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Editorial

Sustainable Buildings: A Choice, or a Must for Our Future?

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Construction is a key sector for green growth on a global scale. Buildings are responsible for more than 45% of final energy consumption, and more than 36% of greenhouse gas emissions. They are also one of the largest producers of waste, mostly generated during the construction and demolition phases. Therefore, this sector should be seen as a crucial area for government action plans, as many countries race to limit rising temperatures and fulfil their commitments according to the Paris Accords. Many countries have committed to achieving energy and environmental transition by 2030, and to having divided construction's CO_2 emissions by four by 2050, when compared to 1990.

The priority of shifting towards sustainable practices lies in the ability to produce efficient buildings and job opportunities. Reducing the energy consumption of the building sector (heating, air conditioning, lighting, etc.) is a prime method for lowering its environmental impact. However, it is also key to promote the use of eco-materials to reduce carbon footprint and valorise construction waste. Thus, these considerations are the basis for the emerging research and innovation programs in energy efficiency and sustainable development. The entire life cycle of a building and the urban microclimate must be considered, by assessing a number of factors: the embedded energy of the materials, energy and water needs, CO_2 and pollutant emissions, the quality of the indoor air, the quantity of waste produced, and the comfort of users.

As populations continue to grow, and nations continue to develop at a breakneck pace previously unseen in our long history, in our ever-growing global infrastructure development boom, smart cities are the future for the better management of these factors. This exponential growth and subsequent increase in demand have understandably led to calls for more streamlined methods and techniques for the design, development, and maintenance of smart buildings, whether through the usage of smart materials during the construction process, the selection of more eco-friendly construction locations, or the utilization of advanced technologies and tools, such as artificial intelligence, big data, and the ever-expanding IoT. However, with such rapid growth comes another set of challenges, the most prominent of which are the consequences of climate change and the subsequent need for energy-efficient and sustainable designs. Climate change is no longer something that can be ignored; a statement by the White House stated that it could cost the US up to USD 2 trillion each year by the end of the century (https://www.cnbc.com/2022/04/04/climate-change-could-cost-us-2-trillion-each-year-by-2100-omb.html, accessed on 22 October 2022).

Urbanization and the growth of smart cities will inevitably require solutions to reduce or entirely negate the harmful effects caused by design, construction, and technology choices of the recent past. This places the development of sustainable and energy-efficient buildings at the forefront of the most critical requirements of the near future. Architects and engineers have responded to this challenge in a number of ways, such as through the use of

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smarter materials that emit fewer greenhouse gasses, making better use of absorbed light, the integration of plant life to provide a cooler building environment, as seen in nations such as Singapore, and the use of more sustainable and renewable sources of energy, such as solar and hydro, to name a few. However, it is worth asking ourselves whether these steps are sufficient, or if there is more that we can be doing to progress development and promote a more sustainable design landscape.

To shed light on this issue we need to consider a number of different overlapping factors, all of which can heavily impact the sustainable design of a building. In this Special Issue, we provide a detailed and thorough view of sustainable and energy-efficient approaches through different eyes, opinions, and contributions from a number of different research areas, all highlighting the increasing interest in the topic. These include the energy efficiency design of buildings [1–8], the simulation of building performance [6,9,10], providing optimal comfort for occupants [2,7,9–11], the constant monitoring of a building's condition [12], energy savings and conservation [5,9,13], renewable energy [8,14], solar passive technologies [11,15], the development of smart cities [2,12], the current condition of our climate and how to manage this moving forward [1–18], how to provide energy-efficient water pumping systems in residential areas [16], the comfort of domestic water usage in residential buildings [17], and the development of what are known as energy commons [18]. As a number of topics overlap, we have separated them into categories. For each of them, a brief synthesis has been provided from the relevant contributions in the literature:

1. **Energy efficiency design of buildings.** Sherman et al. [1] reported an analysis of 2234 small commercial buildings in the US that underwent a retrofitting process to see if they would become more energy efficient. The authors found that a reasonable number of small commercial buildings mostly focused on implementing single energy efficient measures (EEMs), mainly on the lighting as it was cheaper and still beneficial to energy reduction. They also found that buildings that implemented multiple EEMs saw a much higher energy savings rate. Franco et al. [2] proposed a methodology with the intention of providing an optimal level of control over heating, ventilation, and air conditioning (HVAC) systems, while still balancing energy efficiency against comfort, which the authors report is difficult due to the conflicting nature of the requirements of providing both features. Ultimately, after testing their model at their local institution, they found that the optimized control offered results that suggested a reduction in energy consumption as well as a noticeable increase in comfort. Huang et al. [3] focused on a similar idea to that in [1], but instead conducted surveys and interviews with homeowners in central China to see if they would be willing to pay the costs of retrofitting their houses with energy-efficient materials. In this study, they discuss several different factors that might affect the homeowners' willingness to do so, such as age, education, age of the house, etc. Ultimately, they found that only some homeowners would be willing to pay for retrofitting, likely due to differences in age and attitudes towards consumption, and outdated building designs that could not support retrofitting, among other reasons, and that discussions with these homeowners would be necessary to try and shift perceptions amongst the less willing. Soares et al. [4] proposed an ICT platform in which a number of issues and solutions raised in prior works, such as [1–3], could be addressed in one comprehensive system, which they have dubbed the "Feedback Project". This ICT platform offers a number of features, such as energy usage monitoring, balancing the load of appliances, responding to changes in weather and behavioural patterns, and so on, which in turn offer a number of benefits in terms of energy efficiency. Szul et al. [5] conducted a study on the feasibility of using Takagi-Sugeno Fuzzy Modelling to predict the energy efficiency in buildings, particularly in buildings undergoing thermal improvement. They identified a set of variables that classify objects as either thermal or usable, and then used the model on 109 buildings with these variables in mind. In the end, they concluded that fuzzy modelling was slightly

