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Risk Assessment Method and Application of Renewable Energy System Based on the Background of Low-carbon Economy

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Abstract: Energy development has a crucial impact on social progress. Renewable energy power generation has achieved good economic and environmental benefits, and will certainly play an important role in the future energy structure. The purpose of this paper is to study risk assessment methods for renewable energy systems and their applications in the context of a low-carbon economy. The grey relational clustering analysis method is used to attempt to regionally cluster the vulnerability of renewable energy in each province. By introducing risk preference, this paper discusses the impact of different decision makers' risk awareness on the assessment results. The classification results show that the renewable energy vulnerability indicators selected in this paper have good discrimination and representativeness, and can be used as the indicator system of the vulnerability comprehensive decision-making assessment model for decision-making analysis and regional vulnerability comparative analysis.

1. Introduction

With the acceleration of urbanization and the increase of the number of cities in my country year by year, how to solve the contradiction between energy and environment, energy and economy is a prominent issue that governments at all levels must consider within the framework of sustainable development strategies. The construction of renewable energy is one of the effective ways to solve these contradictions [1-2]. The concept of harmonious coexistence between man and nature must be formed, that is, man and nature coexist in harmony and respect each other [3]. This renewable energy construction measure can not only ensure the safety of energy consumption, effectively alleviate the deteriorating ecological environment, but also promote the continuous improvement and gradual maturity of renewable energy-related science and technology. Renewable energy construction is a key way to solve important problems in the process of urban development [4-5].

The development of renewable energy construction can not only control global warming, reduce the occurrence of natural disasters, improve people's living environment, and make society more stable [6]. Rezaei R tested a model on the intentions of rural households in Iran to use renewable energy. The model focuses on the Unified Theory of Acceptance and Use of Technology (UTAUT), which we extend to investigate factors that influence intention to use renewable energy. Using responses from 280 household heads in rural Zabor County (located in southern Iran) and employing multivariate techniques of structural equation modeling, we identified four variables—perceived behavioral control, awareness, comparative advantage, and ethics— There is a statistically significant positive relationship with the intent variable and explains about 46% of the variance [7]. Appino RR proposes an upper-level optimization formulation based on data-driven probabilistic prediction of power and energy output of uncontrollable loads and generators dependent on renewable energy sources. Specifically, relying on probabilistic predictions of power and energy distributions for uncertain demand/generation, a novel framework is proposed to ensure the online feasibility of dispatch plans under a given safety level. Simulations based on real household production and consumption data illustrate the effectiveness of the proposed scheme [8]. Improving the theoretical methods and technical systems of risk assessment of renewable energy systems can promote sustainable urban development in the context of a low-carbon economy.

Under the guidance of the theoretical framework of climate change vulnerability, this paper discusses the main assessment processes, modules and related methods and technologies based on the vulnerability assessment system, aiming at the main problems of risk assessment of renewable energy systems in the context of low-carbon economy. Renewable energy system risk assessment Carry out comprehensive research on climate change vulnerability, provide evaluation methods and technical system tools that can be referenced and referenced, and analyze the future constraints on my country's renewable energy development and the high vulnerability to climate change that renewable energy faces. characteristics, and provide a reference for further comprehensive vulnerability assessment.

2. Risk Assessment Methods for Renewable Energy Systems

2.1. Gray Risk Multi-attribute Decision Making

The grey risk multi-attribute decision-making problem is composed of five elements: decision-making unit, scheme set, attribute set, decision-making rule and decision-making situation. The specific meaning of each element is as follows:

(1) decision-making unit

It mainly refers to the human-computer system that processes information, and is generally composed of decision-making analysts, decision-makers, drawing instruments, and computers. The role of the decision-making unit can be expressed as accepting input information, forming systematic knowledge through certain processing, and serving as the basis for decision-makers to judge and decide [9-10].

(2) Scheme set

A scheme is a statement that the decision maker wants the object to be studied to achieve a certain state. We define the scheme set as A{A1, A2, ..., An}, then there are n kinds of schemes for decision makers to choose [11-12].

(3) attribute set

Attributes are measurable, and are the characteristics, performance or quantitative parameters, quality, etc. of the scheme, which reflect the degree to which the goal associated with the attribute achieves the goal [13-14]. We define the attribute set $u=\{u1, u2, ..., um\}$, then each scheme has m attributes.

(4) decision-making criteria

The basis for sorting or clustering all schemes according to the aggregated attribute values is called decision criterion. Decision criteria can generally be divided into the following two categories: one is the optimality criterion, which can arrange all the alternatives into a complete order, and on this basis an optimal solution can always be found [15]. The other type is the satisfaction criterion, which can simplify the decision-making problem, and the cost is relatively low. larger, while the scheme difference between each category is smaller [16].

