



Green Building Development in China from the Perspective of Energy Conservation and Emission Reduction and the Corresponding Environmental Protection Measures

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 12-09-2018

Accepted: 11-11-2018

Key Words:

Energy saving
Emission reduction
Green building
Environmental measures

ABSTRACT

Rapid development of the traditional construction industry in China has caused increasingly prominent problems, such as environmental deterioration, resource wastage, and depletion of energy resources. To respond to the country's policy of comprehensive energy saving and emission reduction, the construction industry must pay attention to requirements for environmental friendliness, quality, and energy conservation of buildings despite the pursuit of swift development. Industrialization of green buildings is an essential strategy to ensure energy conservation and emission reduction, and relieve environmental pollution caused by traditional construction activities. To comprehend the development status and problems in China's construction industry, this study reviews successful experiences of developed countries in implementation of green building. Subsequently, problems of the green building industry in China and relevant causes are analysed. Finally, specific environmental protection measures are proposed. Research results demonstrate that the "green building" launched by western developed countries can achieve sound development in China. Problems with the development of China's green building industry are mainly manifested by imbalanced regional development, few green buildings in service, poor capacity building, and insufficient green reconstruction projects. Moreover, green building is difficult to promote in China because of an imperfect legal and regulatory system, a poor market atmosphere, inadequate evaluation of the label management system, and the absence of implicit implementation techniques of a standard system. The proposed suggestions include a reasonable layout of green buildings, strengthening supervision throughout the green construction process, updating the technological standard system, and promoting the concept of green building. Research conclusions provide a theoretical basis for the construction department to understand the status of the green building sector and barriers against its development so that relevant development policies can be implemented.

INTRODUCTION

China's construction industry has achieved accelerating development. The scale of housing construction has been expanding gradually with the continuous progress in modern social and economic development. As shown in Fig. 1, the area of buildings under construction (BUCT) in China is 1,286,803,000 m² in 1997 and grew 10-fold to 12,642,162,700 m² in 2016, showing an annual growth rate of as high as 44%. The traditional construction industry is not only the pillar of the national economy, but also one of the country's top three energy-consuming industries. This industry faces many serious environmental problems, such as high emission, large investment, and heavy pollution. Owing to the improving living standards of citizens, a greater number of people propose increasingly high requirements on living and working buildings. Accordingly, green buildings have become the key in the current construction industry because of its good performance in quality

improvement, energy saving and emission reduction, and environmental protection. Green buildings can guarantee that construction products meet the requirements for environmental protection and quality. Furthermore, the industrialized production of buildings can maximize "scaled" advantages, which can reduce construction costs and shorten the construction period significantly under the premise of high quality. Such advantages are also beneficial for the informatization operation and management in the late period. Thus, China has made great efforts to promote green building to increase energy utilization and reduce the waste production of buildings. These objectives are beneficial for relieving social pressure on natural resources.

STATE OF THE ART

Developed countries began to study green buildings early. Special and perfect green building systems are successfully formulated in many countries in accordance with local practi-

