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Application of Variable Fuzzy Sets in the Evaluation of Energy-saving Design of Public Buildings

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Today, the process of economic globalization is accelerating, the construction industry is developing faster and faster, and users have higher and higher requirements for appearance, intelligence, and architecture, but the energy waste that comes with it is also becoming increasingly obvious. In order to improve the energy-saving efficiency of public buildings and realize low-carbon sustainable development, this paper applies variable fuzzy sets to the energy-saving evaluation of public building design. This paper conducts a comprehensive analysis from the aspects of public building energy consumption, collection frequency and energy collection time-consuming test, building's annual cumulative load, energy consumption and energy saving rate. In the collection frequency and energy consumption collection time-consuming test, when collecting once every 6 minutes, theoretically 60 collection points are the same as 40 and 20 collection points, but the actual time consumption is not equal. Therefore, in order to ensure the performance of system data processing, an appropriate acquisition frequency should be set to ensure the normal operation of the system. Comprehensive experimental results show that the variable fuzzy set can achieve a well-controlled level of energy consumption in the design of public buildings.

Keywords: Variable Fuzzy Sets, Public Building Design, Energy Efficiency Evaluation, Energy Harvesting

1. INTRODUCTION

Energy is the basis for human survival and development. With the continuous progress of society and the continuous development of economy, the material conditions for people's development are getting higher and higher, directly or indirectly leading to a growing demand for energy. Unfortunately, in reality, energy consumption is not very efficient, and there is a lot of waste, resulting more limited energy supply. Therefore, researchers in the field of materials have begun to pay attention to how to improve energy efficiency. To fully improve energy efficiency, we can temporarily store unused energy and release it when needed.

Public buildings are an important part of the urban structure, and urban buildings are energy-consuming. Office buildings account for a relatively high proportion of public buildings. There are many small and medium-sized office buildings in most cities. Although the energy consumption per unit area of these buildings is much lower than that of large public buildings, they are widely distributed and large in number. Some of them have not even done energy-saving treatment, so the total energy waste is very huge. In order to solve this problem, it is necessary to start with energy-saving building design, clarifying the characteristics of hot summer and cold winter areas, so that local small and medium-sized office buildings have better in built energy-saving technical measures, and the energy consumption is actually reduced, which is a sustainable development for the country.

Based on the application of variable fuzzy sets in the energy efficiency evaluation of public building design, many scholars at home and abroad have carried out related research. Herrera-Franklin J proposed the variable cost and size packing problem that is a known NP-Hard problem, which includes minimizing

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the cost of all boxes used to pack a group of items. The scholar discussed an unexplored aspect, including relaxing the set of items to be packaged. The main contribution is to allow incomplete packaging of a fuzzy version of VCSBPP, and proposed an experimental study to explore the proposed fuzzy VCSBPP and its solutions. This scholar conducts research on variable fuzzy sets, but lacks the necessary literature review [1]. Ahmed D mainly focuses on the concept of fuzzy rough sets of pictures in two different universes, which depends on the segmentation of the fuzzy relationship of pictures in two different universes. Then, the scholar discussed several interesting characteristics and related results of PFRS, and defined some concepts related to PFRS. The scholar conducts research on fuzzy sets, but lacks relevant applications [2] thus lacking validation of the approach. In order to study the potential scope reductions used in major construction projects of special-purpose buildings, Olsson N collected information on the results of these possible reductions from 11 public construction projects. The study's first study on how to use potential curtailment in public construction projects, these findings are related to the cost control of major investments in facilities. The scholar collected information on public buildings, but did not make proposals improve it [3]. Adedayo O aims to study the nature of the hybrid fence design that is used in public buildings in Kigali, with a view to proposing favorable applications to ensure environmental sustainability in Nigeria. The research method used is a qualitative method, using a case study of selected public buildings in Kigali and buildings in Abuja, Nigeria. The scholar did not introduce concepts from other fields that might improve public buildings [4]. Auh aims to reduce the energy consumption of cooling and heating by recommending the appropriate length and shape of the external horizontal shading devices in public buildings. In this process, actual energy data and the Design Builder simulation program were used. In addition, economic factors were also considered to determine the optimal length of the external horizontal shading device to maximize efficiency. The scholar conducted various researches on energy conservation, but did not propose improvements [5]. Through the analysis of the status quo, Trubaev PA concludes that standard economic analysis methods are used to evaluate the efficiency of energy-saving projects in the heating system, so as to meet their own needs or have difficulties for monopolistic enterprises. It is recommended to use the forecast of the main cost value of heat production in the price of the accounting period instead of the discount method, that is, not to include the cash flow on a unified basis. This scholar conducts energy-saving research on the heating system, but there is no design related model [6]. Rnkk E addresses the challenges and capacity gaps faced by public administration departments in the context of digital transformation and the use of new tools in the context of land use, facilities and urban service planning. Through pilot trials conducted in two Finnish cities, it introduced and reflected the current state of Finnish planning and management processes. The scholar studied public facilities, but did not incorporate related algorithms or models [7].

The present paper conducts related research based on the application of variable fuzzy sets in the energy efficiency evaluation of public building design. In the method part, this paper introduces the concept, advantages and related algorithm applications of variable fuzzy sets. In addition, it also introduces the related knowledge of public buildings and the effects and indicators of energy-saving evaluation. In the algorithm, the theory and theorem of variable fuzzy set are introduced, including relative membership function, fuzzy variable set, variable domain and quantitative variable domain of variable factor set, etc. In the part of experiment and results, this paper conducts a comprehensive analysis from the aspects of public building energy consumption, collection frequency and energy collection time-consuming test, annual cumulative load, energy consumption and energy saving rate. The innovation of this paper is to apply the variable fuzzy set algorithm to the energy-saving evaluation of public buildings to provide a new theoretical basis for the energy-saving design of public buildings.

2. VARIABLE FUZZY SET IN ENERGY EFFICIENCY EVALUATION OF PUBLIC BUILDING DESIGN METHOD

2.1 Variable Fuzzy Sets

Variable fuzzy set theory is a breakthrough in membership degree, membership function uniqueness and static nature of fuzzy set theories, and it provides a new theoretical basis for the study of change models and change parameters in the engineering field. The core concepts of the variable fuzzy set theory are the relative membership function, the fuzzy variable set and the level feature variable value. The change model and model parameters in the engineering field established by it enhance the credibility of evaluation, decision-making and prediction [8–9]. Fuzzy comprehensive evaluation transforms qualitative evaluation into quantitative evaluation based on the membership theory of fuzzy mathematics. A large number of vague concepts such as connotation and extension are not clear enough, and expressed in a quantitative form to improve the objectivity of qualitative evaluation [10].

