Vol. 14, No. 2
2023

Ecological Safety and Balanced Use of Resources

Journal homepage: https://esbur.com.ua/en

Received: 05.06.2023. Revised: 30.08.2023. Accepted: 01.12.2023

UDC 332.82:502/504

DOI: 10.69628/esbur/2.2023.86

The industrialisation of green building: Prospects for introducing a cluster approach in the People's Republic of China

Yevheniia Savchuk*

Senior Lecturer
Odesa National Maritime University
65029, 34 Mechnikov Str., Odesa, Ukraine
https://orcid.org/0000-0002-4108-666X

Abstract. Green building is a way for the resource-intensive construction industry to transition to sustainability in the context of declining non-renewable resources, climate change and a growing global population. For China, which has a large construction market, the transformation of the construction industry according to modern trends that encompass environmental impact, economic and social development is particularly relevant. The purpose of this study was to provide an overview of the features of green building and to demonstrate the specific features of its development in China. The research used empirical and theoretical research methods such as abstraction, induction and deduction, analysis and synthesis, which made it possible to characterise green building technologies in China and the environmental impact of different types of building materials on improving human welfare and the environment condition. The description of empirical information regarding green building and its primary analysis (from theoretical understanding of the issue to the presentation of green building as a coherent object of study) in the context of global development trends is based on the material that included scientific research, scientific and bibliographic reviews of the literature, documents and reports of international organisations highlighting key elements of green building development. It has been identified that over the past decade, sustainable development and green building have been in the focus of attention of the Chinese state, helping to accelerate its development, but at the same time establishing specific barriers due to the high level of centralised decision-making. The results of the study provide a comprehensive overview of the development of the green building, its place in global development trends, and the inherent features that use the cluster approach in this innovative segment of China's development. In practice, the study outcomes can assist other countries in making decisions on green building matters by adopting China's innovative practices

Keywords: green architecture; environmental impact; eco-friendly building materials; ecological standards; sustainable development

Introduction

Countries worldwide are working towards implementing Agenda 21 to achieve sustainable development. This involves maintaining a state of balance between society, the environment, and other areas to ensure the preservation and reproduction of all components in a healthy state for future generations. Agenda 21 includes a dedicated section on sustainable development of human settlements. It highlights the need to improve the planning and management of the settlement network, as well as the development of environmental infrastructure within them. The document also acknowledges the construction industry's commitment to sustainable development, which is achieved through the

Suggested Citation: Savchuk, Ye. (2023). The industrialisation of green building: Prospects for introducing a cluster approach in the People's Republic of China. *Ecological Safety and Balanced Use of Resources*, 14(2), 86-96. doi: 10.69628/esbur/2.2023.86.

*Corresponding author

implementation of green building practices (United Nations, 1992). Green building aims to conserve energy and resources, minimize emissions throughout the life cycle of buildings, and promote a healthy coexistence with nature to safeguard human health.

In 2015, the UN updated and extended the list of Sustainable development goals (2015) to 2030. Other international organisations are implementing the sustainable development agenda. For example, the World Trade Report contains a large theoretical section on the evolution of economic models, technology patterns and governance policies (World Trade Organisation, 2020). For example, the main trends identified in the report for the coming years are a new industrial revolution, the development of innovation, the transition to a digital economy and digital supply chain, and sustainable development, which aims to develop ecosystems using modern innovations. Green building embodies all of these modern trends. These documents, which provide a methodological and theoretical basis for scientific research, offer an opportunity to assess the place and importance of green building in the development of society in general and the economy as its material base. From this point of view, the whole range of instruments used, from management decisions to the technical standards adopted, should be evaluated.

Until recently, research in the field of green building has predominantly concerned itself with energy and resource conservation. X. Zhao *et al.* (2018) delved into this topic by conducting a comprehensive bibliometric review of studies in the domain of green building from 2000 to 2016. Their findings highlight a strong emphasis on economics and ecology, suggesting that these dimensions have been central to the research agenda in this field. Few authors, such as A. Ragheb *et al.* (2016), have explored construction and architecture from the perspective of sustainable development, not only its environmental but also social aspects. In their study, they examined the concept of green architecture in the context of sustainable development, offering insights into how environmentally conscious building practices can also contribute to positive social outcomes.

Scholars such as M.J. Zenglein & A. Holzmann (2019), W. Qiao *et al.* (2022) note that the regulatory instruments for green building in China differ from market-based instruments used in other countries in that they are dominated by explicit government regulation. The first group of researchers conducted a comprehensive analysis of China's industrial policy to achieve global technological leadership, while the second group focused on the government-led synergistic development of the green building market in Tianjin. Together, these studies highlight the significant role of government-led initiatives in shaping the green building landscape in China. It is found that by actively promoting and regulating sustainable building practices, the Chinese government has successfully fostered a robust green building industry with potential implications for global sustainability efforts. A group of Chinese scholars, F. Xue *et al.* (2019), conducted a comprehensive study on green building rating systems in China. They explored the new biophilic trend of green buildings, which together with their natural surroundings create a new quality of life. Among Ukrainian researchers, O. Sierikova & S. Ivanov (2023) were interested in green building and its impact on the environment. The study analysed the potential of green buildings to reduce pollution in the ecosystem, including air and water pollution. In addition, the research highlighted the importance of green building in the midst of the COVID-19 pandemic, as it not only provides safe spaces for residents, but can also help protect the human environment from contamination.

