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Editorial: Smart and healthy within the two-degree limit

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In the 21st Conference of the Parties (COP21) to the 1992 United Nations Framework Convention on Climate Change (UNFCCC), world leaders negotiated the Paris Agreement on limiting greenhouse gas emissions and holding global warming below 2°C of preindustrial levels, with an effort to limit the increase to 1.5°C. According to the Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C, human-induced warming reached approximately 1°C above pre-industrial levels in 2017 and is expected to increase at 0.2°C per decade. The most challenging and critical goal is to reduce carbon dioxide (CO2) emissions by 45% from 2010 levels and achieve net zero by 2050. There is an urgent need for developing measures that contribute to CO2 reduction and achieve the net zero target.

Our built environment plays an important role in response to the urgent climate crisis. As buildings account for approximately 40% of the global carbon emissions, decarbonisation in the building sector provides an effective way to adapt to the changing climate and, more importantly, mitigate the impacts caused by anthropogenic climate change. Building materials and construction, as well as building operations, are the major sources of carbon emission in the building sector. As the global building stock continues to grow for accommodating the rapidly increasing urban population, we need better solutions for building design, materials use, and operations in order to reduce carbon emission and allow building occupants live healthily under the climate challenges.

In his book *Man, Climate and Architecture*, Givoni gave a comprehensive description of the mechanism of thermal balance of human body, and more importantly, provided understanding of how it is affected by indoor climate and corresponding building design. With the evidence from field data, he argued that building envelope plays a crucial part in regulating the heat reflected or absorbed by building surface while the orientation of buildings influences natural ventilation and thermal load of buildings due to the potential in maximising benefits of prevailing wind and minimising absorption of solar radiation. Fifty years onwards, building design has been advanced to be more climatically sensitive and create more comfortable indoor environment. However, the warming world poses unprecedented challenges to the living quality of the built environment. We urgently need solutions to better prepare for these challenges, leading to more resilient cities and buildings.

The 34th Passive and Low Energy Architecture Conference held in Hong Kong on the 10th to 12th December 2018 (www.plea2018.org). Two hundred and eighty one papers were presented on the theme “Smart and Healthy within the Two-degree Limit”. We have selected sixteen papers delivered at the conference for this special issue. They describe the challenges out built environment encounters in the changing climate. The papers also demonstrate how architectural solutions help buildings and their occupants to mitigate and adapt to the impacts caused by climate change, and hence contribute to the target of net zero carbon emissions. What they address raised the key questions to building design and operations that reduce the emission and the impacts on building occupants. Concurrently, they illustrate exceptional visions and explore opportunities for more sustainable, healthy built environment in the future.

Technological advances in building design for smart and healthy living

Building designers play a crucial role in delivering a healthy built environment through innovative and sustainable design to reduce energy consumption and improve indoor environmental quality. In order to enhance their design, they need scientific evidence to help them adopt the innovative and, more importantly, appropriate approach or make the decisions in their design. Whitman, Prizeman,

Gwilliam, Shea and Walker, in their paper on *Energy retrofit infill panels for historic timber-framed buildings in the UK: Physical test panel monitoring versus hygrothermal simulation*, look to establish how interstitial condensation and increased moisture content within replacement infill panels pose risks on timber-framed buildings and surrounding historic fabric. They compared measurements against hygrothermal simulation using panels mounted between two climate-controlled chambers. The performance of three types of replacement infill panels was evaluated in historic timber-framed buildings in the UK, which clearly indicate the need for incorporating the effect of condensation and moisture content in the selection of the infill panels.

Al-Hassawi shows how hybrid, two-stage passive and hybrid downdraft cooling tower outperforms single-stage tower under hot dry conditions in his paper on *Design and evaluation of passive downdraft cooling systems: outcomes from built prototypes of single stage and hybrid downdraft cooling towers*. The concurrent operation of sensible cooling stage, and evaporative cooling and fan contributed to better performance under all ambient conditions. He also provided an alternative application in order to meet the comfort requirements in hot humid conditions. This study highlights the flexibility of the hybrid cooling tower in accommodating the need in different climatic conditions and makes a strong case for an incentive for designers to incorporate passive downdraft cooling into their design as a viable replacement or supplement to conventional air conditioning.

Life cycle of individual components in buildings has tremendous effect on energy efficiency and operational cost. Vuernoz investigates the thresholds for *Assessing the required life-cycle characteristics of electricity storage for ensuring sustainability in buildings*. His study aims to examine how the operational benefits provided by an energy storage unit in buildings balance the potential impacts of the storage unit. He found that the operating cost could be reduced regardless of the export scheme of energy storage and the continuous reduction of battery costs will increase the economic viability of energy storage in buildings. This allows the implementation of renewable energy harvesting which minimises the life-cycle footprint of the electricity produced.

