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Research on the high performance building and its application

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Abstract. With the increasingly scarce energy resources on earth and the enhancement of people's awareness of environmental protection, high performance building (HPB) has become a trend pursued by all countries while providing comfortable space for people and protecting good natural environment. This paper discusses the optimal application of HPB in various countries, and analyses its correct application in the face of China's national conditions and its role in improving the value of buildings. Through the research and analysis of relevant literatures, the following important factors of performance building are summarized: integration of urban block resources, building design and construction, evaluation criteria of efficient building, occupant experience, green energy efficiency and sustainability. These factors play a key role in the construction and operation of HPB. On the basis of further shortening the gap between construction and operation and optimizing the standards and performance of HPBs, they not only improve the actual value of the buildings themselves, but also have a positive impact on the natural environment and human health. HPB is an indispensable part of human development and progress in the future.

Keywords: High Performance Building, Green Building, Sustainability.

1. Introduction

With the aggravation of energy consumption and climate change, how to reduce building energy consumption, improve indoor comfort, and minimize environmental pollution has become an important challenge in the global construction field. Within this framework, high performance structures, emerging as a groundbreaking design and research approach, are pivotal for the construction industry's sustainable growth. The concept of high performance building (HPB) is to maximize energy efficiency and indoor environmental quality by optimizing building design, using advanced technologies and materials, and rational use of renewable energy, so as to meet people's needs for building comfort and sustainability, but also to contribute to society and achieve the goal of sustainable development. In this paper, the research status of high efficiency buildings at home and abroad is sorted out and summarized. Through the research and comparison of various countries, the construction and development of HPB in China will be promoted, and the further optimization of HPB in China will be promoted.

2. Research status of HPB in Germany and the United States

2.1. Research on HPB in Germany and the United States

In the 1980s, Germany proposed the "energy transition". In the 21st century, in order to cope with the pressure of energy shortage, aging population and high wages and benefits, Germany has chosen a path

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of sustainable development dominated by scientific and technological innovation [1]. The German Efficient Cities Research Program is an energy research grant program initiated by the German Federal Ministry for Economic Affairs and Energy. The program focuses on energy optimization in urban community renewal, aiming to reduce energy consumption in urban plots by promoting the development of innovative research projects and applying technological innovations to practice [1]. Since the construction of an energy-efficient city block, it is necessary to start from the conceptual design. Therefore, Germany emphasizes the systematic consideration of functional zoning in energy optimization. The high efficiency City Research Plan and high efficiency heating and cooling network research plan are combined to promote the implementation of the plot optimization plan. Efficient Cities research focuses on total energy solutions at the community level. The High Efficiency Heating and Cooling Research Program focuses on the research of municipal supply technologies, as shown in figure 1 [1]. The design process of an efficient urban research project is divided into several stages: strategic planning stage, preliminary planning stage, detailed planning stage, implementation and monitoring stage and demolition stage, as shown in table 1.

