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Government Performance Evaluation in the Context of Carbon Neutrality: Energy-Saving of New Residential Building Projects

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Abstract: The government's supervision of new residential building projects' (NRBPs) energy-saving can promote carbon neutrality policies within its jurisdiction. A scientific and systematic evaluation of NRBPs energy-saving reflects a government's management performance. However, achieving accurate and reasonable results with unitary evaluation standards without considering regional characteristics is not easy. This study proposes an evaluation method of intelligently evaluating the effectiveness of government energy-saving supervision with regional characteristics weighted in. Consequently, these evaluation indicators can reveal the key issues in carrying out local energy-saving policies and provide concrete guidance for local governments to manage the energy-saving of NRBPs better. The method was tested with ten projects and found to be effective.

Keywords: carbon neutrality; new residential building project; energy-saving management; performance evaluation; energy conservation

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1. Introduction

In recent years, the number of new buildings in China has increased rapidly, and energy consumption is also increasing. In 2015, the construction area in China was 12.4 billion square meters, more significant than all developed countries combined [1]. Due to the enormous demand for new residential buildings, related construction projects continue to increase, leading to large-scale cement production and other energy-intensive materials and increased energy consumption [2]. In China, residential buildings accounted for 29% of the country's primary energy consumption in 2018 [3].

Energy conservation, aka energy-saving, in the construction industry is crucial to China's energy conservation and emission reduction [1]. Energy conservation refers to a series of activities to reduce energy consumption as much as possible by improving energy efficiency. It does not compress the energy consumption but strives to reduce energy consumption while meeting the same needs or to produce more values using the same amount of energy. Energy conservation management means reducing energy consumption by formulating more suitable systems for energy conservation and taking corresponding management measures to achieve the purpose of energy conservation [4].

Internationally, infrastructure development is beneficial for OECD countries' environment by reducing their ecological footprint [5]. It is also a vital link to achieving carbon neutrality. Carbon neutrality refers that if projects are not designed and built with their carbon footprint in mind, the project process may emit more greenhouse gases into the atmosphere than they can reduce over their entire life cycle. Similarly, the government's energy-saving policy for the promotion of economic development needs to be reflected in the long term [6]. The construction of a new residential building, including design and construction, can be seen as an overall engineering project, i.e., a new residential building project (NRBP). In this way, the project's energy savings involve every aspect of energy savings throughout the construction period, from the use of energy efficiency standards at the time of design to the use of energy-saving equipment and materials during construction, and finally, the use of renewable energy after construction. An ecofriendly construction procedure can be attained by rationally utilizing primary resources (capital and labor) and reallocating them from high to low carbon-intensive industries [7]. Since energy conservation and emission reduction is an essential form of "carbon neutrality", reducing the energy consumption of new residential buildings will help achieve "China's 2060 carbon neutrality" target [8].

Many countries are trying to reduce energy consumption in residential buildings by developing and implementing energy efficiency policies to encourage the public to reduce energy consumption in buildings [9]. However, the energy-saving effect of NRBPs in China is not clear or prominent. The proportion of energy consumed by new buildings in cities is higher than the world benchmark. For example, in 2018, the total energy consumption of building construction and operation in China was as high as 37%, of which construction accounted for 14%, and building operations accounted for 23% [10]. More than 50% of NRBPs do not meet energy efficiency standards [11].

Energy conservation helps reduce carbon emissions. Chen et al. (2020) has found that factories and cities are responsible for carbon emissions because of their governors' policies of economic growth and population [12]. It reveals that the government has a positive influence on sustainable development. During the COVID-19 pandemic, the government's lockdown measures in California have reduced emission and improved Air Quality Index by restricting industrial, transportation, and related activities [13]. The government's adoption of policy tools such as carbon market can guide enterprises to save energy and reduce emissions, but it needs the support of relevant laws and regulations [14].

Therefore, the government should carry out energy conservation management: to reduce energy consumption by formulating systems and management methods more suitable for production and energy conservation to achieve the purpose of energy conservation [4] and regularly evaluate the performance of the energy plan implementation [15]. The government can keep building managers under constant pressure and motivate them to upgrade buildings and energy systems to reduce operating costs and improve operational performance to comply with building codes [16,17]. However, local governments lack the corresponding evaluation methods (corruption may be one of the reasons [18]), which dramatically reduces management effectiveness, and the compliance rate of energy policies is low in the region.

The performance of building energy conservation is affected by various factors. For example, improving financing schemes can advance investment performance in energy efficiency [19], and Remeikienė et al. [20] also used the renewable index to evaluate the investment efficiency of energy. In the decision making of building energy conservation, the cost of the whole life cycle should be included [21]. European countries should evaluate the effectiveness of energy conservation policies more effectively to grow a low-carbon economy [22].

Some literature examines the performance evaluation methods of energy conservation regulation, and the Global Building Performance Network's (GBPN's) development of a score-based building-energy performance policy rating methodology is an example. It includes 15 criteria, divided into five thematic categories: a holistic approach, a dynamic process, implementation, technical requirements, and overall performance. This approach allows policymakers to establish a basis for best practice benchmarks and rate BEE (Building Energy Efficiency) policies by considering country-specific heterogeneous characteristics [23]. Chandel et al. [24] propose an integrated approach to measuring energy savings considering energy regulations, implementation standards, strategies, energy efficiency measures, performance evaluation, and regulation development. Tian et al. [25] proposed an improved analytic hierarchy method (AHP) to determine the weighting of government energy-efficiency performance indicators. Zainine et al. [26] point out that there is a problem with the applicability of environmental assessment methods, and the main criteria applicable to environmental assessment should be determined by studying different scenarios and given weights.