yet significantly better than a lot of the other methods present today at predicting energy efficiency in buildings. Raj et al. [6] provided a review of a more numerical approach to energy efficiency, with the aim of improving what they call the 3Es (energy, economy, and environment). This paper makes a lot of similar points to some aforementioned studies, particularly [1–4], but the authors stressed the importance of implementing a building performance simulation as a framework for energy-efficient building development. Anastasi et al. [7] talk about how COVID-19 has led to an acceleration of the transition process of buildings into smart buildings and active environments, especially with regard to areas such as occupant density and air quality. The conclusion they reached at the end of their study was similar to that in [2]. However, their analysis delves deeper into the technical aspects when compared with [2]. Finally, Rehman et al. [8] studied the implications of the integration of electric vehicles towards the energy load of a building, and after reviewing a number of case studies in Europe they found that swapping regular cars for electric models reduced emissions in general; when considering its effect on the building's energy load, it produced the opposite effect to a more devastating degree. The authors concluded by adding that future changes made to electric vehicles should help to reduce emissions to a more manageable level, although further testing is required.

2. **Simulation of building performance**. This has already been briefly discussed in works such as [6]. Other notable examples of this topic include [9] by Motlagh et al., who utilized an advanced trading tool they named "TOPSIS" to determine the best spatial distribution strategy for windows to achieve the most energy-efficient design, among other characteristics. They used three case types, each representing different window types, and applied and measured four different orientations (heating/cooling, lighting, CO_2 emissions, and thermal comfort) for each. The end result was that the B type produced the best results across the tests. Similarly, Sayadi et al. [10] investigated different cases to obtain the optimal WWR (window-to-wall ratio), based on the total energy use of a building in a full year. These simulations were carried out in different climate conditions, resulting in a variety of cases being more useful than others depending on the weather or climate.
3. **Providing optimal comfort for occupants**. The works in [2,7,9,10] placed great emphasis on this, although it was not necessarily the primary focus of all their studies. In [11], author Piotr Michalak measured the performance of HVAC systems in a commercial building office by determining thermal comfort levels. He found that the average results indicated that the rooms were consistently lukewarm, meaning that a thermal-activated building system has the ability to provide optimal warm conditions.
4. **Constant monitoring of a building's condition**, in terms of energy consumption, comfort, and more. One of the key works on this topic is from Lourenço et al. [12], who simulated the usage of key enabling technologies in the management, control and monitoring of near-zero energy buildings. The simulation took place in a laboratory testing room to study the impact of control systems on energy requirements and thermal comfort, respectively, by using two systems known as the BIPV (Building-Integrated Photovoltaic) and earth tubes. Testing found that the BIPV increased comfort and reduced energy consumption, while earth tubes reduced cooling needs by 97%.
5. **Energy savings and conservation**. The works in [5,9] discuss this topic, as does the work by Ghisellini et al. [13], which utilizes construction methods and agri-food waste to provide a potential energy savings roadmap. The authors recycled around a tonne of construction and demolition waste, managing to lower the impact these materials had on the environment and energy conservation while also providing a lot of reusable material that could be repurposed for other uses. Although implementing this plan in practice would require a transition to a circular economy, the authors believe that this transition would be beneficial overall.

6. **Renewable energy**. This was explored in the context of electrical vehicles in [8], but the more intriguing application comes in the form of the work by Yerasimou et al. [14], who proposed designing a smart grid to increase the energy efficiency of buildings. The idea of the nanogrid is to provide a renewable source of energy that can create a sense of self-sufficiency, while also reducing a building's CO_2 footprint. The results from this work are promising in that regard.
7. **Solar passive technologies**, or technologies that utilize solar energy without any active participation in the process, provide a source of renewable energy and a layer of energy efficiency. The topic was briefly covered in [11], but the work by Brito-Coimbra et al. [15] offers a more insightful and theoretical glimpse into the topic. The authors studied works on four different but related topics, which were glazing, sun shading, sunspaces, and Trombe wall technologies, respectively. Their goal was to determine whether retrofitting buildings with solar panels would improve energy efficiency, and based on their analysis they found that it did. More factors have to be considered before coming to a definitive conclusion, but overall the idea has a vast amount of potential.
8. **Development of smart cities** and how energy efficiency ties into the development of such cities. The works in [2,12] are the pair on this list that go into depth regarding the development of smart cities, as both are committed to a sustainable, smart future.
9. **The current condition of our climate and how to manage this moving forward**. All the above works included in this paper try to address this in some way, shape, or form. Other notable works that discuss this include de Souza et al. [16] and their work on the indication of energy efficiency for the water pumping systems found in multifamily buildings, which tested the electrical energy consumption of said pumps, finding that as the energy consumption decreased the energy efficiency rates increased. Marszal-Pomianowska et al. [17] studied two detached Danish houses to test the flow temperature and energy found at draw-off points, with the conclusion being that there are only a small number of areas that would need focusing on if hot water was only siphoned to those areas; this would result in better energy usage and consumption and the development of low-energy-level buildings. Finally, Yang et al. [18] conducted a test where they retrofitted three apartment complexes in Seoul with solar photovoltaics, which was not easy to do given the general opinion surrounding the topic, among other matters. Their analysis found that, on top of providing a more energy-efficient means, it brought communities together and created a unique community model that should serve as an example for future developments.

In conclusion, it is essential to fortify our efforts in responding to the societal concern regarding sustainable building practices, optimizing the design, technology and construction of sustainable buildings via the utilization of green materials and passive heating and cooling techniques. This can be achieved by limiting the negative impact of buildings on climate change and enhancing the management of natural resources, ensuring indoor and outdoor air quality.

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