The application of fuzzy set theory in the energy efficiency evaluation of public buildings is a new attempt, and suitable for complete evaluation of multiple system indicators. The method is quite strict, accurate and reliable. It is not only an innovation in safety assessment methods, but also more open, providing a scientific theoretical basis for the creation of energy efficiency models. Energy-saving estimation based on fuzzy set variable set theory can fully investigate the transformation of various indicators to energy-saving estimation, choose different thresholds, quantify various fuzzy factors, and establish the most suitable mathematical model for the object. And it makes the results of the safety assessment more scientific and logical, and provides a scientific basis for the decision-making and optimization of construction managers [11].

Applying the variable fuzzy set theory to the safety evaluation of existing buildings has the following advantages:

(1) Variable fuzzy method can scientifically determine the relative membership of the sample index to the standard

interval of the indicators at all levels and can change the model and its parameters. It can reasonably determine the evaluation grade of the sample and improve the reliability of the evaluation of the sample grade.

(2) The variable fuzzy method organically combines qualitative and quantitative methods. For qualitative indicators, expert scoring methods can be used. For quantitative indicators, data can be directly collected on-site for safety evaluation, avoiding all data in the safety evaluation process. The shortcomings all come from expert experience, which not only accords with objective reality, but also makes full use of expert experience.

(3) Treating the evaluation criteria in the form of intervals instead of points, taking full account of the fuzzy attributes of things.

(4) The calculation process is simple, there is no complicated calculation formula, and the evaluation result can be easily calculated by excel software [12–13].

2.2 Variable Fuzzy Set Theory and Theorem

(1) Relative membership function

Assuming that M is a fuzzy concept above the threshold K, where k is any element on the threshold K and satisfies $k \in K$, then at any point on the continuous axis of the relevant membership function, the relative feature M of k representing attractiveness is $\lambda_M(k)$. The relative feature of M^b represents the excluded feature [14], namely$\lambda_{M^b}(k)$. Assume:

$$T_M(k) = \lambda_M(k) - \lambda_{M^b}(k) \tag{1}$$

The parameter $T_M(k)$ is called the relative difference of k to M. There is a mapping here:

$$\begin{cases} T_M{:}T \to [-1, 1] \\ k| \to T_M(k) \in [-1, 1] \end{cases} \tag{2}$$

This mapping is called the relative difference function of k to M. And due to:

$$\lambda_M(k) + \lambda_{M^b}(k) = 1 \tag{3}$$

About $D_M(k)$, there exists:

$$D_M(k) = 2\lambda_M(k) - 1 \tag{4}$$

Or:

$$\lambda_M(k) = (1 + T_M(k))/2 \tag{5}$$

(2) Fuzzy variable set

Let the fuzzy variable set F exist:

$$\begin{aligned} F = \{(k, T)\}k \in K, T_M(k) \\ = \lambda_M(k) - \lambda_{M^b}(k), T \in [-1, 1]\} \end{aligned} \tag{6}$$

The variable set F has an attractive domain, a repulsive domain, and a gradual qualitative change domain [15], among which the attractive domain L_+ includes:

$$L_+ = \{k|k \in K, 0 < T_M(k) \leq 1\} \tag{7}$$

The exclusion domains L_- are:

$$L_- = \{k|k \in K, -1 < T_M(k) \leq 0\} \tag{8}$$

Gradual qualitative change boundary L_0 is:

$$L_0 = \{k|k \in K, T_M(k) = 0\} \tag{9}$$

(3) Variable domain and quantitative variable domain of variable factor set

Let H be the variable factor set of F, and its formula is:

$$H = \{H_m, H_n, H_o\} \tag{10}$$

Among them, H_m is the model variable set, and H_n is the model parameter variable set, and H_o is the variable other factor set except the model and its parameters.

Suppose, L^- and L^+ exist:

$$\begin{aligned} L^- = H(L_+) = \{k|k \in K, 0 < T_M \leq 1, -1 \\ < T_M(H(k)) \leq 0\} \end{aligned} \tag{11}$$

$$\begin{aligned} L^+ = H(L_-) = \{k|k \in K, -1 < T_M \leq 0, 0 \\ < T_M(H(k)) \leq 1\} \end{aligned} \tag{12}$$

They are collectively referred to as the variable domain of the fuzzy variable set V on the variable factor set C, and we can get:

$$\begin{aligned} L^{(+)} = H(L_{(+)}) = \{k|k \in K, 0 < T_M \leq 1, 0 \\ < T_M(H(k)) \leq 1\} \end{aligned} \tag{13}$$

$$\begin{aligned} L^{(-)} = H(L_{(-)}) = \{k|k \in K, -1 \\ < T_M \leq 0, -1 < T_M(H(k)) \leq 0\} \end{aligned} \tag{14}$$

The above two are collectively called the variable domain of fuzzy variable set F with respect to variable factor set H [16].

(4) Relative difference function model based on variable fuzzy set theory

Let R be a point of $T_M(k) = 1$ in the range of attraction domain [i,j]. According to physical analysis, it can be concluded that R does not necessarily fall at the midpoint of the interval [i,j]. If m is any point in the interval M, then m falls into the relative difference function model when entering the left side of point R is:

$$\begin{cases} T_M(k) = \left[\frac{m-i}{R-i}\right]^\alpha, m \in [i, R] \\ T_M(k) = \left[\frac{m-i}{l-i}\right]^\alpha, m \in [l, i] \end{cases} \tag{15}$$

