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Solar thermal market in Taiwan

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HIGHLIGHTS

- ▶ Regional subsidy programs will be the main force in influencing the growth in sales.
- ▶ A revised program is needed to promote solar water heaters for industry applications.
- ▶ Solar-assisted cooling systems are potential applications of solar energy in Taiwan.

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ABSTRACT

The long-duration of national programs has been the driving force behind the expansion of the local market of solar water heaters (SWHs) in Taiwan in the last two decades. This study examines the potential market for SWHs using the statistical data from end users and the 2010 Population and Housing Census. The current effective utilization rate of residential SWHs in terms of potential number of systems installed is estimated to be 11.8%. The analyses also show that the current national subsidy program has recently lost its momentum in expanding the market. Therefore, regional subsidy programs should become the main force in influencing the growth in sales. In addition, SWHs of larger scale would be particularly effective in industries. To promote such applications, a combination of performance-based and direct subsidy schemes or tax deductions can be offered to end users to promote the applications of SWHs in the commercial sector. Solar-assisted cooling systems are considered to be another potential application of solar energy, which is associated with energy saving and power consumption in commercial and residential buildings. A short review of the R&D activities is also given in this paper.

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1. Introduction

Taiwan is a densely populated island with limited land-based energy resources, depending almost exclusively on imported fossil fuels to fulfill its energy needs. The ratio of indigenous energy to total energy supply has decreased from 1.23% in 2000 to 0.61% in 2010 (BEMOEA, 2011). In the last decade, electricity constituted from 48.60% to 50.7% of total domestic energy consumption. Note that the power consumption in 2010 was 237,559.4 GWh. With the political commitment to shut down several nuclear power plants in the near future, the use of renewable energy for power generation will play a vital role in national economic development, in addition to the environmental issues surrounding energy production and climate change (Tsai and Chou, 2005; Thavasi and Ramakrishna, 2009; Kikuchi, 2011). In 2010, hydropower contributed 2.94% of gross power generation

while geothermal, solar and wind energy shared 0.42%. In addition, renewable energy contributed 7.20% of the total capacity for power generation in 2011. Substantial efforts are needed to reach the target of 15% power by 2025 (BEMOEA, 2011).

Taiwan is a leaf-shaped island straddling the Tropic of Cancer. Solar energy is one of the major renewable energy resources. The average daily global solar insolation is approximately 3.25 kWh/m² in the north and 4.64 kWh/m² in the south. In the domestic sector and some industries with relatively low energy consumption, such as food, agro, textiles, chemical, and beverage industries, the fraction of energy used for producing water production of 40–80 °C can be quite significant (Karagiorgas et al., 2001). Therefore, applications of solar thermal systems could reduce domestic energy consumption of LPG, natural gas and electricity. Use of SWHs in Taiwan began in 1978. However, the higher initial cost resulted in a lack of effective competition to the conventional gas or electric water heaters. It would be very difficult to promote SWHs without governmental support. To disseminate SWHs, the subsidy programs have been promoted by the governments since 1986, as shown in Table 1. Note that the Energy Research Center,

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Table 1
Subsidy programs in Taiwan (Chang et al., 2011b).

Funding agency	Period	Collector-area-based subsidies
Bureau of Energy, MOEA (BEMOEA)	01.1986–06.1992	Direct subsidy, 2000 NTD/m ² for glazed flat-plate SC and evacuated tube SC; 1000 NTD/m ² for unglazed flat-plate SC
BEMOEA	07.2000–12.2008	Direct subsidy, 1000 NTD/m ² for glazed flat-plate SC and evacuated tube SC; 500 NTD/m ² for unglazed flat-plate SC from 1990 to 1991
BEMOEA	01.2009–present	Direct subsidy, 1500 NTD/m ² for glazed flat-plate SC and evacuated tube SC; 1000 NTD/m ² for unglazed flat-plate SC
Government of Kieman county	03.2008–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 Kaohsiung city	09.2008–12.2010	Direct subsidy, the same amount as BEMOEA subsidizing up to $A_{sc}=6$ m ² after April 1, 2010
Government of Chiayi county	01.2011–12.2011	Direct subsidy, the same amount as BEMOEA
Government of Yulin county	01.2011–present	Direct subsidy, the same amount as BEMOEA

SC: solar collector.