As can be seen from these broad scientific and bibliographical reviews, research on green building has mainly examined the characteristics of green building and identified the distinctive aspects that allow green building to be identified as a separate sector of the construction industry. However, there are only a few studies on the development of green buildings in individual countries, describing what the authors consider to be the most striking examples. There is an increasing need to synthesise it and develop a coherent picture of current developments in the building industry. The increased level of generalisation about green building in general, and about a particular country that is experiencing rapid development in all sectors of the economy, such as China, allows a comparison to be made between the processes occurring in the sector in general and in its geographically distinct parts. The aim of this study was to present green building from the perspective of all the components of ecology and sustainable development, as a prospective area for the development of environmental innovation, highlighting its specific characteristics in the Chinese construction market.

Materials and Methods

The material for this study consists of scientific research, bibliographical reviews, documents and reports from international organisations, emphasising the main elements of green architecture. The methodological foundation for the study of green building development is the UN Agenda 21 (United Nations, 1992), the fundamental programme of action to achieve sustainable development, and the World Trade Report 2020 "Government policies to promote innovation in the digital age" (World Trade Organisation, 2020), which presents the theoretical foundations and chronology of the development of technological patterns and prevailing economic models, identifying trends in the world economy for the short and long term.

Based on this, a hypothetico-deductive method was applied in which several empirical studies by other authors on different aspects of green building were evaluated in terms of their relevance to current global environmental trends. In this way, it was possible to demonstrate a growing link between the processes taking place in green building and global trends and the movement of countries towards sustainable development.

Theoretical study of a selected subject involved the use of scientific methods such as analysis, synthesis, abstraction, induction, and deduction. The study collected information on current trends in green building worldwide and in China, regulatory organizations, green building material standards, and the use of natural renewable materials in construction, new architectural and engineering approaches to the construction and operation of buildings and their elements, the ways of recycling construction waste, the increasing responsibility of the constructor for the entire life cycle of the building, the new trend of green building towards saving resources and providing a comfortable living environment for people, educational activities, ways of cooperation between different businesses, municipalities and the population, etc.

The main method of this study was the induction method. The study examined primary international documents, theoretical works and research materials containing primary analysis of selected aspects of green building and its key features, identified through the analytical method and the method of literature review. The use of the induction method is specific to research in the empirical phase: it allowed for an integrated vision of green building, demonstrating the links with the environment in which it exists. This study used descriptions and primary analyses of existing green building practices, management and technologies, as well as barriers to their development, as presented in the reviewed studies and as dominant in the scientific literature.

Results and Discussion

Ecological aspect of sustainable development of the construction industry

Green building was a response to global resource depletion and was designed to conserve valuable resources, as construction is one of the most resource- and energy-intensive industries. The main reasons for its development were therefore economic and environmental. Carbon emissions and the contamination of large areas of land with construction waste are health and environmental hazards. Increased attention to this factor has emerged in the context of accelerating climate change. However, green buildings have also begun to take into account the social factor – both the physical and social health of people, their comfort in the buildings constructed and in the planned landscapes in which these buildings are located. The focus on social and environmental factors is what drives the green building sector to create artificial ecosystems in the urban environment, where people do not lose their connection with nature.

Green building, as a sector of the construction industry, is increasingly responding to the demands of sustainable development in society. It has great potential for development as it responds to the need for a clean environment, including air and water, and contributes to the preservation of health. The resource and energy savings of green building contribute to the economic sustainability of society, while environmental and aesthetic factors contribute to its psychological and social sustainability. In green building, as in other industries seeking to meet sustainability requirements, the product life cycle is an essential category, as the manufacturer is responsible for the product throughout its life cycle until disposal. In the case of green building, builders are responsible for the life cycle of the building, from design to operation and demolition, whereas in today's conventional construction, builders are not responsible for the actual operation, let alone demolition, of the building without negative environmental impact.

Green building has gone through several stages in its development. The first stage is defined by the economy of resources, the development of closed-cycle circuits in construction, and using materials of predominantly inorganic origin. This phase is now in progress in China, which is actively preparing itself for the second phase by studying the experience of countries that started it much earlier. This, first of all, countries such as Japan and Germany, and several other developed EU countries. With Germany, China has several cooperation programmes in this field, with Germany transferring to China technologies that promote energy- and resource-efficient construction and operation of buildings and expertise in project management throughout their lifecycle.

The second stage is based as much as possible on the social needs of the people living in the area and the local natural conditions. This includes minimising the environmental impact of the construction and operation of the buildings, landscaping the buildings both vertically and using green roof technology, and designing the areas around the buildings to be as harmonious as possible with the surrounding nature.

Increased accountability requires new approaches to project management methods as a long-term process involving all stakeholders in discussion and decision making. Conceptually new approaches to building construction and operation in green building require new building standards that address both the construction process of buildings, their ecological and energy efficient operation, and the sustainability of materials. Several such standards, such as LEED (Leadership in Energy and Environmental Design, USA) and BREEAM (Building Research Institute for the Environment, UK) are used in many countries. Several national standards are used by some countries in the region or, as in the case of China, are applied domestically (Zhao *et al.*, 2018).

New construction includes technologies such as prefabrication, where all or most of the elements of a building are designed industrially in-house. This makes it possible to use materials more economically, reduce construction waste, recycle it to develop new materials and structures, speed up the construction process and reduce the size of the building site. The use of information technology makes it possible to design such buildings even for individual projects. There is a growing demand for renewable energy production systems for buildings, air and water treatment equipment, dual water supply, new roofing and green roof materials, etc., all of which contribute to the development and improvement of technologies in construction-related sectors. Materials for green buildings must meet several criteria – they must be non-toxic, low-carbon, easily recyclable and largely made from renewable materials, recycled construction waste, agricultural waste and municipal solid waste: the use of local materials and structural elements from houses destined for demolition is encouraged.

