermal systems must be developed for disseminating SWHs in the metropolitan areas. Household composition would be another influencing factor.

3.1. Economic Aspects

The economic feasibility of SWHs is mainly determined by their initial cost, long-term efficiency, and payback period. A household would be willing to invest in purchasing an SWH provided that the capital and maintenance costs are less than a specific fraction of the household's disposal income. As shown in Figure 3, low average family disposal income in the early 1980s resulted in limited SWH installation. However, the rapid economic growth and introduction of the first subsidy program around the 1990s rendered SWHs more affordable. In addition, gas or electric water heaters have been widely used in Taiwan. Considering energy savings shows that the monetary benefits accrued to an end user depend on the amount and cost of electricity or fuel saved through the life service of an SWH. As a state-owned public utility, the Taiwan Power Company has restricted the fluctuations of electricity rates to fulfill the governmental energy policy. However, lower electricity rates result in a longer payback period for SWHs. By contrast, a drastic increase in the price of natural gas or liquefied petroleum gas for gas water heaters during the past few years has led to increased annual fuel savings for an SWH installed.

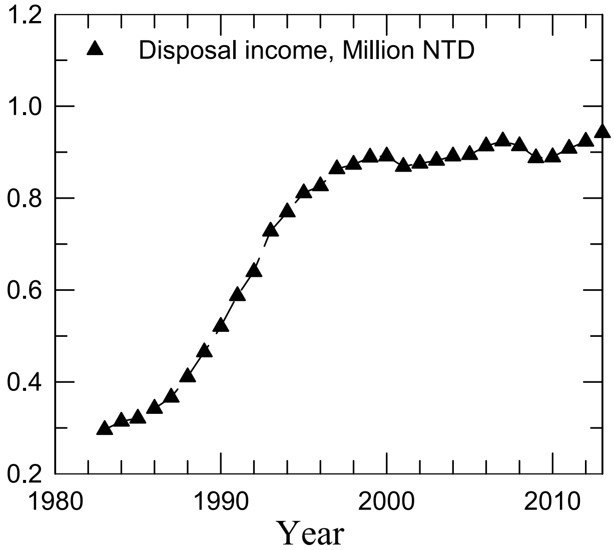

Figure 3. Average family disposal income.

Apart from energy prices, incentives, and total installed costs, the economic payback period of an SWH also depends on solar insolation, hot water consumption, and the expected service life of installation [12]. Pan *et al.* [22] reported that the economic payback period in Taiwan ranged from 6 to 15 years. However, the actual hot water consumption of each household in different districts is not clearly understood; therefore, the payback period may be underestimated. Furthermore, the effect of economic viability on the SWH market expansion in Taiwan is similar to that of international experiences [23]. The efficiency of financial incentives can be valued according to their roles in reducing the effective total installation cost for the end user. Inappropriately designed subsidy programs could end up being counterproductive. From 2000 to 2009, the ratio of the subsidy to total installation cost was approximately 20% in Taiwan. For the subsidy programs implemented by the regional governments, the ratios in Kaohsiung City and Kinmen County in 2009 were 50% and 89%, respectively [16]. The average A_{SC} increased from 3.43 to 5.95 m^2 for residential SWHs in Kinmen County. Because the ratio of household size to A_{SC} is approximately equal to 1 in common practice, some SWHs deployed in Kinmen County were considered to be overdesigned. This resulted in discrepancies between demand and hot water production, and the net energy saving was consequently misrepresented.

