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Editorial

Recent Advances in Residential Energy Utilization Technologies for Low-Carbon Emissions in China

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1. Introduction

In the past decade, renewable energy consumption in China has increased significantly. The Chinese government has established several targets to control carbon emissions and intends to increase the percentage of low-carbon energy usage [1]. China's long-term plan is to achieve carbon neutrality by 2060. Two pathways exist to attain this ambitious goal: one is enlarging the percentage of renewable energy power in the Chinese State Grid; the other is energy conservation and consumption reduction. For the first pathway, solar, wind, and geothermal are the most commercially utilized renewable energy sources in China. According to the latest China 2050 High Renewable Energy Penetration Scenario and Roadmap Study from the Energy Research Institute National Development and Reform Commission of China, the capacity of renewable power will account for over 60% of Chinese total power generation by 2050 [2]. With respect to the second pathway, the rapid growth of urban populations has resulted in an increased housing demand and residential district construction, causing buildings to contribute to a growing proportion of energy consumption. Statistical results indicate that energy consumed by buildings reaches approximately 40% of China's total energy consumption, which is equivalent to 25% of the total greenhouse gas emissions [3]. Consequently, building energy conservation is of vital importance for carbon emission control.

2. Renewable Energy Technologies

Promoting the utilization of solar energy is an effective approach to alleviating the energy crisis and finally achieving the aim of carbon neutrality. Solar trough concentrators (STCs) are commonly employed to increase the solar radiation on absorbers for the purpose of water heating, seawater desalination, and power generation. However, trough concentrators create an uneven energy flux distribution on the absorbers' outer surfaces. This uneven distribution can cause significant thermal stress and potential damage to absorbers in solar thermal utilization, as well as hot spots, current mismatch, and efficiency reduction in photovoltaic panel (PV) systems. Moreover, there is a knowledge gap between solar optical analyses and the thermal and deformation performances of STCs. To provide guidance for scholars, enterprises, and engineers in choosing the STC type for various application fields, the widely used STC types, such as parabolic trough concentrators (PTCs), compound parabolic concentrators (CPCs), surface uniform concentrators (SUCs), and trapezoid trough concentrators (TTCs), were compared by Cao et al. [4]. Through a detailed numerical simulation, they concluded that SUCs hold the smallest equivalent stress, which is favorable for the long-term operation of solar thermal utilization systems.

PV and wind turbines (WTs) are the most profitable among all the renewable technologies. However, solar and wind resources are both susceptible to weather fluctuations. For a typical weather condition, the generated solar PV power in summer is usually higher than that in winter, but WT power generation is usually higher in the winter. Therefore, taking advantage of the complementarity of solar and wind resources and properly combining them together to form a hybrid system can partially overcome the unpredictability of a single system. Yang et al. analyzed and optimized the distribution strategy of a standalone hybrid WT/PV system for rural applications based on different solar and wind resources [5]. They concluded that when the total solar irradiation is lower than 5040 MJ/(m^2·a) and the annual average wind velocity is in the range of 3.0~3.5 m/s, the recommended WT and PV power installation ratio is 5:1. And it is not recommended to use a standalone hybrid system if the total solar irradiation and annual average wind velocity are lower than 5040 MJ/(m^2·a) and 2.0 m/s, respectively.

Geothermal energy is another highly attractive renewable energy source due to its abundant reserves, wide-range distribution, and high stability. The high intermittency and variability of solar and wind energy, as well as their low predictability and controllability, pose significant challenges to the security and management of power grids. Therefore, geothermal energy is recommended to be used as the base load of power grids to guarantee their safe and stable operation. To explore the optimization potential and interactions among the system components of a low-temperature geothermal binary-flashing cycle (BFC) using zeotropic mixtures, Zhao et al. carried out energetic and exergy analyses, with a focus on advanced exergy analyses [6]. They compared the critical parameters in the modified organic Rankine cycle, and their study provides meaningful results for the BFC system's optimization, and practical guidance.

3. Building Energy-Saving Technologies

There is a rapid growth trend in building energy consumption with the continuous development of modern society. The accelerating urbanization further promotes the construction of high-rise buildings and increases the usage of electrical lighting in buildings. Statistical results show that energy consumption in buildings takes up to 21.11% and 19.5% of China's total energy consumption and total CO_2 emissions, respectively [7]. And air conditioning and heating account for 55% of China's building energy consumption, among which the envelope heat loss accounts for 70~80% and the outer façade heat loss accounts for approximately 25%. Promoting the development and utilization of solar energy in buildings is a practical approach to alleviating the energy crisis and achieving the aim of carbon neutrality. Considering this, Li and Cui carried out a comprehensive evaluation of a dual-function active solar thermal façade (ASTF) system based on 3E (energy, economic, and environmental) analyses in China [8]. They found that, compared with a traditional solar water-heating (SWH) system, the ASTF system adds additional energy savings of 5.8%, 7.2%, and 11.4% for Shanghai, Beijing, and Lanzhou and saves 23.0% and 16.4% of cooling energy consumption and 92.4% and 102.3% of heating energy for Beijing and Shanghai, respectively. These results highlight a viable pathway for promoting cost-effective active solar thermal façades in different weather conditions.

Film cooling is one of the most widely accepted technologies for energy recovery in mid/high-temperature components. Shangguan and Cao conducted a study on the interaction between crossflow and jets with two rows of forward and backward injection, which could help us to understand multi-row film cooling with forward and backward jets [9]. This may be meaningful to the development of efficient film-cooling schemes with the understanding of the interaction between crossflow and jets. It also has great significance for energy-saving implications. They carried out an LBM-based investigation on the mixing mechanism of double-row film cooling combined with forward and backward jets. Their study indicates that the film-cooling performance can be improved by using a backward downstream jet with a large blowing ratio.

4. Conclusions

The five papers in the present Special Issue focus on the two pathways of decreasing carbon emissions in China. These studies suggest two main approaches to achieving carbon neutrality in the building sector: one is to expand green energy utilization, and the other is to reduce building energy consumption. It is believed that with continuous and further in-depth studies of renewable energy and energy-saving technologies, carbon neutrality in China should finally be achieved.

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