



Comprehensive Evaluation of Green Office Indoor Environment-Energy Efficiency Based on Data Envelopment Analysis

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SUMMARY: *Manufacturing industry is a major energy consumer and a major source of environmental pollutants. Improving the green total factor efficiency of the manufacturing industry is of great significance in realizing the sustainable development of China's manufacturing industry and the whole national economy. In this paper, a series of assessment indexes for energy efficiency are identified from the perspective of green building assessment, and data envelopment analysis (DEA) is proposed. The relative effectiveness of DMUs is evaluated by comparing the degree of their deviation from the DEA frontier surface. A basic C²R model is established according to the DEA idea, and relevant constraints are introduced to establish a BCC model for energy efficiency during the construction process. Energy efficiency analysis of office indoor environment energy consumption through the above model, the average energy efficiency of 36 green office indoor environments is 0.514 in 2018, and the average energy efficiency rises to 0.61 in 2023. In general, the energy efficiency of 36 green office indoor environments shows an upward trend during 2018-2023. At the same time, the comprehensive efficiency shows a fluctuating change of decreasing and then increasing, and the average value of the comprehensive efficiency in the three years of 2018, 2021 and 2023 is 0.369, and there is still a lot of room to improve the energy efficiency of the green industry.*

KEYWORDS: *DEA; DMU; C²R model; energy efficiency; green office indoor environment*

1 Introduction

With the accelerated pace of China's urbanization and development of the degree of perfection, the transformation of people's work patterns and the continuous improvement of physiological and psychological needs, office buildings have gradually become an indispensable part of the process of urban development, which not only provides a place for the occurrence of office activities, social activities, and meetings and other behaviors in the city, but is also an important way of displaying the image of the city and the cultural inheritance [1]. The increasing number of office buildings is accompanied by a large amount of energy consumption. Since the industrial revolution, the fossil energy used in human activities has had an increasingly profound impact on the development of human society, resources and the environment, and the problems of energy and the environment have become increasingly prominent [2]. The burning of large amounts of fossil energy produces greenhouse gases on a huge scale, which is considered to be the main cause of global climate change [3]. In this context, the construction industry has begun to explore the concepts of building energy efficiency such as solar,

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geothermal, and wind energy as well as the concept of sustainable development, which lays an important theoretical foundation for the formation of subsequent green building concepts [4, 5].

In recent years, different scholars have conducted research on different aspects of “green buildings”, including green office building evaluation standards, indoor environmental quality, energy conservation, actual operational energy consumption, and post-use evaluation [6-8]. Regarding the research on green buildings, Singh, A et al. investigated the effects of indoor environmental quality of green and non-green buildings on the physiological health of office workers and their work efficiency, and found that the indoor environmental quality of certified green buildings can effectively improve the health of employees, such as asthma, respiratory diseases, and depression, and also improve the productivity of employees [9]. Assad, M et al. developed an integrated model that demonstrates the importance of considering energy consumption in advancing the development of green buildings by evaluating the energy consumption of construction projects in the preconstruction phase and their benefits compared to the simulation analysis of an Egyptian building as an example of a practical decision support tool [10]. Rajabi, M et al. explored green building standards suitable for Iran through expert research and Delphi method combined with machine learning and found that the main barriers to green building in Iran are the lack of awareness of green building and underutilization of renewable energy sources, which shows the direction for the development of green building [11]. Alsulaili, A D et al. analyzed on the basis of the actual project cases of energy-saving transformation of existing buildings into green buildings, and the study showed that the use of energy-saving equipment and environmentally friendly materials actually reduces the building operating costs, such as the use of intelligent control of LEDs, the lighting system electrical energy consumption is reduced to 80% of the original; the use of high-performance heat preservation materials and doors and windows, the building cold load can be reduced to 75% of the original [12].

In the study on indicators for green building evaluation, McArthur, J J and Powell, C compared healthy building evaluation criteria such as WELL and Fitwel and green building evaluation systems such as BREEAM, DGNB, HQE, and LEED, which resulted in air quality, thermal comfort, visual comfort, acoustic comfort, ergonomics and exercise, diet and clean water, and social well-being, 8 health themes of mental health [13]. Jin, Q and Wallbaum, H examined user satisfaction, health and working conditions in a newly refurbished office building through the BREEAM certification scheme and found that users preferred comfortable temperature, fresh air, pleasant sound, and plenty of daylight, and that high-performance indoor environmental qualities need to be improved to positively affect user health, well-being and productivity [14]. In addition, a whole life cycle cost evaluation of green buildings in Indonesia by Miraj, P et al. came to similar conclusions and found that green buildings provided significant return on investment in terms of cost, energy consumption, water utilization, and carbon emissions, further justifying their economic rationale [15]. Cedeño Laurent, J G et al. explored the factors that contribute to the quality of the environment in the office over a period of 40 years and summarized nine environmental elements: air quality, wind environment, noise, light environment, water quality, pests, thermal comfort, safety, and mold [16]. Lu, S et al. studied a medium-sized office building and concluded that climatic conditions, building form, and envelope heat transfer performance all had a significant effect on the energy simulation results, and by optimizing the building energy consumption was reduced by 13% compared to the pre-optimization period [17].

In the study of benefit evaluation of green building, it covers the evaluation of cost benefit, economic benefit, energy saving and emission reduction benefit, and comprehensive benefit [18]. Chen, Y et al. explored a new data-driven benchmarking method based on Lorenz curves

for building energy assessment to identify the uneven distribution of energy consumption among buildings, and found that the energy efficiency imbalance of office buildings, shopping centers, and hotels located in Beijing ranged from 0.2 to 0.3, with little difference [19]. Asdrubali, F et al. found that LEED focuses more on material selection and collection, while ITACA favors the management level by comparing the two evaluation systems, LEED in the US and ITACA in Italy, horizontally. He emphasized the differences between the evaluation systems and chose the one that best matches the regional building characteristics as a reference to provide guidance for setting green building evaluation indexes [20]. Šuman, N et al. proposed a framework mainly for determining the optimal refurbishment strategy for completed office buildings, which provides decision support for refurbishment through selected green building rating system criteria and a methodology based on cost-benefit analysis [21]. Kim, Y and Yu, K H discussed Korea's Building Energy Rating and Zero Energy Building Certification Standards, stating that Korea has established a development plan for zero-energy buildings in order to improve the energy efficiency of buildings, achieving a low-energy building target of a 50% reduction in cooling/heating energy in 2012, a passive house building target of an 80% reduction in the cooling/heating energy consumption of a building in 2017, and a 2025 zero-energy building goal of balancing supply and demand [22]. Remizov, A et al. provided an in-depth analysis of several major green building rating systems including BREEAM, LEED, CASBEE and Green Globes and explored the applicability of these systems to existing buildings in Kazakhstan, where only 8 were found to have achieved a high level of rating through the assessment of 43 existing buildings [23].

