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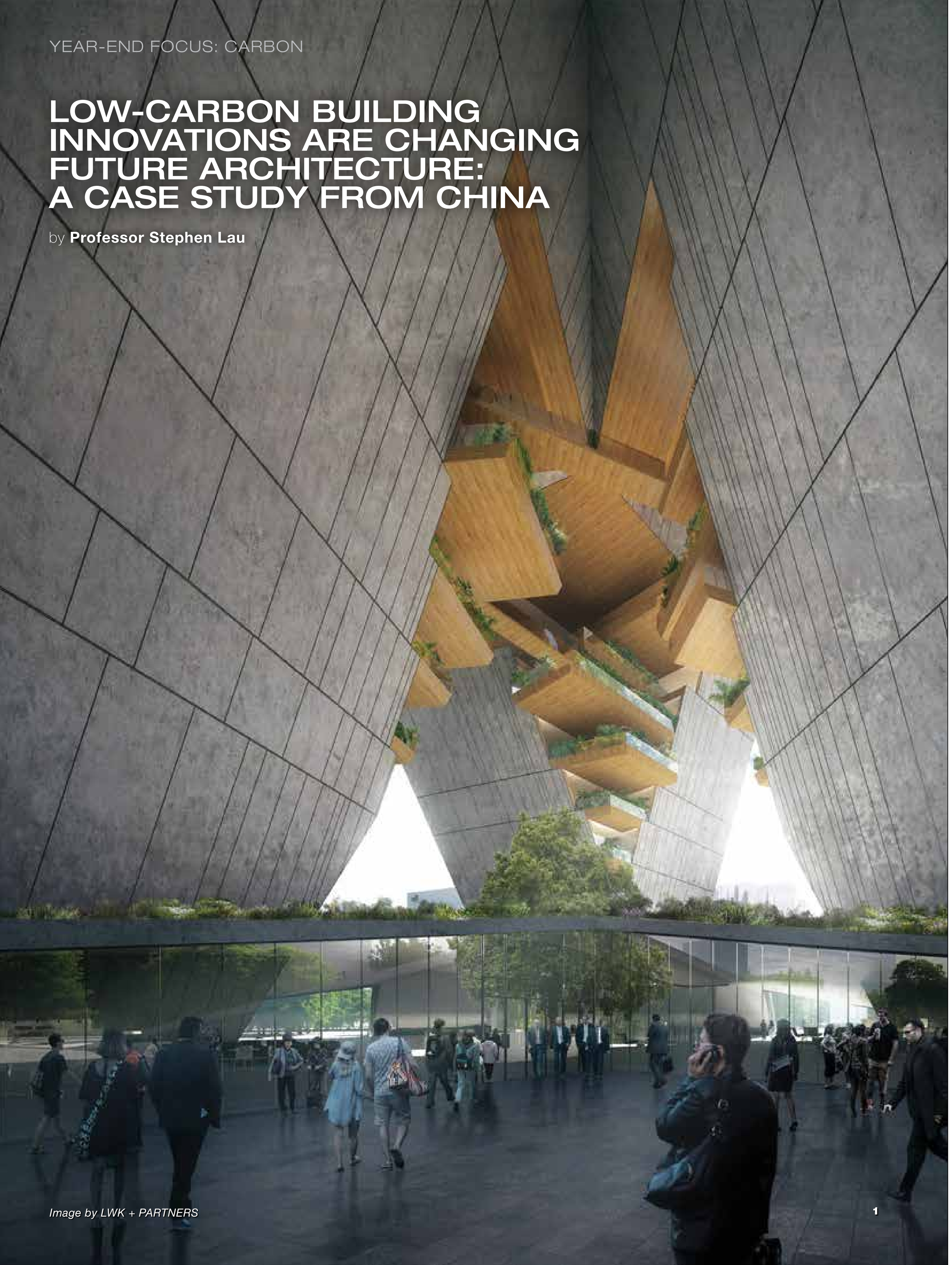
LOW-CARBON BUILDING INNOVATIONS ARE CHANGING FUTURE ARCHITECTURE: A CASE STUDY FROM CHINA

by **Professor Stephen Lau**



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Climate-resilient design as a key tool of passive design needs to reach a higher level to bring down energy demand.

