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Study on Auxiliary Heat Sources in Solar Hot Water System in China

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Abstract

The solar hot water system (SHW) has the potential to reduce household energy usage substantially and also provide external benefits of reducing emissions of CO_2 and other pollutants. But SHW is unstable due to changing outdoor climate, which needs auxiliary heat source to meet continuous hot water demand. Despite previous studies have proposed the suitable solar fraction in different regions of China, the reasonable auxiliary heat source form in different regions should be somewhat different due to geographic variations and local conditions, and needs further study. This paper analyzes the adaptability of the auxiliary heat source s in different regions, which helps to guide the applications of SHW in China. The optimal solar fraction and regional adaptability of auxiliary heat source from aspects of energy efficiency, economic performance and carbon emission reduction during the life cycle in 31 capital cities in China are discussed by using Geographical Information System (GIS) mapping techniques and RETScreen tool. The residential solar hot water system based model is developed, and the geographic variations in the solar resource, supply water temperature, local energy price, hot water usage, and available incentives are selected for analysis. The results show that the suitable auxiliary heat source form and optimized solar fraction vary in different regions. For example, towngas boosted SHW is appropriate for most regions especially in the west region of China. The heat pump boosted SHW is a good choice in the southern coast region. This study helps to guide policy making and design for the solar hot water system.

Keywords: Solar hot water system; Auxiliary heat source; Geographical Information System; RETScreen

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1. Introduction

Solar heat water has the potentials to reduce household water heating electricity consumption, which also provide benefits of reducing emissions of CO_2 and other pollutants. However, the solar heat water system is unstable, and needs auxiliary heat source to overcome the shortcomings. Cassard et al. [1] examined the regional, technical, and economic performance of residential rooftop solar heat water technology in the U.S.A. N.Aste et al. [2] proposed a quick and easy-to-use graphical tool to size and assess the performance of solar thermal system. Li et al. [3] analyzed the evaluation results of conventional solar water heater systems and solar heat pump system for hot water production in Hong Kong. Qi et al.[4] used the f-CHART method to evaluate and optimize thermal performance economics of the solar water system, but didn't consider the proper type of auxiliary heat source. Though previous studies have put forward the suitable range of solar fraction, the suitable auxiliary heat source form in different regions is not fully clarified. There are various types of auxiliary heat sources, such as electricity heater, towngas boiler, heat pump and oil boiler are selected as auxiliary heat source.

In this paper, the optimized solar fraction and regional applicability from the aspects of energy efficiency, economic performance and carbon emissions estimation during the life cycle in the typical cities in China were analyzed in details by using Geographical Information System (GIS) mapping techniques and RETScreen tool. Based on the results, suggestions are given on the selection and design for the solar hot water system.

2. Technical and economic evaluation

Energy demand for hot water is a function of climate conditions, inlet water temperature, fuel price, house size, and usage patterns of the residents. In order to determine the annual amount of energy required for water heating, we used the RETScreen[5], a tool dedicated to the pre-design of renewable energy system developed by the Natural Resources Canada. Detailed evaluation model of the solar hot water system is described as follows.

2.1. Evaluation methods

Firstly, the annual solar fraction F is defined by the following equation,

$$F = \frac{Q_j}{Q_z} \times 100\% \tag{1}$$

where Q_j is heat production by SHW, MJ; Q_z is solar energy capacity per year, MJ.

Secondly, the total annual cost during the life cycle L is given by,

$$L = (L_1 \times S + L_2 + L_{aux} + L_3 \times N)/N \tag{2}$$

where L_1 is plant specific cost per installed unit, RMB/m^2; L_2 is tax fee, RMB; L_3 is fuel cost per year, RMB; L_{aux} is auxiliary plant cost, RMB; N is lifespan of SHW; S is solar collector area, m^2.

Thirdly, the CO_2 reduction rate C calculation is based on the savings compared to that of an electricity heater by,

$$C = \frac{(E_b - E)}{E_b} \times 100\% \tag{3}$$

where E is CO_2 emission of SHW, t/year; E_b is CO_2 emission of electricity water heater, t/year.

Finally, the payback time PBT can be predicted by,

$$PBT = \frac{c_i}{c_s} \tag{4}$$

where c_i is initial cost, RMB; c_s is cost saving per year, RMB.