There are also some scholars, who will turn some advanced building concepts into a framework or methodology for assessment then go on to modify or reconstruct the evaluation criteria for green buildings. For example, Ikudayisi, A E et al. systematically reviewed the Integrated Design Process (IDP) and developed a new set of indicators and a conceptual framework for evaluating green building projects, which identifies the core elements that ensure the success of the IDP by analyzing case studies and extensive literature, including project management, teamwork, design innovation, and environmental performance, and provides a holistic perspective for a deeper understanding of green building benefits [24]. Griego, D et al. optimized the design of an office building in Salamanca, Mexico by applying a sequential search optimization methodology in terms of both equipment performance and lighting approach, which optimized the energy efficiency of the building to more than 49% while enhancing the cost-effectiveness [25]. Son, H et al. formed a dataset consisting of various technical indicators of 53 green building projects through screening and collection, and summarized 10 important factors affecting project cost-effectiveness in the design phase of green building projects by applying the Support Vector Machine (SVM) methodology, which provides an important reference for the cost-effectiveness analysis of green building projects [26]. Dwaikat, L N and Ali, K N combined with the theory of the whole life cycle of construction projects, to carry out the analysis of the impact of project cost price changes on project costing, to form the life cycle budget system of construction projects, to formulate the life cycle cost performance benchmarks of construction projects, and to promote the improvement of project cost control based on the tracking of the performance benchmarks [27]. Latha, H et al. found that significant energy savings can be achieved by optimizing the length, depth and spatial layout of a building, in addition, the orientation and form of a building also have a significant impact on energy consumption, and rational spatial layout and form design can avoid unnecessary energy wastage, improve the overall sustainability of a building, and help to mitigate climate change [28]. Dwaikat, L N and Ali, K N study highlighted the significant benefits of green buildings in Malaysia in terms of energy efficiency, which was found to be about 71.1%, which saves a significant amount of energy over the entire life cycle

of the building [29].

This paper dismantles the specific meaning of green office indoor environment and clarifies the evaluation and certification criteria of green office. The energy efficiency is divided into two parts: energy transfer and utilization efficiency, DMUs are projected onto the DEA frontier with the help of mathematical planning, and their relative effectiveness is evaluated by comparing the degree of deviation of decision-making units from the DEA frontier. The basic model C²R in DEA is applied to the energy efficiency evaluation of green building construction process, and the constraints are introduced to limit the model conditions and construct the BC² model of energy efficiency in the construction process. The input indicators are divided into two types, and the research indicators are designed to carry out the analysis of the energy efficiency of the indoor environment of the office as well as the regression analysis to evaluate the value of the comprehensive energy efficiency of the environment inside the green office.

2 Greening the office environment

2.1 Green buildings

2.1.1 Green office building concept

When the term “green” is used, it is easy to associate it with environmental protection, energy conservation, health, efficiency and so on. In other words, the word “green” has taken on its own conventional meaning. If we do not intend to complicate the issue, a “green building” is a building that creates an energy-efficient, healthy, comfortable, clean and efficient building space for its occupants with the least amount of energy and resources consumed and the least amount of waste produced during the building's life cycle, and that achieves the goal of a harmonious coexistence of the sky, the earth, and human beings.

2.1.2 Assessment and Recognition of Green Office Buildings

A green building evaluation system is a clear set of evaluation and certification system applied to the whole life span of a green building, which measures the degree of “greenness” of the building throughout the entire phase with certain criteria, and at the same time provides specific and clear regulations to guide the practice by defining a series of evaluation indexes for each aspect.

2.2 Energy consumption of green office buildings

2.2.1 Building energy consumption

Building energy consumption, from different perspectives have different understandings, broadly speaking, there are two kinds of narrow and broad sense, the broad sense of building energy consumption refers to all energy consumption including the energy consumed in the production and transportation of building materials, the energy consumed in the process of building construction, the energy consumed in the daily use of the building. Chivalrous building energy consumption only refers to the energy consumed in the normal use of the building. The two have certain differences and connections.

2.2.2 Energy efficiency

Energy efficiency, i.e. the efficiency of energy. In the process of building construction, energy is for the completion of the whole building. In order to analyze the efficiency situation of energy

more accurately, from the flow of energy can be divided into energy transmission efficiency and energy utilization efficiency.

Energy transfer efficiency: the ratio of the total energy obtained at the end of the system to the total energy output of the energy supply system. For the energy transfer efficiency, if E_0 denotes the total energy output in the building construction process, and E denotes the total energy used to the building construction process, then the energy transfer efficiency η can be expressed by equation (1):

$$\eta = \frac{E}{E_0} \times 100\% \quad (1)$$

Energy utilization efficiency: Energy utilization efficiency is used to indicate whether the energy transferred to the construction of a building is fully utilized. If the energy transferred to the building construction is fully utilized during the construction process, the utilization rate is 100%. In reality, it is almost impossible to achieve 100% efficiency in the energy transfer process.

2.3 Application of DEA methodology in the study of energy efficiency in green office buildings

2.3.1 Basic DEA concepts

Data Envelopment Analysis (DEA) is a new field of research at the intersection of operations research, management science and mathematical economics. It is a decision-making method for evaluating the relative effectiveness of similar production systems developed by American operations researchers on the basis of the Farell measure. The method mainly consists of keeping the input or output of the decision-making unit (DMU) unchanged, projecting the DMU onto the DEA frontier with the help of mathematical planning, and evaluating the relative effectiveness of the decision-making units by comparing the degree of their deviation from the DEA frontier.

The C²R model that establishes the basis according to the DEA idea is as follows:

$$\begin{aligned} \min \theta = V_D \\ s.t. \left\{ \begin{array}{l} \sum_{j=1}^n \lambda_j x_j \leq \theta x_{j0} \\ \sum_{j=1}^n \lambda_j y_j \geq y_{j0} \\ \lambda_j \geq 0, j = 1, 2, \dots, n \end{array} \right. \quad (2) \end{aligned}$$

where x_j, y_j are input variables, output variables, λ_j are their weight coefficients, and V_D is the efficiency evaluation result. Introducing slack variables, the above equation can be written as:

$$\begin{aligned}
& \min \theta = V_D \\
& s.t. \left\{ \begin{array}{l} \sum_{j=1}^n \lambda_j x_j + S^- \leq \theta x_{j_0} \\ \sum_{j=1}^n \lambda_j y_j - S^+ \geq y_{j_0} \\ \lambda_j \geq 0, j = 1, 2, \dots, n; S^-, S^+ \geq 0 \end{array} \right. \quad (3)
\end{aligned}$$

For this linear program, the j_0 th DMU is weakly DEA valid if $V_D = 1$. The j_0 th DMU is DEA valid if weak $V_D = 1$ and each of its optimal solutions $\lambda^*, s^{*+}, s^{*-}, \theta^*$ have $s^{*+} = 0, s^{*-} = 0$.

C²R model is the most basic model of DEA theory, which is a simpler planning model to realize the efficiency assessment under the realistic conditions, and lays the foundation for the subsequent development of DEA theory.

2.3.2 Steps of energy efficiency evaluation of DEA model for green office environment

The implementation steps of the DEA model energy efficiency evaluation in the construction process are divided into the following five stages, respectively:

Stage 1: Clarify the research objective of evaluating energy efficiency in the construction process of green offices, analyze the characteristics of the evaluation objective and the depth of the study, and select the appropriate DEA model accordingly.

Stage 2: Establishment of evaluation indexes. There are many sources of energy in the construction process and many flows of energy, and the input and output indicators are determined on the basis of the analysis of the types of energy in the construction process and the principles of the establishment of the indicator system.

Stage 3: Selection of decision-making unit, according to the basic characteristics of DMU to select the appropriate decision-making unit, such as in the construction process is divided by construction phase or by construction period, etc., and finally determine the appropriate decision-making unit and the number of decision-making units.

Stage 4: Substitute the input and output indicators of the decision-making units into the energy efficiency evaluation model of the construction process to obtain the efficiency value of the energy efficiency of the construction process and analyze the meaning of each efficiency value in the energy efficiency evaluation model.