NEW ARCHITECTURAL DESIGN REQUIREMENTS UNDER CARBON NEUTRALITY GOALS

With rapid urban and economic development, energy consumption is increasingly posing threats to the natural environment while the quantity and intensity of energy use in buildings are growing. As the Paris Agreement is leading a global shift towards a Greener economy and setting out the minimum actions required to protect our planet, it is having a huge impact on worldwide political and economic activities. With China's pledge to peak its carbon dioxide (CO_2) emissions by 2030 and achieve carbon neutrality by 2060, carbon has now officially become the world's environmental index. According to the *China Building Energy Consumption Report* published by the China Association of Building Energy Efficiency in 2020, the building sector will be contributing 51.3 per cent of the carbon emissions from industry, building and transportation—the three main sectors in need of Green reform. Therefore, the design, operation, management and use of buildings will directly affect the effectiveness of carbon neutrality efforts in cities. An emphasis on architectural design that can save energy, cut emissions and create carbon sinks is also becoming a preferred strategy for tackling climate change and meeting carbon targets.

This article investigates the aspects of designing zero energy buildings with a case study in China. As Deputy Director of the China Green Building (Hong Kong) Council and Design Research Director leading the Design Research Unit at LWK + PARTNERS, my team and I believe that zero energy buildings are a key means of achieving China's carbon goals and therefore a future market trend. They require a technical approach that prioritises principles in the following sequence: apply passive strategies first before active enhancement; maximise renewable energy use; and a human-oriented post-occupancy evaluation. It aims to ensure healthy building interiors; achieve functionality and efficiency; formulate useful design features; create new low-energy building typologies; improve energy efficiency and smart integration; promote passive design and renewable energy use; and foster better energy-saving performance in buildings.

APPLICATIONS OF LOW-CARBON BUILDING INNOVATIONS

The Carbon-Neutral Building Design project in Guangdong, China is close to transport infrastructure and consists of five large buildings, taking up a site of 80,000 square metres with a maximum building density of 48,000 square metres. During the early design stage, a strength and weakness analysis was conducted on existing solutions, resulting in the decision to integrate the project with low-carbon design. We work closely with the client to evaluate traditional methods and develop better design frameworks. In response to carbon neutrality objectives, it involves a close review of the site, building envelope and roof to inform a low impact development, and low-energy integrated design based on 'passive first' and 'maximising renewable energy' principles. Below details the low-carbon technologies applied by the team.

Building envelope design

The Carbon-Neutral Building Design project is classified under the 'hot summer and warm winter zone B' in the thermal zoning of Chinese buildings, which emphasises natural ventilation, heat insulation and solar shading. According to China's General Principles of Green Factory Assessment and Assessment Standard for Green Buildings, factories are recommended to save materials, energy, water and land; minimise harm; and use renewable energy through the choice of materials, structures and lightings. The thermal insulation performance of the roofs and external walls should also meet requirements stated in the national standard of GB 50176 Thermal Design Code for Civil Buildings. These are why, in addition to maintaining a standard level of insulation of the structures such as focusing on insulating the western side of the building, using materials with lower heat transfer coefficients and applying light-coloured finishes and insulative paints, we propose five key strategies for designing the building envelope:

- Strategy 1: Orient the building to receive more solar radiation
- Strategy 2: Adopt uneven façades to reduce heat transfer
- Strategy 3: Use ventilated façades to improve energy efficiency
- Strategy 4: Adopt intelligent design to optimise energy use and assist with energy management
- Strategy 5: Apply passive design features to save energy

In line with Strategy 2, the Carbon-Neutral Building Design project is slightly slanted and

1 Building form as passive design tool: a central negative space promotes a microclimate in this office building competition proposal, allowing natural light and wind through its core

Post-occupancy evaluation closes the loop by taking into account the experience of real users to inform future design.

