Development situation and analysis of green low carbon buildings in China

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Abstract: In order to study the evaluation system, design methods and management modes of low-carbon buildings were compared and analyzed in China and abroad. Based on that, the deficiencies in the evaluation system, design methods and management modes of low-carbon buildings were produced. The analytical results show that, a diversified system for all classes of town to city should be developed in the evaluation system; the building construction should be optimized and new energy sources, such as: wind, solar, geothermal, nuclear energy, natural gas and coal, should be explored to reduce carbon uses in the design techniques; the promotion of the concept of green low-carbon should be strengthened, economic incentive policies should be implemented, and exchanges of developed countries should be increased in the management model.

1. Introduction

Global warming is an increasingly important issue in contemporary international. In order to respond to climate change and achieve sustainable development, the complete design methods, management models, evaluation systems\(^1\)\(^-\)\(^3\) for green and low-carbon buildings have been established in developed countries such as the United States, France, and the United Kingdom in the past few decades.

The sustainable development of green building design was analyzed and the design cases of the collected green buildings were explained by Zhang Yanling\(^4\); the development status of green buildings was described in China and abroad, based on that, the suggestions on China's green building evaluation system were produced by Zhang Min, Zhang Dingding and Wang Yuanfeng\(^5\); the framework of China's green building evaluation system should be improved from qualitative to quantitative, from standard to refinement, and the third-party certification should be proposed by Chen Liuqin et al\(^6\); the construction of ancient cities were paid attention to rational layout and buildings fusion nature on account of the concept of harmony between man and nature was analyzed by Wang Jun and Zhu Xi\(^7\); combining with the latest national policies, the concept of green construction was elaborated in view of the rapid development of the current economy and the huge demand for the construction industry was produced by Zhang Xiwei, Lin Lin and Wang Jun\(^8\).

Skea Jim\(^9\) pointed out that effective communications between managers and practitioners should be promoted by senior decision makers, and the theoretical research results should be applied to architectural practice to promote the realization of low carbon at the same time in the process of low carbon policy formulation; the low-carbon prospects of China's construction industry were analyzed and predicted on a macro level by Li\(^10\), besides, carbon emissions can be reduced by 100 million tons if appropriate energy conservation measures are taken;

The development process of building energy conservation and green building in China was
reviewed by Qiu Baoxing[11], moreover the development model of China's low-carbon city must start from the green building and low-carbon eco-city construction; the lack of policies, economy and technology in China's low-carbon construction market was pointed out by Zhang Shilian[12]in the stage, which needs a better market operation mode to accelerate its promotion and application; the energy consumption and emissions of buildings from the full life cycle was analyzed by Cai Xiangrong[13], it is pointed out that the energy consumption and carbon daily emissions of buildings in the use and building materials production stage are more than the total emissions, so that energy saving and emission reduction has greater potential; the energy consumption of building features were studied through the building module capacity database by Irene Martini[14]; the key content for evaluation of energy-saving renovation projects have been provided through the intelligent decision-making model by Doukas Haris[15]; the quantitative analysis of carbon emissions from construction and use phases of the building life cycle was concluded and the specific calculation formulas were given through analyzing and synthesizing the vast majority of the literature by Liu Junyi[16].

In the 1990s, China's opening-up has entered a new stage of development: the unprecedented prosperity to the construction industry had been brought by the rapid development of the informatization, industrialization and the construction of new rural areas. However, at the same time, the problems of huge energy consumption and severe environmental pollution are becoming more and more serious. Therefore, we must pay attention to the sustainable development and insist the green low-carbon development path with Chinese characteristics. In the past few decades, the positive momentum from China green low-carbon building design and application has been shown[17-19] under the guidance of international trends and the strong promotion of the Chinese government. Based on the analysis of the connotation of low-carbon buildings, this paper discusses the relevant evaluation systems, design methods and management models in China and abroad. Some good suggestions for the limitations of China's development were put forward.

2. The connotation of green low carbon buildings
   At this stage, there are two processes of the understanding of green and low-carbon buildings in China, such as “process theory” and “goal theory”. That is, the requirements for the planning, design, construction, operation and maintenance of the construction project are separately requested in the whole life cycle of the building. For example, the integrity should be emphasized on the design stage, the surrounding environment should be noticed in the construction phase, resources and energy should be recycled in the operation and maintenance phase, so as to maximize resources, such as: energy saving, land saving, water saving, material saving, protect environment and reduce pollution, and provide people with suitable use of space, that is to say:” four savings and one environmental protection” building.