Stage 5: Analyze and evaluate the resulting efficiency values, and on the basis of the evaluation, gain an in-depth understanding of the reasons for the changes in the efficiency values and give targeted advice and recommendations.

2.4 Design of energy efficiency evaluation methods

2.4.1 DEA data envelopment analysis methods

Using DEA method two perspectives for analysis, on the one hand, the time dimension, vertical analysis, the analysis results reflect the historical trend, such as time series as a DEA decision-making unit, you can analyze the trend of the overall energy use efficiency of the green office, reflecting the effectiveness of the energy management work. On the other hand, the data of the same period are selected for horizontal analysis, and the analysis results reflect the resource utilization efficiency of each unit. Based on the above two points, combined with the energy

consumption operation system, you can also design the analysis of energy efficiency from the energy consumption type and operation center. For example, in a certain time region, selecting green office units in different regions as DEA decision-making units can compare and analyze the efficiency differences between places, facilitate energy-saving and emission reduction performance assessment, and provide quantitative reference for energy-saving and emission reduction target setting.

2.4.2 Two-stage DEA regression methods

Two-stage DEA regression method, that is, in the first stage through the same DEA method of energy consumption and operational data processing, resulting in the efficiency value of each unit, and according to the optimal unit of all the data to correct the processing, and in the second stage through the traditional regression method to process the corrected data, to get the most efficient input and output of the explicit function. DEA method is the use of mathematical models to compare the relative efficiency of decision-making units, the evaluation of decision-making units, and its evaluation is based on the input and output data of the decision-making units. DEA method is to use mathematical model to compare the relative efficiency between the decision-making units and evaluate the decision-making units, and its evaluation is based on the input and output data of the decision-making units. Since the DEA method has been widely used to analyze the production efficiency problem, when the efficiency value of decision-making unit is 1, it reaches the optimization, and the output is maximized. However, in the management of energy consumption is precisely in the minimization of energy consumption is optimal. Therefore, when using the DEA method, the energy consumption is taken as an input, and other indicators are taken as outputs, which can be interpreted as the corresponding energy inputs to support the normal operation of the green office.

Advantages of using the two-stage DEA method over other methods: Firstly, realistic feasibility. Due to the inherent characteristics of the DEA method, the optimum measured by this method is not the theoretical optimum, but the relatively optimal combination of all the data units analyzed, which has actually appeared in historical production, that is to say, this optimum can be fully realized under the real production conditions. Then, in the management sense, it can be understood that this optimal result can be the most appropriate target for future production. Secondly, DEA takes the weights of inputs and outputs of decision-making units as variables, and evaluates them from the perspective of the most favorable decision-making units, thus avoiding the need to determine the weights of indicators in the sense of priority. Again, the DEA method can correct the units that are not optimized according to different needs, which gives a reasonable target for the next optimization. Finally, the two-stage DEA regression method can be used to regression analysis of the data corrected by DEA method, which makes the original efficiency equation implicitly explicit and reflects the economic significance of the efficiency equation more clearly.

2.4.3 Energy efficiency C²R modeling

The basic principles of the C²R model have been presented in 2.3.1, and here this model is applied to the energy efficiency evaluation aspect of the construction process:

$$\begin{aligned} \max \quad & \frac{u^T y_0}{v^T x_0} = V_{\bar{p}} \\ \text{s.t.} \quad & \begin{cases} \frac{u^T y_j}{v^T x_j} \leq 1 (j=1, 2, \dots, n) \\ v \geq 0, u \geq 0 \end{cases} \end{aligned} \quad (4)$$

Mathematically transform the mathematical planning of (4) such that $t = \frac{1}{v^T x_0}$, $w = tv$, $\mu = tu$ by $t = \frac{1}{v^T x_0} \Rightarrow w^T x_0 = 1$. This model is transformed into the following linear programming model P:

$$(P) \begin{cases} \max h_{j_0} = \mu^T y_0 = V_p \\ w^T x_j - \mu^T y_j \geq 0, j=1, 2, \dots, n \\ w^T x_0 = 1 \\ w \geq 0, \mu \geq 0 \end{cases} \quad (5)$$

The effectiveness of the decision unit j_0 is defined in terms of the optimal solution of linear programming, and the amount of effectiveness of the decision unit is all relative to the other decision units, so this is only relative efficiency. The analysis of the dyadic model of the C^2R model is easier to analyze in depth in both theoretical and economic sense.

The dyadic plan of plan P is plan D:

$$(D) \begin{cases} \min \theta = V_D \\ \sum_{j=1}^n \lambda_j x_j \leq \theta x_0 \\ \sum_{j=1}^n \lambda_j y_j \geq y_0 \\ \lambda_j \geq 0, j=1, 2, \dots, n \\ \theta \text{ unconstrained} \end{cases} \quad (6)$$

For further convenience of calculation and discussion, the above linear programming model can be turned into by taking the above linear programming model and introducing the slack variable s^+ and the residual variable s^- to change the inequality constraints into equality constraints, which can be turned into:

$$(D) \begin{cases} \sum_{j=1}^n \lambda_j x_j + s^+ = \theta x_0 \\ \sum_{j=1}^n \lambda_j y_j - s^- = y_0 \\ \lambda_j \geq 0, j=1, 2, \dots, n \\ s^+ \geq 0, s^- \geq 0 \end{cases} \quad (7)$$

where λ represents the weights of each indicator, x denotes the inputs, y denotes the outputs, and the above model is expressed as whether there exists a new input and output based on the combination of each DMU with the outputs remaining unchanged, such that the new inputs are less than or equal to the original inputs, and the outputs are greater than or equal to the original outputs. θ is the ratio of the new inputs to the old ones, and $\min \theta$ denotes the minimum ratio.

In the evaluation of energy efficiency in the construction process, since the purpose of the evaluation is how to improve energy utilization efficiency and reduce energy consumption, it should be based on the possibility of whether there is a reduction in the amount of inputs when the output remains unchanged. Therefore, the above model is applicable to the evaluation model of energy efficiency in the construction process.

The model of energy efficiency C^2R in the construction process is:

$$\begin{cases} \min \theta_j = V_D \\ \sum_{j=1}^n \lambda_{1j} x_{1j} + s_1^+ = \theta_j x_{1j} \\ \sum_{j=1}^n \lambda_{2j} x_{2j} + s_2^+ = \theta_j x_{2j} \\ \sum_{j=1}^n \lambda_{3j} x_{3j} + s_3^+ = \theta_j x_{3j} \\ \sum_{j=1}^n \lambda_{1j} y_{1j} - s_1^- = y_{1j} \\ \sum_{j=1}^n \lambda_{2j} y_{2j} - s_2^- = y_{2j} \\ \sum_{j=1}^n \lambda_{3j} y_{3j} - s_3^- = y_{3j} \\ \lambda_j \geq 0, j = 1, 2, \dots, n \\ s_1^+, s_2^+, s_3^+ \geq 0, s_1^-, s_2^-, s_3^- \geq 0 \end{cases} \quad (8)$$

The above equation represents the combined efficiency value of the j th decision unit.

2.4.4 Energy efficiency BC^2 modeling

(1) Research model

The C^2R model is a model built under the assumption of constant returns to scale, which finds the combined efficiency. And the integrated efficiency can be decomposed by the BC^2 model. Comprehensive efficiency = technical efficiency \times scale efficiency, and technical efficiency is the energy efficiency in the construction process under the assumption of variable scale remuneration. Thus, the BC^2 model of energy efficiency in the construction process is needed.