The development of the fifth technological paradigm and the spread of the circular economy model involves the widespread use of green and information technologies in all phases of production processes, thereby increasing productivity and saving resources, and the use of green materials that contribute to a healthier human environment and reduce non-recyclable waste that pollutes the environment for a long time. For China, which has a rapidly growing construction market, all of the above issues are most acute, as the energy consumption of buildings and their emissions into the environment are among the highest in the world. As a result, China has set a course to achieve the country's sustainable development and develop green building as the industry that consumes the most energy and resources and generates the most emissions.

All the features of green buildings are inherent in their Chinese variety. However, China has its own specific characteristics. While in most countries the development of green building is the result of government policies aimed at developing market mechanisms, in China green building has developed as a result of straightforward policies and corresponding government regulations. Green building standards are set by government agencies, which issue certificates of compliance, and the government sets mandatory green building levels for public buildings and often publicly subsidised levels for private construction. The desire to achieve quick, government-set quantitative results often has adverse effects – distortion of the real demand for green projects, as they depend almost entirely on government or government-subsidised demand; ignoring the use factor of buildings by developers; and low quality of design, as designers tend to complete the design process quickly and follow standards, overlooking the factor of the interaction of all building systems to achieve resource and energy efficiency, environmental friendliness and social attractiveness of buildings.

The financial resources invested in the green building sector are mainly used for straightforward government regulation of the industry. Investing in the establishment and development of new market mechanisms could increase the efficiency of green buildings and create more incentives for their development. China, which defines green building as one of the technological breakthroughs, is establishing innovation clusters for its development. In particular, urban clusters and demonstration clusters should be highlighted. Urban clusters, developed in the same administrative way, often group cities with similar problems, making their solutions more difficult. In addition, the fact that the boundaries of such clusters are defined administratively rather than naturally makes it difficult to objectively assess the urban clusters performance. As a positive example of cluster development, there are demonstration clusters, where the process of their creation and operation is more clearly elaborated. They are designed to demonstrate the positive effects of green building in synergy with other sectors and are a powerful source of demonstration to educate society and businesses about the benefits of this approach.

The construction industry is the world's largest consumer of energy and various types of resources, such as ores, timber, etc., and is a major source of emissions to the environment. The United Nations Environment Programme (UNEP) estimates that energy consumption in the building sector accounts for about 30-40% of global energy consumption. The researchers describe various aspects of construction and building performance in China in terms of energy consumption and emissions, and assess the state of construction as follows. The energy consumption of industrial buildings alone accounts for 38% of China's total energy consumption. According to Y. Shen & M. Faure (2021), China is responsible for almost 27% of global carbon dioxide emissions. W. Qiao *et al.* (2022) note the high rate of construction in China – 1.6-2 billion square metres per year – with energy consumption per unit area 2-3 times higher than in several Organisation for Economic Co-operation and Development countries, leading to a strained energy supply situation. In 2018, energy consumption during the construction phase of civil buildings in China accounted for 11% of total energy consumption and 23% during the operation phase. Carbon dioxide emissions during the construction phase amounted to about 1.8 billion tonnes, while carbon dioxide emissions during the lifecycle of buildings amounted to 4.93 billion tonnes, or 51.3% of the country's total carbon dioxide emissions. In a situation of scarce resources, reform and modernisation of the construction industry has become inevitable.

There is a need to explore and establish a sustainable development regime for the construction industry to change the current acute situation of high resource consumption and pollution, and green building can be the solution. The US Environmental Protection Agency (USEPA) defines green building as construction that adheres to the principles of environmental stewardship and resource conservation throughout the life cycle of buildings, from design and construction to operation, maintenance and demolition. China uses a narrow definition that takes into account the vector of China's policy orientation. Green building refers to construction designed to maximise the conservation of resources, including energy, land, water, materials, etc., to protect the environment and reduce pollution, to provide a healthy and efficient living environment for people, and to coexist harmoniously with nature throughout the building's life cycle, which is in line with China's national conditions and the concept of sustainable development. Such an approach aims to minimise harmful effects on human health and the environment.

According to A. Ragheb *et al.* (2016), the main characteristics of green buildings include the use of energy-efficient ventilation, heating and cooling systems, lighting and appliances, water-saving devices; planning the layout of buildings in relation to the landscape to maximise the use of passive solar energy; causing minimal damage to the natural environment; using alternative energy sources, non-toxic natural materials, responsibly collected local materials; adaptive reuse of materials and structures from old buildings; recycling and use of construction waste; efficient space management. Green buildings should be constructed predominantly with green building materials, which are generally produced from renewable resources. The selection of green building materials is therefore guided by criteria such as recyclability and reusability, zero or low air emissions, zero or low toxicity, sustainability and rapid replacement, strength, durability and local production.

H. Wang *et al.* (2018) define green building materials as similar to the above, emphasising their innovative nature, renewable sources of origin and environmentally friendly production and processing processes, which are essential for saving energy and resources in the construction process. They define a green building material as a type of building material whose production involves the use of environmentally friendly technologies, a significant content of recycled industrial, agricultural or municipal solid waste, the full or partial use of natural resources and energy, and a high degree of recyclability, which should contribute to the protection of the environment and human health. Examples of such new green building materials are fibre concrete or plant fibre reinforced concrete and building insulation materials using locally available fibres and other composites from agricultural waste.