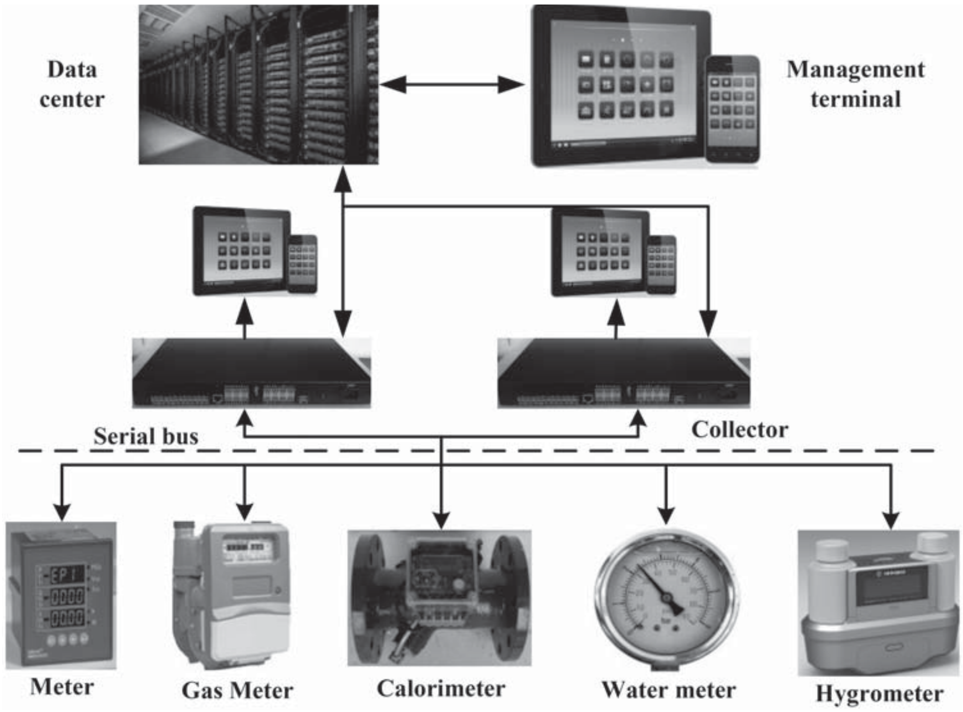


Figure 1 Energy consumption monitoring system.

2.3 Public Building Design

Green building introduces the concept of sustainability into the building. Compared with the traditional architectural design process, it is generally necessary to wait for the design plan to be completed in the preliminary design stage, and then use the preliminary design results to proceed in parallel at the macro and micro levels from the site selection, decision-making, conception, operation planning and technical evaluation of the project, to the operation and management after the completion of the project [17]. In the complete design process of a green building, the entire design process is initially divided into several stages according to the actual situation of the building. The tasks in each stage are specifically for the sub-tasks related to the cycle, so the entire design process is called a cycle. Continuous progress shortens the design cycle and provides real-time feedback on design information and other goals [18]. Figure 1 shows the energy consumption monitoring system.

In the design of green buildings, based on the needs of users for buildings, buildings can be integrated into the environment, emphasizing that the design must take into account nature and not harm the environment as a condition for achieving sustainable development. First of all, green buildings must be environmentally friendly and energy-saving. Architectural design requires comprehensive utilization of environmental protection, saving resources and materials, environment, etc., rationally designing material supply areas, and reducing transportation costs. Priority is given to materials and technologies promoted by countries and regions to extend the life of buildings [19]. Secondly, the development of green buildings requires the designer to have the concept of sustainability in mind, and the user must also have this idea, considering the status quo, location, and long-term considerations. When designing green buildings and constructing ecological construction projects, we must strictly follow the laws of natural development. The immediate benefits are very tempting, but we must not only look at the immediate benefits, but consume our future wealth at the expense of economic growth and achieving its sustainable development. Finally, green buildings focus on the concept of harmony and unity. Of course, green buildings need to stand up over time. From the design stage, consider how to use the least materials to improve structural safety, housing and energy saving; in the construction phase and the final stage of operation, consider the energy load and environmental impact of the building. Later demolition and construction will return to nature to complete and maximize economic growth, social development and environmental harmony [20].

The magnitude of energy saving depends firstly on the energy saving potential of public buildings. Through the analysis of public building site conditions, energy consumption bill analysis, system operation mode analysis, management method analysis, and efficiency analysis of each energy consumption system, we can finally determine whether public buildings have energy-saving potential and whether energy-saving renovations can be carried out. The greater the energy-saving potential of public buildings, the greater the space for energy-saving renovation and the greater the amount of energy saved [21–22]. Figure 2 shows a schematic diagram of a public building.

2.4 Energy-Saving Evaluation

Energy-saving renovation is the concept of energy-saving in existing buildings. As far as traditional building renovation

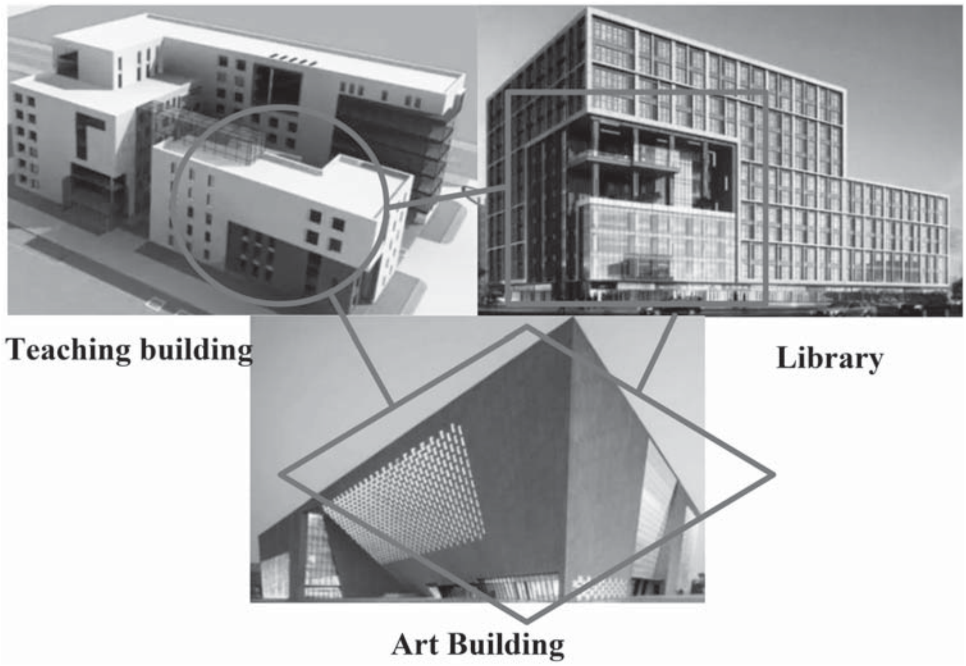


Figure 2 Several public buildings.