Ortega Del Rosario, Chen, Bruneau, Nadeau, Sébastien, Jaupard conducted an *Operation assessment of an air-PCM Unit for summer thermal comfort in a naturally ventilated building* in southwestern France. Their study characterises the system behaviour during a typical summer day and evaluates the performance of the system air phase-change-material (PCM) unit coupled with a natural ventilation strategy. PCMs are recognised for their potential of storing and releasing a considerable amount of energy during phase change, compared to the conventional construction materials. Their experiment shows promising results in meeting the cooling needs during summertime by reducing the temperature increase and maintaining the temperature around the thresholds for thermal comfort. The active PCM system provides an alternative cooling strategy for auxiliary cooling without compromising the thermal comfort of building occupants.

Building performance evaluation (BPE) has long been used as a tool for promoting sustainability in housing by adopting quantitative standards like energy performance and carbon emission. Gwilliam and O'Dwyer, in their paper *Delivering Sustainable Design Excellence in Architecture: The Potential Role of Holistic Building Performance Evaluation*, suggested that Architectural Design Excellence (ADE) and Sustainable Performance Excellence (SPE), as two predominant architectural practice paradigms, have distinctive structure, components and procedures in the design processes. They compared these two approaches and argued that, instead of choosing the better approach, integrating their strengths into a new, holistic paradigm, named as Holistic Design Excellence. This will lead to a knowledge-based architectural

profession and develop BPE as an informative tool for the building industry, contributing to more sustainable design to cope with the challenge posed by climate change.

Building façades are the boundary of building envelope where the indoor environment interacts with the outdoors. The design of building façades is therefore of importance in regulating the indoor climate and hence reducing the energy consumption on mechanical means. Goncalves and dos Santos demonstrated the need for different design strategies in response to the complex built environment in their paper on *The thermal performance of compact housing in tall buildings: an analytical examination for the retrofit of façades in the densified city center of São Paulo*. They adopted a parametric approach to evaluate the performance of retrofit façades in dense urban settings in São Paulo. In their study, the variation of solar radiation and natural ventilation was considered and their effect on indoor thermal comfort due to different heights and orientations of urban canyons, as well as the degree of sky obstruction, was investigated. It raised the question about design solutions for façades in different parts of the building.

Yoon, in her paper on *Design-to-fabrication with thermo-responsive shape memory polymer applications for building skins*, examines the possibility of using smart materials in operating shading devices. This study focuses on using temperature as the stimulus to operate the dynamic shading through opening and closing mechanisms. Ponzio, Ricci, Gaspari, Fabbri and Naboni, in their paper on *Exploring the potential of a self-sufficient dynamic façade*, also concern the development of self-sufficient adaptive façades which respond to outdoor thermal conditions, regulate the thermal and visual comfort in the indoor environment, and reduce corresponding energy consumption of the buildings. Their results from four European cities indicated that the self-sufficient adaptive façades are capable of maintaining indoor thermal comfort and particularly efficient in warmer climates. These two studies highlight the benefits of the research-through-design approach in the development and optimisation in architectural applications.

Natural ventilation is vital to the health and well-being of building occupants as it provides fresh air, removes air pollutants, improves thermal comfort, and hence leads to more liveable buildings. Flow pattern inside buildings is determined by the building layout and its quantification provides insights for building designers to optimise the ventilation in buildings. Mundhe and Damle, in their paper on *A methodology for quantifying flow patterns in a water-table apparatus for naturally ventilated buildings*, developed a new photographic method for quantifying the flow pattern in a water-table apparatus. Using windows for natural ventilation does not only provide a passive, low-cost means of improving comfort but also provides visual and thermal satisfaction for building occupants. They evaluated different configurations of rooms and windows using various ventilation metrics, showing that room configuration is the most critical factor to natural ventilation in the buildings. This new method provides physically realistic results and serves as an alternative tool for examining geometrical configurations during the design stage. It also implies that energy efficient design provides a more sustainable option than energy efficient technology.