In summary, the available literature proposes a few ways to evaluate the management of building energy efficiency. However, the literature related to the performance evaluation method of government energy conservation supervision is still scarce, and the literature on the evaluation of government supervision performance on the energy conservation of NRBPs is not yet available. There is a discussion of regional government performance evaluation methods for energy conservation supervision.

Therefore, this study attempts to construct a set of evaluation index systems and methods to assess government management performance on energy-saving of NRBPs in the region. Through this evaluation index system and method, projects are randomly selected for evaluation, and the energy conservation management level of projects in this area is evaluated reliably and objectively.

This study has two contributions. First, the issue of energy conservation is from the perspective of the management performance of governments, not from the perspective of typical energy-saving projects. This change in perspective reveals the problems existing in implementing energy-saving policies from the root causes. Second, it provides local governments with tools to manage energy conservation and emission reduction policies. Local governments can analyze the key energy-saving areas of NRBPs, identify the weak points that hinder NRBPs' energy saving, and take measures to address them.

This article is arranged as follows: Section 2 discusses the method, including the performance evaluation index system, the matching model, and the data source. Section 3 describes the evaluation results of 10 samples of NRBPs, and the final section concludes and provides policy implications.

2. Methods

This study proposes an innovative way to assess the regulatory performance of NRBPs for energy efficiency. It is a four-step research procedure. The first step is to establish evaluation criteria based on literature reviews, and the second step is to build a performance evaluation index system (PEIS). The third step is to construct a support model based on rough set theory, and the last step is to test the practicality of this method by conducting applied research on randomly selected NRBPs in China.

2.1. Performance Evaluation System

The government performance evaluation means evaluating and classifying the performance reflected in the input, output, interim results, and final government public sector management results. Rotberg [27] advocates for result-oriented performance measurement as the results are the ultimate goal of public policies. However, there is no uniform standard applicable to all government levels or departments in the performance evaluation. As a result, a performance system designed for one government level or department often is used to measure multiple administrative units' performance. This kind of one-fits-all performance system frequently leads to inaccurate or unreasonable results.

To avoid the insensitivity to jurisdictions' characteristics and rigid measuring mechanisms, we propose a new PEIS that is flexible to use and adaptable to reflect the diverse characteristics of different jurisdictions.

Based on the national laws, regulations, and practical requirements, four criteria are summarized in this research to construct the PEIS of government management on NRBPs energy-saving.

Criterion 1: The evaluation indicator system should reflect the goal of controlling the total energy consumption of construction projects. China's 13th five-year plan for Building Energy Efficiency and Green Building Development issued in 2017 states that the proportion of the energy-efficient building area over the urban civil building area should be more than 40% of the total building areas [28].

Criterion 2: The indicator system should evaluate the whole life cycle of the residential projects rather than a phase of the life cycle like some previous studies did. Cárdenas et al. [29] found that residential buildings' energy consumption accounted for 80–90% of the total energy consumption in the operational phase. Ramesh et al. [30] also contended that 80% of the energy consumption in the life cycle of construction projects comes from the operation and maintenance of construction projects.

Criterion 3: The indicator system should reflect the specific energy-saving effects of NRBPs under supervision for both the project's construction and operation. The policy implementation effect varies from location to location; therefore, the regional emission reduction goals and relevant policies should be customized to reflect the actual situation [31].

Criterion 4: The Chinese government has issued many laws and regulations, including the "Energy-saving law of PRC", "Renewable Energies Law of PRC", and "Design standards for energy-saving in residential buildings", among others in recent years. Therefore, the designed indicator system should reflect the total effects of all relevant energy-conservation policies issued by the government.

This study synthesizes the literature on energy efficiency standards, regulation evaluation, and policies in China and relevant government supervision documents to establish a comprehensive indicator system to measure the performance of LGES.

Between August 2019 and August 2020, we distributed 150 paper questionnaires to experts of more than 20 construction enterprises. The respondents were senior managers, engineering department managers, project managers, or government officials from ten different cities in China. A total of 106 complete and valid questionnaires were received, with a response rate of 70.6%. The survey classifies the necessity of each indicator into five levels, from very high to very low. Following the survey, we conducted in-depth interviews with experts from local governments' energy conservation departments to validate these indicators. Three secondary indicators that cannot be accurately measured in practice were removed from the evaluation system.

There are five categories of indicators (representing five attributes), denoted as A = {{A1, A2, . . . , A5}, corresponding to five first-level indicators, with each indicator containing second-level indicators. For instance, A1~A5 refers to the project's energy-saving level, building energy-saving project authentication information, building energy information management, implementing energy-saving policy and system, and controlling project energy-saving scale and intensity. In this way, we get a set of indicators, shown in Tables 1 and 2, to evaluate the government performance of NRBPs energy-saving management.

Table 1. Evaluation indicators of supervision performance.

Attributes	Index	References
A1	X1 Reasonability of building complex layout	[32]
	X2 Between-buildings Orientation and Spacing	[33]
	X3 Landscape	[34,35]
	X4 Design of a single building	[33]
	X5 Sustainable site design	[36]
	X6 Design of equipment configuration	[37]
	X7 Renewable energy utilization	[38]

Table 1. *Cont.*

Attributes	Index	References
A2	X8 If the qualification of enterprise and professionals responsible for project energy-saving satisfies standard	[39]
	X9 Comprehensiveness of certification information of building energy-saving material	[24,40]
	X10 Energy-saving system information of property management enterprise of the project	[41]
	X11 Building energy-saving grade of the project	[32]
A3	X12 Application extent of communication technology of building energy information	[42]
	X13 Completeness of statistics information of building energy consumption	[43]
	X14 Completeness of auditing information of building energy consumption	[44]
	X15 Statistical and auditing information disclosure of building energy consumption	[45]
A4	X16 Application extent of building energy-saving technology	[40]
	X17 Incentive extent of energy-saving policy on the project	[46]
	X18 Duty fulfill extent in the supervision on project energy-saving by local governmental supervisors	[42]
	X19 Effectiveness (extent) of project review mechanism	[47]
	X20 Extent of learning-related policies	[24]
	X21 Clarity of involving policies	[48]
A5	X22 The project does not exceed the total regional residence control	[49]
	X23 Reasonable control of total electric power consumption	[50]
	X24 Reasonable control of total gas consumption	[51]

Table 2. The description and value range of evaluation indicators.