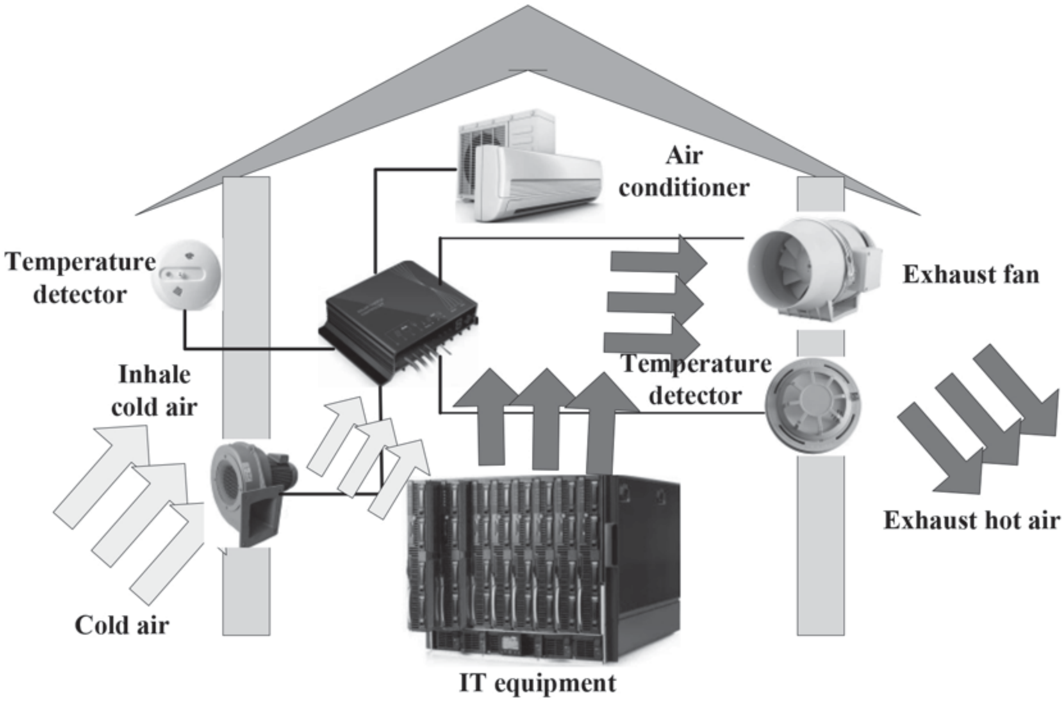


Figure 3 Energy-saving mode in buildings.

is concerned, renovation refers to the renovation of existing buildings that do not meet the current use requirements to improve functional use, enhance the stability of the building structure, and improve the quality of the building environment. Under the current background and trend of green growth, the renovation of existing buildings is often accompanied by energy-saving requirements, especially for existing office buildings with high energy consumption, in order to achieve the goal of green and sustainable development. It can be determined from the concept of energy saving that the specific content of building energy efficiency is based on the principle of improving energy efficiency, not just low energy consumption [23]. The ease of use of space is also an important aspect of energy-saving renovation-the renovation of existing office buildings. Figure 3 shows the energy-saving mode in the building.

For office buildings, the efficiency of the building is largely energy-efficient. The performance of a building is mainly affected by the energy consumption of the building. However, due to the high energy consumption of office buildings,

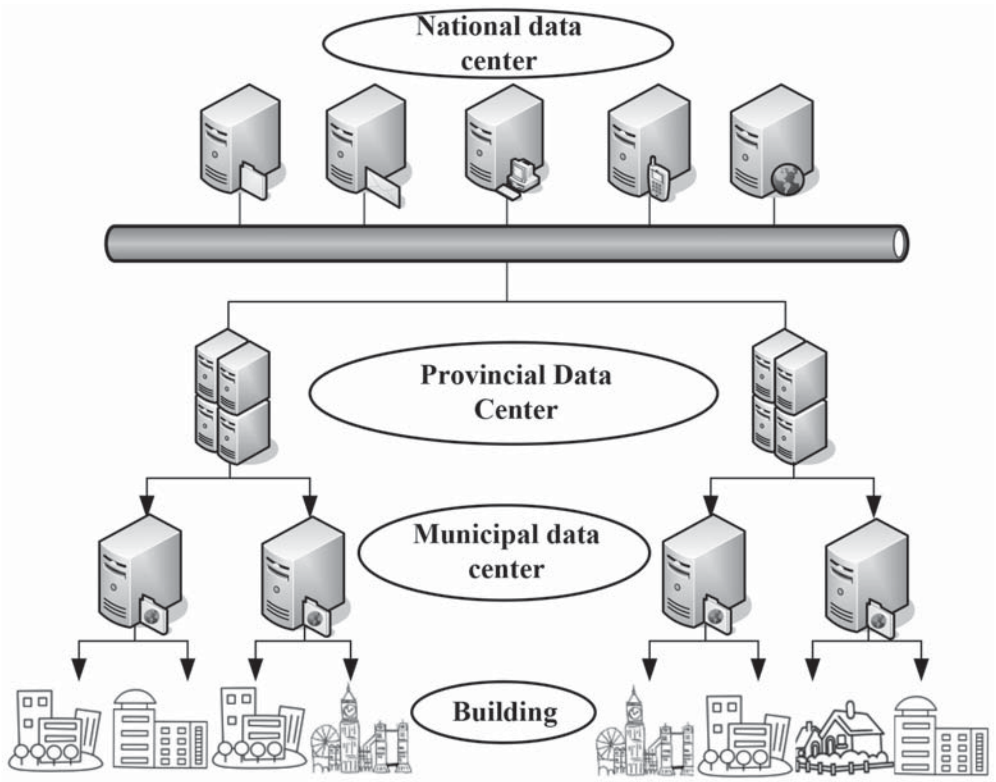


Figure 4 Energy consumption monitoring system for large public buildings.

building performance control technology can change the energy-saving effect of a single unit. Energy consumption and energy-saving renovation refers to the reduction of building resources and energy consumption during the design, construction and use of existing buildings. When carrying out existing energy-saving renovations on existing buildings, on the basis of fully understanding the initial feasibility, renovation costs and operation and maintenance costs are important evaluation indicators, and the most suitable building energy-saving renovation plans are formulated. Of course, energy-saving renovation of existing buildings must also comply with existing building energy-saving codes. When renovating existing office buildings, the energy-saving renovation process should pursue related goals, and ultimately achieve the goals of environmental protection and resource conservation [24]. Second, conduct a comprehensive analysis of the local climate and ecological environment, and use completely different resources such as local materials and water resources to indirectly achieve energy-saving goals. In addition, during the renovation process, minimize damage to the environment, reduce carbon dioxide emissions, and reduce waste of building materials, etc., to ensure the ecological nature of the renovation process. Figure 4 shows the mode of energy monitoring in large public buildings.