cal situations and characteristics, and they perform well. Existing studies on green building development mainly concentrate on assessment, influencing factors, cost effectiveness, and the environmentally sustainable development of green buildings. Ball (2002) evaluated the sustainable construction development of green buildings in accordance with ISO 14000 standards. Tam et al. (2004) proposed a green-building evaluation system that includes management performance and performance indexes. Olgyay et al. (2004) conducted a validity evaluation of environmental architecture design with consideration of the relief of bearing capacity development; they pointed out that ecosystem service standards could be used to evaluate the sustainability of buildings and proposed effective strategies to reduce the typical environmental influences of buildings. Carter et al. (2008) recommended that the government use a green roof system in the urban watershed and drainage basin with high urbanization level. Ortiz et al. (2009) introduced the concept of life cycle assessment (LCA) and analysed the applications of LCA methods and tools in the construction environment; they concluded that understanding LCA applications was conducive to improving the productivity and competitiveness of medium-sized and small enterprises in the green construction market. Gangolells et al. (2009) stated that construction causes nine types of environmental pollution, such as atmospheric emission, water-based emission, waste production, soil changes, and resource consumption, among others. They also constructed an evaluation system composed of 20 performance indexes. Chan et al. (2009) believes that green building plays a role in promoting sustainability. According to a questionnaire survey and data collection of architectural design in Hong Kong and Singapore, the authors examined the factors in favour of popularity of green building and the barriers against its market development. Alexandre et al. (2011) concluded that approximately 40% of energy supply in Europe was consumed by buildings; this research group also analysed the interaction between the European building standards (EN15251) and energy efficiencies. Marker et al. (2014) factors that influence the barriers and stimuli pertaining to green building development through a questionnaire survey; some proposed measures encouraged construction sector employees to use an environmentally friendly mode of operation. Qiu et al. (2014) emphasized the importance of understanding the diffusion mode of green commercial buildings and key influencing factors of architectural decisions. The diffusion of green building certificates also presented strong spatial correlations. Zuo et al. (2014) considered green building as one of the measures to reduce the influence of building stocks on the environment, society, and economy. Reviewing current studies on the environmental influences of green

buildings, the researchers suggested studying the effects of climatic conditions on the validity of evaluation tools and the verification of real performance and special demands in the future. Akanni et al. (2015) assessed the influences of environmental factors on construction projects in the Niger Delta. Labanca et al. (2015) pointed out an urgent demand for energy efficiency policies to support the architectural construction field. The government or local governments of many European countries needed to strengthen cooperation with banks. Yu et al. (2016) studied the basic building information, living behaviour, indoor heat environment, and family structure in urban areas in cold regions. This research team recognized major influencing factors of energy consumption in existing local buildings, and their conclusions provided references for the green reconstruction of existing buildings. Zhang et al. (2017) argued that buildings might consume abundant energies and resources and significantly influence the environment; the authors pointed out that the problem of facilitating green building development should be solved urgently in China. Additionally, they introduced the latest evaluation standards for green buildings in China, the United Kingdom, and the United States and issued suggestions for perfecting the evaluation standards of green buildings in China. Huo et al. (2018) found that site planning and design (SPD) was the key problem against site sustainability in green building development; the perceptions of respondents regarding SPD in green buildings were also identified through a questionnaire survey and subsequently examined. The concept of green building was proposed by Western developed countries in the 1960s based on the existing associated studies. Such countries have reported abundant studies on the evaluation system for green buildings, key factors on energy consumption of green buildings, and major influencing factors of the industrialization of green buildings, thereby achieving rich results. Most studies confirm that the concept of green building depends highly on government policy guidance. Good national policies may significantly facilitate the development of green buildings. In this study, problems of green building development in China and relevant causes were analysed from the perspective of the country's energy-saving and emission-reduction policy. Some environmental protection measures were proposed to accelerate the ecologicalization and greening of the construction industry in China and realize the harmonious development between this industry and the environment.

PROBLEMS OF GREEN BUILDING DEVELOPMENT IN CHINA

Imbalanced regional development: The overall development of green buildings in China is imbalanced and slow.

Limited by economic development and climatic conditions, green buildings are mainly located in East China, North China, and South China (Fig. 2). Jiangsu, Guangdong, Shandong, Shanghai, and Hebei are top ranked in terms of the number of green buildings. The development level and degree of promotion of green buildings vary significantly in different regions of the same province. Thus, Central China and Western China must coordinate in green building development to prevent polarization that may bring a series of problems.

Few functional green buildings: In China, functional green buildings account for a very small proportion of the total number of buildings, and their performance remains unsatisfactory despite continuous development. Moreover, the national approval standards of green buildings are in conflict with the regional approval standards. Without adequate knowledge of the relevant policies for standardized management and development, construction enterprises would have difficulty solving problems in actual architectural development.

Capacity building requires fortification: The Ministry of Housing and Urban-Rural Development of China published the “13th Five-year Plan for Energy Saving of Buildings and Development of Green Buildings” in March 2017. The policy promotes revolution of energy consumption and production, constructs an ecological civilization, adopts a new urbanization strategy, and implements green development throughout the urban-rural planning and construction management sector. Major contents are listed in Table 1.