The BC^2 model has one more constraint compared to the C^2R model. That is, the sum of the weights is equal to 1. By the restriction of this condition, the influence of scale efficiency on energy efficiency is eliminated, and the relative technical effectiveness between decision units can be compared. Each indicator and the slack and residual variables in the model

represent the same meaning.

The BC^2 model allows the technical efficiency θ^* , the slack variable s^+ , and the residual variable s^- to be found for each month. The returns to scale are represented in the BC^2 model:

- 1) $\theta^* = 1$ with constant returns to scale.
- 2) $\theta^* < 1$ and $\sum_{j=1}^n \lambda_j / \theta^* > 1$, diminishing returns to scale.
- 3) $\theta^* > 1$, and $\sum_{j=1}^n \lambda_j / \theta^* < 1$, increasing returns to scale.

Based on the above principle, combined with the energy efficiency input and output indicators in the construction process, the energy efficiency BC^2 model in the construction process is derived as Equation (9):

$$\begin{aligned} \min \theta_j = V_D \\ \left\{ \begin{array}{l} \sum_{j=1}^n \lambda_j x_{1j} + s_1^+ = \theta_j x_{1j} \\ \sum_{j=1}^n \lambda_j x_{2j} + s_2^+ = \theta_j x_{2j} \\ \sum_{j=1}^n \lambda_j x_{3j} + s_3^+ = \theta_j x_{3j} \\ \sum_{j=1}^n \lambda_j y_{1j} - s_1^- = y_{1j} \\ \sum_{j=1}^n \lambda_j y_{2j} - s_2^- = y_{2j} \\ \sum_{j=1}^n \lambda_j y_{3j} - s_3^- = y_{3j} \\ \sum_{j=1}^n \lambda_j = 1 \\ \lambda_j \geq 0, j = 1, 2, \dots, n \\ s_1^+, s_2^+, s_3^+ \geq 0, s_1^-, s_2^-, s_3^- \geq 0 \end{array} \right. \quad (9) \end{aligned}$$

The above formula represents the technical efficiency value of the j th decision unit. The meaning of each indicator in Equation (9) is the same as Equation (8). In this paper, MaxDEA software is used to realize the process of data processing.

(2) Design of research indicators

This paper divides the input indicators into two types, the first is the energy input indicators, mainly the total energy consumption (tons/standard coal), which represents the overall energy consumption level of the green office, and the energy consumption of the industrial added value of the green office on a regular basis (tons/standard coal/million yuan), which represents the energy use of the green office. The second is the economic input indicators, including fixed asset investment (billion yuan), which represents the green office machinery and equipment and other infrastructure investment, and the on-board industrial R&D expenditure as a proportion

of operating income (%), which represents the green office technology innovation investment. Output indicators are mainly 2, one represents one of the overall financial indicators of operating income (billion yuan), said the current economic strength of the green office, the higher the operating income represents the larger the scale of development of the green office, the other is the proportion of added value of green industry to the value added of industry (%), which is a structural indicator, representing the type of green industry structure, the added value of green industry accounted for the industrial added value of the higher the proportion, the green office of low carbon and low energy consumption. The higher the proportion, the greater the potential for low-carbon development of green office. The meaning of specific indicators is shown in Table 1.

Table 1: Research index

Indicator	Green office environment energy consumption input-output efficiency e
Input indicators	Fixed asset investment (billion yuan)
	The proportion of R&D expenditure of large-scale industrial enterprises to operating income (%)
	Total energy consumption (tons/standard coal)
	Energy consumption of industrial added value in large-scale office buildings (tons of standard coal / 10,000 yuan)
Output indicator	Operating income (billion yuan)
	The proportion of added value of high-tech industries in industrial added value (%)

3 Comprehensive evaluation of indoor environmental energy efficiency in green offices

3.1 Office energy efficiency and regression analysis

3.1.1 Energy efficiency analysis of the office indoor environment

Using the software DEAP2.1 to measure the efficiency of four input indicators and two output indicators of 36 green office indoor environments in 2018 and 2023, the comprehensive efficiency value of BC² model was selected to ensure the scientific and reliable results, and Figure 1 shows the results of the energy input and output efficiency of green office indoor environments.

(1) From a general perspective, from 2018 to 2023, the energy consumption efficiency of the 36 green office indoor environments all showed an upward trend, and the average energy consumption efficiency of the 36 green office indoor environments was 0.514 in 2018, and the average energy consumption efficiency rose to 0.61 in 2023.

(2) It is noteworthy that four of the 36 green office indoor environments have achieved DEA effectiveness in both 2018 and 2023, namely AY, GQC, LS, and GY.

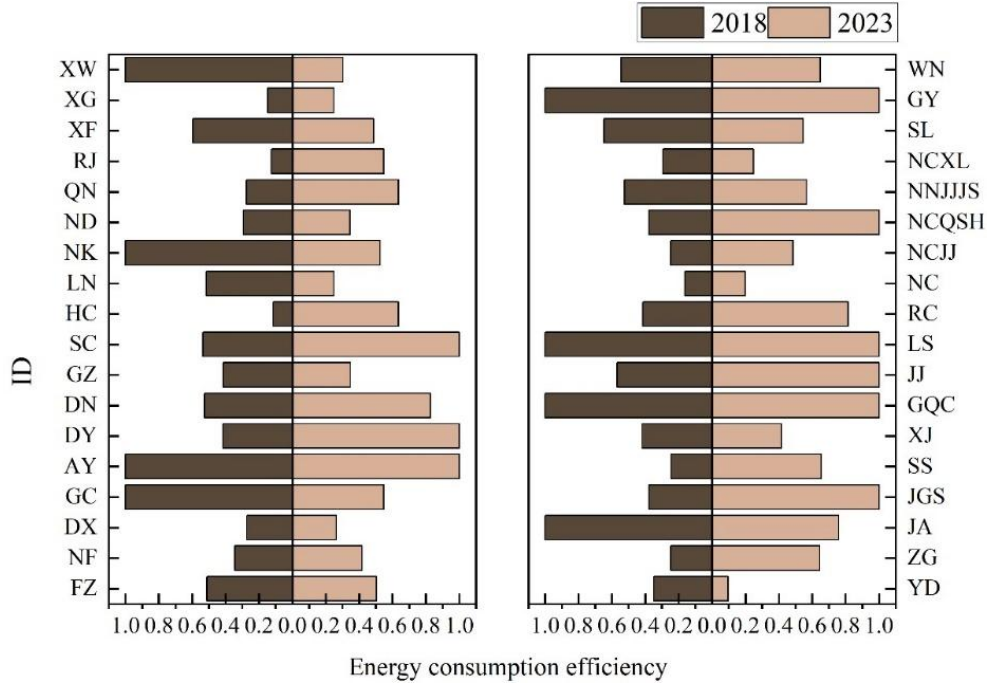


Figure 1: Energy consumption input output efficiency measurement

3.1.2 Energy efficiency regression

The data of 36 green office-related indicators in 2023 are selected to conduct multiple regression analysis on the input-output efficiency of office energy consumption, and the specific expressions are as follows:

$$Y_i = \alpha_i + \sum_{j=1}^n \beta_j X_{ij} + \varepsilon_i \quad (10)$$

where Y_i denotes the energy input-output efficiency of the park, X denotes the dependent variable, i denotes the number of offices, j denotes the number of factors influencing the frequency of inputs and outputs, α_i denotes the intercept term of the model, β_j denotes the regression coefficients of the respective variables, ε_i is the error term of the regression equation.

