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Editorial

Building Energy-Saving Technology

Yaolin Lin [1,*] and Wei Yang [2]

[1] School of Environment and Architecture, University of Shanghai for Science and Technology, Shanghai 200093, China
[2] Faculty of Architecture, Building and Planning, The University of Melbourne, Melbourne 3010, Australia; wei.yang@unimelb.edu.au
* Correspondence: ylin@usst.edu.cn

Abstract: Buildings consume about 40% of the global energy. Therefore, the building sector plays a key role in achieving the goals of carbon peak and carbon neutrality. Various energy-saving technologies for buildings, such as building envelops, mechanical systems, and energy resources, have been developed to help to achieve zero- or even net-energy buildings while maintaining comfort and a healthy indoor environment. This Special Issue on building energy-saving technology was open to all contributors in the field of building engineering. The original experimental studies, numerical simulations, and reviews in all aspects of building energy utilization, management, and optimization have been considered. For this event, all of these topics were covered in the extensive submissions which were accepted, but interesting papers on other aspects of building energy efficiency were also received. The purpose of this editorial is to summarize the main research findings of the accepted papers in this Special Issue, including the energy-saving technologies involved in building envelops, mechanical systems, and occupant behaviors, and to identify a number of research questions and research directions.

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1. Research Topics Investigated

The accepted papers cover the energy-saving technologies related to the improvement of building envelops, mechanical systems, occupants' behavior, renewable energy utilization, energy prediction and disaggregation, building planning, and climate-adaptive design. All of the technologies can be used for low-carbon building design.

1.1. Energy Saving through Building Envelop

The thermal performance of the building envelop determines the amount of heat gain/loss that needs to be addressed by the heating, ventilation, and air-conditioning (HVAC) systems. Alghamdi et al. [1] proposed structural insulated panels (SIPs) joined with embedded camlock systems to solve the thermal bridge problem due to using framing members and nails to join SIPs. They found that SIP thickness is the dominant factor that affects its thermal performance, and the reduction in the R-value of the SIP caused by the embedded camlock systems is less than 13.8%. AlZahrani et al. [2] performed optimization on concrete walls using 3D-printed technology. They found that the infill structure of the walls affects their thermal conductivities and, thus, their thermal performance. Compared to conventional walls, the energy cost savings of the 3D-printed concrete (3DPC) walls were about USD 1/m^2. Šadauskienė et al. [3] investigated the effect of installation methods on the thermal performance of a new, high-performance window and found that the difference in the calculation results using the 2D method and the 3D method could be up to 68%. They insulated the window frame with SWB, not evaluating that the mental fastener could reduce the thermal bridge at the junction and frame by 80% (up to 37% when evaluating the mental fastener) compared to the traditional choice without insulation. Li et al. [4] evaluated the energy-saving potential of improving the insulation and air-tightness level of windows and doors for a passive house in regions with hot summers and cold winters in China. A reduction in heating energy consumption of up to 62% was found. However, overheating during the transition and summer seasons also occurred, which need to be resolved using natural and hybrid ventilation.

1.2. Energy Savings through Mechanical System

Mechanical systems account for a large proportion of building energy consumption. Determining how to improve their energy efficiency is crucial for improving the building performance. Zhang et al. [5] proposed a vacuum refrigeration energy-saving device with a new sealing door structure to reduce the number of vacuum refrigeration pumps and reduce the energy loss during operation.

1.3. Energy Savings through Occupants' Behavior Regulation

As people spend most of their time indoors, their energy usage behavior plays an important role in determining the building's energy consumption. Wang et al. [6] used the theory of planned behavior (TPB) and two extension models to evaluate the factors affecting the energy-efficient intentions and behaviors of the hotel guests. They found that past behaviors and self-determined motivation have strong correlations with hotel energy savings, and they suggest encouraging hotel guests to engage in pro-environmental behaviors.

1.4. Energy Savings through Renewable Energy Usage

The usage of renewable energy resources helps to reduce building energy consumption. Lin et al. [7] performed a review on the research and development of solar-assisted heat pumps for buildings in China. They found that the current research focuses on the theoretical and experimental investigation of the energy performance of the main components of the heat pump system, but less attention was paid to intelligent control, operation optimization, and integration with buildings. Building-integrated photovoltaic (BIPV) modules can be adopted to achieve net-zero energy buildings (NZEBs); however, this is not widely accepted by the architects and builders [8]. Basher et al. [8] performed a review on aesthetically appealing BIPV systems and recommended the development of high-definition colored PV (HDPV) modules with adequate image contrast in order to boost the productions and expand the BIPV market. The power conversion efficiency (PCE) of this product outperformed 85% of a bare panel.