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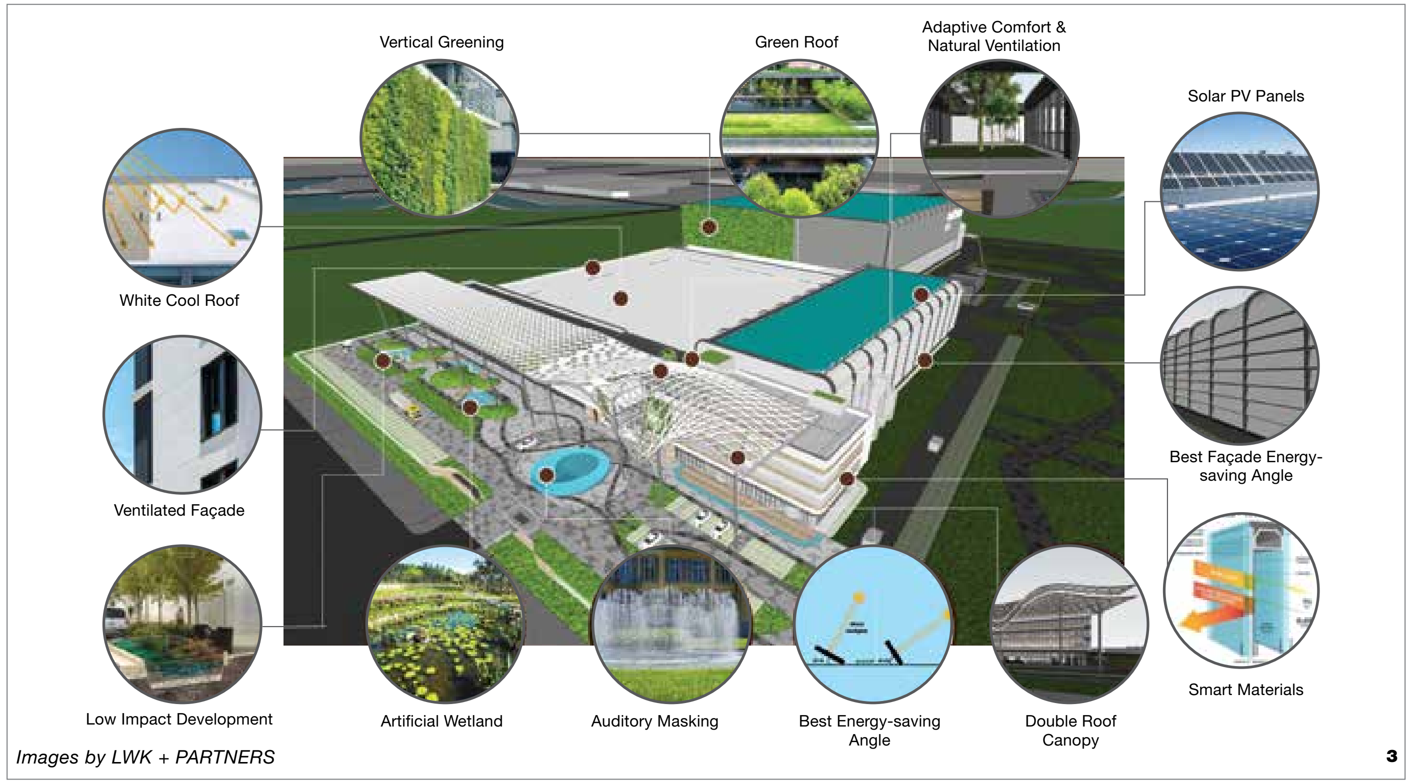

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adopts uneven façades to raise energy efficiency and cut CO_2 emission. For example, on the summer solstice, for the best results in cooling and smoke extraction, horizontal devices along the façade can be adjusted at 28° 27', which is exactly the same as the respective angle of the sun. This setting is recommended to last until 5pm on the day. Under Strategy 3, ventilated façades are designed to form double-layered curtain walls through supporting structures, creating a chimney effect to activate convective air circulation and improve the acoustic and thermal insulation of the building, thus increasing energy efficiency.