3.2. Residential Systems (Types of Building Architecture and Household Structures)

Barring local climatic conditions, Chang *et al.* [15] reported that the degree of urbanization and household structures were also key factors influencing the dissemination of SWHs in Taiwan. Because most SWHs were installed on the flat roofs of buildings, available installation sites were essentially associated with the types of building architectures, in which approximately 75% of SWHs were installed on the flat roofs of three- and four-story houses. However, apartments and group housing are the major types of housing in urban areas (e.g., Taipei City and New Taipei City). Related architectural laws should be amended in favor of SWH installation. The architectural integration is also important in the spreading of solar thermal technologies [24] and developing building-integrated solar thermal systems. Chang *et al.* [15] also indicated that the promotion of SWHs was strongly related to the number of new buildings. As illustrated in Figure 4, in 2009–2013, 55% of SWHs were installed in buildings constructed within three years. Furthermore, Figure 5 depicts the status of occupancy permits for one- to five-story houses. The construction sector boomed in 2006 (62,923 units), declined between 2007 (57,525 units) and 2009 (25,154 units) and increased from 2010 (33,711 units) to 2012 (39,709 units). This partially corresponded to the stagnant SWH market (Figure 3). However, for the revised national subsidy program in 2009, the financial incentives resulted in an increase of 31.4% for old buildings that installed SWHs. A few SWHs were also installed in eastern Taiwan, and this was associated with the high rate of vacant houses.

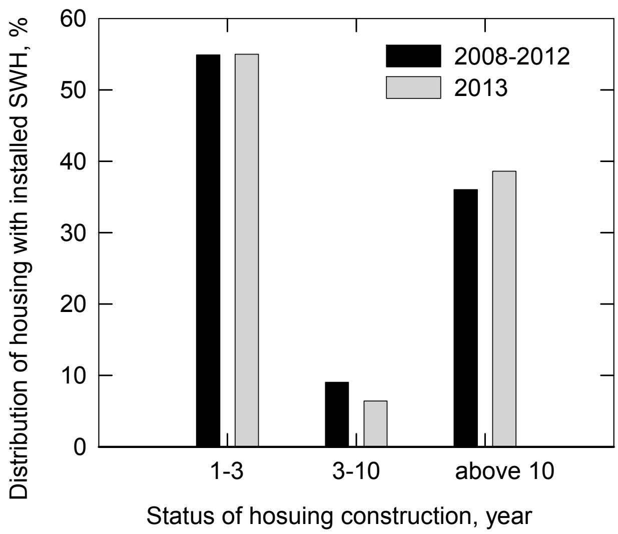

Figure 4. Status of house construction with SWH installed.

As previously mentioned, a rule of thumb for designing a residential SWH system is that the A_{SC} per person is approximately equal to 1. The A_{SC} of most systems (more than 80%) ranged from 3 to 10 m^2. As illustrated in Figure 6, 0.96% of households using SWHs are one-person households. A family size of four–six persons is more favorable for installing an SWH (nearly 75% users). However, because of the outflow of employed population, schooling population, or marital status, one-person households (30.5%) have gained the highest level among the total number of households [19]. In addition, the unit price of an SWH decreased with a large A_{SC} [18]. Thus, applying larger scale systems may benefit from the economies of scale. A high unit price with a subsequent long economic payback period is another critical concern that must be addressed in marketing campaigns. Further, Crawford and Treloar [8] indicated that the embodied energy for SWHs is insignificant in terms of its net energy consumption. To minimize operational energy consumption, the solar fraction (ratio of the solar heat yield to the total energy required for hot water production) can be used as an indicator of energy payback period. In Taiwan, the values of solar fraction range from 0.4 to 0.9. Location of SWHs installed and hot water consumption patterns are among the dominant factors. Nevertheless, more studies should be done in improving the energy return or energy payback period of SWHs.

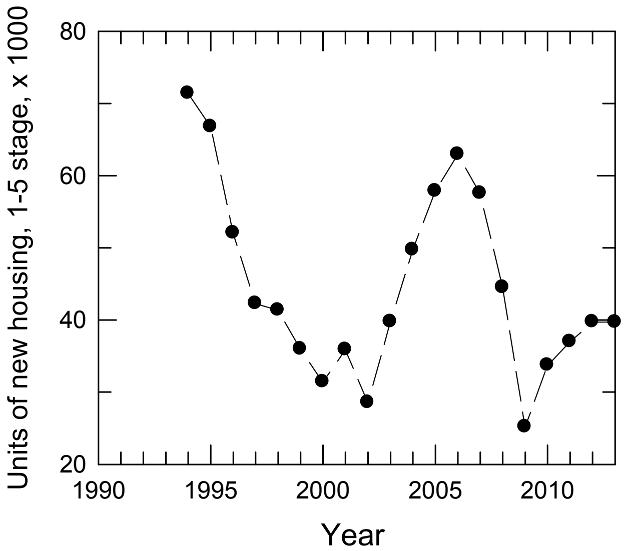

Figure 5. Usage licenses for houses with 1–5 stages.

