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The Ecological Improvement of Architectural Design by Renewable Energy Equipment

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Abstract. Renewable energy is an important part of green building, which will directly promote the development of a low-carbon economy and have a direct or indirect impact on the regional ecological improvement. At present, the ecological evaluation research of renewable energy green building mainly focuses on the theoretical aspect, explaining green materials, low-carbon recycling, social responsibility and other contents, which lacks practical discussion and analysis, but ignores the impact of green ecological improvement. In order to deeply study the impact of renewable energy equipment on the ecological improvement of architectural design, this paper extracts the content and indicators of green building analysis of renewable energy equipment by the factor regression analysis method of ecological footprint, standardizes the indicators, and eliminates the invalid indicators. Then, the green building of renewable energy equipment is analyzed according to the index to find out the main impact aspects. Finally, the problems are analyzed, the reasons are explored, and relevant countermeasures are proposed according to the regression results. The research results show that the renewable energy equipment has a significant impact on the ecological improvement of architectural design, and the ecological footprint model has certain practicability and reliability in the evaluation of green buildings of renewable energy.

Key words. Renewable Energy, Architectural Design, Ecology.

1. Introduction

The rapid growth of the global economy has increasingly raised the environmental standards for renewable energy green building projects, and the scale of renewable energy green buildings is also expanding [1],[2]. The excellent comprehensive evaluation system of renewable energy green buildings directly determines the success of green buildings [3],[4]. This paper takes the ecological footprint as the starting point, designs the ecological index of renewable energy green building, constructs the ecological footprint reduction model of renewable energy green building, and takes the construction project of New City as an example to analyze. By comparing the project's ecological footprint reduction and ecological deficit, we can see the implementation effect of renewable energy green buildings [5].

China's construction industry is progressing faster than in other sectors at this stage. Although the rapid rise of this field has driven China's economic growth, it has brought negligible damage to China's natural ecological environment [6],[7]. Continuous disorderly mining leads to the loss of coordination between various modern buildings and the surrounding natural environment, causing irreparable damage to natural and social resources and increasing the pressure on these resources [8],[9]. EU data show that the consumption of resources in the construction process is as follows: 50% energy, 42% water, 50% raw materials, 48% farmland, 34% natural environmental pollution, and 34% waste production, especially with the continuous growth of China's population. As the city continues to expand, the surrounding land is being eroded by new facilities and the ecological environment is being damaged. As part of a developing country, we must recognize the importance of using renewable energy green buildings to save energy, reduce pollution, and improve residents' living environment [10].

2. The concept of ecological footprint and renewable energy green building

A. The Ecological Footprint

Rees and Wackernagel first introduced and further expanded the concept of an ecological footprint in the early 1990s, as defined by the entire ownership of ecologically productive land that has a lasting need for humans and also produces large amounts of waste. These ecologically productive land use directions are usually relative, mainly including fossil fuel use areas, farmland, pastures, forests, developed areas, and lakes. When calculating our ecological footprints, there are two key factors that we need to consider. First, we should determine most of our resources, energy, and the amount of waste they bring. Second, we can convert the flow of these resources and wastes into biological production areas for production and reception."Ecological footprint analysis" is a technology that closely combines human life, work and environmental production areas. The technology puts all kinds of material resources used and waste released into the category of ecological footprint. In other words, this can be vividly compared to the traces left on the earth, and the deeper the traces, the more resources are consumed or the more pollution is produced.

B. Renewable Energy Green Buildings

Renewable energy green building is defined as using as many resources as possible (such as saving energy, land, water, and materials) during the entire service life of the building to maintain the environment and reduce pollution. This architectural method aims to create a practical and efficient living space that benefits human beings and forms a coordinated relationship with nature. It adopts the overall layout of science, the use of advanced scientific and technological means, such as the reuse of natural resources and energy, to achieve the perfect combination of the building and its natural environment to realize the green building, and meet the needs of the public. The advantages of this building include reasonable location design, efficient conservation of energy and water resources, reduced pollution to the atmosphere, waste water and waste, and effective use of energy, and the creation of a healthy and pleasant building space. At present, the evaluation system of renewable energy green buildings at home and abroad mainly relies on the weight allocation and evaluation methods conducted by professionals. All assessments are based on a qualitative, subjective assessment of a renewable energy green building. For example, LEED, BREEAM, and NABERS are from the United States and Australia. Their research, based on the ecological footprint evaluation model of renewable energy green buildings, evaluated the various ecological characteristics of renewable energy green buildings and calculated the load and ecological value of buildings to the environment to more directly understand the relationship between buildings and the ecological environment (Figure 1).

