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SCIENTIFIC RESEARCH ANALYSIS OF THE REGULATORY AND LEGAL FRAMEWORK IN THE FIELD OF GREEN BUILDING TECHNOLOGIES

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The article presents an analysis of international experience in green construction and compares the criteria for assessing international standards LEED, BREEAM, DGNB.

Global climate change is the most severe environmental and development challenge facing the world today and the long-term human beings, and buildings are one of the most important areas for energy conservation, emission reduction and response to climate change. International building energy-saving technologies are progressing very fast, from low-energy buildings to ultra-low-energy buildings to capacity building.

On September 22, 2020, General Secretary Xi Jinping delivered an important speech at the general debate of the 75th United Nations General Assembly, saying that China "strives to peak carbon dioxide emissions in 2030 and achieve carbon neutrality in 2060", while the construction industry is the largest energy source in the country. About one-fifth of the total consumption of "large energy households", greening has become an inevitable trend of its development. According to the United Nations Intergovernmental Panel on Climate Change, the carbon reduction effect of green buildings is the highest of any industry. Under the goal of carbon neutrality, the development of ultra-low energy buildings, near-zero energy buildings and related industries will enter an accelerated period in the next few years.

In 2020, China's building energy consumption reached 1.089 billion tons of coal equivalent, more than three times the 2000 figure. The introduction of energy-saving building design standards and the implementation of energy-saving renovation of existing buildings will save 420 billion kWh of electricity and 260 million tons of conventional coal each year and reduce CO_2 and other greenhouse gas emissions by 846 million tons. Thus, the development of energy efficiency in buildings and green buildings is relevant for China [1].

Green buildings improve the efficiency of building resource utilization, thereby reducing its negative impact on the environment at all stages of its life cycle, laying the foundation for the sustainable development of the human environment, contributing to the sustainable development of human beings, and improving the quality of life of citizens.

Historical aspects of the development of the concept of "green" building.

As early as the 1970s, in the context of the energy crisis, the concept of green buildings appeared. A brief development of green buildings is shown in Figure 1.1 below. In the past few decades, green buildings have grown from developed countries. From the beginning, from the rich expansion of theoretical concepts to the actual practice of projects, green buildings have gradually developed from a single green technology to a single green building and even a green building system. The research coverage of factors is also becoming more and more extensive [2].

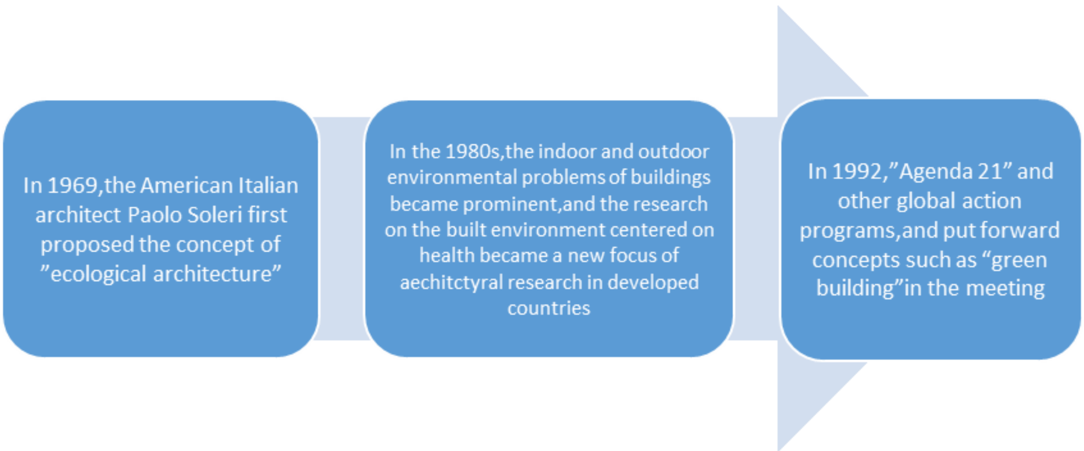

Figure 1. – Brief outline of green building development
(Image source: The author draws it according to the data)

The traditional green building evaluation standards were born from the green concepts and norms of many researchers. Most of these standards are based on objective and fixed perspectives such as the energy saving rate, water saving rate, and the proportion of materials used for energy saving and emission reduction in green buildings.

