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Editorial

Low Energy Architecture and Low Carbon Cities: Exploring Links, Scales, and Environmental Impacts

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Abstract: Projected population growth and urbanization rates will create a huge demand for new buildings and put an unprecedented pressure on the natural environment and its limited resources. Architectural design has often focused on passive or low-energy approaches to reduce the energy consumption of buildings but it is evident that a more holistic, whole-life based mindset is imperative. On another scale, the movement for, and global initiatives around, low carbon cities promise to deliver the built environment of tomorrow, in harmony with the natural boundary of our planet, the societal needs of its human habitants, and the required growth for economic prosperity. However, cities are made up of individual buildings and this intimate relationship is often poorly understood and under-researched. This multi-scale problem (materials, buildings, and cities) requires plural, trans-disciplinary, and creative ways to develop a range of viable solutions. The unknown about our built environment is vast: the articles in this special issue aim to contribute to the ongoing global efforts to ensure our built environments will be fit for the challenges of our time.

Keywords: low carbon cities; low energy buildings; sustainability transitions; shelter; building stock; building lifetime; carbon flux

1. Introduction

Projected population growth and urbanization rates will create a huge demand for new buildings [1,2] and put an unprecedented pressure on the natural environment and its limited resources [3,4]. Architectural design has often focused on passive or low-energy approaches to reduce the energy consumption of buildings [5] but it is evident that a more holistic, whole-life based mindset is imperative [6]. On another scale, the movement for, and global initiatives around, low carbon cities promise to deliver the built environment of tomorrow, in harmony with the natural boundary of our planet, the societal needs of its human habitants, and the required growth for economic prosperity. However, cities are made up of individual buildings and this intimate relationship is often poorly understood and under-researched (e.g., [7,8]). UN Secretary-General Ban Ki-moon said "Our struggle for global sustainability will be won or lost in cities." [9]; the scale of the challenge is enormous and at stake is our planet and the very livability of a human existence as we know of it, and as we imagine and hope our lives could, and should, be. Truly understanding the problem is intimately interwoven with a sense of urgency and a great worry. We hope that the contributions in this special issue can go some way towards mitigating the environmental impacts of buildings and cities, advancing the still very limited understanding of our own built environments, and contributing to the global movements for regenerative approaches to the design of buildings and cities in order to protect the life we have on the planet and, if possible, restore the life we have lost.

2. Context

The sustainability of buildings and cities is a long-standing, contentious issue. The movement of the Garden City, for instance, started at the beginning of the previous century and clearly clashed with the over high-rise construction in many parts of the world in the 1950s due to housing shortage [10]. Towards the end of the 20th century, technology and computer modelling pushed strongly towards a positivist paradigm of techno-optimism led to believing the problem had been sorted [11]: we simply needed computer models (and their continuous refinement) in order to simulate, measure, and improve everything. An unrealistic techno-optimism has also been identified as a cause to lack of progress on resource efficiency [12]. This lasts to these very days, with the next big step seemingly being a full integration between Building Information Modelling (BIM) and Geographic Information System (GIS) "for the future development of society, especially in the field of the sustainable built environment" (p. 50) [13]. However, it took nearly 400 years to advance—with pretty simple algebra—Galileo Galilei's square-cube law [14] to discover a dimensionless factor that consistently quantifies the degree of compactness of building forms only as a function of their shape, thus regardless of their size (and volume) [15].

On another scale, the circular economy has emerged as a wholly alternative paradigm to mainstream growth policies. The idea is simple: decoupling economic growth from environmental impacts, but with its 114 definitions (and counting . . .) [16] a widely agreed understanding of what it actually is seems to still be lacking. Also, its materialization is stagnant: while there are significant advances in many sectors, these are often misrepresented or misinterpreted applications of the 3R principle (reduce, reuse, recycle) and the waste hierarchy. The complexity of the built environment further hinders a straightforward applicability of the concept of the circular economy [17], and while it is clear that technological and regulatory development will be needed [18], it is equally clear they will not suffice and need to be complemented by shifts in business models and people's behaviors [19].

Another barrier to a comprehensive understanding and advancement of the sustainability discourse in the built environment is the recurring, and wholly unnecessary, division between embodied and operational energy, CO_2 emissions, and—in general—environmental impacts [20]. Previous beliefs assumed operational energy would be all that matters since buildings have long lifespans. However, with increased energy efficiency and thus a reduction in operational energy demand, the balance is shifting, with embodied carbon quickly rising to dominate the global agenda on how to reduce the climate change impacts of buildings [21,22].