In addition, green building technologies (GBTS) have their own specific features designed to improve energy efficiency. GBTS include the installation of solar panels, dual water systems (for clean and service water from rainwater collected on the building itself), heat pumps, the installation of green roofs and walls, and the application of appropriate technologies at all stages of the project. Collaboration between different design disciplines is essential to the development and application of GBTS. It increases the importance of the designer's ability to implement environmentally friendly technologies and to develop an architectural design that is best suited to local conditions.

S. Jones (2021) provides an overview of sustainable green building methods. These include lean construction, the use of diverse designs and information technology, the use of sustainable building materials, new standards and new tools for measuring hydrocarbon emissions. Lean construction involves stakeholders working together to optimise a project and minimise potential damage. The industrial approach (use of prefabricated, modular and industrial structures) in the pre-construction phase makes it possible to use fewer natural resources, reduce pollution and optimise materials management. It determines the environmental and economic benefits.

The use of sustainable building materials requires that they are recyclable, contain recycled content and have a minimal impact on the environment. The study of materials is not limited to their environmental performance, but also includes social aspects that are influenced by companies. Circular or closed-loop construction approaches design and construction to reduce the primary use of resources while increasing their recycling and reuse. Developers can use construction and demolition materials intended for recycling, practise source reduction, recycle to reuse existing materials, and purchase used or recycled materials. The role of the developer is essential in this process.

International green building standards and certification

Two sets of material standards are becoming common: environmental product declarations (EPDs) and a second, more recent set called multi-attribute standards (MAS). An EPD is an assessment of the life cycle of materials. MAS, on the other hand, targets specific material classes and is endorsed by special standards groups. Thus, it is a matter of applying material standards that comply with the requirements of sustainable development – environmental, economic and social.

New tools for carbon reduction have emerged as building materials have a high carbon emission rate, requiring a quick and accurate estimation of their carbon content. The Efficiency Carbon Calculation Calculator (ECC), a free and open-access platform, has proven effective in determining the carbon content and therefore the sustainability of materials. Based on third-party verified EPD data, the ECC tool compares the carbon content of materials, allowing for quick selection of carbon efficient purchases. Information technology, in particular BIM (Building Information Modelling), has been used in sustainable construction. It is mainly concerned with design and pre-construction, but benefits all phases of the project life cycle. Through the accuracy of calculations, 3D modelling and the production of precisely fitting structural elements in industrial pre-construction, material savings are achieved and heat loss during the operation of the building is reduced. BIM processes are therefore efficient in that their implementation almost always reduces the environmental impact of a construction project.

In green construction, the use of green roofs is gaining ground. In general, roofs account for about 20-25% of the total urban area. Green roofs are a natural solution to the environmental problems caused by climate change and rapid urbanisation, providing man-made ecosystem services and having a positive impact on human welfare. According to H. Liu *et al.* (2021), in urban areas, green roofs can mitigate the urban heat island effect, help reduce energy consumption of buildings, regulate rainfall absorption and reduce runoff from roofs, extend the life of roofing materials, improve urban water and air quality, reduce noise, enhance urban biodiversity and harmonise urban landscapes. Assessing the economic impact of green roofs on building maintenance, they estimate that green roofs can reduce maintenance costs by between 60% and 100%, based on one parameter of stormwater runoff alone. Future research, they believe, should focus on low-cost and ingenious green roof designs, taking into account climatic conditions and realising environmental, social, economic and other benefits, while striking a balance between costs and results.

Green building management uses the Green Globes™ system, which includes an assessment protocol, rating system and guidelines for applying sustainable design to commercial buildings (What is sustainable..., n.d.). Other well-known standard systems for assessing green building projects are listed in Table 1. All of these systems are designed to assess a building's compliance with green standards and issue a certificate. All of these systems are designed to assess whether a building meets green standards and issue the appropriate certificate.

Table 1. The most widely used green building standards in the world

System	Origin
LEED (Leadership in Energy and Environmental Design)	USA
Green Mark Scheme	Singapore
CASBEE (Comprehensive Assessment System for the Built Environment Efficiency)	Japan
Building Research Establishment Environmental Assessment Method (BREEAM)	UK
Green Building Council of Australia (GBCA)	Australia
Building Environmental Assessment Method (BEAM)	Hong Kong

Source: made by the author

Green building has expanded the scope of the construction industry by placing new energy, resource, environmental and social demands on it. At the same time, the economic imperative to minimise costs has forced the construction industry to explore new materials, develop new technologies for both the construction and operation of buildings, and develop new conceptual models for buildings that take into account their location. Current green building standards unify the requirements for all its phases and components, allowing them to be manufactured on an industrial scale. In addition, the industry is beginning to adapt to the new demand for buildings. New companies are emerging that focus on the production of green materials, design elements made from natural and recycled materials, and innovative equipment for the maintenance of green buildings. In addition, pre-construction techniques are becoming more widespread, where all the structures of the future building are manufactured in an industrial plant. The use of IT (information technology) in this process allows structures to be manufactured on a project-by-project basis, which is particularly important in green construction in order to maximise the specific characteristics of the future building site. For this process to be successful, the chain from the designer to the manufacturer to the constructor of the building must work harmoniously. This overview shows that the development of green building is pushing the construction and related industries towards higher technological sophistication, higher productivity, new technology chains or natural vertical and horizontal clusters. At the same time, it creates the conditions for a better quality of life for the occupants of green buildings.

Faced with growing environmental problems (water scarcity, air, soil and water pollution, accumulation of solid domestic and industrial waste, resource scarcity) exacerbated by rapid industrialisation, China has, over the past decade, adopted an active policy of sustainable development. The material foundation of this policy is the transition to a "green" economy, i.e. a circular or closed-loop economy that incorporates social and environmental elements into economic processes that cannot always be precisely quantified but that improve the quality of life, including the living environment. The cost of financing China's transition to a green economy is estimated at $19.4 trillion, with an additional financing requirement of $6.4 trillion (Here's how China..., 2018). The main areas of transition include energy and resource conservation, renewable energy generation, a shift to electric transport, recycling and a shift to clean industrial technologies. The development of green building is one of the key areas for building a green economy, as it solves a number of the above issues.