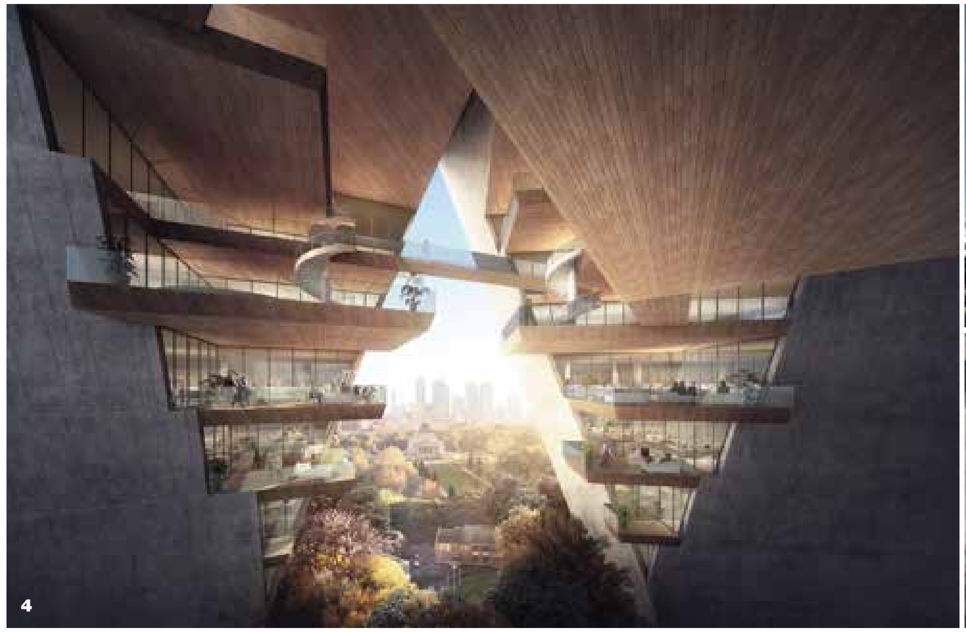
Canopy design

Climate-resilient design as a key tool of passive design needs to reach a higher level to bring down energy demand for heating and air-conditioning in buildings, while giving architects and designers greater opportunities to implement design objectives. Based on climate analysis, the most appropriate passive design strategies are shading, indoor heat gain, natural ventilation for cooling, dehumidification and optimisation of air-conditioning efficiency. These strategies are effective in improving energy efficiency and indoor comfort. The following example from the Carbon-Neutral Building Design project shows how canopy design can facilitate shading.

The project's canopies are designed in response to the angle of the sun's shadow. Considering the canopy's position in relation to the façade, two types of canopies have been adopted. Type 1 canopies are designed to shield building walls, which means they fend off direct exposure to the sun during spring, summer and autumn to minimise the heating or cooling load of the building surfaces. Type 2 refers to canopies over entrances and glass curtain walls. These are spots where people usually gather, so the main consideration is to bring sunlight inside the spaces during winter for lighting and warmth. Combined with calculations of the canopy dimensions and height of the building's southern façade, Type 1 features louvres for shielding radiation when the angle of the sun exceeds 13°. From site analysis of sun paths, we discovered that aluminium louvres can provide good shading from noon to around 5pm. For the canopies to be excluded from plot ratio calculations, they must be at least 80 per cent hollow while the slanting of aluminium louvres must be less than 11.5°. To optimise slanting for shading, the canopy itself must be slanted at 11.5°.

Moreover, we propose to add a second layer of canopy above the first, further shading the roof while squeezing out the heat between the first

2 Canopies at the Carbon-Neutral Building Design project in Guangdong, China improve energy efficiency and indoor comfort by optimising exposure to sunlight **3** Low-carbon features of the Carbon-Neutral Building Design **4 to 6** The same office building competition proposal (as per image 1) provides porous layers of experiential, landscaped spaces around the airy atrium; with shared facilities and communal areas centralised to take advantage of the natural lighting and ventilation; and shading provided over social spaces to enable an open-air experience



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and second canopy layers and the roof, helping to reduce the cooling load on the building space. The double roof structure works with an air chamber to achieve separation, while the layer in between provides additional architectural lighting. If the layers have the same rate of hollowness, this kind of design also provides more shaded areas, creating a sheltered outdoor living space.

Aquatic design and landscape system for low impact development

In terms of climate, the Carbon-Neutral Building Design project sits on subtropical land susceptible to monsoons, humid weathers and generous rain. To reduce water consumption, which indirectly increases carbon emissions, the project contains features that collect rainwater from different sources including the roof, surface run-off and vegetation catchment. Water from initial disposal tends to be cleaner and can be reused for miscellaneous purposes after a simple treatment. It is estimated that reusing rainwater alone can supply 100 per cent of the miscellaneous water use for this project. The area's water supply will mainly serve office buildings, factories, plant watering and road sprinkling.