Index	Description	Index Value
A_1		
X_1	Reasonable building layout can make each building obtain good protection, shadow effect, sunlight, and wind utilization conducive to building energy conservation.	Adopting 5-level scoring: 1 represents very unreasonable. 5 represents very reasonable.
X_2	The combined annual electricity consumption of buildings on the east and west sides increased by 20% compared with buildings on the south side. (good/bad)	Adopting 5-level scoring system
X_3	Conducting greening after completing buildings, roads, pipeline networks, and other facilities is a key factor in improving microclimate. (good/bad)	Green land rate: not less than 30% for new zone construction; (per capita public green land area: not less than 1 m^2 for new zone).
X_4	Including average window-wall ratio and building shape coefficient. (good/bad)	Adopting 5-level scoring system
X_5	During building structure design, if site-saving is considered, underground space or abandoned site is used or not if the polluted abandoned site is re-used after standard-satisfied treatment.	Adopting 5-level scoring system
X_6	Referring to cold and heat source of air-conditioner and heating system, pipeline network efficiency, elevator energy-saving efficiency, energy-saving system efficiency of power distribution and lighting.	Adopting 5-level scoring system
X_7	Design considers forced heat recovery of a ventilation system, and natural recycling, and renewable energy.	Ratio (%) of recyclable material to all construction material
A_2		

Table 2. *Cont.*

Index	Description	Index Value
X_8	Reviewing the qualification of construction enterprise, qualification of engineering investigation and design enterprise, technicians and professionals in energy-saving, the capability of supervision on energy-saving technique. Checking the quality and qualification of building energy-saving certification enterprise and professional ethics of supervision enterprise.	Adopting 5-level scoring system
X_9	The energy-saving material has been certified. (There is energy-saving construction material with nationally certified identification, e.g., refrigerator, air-conditioner, etc.).	Adopting 5-level scoring system
X_{10}	The property management enterprise of the project establishes a sound energy-saving assessment system, and energy consumption records.	Adopting 5-level scoring system
X_{11}	Building energy-saving information provided by the project.	Adopting 5-level scoring system
A_3		
X_{12}	The communication technology tool of building energy information is used during the project implementation, e.g., MES (manufacturing execution system) and ERP (enterprise resource planning system). It satisfies the communication technology codes.	Adopting 5-level scoring system
X_{13}	The construction project property management company reports the energy consumption data of the project. The local government reports this information.	Adopting 5-level scoring system
X_{14}	The energy-saving auditing institution conducts a good job of auditing reporting of energy consumption data and confirms using in-situ testing. The local government summarizes the energy consumption data.	Adopting 5-level scoring system
X_{15}	The statistics and auditing information of energy consumption of the project is publicized regularly by the government.	Released = 1, Otherwise = 0
A_4		
X_{16}	Based on design standards for energy-saving in NBRB's, the application extent of hardware and software technology (e.g., EMS, energy management system).	Adopting 5-level scoring system
X_{17}	Incentive policy is effective. When the legal interest of the project is damaged, the project can get reasonable compensation.	Adopting 5-level scoring system
X_{18}	The project is listed in the reporting information by the grass-root administrative department. False, deceptive, and concealing behaviors in the project are checked.	Adopting 5-level scoring system
X_{19}	The grass-root administrative department conducts a pre-event review, in-event check, and after-event investigation for the project and enterprise.	Adopting 5-level scoring system
X_{20}	Periodic training on policies and knowledge or courses, are organized for project management personnel and construction personnel.	Adopting 5-level scoring system
X_{21}	Every policy or regulation is clear and coordinated (A more coordinated and more transparent system reflects a higher score.).	Adopting 5-level scoring system.
A_5		
X_{22}	Project does not exceed the total regional residual building scale control.	Within the regional control range = 1; Otherwise = 0
X_{23}	Energy consumption intensity control during operation, total electric power consumption of the comprehensive operation through the whole life period of the project.	Annual electric power consumption (unit is in KWh)
X_{24}	Total gas consumption of the comprehensive operation through the whole life period of the project.	Annual gas consumption (unit is in m^3)

2.2. A Supporting Model Based on the Evaluation Index System

The effects of government management performance evaluation are highly uncertain if the prior knowledge of performance evaluation is limited. It is also complicated for the evaluation model to manage both quantitative and qualitative measurements and positive and negative values. However, the rough set theory (RST) is pertinent to processing imprecise or uncertain information within the known knowledge base. RST can be used to reveal the foci of government energy-saving supervision by analyzing government supervision indicators' weights. It can discover data dependencies and reduce the number of attributes in the data set, thus effectively processing uncertain information without additional information [52–54].

The evidential reasoning (ER) method can unify the evaluation levels of various attributes, facilitate the comparison, accumulation, and synthesis of different indicators, and achieve the final evaluation results via information fusion [55]. However, the evaluation model takes multiple calculation steps [56].

Step 1: Construction of an evaluation indicator information system.

