Renewable and Sustainable Energy Reviews 28 (2013) 92–106

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

The effect of renewable energy application on Taiwan buildings: What are the challenges and strategies for solar energy exploitation?

Shih-Yuan Liu [a,*], Yeng-Horng Perng [a], Yu-Feng Ho [b]

[a] Graduate Institute of Architecture, National Taiwan University of Science and Technology, #43, Section 4, Keelung Road, Taipei 10607, Taiwan, ROC
[b] Graduate School of Architecture and Urban Design, Chaoyang University of Technology, #168, Jifeng East Road, Taichung 41349, Taiwan, ROC

ARTICLE INFO

Article history:
Received 20 July 2012
Received in revised form
10 July 2013
Accepted 14 July 2013
Available online 14 August 2013

Keywords:
Renewable energy
Solar energy
Taiwan
Evaluation decision-making system
Fuzzy Delphi method
Influence factors

ABSTRACT

Global warming or environmental issues in countries with effective energy applications and management of environmental resources have become key concerns. Energy is an important factor for countries to achieve sustainable development. Therefore, we need to actively seek renewable energy technology innovations, assess for optimization of resource inputs and strategize to proceed with effective energy strategic planning. Presently, international renewable energy technologies have been undergoing gradual and steady development. Taiwan is highly vulnerable in energy security, but geographic conditions for the development of solar energy applications have created a considerable advantage. However, the total installed solar energy capacity is far less than might be expected. Consequently, this study proceeds to explore the main resistance and key factors that affect renewable energy application concerning Taiwan buildings. Through the evaluation decision-making system model and expert decision-making groups giving evaluation values and feedback, the study found the main influences and key factors, and propose strategies for energy development in the future to improve the quality and quantity of renewable energy applications and competitiveness of national energy. This research, in addition to providing references to relevant environmental energy systems for deployment and technological research and development, also provides developing and underdeveloped countries access to applications of solar energy technology assessment and forecasts for the future.

Contents

Abbreviations: 3E, Economic development and Energy Exploitation and Environmental Protection; ACRE, Australian Centre for Renewable Energy; ASI, Australian Solar Institute; BEMOEA, Bureau of Energy under the Ministry of Economic Affairs; BIPV, Building Integrated Photovoltaic systems; CSP, Concentrating Solar Power; EPIA, European Photovoltaic Industry Association; FDM, Fuzzy Delphi method; FIT, Feed-in tariff; GW, gigawatt; H_0, Null hypothesis; H_1, Alternative hypothesis; IEA, International Energy Agency; kW, kilowatt; MBIPV, Malaysian Building Integrated Photovoltaic Project; MOEA, Ministry of Economic Affairs; MW, megawatt; PV, Photovoltaic; R&D, Research and Development; RD&D, Research and Development and Demonstration; RE, Renewable Energy; REP, Renewable Energy Plan; RES, Renewable Energy Source; RET, Renewable Energy Target; RETs, Renewable Energy Technologies; RPS, Renewable Portfolio Standard; SFP, Solar Flagship Program; SHCP, Solar Homes and Communities Plan; SPSS, Statistical Package for Social Science; SWH, Solar Water Heaters system

* Corresponding author. Tel.: +886 2 27376570, mobile: +886 958 855216; fax: +886 2 27376721.
E-mail addresses: D9913005@mail.ntust.edu.tw, Liu06242003@yahoo.com.tw (S.-Y. Liu), perng@mail.ntust.edu.tw (Y.-H. Perng), hyfarch@ms32.hinet.net (Y.-F. Ho).