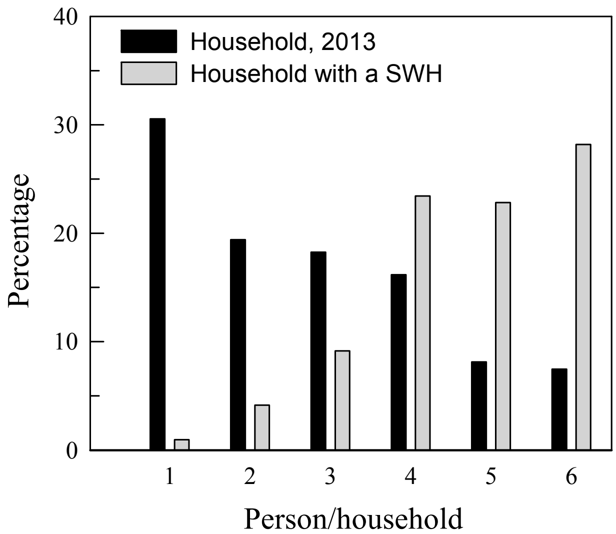

Figure 6. Household structure.

3.3. Large-Scale Systems (System Design and Maintenance)

In 2000–2013, more than 98% of SWHs were used for producing hot water in the domestic sector, and the $A_{SC} \leq 10$ m^2. Only 154 systems with $A_{SC} > 100$ m^2 were implemented for dormitories, swimming pools, manufacturing plants and restaurants. In addition, only a few installers designed more than 10 systems during this period, indicating the lack of experience in large-scale system design among most installers. Furthermore, a large-scale SWH is generally integrated with a kerosene heater as an auxiliary element. Regarding utilization efficiency, field piping and regulating hot water supply are critical factors in system design. Lin *et al.* [25] conducted a field survey of a dormitory system. The daily records indicated that hot water consumption was mostly concentrated in certain periods. According to the daily heating energy required for producing hot water, the solar fraction was less than 50%. The measured data also showed that the overnight water temperature at the upper level in the storage tanks exceeded 35 °C, indicating an improper operation of the auxiliary heater (energy waste) and low utilization efficiency.

Maintenance is another critical concern for long-term operation of a large-scale SWH. This is generally associated with after-sale service and technical support. However, most large-scale systems in Taiwan have not been adequately maintained because of maintenance negligence or unqualified maintenance staff. Gate valve leakage and deteriorated sealing have been reported occasionally, and thermal insulation degradation is common. Low thermal efficiency of solar collectors can also be expected when dust accumulates on the glass surface. Thus, the government should play an integral role by providing intensive courses to managers and technicians. Strong emphasis must be placed on training all market players to enhance their technical knowledge and customer service levels. In addition, Islam *et al.* [26] reported that a large-scale SWH is more financially attractive compared with that in the domestic sector. More efforts must be placed in prompting SWHs for industrial heating processes. Therefore, the BEMOEA must introduce alternative financial incentives (e.g., performance-based subsidy program).