Using the previously established indicator system, we construct a quadruple $S = (U, M, V, f)$, denoting the evaluation indicators of government's supervision performance for energy-saving of NRBPs, where:

$U = \{c_1, c_2, \ldots, c_m\}$ is the domain and stands for m projects;

$A = \{A_1, A_2, A_3, A_4, A_5\}$ is called the attribute set;

Then, $\{X_1, X_2, \ldots, X_L\}$ is the next level indicator of A_i. $\{X_1, X_2, \ldots, X_L\}$ needs to be processed dimensionless;

$V = \cup_{A_i \in A} V_{A_i}$, V_{A_i} is the value range of attribute A_i;

$F : U \times A \rightarrow V$ gives each object an information value. $\forall a \in A \Rightarrow f(x, a) \in V_{Ai} \subseteq V$.

The first step essentially describes the characteristics of the indicator system.

Step 2: Reduction of performance evaluation indicators.

Step 2.1: Calculation of information entropy $H(A_i)$.

Shannon [57] used information entropy to measure the uncertainty of information sources A. In the domain U, $X_1, X_2, \ldots, X_L$ represent the divisions of U. Therefore, the information entropy of the information source A is defined as follows:

$$H(A) = -\sum_{i=1}^{L} P(X_i) ln P(X_i), \tag{1}$$

where the probability of the equivalence class in U is $P(X_i) = \frac{|X_i|}{|U|}$.

$|X_i|$ is the potency of the set X_i and $|U|$ is the potency of the set U.

Step 2.2: Calculation of importance $S_{Ai}(X_i)$.

Based on the information entropy, the occurrence of classification change and the change's extent are checked. In the government-supervision performance evaluation indicator system $S = (U, a, V, f)$, the importance degree $a \in A$ is defined as follows:

$$S_A(a) = |H(A) - H(A - a)|, \tag{2}$$

where $H(A)$ is the information entropy of set A of all attributes; $H(A - a)$ is the information entropy in set A excluding attribute a. A larger value $S_A(a)$ indicates a more important attribute.

Step 2.3: Calculation of the weight of the evaluation indicator to clarify the importance of each indicator, W_i

$$W_i = \frac{S_A(a)}{\sum_{i=1}^{n} S_A(a)}, \tag{3}$$

Step 2.4: Calculation of the deviation D_i of the ith indicator

$$D_i = \frac{W_{max} - W_i}{W_{max}} \times 100\%, \tag{4}$$

where $W_{max} - W_i$ denotes deviation of the indicator i from the most maximum weight W_{max}.

Step 2.5: Reduction of evaluation indicators.

The reduction of performance evaluation indicators is quantified by the degree of deviation. The reductions are made for the indicators that do not satisfy the standard

$D_i < 90\%$ suggested by Zhang et al. [58]. After removing specific performance evaluation indicators, we repeat steps 2.1 to 2.4 until $D_i < 90\%$. Finally, the weights of indicators at all levels of the new system are sufficient.

The essence of the second step is to select appropriate indicators (subsets) from the indicator system (set). Meng et al. [59] believe that regional emission reduction goals should be customized to suit the actual situations of different juridical regions, rather than applying the same energy-saving goal to different regions. Therefore, the local government should focus on the regional NRBPs' compliance with the regional energy-saving policies.

Step 3: Use evidential reasoning approach to evaluate.

Step 3.1: Determination of the level of evaluation.

Let the evaluation level set $H = \{H_1, H_2, H_3, H_4, H_5\}$ = {worst, poor, average, good, excellent}.

The evaluation of each indicator X_i is defined by:

$$S(X_i) = \{(H_n, \beta_{n,i})|n = 1, \ldots, 5\}, i = 1, \ldots, L, \tag{5}$$

$\beta_{n,i}$ is the belief degree, such that $\beta_{n,i} \geq 0$, $\sum_{n=1}^{N} \beta_{n,i} \leq 1$. It indicates that the evaluation indicator X_i is rated as H_n level to the extent of $\beta_{n,i}$. When $\sum_{n=1}^{N} \beta_{n,i} < 1$, it is not fully evaluated, while $\sum_{n=1}^{N} \beta_{n,i} = 1$ gives a complete evaluation. Based on the improved indicator system from Step 3, we used the Evidential Reasoning Approach to assign corresponding H_n and confidence $\beta_{n,i}$ to the indicator.

Step 3.2: Transformation of the belief degrees to the underlying probability assignments:

Assuming that only two evaluation levels are considered, Y is the total indicator in the upper layer, $X = \{X_1, X_2, \ldots, X_L\}$ is the secondary indicator of the lower layer.

Assuming that m is a mass function, the indicator X_i supports the degree to which the total indicator Y is rated as H_n. The term $m_{H,i}$ is the unallocated residual mass function, then $m_{n,i}$ and $m_{H,i}$ can be obtained from Equations (6) and (7), respectively.

$$m_{n,i} = W_i \beta_{n,i}, \tag{6}$$

$$m_{H,i} = 1 - \sum_{n=1}^{N} m_{n,i} = 1 - W_i \sum_{n=1}^{N} \beta_{n,i}, \tag{7}$$

where W_i is the weight of the indicator X_i with $0 \leq W_i \leq 1$ and $\sum_{i=1}^{L} W_i = 1, i = 1, 2, \ldots, L$

$$m_{n,I(i+1)} = K_{I(i+1)} \left[m_{n,I(i)} m_{n,i+1} + m_{H,I(i)} m_{n,i+1} + m_{n,I(i)} m_{H,i+1} \right], \tag{8}$$

$K_{I(i+1)}$ is the coefficient adjusting evidence conflicts.

Calculate the comprehensive belief degree of secondary indexes $X = \{X_1, X_2, \ldots, X_L\}$ to the grade H_n.

$$\beta_n = \frac{m_{n,I(L)}}{1 - m_{n,I(L)}}, \tag{9}$$

β_n is the belief degree of the aggregated assessment.

The third step is to use the evidential reasoning method to select the new residential projects in the region and evaluate the management performance of the local government.