Taking the data of 36 green office indoor environments in 2023 as an example, Eviews 10.0 software was used to conduct multiple regression analysis on the factors influencing the energy efficiency of green office indoor environments, and the results are shown in Table 2.

The model as a whole passed the F test, and the R^2 reached 0.569, indicating that the influencing factors can explain the dependent variable to a greater extent, and the selection of indicators is reasonable. From the analysis of explanatory variables, industrial added value, fixed asset investment, industrial technology reform investment, energy consumption per unit of output value, and industrial solid waste utilization rate all have a significant impact on the energy efficiency of green office environment. Among them, the value added of industry, the amount of investment in industrial technology reform and the utilization rate of industrial solid waste play a positive role, and the energy consumption efficiency is increased by 0.169, 0.024 and 2.548 units for every increase of 1 unit, respectively. The amount of investment in fixed assets, unit output value of energy consumption on the green office environment energy

efficiency plays a negative role, every increase of 1 unit, the green office environment energy efficiency decreased by 0.204 and 0.056 units respectively. The value added of industry is directly related to the development of green industry, indicating that the development of green industry is good to effectively play the scale effect, thus improving the energy efficiency of green office indoor environment, the larger the amount of investment in industrial technological transformation, the higher the level of green technological innovation, the high level of technological innovation is conducive to reducing energy consumption, the utilization rate of industrial solid waste is an important indicator of the impact of recycling of resources in the green office environment, and the recycling of energy can be Directly and effectively enhance the efficiency of energy consumption, the amount of investment in fixed assets is very important to the green office environment infrastructure construction, but when the green office environment industry development does not keep up with the green office environment infrastructure construction in a timely manner will result in a waste of resources.

Table 2: Multiple regression results of energy consumption efficiency

Explanatory variable	Coefficient
Industrial added value	0.169***
Investment in fixed assets	-0.204***
Investment in industrial technological transformation	0.024**
Energy consumption per unit output value	-0.056*
Industrial solid utilization rate	2.548***
Intercept term	0.529***
R ²	0.569
Prob (F-Statistic)	0.000

3.2 Analysis of the results of the comprehensive evaluation of the indoor environment of green offices

3.2.1 Consolidated energy efficiency values

Figure 2 shows the comprehensive evaluation value of the energy consumption efficiency of the green office indoor environment, and the comprehensive evaluation value of the energy consumption efficiency of the green office indoor environment in the test area shows a fluctuating growth trend, and the indicator has been significantly improved. The value of the green office transformation evaluation index was 0.385 in 2008, and it has already reached 0.825 in 2023, with a growth rate of about 114%, and the data show that during the period from 2008 to 2023 The data show that between 2008 and 2023, the comprehensive evaluation value of energy consumption efficiency in the test area has improved, from the average level to the excellent level, especially since 2020, the comprehensive evaluation value of energy consumption efficiency of the green office indoor environment has increased even faster, which indicates that the green transformation of the office indoor environment in the test area has gained momentum, and that the economy, technology, energy and ecology have developed in a coordinated manner. In general, the overall situation of the green transformation of the indoor office environment in the test region is good, with continuous economic development, technological innovation, optimized energy consumption efficiency and stronger environmental support, and the green transformation of the indoor office environment has made certain achievements and gained sufficient momentum for development.

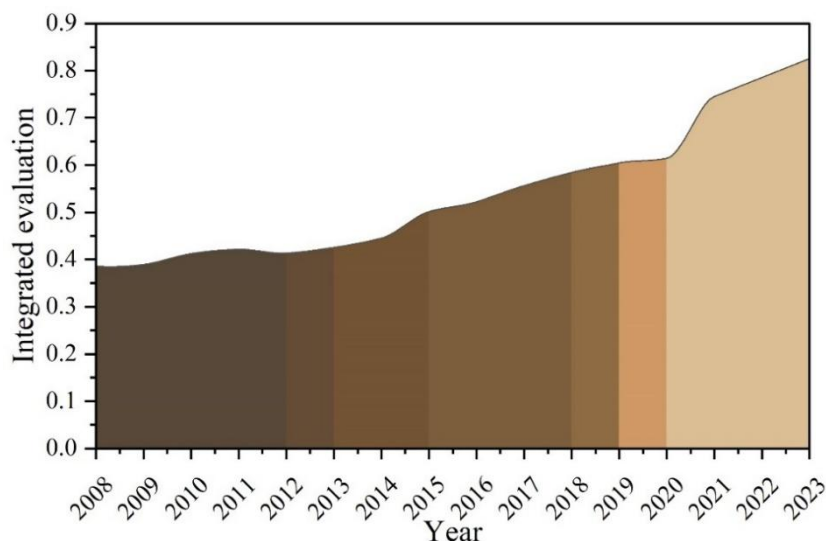


Figure 2: Comprehensive evaluation of energy efficiency

3.2.2 Evaluating energy efficiency

Figure 3 shows the trend of changes in the evaluation value of energy efficiency and specific indicators. Between 2008 and 2023, the evaluation value of the green office indoor environment value added electricity consumption and the evaluation value of the green office indoor environment value added energy consumption are both continuously increasing, indicating that the green office indoor environment value added electricity consumption and energy consumption are decreasing, alleviating the consumption of energy resources, while improving the utilization rate of energy efficiency, which is sufficient to prove that the development level of green transformation of office indoor environment in the test area is effective. The evaluation value of the energy efficiency of the green office indoor environment in the test area shows a “one-word” growth between 2008 and 2023. Power consumption and energy consumption increased from 0.00893 to 0.02711 and 0.01698 to 0.05146, respectively, and the energy efficiency reached 0.07768 in 2023.

Green transformation of the office environment is to improve energy efficiency as the core, reduce environmental pollution for the purpose of realizing the characteristics of the office environment with low consumption and low emissions, and forming a resource-saving manufacturing system. Based on the data envelopment analysis method of specific indicators objectively get the results of the correlation value, in which the weight of the green office environment value-added energy consumption accounts for the largest proportion of energy efficiency, and continued to rise in the “one word” trend and the manufacturing industry energy efficiency is similar. It can be seen that in the evaluation of energy consumption efficiency dimensions, the green office environment value-added energy consumption accounts for the largest role.