Lastly, a Global North-centric approach may also limit significant sustainability breakthroughs when 7 in 10 urban residents of our urbanized world live in developing countries, with the greatest urban population growth and urbanization expected to take place in Africa, Asia, and Latin America [9]. To this, one should add the increasing trend of worrying figures on global displacement due to natural disasters and human caused conflicts: there were 79.5 million forcibly displaced people worldwide at the end of 2019 (1% of the global population). Approximately 68% of them came from just five countries in the Global South and 73% are hosted by neighboring, likely developing, countries [23]. This South-South migration is often dominated by an urgency that impedes consideration of sustainability, despite refugee camps that are as big as medium-sized cities. As a consequence, our understanding of what actually matters in such contexts from an interdisciplinary sustainability perspective has only just began [24].

3. Content

It would be impossible for any collection of studies to comprehensively address the breadth, depth, and overall research size of the issues presented above. However, the articles in this special issue cover well several key elements that are crucial to foster our understanding of low energy architecture and low carbon cities.

Wang et al. [25] translate China's emission reduction regulations into a contextualized and tailored approach for a specific building type: high-speed railway station buildings in cold climates.

They reconcile the embodied and operational energy and emissions, through life cycle assessment (LCA) which is used in combination with BIM. Their analysis concludes that the ratio between embodied and operational impacts is 1:4, and they identify mitigation strategies that can address both. Space optimization for instance, reduces operational greenhouse gas (GHG) emissions as well as embodied emissions through reduced material demand. The highest reduction strategy, which combines interventions on space, envelope, and materials, shows a 28.2% improvement compared to a baseline scenario, and they also conclude on the important point of implementing measures that focus on space optimization early in the building design stage.

Zhang et al. [26] focus on the multi-scale carbon-carbon dioxide (C-CO_2) dynamics of subtropical urban forests and other green and grey infrastructure in Shanghai, China. Their work measures the C-CO_2 flux from different contributing areas depending on wind direction and atmospheric stability. Although the urban landscape they assessed is a net carbon source, urban forest patches functioned as a carbon sink. Their results aim to establish low-carbon-emitting planning and planting designs in the subtropics. Given China's rapid urban development, embedding green infrastructure in urban planning can represent a significant step forward towards the partial mitigation of impacts caused by urban agglomerates.

China is also the focus of the article by Zhou et al. [27]. They analyze building lifetime and stock turnover as the key determinants in modelling energy demand and emissions of building stocks. To address the data scarcity in official statistics or empirical data, they present a novel system dynamics model that adopts survival analysis to characterize the temporal differences between new construction, aging, and demolition of residential buildings in the Chinese context. The authors cover the entire residential stock of China over 11 years (2007–2017) and find that the average lifetime of urban residential building is around 34 years and that the overall stock size reached 23.7 billion m^2 in 2017. The implications of their results are profound if we reflect on the improvements that could be achieved by extending the service life to meet the full potential offered by materials and construction techniques, which generally goes well beyond a whole century.

China is a top contributor to both global energy demand and GHG emissions, and as such its low-carbon policies will have profound effects on us all. The effects of one such policies, the Low-Carbon Pilot Initiative (LCPI) that was implemented in July 2010, have been scrutinized in detail by Yu et al. [28]. Significantly, the authors moved from previous approaches based on estimates and worked on unified carbon emissions data for 1997–2015 obtained from the China Emission Accounts and Datasets. Their analysis employs a novel synthetic control method to establish the impact of LCPI on regional carbon emissions and uses the Guangdong Province—the largest of China's low-carbon pilot provinces—as a case study. Their results show a 10% abatement of emissions due to the implementation of LCPI, demonstrating the effectiveness of such policy but also warning on the need for continuous adjustments during the implementation.