However, the construction industry not only causes heavy environmental pollution, but also consumes an abundant amount of energy and resources. The importance of

energy saving and environmental protection is increasingly accepted by people today. Green construction now represents a fast-growing industry. Nevertheless, the development of green buildings must be perfected from design, counselling, evaluation, and management. Most green buildings are designed and perfected by general architects, and few professional designers of green buildings exist. No qualification assessment standards have been formulated yet. Chinese practitioners of green buildings are not experienced due to the short development history of such buildings. Many green buildings are only reconstruction projects accomplished by traditional construction enterprises. On the one hand, the green building market in China is in the beginning stages and the associated certification standards are imperfect. Relevant project leaders are mainly responsible for compiling and organizing application materials, but they hardly participate in green building construction. Therefore, effectively meeting the demands in the construction of green buildings is difficult. Furthermore, the service systems of professional evaluation institutes and counseling institutes are unsatisfactory. Nowadays, the green building industry in China, mainly focuses on the evaluation reports on development from counseling institutes. However, these institutes can hardly propose specific countermeasures to problems that hinder green building development, thereby failing to influence the development of green buildings.

Insufficient green reconstruction projects of existing buildings: Traditional buildings based on the philosophy of architectural development in the past are affected by various problems, such as serious light and noise pollution, waste disposal and landfill issues, and excessive resource consumption. Thus, the green reconstruction of these buildings is extremely important. Governments at all levels in China

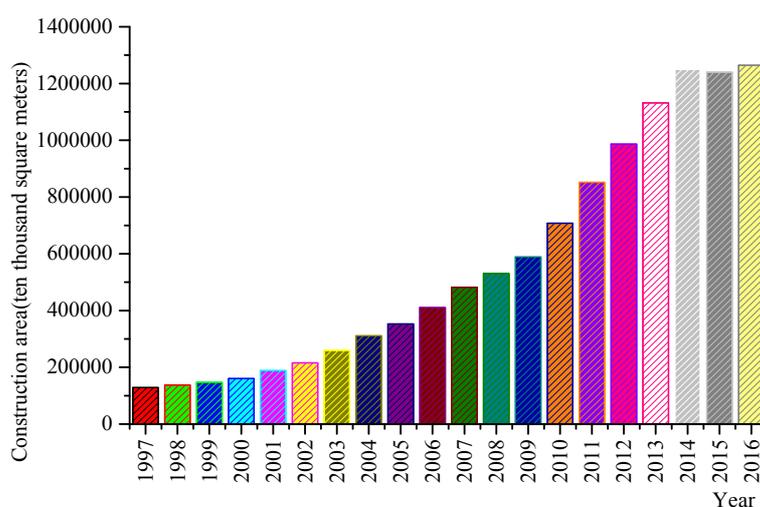


Fig. 1: Area of BUCT in China from 1997 to 2016. [Data source: National Bureau of Statistics of China (<http://data.stats.gov.cn/>)]

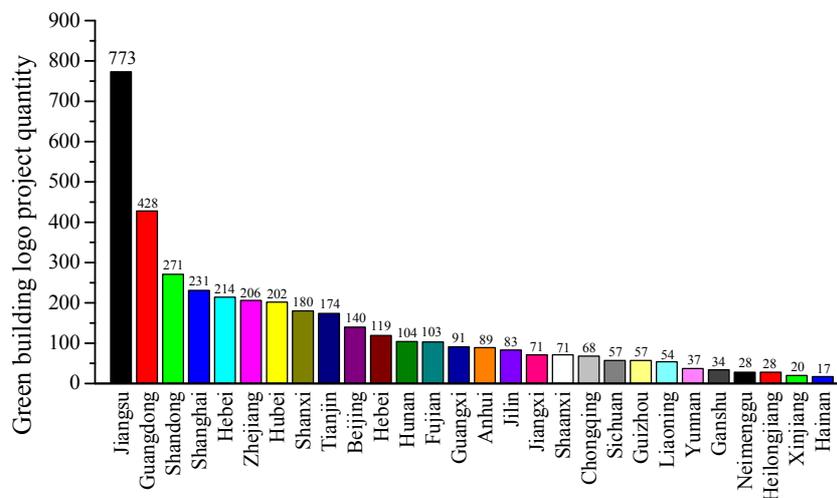


Fig. 2: Number of green buildings in different provinces of China in 2008-2015.
[Data source: Green Buildings in China (Series Report of China Urban Scientific Research), 2017]