2.3. Data Sources

We will illustrate the application of the proposed evaluation indicator system and model in the performance evaluation of government energy conservation regulation. The data set comes from ten NRBPs in Changsha City, Hunan, China, randomly selected by the Energy-saving Supervision Department of Hunan Province Government (ESDPG) in 2020. Information about these ten projects is shown in Table 3.

Table 3. Names and address information of NRBPs.

Order	Project Address (Changsha City)
Project 1	No. 408, Tongzipo West Road, Gaokai District
Project 2	Wangcheng District, Golden Street, North Side of Golden Avenue
Project 3	Pingtang Town, Yuelu District,
Project 4	Chiling Road
Project 5	Star Town, Wangcheng County
Project 6	No. 74, Chiling Road, Tianxin District
Project 7	No. 215, Chiling Road, Tianxin District
Project 8	Intersection of Kaiyuan East Road and Dongba Line, Xingsha
Project 9	Junction of Lantian Road and Jintang Road, Changsha County Economic and Technological Development Zone
Project 10	Meixi Lake International New City, Yuelu District

3. Results

We distributed questionnaires to 10 experts, including construction sector experts and energy management experts, asking them to assign scores to the initial indicators. Table 4 shows the normalized raw data of evaluation indicators.

Table 4. Normalized raw data of evaluation indicators.

Index/Expert		1	2	3	4	5	6	7	8	9	10
A_1	X_1	0.80	1.00	0.80	0.20	0.20	1.00	0.60	0.20	0.40	0.60
	X_2	1.00	0.80	0.80	0.40	0.40	0.60	1.00	0.20	0.80	0.80
	X_3	1.00	0.32	0.45	0.08	0.16	0.20	0.27	0.00	0.22	0.19
	X_4	1.00	0.60	0.80	1.00	0.60	0.40	0.40	0.60	0.80	0.80
	X_5	1.00	0.60	1.00	0.60	1.00	0.80	0.60	0.60	0.40	0.80
	X_6	0.80	0.40	0.60	1.00	0.80	0.20	1.00	0.60	0.60	0.40
	X_7	1.00	0.67	0.00	0.33	0.00	0.00	0.00	0.40	0.20	0.13
A_2	X_8	0.80	0.80	0.60	0.60	0.40	0.80	0.80	0.60	0.80	0.60
	X_9	0.80	0.80	0.80	0.60	0.60	0.60	0.80	0.80	0.80	0.60
	X_{10}	0.60	0.60	0.60	0.60	0.40	0.80	0.80	0.60	0.80	0.40
	X_{11}	0.80	0.80	0.60	0.80	0.40	0.80	0.80	0.60	0.80	0.40
A_3	X_{12}	0.00	0.20	0.80	0.40	0.20	0.60	0.20	0.40	0.60	0.20
	X_{13}	0.40	0.40	0.40	0.20	0.20	0.00	0.40	0.60	0.40	0.20
	X_{14}	0.80	1.00	0.60	0.80	0.80	0.60	0.40	0.80	0.60	0.60
	X_{15}	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	0.00
A_4	X_{16}	0.80	0.60	0.60	0.80	0.40	0.40	0.40	0.40	0.20	0.40
	X_{17}	0.80	0.60	0.60	0.60	0.40	0.40	0.60	0.20	0.20	0.20
	X_{18}	0.80	0.80	0.60	0.60	0.60	0.40	0.60	0.60	0.80	0.40
	X_{19}	0.80	0.80	0.60	0.60	0.40	0.80	0.80	0.60	0.80	0.60
	X_{20}	0.80	0.60	0.80	0.80	0.40	0.60	0.80	0.40	0.80	0.60
	X_{21}	0.80	0.60	0.40	0.80	0.60	0.80	0.80	0.80	0.80	0.40
A_5	X_{22}	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	X_{23}	0.57	0.50	0.77	0.19	0.24	0.00	0.45	1.00	0.33	0.24
	X_{24}	0.80	0.60	0.00	0.80	0.60	0.35	0.64	0.80	1.00	0.84

The values are calculated using Equations (1)–(4) after removing the variables X_1, X_2, X_4, X_8, X_{12}, X_{13}, X_{23} and X_{24} that have a deviation degree exceeding 90%. Thus, the simplified evaluation index system, with the attribute importance and weight of indicators, is shown in Table 5.

Table 5. Simplified evaluation index system.

Attribute	Index	H(A)	H(A-{x_i})	$S_A(x_i)$	W_{xi}	W_{Ai}
A_1	X_3	2.2498	2.2655	0.0157	0.1264	0.1977
	X_5		2.1903	0.0595	0.4791	
	X_6		2.2133	0.0365	0.2939	
	X_7		2.2623	0.0125	0.1006	
A_2	X_9	2.2875	2.2765	0.011	0.6667	0.2010
	X_{10}		2.2896	0.0021	0.1273	
	X_{11}		2.2909	0.0034	0.2061	
A_3	X_{14}	2.2546	2.0794	0.1752	0.8939	0.1981
	X_{15}		2.2754	0.0208	0.1061	
A_4	X_{16}	2.2865	2.2872	0.0007	0.0461	0.2009
	X_{17}		2.2903	0.0038	0.2500	
	X_{18}		2.2843	0.0022	0.1447	
	X_{19}		2.2833	0.0032	0.2105	
	X_{20}		2.2854	0.0011	0.0724	
	X_{21}		2.2823	0.0042	0.2763	
A_5	X_{22}	2.3026	-	-	1	0.2023

Another five experts (S_1, S_2, S_3, S_4,S_5) were selected from the construction and energy-management departments of Hunan Provincial Government, with weights assigned to them based on their influences in the field. Each expert's influence starts with an equal weight of 0.2.

