Renewable and Sustainable Energy Reviews 20 (2013) 385–396

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Dynamic simulation of government subsidy policy effects on solar water heaters installation in Taiwan

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ARTICLE INFO

Article history:
Received 30 October 2011
Received in revised form
1 December 2012
Accepted 9 December 2012
Available online 9 January 2013

Keywords:
Government policy
Solar water heaters
System dynamics
Dynamic simulation

ABSTRACT

Because of the increasing shortage of international energy sources and greater climate change related to global warming, developing renewable energy sources has been emphasized by numerous countries. Solar energy provides a type of clean and non-polluting renewable energy source and contributes greatly to relieving the energy and environment crises. In response to the international increase in energy prices, and under environmental pressure to reduce global emissions of greenhouse gasses, promoting solar water heaters (SWHs) has become a crucial aspect of the Taiwanese government's energy saving policies. This study used system dynamics to explore the causal relationship of solar water heater installation in Taiwan and simulated relevant government policies. The results showed that if the government in Taiwan continues to subsidize SWH installation with NT$2250/m^2, SWH installation areas will reach the promoted target of 1,40,000 m^2 by 2020.

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http://dx.doi.org/10.1016/j.rser.2012.12.009

1. Introduction

Saving energy and reducing carbon emissions are the core of government policies in Taiwan. In response to the international increase in energy prices, and environmental pressures to reduce global greenhouse gas emissions, promoting solar water heaters (SWHs) has become a significant aspect of the Taiwanese government's energy saving policies [1]. However, can the annual SWH installation area target be reached by 2020 if the government continues to provide the current NT$2250/$m^2$ in SWH installation subsidies? How do increases or decreases in government subsidies and raw material prices influence the SWH installation area? Government authorities and SWH business managers all want the answers to these questions.

In recent years, countries worldwide have focused on climate change and global warming. An increasing shortage of international energy sources, greater climate change caused by global warming, and rising energy prices has motivated numerous countries to emphasize the development of renewable energy sources. Fairey [2] highlighted that the world has between 30 and 60 years of oil remaining. Roaf et al. [3] believed that stocks of natural gas could last for a further 65 years at the current rate of consumption. Sovacool and Watts [4] suggested that at the current rate of consumption, the world has less than 200 years of fossil fuel supplies, 65 years of natural gas, 70 years of uranium, and 164 years of coal remaining. Roulleau and Lloyd [5] stated that anthropogenic global warming and resource depletion has led many countries to attempt to reduce their fossil fuel use and CO_2 emissions by switching to renewable energy sources.

Taiwan is an island country lacking traditional energy sources. Statistics show that more than 96% of the energy used in Taiwan is imported from foreign countries [6]. With Taiwan's flourishing economic development, the need for energy has consistently increased, leading to greater dependence on imported energy sources, which significantly influence socioeconomic developments. Renewable energy sources should be the focus of independent energy resource developments in Taiwan; its development will also provide long-term benefits to environmental protection. Renewable energy sources refer to energy sources where a constant provision is guaranteed. The renewable energy sources currently used by humans include solar energy, wind power, geothermal energy, water power, tidal energy, marine thermal energy, and biomass. Among these energy sources, solar energy refers to the radiant energy received by the earth from the sun, which directly or indirectly provides most of the energy on the earth.

Solar energy is an inexhaustible resource and SWH business is a part of the solar energy industry. Transforming sunlight into thermal energy using SWHs can reduce carbon emissions to the standard agreed in the Kyoto Protocol. The Bureau of Energy [6] stated in its report that every square meter of an SWH collector area can save 68 l of oil each year, and every square meter of an SWH collector area can reduce 190 kg of CO_2 emissions. Baumert et al. [7] highlighted that each home could save 5000 t of CO_2 per year through the elimination of liquefied petroleum gas leaks and the installation of SWHs. Islam et al. [8] highlighted that SWHs can make a significant contribution to CO_2 emission reduction as each installation reduces conventional energy use by 40–50%. SWHs industry is a significant green industry enabling the sustainable human development.

An SWH is a device that heats water using the solar energy collected by a solar thermal collector. SWHs are a commodified product with significant economic value and the most mature technology of all solar thermal energy applications. Taiwan is located at 120°–121° east longitude and 22°–25.5° north latitude, with an average annual temperature of 22 °C. The northern and central areas receive an annual average of approximately 1500 h of sunlight, and the south receives 2000–2500 h. The average radiant heat intensity is 716–1027 kcal/day m^2 [9]. Therefore, Taiwan is a very suitable location for developing SWHs.

Chang et al. [10] highlighted that the factors influencing the installation of SWHs in Taiwan include the sunshine duration and solar intensity, cost of SWHs, energy prices, typhoons, and the type of buildings. Almost all SWHs were installed on the flat roof of building. An average of three to four typhoons each year affects Taiwan. When a typhoon passed over Taiwan, numerous damaged SWHs were reported. The potential number of households using SWHs also depends on the availability of space for installation. Over 60% housing in Taiwan is cottage or duplex houses, which are more likely to install SWHs on the roof. Han et al. [11] emphasized that solar energy utilization is highly dependent on the climate conditions at specific sites and the most important climate factors are the sunshine hour and sunshine radiation. Liu and Wang [12] believed that with the rapid increase in the energy prices, SWH has better competition and is more popular compared with conventional gas combustion and electric-driven water heaters. Taiwan has a subtropical climate with an average daily insolation of 3000–4300 kcal/m^2. Compared with other regions in the world, Taiwan has a high exposure to solar energy, rendering it extremely suitable for applications of SWHs [13]. Xia et al. [14] stated that solar energy systems have the advantages of reliability and safety without any environmental pollution as compared with conventional energy.

Roulleau and Lloyd [5] reported emphasized that government policy types to increase the uptake of solar water heating include collector-area-based subsidies, performance-based subsidies, tax credits, tax deductions, and mandatory policies. The countries that have adopted collector-area-based subsidy policies include Germany, Austria, the Netherlands, and Taiwan. The countries that have adopted performance-based subsidy policies are Sweden and Netherlands. France has adopted the tax credit policy, and Greece has adopted the tax deduction policy. Spain and Israel have adopted mandatory policies. The Taiwanese government's policy support tools for the SWH industry include system cost subsidies, research and development sponsorship, and production equipment tax remittance [15].

The European Solar Thermal Industry Federation (ESTIF) [16] has reported that financial incentive schemes (FIS) in the form of direct grants have played an important role in the development of the leading solar thermal markets in Europe (Germany, Austria, and Greece). In the fastest growing solar thermal market (France), income tax reductions have significantly accelerated the market growth since 2005. Chang et al. [10] reported that the Taiwanese government initiated a 6-year incentive program (1986–1991) to increase the installation of SWHs. Subsidies were granted for purchasing SWHs. Consequently, the installation area of solar collectors reached approximately 60,000 m^2/year in Taiwan.

Numerous factors influence the installation of SWHs, such as government policies; safety, climate, and economic factors; and