   Green building is a broader definition than building energy efficiency. It contains the concept of sustainable development. Based on the environmental protection, the essence is saving energy, reducing emissions, and improving the efficiency of resource and energy utilization. At this stage, policies such as “Energy Efficiency Design Standards for Public Buildings” and “Energy Conservation Law” were adopted to improve green energy conservation standards in China. In response to the government's call for the low carbon buildings, technology innovations, inverter air conditioners, drum washing machines and soon have been produced by enterprises. Energy-saving products have become the mainstream. With the in-depth exploration of green buildings and new energy sources, passive buildings have emerged. To sum up, the work in building energy efficiency has made certain achievements in China, which lays the foundation for the future development of green buildings.

3. Development status of green and low carbon buildings
   With the progress of globalization, the understanding of green and low-carbon buildings has been changed. Due to the influence of economic factors, cultural traditions and natural conditions of various regions, cities and countries at different stages, the green buildings have developed distinctive forms.
3.1 Foreign status
The first book on environmental protection in the world, Silent Spring, was launched in 1962; due to the oil crisis broke out, developed countries began to amend building standards in 1970; the building energy efficiency standards were revised in developed countries such as Britain, France, and so on in 1972; the "United Nations Framework Convention on Climate Change" was adopted in 1992; the concept of a low-carbon economy was proposed by the UK in 2003; the "Kyoto Protocol" came into force in 2005; a long-term goal of reducing greenhouse gas emissions by 50% by 2050 has been formulated in 2008; the task of reducing carbon dioxide emissions has become the main theme of the development of the construction industry in 2009; the "Copenhagen Protocol" was enacted in the early 21st century.

| country       | U.S. | U.K. | Sweden | Denmark | Italy | Japan |
|---------------|------|------|--------|---------|-------|-------|
| proportion    | 31.9 | 34.3 | 33.9   | 42.4    | 27.4  | 20.3  |

Building energy consumption in countries around the world is huge (Table 1), which has caused the thinking and yearning for green and low-carbon buildings. In recent years, the field of green and low-carbon buildings has been developed constantly in Europe, however, 20% of the total energy consumption has been unintentionally wasted every year, and this number will increase to 70% in 2030. In this process, global climate and environment are challenged severely. Therefore, based on the realization of "low energy consumption, high comfort", natural energy is being used to its fullest extent, energy and resources waste is being controlled to its' maximize degree, and low-carbon, green sustainable development is being promoted in Europe.

The UK has always been a leader in low-carbon building research. In the 1990s, the "Ecological Housing Evaluation System" has been enacted by the UK, which took the lead in including "carbon emissions". After 20 years of updating, the policy has been improved and a complete evaluation system has been gradually established. In 1997, the "Kyoto Protocol" has been established by the United Nations in Kyoto, Japan. Energy conservation and emission reduction has been promoted in Japan with the goal of stabilizing the greenhouse gas content in the atmosphere at an appropriate level. Furthermore, a plan called "low carbon society" has been proposed. Besides, "3 liters of housing (Figure 1)" have been designed and modified in order to pursue the concept of green environmental protection in Germany, "Atika residential (Figure 2)" has been built in Spain. All of these are the efforts in the development of green and low carbon construction by various countries.

![Figure 1. 3 liters of housing, Germany.](image1)

![Figure 2. Atika residence, Spanish.](image2)

3.2 Domestic status
As shown in Figure 3, the "Eleventh Five-Year Plan" and "Twelfth Five-Year Plan" has been implemented between 2006 and 2015, which has made our green building construction in a period of rapid development. The total output value of the construction industry is increasing year by year. The "13th Five-Year Plan for Energy Saving and Emission Reduction" has been issued by the State Council in January 2017. The main objectives and key tasks of the "13th Five-Year Plan" have been clarified for energy conservation and emission reduction by this program. Building energy conservation has been listed as a key implementation area. The "Proposal" requires that, the proportion of green building area in new building area will be increased to 50% by 2020 firstly. The energy-saving renovation of existing residential buildings should be strengthened secondly. The transformation area of more than 500 million square meters should be implemented thirdly. To sum up, the transformation value of the northern heating area should be completed basically by 2020.