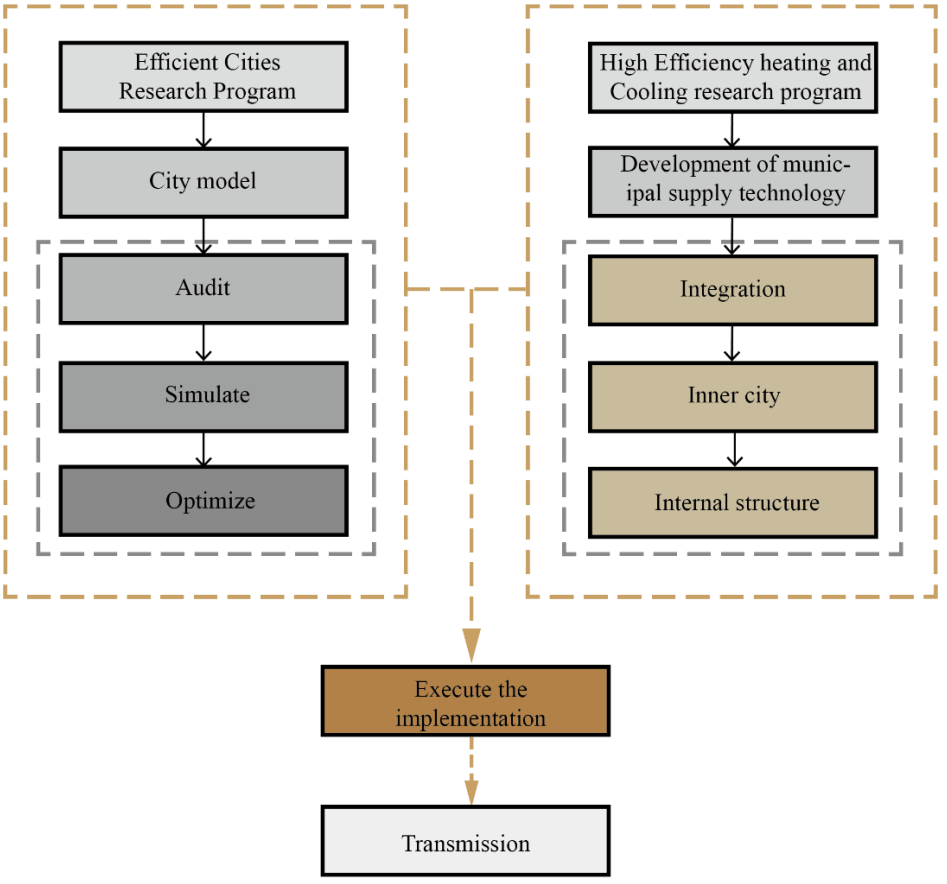

Figure 1. Link chart of funding content of the Efficient City Research Project and the Efficient Heating and Cooling Network Research Project [1].

Table 1. The main task flow table for each phase of the project.

Planning stage	Main task
Strategic planning	Set up working groups, develop ideas, collect data, select planning tools, make remediation agreements, mobilize action, define goals, create communication concepts, and develop strategies

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Table 1. (continued).

Preliminary planning	Financial/cost analysis, collection of inventory data, concepts of selection, risk assessment, selection planning tools, technical research
Detailed planning	Inventory data acquisition, company implementation, legal approval, simulation/optimization, sizing
Implementation and monitoring	Construction management, supervision of project implementation; Maintenance, troubleshooting, evaluation
Demolition	Handling equipment and materials

2.2. Research on HPB in the United States

HPBs in the United States have experienced rapid development and change since the 21st century, from the initial model of mainly commercial buildings to a full range of building types. The United States Congress, the Department of Energy, and the Efficient Building Council are gradually defining standards for efficient buildings. Moreover, the Science and Technology Division of the Department of Homeland Security has partnered with the Department of Energy to establish a unified definition for zero-energy structures by advancing the Owner Performance Requirements instrument and the Enhanced Building Envelope Design initiative. [2]. In 1998, the United States Department of Energy developed a high efficiency commercial building research and development program; From 2005 to 2007, the US Congress passed the Energy Policy Act and the Energy Independence and Security Act to improve the definition of efficient buildings and reduce the energy consumption related to buildings. In the same year, the National Academy of Building Sciences established an Efficient Building Committee to further evaluate the evaluation criteria for efficient buildings. In 2008, the High Efficiency Building Committee presented an assessment to the US Congress and the US Department of Energy on HPBs, elucidating the characteristics of energy-efficient structures. Evaluate the current optimization strategies and appropriate indicators for high performance attributes [3]. In 2011, the Efficient Buildings Council planned the Efficient Standards Matrix, which initially identified four levels of attributes, measures and criteria, from baseline to efficient. In 2014, the National Performance Based Design Guide, NPBDG, published by the Council on Efficient Buildings and the Public Building Services Division of the U.S. General Services Administration, defined four levels of performance. Metrics are provided for overall building commissioning at all stages of design and construction to verify performance objectives.

In the United States, the design approach of the Overall Building Design Guide delineates efficient buildings. Beyond being the premier and exhaustive reference on building design and construction in the nation, the Guide holds paramount significance. Notably, the Committee identifies that a high-performance building "harmonizes and elevates all principal high-performance building features," as accentuated in Section 914 of the Energy Policy Act, detailed in table 2 [2].

Table 2. High performance building features and content.