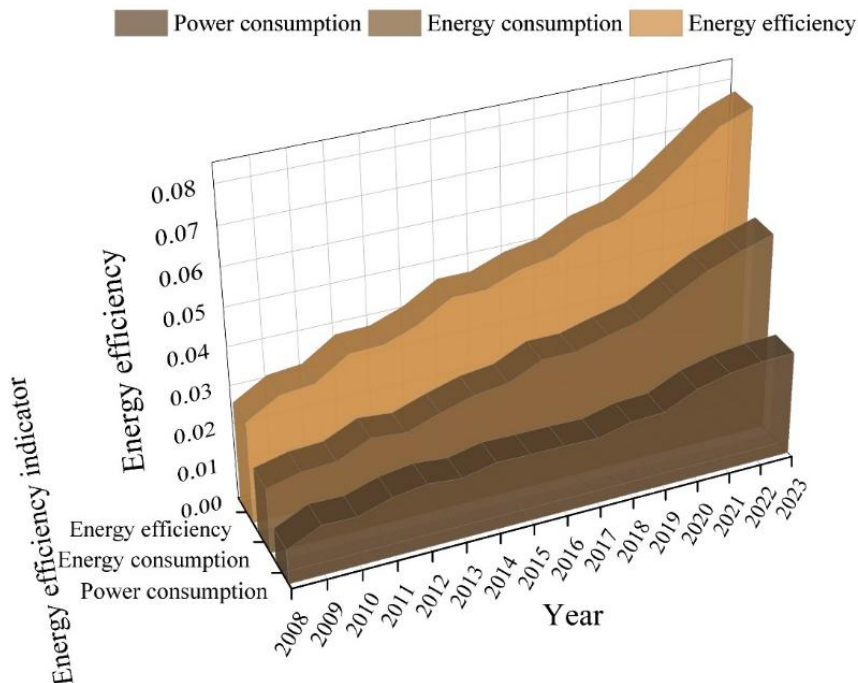


Figure 3: Energy consumption efficiency and specific index evaluation changes

3.3 Evaluation and analysis of environmental energy efficiency in green offices

3.3.1 Combined efficiency

Table 3 shows the comprehensive efficiency analysis, from the overall point of view, the comprehensive efficiency of the technology input of the green office environment in the subject area shows the change of rising first, and the average value of the comprehensive efficiency in 2018, 2021 and 2023 is 0.369. The number of offices whose comprehensive efficiency is in the optimal state, i.e., the DEA efficiency value of 1, in 2018, 2021 and 2023 are respectively 0, 5 and 3, which accounted for 0%, 13.89%, and 8.33% of the total number of sample firms. The DEA efficiency indicates that the technical inputs and outputs of these offices have reached the optimal effect, and the technical resources have been fully utilized. But the proportion of offices with effective comprehensive efficiency in the total number of samples is small. On the other hand, in 2018, there are 19 green offices less than the mean value of comprehensive efficiency of 0.349, accounting for 52.78% of the total sample, in 2021, there are 21 companies less than the mean value of comprehensive efficiency of 0.353, accounting for 58.3% of the total sample, in 2023, there are 20 companies less than the mean value of comprehensive efficiency of 0.405, accounting for 55.56% of the total sample. And the average value of comprehensive efficiency in three years has been at a low level, fluctuating between 0.349~0.405, which indicates that most of the green office indoor environments have a waste of resources in technical input, and there is still a lot of room for improvement in the technical input efficiency of the industry as a whole.

Table 3: Comprehensive efficiency analysis

ID	2018	2021	2023	Mean	Variance
FZ	0.383	0.283	0.555	0.407	0.024
NF	0.138	0.903	0.543	0.528	0.142
DX	0.355	0.219	0.535	0.369	0.026
GC	0.086	0.099	0.245	0.143	0.008
AY	0.086	0.169	0.237	0.164	0.007
DY	0.820	0.349	0.562	0.577	0.042
DN	0.251	0.524	0.794	0.523	0.063
GZ	0.420	0.632	0.625	0.559	0.015
SC	0.020	0.089	0.174	0.094	0.005
HC	0.185	0.083	0.362	0.210	0.013
LN	0.108	0.237	0.239	0.195	0.004
NK	0.765	1.000	0.335	0.700	0.125
ND	0.315	0.482	0.159	0.319	0.026
QN	0.486	0.329	0.717	0.511	0.034
RJ	0.096	0.081	0.085	0.087	0
XF	0.403	0.345	0.210	0.319	0.015
XG	0.060	0.037	0.196	0.098	0.014
XW	0.245	0.084	0.342	0.224	0.005
YD	0.639	0.177	0.248	0.355	0
ZG	0.348	1.000	1.000	0.783	0.053
JA	0.715	1.000	0.535	0.750	0.012
JGS	0.283	0.068	0.142	0.164	0.019
SS	0.996	0.565	0.410	0.657	0.012
XJ	0.392	0.378	0.344	0.371	0.032
GQC	0.965	1.000	1.000	0.988	0
JJ	0.992	0.599	0.454	0.682	0.052
LS	0.204	1.000	0.825	0.676	0.014
RC	0.934	0.595	0.915	0.815	0.018
NC	0.517	0.227	0.904	0.549	0.002
NCJJ	0.412	0.401	1.000	0.604	0
NCQSH	0.078	0.051	0.068	0.065	0.023
NNJJJS	0.086	0.282	0.015	0.128	0.005
NCXL	0.430	0.033	0.013	0.159	0.045
SL	0.026	0.361	0.180	0.189	0.152
GY	0.009	0.031	0.213	0.084	0.125
WN	0.226	0.209	0.086	0.174	0.034
Mean	0.349	0.353	0.405	0.369	0.002
Variance	0.012	0.008	0.005	0.008	

3.3.2 Technical efficiency

Pure technical efficiency is the input-output efficiency without considering the factor of scale compensation, which refers to the degree of technical input efficiency improvement driven by the enterprise after improving the ability of technology utilization, and it is mainly used to evaluate whether the sample green office can obtain the optimal output of each input factor under the level of technology and management, and it also reflects the ability of the green office to control the technical input factors and management ability. When the value of pure technical efficiency is equal to 1, it indicates that the technology and management level of the green office has reached the optimization, and when the value of pure technical efficiency is less than 1, it indicates that the technology and management level of the green office still needs to be improved. The results of the pure technical efficiency measurement of the 36 green offices in 2018, 2021 and 2023 are shown in Table 4.

On the whole, the mean values of pure technical efficiency of the sample green offices in 2018, 2021 and 2023 are 0.519, 0.539 and 0.582, respectively, showing an increase as the change of the mean value of comprehensive efficiency. The number of green offices with optimal pure technical efficiency in 2018, 2021 and 2023 is 7, accounting for 19.44% of the

total number of sample green offices. 19.44%. It shows that these green offices have achieved good results in terms of proprietary technology mastery, technological innovation and internal management control. Moreover, compared with the green offices with the best overall efficiency, the number of green offices with the best pure technical efficiency increases significantly. This also indicates that some green offices have achieved optimal outputs in terms of technical and managerial inputs, regardless of the returns to scale. This shows that green offices need to pay more attention to their technical level and management mechanism, and need to continue to strengthen the investment in technical research and development and the internal management of technical staff in green offices, and further improve their own management policy and management system. However, the average value of pure technical efficiency in 2023 has increased compared with the previous two years, which also indicates that with the strengthening of China's attention to the green industry, the implementation of a number of industrial policies to enhance the level of technology, so that the overall technological content of green industry technology has been improved, and technology management tends to be standardized, so that the pure technical efficiency has shown an upward trend.