1364-0321/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.rser.2013.07.018

1. Introduction

Global environmental concerns and the escalating demand for energy have accelerated worldwide attention on green energy, especially solar energy [1]. In recent years the international effort to reduce carbon emissions, thus, protecting the environment, while not stopping economic growth, has been a serious challenge and an important issue [2]. Many countries have put into use various types of renewable energy technologies (RETs) to promote research, development and demonstrations (RD&D). Therefore, RETs have become an important field of industrial competition internationally [3]. In Taiwan the green energy industry is also included in the development of key industries. Currently, both developed and developing countries are actively seeking alternative renewable energy sources. The European Union currently has provided input of the most resources between countries [4]. There are many types of renewable energy (RE) resource applications. Solar energy is the most dominant source among the renewable energy resources and appears quite attractive for electricity generation because it does not increase carbon dioxide emissions, is not harmful to the environment and is nature friendly [5]. Being able to direct and facilitate the application to daily needs for energy in various types of buildings, it has attracted worldwide attention [6].

The International Energy Agency (IEA) envisaged solar power accounting for 11% of global electricity production by 2050 and solar electricity contributing about 20% of the world's energy supply by 2050 and over 60% by 2100 [7]. It is clear that solar energy will play an important role in the future of energy. Thus, it will become the first choice of governments and private enterprises of many countries [8]. Renewable energy inputs have proven effective in developed countries (such as the United States, Germany and Japan), as well as in recently emergent countries (such as Spain, Italy and the Czech Republic); these countries continue to input and promote solar energy applications [9]. However, the main objective of Taiwan's renewable energy policy is to promote more diversified applications in Taiwan. In accordance with the Bureau of Energy under the Ministry of Economic Affairs (BEMOEA) “Energy White Paper”, “Challenge 2008: National Development Plan” indicated that the key project of renewable energy development and application in the future was solar energy. Taiwan is a very densely populated island, so the application of solar energy is mainly combined with buildings. Thus, the application of renewable energy in buildings is mainly solar energy [10,11]. This becomes the supporting background of this study.

However, through literature surveys and analysis this study discovered that there are many RE research documents concerned mostly with the development of energy application system technology research and development (R&D) and simulation, evaluation and forecasts of systems of innovative technologies. Application technologies for solar energy occupy most of these studies [5]. However, a country's input and the import of the applications of new energy technologies, according to the present state and resource conditions for preliminary planning, assist with the assessment of applications technology, the forecast of effects of imported technology and the review and improvement of import difficulties and obstacles. These relevant research documents have not received much attention. This study uses Taiwan as an example to conduct in-depth research and explore the practical application and situation of solar energy at present. These become the major support motivations of this study.

Presently, in the statistics on the cumulative installed capacity of renewable energy in Taiwan there is a considerable gap between planning objectives and practical solar energy applications. In order to explore and seek the main resistance and key factors influencing solar energy applications and development, this study is composed of three parts: (1) *Establishment of assessment factor variables*: Through literature review and systems engineering analysis the research can retrieve factor variables that affect solar energy applications; (2) *Establishment of an evaluation decision-making system*: The evaluation values and feedback from the Fuzzy Delphi Expert Questionnaires and expert decision-making groups (industry, government, research and academic) are used to find key influencing levels and factors in Taiwan; (3) *Draw up energy development strategy proposals for the future*: According to the results of the study, energy development strategies were proposed for the future. The results of this study are expected to improve and enhance the quality and quantity of renewable energy applications and the competitiveness of national energy. Moreover, the study findings will help to provide references for relevant environmental and energy systems concerning deployment and technological aspects of R&D, as well as provide developing and underdeveloped countries' applications of solar energy technology assessment and forecasting for the future.

2. Current status and trends of solar energy applications globally

In recent years, solar power generation systems have gained unprecedented attention as a method to solve the energy problem. Thus, solar energy is obviously environmentally advantageous relative to any other energy source. Nowadays, about 46 countries actively promote RD&D to deploy solar energy systems. The worldwide solar photovoltaic (PV) generation capacity continues to increase and has become a rapidly growing industry [12]. According to the European Photovoltaic Industry Association (EPIA) the installed capacity of solar PV systems may reach 688 GW in 2020. With an annual investment value of about 620 billion Euros from now until 2020, there will be more than one billion