Application of the evidential reasoning approach: based on their knowledge, experience, and personal preferences, the five experts combined the simplified evaluation indicators to give the corresponding level and confidence. Taking Project 1 as an example, the scores of the five experts on Project 1 are shown in Table 6. For example, the expert S1 measures the secondary level indicator X_5 as H5 (0.7) and H4 (0.2), with a 70% confidence being excellent and a 20% reasonable confidence. Next, based on the weights derived from steps 2–4, Equations (6)–(9) were used to calculate each expert's evaluation level and confidence in each dimension and then each dimension's total evaluation level and confidence. Then we can calculate the supervision performance, shown in the last column of Table 6, based on the combinational algorithms. The calculated data and evaluation results related to project one are shown in Table 6.

Finally, we can obtain the results of project one at the target layer according to the overall rating data. That is, H2(0.001), H3(0.018), H4(0.624), and H5(0.344). The expert evaluation of projects 2 to 10 follow the same procedure, and Table 7 summarizes the evaluation results.

Table 6. Project 1's calculated data and evaluation results.

Attribute	Index	S1	S2	S3	S4	S5	Overall Rating
A_1	X_3	H5(1.0)	H5(1.0)	H5(1.0)	H4(0.1) H5(0.9)	H5(0.9)	H3(0.011) H4(0.292) H5(0.681)
	X_5	H4(0.2) H5(0.7)	H4(0.3) H5(0.7)	H4(0.2) H5(0.8)	H4(0.2) H5(0.8)	H4(0.1) H5(0.9)	

Table 6. *Cont.*

Attribute	Index	S1	S2	S3	S4	S5	Overall Rating
	X_6	H4(0.7) H3(0.3)	H4(1.0)	H4(0.8) H5(0.2)	H4(0.9) H5(0.1)	H4(0.7) H5(0.3)	
	X_7	H4(0.1) H5(0.7)	H5(1.0)	H4(0.1) H5(0.9)	H4(0.2) H5(0.8)	H4(0.3) H5(0.7)	
	combination	H5(0.555) H4(0.304) H3(0.072)	H5(0.575) H4(0.425)	H5(0.697) H4(0.303)	H5(0.641) H4(0.359)	H5(0.757) H4(0.231)	
A_2	X_9	H4(0.8)	H4(1.0)	H4(0.8) H5(0.2)	H4(0.7) H5(0.3)	H4(0.8) H5(0.2)	H2(0.008) H3(0.031) H4(0.828) H5(0.101)
	X_{10}	H2(0.3) H3(0.7)	H3(0.8)	H2(0.2) H3(0.8)	H2(0.2) H3(0.8)	H2(0.3) H3(0.7)	
	X_{11}	H4(1.0)	H4(0.5) H5(0.5)	H4(0.8) H5(0.2)	H4(0.8) H5(0.2)	H4(0.7) H5(0.3)	
	combination	H2(0.021) H3(0.048) H4(0.789)	H3(0.042) H4(0.885) H5(0.048)	H2(0.011) H3(0.042) H4(0.776) H5(0.171)	H2(0.011) H3(0.043) H4(0.696) H5(0.251)	H2(0.016) H3(0.037) H4(0.760) H5(0.187)	
A_3	X_{14}	H4(0.8) H3(0.2)	H4(0.9) H3(0.1)	H4(0.8) H5(0.2)	H4(0.9) H5(0.1)	H4(0.9) H5(0.1)	H3(0.042) H4(0.886) H5(0.073)
	X_{15}	H5(1.0)	H5(1.0)	H5(1.0)	H5(1.0)	H5(1.0)	
	combination	H3(0.197) H4(0.789) H5(0.014)	H3(0.099) H4(0.888) H5(0.014)	H5(0.229) H4(0.771)	H5(0.123) H4(0.877)	H5(0.123) H4(0.877)	
A_4	X_{16}	H4(0.8)	H4(1.0)	H4(0.8) H5(0.2)	H4(0.7) H5(0.3)	H4(1)	H3(0.027) H4(0.894) H5(0.064)
	X_{17}	H4(0.8) H3(0.2)	H4(1.0)	H4(0.8) H5(0.2)	H4(0.8) H5(0.2)	H4(0.9) H5(0.1)	
	X_{18}	H4(0.8) H3(0.2)	H4(0.9) H5(0.1)	H4(0.8) H5(0.2)	H4(0.9) H5(0.1)	H4(0.9) H5(0.1)	
	X_{19}	H4(0.8) H3(0.2)	H4(0.8) H5(0.2)	H4(0.8)	H4(0.7) H5(0.3)	H4(0.9) H5(0.1)	
	X_{20}	H4(0.8) H3(0.2)	H4(0.8) H5(0.2)	H4(0.6)	H4(0.8) H5(0.2)	H4(0.9) H5(0.1)	
	X_{21}	H4(0.8) H3(0.2)	H4(0.8) H5(0.2)	H4(0.8) H3(0.2)	H4(0.6) H5(0.4)	H4(0.9) H5(0.1)	
	combination	H3(0.150) H4(0.841)	H4(0.909) H5(0.091)	H3(0.043) H4(0.822) H5(0.064)	H4(0.774) H5(0.226)	H4(0.933) H5(0.067)	
A_5	X_{22}	H5(0.8) H4(0.2)	H5(1.0)	H5(1.0)	H5(1.0)	H4(0.3) H5(0.7)	H4(0.068) H5(0.932)
	combination	H5(0.8) H4(0.2)	H5(1.0)	H5(1.0)	H5(1.0)	H4(0.3) H5(0.7)	

The evaluation results of the first-level indicators A1–A5 of the calculated project 1 are shown in Figure 1, in which the evaluation level H_n is taken as the *x*-axis, the confidence level $\beta_{n,i}$ of each evaluation level H_n as the *y*-axis.