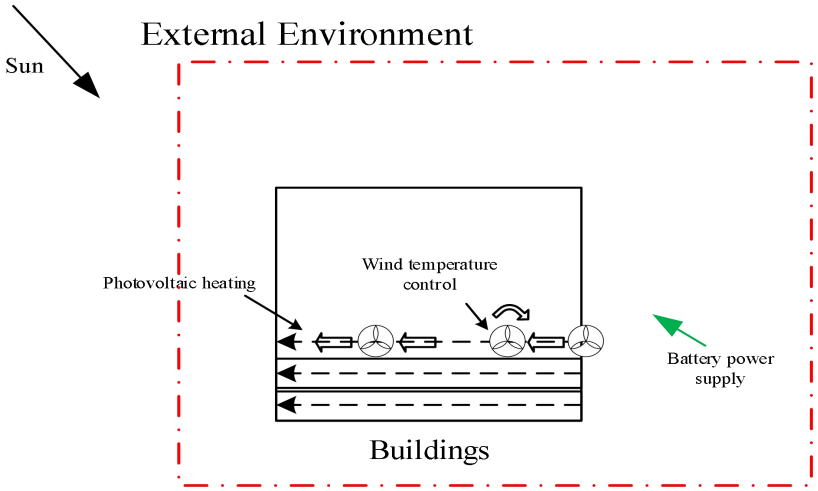

Figure 1. Ecological Demonstration Diagram

3. Build an Index System for Reducing the Ecological Footprint of Renewable Energy and Green Buildings

Whether they are environmentally friendly or conventional buildings, they all need to invest resources to form ecological traces. However, in view of the energy-saving and environmental protection properties of environment-friendly buildings, we can regard their resource savings over conventional buildings as a reduction of ecological traces. According to the evaluation standard system and ecological trace evaluation method of environmentally friendly buildings, we have constructed an ecological trace reduction index system of environmentally friendly buildings (Table 1).

Table 1. Ecological Index System of Green Building of Renewable Energy

LEVEL 1 INDICATORS	SECONDARY INDICATORS
Land saving and outdoor environment	site selection Per capita footprint zone bit supporting facilities Energy-saving lighting
Energy saving and energy utilization	energy recovery renewable resource Non-traditional water resources utilization
Water-saving and water resource utilization	Green water-saving irrigation Rainwater osmosis
Nodal wood	Utilization of circulating materials
Environmental protection	green area

4. Evaluation Model of Renewable Energy Green Building Project Based on Ecological Footprint Analysis Method

A. Basic Calculation Formula of Ecological Footprint

There are two main steps in the ecological footprint estimation process: first, turn consumption (i.e., waste) into related types of land share. Specifically, the six types of land share are farmland, livestock farms, forests, land for renewable energy use, sites for construction projects, and lakes. As shown in formula (1):

$$D_j = \sum_{i=1}^{n} \frac{R_j \times C_i \times B_j}{A_i} \tag{1}$$

In formula. (1), D_iFor the average annual use of class *j* land in ghm²/year. R_i Adjust for the balance factors of *i* consumer goods.C_iRepresents the annual usage of i consumer goods in t/year. B_i Represents the energy density of *i* consumer products in GJ/t; A_i Represents the global average production capacity of *i* consumer goods in GJ/ghm². The next step is to integrate the calculations of the six land types to construct the final ecological footprint indicator, as shown in Equation (2):

$$ef = \sum_{j=1}^{6} \frac{S_j \times D_j}{P} \tag{2}$$

In formula (2), *ef* represents the average annual ecological footprint *j*, measured in ghm²/cap year. The balance coefficient of the planting soil is the balance coefficient S_j. For the land of type D_j, the average annual use area is ghm ²/year. P represents the number of the entire population, the cap.

B. Build the Ecological Footprint Reduction Model of Renewable Energy Green Building

DEF, the degree of ecological reduction of renewable energy green buildings, represents the overall decline of all environmental factors. As we can see from Table 1, these reduced ecological factors mainly include the reduction of land utilization rate, the utilization rate of water resources, the utilization rate of energy, building materials, and the reduction of environmental friendliness.