3.4. Wind Loads

Thermal performance and energy savings are definitely the primary concerns of SWH users. However, typhoons frequently occur over the western North Pacific and South China Sea each year and some of them affect Taiwan in the summer and autumn. Because most SWHs are installed on the flat roofs of buildings, typhoon attacks must be considered when designing the aerodynamic characteristics of solar collectors and supporting structures. The glass covers of solar collectors, in particular, are often broken by strong wind uplift because of the associated high deflection (Figure 7). The wind uplift produced by typhoons must be considered when installing SWHs in Taiwan. Previous studies conducted by Radu *et al.* [27,28] investigated the characteristics of steady-state wind loads of solar collectors in clusters on the flat roofs of five-story buildings in a boundary-layer wind tunnel. They discovered that the sheltering effects of the first row of collectors and of the building itself considerably reduced the wind loads exerted on the solar collectors. The flat-plate solar collectors with glass covers are widely used in Taiwan. Chung *et al.* [29,30] reported that the localized loads of a glazed flat-plate solar collector were higher near the front edge. The wind uplift of a solar collector considerably increased with the tilt angle (β) of the collector for both residential (a tilt solar collector with a horizontal cylinder as water storage tank) and large-scale (tilt solar collectors only) SWHs (Figure 8). A reduction in wind uplift should be addressed to prevent the devastating damage caused by typhoons.

Figure 7. Solar collector damaged by typhoon.

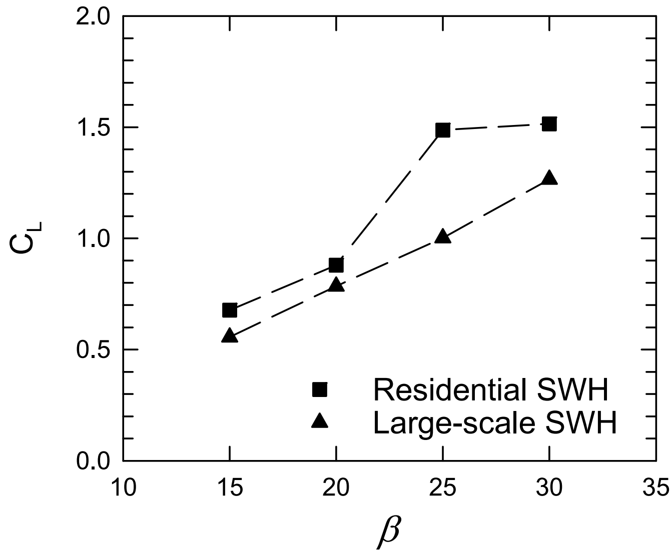

Figure 8. Uplift coefficient of solar collector.

4. Conclusions

The well-orchestrated and concerted efforts introduced by the government of Taiwan, particularly with the Renewable Energy Development Bill promulgated in 2010, have played a crucial role in the increased dissemination of SWHs. However, a more aggressive legislation that requires mandatory installation in new constructions must be implemented. The long-term national subsidy programs constitute the main driving force for local market expansion. For maintaining a free and open market, subsidies must be implemented only throughout the business phase. The negative impact of cross-subsidy programs implemented by the regional governments on the long-term development of the local market should be carefully addressed. The mass media should be used more aggressively for enhancing public awareness and promoting the use of SWHs. Organizations must also consider the interests of society by being accountable for their business practices and being responsible for the impact of their activities on the environment (reduction of carbon emissions). Finally, alternative subsidy programs for building-integrated solar thermal collectors and industrial heating processes are required for sustainable development of solar heating systems in Taiwan.

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Author Contributions

Keh-Chin Chang was the principal investigator and edited the manuscript. Wei-Min Lin carried out the analysis of SWH market in Taiwan. Kung-Ming Chung drafted the manuscript. All authors read and approved the final manuscript.

Acronyms

$(\tau\alpha)$	Value of transmissivity and absorptivity for solar energy
A_{SC}	Area of solar collector, m^2
BEMOEA	Bureau of Energy, the Ministry of Economic Affairs
CNS	Chinese National Standards
$F_R\ (\tau\alpha)$	Slope of the collector efficiency curve
$F_R\ U_L$	Intercept of the collector efficiency curve
kLOE	Kiloliter of oil equivalent
NTD	New Taiwan Dollar
PV	Photovoltaic
SWHs	Solar water heaters
SC	Solar collector
β	Tilt angle of solar collector
ΣAsc	Total area of solar collector installed per annum

Conflicts of Interest

The authors declare no conflict of interest.

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