Quantitative parameter indicators to define green building: During the life cycle of building construction and use process, including pre-site selection, building design, engineering construction, building operations, post-building maintenance and renovation, it is necessary to save resources and Maximum environmental responsibility [3]. In the whole life cycle, save resources, protect the environment, reduce pollution, provide people with healthy, suitable and efficient use space, and maximize the realization of high-quality buildings that live in harmony with nature [4]. The new green building construction technology requires people's environmental protection awareness to keep pace with the times. At the same time, the concept of the original standard will be retained, which is a dialectical inheritance, so that green buildings are more in line with the trend of the times in today's society and better serve human beings. In general, it is not difficult to see from the literal definition that each country may have its own set of green buildings, but in fact, the core concepts and ideas are not much different.

Due to the huge differences in natural resources, human environment, economic conditions and other factors in modern green buildings around the world, it is necessary to comprehensively refer to various factors when evaluating the same green building; the application of green building technology will also vary with different building types. It is not difficult to understand the difference. Therefore, different countries and regions will adapt to local conditions according to their own actual conditions. The traditional standards for green buildings are one-sided, isolated and static. The standards of different times in different regions, traditional green building standards cannot define modern green buildings. We need a holistic, joint, and campaign criteria for evaluating green buildings [5].

The regulatory framework for the adoption of "green" technologies in modern buildings is based on carbon emissions. Carbon emissions are defined as the amount of greenhouse gas emissions produced when a product is produced, transported, used and recycled. Buildings themselves are large energy consumers and have a significant impact on the environment. According to statistics, 50% of the world's energy is used for construction, and more than 50% of the material raw materials obtained by humans from nature are also used to build various buildings and their ancillary facilities. In addition, air pollution, light pollution and electromagnetic pollution caused by buildings account for more than 1/3 of the total environmental pollution. 40% of the waste generated by human activities is construction waste. For developing countries, due to the influx of a large number of people into cities, the demand for housing, roads, underground works, and public facilities is getting higher and higher, and the energy consumption is also increasing. Resources create irreconcilable contradictions [6].

In the first half of the 21st century, China's resource supply situation is much more severe than in the 20th century, especially the shortage of water, arable land and petroleum energy. If no corresponding effective measures are taken, the material base of natural resources for economic prosperity will appear a comprehensive crisis. In the face of such severe resource shortage and environmental crisis, saving resources is a realistic choice for China to ease resource constraints. At present, China's construction industry is a large consumer of land, water, consumables and energy, and there are serious problems such as waste of resources and environmental pollution. It is imperative to vigorously develop building energy conservation and actively promote green buildings. This is of strategic significance for fully implementing the Scientific Outlook on Development and building a resource-saving and environment-friendly society [7].

Vigorously developing green buildings is an urgent need to reduce environmental pollution, protect the ecological environment, improve the quality of life, and protect people's health. At present, rural environmental problems are becoming more and more prominent, domestic pollution is intensifying, industrial and mining pollution is prominent, and drinking water safety has hidden dangers, showing a trend of pollution shifting from cities to rural areas. The construction industry is one of the main sources of pollution. To change this situation, it is necessary to vigorously promote the green building system and ecological city construction with the main features of saving resources, protecting the environment and reducing pollution. This is an urgent need to protect the health of urban and rural people [8].

The rise of green building in the United States began with the 1973 oil embargo crisis, and energy costs became public concern, and some office buildings with sustainable measures began to appear. In the early 1980s, the United States began to develop building energy efficiency, and many private green building organizations took this opportunity to emerge and grow in more than ten years. The United States Green Building Council (USGBC) established in 1993 is a typical representative of these organizations, which successfully guides green building to a more systematic level [9].

The development of green buildings in the United States can be divided into three stages:

Start-up stage: marked by the establishment of the United States Green Building Council (USGBC) in 1993, a third-party independent agency, in 1998, the agency developed a green building evaluation system - LEED (Leadership in Energy and Environmental Design), and began to carry out Evaluate. Under the promotion of this institution, the concept of green building has been gradually promoted, followed by a change in policy focus [10].

Development stage: marked by the promulgation of the 2005 "Energy Policy Act", which embodies the country's energy development strategy, the Act's attention to building energy efficiency is unprecedented.

Expansion stage: marked by the "Economic Stimulus Act" signed by Obama in 2009, there are more than 25 billion US dollars in the bill to promote the development of green buildings and make it an important part of energy reform and economic recovery [11].