1) Land Reduction in Section

The key to land conservation in renewable energy green buildings is to improve land use efficiency to reduce the occupation of farmland. This study estimates the ecological reduction of land saving by renewable energy green buildings from four perspectives: site selection, per capita footprint, geographical location, and supporting facilities. In terms of geographical location and supporting facilities, because the relevant data is difficult to obtain and there is no standard calculation method, we used a similar project comparison method to calculate the ecological reduction. The specific calculation formula is as follows:

$$\mathrm{DEF}_i = (\mathrm{S}_j \rightarrow \mathrm{S}_H) \times SH \otimes year \tag{3}$$

2) Reduction of Water Saving

The impact of ecological footprint on water resources is mainly reflected in the energy consumption during the processing process. According to the study, the electricity consumption of collecting and cleaning per ton of tap water is about 0.25~0.33kw h, while the use of tap water at 1t leads to about 0.0001 ghm². The ecological footprint. The specific calculation methods are described as follows:

$$\mathrm{DEF}_i = (\mathrm{T}_h \rightarrow \mathrm{T}_k) \cdot 0.01 \tag{4}$$

3) Energy Saving and Reduction Amount

When the calculation of the ecological footprint of reducing energy use is conducted, the energy use is generally converted into the electricity used due to the difficulty of data collection and the complexity of the calculation. According to Yan Zhe and Ying Le's study on the ecological footprint of reducing energy use, the ecological footprint of electricity use per 1 kWh in China is 0.00023 ghm². So the ecological footprint of the energy use of energy is calculated:

$$\mathrm{DEF}_{\mathrm{save}} = 0.00023 \cdot I_j \tag{5}$$

4) Reduction of Material Saving Quantity

In the process of implementing building energy saving, we mainly pay attention to the use of circulating materials. This method can reduce the demand for building materials, and thus reduce the ecological damage. We can convert the circulating materials used into the corresponding ecological output land area, and then calculate a unified land area according to the balance factors. This formula is this:

$$\mathrm{DEF}_o = \mathrm{D}_r \Rightarrow \mathrm{S}_g \tag{6}$$

5) Environmental Protection Reduction Amount

At present, China mainly takes carbon dioxide emissions and green rates as the standard to measure environmental protection. Therefore, we can reflect the reduction degree of environmental ecological footprint by calculating the reduction of carbon dioxide and green land rate. Often, CO_2 emission reductions can be converted into woodland indicators. According to the data provided by WWF in its LPRZO2002 report, the global average of woodland can absorb 5.2 tons of CO_2 per hectare per year, and the equilibrium factor of woodland is 0.62. At the same time, improving the rate of green land buildings can also have a positive impact on the ecological environment. Because the green environment is most similar to the pastures of the 6 lands, the balance factor is 0.61. Therefore, the formula for

calculating the reduction of environmental ecological footprint is:

$$f(x)=\sum D_i \cdot S_j \quad (7)$$

C. Evaluation Criteria for Renewable Energy Green Building Projects

Top Energy Members of the Renewable Energy Green Building Forum set an ecological goal of renewable energy green buildings, namely, to reduce the ecological footprint of renewable energy green buildings over that of ordinary buildings, and this value should be consistent with the ecological goal of the whole society. Therefore, the evaluation of the green degree of a building, needs through the ecological footprint cuts and its environmental deficit, if the value exceeds the environmental deficit, then the building will meet the requirements of renewable energy green building, on the contrary, if not meet, then the building cannot be identified as renewable energy green building. According to Ren's view, Peng Weihua and his team obtained detailed data through an in-depth discussion of ecological carrying capacity between 2011 and 2021, as shown in Table 2. In addition, they forecast the 2025 ecological deficit, which is at 1.59. There is no doubt that environmental protection has become worse in recent years, and the ecological conditions have continued to deteriorate.