As of the end of 2017, a total of 1021 construction projects have been certified by the China Green Building Mark, including 455 public buildings, 559 residential buildings and 7 industrial buildings. Among these buildings, there are 966 design identification items and only 55 operation identification items. According to the geographical distribution, the top five cities are 95 in Shenzhen, 87 in Suzhou, 85 in Shanghai, 51 in Beijing and 43 in Tianjin. Nanjing and Wuhan tied for the sixth with 31 (Figure 4). The top five provinces are Guangdong, Jiangsu, Shanghai, Beijing and Tianjin. The developed areas in the southeast are far beyond the remote areas of the northwest, and the south is beyond the north.

Based on the above development history and situation in China and abroad, there are also many differences between China and the international community on green building assessment systems, design methods and management models, as shown in Table 2-Table 4:
Table 2. Green building assessment system at home and abroad.

| Evaluation system | Evaluation content | Evaluation method |
|-------------------|--------------------|-------------------|
| BREEAM            | New building, community building, operational building, old building renovation building, ecological, sustainable | Management, comfort, energy consumption, transportation, materials, land, ecology, pollution | $\sum W_i \times \frac{\sum Q_i}{Tot_i}$ |
| CASBEE            | Multi-system CASBEE - home, CASBEE - collection residence, CASBEE - non-residential building, CASBEE - urban development, CASBEE - city | Building life cycle | $SQ = \sum W_i Q_i$, $SLR = \sum W_i LR_j$, $BEE = \frac{SQ}{SLR}$ |
| Green Mark        | New building, existing building, residential building, non-residential building | Energy saving, other green environmental protection | $GM = \sum Q_i$ |
| China green building assessment system | Residential buildings, public buildings | Ecological environment, land, water, energy, materials | $\frac{\sum Q_i}{Tot_i} + C$ |

In which, $Q_i$: Scores for each category of evaluation indicators; $Tot_i$: Total number of evaluation indicators in each category; $W_i$, $W_j$: Weight of each evaluation index; $i$: Land, transport, energy, environment, pollution and other parameters; $LR_j$: Indicators of energy, materials, and building impacts on the environment; $BEE$: The comprehensive evaluation degree of EE's high and low architectural environment; $C$: Innovation indicators.

Table 3. Green building design methods at home and abroad.

| Design method | Main content and features |
|---------------|---------------------------|
| Building performance simulation method based on mathematical model | The calculation results are accurate. According to the characteristics of incomplete information and large variability in the design stage, a simplified mathematical model is established and the computer software platform is used to provide technology for energy saving design. In this way, the performance of building wind, light and heat can be calculated accurately and multiple schemes can be selected comprehensively. |
| Single factor method | Taking the most important factors affecting building carbon emissions as the starting point of the research, the researchers generally recognized that building forms are generated in the mutual adaptation with the external environment under certain technical support. |
| Energy saving strategy | Taking the design strategy as the research object, the methods and strategies of low-carbon energy saving design are summarized and sorted out in detail, so as to establish a complete set of strategies from overall layout to detailed processing. |
| Methods using BIM technology | A virtual model containing all the information of the building is established by using BIM software, which is combined with the energy analysis tool to evaluate the indicators such as carbon footprint, energy consumption and energy balance. It has prominent advantages of fast, real-time and accurate, but the process of input information is relatively complicated. |
| Establishing | A complete set of indicators system has been established to comprehensively and |
evaluation system quantitatively evaluate and control the final results of the building, which is of great significance in guiding practice.

Combined with typological methods It is a research direction worth further exploration to establish the connection between building energy consumption and typology and to study the design requirements of low-carbon energy saving from the perspective of architectural form language.

Table 4. Green building management mode at home and abroad.

| Relevant policy standards | Management mode |
|---------------------------|-----------------|
| US The national energy conservation policy act of the United States(2005) | • First, the government supports the green building industry through legislation.  
• Second, Economic subsidy policies;  
• Third, strongly support the research on green building energy-saving materials;  
• Fourth, Implementation of the assessment standard of "energy star";  
• Fifth, reasonable and effective mass media work;  
• Sixth, Green building assessment system (LEED). |
| UK 《Urban improvement act》 Mid-19th century | • First, Residential energy rating system;  
• Second, tax leverage policy;  
• Third, Standardizing architectural design;  
• Fourth, Energy conservation renovation plan;  
• Fifth, Building environment evaluation system (BREEAM) |
| China 《Green building evaluation standards》 GB/T50375—2006 | • First, government support and nationwide promotion of green building;  
• Second, establish "national green building innovation award";  
• Third, promulgate the "green building evaluation standard";  
• Fourth, establish green building evaluation organization in the country. |