Energy efficiency is a key factor in the feasibility of energy-saving renovation of public buildings, and is the goal of project implementation. In the energy-saving renovation of public buildings, energy-saving benefits are mainly manifested in three aspects: one is the saved energy costs, which are direct economic benefits; the second is social benefits; the third is environmental benefits. Both social and environmental benefits are difficult to quantify, and they are the long-term neglected part of the implementation of energy-saving renovation projects [25].

(1) Saving energy costs. The pros and cons of the economic effects of energy-saving projects are first manifested in whether the building's energy consumption can be reduced to the range specified in the contract. The saved energy costs directly come from the analysis of the energy bills of the buildings. By comparing the energy bills before and after the energy-saving renovation of public buildings, combined with the impact of the external environment, the saved energy costs can be determined. Compared with other benefits, economic benefits are the easiest to quantify and the most easily accepted part by people.

(2) Social benefits. The energy-saving renovation of public buildings has positive externalities. The social benefits of the energy-saving renovation of public buildings are mainly manifested in: first, the reduction of public building energy consumption is conducive to establishing the image of public building owners to be actively energy-saving, and building a reputation in the community; second, proactively carrying out the energy-saving renovation of public buildings reflects the social responsibility of public building owners; third, the successful implementation of the energy-saving renovation of public buildings will promote the enhancement of energy-saving awareness of the entire society and serve as an example for other building energy-saving renovations.

(3) Environmental benefits. This part of the benefit is the same as the social benefit, and it is more difficult to

Table 1 Standard values for sub-item energy consumption testing of various public buildings.

Statistics project	Office building	Hotel building	Commercial Building	Large commercial building
Total energy consumption per unit area	75	130	120	235
Air conditioning system energy consumption per unit area	23	53	39	116
Energy consumption per unit area of lighting system	16	19	22	77
Equipment system energy consumption per unit area	21	14	36	9
Elevator system energy consumption per unit area	2.8	2.8	2.8	13
Power system energy consumption per unit area	1.3	2.8	1.3	0.19
Heat consumption per unit area	0.32	0.47	0.23	0.24

quantify, and it is an economic benefit that is not easily seen by people. In the analysis, we temporarily ignore the impact of this part of the benefit, and only use it serve as an auxiliary criterion for the evaluation of the project.

3. VARIABLE FUZZY SET IN ENERGY EFFICIENCY EVALUATION OF PUBLIC BUILDING DESIGN EXPERIMENT AND RESULTS

3.1 Development Environment and Related Technologies

When designing and implementing the public building energy prediction and energy-saving analysis system, the MATLAB language is used to realize the neural network algorithm. Use advanced ASP.NET language to develop the Web application system to improve the usability of the application system. Use COM technology for data communication between MATLAB and ASP.NET, use Web Services technology to move neural network calculations in Web services, complete the logic system transaction processing and neural network calculations on the Internet, and improve the overall performance of the system. Development tools: Microsoft Visual Studio 2019, MATLAB. Development language: C# Development environment: .NET. Database: My SQL.

3.2 Energy Consumption of Public Buildings

From the data given in Table 1, the energy consumption of shopping malls is generally the highest, most of which are between 120 and 235kWh/m^2· a. Shopping malls have long operating hours, generally open for more than 12 hours a day, with a large flow of people, and some shop windows require lighting equipment. The lighting and equipment of some underground shopping malls consume more energy, which requires lighting equipment on the one hand and cooling equipment on the other. These are the reasons for the high energy consumption of commercial buildings.

3.3 Collection Frequency and Energy Consumption Collection Time-Consuming Test

In this test, the collection points are set to 20, 40 and 60 respectively, and the collection frequency is 15 minutes, 25 minutes, 35 minutes, 45 minutes, 55 minutes, and 65 minutes, and the total consumption of 24 hours is counted. It can be seen from Figure 5 that the shorter the sampling interval, the more the number of collection points, and the more time it takes to collect energy consumption. For example, when collecting once every 16 minutes, 60 collecting points theoretically take the same time as 40 and 20 collecting points, but the actual time consumption is not equal. Therefore, to ensure the performance of system data processing, an appropriate acquisition frequency should be set to ensure the normal operation of the system.

Table 2 shows the parameter table of several energy-saving curtain wall materials, including ordinary tempered glass, vacuum glass, photovoltaic glass and low-e glass. Among them, low-e glass has the lowest heat transfer coefficient of 1.3, the highest transmittance is photovoltaic glass, and the lowest transmittance is low-e glass, which is 32%.

3.4 Energy Saving Rate of Different Curtain Wall Materials

Compared with the low-coated hollow glass curtain wall structure, it has a better energy-saving effect, and the air consumption is significantly reduced. The photovoltaic curtain wall structure also has a better energy-saving effect, slightly stronger than the coated glass curtain wall, and the low-emission glass curtain wall structure with the best energy-saving effect. The same analysis takes the

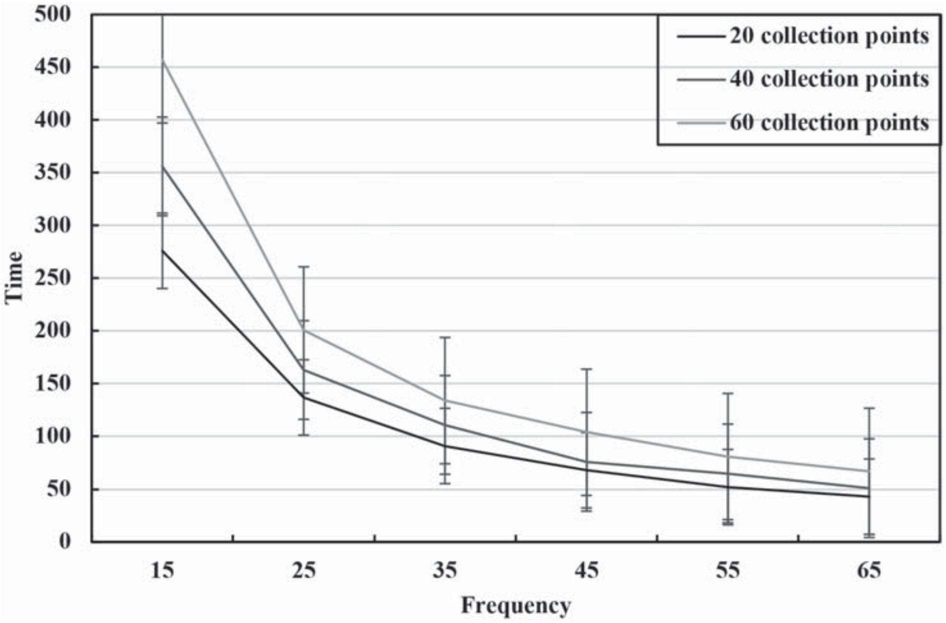


Figure 5 Collection frequency and energy consumption collection time-consuming test.