The increasing temperature causes tremendous challenges to the comfort and health of building occupants. To maintain a comfortable and healthy living environment becomes the priority of building design. User experience provides invaluable information about the perception of building occupants for building designers to optimise their design. Rijal, Yoshida, Humphreys, Nicol *developed an adaptive thermal comfort model for sustainable housing design in Japan*. With a sample size of near 20,000 responses, they established a domestic adaptive model for highly insulated Japanese dwellings by conducting thermal measurements and a thermal comfort survey. Seasonal variations in comfort temperature imply that occupants are highly adapted to the thermal conditions of the dwellings. Their adaptive model is important for energy conservation and efficiency in domestic dwellings, without compromising the comfort and health of building occupants. Kubota, Sani, Hildebrandt, Surahman conducted a questionnaire survey on *Indoor Air Quality and Health of Occupants in Newly Constructed Apartments in Indonesia*. They found that occupants in the newly constructed apartments suffered from risks of multiple chemical sensitivity (MCS) as concentrations of formaldehyde and total volatile organic compound (TVOC) were higher than

the standards in these units. Their results indicate that higher MCS risks were associated with increased TVOC concentrations. Indoor air quality (IAQ), together with stress level and personal attributes, are influential factors to MCS risk. It raises questions about the health issues as affected by IAQ in different types of dwellings, implying that we need to revisit the design of our cities to reduce the impacts of ambient environmental conditions so as to provide healthy and comfortable indoor environment for urban populations under the changing climate.

Santos and Caldas, in their paper on *Assessing the glare potential of side-lit indoor spaces: A simulation-based approach*, proposed a new simulation-based tool to explore the relationship between glare and vertical illuminance. By adopting the forward ray tracing in daylight simulation, their tool was able to evaluate and glare potential in different spaces and fenestration systems. The indicators they employed in their work were able to assess the visual comfort inside buildings. Rodriguez, Allan and Isoardi pointed out that luminous conditions were closely related to restorative experience and recovery from psychological stress in their paper on *Appraising daylight changes in window views: Systematic procedures for classifying and capturing dynamic outdoor scenes*. Luminous conditions of outdoor view were highly dependent on the dynamic changes in sky conditions and outdoor elements. Their proposed methodology of examining outdoor views using photometric measures provides contextual environmental information for describing and analysing changes in view luminous conditions. These studies reiterate the need for innovative tools to evaluate the indoor environmental quality for more liveable and comfortable environment.

Daylight is regarded as a key component for the design of a human-centred and energy efficient built environment for visual comfort of building occupants. It is also an important resource for creating a health indoor environment. However, there is a deficiency in the knowledge about lighting retrofitting and energy performance evaluation of modern lighting systems, as well as a need for simple methods for daylighting design in the early design stages. Giuliani, Sokol, Lo Verso, Viula, Caffaro, Paule, Diakite and Sutter presented *A study about daylighting knowledge and education in Europe: Results from the first phase of the DAYKE project*. From the survey results, they found that comfort and mood were influenced by the perception of sky conditions and where the respondents were located in the indoor spaces while subjective judgements showed good agreement with objectively measured daylight factor. There were also a wide range of views expressed by different stakeholders, ranging from academia to professionals. They conclude that daylighting design requires a more comprehensive and inter-disciplinary approach to ensure the delivery of good design practices.

Carbon emission is not just an issue for urban areas. Housing in regional context also has large potential in low-carbon living, especially under vastly growing sub-urbanisation. Suburban sprawling is one of the major contributors to carbon emission at regional level. In *RURAL+: The plain, the beautiful, the sustainable in rural housing*, Burford and Robertson argued to rethink current practices that are fragmented in nature, leading to disaggregation between planning approach, carbon abatement, energy efficiency at various scales. Using a conceptual case study in rural housing community in Scotland, they proposed three prototypes of architectural planning for sustainable and low-energy rural housing. Low-carbon and energy self-sufficient housing can stimulate sustainable economic development in rural regions, which provides resilience to the local community and contributes to energy requirements. This raises the need for reconsidering current policies and regulations at national and regional levels. Collo and Yannas carried out a *Contemporary review of housing typologies for Argentina's countryside by Grupo Austral*, which aims to evaluate the design features of houses designed in 1939 using current knowledge and modern simulation tools. They found that the design proposals show extraordinary awareness to the environmental conditions, particularly the thermal performance of the buildings with virtually no overheating. It shows that designers still have plenty to learn from past experience in passive strategies in regional context.

Forward-looking stakeholders and innovative ways to tackle climate change

Nowadays climate-sensitive building design receives wide recognition for its capability of adapting to local climate and contribute to the target of net zero carbon emission. Buildings are designed for "passive survivability" so that they will stay habitable without external power for an extended period. Givoni's work laid down the foundation and inspired numerous designers and researchers in the last five decades. The modern architectural field requires new directions and practical solutions to deal with modern challenges. Each paper in this special issue highlights a current issue we must conquer in order to create a more resilient and sustainable built environment. It also identifies the opportunities for pioneering thinking and emerging new design.

Apparently, the technological advance and design thinking in the architectural field contributing to net zero carbon emission do not only provide solutions for the industry, but also, in a broader sense, affect government policy-making, practical guidance, and people's behaviour and attitude towards energy implications and climate change. Papers in this special issue show visions and demonstrate evidence-based research to combat with future climate change, pursuing a change in practices, markets, and policies.

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