In exploring the history of green building development in modern China, Y. Zhang *et al*. (2018) note that as an economic sector, it has developed relatively recently – after the 2005 Beijing International Conference on Green Building. Since then, green building has been in the spotlight of the Chinese leadership, although it has not always been consistently implemented at the administrative level. In 2016, for example, there was a list of more than 4,500 green building projects, representing more than 500,000,000 m^2 of building space. By 2020, it is expected that 50% of new residential buildings will meet the green building standard. In the "National Medium and Long Term Programme for Science and Technology Development (2006-2020)", the key section "Urbanisation and Urban Development", and "Energy-efficient buildings and green construction" are identified as priorities. In addition, scientists note that the national plans for the 11th and 12th Five-Year Plans set a course for energy conservation and use, considering modern architectural solutions, and identified design and construction with green technologies with responsibility throughout the life cycle of buildings as priority technologies.

New materials manufacturing, relevant to green building development, is named among the top ten priority sectors for development in the Made in China 2025 Programme, with this sector being the fastest growing after the new generation IT sector in China during 2016-2018 (Zenglein & Holzmann, 2019). A special office has been established to manage the assessment and identification of green buildings, the adoption of green building assessments and the management of the assessment and identification of green buildings with one and two stars by government agencies (Zhang *et al*., 2018).

The construction industry is guided in its activities by building standards. Green building as a sector has its own standards, which include environmental and social requirements for all buildings, operational processes and responsibility for them throughout their lifecycle. Examining the implementation of green building standards in China, Y. Shen & M. Faure (2021) note that a green building rating standard has been developed under the leadership of the central government. It has been incorporated into China's national Green Building Energy Label (GBEL). In contrast, the widely used LEED environmental design standard is based on private standards developed in the US. Both LEED and GBEL include basic requirements for energy use, land use, indoor air quality, water and waste management. The original GBEL standard, published in 2006, was quite comprehensive. The later version of the GBEL standard (2019) includes elements such as durability, real-time resource monitoring, building operations, and usability and accessibility for end users during the operational phase.

A peculiarity of using green building standards in China is that the GBEL standard is mandatory for government buildings, but can be used voluntarily in private construction. The LEED standard only applies to private construction in China. China uses the UK's BREEAM certification system, Germany's DGNB (German Sustainable Building Council) and Singapore's Green Mark, but to a much lesser extent than LEED. A total of 19 million square metres of new and existing buildings will be certified by 2020, with the area of certified new green buildings accounting for 2% of all new buildings constructed in China (China green building..., 2021).

In addition, Y. Shen & M. Faure (2021) examine the management and control methods of green building in China, where the main method is explicit government regulation. It determines the peculiarities of its development, with both positive and negative aspects related to government regulation, and therefore requires more detailed consideration. Alongside explicit government regulation, market-based instruments imply financial incentives or disincentives to influence the level of economic activity. These include taxation, subsidies and government support. In addition, persuasion instruments are used, which use information to encourage voluntary compliance and self-regulation in a green building, most often in the form of private certificates. They note that while the use of each of these tools is essential, none of them alone can be sufficient to promote green building due to high up-front costs, lack of reliable information and the influence of private interests. Although green building has been listed as a development priority in Chinese government documents since 2006, its development faces a number of difficulties that researchers have highlighted. Green building still accounts for a minimal proportion (around 1%) of all existing buildings in China. However, priority is given to the rapid construction of new buildings, neglecting the repair and renovation of existing buildings.

China's central government, which plays a leading role in promoting green building, requires all public buildings to be certified as green under China's GBEL system. GBEL is available for certification of residential, commercial and non-residential buildings and can be chosen on a voluntary basis. The number of new green buildings in China is growing rapidly, largely due to policies and regulations that support green building. And while there is a growing number of commercial green building projects using private certificates, the state-owned GBEL still dominates the Chinese market as most laws and regulations refer to GBEL.

The GBEL standards were developed by a government-owned company, and the certification of projects is carried out by a commission linked to the government. Certification to GBEL standards does not always provide a sufficient assessment of a project's green building practices compared to several private standards such as LEED. In addition, the GBEL standards are constantly being updated, which increases the administrative costs of regulating green buildings. The Chinese government encourages the accelerated development of green buildings in a number of ways – through public procurement, subsidies and lax enforcement of laws.

Furthermore, Y. Shen & M. Faure (2021) analysed the positive and negative aspects of each of the instruments used by the Chinese government. For example, government procurement can increase the demand for green building facilities and products in the short term when the state has required all central government agencies to purchase Chinese Eco-Label (CEL) certified building materials. Government subsidies can reduce the up-front cost of green building, thereby providing an incentive for private developers. However, the pursuit of subsidies can create perverse incentives and contribute to increased environmental impacts.

For example, Chinese legislation on green building at the corporate level requires companies to obtain construction permits that include an Environmental Impact Assessment (EIA). China's 2003 EIA law allowed violators to submit an EIA after a project had started. The 2014 Environmental Protection Law abolished post-EIA, but in practice post-EIAs still exist in two of the eight jurisdictions to attract companies that can supplement local tax revenues. However, subsidies and public procurement alone cannot ensure the long-term growth of green buildings without public financial incentives for the market. New green building projects initiated and subsidised by the government do not always reflect the actual demand for these facilities. Some green building complexes become ghost towns and are likely to consume more energy than they save. Too much public spending on green building can crowd out private investment and make the green building market unnecessarily dependent on the state. At the same time, regulatory planning for green buildings encourages more sensible management of urban land and the siting of buildings away from areas of environmental disadvantage.