Table 2 Several energy-saving curtain wall materials parameter table.

Curtain wall type	Heat transfer coefficient	Transmittance	Reflectivity	Shading coefficient	Solar heat gain coefficient
Ordinary tempered glass	5.3	68	22	0.82	0.724
Vacuum glass	2.4	61	28	0.43	0.415
Photovoltaic glass	3.2	88	13	0.34	0.725
Low-E glass	1.3	32	7.2	0.75	0.332

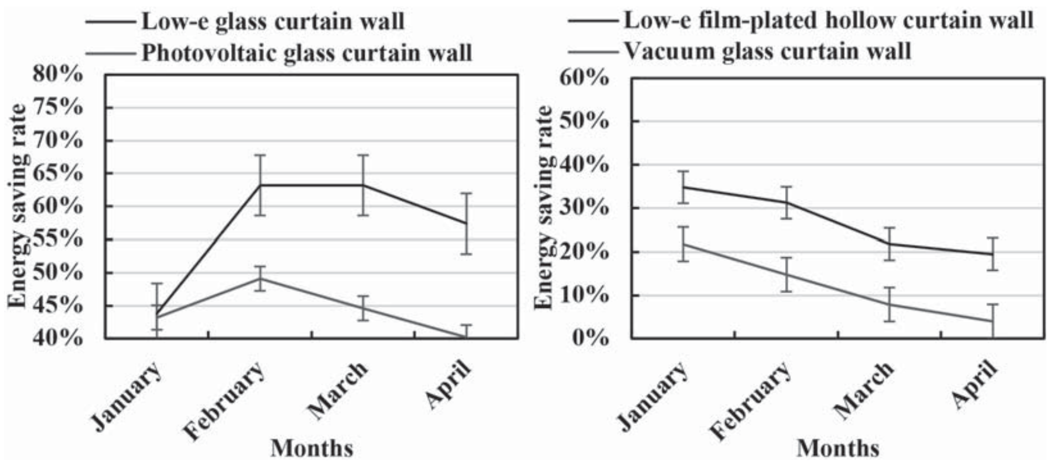


Figure 6 Energy saving rate of different curtain wall materials.

ordinary toughened glass curtain wall structure as unit 1, and the comparison chart of energy saving rate is shown in Figure 6.

3.5 Energy Consumption and Energy Saving Rate

Figure 7 shows the simulated air conditioning energy consumption and the corresponding energy saving rate. It can be concluded from Figure 7 that the energy-saving rate and the thickness of the insulation layer are proportional within a certain range, but the energy-saving rate changes little after a certain thickness. The reason for this phenomenon is that the increase in the insulation thickness greatly reduces the outdoor the environment has an impact on indoor temperature changes, but the increased insulation layer will greatly hinder indoor heat dissipation, and the requirement for cooling capacity increases, which causes an increase in air-conditioning energy consumption. The selection of insulation layer should comprehensively consider building information, environmental information, etc. to select the best insulation

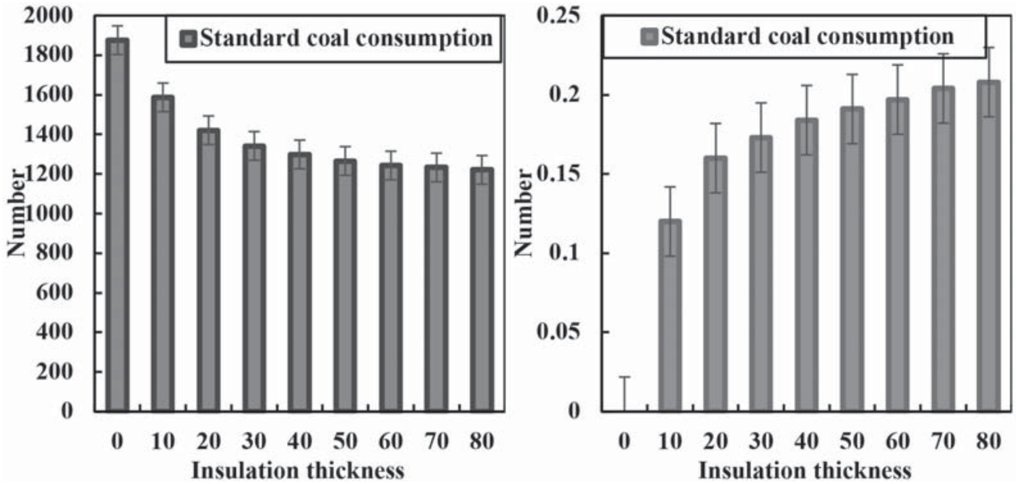


Figure 7 Energy consumption and energy saving rate under different insulation thickness.

layer.

Figure 8 shows the standard coal consumption and energy-saving rates for different types of glass, including ordinary flat glass, heat-reflective glass, heat-insulating glass, low-e glass and low-altitude glass. It can be seen that the energy consumption of ordinary glass is the largest, the energy consumption of low-altitude glass is the smallest, and the energy saving rate is the highest.

Short-term accommodation includes publicity spaces and commercial facilities such as shopping malls, stations, business halls, exhibition halls, entrance halls, bookstores, etc. Supermarkets and showrooms are located in short-term residential areas, and offices and guest rooms are located in long-term residential areas. Therefore, the design temperature and humidity limits and fresh air volume limits for each functional room are shown in Table 3.

It can be seen from Table 4 that the level feature values of the apartment building under the four parameter combinations are respectively 2.08, 2.21, 1.89, and 1.97, which are relatively stable, and the comprehensive level feature value $H = 2.07$. According to the classification criteria, the apartment building is in the second position. Level-State of concern: the apartment building is in a relatively safe state, but it needs to continue to detect data and analyze the safety development trend of the building.