(5) Decision-making situation

It is the basis of risk-based decision-making, which mainly refers to the boundary and basic composition of the decision-making environment and decision-making problem; specifically, the decision-making situation includes not only the scheme set and attribute set, but also the state of the natural environment [17].

The grey-risk multi-attribute decision-making process generally includes analyzing the problems to be solved, constructing a decision-making scheme, determining attribute weights, normalizing the decision matrix, establishing a model, solving the model, determining the pros and cons of the scheme, and analyzing the final scheme. , the specific solution process is shown in Figure 1.

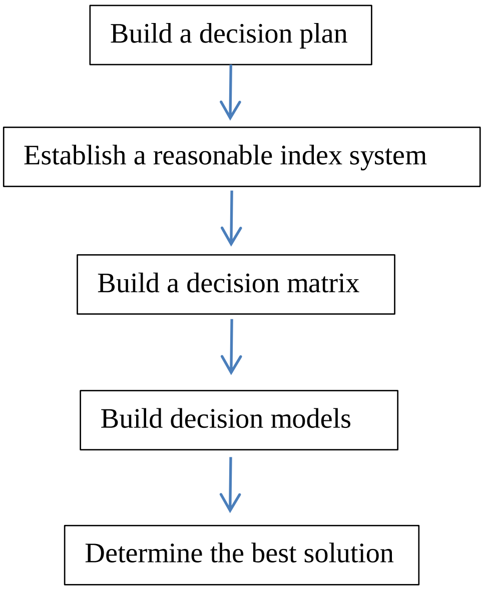

Figure 1. The solution process diagram of grey risk multi-attribute decision making

2.2. Renewable Energy Climate Change Risks

"Low-carbon city" should be understood as the transformation of economic development model, urban spatial development model, consumption concept and lifestyle, and on the premise of ensuring the continuous improvement of life quality, to achieve urban construction that helps to reduce carbon emissions, and the development model includes industrial development, urban space, energy consumption, etc. Therefore, the research and comprehensive assessment of climate change in urban areas is an important basis for implementing the scientific planning of "low carbon city" [18].

This paper summarizes climate change vulnerability into the following three basic characteristic elements:

(1) System attributes: including socio-economic systems, natural systems, and coupling systems between humans and the environment.

(2) Time marker: From the time dimension, climate change vulnerability can be divided into historical and current vulnerability and vulnerability under future climate change scenarios; or vulnerability at a certain time point and time period. Different vulnerability factors have different time stamp characteristics [19].

(3) Spatial scale: including intrinsic (indigenous, local spatial scale) vulnerability factors, which refer to the attributes of vulnerability or the community itself; external (external, out-of-place) vulnerability factors, which refer to outside the vulnerable system elements. It should be pointed out that the spatial scale of the same vulnerability factor will change with the change of the geographical category of the evaluation system. For example, in the Gujia assessment, national policies are considered as internal factors, while as regional assessments, they are regarded as external factors.

2.3. Selection of Vulnerability Indicators of Renewable Energy System

(1) Renewable energy exposure

We define exposure as the degree of impact of the development of renewable energy systems in each region on climate change (climate variability and extreme climate events), that is, the economic, human, land, and environmental conditions (extreme climate change) required for the development of renewable energy climate). Specifically, renewable energy exposure is divided into five parts: economic exposure level, population exposure level, historical overview of extreme climate events, energy structure exposure, and land use.

(2) Sensitivity to renewable energy

Sensitivity can be defined as the dependence of each region on renewable energy and the changes in climate elements on which the development of the renewable energy system depends, mainly including five factors such as rainfall, wind speed, sunshine, temperature, and humidity that are closely related to the development of renewable energy. Climate factors and the level of reliance on renewable energy in each region are represented by the proportion of installed renewable energy power generation.

(3) Adaptability of renewable energy systems

Adaptability can be seen as the ability of renewable energy systems and even the entire socio-economic system of a region to effectively respond to and deal with risks when faced with climate risks. As far as the adaptability of the renewable energy system is concerned, we divide it into four aspects: assets, learning ability, flexibility, and social organization ability.

3. Application of Risk Assessment Methods for Renewable Energy Systems

3.1. Research Methods and Data

In this paper, the vulnerability of different provinces and cities in my country can be divided into several categories through grey relational clustering, so as to identify and classify the vulnerability and evaluate the rationality of the vulnerability evaluation system. Five provinces and cities across the country are selected as observation objects, and each object observes m characteristic data (the number of characteristics of each aspect of vulnerability in this study is different, specifically, exposure system = 7, sensitivity system = 6, capability system = 8), the upper triangular matrix is obtained, which is called the eigenvariable correlation matrix, as shown in formula (1).

$$A=\begin{bmatrix} \varepsilon_{11} & \varepsilon_{12}\cdots & \varepsilon_{1\mathrm{m}} \\ & \varepsilon_{12} \quad \cdots & \varepsilon_{2\mathrm{m}} \\ & \cdots \quad \cdots & \\ & & \varepsilon_{\mathrm{mm}} \end{bmatrix} \tag{1}$$

According to the defined grey absolute correlation degree and properties, we can obtain the grey correlation matrix of the three levels of the vulnerability of renewable energy to climate change. In this paper, the clustering standard r=0.9 is selected, that is, when εij ⩾ 0.9, Xi and Xj are of the same class, so that the clustering analysis result can be obtained.