Table 4: Pure technical efficiency

ID	2018	2021	2023	Mean	Variance
FZ	0.415	0.348	0.648	0.470	0.034
NF	0.265	0.969	0.858	0.697	0.145
DX	0.468	0.425	0.748	0.547	0.035
GC	0.348	0.526	1	0.625	0.185
AY	0.248	0.348	0.369	0.322	0.003
DY	0.856	0.415	0.642	0.638	0.034
DN	0.296	0.636	0.848	0.593	0.085
GZ	0.648	1	1	0.883	0.034
SC	0.074	0.148	0.245	0.156	0.015
HC	0.536	0.266	0.569	0.457	0.024
LN	0.154	0.315	0.284	0.251	0.005
NK	1	1	0.348	0.783	0.124
ND	1	1	0.748	0.916	0.023
QN	0.526	0.348	0.768	0.547	0.048
RJ	0.345	0.315	0.348	0.336	0
XF	0.418	0.364	0.248	0.343	0.015
XG	0.175	0.148	0.266	0.196	0.001
XW	1	0.458	0.548	0.669	0.096
YD	1	0.248	0.297	0.515	0.005
ZG	0.348	1	1	0.783	0
JA	0.715	1	0.648	0.788	0.031
JGS	0.348	0.185	0.185	0.239	0.015
SS	1	0.596	0.448	0.681	0.019
XJ	0.415	0.436	0.428	0.426	0.034
GQC	0.965	1	1	0.988	0
JJ	1	0.636	0.485	0.707	0.018
LS	0.215	1	1	0.738	0
RC	1	0.636	1	0.879	0.034
NC	0.526	0.248	0.987	0.587	0.185
NCJJ	0.526	0.485	1	0.670	0.096
NCQSH	0.101	0.241	0.163	0.168	0.035
NNJJJS	0.348	0.548	0.615	0.504	0.002
NCXL	0.515	0.096	0.085	0.232	0.048
SL	0.048	0.485	0.516	0.350	0.158
GY	0.185	0.696	0.248	0.376	0
WN	0.648	0.856	0.348	0.617	0.465
Mean	0.519	0.539	0.582	0.547	0.057
Variance	0.145	0.096	0.084	0.064	

3.3.3 Efficiency of scale

Table 5 shows the scale efficiency, the mean values of scale efficiency during 2018, 2021 and 2023 are: 0.673, 0.655 and 0.696 respectively. In general, the scale efficiency of green offices during the study period is at a high level. The number of firms with a scale efficiency value equal to 1 in both 2018 and 2023 is 3, which is 8.33% of the total number of the sample, and in 2021 the number of firms with a scale efficiency value equal to 1 in 2021 is 5 firms, accounting for 13.89% of the total sample. Among them, two enterprises keep the scale efficiency of 1 for three years, indicating that these enterprises have reached the scale efficient state and realized the optimal ratio of technical inputs and outputs. There are 15 enterprises with scale efficiency less than the mean in 2018, and 16 enterprises with scale efficiency less than the mean in 2021. In 2023, there are 13 enterprises with scale efficiency less than the mean, and 23 enterprises with scale efficiency greater than the mean, accounting for 63.89% of the total number of the samples. In 2023, there are 13 enterprises with scale efficiency less than the mean and 23 enterprises with scale efficiency greater than the mean, accounting for 63.89% of the total number of the sample. This shows that the actual size of most green offices matches their technology and management level.

It should be noted that there is still a gap between the actual size and the optimal size of enterprises, which requires enterprises to consider expanding or downsizing on the basis of strengthening technology and management level. The vast majority of green offices have increasing returns to scale, with only two to three having decreasing returns to scale. This indicates that the green industry is in a period of rapid development and has good development prospects, so it should invest more in technology in order to obtain more benefits. The increasing returns to scale of green offices are mainly caused by technology, management and other factors. The green industry has been adhering to the development concept of “more light, less water, new technology, high performance”, and the offices in the green industry have been paying great attention to the investment and application of technology, expanding the scale of the enterprise and improving the production efficiency through the introduction of domestic and foreign advanced equipment, technology or increasing financial support.

Table 5: Scale efficiency

ID	2018	2021	2023	Mean	Variance
FZ	0.924	0.812	0.856	0.864	0.035
NF	0.521	0.932	0.633	0.695	0.024
DX	0.758	0.515	0.715	0.663	0.012
GC	0.248	0.188	0.245	0.227	0.002
AY	0.345	0.485	0.642	0.491	0.023
DY	0.958	0.842	0.875	0.892	0.005
DN	0.848	0.824	0.936	0.869	0.002
GZ	0.648	0.632	0.625	0.635	0
SC	0.264	0.602	0.712	0.526	0.054
HC	0.345	0.312	0.636	0.431	0.036
LN	0.704	0.752	0.842	0.766	0.008
NK	0.765	1	0.963	0.909	0.012
ND	0.315	0.482	0.212	0.336	0.018
QN	0.924	0.945	0.934	0.934	0
RJ	0.278	0.256	0.245	0.260	0.002
XF	0.965	0.948	0.845	0.919	0.001
XG	0.345	0.248	0.736	0.443	0.065
XW	0.245	0.183	0.624	0.351	0.042
YD	0.639	0.715	0.836	0.730	0.013
ZG	1	1	1	1.000	0
JA	1	1	0.826	0.942	0.002
JGS	0.812	0.369	0.765	0.649	0.043
SS	0.996	0.948	0.915	0.953	0
XJ	0.945	0.866	0.804	0.872	0.004
GQC	1	1	1	1.000	0
JJ	0.992	0.942	0.936	0.957	0.005
LS	0.948	1	0.825	0.924	0.008
RC	0.934	0.936	0.915	0.928	0
NC	0.983	0.915	0.916	0.938	0.002
NCJJ	0.783	0.826	1	0.870	0.013
NCQSH	0.768	0.212	0.415	0.465	0.083
NNJJJS	0.248	0.515	0.025	0.263	0.125
NCXL	0.835	0.345	0.154	0.445	0.325
SL	0.548	0.745	0.348	0.547	0.012
GY	0.048	0.045	0.858	0.317	0.125
WN	0.348	0.244	0.248	0.280	0.024
Mean	0.673	0.655	0.696	0.675	0.002
Variance	0.086	0.086	0.056	0.076	

4 Green Office Indoor Environment Energy Saving and Emission Reduction Suggestions

After a comprehensive evaluation of the energy efficiency of 36 green office indoor environments, it is known that most green office indoor environments have a waste of resources of technical inputs, and there is still a lot of room for improvement in the energy efficiency of

the green industry as a whole, for which this paper extracts the following suggestions:

4.1 Conduct comprehensive equipment energy-saving renovation

Green office indoor environmental transformation, should be based on the climate of the region where it is located, the use of appropriate wall insulation methods, so that it obtains good thermal insulation capacity, at the same time, can also make the office energy consumption has been significantly reduced. In winter or summer, you can always open the door into a revolving door or the first door and the second door in a vertical staggered direction, in addition to the staff channel as well as the goods channel and the door hopper, such as the addition of door curtains, in order to avoid the escape of indoor temperature. In the office facade of the glass curtain wall, should be based on the actual needs of the appropriate glass reflectivity of the film, translucent curtain wall should be partially open or set up a breathable device, and excellent airtight.

4.2 Strengthen operation and maintenance management intelligent management system

Increase budgetary funds for the operation and maintenance of the intelligent management system. Problems such as mismatches between office site equipment and back-office design and irregularities in construction and installation are problems arising from the design and construction phases, while the technical level of operational managers at the operation and management phase is insufficient to solve the above problems, so it is necessary to increase budgetary funding for system operation and maintenance, and a third-party company will carry out operation and maintenance of the system.

4.3 Strengthen the operation standard and maintenance assessment of property management personnel

Mechanical and electrical equipment operating standards and maintenance programs developed after the implementation of the individual, the good operation of equipment and facilities also depends largely on the daily standardized operation and efficient maintenance. Therefore, it is necessary to strengthen the operation specification and maintenance assessment of property management personnel.

5 Conclusion

This paper proposes a formula for calculating the energy transfer efficiency of green office indoor environments based on the assessment and recognition guidelines for green office buildings. Using the data envelopment analysis method, C^2R and BC^2 models were established through two-stage DEA regression to analyze the energy efficiency of green office indoor environments, respectively.