It can be seen from Figure 9 that the temperature change law of the west wall is basically the same as that of the east, but because the west wall receives direct sunlight after noon, the temperature of the west wall in the morning does not change much, until after noon the temperature rises sharply, reaching a peak at about 14h, and then the temperature gradually decreases. Similarly, after 14h, there is a short temperature rise and then fall again. The change trend of the whole process is similar to that of the east, so it will not be described in detail here.

3.6 Annual Cumulative Load of Buildings

Figure 10 shows the average arc elasticity of the building's annual cumulative load under different external wall shape heat transfer coefficients. It can be seen from Figure 10 that the heat transfer coefficient of the external wall is more sensitive to the cumulative heating load of the building throughout the year than the cumulative cooling load of the building.

4. DISCUSSION

Compared with traditional construction projects, building energy conservation not only makes a great contribution to improving energy efficiency and reducing pollution, but also improves the comfort of users and reduces harm to users in the small environment of the building itself. Applying the variable fuzzy set theory to the energy-saving evaluation of public buildings can reduce the excessive dependence on expert experience in the evaluation index data collection process in the past evaluation process, and directly apply the objective data on the spot to the safety evaluation. It makes the evaluation result objective and reasonable. At the same time, through the transformation of model parameters, the evaluation results under four different parameter models can be obtained. Through the result analysis, the evaluation results under the four models are relatively close and the data is relatively stable. In areas with hot summers and cold winters, the cold weather in winter is relatively short, and the hot and humid weather in summer is longer. In the summer and transition period, it is necessary to open windows to enhance natural indoor ventilation. Especially Chongqing is an area with insufficient sunshine and strong sunshine. Reducing windows will not only hinder the natural ventilation of the building, but also reduce the natural light in the room. Therefore, a proper window-to-wall ratio can not only create a good indoor environment, but also reduce the energy consumption of the building. In terms of the light weight characteristics of the external protective structure, since the transparent glass system is usually the main component, the light transmittance is higher, and the total natural light is obviously better than that of heavy objects. Therefore, sometimes in order to prevent overheating and soften the light entering the room, it is necessary to maintain the appearance of the glass system and modify the shading design. The shading design is firstly related to direct and diffuse local sunlight. Secondly, shading coefficient is also

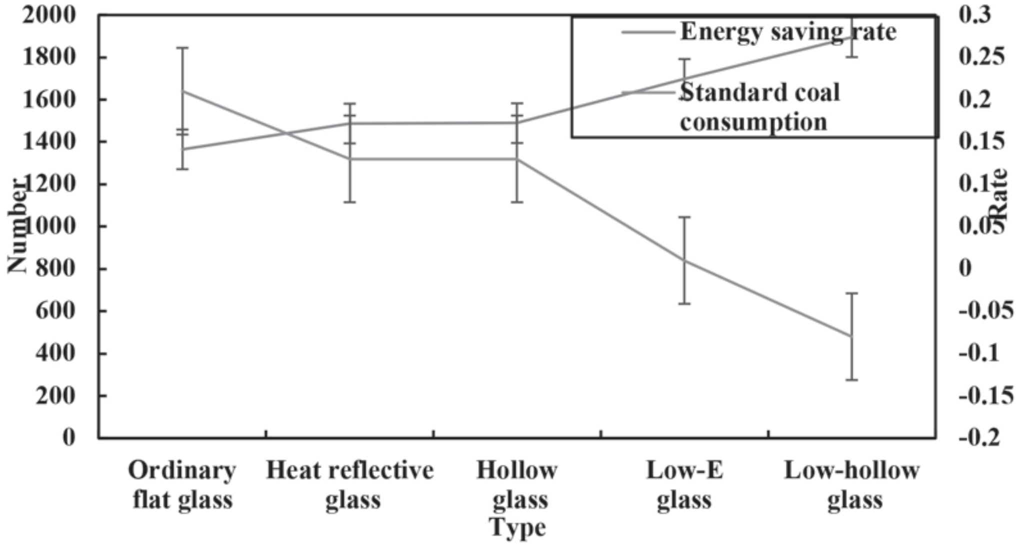


Figure 8 Standard coal consumption and energy saving rate corresponding to different types of glass.

Table 3 Main functional room interior design temperature and humidity limits and fresh air volume limits.

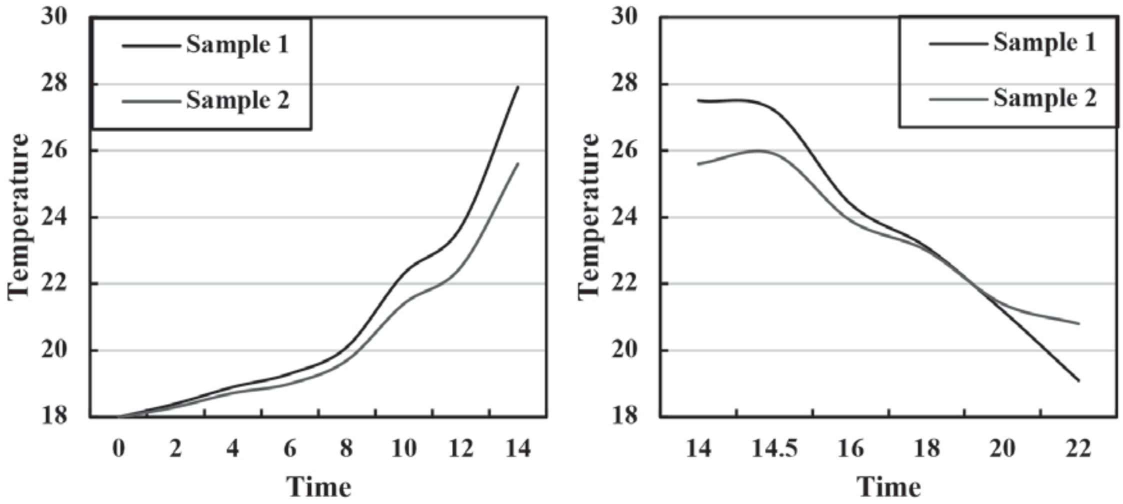
Name	Summer		Winter		Minimum fresh air volume
	Temperature	Relative humidity	Temperature	Relative humidity	
Supermarket	23	47	17	52	21
Exhibition hall	23	47	22	46	21
Office	25	47	22	46	31
Room	25	47	22	46	31

Table 4 Comprehensive relative membership degree and grade feature value calculation table.