3.2 Comprehensive Assessment of Renewable Energy Climate Change Vulnerability

We assume that the elements are interchangeable, and the following formula (2) is used to standardize each element to each index value in the 0-1 interval, and the average can be obtained by adding the three elements of vulnerability. The range of variation is 10 to 100, which can be transformed using formula (3), and the climate change vulnerability faced by the renewable energy system in each region can be calculated using formula (4), where E, S, AC represent exposure, respectively, Sensitivity and adaptability.

$$x=(X-X_{\mathrm{min}})/(X_{\mathrm{max}}-X_{\mathrm{min}}) \tag{2}$$

$$y=10+(Y-Y_{\mathrm{min}})/(Y_{\mathrm{max}}-Y_{\mathrm{min}})\times 90 \tag{3}$$

$$V=(E+S)-AC \tag{4}$$

Assuming that the index of each element of vulnerability is assigned as [0, 1], so according to formula (4), we can obtain the value range of vulnerability as [-1, 2]. After data sorting, we can obtain the value range of vulnerability is [0, 3]. These values are only meaningful in comparative contexts, when the vulnerability is high, it means that it faces a higher vulnerability compared to other regions.

4. Analysis of the Application of Risk Assessment Method for Renewable Energy System

4.1. Analysis of the Impact of Risk Preference on Model Results

This paper introduces risk preference to measure the impact of different risk preference on decision-making results. Table 1 lists the changes of gray correlation between M province and other provinces and cities under different risk preferences. It can be seen from Figure 2 that the change of risk preference affects the value of each gray correlation degree, but the classification results related to M province have not changed when the clustering standard of this paper is unchanged.

To sum up, when the clustering standard remains unchanged, the risk preference of the decision makers basically does not affect the results of the clustering analysis. changes, the gray absolute correlation value basically does not change.

Table 1. Relative changes of grey correlation degree under different risk preferences

Area	Risk hobby	Risk neutral	Risk aversion
Province a	0.84	0.88	0.92
Province b	0.79	0.81	0.80
Province c	0.71	0.72	0.74
Province e	0.75	0.76	0.74

