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Editorial

Global Building Decarbonization Trends and Strategies †

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It is evident from extreme weather patterns that climate change is impacting the whole world. The consequences in the form of unpredicted severe weather conditions, hurricanes, floods, and wildfires have been disrupting national economies and affecting lives across the globe. As the global economy is recovering from the COVID-19 pandemic, the temporary drop in greenhouse gas (GHG) emissions mainly caused due to travel bans and economic slowdowns is no longer the case and, moving forward, controlling the increase in GHG emissions has emerged as a global challenge. The impact of climate change has enabled an acknowledgement of the challenge and this coincided with the rapid development of clean energy technologies for buildings, transportation, and industrial sectors, while ensuring a significant reduction in costs for their wide implementation.

Owing to the extreme importance of building energy decarbonization in achieving global carbon emission reduction goals, this Special Issue, titled "Global Building Decarbonization Trends and Strategies", focuses on various technology and policy approaches and regional case studies in achieving the decarbonization of buildings. In this issue, we provide a comprehensive overview of the requirements of net-zero buildings [1], the state of the art of different building-related technologies [2] and their economic benefits [3], improvements to renewable technologies [4], the development of CCUS technologies and their applicability in buildings [5], control strategies [6,7], and case studies of energy districts [8]. The eight papers featured were selected to emphasize building decarbonization from a global perspective. A brief outline of the subject matter discussed in these selected articles is included below.

The significance of definition and strategy towards achieving net-zero globally was highlighted by Moghaddasi et al. [1], recognizing the need for a process to clarify and accelerate the adoption of net-zero approaches in the context of buildings (NZB). Based on the differences in existing standards, calculation strategies, and requirements, the authors proposed a new methodology which they coined as the "Process for Clarification to Accelerate the Net Zero (PC-A-NZ)" to optimize and expedite the use of renewables, while ensuring energy efficiency upgrades, in addition to electrification whenever possible. This new methodology focuses on supply and source variations, energy balance parameters such as timescale, emission source and grid connection, etc., while also considering requirements and strategies, all presented as flow charts to achieve a net-zero infrastructure.

Similarly, a comprehensive review of various aspects of positive energy buildings (PEB) and communities (PEC) such as energy supply and demand, energy storage and management, stakeholder challenges, etc., was provided by Kumar G. and Cao S. [2]. This study highlights the importance of new energy consumers such as vehicles and the required energy flexibility for shifting from zero energy to a positive energy system. The requirements of a holistic energy management system in realizing deep energy savings were presented. Positive energy systems involving the interaction of vehicles with buildings and the grid, in order to optimize renewable energy consumption, were discussed.

The impact of adding organic and inorganic internal wall insulation on the total energy consumption of a residential building was studied by Basinska et al. [3]. The need for internal insulation as a retrofit solution to avoid thermal bridges in buildings and improve energy efficiency was recognized and investigated. The authors considered four types of insulation in three different locations and analyzed the energy savings in a low energy building. Heating and cooling energy consumption was assessed with and without considering moisture. The positive impact of adding internal insulation was shown in the case of heating load curtailment; however, the economic savings were not favorable due to the significantly longer payback time. This study provides interesting insights into addressing the energy consumption of existing building stock for a sustainable net-zero energy transition.

Net-zero buildings, positive energy buildings and communities require a deep penetration of onsite renewable energy technologies that are affordable and energy efficient. Photovoltaic (PV) technology is the most promising technology and offers installation flexibility, but suffers from low energy efficiency under high solar radiation conditions due to thermal drift. In this context, Bevilacqua et al. investigated four different cooling systems integrated with PV panels, installed on the roof of a building [4]. The authors concluded that a 8% increase in power generation capacity via spray cooling during hot months was most effective, and recommended the use of a nonmetal-based back panel for efficient operation in hotter months, which resulted in economic benefits.

A drastic reduction in global carbon emissions requires each energy consumption sector to integrate technologies which can significantly improve energy efficiency, utilize renewable energy and capture/utilize and sequester (CCUS) the carbon dioxide where possible. The Paris Agreement, established in 2015, resulted in a global commitment to ensure that the average global temperature does not increase beyond 1.5 °C above pre-industrial levels. To meet this target, direct carbon removal from atmosphere has been defined as a major technological development. Regufe et al. reviewed the state of the art and recent progress of CCUS technologies [5]. This study discussed the advantages and challenges associated with all available CCUS technologies involving chemical, physical, separation, cryogenics, algal and hydrate pathways. The current progress of global CCUS facilities was provided, in addition to highlighting their impediments, such as political, economic, technical and social impediments. The authors also presented climate-positive solutions, such as direct air capture and bioenergy-integrated CCUS technologies.

Given the high global energy use (40%) and carbon footprint (36%) of buildings, a significant amount of research efforts have focused on the energy efficiency improvements of thermal technologies by utilizing advanced control systems and energy management strategies in buildings. In this context, Coraci et al. developed a soft actor–critic agent-based control scheme using deep reinforcement learning (DRL) [6] for improving energy efficiency and reducing temperature violations compared to a baseline control algorithm in a water-based office building heating system. The study also investigated the adaptability and flexibility of the new controller under various deployment scenarios in both static and dynamic environments, and here, the authors identified the potential advantages of the control logic for applications in different climate zones. Similarly, Asfahan et al. developed and reported a deep learning artificial intelligence (AI) model [7] to forecast the thermal performances of three different evaporative air conditioning systems: direct, indirect and Maisotsenko cooling systems. The developed AI model was trained and optimized to achieve a desired learning rate and batch size and agreed well with the performance of the installed systems. The AI model's accuracy and simplicity were shown to be adaptable in any evaporative cooling technology.

The realization of net-zero communities may require energy efficient district heating and cooling technologies, in addition to the adoption of enormous amounts of renewable energy sources, such as solar and geothermal sources, combined with waste heat recovery to enable sector coupling. In this framework, Calise et al.'s study of a heat pump- and PV-supporting energy district's techno-economic performance model [8] offers deep insights into potential approaches for decarbonizing buildings in varied climate zones. The model utilized a solar evacuated collector for domestic hot water, while PV was employed for electric demand, including that of heat pumps. The authors' proposed renewable district was shown to significantly reduce primary energy consumption, while simultaneously lowering carbon emissions.

In conclusion, the Special Issue "Global Building Decarbonization Trends and Strategies" provides an overview of diverse technological developments with a focus on reducing the carbon footprint of the building sector. Another unique aspect of this Special Issue is the engagement of authors from various regions of the world.

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