4. China's development problems and analysis

1) Firstly, the concept of green building is unclear. Secondly, the policy is too broad without specific legislation and mandatory regulations. Thirdly, the evaluation system is imperfect. It is found that, base on the "sustainable development", the evaluation system was formulated all over the world at this stage by comparative analysis of the evaluation systems in the United Kingdom, the United States, and China (Table 2).

In terms of content, it generally revolves around the use of land, the recycling of resources, and the creation of a healthy and comfortable environment. In the scope of evaluation, it generally pays attention to the concept of protecting ecology and green energy within the life cycle of the operational phase. The "Green Building Evaluation Standards" has developed evaluation criteria with Chinese characteristics on the basis of the evaluation system of the United Kingdom and the United States. In the analysis process, it finds that understanding of green buildings is divided into two aspects of "process theory" and "goal theory" in China at this stage without combination of two perspectives to see the problem. Besides, the current standard lacks the pluralism of evaluation system like that of the United States, and the evaluation of different situations in different regions is not meticulous enough. We need to work out an evaluation system with strong applicability according to different situations in different regions.

2) The coordination of the system is not in place, and the design method is not comprehensive enough. The characteristics of the various methods have been analyzed in detail by combing the existing low-carbon building design methods (Table 3). At present, the various methods have their own strengths, each has its applicable scope and stage. In the process of application, it is necessary to establish the relationship between building carbon emissions and architectural design techniques by comprehensive scientific and architect's design.

Finally, the internal relationship between energy consumption, carbon emissions and formal operation process is found from the architectural form, so that scientific research and conscious thinking can be perfectly integrated, and a suitable design method can be obtained.
3) Lack of policy incentive mechanism and insufficient government supervision. After a comparative analysis of the green building management system in China and abroad (Table 4), we can find that there are still room for improvement in many aspects of our management model. First of all, the popularity of green ideas is not in place. Some people and evaluators have not understood the "green building" in depth, so that the standards and legislative priorities are biased. As a result, the focus of standard-setting has deviated, which makes it difficult to develop green buildings. So that it is necessary to do a reasonable and effective popularization work. Secondly, the development of green building strategy does not have Chinese characteristics. In 2000s, the construction of green energy-saving in China is at the initial stage. We should not excessively quote the understanding of green building from foreign capitalist system, and work out a green building strategy suitable for our socialist system.

| Month       | Regulations                                      |
|-------------|--------------------------------------------------|
| March 2003  | 《GBCAS》                                         |
| March 2006  | 《the green building assessing standard》           |
| November 2010 | 《Green construction evaluation standards for construction projects》 |
|             | 《Green design code for civil buildings》           |
| October 2014 | 《Green construction evaluation standards for construction projects》 |
| August 201  | 《Green building operation maintenance technical specifications》 |

Finally, our legislative system is insufficient and the progress of industrialization is slow. It can be seen from the comparison of the table (Table 5), the imperfection of the economic incentives for green building industry leading to a lack of interest of people and contractors in green and energy-efficient buildings. In addition, the research on green energy-saving technologies is slow. To sum up, we should combine the conditions of each region to formulate applicable standards and gradually improve our legislative system.

5. Conclusions and recommendations
Green building development is a comprehensive consideration of all-round engineering. It is necessary to make common progress and common development in all aspects in order to better promote sustainable development. Therefore, in accordance with the basic status quo of China, the following suggestions are proposed:

1) The reform of the science and technology management system should be deepened; the allocation of scientific and technological resources should be optimized. The institutional guarantee, policy system, driving mechanism, and market environment that encourage technological innovation should be perfected. At last, the technological achievements should be improved;

2) A good environment for foreign exchanges should be created, exchanges with countries such as the UK, Germany, Japan and other low-carbon buildings with rapid development should be strengthened, the introduction of low-carbon technologies from abroad should be accelerated, and the development of low-carbon construction in China should be promoted;

3) The concept of ecological protection should be advocated and take the road of sustainable development. New energy sources should be explored continuously in order to increase the application of new energy; science and technology design, should be innovated to build smart cities.

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