A regional perspective also characterizes the work by Li et al. [29], who employed Social Network Analysis (SNA) to investigate the spatial correlation network structure of the CO_2 emissions in the Beijing–Tianjin–Hebei urban agglomeration. The authors construct a synergetic abatement effect model to calculate its effect in the cities and examine the influence that spatial network characteristics have on it. They find that Beijing and Tianjin are at the center of the emissions' spatial network, thus playing important roles that can control other carbon emission spillovers between the cities, obtaining a center-periphery structure of their network. This is useful in regional coordinated development, where areas with higher economic growth and lower pollution levels can be regarded as learning examples, and thus lead the way for other regions. Notably, their research shows that it is hard to achieve long-term emission reductions by solely imposing reduction targets in each individual city, whereas establishing a trans-regional emissions reduction coordination mechanism is suggested as the way forward. Similarly to Yu et al. [28], Li et al. [29] also call for a continuous adjustment and optimization of the spatial network structure of the CO_2 emissions.

Shi et al. [30] bring the focus back to cities and offer us a novel, standardized evaluation index system for low-carbon cities in China, applied to Xiamen as a case study. Notably, the authors integrate the perspective from thee index systems—(i) the Drivers, Pressures, State, Impact, Response model of intervention (DPSIR), (ii) a complex ecosystem, and (iii) a carbon source/sink process—to extract common indicators for low-carbon cities. They focus on quantitative input data to remove potential biases introduced by human subjective judgements. In the application to Xiamen as a case study over the 2010–2015 period, their analysis shows that the index of low-carbon development in 2015 was higher than that in 2010, while the rate of economic growth was greater than the growth rate of carbon emission, thus indicating that the relative decoupling of economic growth from carbon emission was to an extent partly achieved.

This concludes the works focused on China covered in our special issue. Such breadth of topics with some very novel contributions is refreshing given the sheer volume of impacts and building stock associated with China. The focus, spanning across different scales of analysis–from individual buildings to the trans-regional dimension of multiple cities–also demonstrates a much-needed multi-disciplinary approach to foster sustainable architectures and urban development.

The remainder of contributions in the special issue address three distinct topics, but the common theme is that none of them focuses on buildings or cities of well-known developed countries. We see this as a strength of the special issue, as seeking contributions from under-researched and underexplored areas has been one of our main objectives since the outset.

Abdullah and Alibaba [31] address the key topic of thermal comfort by focusing on window design and natural ventilation. This is already a crucial element in building design and will become even more important with a growingly warming global climate. Natural ventilation is a well-known passive design strategy that costs nothing but introduces the "indoor air quality-thermal comfort" dilemma, as the authors define it. Their analysis, which is based on computational modelling and simulation, addresses various degrees of window opening as well as different window-to-floor rations. In the Mediterranean climate of Cyprus, they find that unshaded windows under the most effective design and ventilation strategy are able to provide thermally comfortable indoor environment for 50–60% of the occupied hours. In addition to the factual finding, and in concordance with Wang et al. [25], they emphasize the importance of non-siloed sustainability considerations early in the design stage when room for improvement is at its maximum and the impact on costs minimal.

Reus-Netto et al. [32] offer a key contribution to mitigate the lack of utilization of energy rating systems in Latin America. They identify two issues: a lack of building energy efficiency regulations in some countries and an excessive complexity of such ratings or tools—where they do exist—that limits their adoption. To this end, they develop a simplified calculation method to estimate energy consumption of residential buildings. Their model is tested on 42 locations, by considering diverse climatic conditions and the fulfilment of different thermal transmittance requirements. The model offered in the article—which demonstrated a high reliability in a thorough statistical analysis presented by the authors—requires seven climatic characteristics as input data, and within the sociocultural context of Latin America has, according to the authors, more chance of being accepted and applied, thus increasing the rate of buildings with an energy assessment.

We conclude this editorial by presenting the only paper we co-authored in the special issue, in which Alshawawreh et al. [33] qualify the sustainability of novel designs and existing solutions for post-disaster and post-conflict (PDPC) sheltering. In this article the authors show that due to the constrained environment in which PDPC sheltering takes place, sustainability is seldom considered in spite of the severe practical consequences that doing so inflicts, both on people and the environment, as well as incurring higher costs in the long run. Significantly, Alshawawreh et al. [33] systematically categorize both existing solutions and novel designs along key (social, environmental, and economic) sustainability dimensions to identify best practices and learn lessons from what worked in the field and what did not. Each sustainability dimension is extensively discussed and analyzed and the article offers key recommendation for both the design stage and material choices. It is hoped that this work will represent a stepping stone to enable the growth of a new research area, that considers the sustainability of refugee shelters and camps as seriously and as imperatively as the sustainability of the buildings and cities that host us all.

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