A major contribution of the USGBC is the initiation and implementation of the LEED Green Building Evaluation Standard, a third-party certified, quantifiable green building solution applicable to many types of buildings. The LEED standard is one of the most influential green building evaluation standards in the world. China, Australia, Spain, Japan, India and other countries have all provided reference for the formulation of their own green building evaluation standards through the study of LEED standards. The LEED standard is also one of the green building evaluation standards with the greatest market promotion in the world.

The wide application of LEED standards has promoted the rapid development of green buildings, and at the same time, feedback from green building practices has also promoted the continuous updating of LEED standards. In November 2013, the LEED Standard V4 version was released after 6 consultations; in April 2016, the LEED Standard V4 version was most recently updated [12].

The LEED plaque on a building is a mark of quality and achievement in green building. Leaders across the globe have made LEED the most widely used green building rating system in the world with 1.85 million square feet of construction space certifying every day. LEED certification provides independent verification of a building or neighborhood's green features, allowing for the design, construction, operations and maintenance of resource-efficient, high-performing, healthy, cost-effective buildings. LEED is the triple bottom line in action, benefiting people, planet and profit [13].

LEED projects are responsible for diverting over 80 million tons of waste from landfills. Compared to the average commercial building, LEED Gold buildings in the General Services Administration's portfolio consume a quarter less energy and generate 34% lower greenhouse gas emissions [14].

"More than 79,000 projects are participating in LEED across 160 countries and territories, comprising over 15 billion square feet. You´ve seen a LEED plaque before – USGBC estimates that nearly 5 million people experience a LEED building every day. Many of the world´s most well-known buildings have earned LEED certification" [15].

Based on the number of points achieved, a project earns one of four LEED rating levels (Figure 2.):

Figure 2. – LEED rating levels [16]

LEED works for all buildings at all phases of development, from new construction to existing buildings, as well as all building sectors, from homes to hospitals to corporate headquarters.

The development of green buildings in the United States presents the following characteristics:

The legal system is perfect and the policy foundation is good: the federal government has issued a series of policies and regulations such as the energy bill and the presidential decree, and the states have proposed development goals and formulated mandatory standards;

Improve the supporting system to ensure the smooth development of various tasks: establish supporting systems in combination with relevant policies, introduce a number of incentive policies, and formulate mandatory standards to establish a certification system;

Emphasize economic incentives and focus on mobilizing market enthusiasm: promote through various energy efficiency contracts, establishment of public welfare funds, cash subsidies, tax credits, mortgage loans, accelerated depreciation, etc.;

Emphasize third-party mechanisms to ensure fair and impartial evaluation: attach importance to third-party organizations for certification, such as LEEDNGBS Energy Star and other evaluation systems;

Emphasize Life Cycle Cost Analysis: Emphasize during Capitol Energy Efficiency Programs and Support for Renewable Energy to identify appropriate measures and technologies [17].

Singapore's natural resources are very scarce, and a large amount of water, electricity, building materials, etc. are all dependent on imports. At the same time, the consumption of the construction industry is huge, so sustainable development has to become an important issue for Singapore's national development.

The second oil crisis had a huge impact on a country like Singapore that relied on imported energy. In 1980, the Singapore Building and Construction Authority (BCA) promoted energy conservation in the building industry by promulgating the "Building Energy Conservation Standard". The road to energy-saving construction.

In 2004, with the support of the National Environment Agency, BCA developed the evaluation standard-green mark, and in January of the following year, it began to implement the green mark certification program to raise the awareness of the whole society. As of May 2013, Singapore has passed the green mark certification. There are 1,574 projects in total, with a construction area of 46.9 million square meters, accounting for 20% of the country's total construction area. At the same time, the country has formulated the development goals and plans for green buildings, namely: 80% of new buildings in 30 years will be green buildings, and energy efficiency will be increased by 35% compared with 2005. The "Second Phase Green Building Master Plan" promotes the development of green buildings, the government takes the lead in construction, rewards high-star projects, strengthens training and promotion, and formulates the "Third Phase Green Building Master Plan" [18].

Singapore's green building development policy presents the following characteristics:

1. The government takes the lead, forcing the public buildings invested by itself to pass the green standard first, and on the other hand, take different measures for different objects, and formulate minimum performance standards to meet the promotion of other types of buildings;

2. Pay attention to the promotion of ideas. The government has always emphasized the promotion of green buildings to the public during the promotion process, and actively studied and identified the advantages of green buildings in terms of investment income;

3. Focus on professional certification and training, and standardize the market access mechanism: Singapore has established a sound social and university training mechanism, and formulated a related vocational certification mechanism;

4. Improve the supporting mechanism: Singapore has established relevant supporting systems while improving the evaluation system, which provides a basis for developers and owners to choose green building materials, home appliances and other related products when constructing and renovating projects. At the same time, it will drive the development of upstream and downstream industrial chains and "green" upgrades, improve the environment, and ease the pressure on resources and energy [19].