The evaluation results of ten projects are shown in Figure 2, in which the project name is the *x*-axis, the project evaluation level Hn (unqualified, fair, average, good, excellent) the *y*-axis, and the belief degree βn,i of each evaluation level Hn the *z*-axis. Similar to the analysis of project one, we can obtain the functional relationship of the ten projects with their respective evaluation levels Hn and the confidence level βn,i. of each evaluation level.

Table 7. Evaluation results of 10 projects.

Order	Target Layer
Project 1	H2(0.001) H3(0.018) H4(0.624) H5(0.344)
Project 2	H1(0.010) H2(0.085) H3(0.208) H4(0.294) H5(0.393)
Project 3	H1(0.008) H2(0.119) H3(0.340) H4(0.187) H5(0.323)
Project 4	H2(0.059) H3(0.396) H4(0.272) H5(0.262)
Project 5	H1(0.024) H2(0.168) H3(0.224) H4(0.248) H5(0.343)
Project 6	H1(0.051) H2(0.151) H3(0.330) H4(0.230) H5(0.225)
Project 7	H1(0.041) H2(0.206) H3(0.159) H4(0.315) H5(0.264)
Project 8	H1(0.042) H2(0.069) H3(0.247) H4(0.376) H5(0.249)
Project 9	H1(0.063) H2(0.138) H3(0.223) H4(0.358) H5(0.209)
Project 10	H1(0.062) H2(0.238) H3(0.309) H4(0.165) H5(0.206)

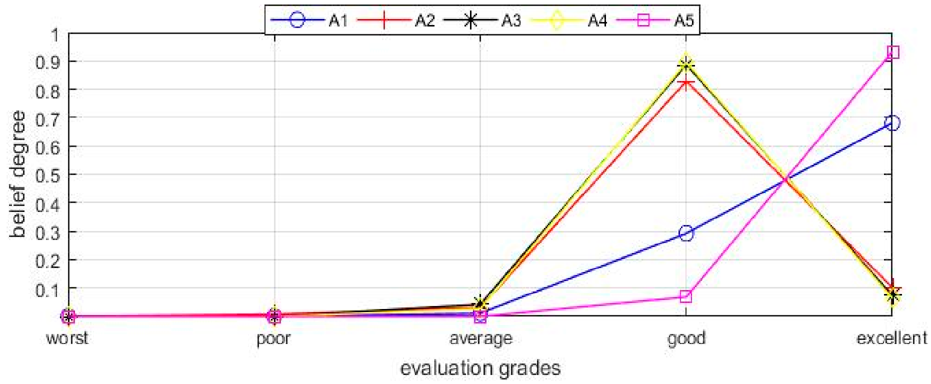

Figure 1. Results of the evaluation of indicators A1–A5 for project 1.

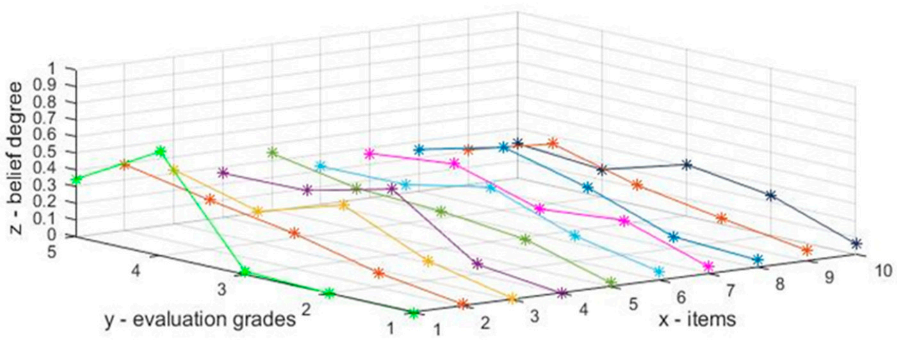

Figure 2. Evaluation results of 10 projects in Changsha.

4. Discussion

4.1. Indicator Systems

The weights of the first-level indicator Ai in evaluating the regulatory performance of the Changsha Municipal Government (CMG) are different. Although the scale intensity control effect and the comprehensiveness of the project's certification information are high, the overall weight is not much different. The weight vector WA = (0.1977, 0.2010, 0.1981, 0.2009, 0.2023) corresponding to the five first-level indicators can be considered of equal importance to the five aspects of government regulatory performance of energy-saving buildings in Changsha.

The energy-saving degree of the project in Changsha has the highest weight of the housing structure design (0.4791), which is much greater than the equipment configuration design (0.2939), the green layout (0.1264). Moreover, the renewable energy utilization information (0.1006) is different from the researchers' past emphasis on land protection [60–62].

Government regulation should first consider the qualification criteria for enterprises and professionals [39], building energy-efficient material certification information [24], energy-saving certification of property management enterprises [41], building energy efficiency level, and other information. In this case, the energy-saving degree of 10 projects in Changsha is reflected in the three factors: building energy-saving material certification information, property management energy-saving certification information, and building energy-saving level information. Among them, the weight of X9 (0.6667) of the comprehensiveness of the building energy-saving material certification information in the project is much higher than that of other factor indicators, indicating that this indicator is the most important, followed by the project's building energy-saving level information X11 (0.2061), and the weight of the property management energy-saving certification information (0.1273) is low.

It is crucial to explain the audit information of buildings' energy consumption and adequate supervision of new energy-saving building projects. Based on the energy plan proposed by [15] as a performance criterion, we extend the indicators to energy information and communication technologies, energy consumption statistics, energy consumption audits, and degree of information disclosure. However, through calculation, the simplified evaluation indicators (Table 5) include only two items: building energy consumption audit information and information disclosure. It shows that the performance of these two indicators determines the performance of government supervision in terms of the energy information manager of the project. Among them, the weight of building energy consumption audit information of 0.8939 is much higher than the degree of information disclosure (0.1061).