must evaluate the reconstruction status effectively and adopt appropriate measures (i.e., energy-saving reconstruction of existing buildings and rehabilitation of shanty towns) in accordance with a strict general survey. These approaches can successfully address the heavy pollution and excessive resource consumption of the construction industry in China.

CAUSES OF DIFFICULT GREEN BUILDING DEVELOPMENT IN CHINA

Imperfect legal and regulatory system: The development of green buildings requires a complete and perfect legal and regulatory system rather than merely depending on modernized construction enterprises. Although China has exerted great effort to promote green buildings in recent years, the specific policy guidance exhibits hysteresis. In particular, local governments with limited economic development (as measured by GDP) are lagging behind in the promotion of practical policies.

Unhealthy market atmosphere: The development and promotion of green buildings require a healthy market atmosphere which, however, remains unavailable. Without a sound development system, any enterprise can develop green buildings only to gain financial rewards for their application. Consequently, the development of green buildings is distorted due to competition among enterprises for resources. Such an unhealthy market atmosphere can easily destroy the intention of green building development to achieve harmonious human and environmental development.

Imperfect management system of evaluation indexes: The development goal of green buildings is to effectively reduce resource consumption, land, material and energy

wastes, and environmental pollution as well as protect the ecological environment throughout the construction process. To achieve these goals, all involved parties should cooperate mutually and the index management system should be perfected. However, the market development is restricted significantly for two reasons. First, the evaluation system for green buildings has no effective and feasible labels. Second, the design label management items are unscientific and inaccurate. Thus, labels are difficult to use completely and may even cause market chaos.

Implicit implementation measures of standard system: The standard system of green buildings is a systematic, complete, and comprehensive system to guide and standardize green building development. Currently, the green building development in China lacks support from a perfect standard system. Some regions may cheat in approval standards to meet the national preference conditions or reward policies for green building development. Consequently, implementation of the same standard system might vary, accompanied by a sharp reduction of the development efficiency. The development standards of green buildings should be coordinated with local characteristics. Nevertheless, many local governments have not formed implementation techniques for the perfect standard system of green buildings.

ENVIRONMENTAL PROTECTION MEASURES OF GREEN BUILDINGS

Reasonable plan layout of green buildings and implementation of corresponding fiscal subsidies: China should release policies on the layout of green buildings, formulate scientific and reasonable top designs, and propose a reasonable goal as well as scientific, reasonable directions. Stand-

Table 1 Major goals of energy-saving buildings and green building development in the 13th Five-year Plan.

No.	Major contents
1	The goal is to complete over 0.5 billion m ² of existing residential building retrofit area.
2	The proportion of green building materials should be higher than 40% of the total.
3	The proportion of green building area in new buildings in urban areas should be higher than 50%.
4	The energy efficiency of new buildings in urban areas should be 20% higher than that in 2015.
5	The proportion of energy-saving buildings in existing residential building in urban areas should be higher than 60%.
6	The energy-saving reconstruction area of public buildings should reach 0.1 billion m ² .
7	The proportion of the replacement of conventional energy resources by clean and renewable energy sources should be higher than 6%.
8	Energy-saving standards in some regions and for key components (e.g., windows) should be close to or reach the international advanced level.
9	New breakthroughs in energy saving of buildings in regions with high economic and social development level as well as key rural areas shall be achieved. The proportion of energy-saving measures should be higher than 10%.

ardized scientific monitoring of green buildings and standardized green reconstruction are needed in the development process. Furthermore, relevant technologies, standards, and strict requirements for the testing of performance, energy consumption, and indoor comfort level of green buildings should be proposed. Relevant policies of fiscal subsidies should be perfected and implemented. Economic subsidies should be increased for projects labelled as “green building design,” “green building completion,” and “green building.” Different economic subsidies should be offered to participating parties in accordance with contributions, including development, construction, and design units; department of property management; and users. The increased cost of development and utilization of green buildings shall be at the expense of the government as much as possible.

