Building integrated renewable energy

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Abstract
About one-third of the primary energy in the world is consumed by buildings. A large amount of CO\textsubscript{2} emission due to building energy consumption has threatened the sustainable development of the world. Improvement on the building energy performance, especially by integration with renewable energy resources has attracted interest worldwide to reduce greenhouse gas emission to make our society more sustainable. This Special Issue on building integrated renewable energy was open to all contributors in the field of building energy efficiency. The original experimental studies, numerical simulations, and reviews in all aspects of renewable energy utilization, management, and optimization have been considered. In the event, all these topics were covered in the extensive submissions 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 accepted papers in this Special Issue, including the use of renewable energy and energy saving technologies in buildings and identify a number of research questions and research directions.

Keywords
Editorial, building, renewable energy, Special Issue, communication

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Research topics investigated

The papers accepted cover the energy savings through renewable energy usage, heating, ventilation and air-conditioning system, building envelop, load forecasting and rating system, all of which can help improve the energy performance of the building. All the technologies employed in those papers can be integrated with building design to make the building more sustainable.

Energy savings through renewable energy usage

Geothermal energy and solar energy are the energy sources to help achieve zero energy buildings (Cabeza and Chafer, 2020). Geothermal energy can be used for building heating. Xu et al. (2020b) developed a mixed convective–conductive fluid-flow model of a co-axial closed-loop geothermal system to investigate its heat extraction performance for heating. It was found that a geothermal well could provide enough heat for a building with an area of 10,000–20,000 m². The heating area under intermittence operation was 4000 m² more than that under continuous operation. Xu et al. (2020a) further simulated the performance of a single-well groundwater source heat pump system in Beijing, China and found that the output temperature for a single well serving an area of 9000 m² during the heating season was 11–15°C.

Solar energy utilization is very important to help reduce the building energy consumption and even achieve net zero energy buildings. Zhou et al. (2021) proposed a solar integrated vacuum freeze-dryer and building air conditioning system, where a solar absorption refrigeration system provides cooling to both the building space and the freeze-dryer. Through computer simulation under the TRNSYS environment, it was predicted that 35.2% of the total energy was provided by solar energy. Gong et al. (2020) developed a single box model to evaluate the energy performance of perovskite-based building-integrated photovoltaics. Simulation results showed that a single box could achieve zero energy demand except for January and December while maintaining the indoor air temperature at 18°C in winter and less than 26°C in summer.

Renewable energy can be used to power barrier-free intelligent surveillance systems. Peng et al. (2020a) develop algorithms to improve the accuracy and reduce the work load for night time pedestrian detection, which can improve the correct rate of detection to 92.4%, thus reducing the energy requirements of the power station.

Energy savings technologies for heating, ventilation and air-conditioning system

The heating, ventilation and air-conditioning system consumes about 1/3–2/3 of the total building energy. Therefore, studies on the operation strategies of the air-conditioning system and building envelope thermal properties have always been a hot topic. Deng et al. (2021) studied the effects of air-conditioning operation mode on the energy consumption of a model building with different external wall insulations in the hot summer and cold winter region in China. It was found that the energy saving effect of external insulation was better than that of internal insulation under continuous operation mode, and vice versa under intermittence mode with low-and-medium-temperature tolerance.

As the number of subway lines increased with rapid speed in China, the research on how to improve the energy efficiency of metro stations becomes particularly important. The heating, ventilation and air-conditioning system account for more than 30% of the
total operating energy consumption of the subway systems (Wang et al., 2017). Li et al. (2020) performed field measurements on the ventilation and air-conditioning system in a subway station in Changsha, China and found that the air-conditioning system was operating at 10–50% of the design load during testing period with most of the thermal loads were sensible and the night time cooling load was about 80% of that in the daytime.

Data center consumed about 1 percent of global electricity use (Masanet et al., 2020), and has attracted many researchers to find innovative technologies to reduce its energy consumption. Heat pipe is one of the technologies that can be used to cool the data center with low energy consumption while reducing the local hot spots problem. Meng et al. (2020) developed a 1-D steady-state mathematical model of a novel loop heat pipe that removes the compensation chamber of the loop heat pipe and adds capillary wick at the end of liquid line. The model was able to calculate the operation temperature with small relative errors of <13%, which could provide help to the design of a novel loop heat pipe experiment.

Water atomization process is worth studying in mine exhaust heat recovery system. Chen et al. (2021) carried out an experimental study on the influence of gas disturbance on water atomization in a curved diffuser in a ventilation system and found that injection pressure is the dominant factor affecting the breakup length of liquid film near the atomizing nozzle and dispersed phase fraction for droplets reaches the maximum with an air flow rate equal to 3.2 m³/s.

Energy savings through building envelope, load forecasting and rating system

Zero energy buildings are based on a bioclimatic architecture concept and demand responses to internet of things control strategies (Cabeza and Chàfer, 2020). From the architectural design perspective, vertical greening system and green roof have received more and more attention worldwide recently as a passive measured to reduce building energy consumption and improve indoor thermal comfort. Tan et al. (2020) proposed an energy saving method by covering both the vertical facades and building roof with green plants. Through the experiment, it was found that the building integrated green plants help to achieve energy savings in winter by 18% and in summer by 25%.

Load forecasting is very important in the building energy management system which helps to improve the energy efficiency of the heating, ventilation and air-conditioning system by matching the equipment output capacity with the thermal load of the building. It can also integrate with the internet of things for renewable energy generation (Pawar et al., 2020). Lee (2021) developed load forecasting models for office buildings in Korean using calendar data and weather data and found that the quadratic model was most suitable to be used in Korea’s climate. Peng et al. (2020b) used a long short-term memory neural network method and developed a regression model to predict the energy consumption of a shopping mall in Shenzhen with an average relative error of less than 10%.

A number of rating systems have been developed to evaluate the performance of green/sustainable buildings, with different methods and the number of indicators. Al-Addous and Albatayneh (2020) performed a review on the energy rating method for housing and evaluated the limitation of the assessment systems. The authors raised concerns on using the R-value alone to evaluate the building thermal performance in the rating system and the accuracy of the building energy simulation software.
Conclusion
The papers in this Special Issue generate new insights into building integrated renewable energy from various subjects (i.e., building greenery system, air-conditioning system, rating system, load forecasting, energy management, solar energy utilization, etc.). The following sets of research questions and research directions are compiled:

1. Passive building design with photovoltaic integration is a trend to achieve high performance and even zero energy buildings, and
2. Data centers and metro stations are energy glue and how to improve their operation efficiency and reduce energy consumption will continue to be hot topics.
3. Load forecasting in the energy management system and internet of things would be important areas in the energy efficient operation of the building mechanical system.

Acknowledgements
We would like to thank the authors for their contribution to the special issue and thank the reviewers for their thorough and timely reviews. We believe the special issue provides a valuable contribution to building and renewable energy integration, which will generate insights for achieving building energy efficient systems.

Declaration of conflicting interests
The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding
The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The author(s) acknowledge the grants from Hunan City University Design and Research Institute Co., Ltd, for technical support of barrier-free construction in Hunan Province.

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