Editorial

Sustainable Buildings: Heating, Ventilation, and Air-Conditioning

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1. Introduction

The built environment sector is responsible for a significant proportion of the final global energy consumption [1] and carbon emissions. The energy demand from buildings is expected to continue to rise and will have major social consequences and climate change impacts [2]. Drivers include population growth, improved access to electricity and adequate housing around the world, and growing demands for air conditioning.

A large portion of energy use in the building is due to heating, ventilation, and air-conditioning (HVAC) systems [3]. While reducing the energy consumption of HVAC presents a great opportunity to curb energy demand growth rates, occupancy comfort and health must not be compromised [4]. HVAC regulates the temperature, humidity, and quality of air in a building, which is essential for maintaining a comfortable and healthy indoor environment [5]. The indoor environment quality also affects our productivity and wellbeing and, hence, must be carefully considered when designing HVAC systems [6]. The challenges to achieving sustainability in HVAC systems are extensive and, therefore, present a plethora of opportunities for researchers and industries to improve the performance and efficiencies of HVAC systems.

The contents of this Special Issue reflect the scientific community’s ingenuity and commitment to addressing these challenges by carrying out high-quality research and knowledge dissemination. It can be established that research into the field of sustainable HVAC technologies in encouraging low-carbon environments is diverse and multidisciplinary in nature, and it is widespread among scientists and scholars.

The articles that were submitted, as well as the ones finally selected for publication, cover a broad range of thematic areas ranging from the science and technology of low energy systems, data-driven parametric studies, and social analysis to investigations of low-energy technologies within a global climate. The eight selected research papers can be grouped into three main themes: (1) ventilation systems, (2) intelligent building energy management systems, and (3) energy-efficient heating and cooling systems.

As Guest Editors, we were pleased to receive several papers on these topics from authors and institutions from many countries. Figure 1 shows the geographical distribution of the authors and their institutions.
2. A Brief Review of the Articles in the Special Issue

Here, we provide a brief review of the articles [7–14] published in the Special Issue. A graphical summary of the key areas covered in the Special Issue is shown in Figure 2.

Figure 2. An overview of the key areas covered in the special issue. Image adapted from [15].

Contributions dedicated to the evaluation of different types of ventilation systems and strategies include four articles. The recent COVID-19 pandemic has further raised our awareness of the importance of good ventilation in buildings. Many institutions and organisations, such as the World Health Organisation (WHO), recommended ensuring
adequate ventilation and increasing the total supply airflow in buildings to minimise the spread of the coronavirus and other respiratory viruses. However, this could impact the energy efficiency of buildings; for example, increased ventilation in cold-mild climates could lead to increased heat loss [16]. Hence, it is essential to achieve a balance between indoor air quality and energy consumption when developing ventilation systems [17].

Andersson et al. (2020) [7] studied the ventilation performance of a low momentum confluent jet supply device in a classroom environment. Various cases have been investigated experimentally with different airflow rates, supply air temperature, and supply device configurations. Four types of supply devices were compared to investigate the indoor climate. The performance was also investigated regarding indoor air quality (IAQ), thermal comfort, and energy efficiency. The results show that confluent jet ventilation produced more stratified conditions at higher airflow rates, leading to greater heat removal efficiency. The study concluded that the modified low momentum confluent jets provided improved indoor climate with the highest energy efficiency of all devices.

In their recent study, Andersson et al. (2022) [8] developed a numerical model to evaluate further the performance of ceiling-mounted confluent jet ventilation supply devices. The study investigated the impact of design and operation parameters on comfort, air quality, and heat removal efficiency. The developed numerical computational fluid dynamics model agreed well with the experimental data. The findings indicated that the array of jets’ size had a significant influence on indoor conditions. The larger array of jets with multiple rows led to greater indoor air quality and heat removal. It was also observed that lower inlet velocities also reduced the risk of draft and occupant discomfort.