Strengthening supervision and management of green buildings in the construction process: Green buildings shall be supervised and managed strictly throughout their entire service life. Approval of designs shall be strengthened and supervision of the actual quality of green buildings during and after the construction process shall be promoted. Suggestions to guarantee the quality of green buildings include supervising the use of green building materials and performance of equipment throughout the construction process, as well as protecting the standardized operation of the green building material market. In addition, China should not only enhance supervision on service conditions of completed green buildings but also offer professional education and guidance regarding unreasonable and nonstandard use behaviours. The central and local governments should set up professional institutes to supervise and manage the implementation of related national mandatory standards and assure the proportion of green buildings in new construction projects. In addition, all technological indexes of green buildings should completely meet the national

evaluation standards of scientific soundness and strictness.

Updating the technological standard system and improving its management: With the rapid development of relevant technologies, new forms of the approval standards for green building have been proposed. Accordingly, the relevant management standards must be further revised and updated, and the relationship between the evaluation standards and design standards of green buildings should be identified to prevent increasing cost to developers and influence developer enthusiasm. At present, green building in China is developing rapidly from key demonstration to comprehensive implementation and from design label to operation management. In the future, energy saving during service is not only a key aspect of the construction industry, but also the core feature for developing the effects of green buildings. Generating energy audit and energy consumption statistics of existing green buildings, and determining the energy consumption baseline based on the collected data on energy consumption are suggested. Energy consumption units are encouraged to adopt relevant energy-saving measures consciously. However, they can choose excessive energy consumption projects freely, assisted by additional energy requirements. These techniques promote the concept of energy-saving construction and reduce energy consumption to below the baseline.

Enhance publicity of low-carbon environmental protection and concept of green buildings: Governments are advised to strengthen subjective units and consumers’ consciousness on green construction, environmental protection, and social responsibility. Social propaganda and education activities related to low-carbon environmental protection should be performed positively and extensively. Energy saving and emission reduction as well as low-carbon environmental protection are the key themes of the current era. Great efforts should be made towards extensive propaganda and education on low-carbon environmental protection,

promoting low-carbon development, and constructing a resource-saving and environmentally friendly society. The government should advocate and practice energy saving and emission reduction in the architectural industry, encourage low-carbon environmental protection, help consumers to set up a new consumption concept and a new lifestyle, decrease carbon emission of buildings, and promote the harmonious development between humans and nature. Large-scale green buildings are conducive to communication and education activities in energy saving and emission reduction. Attention should be paid to propaganda and education for relevant employees to achieve popular support for green buildings.

CONCLUSIONS

The construction industry is one of the major energy-consuming industries in China. Production, utilization, and vast amounts of building material waste all cause certain pressures on China's sustainable development of environmental protection and energy resources. Comprehensive promotion of energy-saving construction mode and green buildings can assure sustainable development of the construction industry. In this study, successful experiences of developed countries in the implementation of green buildings were first summarized. Then, problems and causes of green building development in China were analysed. Finally, specific environmental protection measures were proposed. Research results demonstrate that green building construction has achieved adequate development in China. However, numerous problems are encountered, such as imbalanced regional development, few functional green structures, poor capacity building, and limited green reconstruction projects. Moreover, green building is difficult to promote in China because of an imperfect legal and regulatory system, a poor market atmosphere, imperfect evaluation of the label management system, and inadequate implementation of quality standards. Thus, further studies on green buildings from the perspectives of influencing factors of energy saving, environmental risk evaluation, stimulus strategies based on game theory, environmental benefit analysis, and environmental protection evaluation index are necessary.

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