Taking the data of 36 green office indoor environments as an example, the multiple regression analysis was conducted to analyze the influencing factors of energy consumption efficiency of green office indoor environments, and the model as a whole passed the F test, and the R^2 reached 0.569, and the influencing factors were able to explain the dependent variable to a greater extent, and the indexes were selected with reasonableness to enable a deeper level analysis.

The comprehensive evaluation value of energy consumption efficiency shows that the comprehensive evaluation value of energy consumption efficiency of green office indoor

environment in the test area shows a fluctuating growth trend, and the index has been significantly improved in recent years, compared with the evaluation index value of 0.385 in 2008, the index value of 0.825 in 2023, with a growth rate of about 114%. It shows that the overall condition of the green transformation of the indoor environment of the office in the test area is good, and the energy consumption efficiency has been optimized.

However, from the point of view of the comprehensive efficiency of green office environment energy consumption, the comprehensive efficiency in 2018, 2021 and 2023 fluctuates between 0.349 and 0.405, indicating that there is still a lot of room for improvement in the efficiency of the technical input of the industry as a whole. Therefore, to address this situation, this paper proposes a corresponding solution to further optimize the energy efficiency situation of green office indoor environment.

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References

- [1] Ashmawy, R. A. E., Ragheb, A. A., Ragheb, G., & Marouf, O. (2024). Sustainable Design Principles for Green Office Buildings: A Comprehensive Review. *International Journal of Sustainable Development & Planning*, 19(6).
- [2] Chen, X., Yang, H., & Lu, L. (2015). A comprehensive review on passive design approaches in green building rating tools. *Renewable and Sustainable Energy Reviews*, 50, 1425-1436.
- [3] Wu, X., Lin, B., Papachristos, G., Liu, P., & Zimmermann, N. (2020). A holistic approach to evaluate building performance gap of green office buildings: A case study in China. *Building and Environment*, 175, 106819.
- [4] Cai, S., & Gou, Z. (2023). A comprehensive analysis of green building rating systems for data centers. *Energy and Buildings*, 284, 112874.

- [5] Geng, Y., Lin, B., & Zhu, Y. (2020). Comparative study on indoor environmental quality of green office buildings with different levels of energy use intensity. *Building and Environment*, 168, 106482.
- [6] Zuo, J., Xia, B., Chen, Q., Pullen, S., & Skitmore, M. (2016). Green building rating for office buildings—Lessons learned. *Journal of Green Building*, 11(2), 131-146.
- [7] Jasimin, T. H., & Ali, H. M. (2015). Valuation of green commercial office building: A preliminary study of Malaysian valuers' insight. *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, 9(8), 1156-1161.
- [8] Yau, Y. H., & Lim, K. S. (2016). Energy analysis of green office buildings in the tropics—photovoltaic system. *Energy and Buildings*, 126, 177-193.
- [9] Singh, A., Syal, M., Grady, S. C., & Korkmaz, S. (2010). Effects of green buildings on employee health and productivity. *American journal of public health*, 100(9), 1665-1668.
- [10] Assad, M., Hosny, O., Elhakeem, A., & El Hagggar, S. (2015). Green building design in Egypt from cost and energy perspectives. *Architectural Engineering and Design Management*, 11(1), 21-40.
- [11] Rajabi, M., Sardroud, J. M., & Kheyroddin, A. (2021). Green standard model using machine learning: identifying threats and opportunities facing the implementation of green building in Iran. *Environmental Science and Pollution Research*, 28(44), 62796-62808.
- [12] Alsulaili, A. D., Al-Matrouk, M. F., Al-Baghli, R. A., & Al-Enezi, A. F. (2020). Environmental and economic benefits of applying green building concepts in Kuwait. *Environment, Development and Sustainability*, 22(4), 3371-3387.
- [13] McArthur, J. J., & Powell, C. (2020). Health and wellness in commercial buildings: Systematic review of sustainable building rating systems and alignment with contemporary research. *Building and environment*, 171, 106635.
- [14] Jin, Q., & Wallbaum, H. (2020, November). Improving indoor environmental quality (IEQ) for occupant health and well-being: A case study of Swedish office building. In *IOP Conference Series: Earth and Environmental Science* (Vol. 588, No. 3, p. 032072). IOP Publishing.
- [15] Miraj, P., Berawi, M. A., & Utami, S. R. (2021). Economic feasibility of green office building: combining life cycle cost analysis and cost-benefit evaluation. *Building Research & Information*, 49(6), 624-638.
- [16] Cedeño-Laurent, J. G., Williams, A., MacNaughton, P., Cao, X., Eitland, E., Spengler, J., & Allen, J. (2018). Building evidence for health: green buildings, current science, and future challenges. *Annual review of public health*, 39, 291-308.
- [17] Lu, S., Li, J., & Lin, B. (2020). Reliability analysis of an energy-based form optimization of office buildings under uncertainties in envelope and occupant parameters. *Energy and Buildings*, 209, 109707.

- [18] Zhao, W., Peng, P., Guo, B., Deng, X., & Wu, W. (2023). Comprehensive social cultural and economic benefits of green buildings based on improved AHP–FCE method. *Buildings*, 13(2), 311.
- [19] Chen, Y., Tan, H., & Berardi, U. (2018). A data-driven approach for building energy benchmarking using the Lorenz curve. *Energy and Buildings*, 169, 319-331.
- [20] Asdrubali, F., Baldinelli, G., Bianchi, F., & Sambuco, S. (2015). A comparison between environmental sustainability rating systems LEED and ITACA for residential buildings. *Building and Environment*, 86, 98-108.
- [21] Šuman, N., Marinič, M., & Kuhta, M. (2020). A methodological framework for sustainable office building renovation using green building rating systems and cost-benefit analysis. *Sustainability*, 12(15), 6156.
- [22] Kim, Y., & Yu, K. H. (2020). Study on the certification policy of zero-energy buildings in Korea. *Sustainability*, 12(12), 5172.
- [23] Remizov, A., Tukaziban, A., Yelzhanova, Z., Junussova, T., & Karaca, F. (2021). Adoption of green building assessment systems to existing buildings under Kazakhstani conditions. *Buildings*, 11(8), 325.
- [24] Ikudayisi, A. E., Chan, A. P., Darko, A., & Adegun, O. B. (2022). Integrated design process of green building projects: A review towards assessment metrics and conceptual framework. *Journal of Building Engineering*, 50, 104180.
- [25] Griego, D., Krarti, M., & Hernandez-Guerrero, A. (2015). Energy efficiency optimization of new and existing office buildings in Guanajuato, Mexico. *Sustainable Cities and Society*, 17, 132-140.
- [26] Son, H., Lee, S., & Kim, C. (2015). An empirical investigation of key pre-project planning practices affecting the cost performance of green building projects. *Procedia Engineering*, 118, 37-41.
- [27] Dwaikat, L. N., & Ali, K. N. (2018). Green buildings life cycle cost analysis and life cycle budget development: Practical applications. *Journal of Building Engineering*, 18, 303-311.
- [28] Latha, H., Patil, S., & Kini, P. G. (2023). Influence of architectural space layout and building perimeter on the energy performance of buildings: A systematic literature review. *International Journal of Energy and Environmental Engineering*, 14(3), 431-474.
- [29] Dwaikat, L. N., & Ali, K. N. (2018). The economic benefits of a green building—Evidence from Malaysia. *Journal of Building engineering*, 18, 448-453.