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China Building Energy and Emission Yearbook 2022

清華大學 Tsinghua University

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Preface

As United Nations Secretary-General António Guterres said: The impact of the coronavirus is both immediate and dreadful. But there is another deep emergency—the planet's unfolding environment. Fulfilling the low-carbon strategy is not only to address the challenge of climate change but also a new mode of the human development under the concept of ecological civilization. Only in this way can we wean the world off its dependence on fossil fuels and achieve sustainable development goals.

In order to achieve the peak carbon dioxide emission and carbon neutrality strategy, many projects are actively promoted nationwide. The ensuing energy revolution will bring great changes to our development, economy, and people's life. It is a great opportunity and challenge for the Chinese people to achieve the goals of this energy revolution while realizing China's national rejuvenation.

Public and commercial building sector is an important battlefield to realize building low-carbon goals. Low-carbon development strategy has proposed many new subjects and new tasks for the development of P&C buildings, which are worthy of research. From the perspective of building energy conservation, we proposed reducing the energy demand by passive design of architecture and improving the efficiency of energy use by active optimization of electromechanical system. Nowadays, a requirement should be added on the basis of the passive design of architecture: how to optimize the building construction to make full use of its own surface resources in the utilization of building photovoltaic, so as to transform the buildings from energy consumers to energy prosumers? For electromechanical systems, there are four requirements: complete electrification to eliminate fossil fuels; improve system efficiency to reduce energy consumption; promote decentralized methods to avoid excess supply; develop flexible power to achieve effective consumption of wind power and solar power. These 2+4 requirements mentioned above are the basic principles for P&C buildings to achieve low-carbon goals. At present, some new technologies based on these basic principles are under research and pilot demonstration.

This publication summarizes and analyzes the current situation of the stock, energy consumption, and carbon emissions of China's public and commercial buildings. It is expected to provide data and references for building and system engineers

and policymakers on the topic of the energy conservation and low-carbon development of China's P&C buildings. At the same time, it is also available for international counterparts to understand the development of P&C buildings in China and jointly promote energy conservation and low-carbon development of the global building sector.

2022 is coming. I hope that, this year, we can all stay away from COVID-19, and the world and China will become better.

Beijing, China Yi Jiang
March 2022

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Building Energy Research Center of Tsinghua University

The Building Energy Research Center (BERC) of Tsinghua University was founded in 2005 by Professor Yi Jiang and his colleagues. The mission of BERC is to be devoted to the development of energy-efficient and environmentally responsible buildings in China in accordance with national and international energy and environmental targets, including buildings research and innovation.

The principal research activities within BERC include:

- Assessment of the current buildings status in China and the provision of strategic outlooks on buildings energy consumption and efficiency.
- Occupant behavior and building simulation research.
- Research and development (R&D) of innovative high-efficiency buildings technology and systems.
- Energy efficiency application research on subsectors, including: space heating in Northern China; rural residential buildings and urban residential buildings; and public and commercial buildings.

Since 2007, BERC has published *Annual Report on China Building Energy Efficiency (in Chinese)*, to provide data references, technical and policy suggestions to policy makers and engineers in the building energy conservation sector. BERC is also involved in international exchange and cooperation, including on-going collaboration with the International Energy Agency.

Executive Summary

Building Construction Speed in China Has Slowed Down

In 2020, China's urbanization rate rise from 37.7% in 2001 to 63.9% in 2020. Rapid urbanization drives the continuous development of the construction sector. From 2014 to 2019, the newly built building stock of civil buildings in China slowly decreased year by year. In 2020, the newly built building stock of civil buildings dropped to 3.8 billion m^2 due to the impact of COVID-19. In 2020, the total building stock in China was about 66 billion m^2, including urban residential buildings accounted for 29.2 billion m^2, rural residential buildings accounted for 22.7 billion m^2, and public and commercial (P&C) buildings accounted for 14 billion m^2. The floor area for northern urban heating was 15.6 billion m^2.

Compared with developed countries, the per capita floor area of residential buildings in China is close to that in developed countries such as the EU and Japan. But the per capita floor area of public and commercial buildings in China is still relatively low. Hospitals, schools, transportation hubs, and service buildings will be the main items for new building construction in the future.

Transformation of Building Construction Mode is Ongoing

Building construction-related embodied energy in China was 0.52 Gtce in 2020, accounting for 10% of China's total energy consumption. The embodied energy uses of urban residential, rural residential, and P&C buildings accounted for 71%, 6%, and 23%, respectively.

In 2020, the total carbon emissions from civil building construction in China was about 1.5 $GtCO_2$, mainly including carbon emissions from manufacturing and transportation of building materials (77%), emission from cement industrial process (20%), and building on-site construction (3%).

The fast pace of urbanization in China drove the demand for building materials. As urbanization and infrastructure development have achieved initial progress in China, the transformation of the construction mode is ongoing. For the next round of urbanization, the demolition of buildings that have not reached the end of life shall be abolished. Technologies to extend the building life cycle shall be invented. Buildings and infrastructures should be properly repaired, and the building life cycle should be extended to facilitate industry transformation and total energy and emission control.

Building Operation Energy and Emission Increasing Steadily

The total commercial energy consumption of building operations was 1.06 Gtce, accounting for 21% of total primary energy consumption in China. Energy use intensity of public and commercial buildings was highest among the four energy use categories and continued to increase.

In 2020, the total carbon emissions during building operations in China was 2.18 billion tCO_2, the carbon emission intensity was 1.5 t/cap and 33 kg/m^2.

Total building energy use and emissions in China are high, but their intensity is still very low. A global comparison of building energy consumption and emissions shows

that China needs to find a unique pathway to achieve sustainable and decarbonized development in the building sector.

The shares of direct carbon emissions, indirect carbon emissions from electricity use, and indirect carbon emissions from heating in total building carbon emissions were 27%, 52%, and 21%, respectively. Direct carbon emissions have already peaked, while indirect emissions from electricity and heating may peak by 2030. Technological innovations and appropriate policy instruments are needed to reach the peak of carbon emissions and carbon neutrality in the building sector. Electrification of energy use in buildings is key to reducing direct emissions in buildings. PEDF (photovoltaic, energy storage, direct current, and flexibility) buildings and a zero-carbon heating system in northern China are critical to reducing indirect emissions from buildings.

Carbon Neutrality Goal Gives Public Building New Role than Energy Saving

Energy use intensity and carbon emission intensity of public and commercial buildings are the highest among civil buildings. To decarbonize public and commercial buildings, passive measures must be taken first to reduce demand and then active measures to optimize efficiency. Passive technologies used in the design and construction of buildings minimize the demands of buildings for cooling, heating, and artificial daylighting. The electromechanical system of each building should follow the principle of "electrification, distributed, high efficiency, and flexible electricity consumption."

The goal of carbon neutrality drives the organic unification of low-carbon and energy-saving public building goals. Energy conservation is an important foundation for achieving the low-carbon goal, while the low-carbon or even zero-carbon goal sets new and higher requirements for building energy conservation in buildings. The new power distribution systems of the PEDF buildings are expected to enable flexible energy use of buildings to better support the whole energy system or even the whole society in achieving the low-carbon target.

Contents