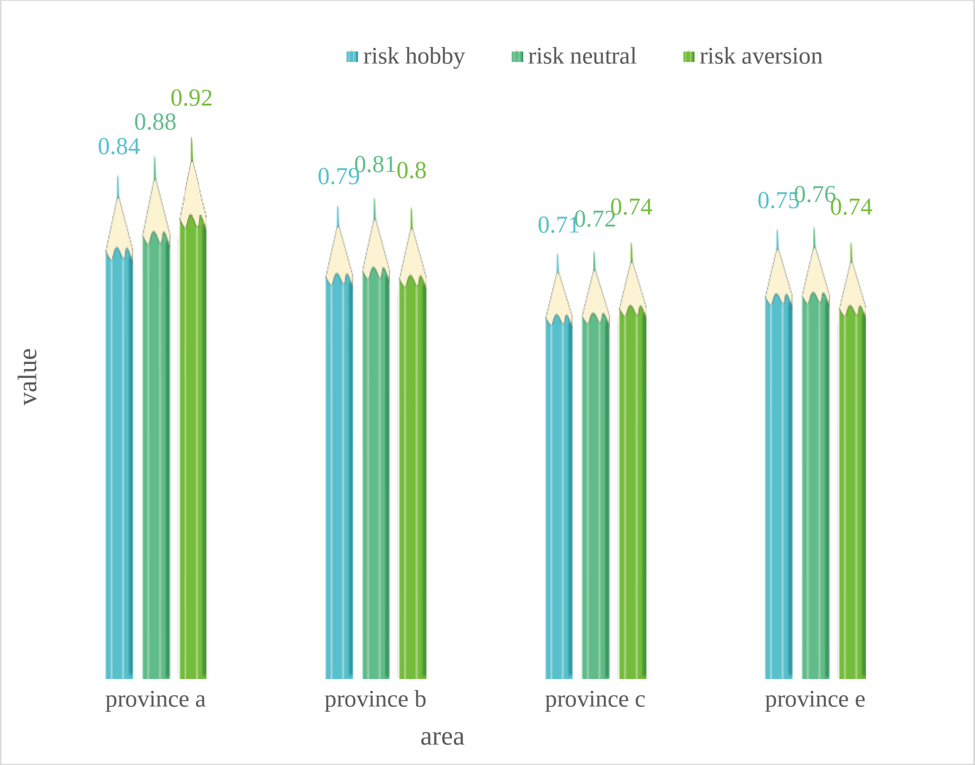

Figure 2. Impact of risk appetite on model results

4.2. Climate Change Vulnerability of Regional Renewable Energy Systems

The vulnerability score of each region varies from 20 to 150. Among them, the renewable energy system in province a has the highest vulnerability because of its high sensitivity and exposure, frequent climatic extreme events, and relatively low adaptive capacity. It is difficult to cope with the negative impacts of climate change; the lowest vulnerability is province b, which has strong adaptive capacity, but low sensitivity and exposure, and the renewable energy system can effectively deal with climate risks. The cointegration analysis results of a single indicator showed a relatively strong correlation between sensitivity, exposure and vulnerability composite score, as shown in Figure 3, while the principal component analysis results revealed exposure, sensitivity and adaptive capacity The shares of explanation for the vulnerability composite score were 50%, 30%, and 20%, respectively. Given that exposure has a strong impact on the comprehensive vulnerability score, the specific exposure analysis found that province a, province c and province e have the largest values (110, 90 and 77, respectively), and their renewable energy has the greatest impact on climate change. Facing the strongest exposure, as shown in Table 2.

Table 2. Vulnerability of renewable energy systems by region

Area	Sensitivity	Exposure	Adaptability
Province a	53	110	42
Province b	21	45	89
Province c	44	90	60
Province e	40	77	78

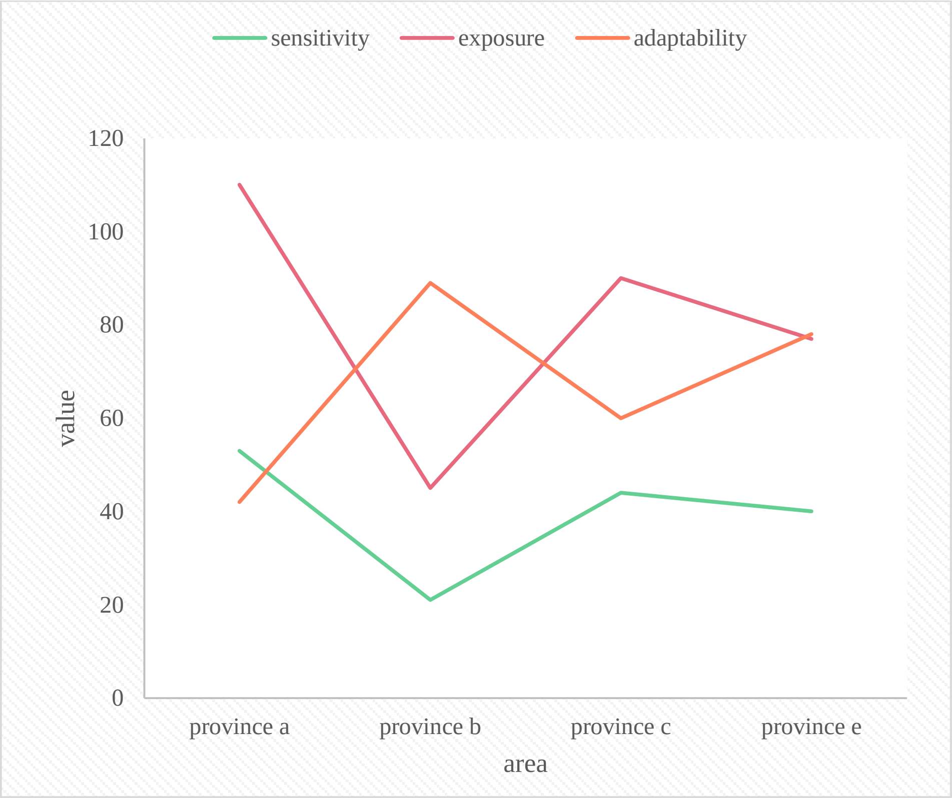

Figure 3. Performance of the three dimensions of vulnerability

5.Conclusion

Research on risk assessment of renewable energy systems is a huge systematic work. At present, this field is still in its infancy in my country and lacks a relatively mature theoretical method system. Due to time and data constraints, this paper only covers part of the overall assessment of climate change vulnerability in urbanized areas. Regarding the theoretical method system and climate change vulnerability assessment work, further research is needed. For example, the climate change vulnerability theory and methodological system in the risk assessment of renewable energy systems need to be further improved, especially the theory and method for future climate change vulnerability assessment.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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