Table 2. Changes in Architectural Ecological Footprint and Ecological Carrying Capacity from 2011 to 2021

INDICATOR YEAR	ECOLOGICAL FOOTPRINT PER CAPITA / HM ² / PERSON	PER CAPITA ECOLOGICAL BEARING, PER CAPITA ECOLOGICAL RED FORCE / HM ² / HERRINGBONE / HM / PERSON
2011	1.4268	0.4860	-0.9408
2012	1.4662	0.4429	-1.0233
2013	1.4651	0.4410	-1.0241
2014	1.5274	0.4115	-1.1159
2015	1.4659	0.4126	-1.0533
2016	1.6072	0.4204	-1.1868
2017	1.6443	0.4183	-1.2260
2018	1.6587	0.4149	-1.2438
2019	1.6815	0.4117	-1.2698
2020	1.7842	0.4105	-1.3737
2021	1.8769	0.4088	-1.468

5. Example Analysis

A. Overview and Main Data of Renewable Energy Green Building Projects

The construction project of New City constitutes an important part of New City. The planning of this project covers an area of 82,500 square meters, while the actual construction area reaches 244,100 square meters, with a total of 2,658 households, and its overall volume ratio reaches 2.3. The project is scheduled for November 1,2007, and is expected to be completed by October 1,2016, with a service period of 70 years. Within this 500-meter range, there will be four bus stations and five bus routes. According to the application documents of the star-level renewable energy green building submitted by Greenland Group for this project, we have obtained the following important information, as shown in Table 3.

Table 3. Main Parameters of the Renewable Energy Green Building Project in New City

METRIC	UNIT	DATA	METRIC	UNIT	DATA
Land area	ten thousand m²	8.25	Weight of the recyclable material	t	55219.89
Area of structure	ten thousand m²	24.41	Total renewable energy sources	mj/a	10743176.59
Energy consumption per unit area	kwh/m²a	33.36	CO_2 carbon emission reduction	t	86.53
Fractional energy saving	%	50%	Photovoltaic power generation	ten thousand kWh	15.84
Non-traditional water quantity	m³/a	7747.3	Per capita green space area	m²	3.44

B. Ecological Footprint Reduction Calculation

According to the established ecological footprint reduction model of renewable energy green building and the information in Table 3, we can deduce the ecological footprint reduction of New Town construction project, as shown in Table 4.

Table 4. Evaluation Results of Ecological Footprint Reduction of Renewable Energy Green Buildings

LEVEL 1 INDICATORS	SECONDARY INDICATORS	INDIVIDUAL DEF REDUCTION VALUE	CLASSIFY DEF	TOTAL DEF OF THE PROJECT
Land saving and outdoor environment	site selection	0	1.74	2.71323
	Per capita footprint	1.74		
	zone bit	0.0137		
	supporting facilities			
Energy saving and energy utilization	Energy-saving lighting	0.0153	0.055	
	energy recovery	0.026		
	renewable resource			
	Non-traditional water resources utilization			
Water-saving and water resources utilization	Green water-saving irrigation	0.77473	0.77473	
	Rainwater			
Nodal wood	Utilization of circulating materials	0.0976	0.0976	
Environmental protection	green area	0.042	0.0459	
	CO_2 decrement	0.0039		

C. Results Analysis

According to the per capita deficit data in 2014, the average value is 1.59. However, the annual per capita reduction of the project is 2.71323, significantly higher than our province's average deficit level in 2014. Therefore, the project meets the standard of ecological renewable energy green building.

By calculating the proportion of the classified DEF value of each green evaluation, obtained the proportion result of the ecological contribution. In this project, the ecological contribution of land saving and the outdoor environment is the largest, followed by water saving and water resources utilization. In terms of energy conservation, energy use and environmental protection, its contribution is relatively low, which indicates that the project should increase investment in these two ecological indicators, to improve the green level of the whole project and further enhance the green level of the building.

6. Conclusion

To sum up, promoting the progress of green building in renewable energy is beneficial to optimizing the ecological environment. In recent years, China's big cities' ecological burden is increasing. Therefore, the future construction work needs to pay attention to the promotion of renewable energy green buildings, in order to reduce the ecological pollution per capita. Specifically, people's high energy consumption and high consumption lifestyle can be transformed by enhancing the ecological influence of buildings, using renewable materials, and using solar energy and other resources. To evaluate renewable energy green buildings from an ecological perspective and the ecological benefits of renewable energy green buildings by comparing their ecological value and local ecological goals. The criteria for green building evaluation of renewable energy should pay more attention to its ecology, fairness and precision. Although the difficulty in collecting some data in the project leads to the calculation bias of the empirical analysis, the analysis results are quite close to the evaluation results of renewable energy green buildings. This suggests that the ecological footprint evaluation model is feasible in the green building evaluation of renewable energy sources.

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