1.5. Energy Savings through Energy Modeling, Prediction and Disaggregation, Building Planning, and Climate-Adaptive Design

It is crucial to know the importance of the factors that affect building energy consumption in order to determine the energy consumption of the buildings. Big data analysis based on field data collection can be employed to find the variable importance (VI) of each variable during the prediction of building energy consumption. Lin et al. [9] developed and compared the performance of eight data-driven energy prediction models for residential buildings in Oshawa, Canada. They found that back propagation neural network (BPNN) models had the best performance in terms of predicting both annual building electricity consumption and gas consumption, with mean absolute percentage errors (MAPEs) of less than 2.63%. The heating system type, fuel type for domestic water heaters, floor area, heating system efficiency, age of the heating system, and fuel type for the heating system are the most influential factors on electricity consumption, while the fuel type for the heating system, air change rate per hour (ACH), heating system efficiency, number of fluorescent bulbs used outdoors, and fuel type for domestic water heaters are the most important factors for gas consumption.

Despite knowing the individual building's energy performance, it is also very important to determine the whole building's energy consumption at a larger scale, as buildings interact with each other as well as the local environment. Ji et al. [10] developed a physical-based bottom-up method to predict the building operation energy consumption at the urban scale, and used imported topography to consider the shading effects on buildings. The outcomes of the results were found to agree with the benchmark. Commercial and transport buildings were found to have large energy use intensity (EUI), where the cooling energy demand is far greater than the heating energy demand.

It is equally important to determine the contribution of each electrical power appliance to a building's energy consumption. Buddhahai et al. [11] proposed an experimental design to disaggregate home energy consumption under a multi-target learning framework. They found that the performance of a prediction mode using the F-score (micro-averaged) and the power estimation accuracy index was better than that of a deep-learning-based denoising auto-encoder network approach, and was able to be used for home energy monitoring.

Building planning has an impact on the local micro-climate, which indirectly affects the energy consumption of the buildings in the community. Yang et al. [12] carried out a study on the influence of building density on the outdoor environmental thermal comfort of residential buildings in different climatic regions in China. They found that, when the building distance was in the range of 20–50 m, the mean radiant temperature (MRT) of the outdoor environment increased by 1.25 °C for every increase of 10 m in the distance.

Due to the global warming effect, there is a need to know the adaptivity of the buildings against climate change. Ruiz et al. [13] examined the performance of a semi-detached house with different Spanish energy regulations in different future climate change scenarios. They found that the buildings with nearly zero energy building (nZEB) criteria outperformed buildings with the other two energy regulations by an average of 84.36% in energy consumption reduction, while, at the same time, the "slightly cool" hours were reduced by 57% and there was an improvement by up to eight times in the "slight warm" category.

As difference sources of energy vary in qualities, emergy is used to overcome this barrier. Chang et al. [14] employed a dynamic emergy analysis method for the design of a rural human settlement unit integrated with product-living-ecology. They found that the emergy self-sufficiency ratio and sustainable indices decreased over time, from 0.34 to 0.15 and from 0.76 to 0.57, respectively. At the same time, the values of the emergy investment ratio, net emergy yield ratio, and environmental load ratio increased.

2. Conclusions

The papers in this Special Issue generate new insights into energy-saving technologies for buildings from various aspects (i.e., building envelop systems, building mechanical systems, occupants' behaviors, building density, solar energy utilization, etc.). The following sets of research questions and research directions are compiled:

(1) Low-carbon buildings require the integration of building energy-saving technologies in building envelops and mechanical systems, as well as regulation of the building occupants' behavior.
(2) Integration of buildings with renewable energy sources is the key to achieving carbon peak and carbon neutrality, and ways to improve building energy efficiency with the integration of renewable energy technology will continue to be a hot topic.
(3) A big-data-driven approach is very important in building energy prediction and energy-efficient operation of a building's mechanical system, and will be an interest of many researchers in building energy-saving and mechanical system control.

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