National Cheng Kung University have been authorized to organize an operation unit to carry the subsidy programs since 2000, including filing and auditing of applications, allocation of the funding, and appealing process (Chang et al., 2011b). The subsidy to total installed cost ratio ranged from 15% to 89% (Chang et al., 2011a), and the standards (energy collected and heat loss) on SWHs have also been enforced, resulting in substantial growth in the sales of SWHs (Chang et al., 2006). In addition, Chang et al. (2008, 2009) found that the utilization rate and potential market of SWHs in Taiwan are associated with public attitude, economic feasibility (initial cost and energy price), household structure, type of buildings (or degree of urbanization) and typhoons.

Chang et al. (2009) analyzed the possible potential SWHs installed in Taiwan. Based on the statistical information of SWH users, housing units and number of households in 2006, the potential SWH market in Taiwan would be about 3.52 million households. Note that there are about 0.3 million SWHs in operation now. Thus, there still exists much room for further promotion of SWHs within the domestic sector. Furthermore, the population and housing census is conducted every ten years in Taiwan. The census collects information on the quality and quantity of the population, household composition, housing usage, etc. As mentioned above, household structure and type of buildings are among the dominant factors in dissemination of SWHs in the domestic sector. The newest census data in 2010 has provided factual information to assess the potential SWH market in Taiwan. In addition, there is lower hot water consumption in summer and SWHs would contribute less than 50% of annual water heating energy for households. To expand the solar thermal market and maximize energy savings with solar energy, the development of combi-solar systems for producing hot water and air-conditioning is addressed in this paper.

The paper is organized as follows: Section 2 gives a description of SWHs in Taiwan. Section 3 presents potential solar thermal market. Housing usage and demographic characteristics on the SWHs market are reviewed, and potential applications of large-scale SWHs and solar-assisted cooling systems are addressed. Conclusions are drawn in Section 4.

2. Solar water heaters in Taiwan

Electric and gas water heaters are the most common methods of producing hot water in Taiwan. According to the statistical data by the Taiwan Gas Appliance Manufacturers Association, gas water heaters (73.8%) dominated the market while the market

share of electric water heaters was 23.5% in 2011. Installation of SWHs was still very limited, even with the subsidy programs activated by the Bureau of Energy, Ministry of Economic Affairs (BEMOEA). According to the classical work by Rogers (2003), there are five factors influencing an individual's decision to adopt or reject innovation, including relative advantage, compatibility, complexity or simplicity, trialability and observability. In general, SWHs are easy to use, having low complexity. Then with public awareness of global warming, there has been strong recognition of the increasing social and environmental costs associated with the use of fossil fuels. SWHs could be perceived as being consistent with the values and norms of a social system (or compatibility). Trialability and observability would also be associated with more than 0.3 million SWHs installed in the last two decades following the national and regional subsidy programs. Adoption of SWHs would then not be solely based on word of mouth but with the accumulation of manufacturing and operating experiences. Further, the degree of relative advantage might be measured in economic terms. Therefore, the higher initial cost of a SWH in comparison with that of electric or gas water heaters would affect the rate of adoption. Furthermore, the payback period of SWHs in Taiwan was about 5–6 years, which was estimated by Industrial Technology and Research Institute (ITRI, Taiwan). However, Pan et al. (2012) indicated that the payback period varies 6–15 years in different regions and heater types being replaced. Further study is required.

2.1. SWHs market (2001–2011)

The area of solar collectors installed during 1999 (56,500 m²) was less than that at the end of the first subsidy program (1991, 60,300 m²). To further promote the application of SWHs, a second subsidy program was activated by the BEMOEA in 2000, creating an economic incentive for end users. The units of SWHs and area of solar collectors installed (A_{sc}) per annum are shown in Fig. 1. The subsidy programs and the significant increment in new housing units resulted in increasing sales of SWHs from 2001–2006. It is also seen that A_{sc} has been over 100,000 m² per annum since 2004. Then the local market was almost constant in the period of 2006–2008, and a drop in 2009 was also observed. Chang et al. (2009) indicated that a faltering economy and declining rate of construction of new buildings might have played a major role. With the regional subsidy program by the government of Kaohsiung city, there was a significant increase in the sales of SWHs in 2010. Indeed, there were 5902 ($A_{sc}=27,772$ m²) and 8391 ($A_{sc}=43,235$ m²) units of SWHs installed in 2009 and

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