Sustainable green construction in the Chinese context

Green building is seen as one of the achievements of China's environmental policy. The example of China shows that when green technologies are promoted, construction can be complicated without government intervention (Shen & Faure, 2021). At the same time, the extent of government regulation of green building and private initiative should be balanced. Green building in China has shown that excessive government involvement in the process can lead to negative outcomes, often the opposite of the original purpose, as noted by W. Qiao *et al.* (2022). They suggest that in order to overcome the negative phenomena in green building, it is essential to seek synergies between all stakeholders in the green building market, strengthen market-based influence mechanisms, and explore more efficient methods of public administration tailored to China's specific characteristics. The Chinese government has so far invested a lot of money in subsidies to promote green building, but these often have a short-term effect and create perverse incentives.

For example, the desire to quickly achieve positive externalities in the green building market, and the lack of information for clients about the real state of the market, leads some participants to exaggerate the environmental performance of projects in order to obtain subsidies. Even if developers want to enter the market, they will pay attention to the construction of green spaces and neglect the maintenance during their long life cycle due to high financial costs. Therefore, there is mistrust between developers and consumers, and consumers' willingness to pay is still low (Qiao *et al.*, 2022).

The problems of green building development in China caused by an explicit state regulation are mentioned by W. Wang *et al.* (2018). State management of the green building sector leads to a desire to demonstrate quick external results, regardless of the possible negative consequences of such an approach. In the Chinese green building market, theoretical and scientific research has been emphasised in previous periods, which has allowed some progress to be made. The green outcome and the cost of maintaining the buildings were of interest and value to both the government and society. However, this middle ground between the idea of a "green" building and an understanding of what it should be as an architectural design was ignored by both government and society. This has affected the quality of construction. Research by W. Wang *et al.* (2018) shows that the performance of green buildings is dependent on planning and design. For example, more than 40% of the energy savings of buildings are incorporated at the design stage.

Construction in China prioritises the pace of construction, therefore, designers are always interested in producing a project quickly. They design predominantly to standard, lacking innovation and sufficient environmental support, ignoring the specifics of the area and neglecting the whole process of the building's operation. This leads to an imbalance in the Chinese green building market. In addition, due to the fast pace of work, planners are not eager to learn and master green building design, but rather pay excessive attention to planning results, i.e. quick design production, ignoring planning processes and methods. Due to a lack of awareness of the nature of a green building and its specific design features, there have been cases where green structures and technological equipment have simply been piled into a single project, rather than creating a coherent complex. Providing the wrong incentives and misunderstanding the nature and purpose of a green building leads to the opposite result in terms of additional resource expenditure and increased environmental damage rather than energy and resource savings. Other researchers, such as the author of this article, share this view.

Low levels of governance and lack of transparency in the design, construction and operation of buildings make it difficult to implement truly green building practices. As an industry that highlights both challenges and opportunities in the transition to a new circular economy model, the construction industry and its innovative green building sector face particular barriers to its development. These include high costs for economic actors in the circular economy model compared to conventional models, lack of market incentives and low awareness of green industrial activities (Ogunmakinde, 2019). These barriers are being overcome in many countries through the development of innovation clusters.

Functionally concerning green building in general, the scientific literature distinguishes clusters such as green building technology implementation, material selection, project development, green building project management and the green building itself. The evaluation system can be divided into the technology sector, the management system and the evaluation using cluster analysis, which can be considered as a separate area of green building research. In order to accelerate successful innovative development, many countries encourage the development of various clusters by locating breakthrough points. These include technology parks, industrial clusters and urban clusters. In China, the network of development clusters has grown steadily over the past decade and a half. For example, the first project list of the urbanisation programme in 2005 included 56 enterprises, 13 industrial parks, 7 provinces, 5 cities and 1 town (Ogunmakinde, 2019). Over time, this network has expanded vertically and horizontally, and there has been a conceptual redefinition of the role of clusters in achieving the country's strategic development objectives (Zhanhao, 2022).

Y. Huang *et al.* (2018) in their work explore the development of urban clusters as an essential field of spatial innovation development in China. The 13^{th} Five-Year Plan and the "New National Urbanisation Plan (2014-2020)" have recognised the strategic importance of urban cluster development in achieving China's sustainable development. Urban clusters are becoming the fastest growing and most promising areas for economic development. At the same time, the administrative way in which they are established is developing some complications. They focus on environmental problems, which are exacerbated by the phenomena of similar industrial structure of cluster members, homogeneous competition, homogeneous resource costs and the spread of pollution. At the same time, Y. Huang *et al.* (2018) point out that there is an imbalance between the economic and environmental development of urban clusters. Once several cities form an urban cluster, it becomes crucial for the economic growth of each city in the urban cluster due to human capital accumulation and knowledge diffusion. When analysing the environmental performance of an urban cluster, researchers believe that it is more correct to consider a particular urban cluster as a separate object of study, since both the boundaries and the participants of the urban cluster are defined by the state rather than by an objective assessment. It is difficult to make an objective assessment of the urban cluster, which would not allow the impact of the urban cluster on the environmental performance of its member cities to be assessed. To inform and promote innovation and sustainable development, China has established a network of eco-innovation demonstration parks consisting of technology parks and urban clusters.