Among the government supervision performance of the energy-saving policies and system arrangement effects of the projects in Changsha, the incentive degree of the energy-saving policies X17 and the clarity of the policies X21 had the highest weights, 0.2500 and 0.2763, respectively; the effectiveness (degree) of the project review mechanism X19 was weighted third highest (0.2105), so these three factors are the most important in the evaluation of the performance of the CMG. This finding agrees with the research results of Mohammed et al. [63] and De Vries and Verhagen [46]. This shows that the degree of incentive of energy-saving policies, the clarity of policies, and the effectiveness of the project review mechanism must be paid attention to by the government, and the implementation of incentives, more publicity policies, and strict review are conducive to the energy-saving work of the project. Incentives are proposed that specific construction sites and construction personnel should be encouraged to save energy.

Not exceeding the total regional residential control X22, the rationality of the total power consumption index control X23, and the rationality of the total gas consumption index control X24. This is consistent with the "China Building Energy Conservation Annual Development Research Report 2018" which pointed that the total scale of residential buildings should be strengthened to clarify whether the project exceeds the total scale of residential buildings in the area. In this case, the simplified evaluation indicators (Table 5) only reflects that the project does not exceed the regional total residential control indicator X22, which shows that the regulatory performance of the CMG in terms of scale intensity control effect is reflected in one of the indicators of total residential control. In particular, it is worth mentioning that this indicator accounts for the highest proportion of all indicators at the first level (0.2023), indicating that the indicator has the most significant impact on the regulatory performance of the CMG. Therefore, the CMG should prioritize the control of the total number of residential buildings in the area, which has the most significant effect on improving energy saving.

The performance of the energy-saving index A1 of the project depends on the second-level indicators X5 and X6, i.e., the design of housing structure and equipment configuration. The weights of the second-level index Xi under the first-level index Ai are different. For example, the first-level indicator A1 includes four second-level indices X3, X5, X6, and X7, sorted by their weights as WX5 > WX6 > WX3 > WX7. These 16 indicators, extracted from the original 24 energy-saving supervision performance indicators, are aimed at this area, which together reflects the key content of the CMG's energy-saving supervision of new projects in this area.

4.2. Case Performance Evaluation Results

The comprehensiveness of the certification information of project A2, the energy information management of project A3, and the arrangement effect of the energy-saving policy and system A4 can be seen in Figure 1. From the figure, we can see that the five aspects (A1–A5) exhibit a high degree of confidence, with the level of good grades reaching the highest (0.828, 0.886, and 0.894). The confidence level and grade of the project's energy-saving degree A1 and scale intensity control effect A5 showed an increasing trend, reaching the highest confidence level in the excellent level (0.681 and 0.932). It can be inferred that the government regulatory performance of Project One is good, especially in terms of the energy-saving degree and scale intensity control.

The evaluation grades of project 3, project 4, project 6, and project 10 are average while the evaluation grades of project 1, project 7, project 8, and project 9 are good. The evaluation grades of the remaining two projects are excellent. If we assume that ten projects are not graded and have equal weights of 0.1, we can use the E-R model combination algorithm to obtain the CMG Energy Conservation Regulatory Performance Evaluation H1 (0.0269). H2 (0.1155), H3 (0.2441), H4 (0.3150), and H5 (0.2862). That is, 31.5% confidence level is good, and 28.62% confidence is excellent. This result is consistent with the analysis in Figure 2.

The CMG has an excellent regulatory performance on energy conservation of new residential buildings. It notices the effect of scale intensity control, energy information management, and the comprehensiveness of project certification information. The project's energy-saving degree A_1 and the energy-saving policy and system arrangement effect A4 score are relatively low, which thus need to be strengthened.

Consequently, the evaluation results can guide local governments to save energy and reduce emissions. For example, the energy efficiency of the ten NRBPs in Changsha, Hunan Province is mainly reflected in the design of sustainable site design and equipment configuration. Therefore, the CMG should pay more attention to the evaluation of energy consumption audit in policy supervision. Moreover, the government should emphasize the use of energy-saving material certification and energy-saving level information due to their significant weights.

Researchers should be cautious that all ten projects in this study were from the same area. To apply the research method in other geographic locations, researchers need to integrate the regional regulations and characteristics, repeat the calculation process, find the key energy-saving supervision issues, and then conduct a grade evaluation.

5. Conclusions and Implications

To effectively measure the local government's management on NRBPs, we proposed an evaluation system based on the literature, expert inputs, and evidential reasoning model from the rough set theory. We proved the method's effectiveness by evaluating ten randomly selected building projects in Changsha, Hunan. The weights of the five primary indicators can be ranked from high to low to identify the critical aspects of performance management. The same is also true for the secondary indicators.

The effects of energy regulations are regionally different [64]. Researchers can combine the proposed indicator system with domestic laws and regulations to increase applicability and effectiveness. The local governments can use the derived indicators to prioritize NRBPs' energy-saving supervision.

Our method has two differences and improvements over previous studies. First, the indicators are not static for the evaluation. The proposed system provides a fundamental evaluation framework, which will be supplemented with energy experts' input. Second, the energy-saving goals are not fixed but are selected from the jurisdictions to warrant objectivity. Our proposed method is thus applicable and meets the management knowledge standard proposed by HakemZadeh and Baba [55].

The evaluation system can help reveal the NRBP energy-saving loopholes and take remedial actions such as promoting green building materials or issuing a special fund policy. The government can also enhance NRBP stakeholders' energy conservation awarenessand take corresponding energy measures. As a result, for example, architecture design companies will comply with energy standards in their residential building design work.

The construction industry changes fast and frequently, which accordingly brings in changes in environmental regulations, the use of new materials and new building technologies. These changes will drive the change of the indicators and weights in the evaluation system, which need to be considered when using our research methods in the future.

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