Referencing local low impact development (LID) requirements, the project also includes a range of other green features. These are often landscape features based on blue-green design principles that aim to promote carbon sinks, water recycling, sponge city concepts, artificial wetland landscapes and water savings. A LID strategy is mainly proposed for the southern side of the site. The first strategy addresses the large volume of rainwater run-off and potential overflow from the project site. This water can be used for a storm water wetland, retained through physical devices, aquatic plants and microorganisms. The wetland can be both an ecological landscape as well as a public space. The second strategy addresses the body of underground still water. Multiple layers of vegetation are used to build a revetment with permeable paving, rain gardens and other measures to create artificial wetlands. This way, rainwater undergoes infiltration, storage, regulation and purification, simulating the natural environment. The stepped arrangement of these semi-natural structures not only meets LID objectives, but also serves a variety of other functional needs.

Photovoltaic (PV) system

Maximising renewable energy entails offseting and balancing a building's energy consumption through the utilisation of renewable energy. In the Carbon-Neutral Building Design project, we make use of the building skin and nearby sources to generate renewable energy. Again, the local climate and angle of the sun were studied. PV simulation software was used to analyse rooftop radiation, optimal tilt angle of the PV panels and distance between the panels to derive the optimal amount of solar power to be generated annually, thereby estimating the reduction in the building's electricity consumption. This is then used to calculate how much electricity-related CO_2 emissions are saved after the use of PV panels.

Information on electricity emission factors was obtained from a report on the average CO_2 emission factors of China's regional and provincial power grids in 2010, published by the Department of Climate Change of the National Development and Reform Commission of China on 11 October 2013, on the China Climate Change Information website. The preset value of the electricity emission factor is 6,379 tonnes of CO_2 per million kWh, according to a carbon dioxide emission information reporting guide for Guangdong enterprises (revised in 2020). By multiplying the amount of PV-generated power and the electricity emission factor, we obtained the amount of carbon emissions saved. In the Carbon-Neutral Building Design project, PV panels are estimated to save approximately 89.3 tonnes of CO_2 emissions per year and will reduce 1,339.6 tonnes of CO_2 emissions over its entire life cycle, assumed to be 15 years.

CONCLUSION AND PROSPECTS

In general, all buildings take more or less the same technical approaches to save energy and reduce emissions. In 2019, China authorities launched the Technical Standard for Nearly Zero Energy Building. For the Carbon-Neutral Building Design project illustrated above, the design strategies mainly centred on 'passive first' and 'maximising renewable energy use' principles. To supplement the three approaches set out by this standard, we propose a fourth element, which is 'human-oriented post-occupancy evaluation'. This closes the loop by taking into account the experience of real users to inform future design and further enhance a building's performance in carbon reduction. We will apply this to the Carbon-Neutral Building Design project throughout the whole building's life cycle, from design to operation, management and use, tracking post-occupancy data through digital platforms. The practice believes that closely monitoring post-occupancy data has an informative effect on a project's carbon emission control, the improvement of user experience as well as construction cost control. In the long term, such data is also key to achieving carbon reduction goals.

Passive design is an effective tool to enhance building form and spatial design while upgrading the energy system. At the same time, low-carbon innovations are vital for integrating renewable energy use in architectural design and capturing human factors through user behaviour. As the threat of climate change looms large, architects and engineers have a leading role to play in China's carbon reduction goals and our future urban development as a whole.

Professor Stephen Lau leads the LWK + PARTNERS Design Research Unit as Design Research Director in its efforts to study the impact of buildings on its occupants and surroundings, focusing on eco-cities to help the practice bring about sustainable development. He is also Deputy Director of the China Green Building (Hong Kong) Council. Professor Lau is Honorary Professor of The University of Hong Kong, Adjunct Professor at Beijing University of Civil Engineering and Architecture, as well as Visiting Professor at Shenzhen University. He oversaw the building technology research and teaching division at the National University of Singapore's Department of Architecture, and served three times as Associate Dean at The University of Hong Kong's Faculty of Architecture.