Examples of eco-industrial parks in China include Guanzhang National Eco-Innovation Demonstration Park, Nanhai National Eco-Innovation Demonstration Park, Tianjin Economic Development Zone, Suzhou, Sichuan, Tuopai Industrial Eco-Innovation Parks, Xian High Technology Zone and Yantai Eco-Innovation Development Zone. In these eco-innovation parks, waste from one of the participating enterprises serves as a raw material or part of the materials for others. These eco-innovation parks successfully exchange waste, including ash, sludge, plastics, wood and paper. One example is the production of copper from wastewater in the Suzhou park. The Tianjin Economic Development Zone has successfully implemented a symbiotic relationship between companies producing electronics, automobiles, food and biotechnology. In addition, the Xi'an High-Tech Zone has created synergies between automobile manufacturers, cement companies and processors. The issue of greening park areas and the impact of various indicators on ecological diversity in Ukraine has been considered by such scientists as H. Lukashchuk *et al.* (2023).

Several cities and districts, including Shenzhen in Guangdong province, Wuhan, Huashan in Hubei province, Zhenjiang, Guantang in Jiangsu province, Kunming, Chenggong in Yunan province, Sanming in Fujian province and Zhuhai, Hengqin in Guangdong have been identified as low-carbon pilot cities. The purpose of these low-carbon cities was to reduce carbon emissions (e.g. carbon dioxide and methane), collect data on greenhouse gas emissions, and promote green consumption among residents and appropriate management to maintain economic efficiency and economic growth.

For the development of innovative "smart" and "green" technologies, China's "Made in China 2025" programme aims to develop the following industrial clusters: green manufacturing, smart manufacturing, manufacturing and technological innovation, manufacturing and internet integration, and industry leaders (Zenglein & Holzmann, 2019). As the survey shows, cluster development in China is evolving from year to year, encompassing more sectors and areas, and taking on new forms and combinations. All of these processes are aimed at fully transitioning China to a new and innovative economic model and, as far as possible, achieving sustainable development objectives.

An examination of the scientific work on green building shows that the vast majority of it is still at the level of empirical data description and primary analysis of its various aspects. This is a characteristic of the general academic literature on the subject. However, when selected and synthesised, they provide a coherent picture of green buildings and their place in the modern world. Green building has become a fast-growing sector of construction, innovative for the development of the construction industry as a whole. It is in the green building sector that new construction technologies, new materials and new management methods are being tested.

Conclusions

This study covered a wide range of issues related to green building and its specific characteristics in China. Green building is the construction of buildings in an environmentally responsible and resource-efficient manner throughout their lifecycle, minimising their negative impact on human health and the environment. All these trends are designed not only for aesthetic and social aspects, but also as elements of resource conservation in the operation of the building. Non-renewable materials in building structures are gradually being replaced by renewable ones, such as concrete reinforced with plant fibres, which allows the use of local features and the recycling of products or agricultural waste. In addition, the pre-construction sector, which is essential for green building, is developing, using IT technologies along the entire chain from design to structural fabrication and assembly. All this opens up new business opportunities.

Being included later than other industrialised countries in the process of transition to sustainable development with the development of an appropriate model of circular economy, the green economy, as a more extended understanding of it, China concentrates innovative green building technologies primarily in various types of clusters – from industrial to urban and demonstration, which are developed and expanded year after year in China, which is demonstrated by the results of the study. In addition, the study identified several challenges and barriers to the development of green building in China. It has been the focus of Chinese government authorities, which has allowed the legislative and regulatory administrative environment for green buildings to be established and adjusted quickly, financially stimulating its development and preventing green buildings from being located in environmentally disadvantaged areas.

At the same time, over-administration of the sector hinders the implementation of green projects. Encouraging quick results often has short-term effects and can lead to economic and environmental losses in the long term.

The limited use of market mechanisms in the green building sector reduces competition, which affects the quality of construction. In addition, false financial incentives are often created for the rapid construction of buildings, neglecting the whole process of their subsequent use. China is developing rapidly and is quick to learn from and correct its mistakes. Each of the issues discussed in this study could be the subject of separate further research, for example a detailed overview of modern building materials and their classification for green building.

Acknowledgements

None.

Conflict of Interest

None.