Comparative analysis of existing "green" building standards

The first corporate green standard for assessing the performance of buildings at the international level BREEAM (BRE Environmental Assessment Method) was developed in the UK in 1990.

Currently, this system is represented in 71 countries of the world, 532,615 certificates of conformity have been issued [20]. In its own way, the BREEAM system is represented in Northern Europe (3,567 projects) and Western Europe (739 projects) [21].

The certification system itself includes 9 sections: Management; Health; Energy; Transport; Water; Materials; Recycling; Land use; Pollution.

In 1993, the LEED certification system appeared in the United States as a standard for measuring energy efficient, environmentally friendly and sustainable (sustainable) building projects to facilitate the transition of the building industry to the design, construction and operation of such buildings.

Figure 3. – BRE Environmental Assessment Method

Figure 4. – International LEED system

LEED-2009 (v3) has six sections [22]:

– Construction site (building site), taking into account future needs (sustainable sites, SS);
– Water efficiency (WE);
– Energy consumption and atmosphere parameters (energy and atmosphere, EA);
– Consumption of materials and resources (materials and resources, MR);
– Indoor environmental quality (IEQ);
– Innovation in design (innovation in design, ID).

Each of the sections includes a certain set of specific requirements. For example, the item "efficient water consumption" includes three requirements: the study of the natural landscape; innovative wastewater treatment technologies; reduction in water consumption.

In Germany, the German Sustainable Building Council (Deutsche Gesellschaft für nachhaltiges Bauen e.V., DGNB) introduced its own green building certification in 2009 [23].

Figure 5. – German Sustainable Building Council (Deutsche Gesellschaft für nachhaltiges Bauen e.V., DGNB) [23]

This standard is based on a rating on six aspects: ecology, economics, socio-cultural and functional aspects, methods, processes, location. Initially, this standard was developed for new construction of administrative and office buildings. Then other types were added, in particular commercial, industrial, institutional and residential buildings [24].

The series currently includes 21 standards. Somewhat earlier in the United States, and a little later - in the EU countries, regional and interstate standards for sustainable development in construction are being formalized. The basic European document on the assessment of sustainable buildings CEN - EN 15643-1 "Sustainability of construction works - Sustainability assessment of buildings - Part 1: General framework" appeared in 2010.

Research on green building labelling systems was launched in Mainland China in the late 1990s. The first trial was the ‘Chinese Eco-housing Rating System’ (CEHRS), developed in 2001 with a checklist structure similar to that of LEED. In 2002, the Chinese Ministry of Science and Technology (MOST) initiated a project for developing a green building assessment system for the 2008 Olympics’ buildings. Based on the experience obtained through the development and application of CEHRS, using a checklist system was found to be impractical for a number of reasons; therefore, the research group set out to find better experience and a more reasonable system configuration. As a result – and contrary to CEHRS – the first formal green building rating system in Mainland China, the Green Olympic Building Assessment System (GOBAS), adopted the scoring system framework of CASBEE: 5-points scores and a hierarchical scoring system with weighting coefficients, as well as a 2-D chart analysing the relationship between the quality of the internal environment and the load on the external environment. GOBAS was issued in 2003 and applied to the design of many buildings designed for the 2008 Beijing Olympics. These are the elements which laid a foundation for the subsequent development of Chinese green building evaluation standards [25].

The current national standard Green Building Evaluation Standard GB/T 50378 [26], usually referred to as the «3-star standard», was issued in 2006, has a checklist-type rating system: a building or building cluster will be assessed along six topics: Site and outdoor environment, Energy efficiency, Water efficiency, Materials & resources, Indoor environment quality and Operation & management.

Each topic is evaluated independently, and scores for different topics cannot be added together. The rating results are labelled as 1-star, 2-star and 3-star of which 3-star is the highest evaluation.

Residential buildings and public buildings are evaluated with different articles and indexes, with commercial buildings being regarded as a kind of public buildings.