Parameter combination	Membership	Level 1	Level 2	Level 3	Level 4	Level feature value F	$\overline{F}$
$m = 1$	Relative membership	0.28	0.28	0.25	0.09	2.11	2.07
$n = 1$	Membership after normalization	0.28	0.28	0.25	0.09		
$m = 1$	Relative membership	0.36	0.31	0.31	0.13	2.19	
$n = 2$	Membership after normalization	0.30	0.26	0.26	0.11		
$m = 2$	Relative membership	0.22	0.17	0.14	0.00	1.93	
$n = 1$	Membership after normalization	0.35	0.33	0.22	0.02		

an important indicator that affects shading performance. The shading factor is applied to the window system. Refers to the heat (solar energy) received by the solar energy received from the window under transparent and unprotected conditions: the smaller the ratio, the better the efficiency of blocking direct sunlight. Shading performance includes indicators such as the depth of the skylight. In the transformation process, it is advisable to compare and optimize the model selection based on the simulation results.

The characteristics of large public buildings indicate that the envelope structure has its own air-conditioning system and energy-saving and consumption-reducing system. The main factors affecting energy consumption are compared with several wall curtain structures in the existing market. Photovoltaic curtain walls can achieve the energy-saving effect of a long building life cycle, but the initial investment is very large and the potential is huge. When designing energy-efficient buildings, there are many issues to consider, such as the shape of the building, the distance between each building, the interior design of the building, and the layout of green spaces. In addition, after the entire building is completed, lighting design, ventilation design, electrical design and heating must be considered. All problems must be clearly resolved. Otherwise, some problems will definitely occur



(a) Endothermic (b) Exothermic

Figure 9 Temperature change diagram when different ratio wall absorbs and releases heat.

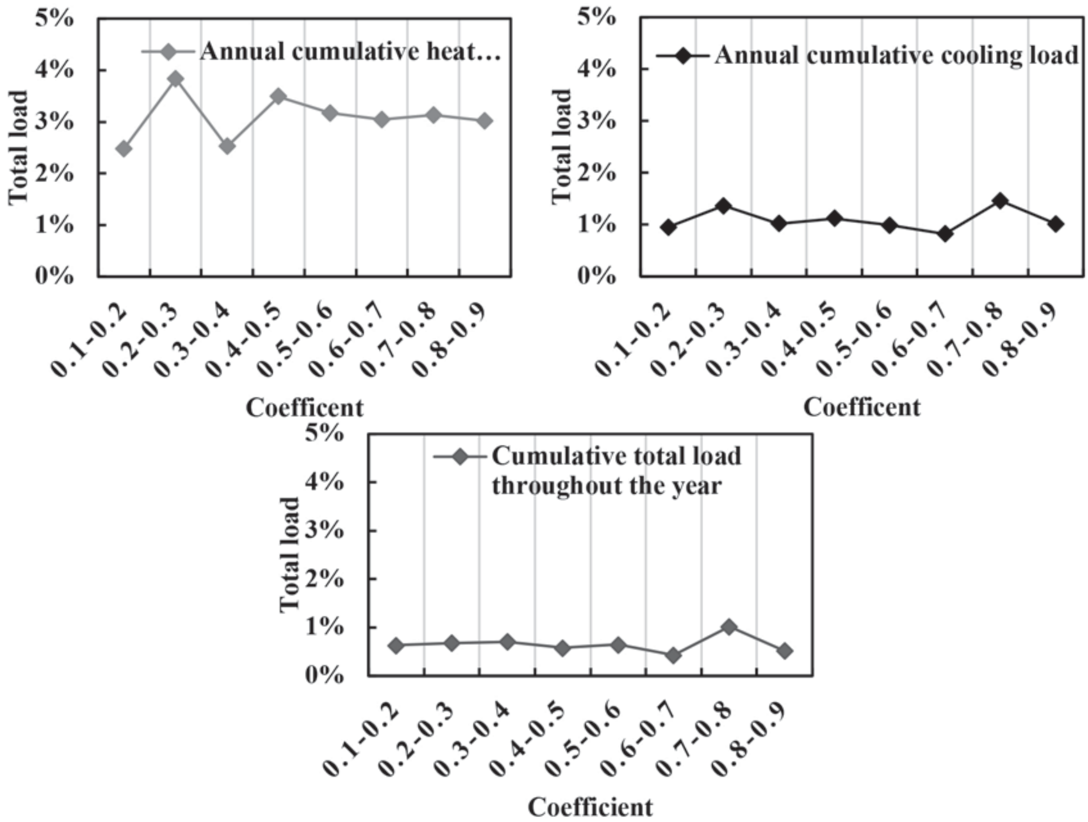


Figure 10 The arc mean elasticity of the building's annual accumulated load.

during the construction process, which will not only affect the construction progress, but even affect the construction quality. When designing the energy efficiency of buildings, the principle of integrity must be observed. The annual cumulative heat load of a building increases with the increase of the window-to-wall ratio in all directions. As the ratio of the west window wall to the north window wall increases, the cumulative annual growth rate of the building's heat load will also increase; and as the ratio of the east window wall to the south window wall increases, the cumulative annual growth rate will increase. The heat load of the building will become smaller.

5. CONCLUSION

The energy efficiency of a building is the scientific, efficient use of resources and the minimization of energy consumption during the construction, use, and production phases of engineering materials, provided that the safety functions and structural use of the building to meet energy efficiency and comfort. Therefore, strengthening the R&D and application of thermal insulation technology in the construction of regional energy-saving structures is of great significance for promoting the sustainable development of our country's energy resources and ensuring social stability. This paper conducts related research based on the application of variable fuzzy sets in the energy efficiency evaluation of public building design. The concept, advantages and related algorithm applications of variable fuzzy sets are introduced. In addition, the related knowledge of public buildings and the effect of energy efficiency evaluation are introduced. It is concluded from the experiment that the energy-saving rate is proportional to the thickness of the insulation layer within a certain range, but the energy-saving rate changes little after reaching a certain thickness. Therefore, the energy-saving design of public buildings needs to be improved in depth. The shortcomings of this article are the lack of analysis of related materials, no specific energy-saving materials are listed, but the research on glass materials is not comprehensive enough, and it is hoped that with in-depth research on building energy-saving design, it can be further improved and optimized.

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