References

[1] China green building market snapshot 2020. (2021). Retrieved from https://edgebuildings.com/wp-content/uploads/2022/05/IFC0077-2021-China-Green-Building-Market-Maturity-Sheet_R1.pdf.
[2] Here's how China is going green. (2018). Retrieved from https://www.weforum.org/agenda/2018/04/china-is-going-green-here-s-how.
[3] Huang, Y., Li, L., & Yu, Y. (2018). Does urban cluster promote the increase of urban eco-efficiency? Evidence from Chinese cities. *Journal of Cleaner Production*, 197(1), 957-971. doi: 10.1016/j.jclepro.2018.06.251.
[4] Jones, S. (2021). *Sustainable construction: Why building for a better world is better for business*. Retrieved from https://redshift.autodesk.com/articles/sustainable-construction.
[5] Liu, H., Kong, F., Yin, H., Middel, A., Zheng, X., Huang, J., Xu, H., Wang, D., & Wen, Z. (2021). Impacts of green roofs on water, temperature, and air quality: A bibliometric review. *Building and Environment*, 196, article number 107794. doi: 10.1016/j.buildenv.2021.107794.
[6] Lukashchuk, H., Onufriv, Ia., & Tupis, S. (2023). Green space and planning structure optimisation ways in parks and monuments of landscape architecture. *Architectural Studies*, 9(1), 23-35. doi: 10.56318/as/1.2023.23.
[7] Ogunmakinde, O.E. (2019). A review of circular economy development models in China, Germany and Japan. *Recycling*, 4(3), article number 27. doi: 10.3390/recycling4030027.
[8] Qiao, W., Dong, P., & Ju, Y. (2022). Synergistic development of green building market under government guidance: A case study of Tianjin, China. *Journal of Cleaner Production*, 340, article number 130540. doi: 10.1016/j.jclepro.2022.130540.
[9] Ragheb, A., El-Shimy, H., & Ragheb, G. (2016). Green architecture: A concept of sustainability. *Procedia – Social and Behavioral Sciences*, 216, 778-787. doi: 10.1016/j.sbspro.2015.12.075.
[10] Shen, Y., & Faure, M. (2021). Green building in China. *International Environmental Agreements: Politics, Law and Economics*, 21, 183-199. doi: 10.1007/s10784-020-09495-3.
[11] Sierikova, O., & Ivanov, S. (2023). Green building as a factor of environmental safety of urbanised areas. In *Proceedings of X international scientific and practical conference "Progressive research in the modern world"* (pp. 151-154). Boston: BoScience.
[12] Sustainable development goals. (2015). Retrieved from https://www.un.org/sustainabledevelopment/ru/sustainable-development-goals.
[13] United Nations. (1992). *Agenda 21*. Rio de Janerio: UNCED.
[14] Wang, H., Chiang, P.-C., Cai, Y., Li, C., Wang, X., Chen, T.-L., Wei, S., & Huang, Q. (2018). Application of wall and insulation materials on green building: A review. *Sustainability*, 10(9), article number 3331. doi: 10.3390/su10093331.
[15] Wang, W., Zhang, S., Su, Y., & Deng, X. (2018). Key factors to green building technologies adoption in developing countries: The perspective of Chinese designers. *Sustainability*, 10(11), article number 4135. doi: 10.3390/su10114135.
[16] What is sustainable building? (n.d.). Retrieved from https://www.greenbuildingsolutions.org/what-is-sustainable-building/.
[17] World Trade Organisation. (2020). *World trade report 2020. Government policies to promote innovation in the digital age*. Geneva: WTO Publications.
[18] Xue, F., Lau, S.S.Y., Gou, Z., Song, Y., & Jiang, B. (2019). Incorporating biophilia into green building rating tools for promoting health and wellbeing. *Environmental Impact Assessment Review*, 76, 98-112. doi: 10.1016/j.eiar.2019.02.004.
[19] Zenglein, M.J., & Holzmann, A. (2019). *Evolving made in China 2025: China's industrial policy in the quest for global tech leadership*. Berlin: MERICS.
[20] Zhang, Y., Kang, J., & Jin, H. (2018). A review of green building development in China from the perspective of energy saving. *Energies*, 11(2), article number 334. doi: 10.3390/en11020334.
[21] Zhanhao, L. (2022). Key indicators for assessing the level of technopark development as a national innovation system of China. *International Research Journal*, 120(6), 133-136. doi: 10.23670/IRJ.2022.120.6.117.
[22] Zhao, X., Zuo, J., Wu, G., & Huang, C. (2018). A bibliometric review of green building research 2000-2016. *Architectural Science Review*, 62(1), 74-88. doi: 10.1080/00038628.2018.1485548.

Індустріалізація зеленого будівництва: перспективи впровадження кластерного підходу в Китайській Народній Республіці

Євгенія Вікторівна Савчук

Старший викладач
Одеський національний морський університет
65029, вул. Мечникова, 34, м. Одеса, Україна
https://orcid.org/0000-0002-4108-666X

Анотація. Зелене будівництво – це спосіб переходу ресурсомісткої будівельної індустрії до сталого розвитку в умовах скорочення невідновлюваних ресурсів, зміни клімату та зростання населення планети. Для Китаю, який має великий будівельний ринок, трансформація цієї галузі до сучасних тенденцій, які охоплюють вплив на навколишнє середовище, економічний і соціальний розвиток, є особливо актуальною. Мета цього дослідження полягала в тому, щоб надати огляд особливостей зеленого будівництва й продемонструвати особливості його розвитку в Китаї. У дослідженні використовувалися емпіричні та теоретичні методи дослідження, такі як абстракція, індукція та дедукція, аналіз та синтез, що дали змогу охарактеризувати технології зеленого будівництва в Китаї та екологічний вплив різних типів будівельних матеріалів на покращення життєдіяльності людини та стану довкілля. Опис емпіричної інформації щодо зеленого будівництва та його первинний аналіз (від теоретичного розуміння питання до представлення зеленого будівництва як узгодженого об'єкта дослідження) в контексті глобальних тенденцій розвитку виконано на основі матеріалу, що включав наукові дослідження, науково-бібліографічні огляди літератури та документів, звітів міжнародних організацій, що висвітлюють ключові елементи розвитку зеленого будівництва. Встановлено, що останнє десятиліття сталий розвиток і зелене будівництво були в центрі уваги китайської держави, допомагаючи прискорити її розвиток, але водночас встановлюючи певні перешкоди через високий рівень централізованого прийняття рішень. Результати дослідження дають комплексне уявлення про розвиток зеленого будівництва, його місце в світових тенденціях розвитку та притаманні особливості, що використовують кластерний підхід у цьому інноваційному сегменті розвитку Китаю. На практиці результати дослідження можуть бути використані для прийняття рішень із питань зеленого будівництва іншими країнами, спираючись на інноваційний досвід Китаю

Ключові слова: зелена архітектура; вплив на довкілля; екологічні будівельні матеріали; екологічні стандарти; сталий розвиток