The rating system divides the assessment process into two stages: (1) Planning and design stage (shortened to «design stage»), (2) Acceptance and operation stage (shortened to «operation stage»). Different elements are assessed at each stage. At the planning and design stage, design documents are assessed, and the green design label awarded is only valid for one year. The formal green label will be issued after one year of operation, with a rating based on operation data.

So far, the local administrative departments in charge of construction in about 20 provinces and municipalities have issued local green building evaluation standards adapted to the local climate, resources, economy level and culture [27].

The purpose of the analysis of "green" building certifications is to demonstrate the various emphases on the subject, each system requiring the same preconditions. The categories of application assessments are a combination, and the three certification systems will have parts that are currently in common use. LEED and its parts serve as the foundation, and the remaining two covered parts combine and/or add to the certification system. Table 2 shows the use of all categories for analysis of their composition.

A separate analysis is performed for each system. In addition, assessments were performed individually, categorized by each criterion group and listed in tables (Tables 3-5). This is compared to the average percentage of the overall contribution to obtain the average percentage of green building certification system scores for each group calculated for the different types of buildings certified by the system, such as: office buildings, shopping malls or educational buildings. Display percentages within the average percentage range. During the analysis of BREEAM and DGNB, their associated parts were compared with the baseline group. LEED provides the benchmark group for the vast majority of them, so no additional column listing LEED as a comparison is inevitable, in the case of LEED, the first column is named the benchmark group, the second column shows the criteria involved, and the last column Displays the average percentage contribution to the total score. For BREEAM and DENB, an additional column that provides their own named part of the column after the first column.

Table 2. – Formation of Benchmark Categories

Categories	LEED	BREEAM	DGNB
Sustainable Sites	Sustainable Sites	-	-
Water Efficiency	Water Efficiency	-	-
Energy and Atmosphere	Energy and Atmosphere	-	-
Materials and Resources	Materials and Resources	-	-
Indoor Environment Quality	Indoor Environment Quality	-	-
Innovation and Design Process	Innovation and Design Process	-	-
Regional Priority Credits	Regional Priority Credits	-	-
Construction and Management	-	Management	Construction
Life Cycle Costs	-	-	▪ Life Cycle Cost ▪ Progress of Value
Technical Aspects	-	-	Technical Quality

The following table (Tables 3 – 5) shows an example calculation using the concept of comparing green building certifications. The average percentage of ratings determines the contribution to the total score to demonstrate the influence of various factors.

Table 3. – Example of Calculating Percentage Contribution with LEED

Project Type	Percentage Contribution to Overall Score
New Construction	9.1%
Schools	10.0%
Retail	9.1%
Healthcare	8.2%
Average	9.1%

Table 4. – Example of Calculating Percentage Contribution with BREEAM

Project Type	Percentage Contribution to Overall Score
Office	6.0%
Retail	6.0%
Industrial	6.0%
Healthcare	6.0%
School	6.0%
Higher Education	6.0%
Prisons	6.0%
Courts	6.0%
Mulitresidential	6.0%
Other buildings	6.0%
Average	6.0%

Table 5. – Example of Calculating Percentage Contribution with DGNB

<table>
<tr><th>Project Type</th><th>Percentage Contribution to Overall Score</th></tr>
<tr><td>Office</td><td rowspan="6">0.0%
(Considered partially in DGNB category “Resources and Waste”)</td></tr>
<tr><td>Education</td></tr>
<tr><td>Hotel</td></tr>
<tr><td>Industrial</td></tr>
<tr><td>Mulitresidential</td></tr>
<tr><td>Retail</td></tr>
<tr><td>Average</td><td>0.0%</td></tr>
</table>

Conclusions:

1. In the review of the green building policies, regulations and evaluation systems of the United States and other countries, these countries have adopted different development methods and have entered a relatively mature implementation stage. The United States mainly develops by improving the legal and regulatory system, while Singapore tends to It is necessary to use special actions to penetrate the legal system to accelerate development.

2. In the standard system of green buildings in developed countries, in addition to evaluation standards, there are more mandatory or recommended design codes and standards. Only by simultaneously setting valuation standards and building standards can the adoption of green buildings be promoted.

3.The standards of different countries contain some unique evaluation criteria due to socio-cultural, economic and other characteristics. This proves the impossibility of fully adopting any foreign assessment system. For each country, it is relevant to develop its own standard, adapted to the conditions of the country.

4.China's existing evaluation standards were first revised in 2014 from the introduction in 2006, which took 8 years, while the evaluation standard system of developed countries is adjusted every 1-2 years on average to better adapt to the development of society.

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