In the study by Javed et al. (2021) [9], numerical and experimental evaluations of a displacement ventilation system for the provision of space pre-heating in cold climates were carried out. Unlike traditional systems, displacement ventilation without a separate heating system was proposed to lower the cost and energy use. Experimental tests were carried out in a lab-scale classroom under regulated conditions and in a real classroom with dynamic occupancy and environmental conditions. Several comfort and IAQ parameters were evaluated. The findings showed that the proposed system could maintain comfortable indoor conditions even under extreme operational conditions. Results from numerical modelling highlighted the limitations of the existing simulation model, which was not capable of capturing the thermal behaviour of the system. They suggested that future studies should focus on advanced transient simulations and incorporate detailed stratification and more-sophisticated nodal models.

Yau et al. (2022) [10] proposed a hybrid system that combines a variable refrigerant flow system with stratum ventilation to provide energy-efficient cooling in buildings. The focus of the work was on the influence of the design of air supply terminal devices on the ventilation and thermal comfort performance of the hybrid system. Experimental tests were carried out to evaluate five different types of air supply terminal devices. The findings showed that the bar grille led to an improved airflow velocity distribution and thermal environment than all other diffuser types.

The role of smart technology in the dynamic control of building HVAC is analysed in the next article. Roccotelli et al. (2020) [11] proposed an integrated method to model the behaviour of occupants in a building and employ intelligent building energy management for passive cooling techniques. The study focused on optimising the control of natural ventilation and shading to minimise thermal discomfort and energy use in a building in a warm climate. The integrated method employed several tools, including TRNSYS, Matlab, and Daysim. The results showed that the optimisation method led to the improved control of the BMES, which reduced thermal discomfort and cooling energy demands. The study highlighted the importance of considering the stochastic behaviour of occupants when designing control systems for passive cooling strategies.

Contributions relating to energy-efficient heating and cooling systems are highlighted in the following three articles. Amanowicz and Wojtkowiak (2021) [12] evaluated the use of a multi-pipe structure for the earth-to-air heat exchanger system for ventilating a
building. Thermal and energy performances of various multi-pipe systems were compared against a single pipe system. A lab-scale experiment was conducted to evaluate the flow characteristics of different earth-to-air heat exchanger configurations, and a simple mathematical model was used to calculate energy consumption. The findings showed that a single pipe configuration with an appropriate tube diameter was able to achieve similar thermal performances and pressure losses as the multi-pipe system. At the same time, a multi-pipe system can also have larger diameter tubes, which enhance its energy efficiency. The study highlights the challenges of the design of such a system and the importance of using evaluation methods that consider techno-economic aspects.

Eveloy and Alkendi (2021) [13] proposed a solar-assisted multi-ejector space cooling system as an alternative to conventional air-conditioning to minimise energy demands in buildings in hot climates. A mathematical model was used to carry out the evaluation. The performance of the systems was evaluated for a typical residential building in terms of the system coefficient of performance and exergy rates. The findings indicated that the proposed system reduced cooling loads by up to 42% compared to a conventional air-conditioning system. In addition, the results showed that the increase in evaporator-temperature and reduction in generator temperature enhanced the systems’ cooling capacity and coefficient of performance.

The following contribution evaluated the provision of cooling in large semi-outdoor spaces such as stadiums. Extending their work [18] on the use of cooling air jets in stadiums, Zhong et al. (2021) [14] conducted an in-depth study on the effect of roof cooling and air curtain gates on thermal and wind conditions in stadiums in hot climates. Their recent work attempted to address the challenge of external hot air entering the stadium through its roof opening and gates, resulting in higher stadium pitch temperatures. They proposed the use of air curtains that project continuous airstream across the openings, which limited or prevented unconditioned air from entering the stadium. The study used a combination of Computational Fluid Dynamics (CFD) and Building Energy Simulation (BES) modelling to evaluate the aero-thermal and energy performance of the configurations and scenarios evaluated. The findings indicated that the proposed cooling strategy improved the thermal conditions in the spectator zones, and on the pitch, average temperature reductions of 15 °C and 14.6 °C were achieved in two zones.

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References