Features	Content
Cost-effectiveness	Conduct rigorous cost and benefit analysis to account for tangible and intangible benefits throughout the life cycle of high-performance buildings
Security	Property owners have the capability to design and construct buildings that surpass basic life safety benchmarks, catering to distinct mission objectives, property safeguarding, or enhanced building quality standards.
Sustainability	The focus is on comprehensive building design, energy performance optimization, water conservation, indoor environmental quality, material environmental impact, and more.

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Table 2. (continued).

reachability	Throughout the planning, design, construction, operation and maintenance of the building, the barrier-free function is seamlessly integrated with the building
Functionality	Function is also considered a key attribute of a high-performance building, while maintainability represents the building's ability to maintain that function over time
Production efficiency	Enhancing organizational productivity necessitates fostering communication and collaboration, coupled with nurturing individual cognitive growth.
Historical preservation	In the attribute priority of high-performance buildings, the cultural value of important historical buildings should be considered
Aesthetics	High performance architecture is the result of optimizing a series of hard-to-prioritize attributes using limited resources in a given environment, and its aesthetic form comes from an integrated design approach

3. The development of HPB in China

As living standards elevate, there's a marked increase in the energy consumption of buildings. According to research, only 1% of existing buildings in China in 2012 met the green building energy efficiency standards. However, only 5% of new buildings meet the standard, and most of the buildings have a problem of high energy consumption and low energy efficiency [4]. China's energy-saving buildings have not started long, and there are some problems such as low starting point, low level of technology and management, weak innovation ability, insufficient technical input, and insufficient supply of high-quality materials and equipment [4].

Construction enterprises are important subjects to achieve building energy conservation, most of the promotion of exterior wall design, the use of new materials or plants to achieve the effect of shading and heat insulation. Among them, wall greening was used more in early China, because wall greening has high ecological energy efficiency while beautifying the environment, can absorb dirt and dust, reduce temperature and increase humidity, and alleviate urban heat island effect to a large extent. It is an important means to realize green buildings.

An efficient sustainable facade is defined as an exterior shell that minimizes energy usage while ensuring a conducive indoor setting that enhances the well-being and efficiency of its inhabitants. Beyond acting as a mere separator between the interior and exterior, sustainable facades function as architectural systems, crafting pleasant spaces that proactively adapt to the external surroundings of the building and drastically cut down on energy use [5]. Due to the large latitude span of China, which encompasses the cold temperate zone, middle temperate zone, warm temperate zone, subtropical zone, and tropical zone, the technical means of exterior wall design need to be diverse. The exposure to sunlight is also influenced by the building's orientation. Buildings in cold climates can be benefited by the increase in solar heat. On the other hand, in warmer climates, it is necessary to shield interior spaces from direct sunlight for the majority of the year. The orientation of the facade should be taken into account early in the design process due to the significant passive effect of solar orientation. Distinct environmental scenarios and sun exposure necessitate varied facade treatments for north, south, east, and west orientations, as illustrated in table 3 [5].

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Table 3. Strategies for designing facades for different climates [5].

Climate type	Design strategies for sustainable facades
Heating-dominated climates	The collection of solar heat through the building envelope is referred to as solar collection and passive heating. The mass of the walls is used for heat storage in building types that are occupied 24 hours a day. The preservation of heat within the building is achieved through improved insulation
Cooling-dominated climates	The facade can be protected from direct solar radiation through self-shading methods (building form) or shading devices for solar control The use of exterior shading devices and insulation can help reduce external heat gains The use of natural ventilation for cooling is permitted by environmental characteristics and building function
Mixed climates	Solar control involves protecting the facade from direct solar radiation (shading) during warm seasons Solar collection and passive heating are complementary: solar collection during cold seasons

3.1. Occupant experience

As a kind of building form that pursues energy efficiency and sustainability, the design and construction process of high efficiency building should also pay attention to the experience of residents. Enhancing the occupant experience not only increases occupant satisfaction, but also helps to increase the market value of the building.

(1) Providing a comfortable indoor environment

In HPBs, providing a comfortable indoor environment is the key to enhancing the occupant experience. Reasonable design of indoor temperature, humidity and ventilation system, and the use of efficient sound insulation materials to reduce noise impact can improve the comfort and living quality of occupants [6].

(2) Focusing on natural lighting and views

In efficient buildings, a focus on natural lighting and good views can enhance the experience of the occupants. Through rational window design and layout, maximize the use of natural light and provide a good view of the landscape, so that the occupants feel pleasant and comfortable.

(3) Emphasizing social space and healthy lifestyle

Efficient buildings take into account the social needs and healthy lifestyles of their occupants. The design of spacious and comfortable public Spaces encourages interaction and communication between occupants. At the same time, supporting facilities such as fitness facilities, green leisure areas and bicycle parking are provided to promote a healthy lifestyle of residents.

(4) Advocating the concept of sustainability and environmental protection

Efficient buildings should promote the concept of sustainability and environmental protection, which is also an important way to enhance the experience of residents. The use of renewable energy, the use of environmentally friendly materials and the establishment of waste treatment systems can provide a healthy, sustainable and environmentally friendly living environment for residents [6].

4. The inspiration of HPB for the development of Chinese architecture

In order to effectively meet people's demand for a better life, China's newly revised green building evaluation standards take "people-oriented, emphasizing performance and improving quality" as the

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technical route to develop high-performance buildings with healthy, efficient and harmonious environment [7].

It's essential to understand that enhancing the features of a high-performance building doesn't equate to maximizing every single property. Often, these properties can conflict, making it challenging to pinpoint an absolute design solution. Therefore, the development of China's green buildings to high-performance buildings should not only improve the comprehensive participation process of all related disciplines in the whole life cycle from design, construction, maintenance, use to renovation. In order to maximize building performance and benefit, it is necessary to establish the integrated design method and the whole building performance debugging method with performance as the index.

Focus on energy optimization in existing communities. In recent years, China's urban development has gradually begun to transition from incremental expansion to stock renewal. The number of residential buildings in the city in the 1980s accounts for a large proportion of the total existing residential buildings, and the renewal and transformation potential are huge. To optimize community energy from a systematic point of view, it is not only necessary to consider the systematic integration of different energy sources within the community [8]. At the same time, considering the impact of the renovation on the surrounding land, the best combination method is selected to achieve the efficient use of energy. To formulate monitoring and evaluation standards for community energy optimization, the lack of standards is not conducive to encouraging community energy optimization construction work, and is not conducive to summarizing relevant construction experience [9]. Experts and professional advisory bodies can be organized to conduct scientific and standardized monitoring of the actual effectiveness of community renewal through the establishment of evaluation models and data analysis. On this basis, the evaluation standard is set up as the assessment basis for land renewal [10].

5. Conclusion

This paper studies the development and methods of high efficiency buildings in various countries, and draws the following main conclusions:

(1)In the face of national development pressure, Germany put forward the "energy transformation" plan, starting from urban blocks to carry out high performance construction, focusing on functional zoning combined with high performance cooling and heating networks to achieve energy conservation and sustainable development goals. The United States focused on the definition and specification of efficient construction, and gradually improved the attributes and evaluation standards of efficient construction from 1998 to 2014. The commonality of the two countries is detailed in the design and construction of buildings. China is also gradually transitioning from green buildings to HPBs that contribute to the environment and humanity.

(2)The realm of energy-efficient buildings presents certain challenges and issues. Primarily, there's a discernible disparity between the design and actual operation of these structures, which needs bridging to harness the complete potential of the architectural design. Secondly, the cost factor is also one of the difficulties in the promotion and application of efficient buildings, which needs to be solved through technological innovation and policy support. In addition, standards and certification systems for HPBs also need to be further improved to ensure their actual performance and indoor comfort.

(3)The new "Green Building Evaluation Standard" ADAPTS to the changes in national conditions and determines the development direction of green buildings that are people-oriented, emphasize performance, improve quality, and enhance owners' satisfaction. As Building Information Modeling (BIM) technology continues to advance, it now permits the utilization of comprehensive three-dimensional building models in tandem with real-time data and analytical tools. For cost, constructability, manufacturing details, scheduling, energy analysis and many other aspects, can greatly promote the development of the overall building design process of green buildings. The development of codes and standards related to building performance is bound to be further driven by technology as BIM makes it easy to assess building performance and significantly improve the performance level of selected indicators.

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