ISSN: 2688-9323

# Study on the Risk Identification and Optimization Mechanism of Energy Security Transformation

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## Abstract

**In the context of the current national effort to deal with global warming, what China needs to do is to change from traditional energy source to solar energy, wind energy, geothermal energy, natural gas, hydrogen energy, etc. diversified forms of renewable energy and clean energy mainly transformation. Under the new circumstances, China's energy development faces complex challenges and severe challenges. On the premise of ensuring energy security, we should also promote low-carbon energy consumption. Energy is the basic material that human beings depend on survival, and is an important support for developing the national economy and maintaining social stability. Energy security is of paramount importance in today's industrial society in the event of an energy shortage or disruption. It will have a serious impact on the national economy and national defense and security system. Energy security not only refers to the provision of stable energy supply to ensure the normal needs of national survival and development. It also means that energy is produced and consumed without threatening the normal functioning of other aspects of society. China's energy transition faces security risks such as large total energy consumption, large carbon emissions, a more coal energy mix, high dependence on oil and gas, and weak development of renewable energy. The energy security transition under the dual carbon target should accelerate the implementation of comprehensive energy conservation strategies. The K-means clustering model was established to turn it into high, high, general and low levels green development areas, and the spatial dimension analysis was conducted.**

## Keywords

**Energy Security; Energy Transformation; Risk Identification; Optimization of Mechanism; K-Means Clustering.**

## 1. Introduction

With China's booming economy, the demand for energy is growing. The transformation of energy security is not only about the substitution of energy variety, it also involves the adjustment of the entire energy production, consumption, market, policy and regulatory system. Sustainable energy strategy is of great significance to ensuring national energy security. The energy security and energy security transformation strategy has increasingly become a major issue in the current international community and national security strategy[4]. On December 1,2022,The CNPC Economic and Technology Research Institute and S & P Global held the theme of "Energy Transformation and Energy Cooperation under the New Situation'', closely combined with the latest strategic deployment of the Party's 20th plan for energy development. By analyzing the important opportunities and major challenges facing the energy industry, we will seek common development plans and jointly promote energy transformation. To guide the development of China's national economy in a sustainable and low-carbon direction, put forward the strategy of guaranteeing China's energy security transformation and make the risk assessment and the corresponding countermeasures[5]. To establish an evaluation index

ISSN: 2688-9323

system for the energy security transformation. Collect the relevant data. Integrated principal component analysis, K-means cluster analysis and other methods. It was solved by using the SPSS software.

In summary, at present, the research on the energy security transition is still not mature enough. Few research results on the risk identification and optimization mechanism of China's overall energy security transformation. Most choose to analyze a certain province, and there are the following shortcomings. (1)Research perspectives have mainly focused on the individual energy security segments. Basically focus on energy supply and use security. In the context that the country attaches great importance to energy security. Domestic research on quantitative energy security is relatively weak. The main performance is the lack of research results, the lack of consensus; It is particularly important to study the risk identification and optimization mechanism of energy security transformation. We need to make an exact analysis of the different energy sources. To explore the transformation and optimization conditions: at the same time. National and regional governments are investing more in the new energy industry, energy conservation, environmental protection and scientific research. Therefore, the connotation of energy security evaluation should further expand the economic and environmental aspects. But there are still a few related studies, especially for energy and environmental impacts.(2)In this paper, principal component analysis is used to determine the selection of evaluation weights. The determined weights are more influenced by subjective factors. During the rapid extraction of the principal components. It will inevitably cause the loss of information. And the lost information is positively correlated with the number of indicators. For that reason, this method, using K-means cluster analysis and principal component analysis. On the basis of studying the stable and safe use of energy supply, two dimensions of energy economic input and environmental protection are added. The quantitative evaluation and analysis of China's regional energy security level are conducted from four dimensions to provide scientific reference for regional governments or enterprises to formulate energy security or environmental protection policies.

## 2. Construction of Evaluation Index System

The development of the regional energy security transition level is related to various factors. Involves a wide range of areas. Therefore, n order to accurately evaluate the level of energy security transformation and development in some parts of China. We need to select multiple influence indicators for their comprehensive evaluation[6] . This paper selects 12 indicators from three aspects of science and technology level, economic development level and system and policy influence. It includes the exploration and development of new energy, the utilization rate of new energy, the per capita income of residents, urban resource allocation, fiscal subsidy policies and green energy consumption system. A comprehensive evaluation index system for the level of energy security transformation and development in some regions of China is constructed for comprehensive evaluation. The evaluation indicators are shown in the Table1:

The level of science and technology reflects the main level of the energy security transition in the region. The exploration and development of new energy should be carried out reasonably in this area. And the energy security transition to realize the secondary utilization of resources has an absolute impact; The level of economic development is mainly measured by the per capita income of local residents and the infrastructure level. At the same time, through the allocation of urban resources and the cultural and education level of residents to reflect the residents' recognition of energy security transformation. Is the most direct impact factor on the transformation of urban energy security. It can more reflect the progress level of urban energy security transformation; The impact of policies includes the government's human intervention in residents and the market, and guides people to use new energy rationally through laws,

ISSN: 2688-9323

regulations, financial subsidies and other policies, which plays a role in guaranteeing the development of energy security transformation.

**Table 1.** Comprehensive evaluation index system for the level of energy security transformation and development in some regions of China

| Level 1 indicators | Level 2 indicators | Level 3 indicators |
|---|---|---|
| Level of the transformation and development of energy security (A) | Science and technology level (B1) | Speed of the existing energy transition (X1) |
| | | Exploration and development of new energy sources (X2) |
| | | New energy utilization efficiency (X3) |
| | | Environmental pollution (X4) |
| | Economic development level (B2) | Per capita income of residents (X5) |
| | | Infrastructure level (X6) |
| | | Allocation of urban resources (X7) |
| | | Cultural and educational level of the residents (X8) |
| | Institutional and policy influence (B3) | Renewable energy quota policy (X9) |
| | | Fiscal subsidy policy (X10) |
| | | Green energy consumption system (X11) |
| | | New energy feed-in tariff policy (X12) |

# 3. Comprehensive Evaluation Model based on Principal Component Analysis

## 3.1. Research Ideas

According to the data of various evaluation indicators in the China Statistical Yearbook 2022, combined with the principle of principal component analysis and its model. Due to the latency of statistics. Based on SPSS27.0 software, a comprehensive evaluation was carried out to select the development level of energy security transition in some parts of China in 2022.

## 3.2. Research Methods

1) Standardize the raw data

Suppose there are$m$indicator variables for principal component analysis$x_1, x_2, \dots, x_m$. There are$n$evaluation subjects, The value of the$j$th indicator of the$i$th evaluation object is$a_{ij}$.Convert the value of each indicator$a_{ij}$into a standardized indicator,

$$\tilde{a}_{ij} = \frac{a_{ij} - u_j}{s_j}, (i = 1,2, \dots, n; j = 1,2, \dots m),$$

Thereinto:

$$\mu_j = \frac{1}{n}\sum_{i=1}^{n} a_{ij}, s_j = \frac{1}{n-1}\sum_{i=1}^{n}(a_{ij} - \mu_j), (j = 1,2, \dots m).$$

ISSN: 2688-9323

That is, the sample mean and the standard deviation of the sample for the $j$ th indicator. Correspondingly, weighed:

$$\tilde{x}_i = \frac{x_i - \mu_j}{s_j}, (i = 1,2, \dots, m),$$

is a standardized metric variable.

2) Calculate the correlation coefficient matrix R

Correlation coefficient matrix $R = \left(r_{ij}\right)_{m \times n}$.

$$r_{ij} = \frac{\sum_{k=1}^{n} \tilde{a}_{ki} * \tilde{a}_{kj}}{n-1}, (i = 1,2, \dots m),$$

Formula $r_{ij} = 1, r_{ij} = r_{ji},\ r_{ij}$ is the correlation coefficient between the $i$th indicator and the $j$th indicator.

3) Calculate eigenvalues and eigenvectors

Calculate the eigenvalues of the correlation coefficient matrix R $\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_m \geq 0$, and the corresponding feature vector thereinto $u_j = \left(u_{1j}, u_{2j}, \dots, u_{ij}\right)^T$, m new indicator variables consist of eigenvectors:

$$\begin{cases} y_1 = u_{11}\tilde{x}_1 + u_{21}\tilde{x}_2 + \dots + u_{m1}\tilde{x}_m \\ y_2 = u_{12}\tilde{x}_1 + u_{22}\tilde{x}_2 + \dots + u_{m2}\tilde{x}_m \\ \vdots \\ y_m = u_{1m}\tilde{x}_1 + u_{2m}\tilde{x}_2 + \dots + u_{mm}\tilde{x}_m \end{cases},$$

Formula $y_1$ is the first principal component, $y_2$ is the second principal component and $y_m$ is the $m$th principal component.

4) Select the principal components of $p(p \leq m)$ and calculate the comprehensive evaluation value

(1) Calculate the information contribution rate and cumulative contribution rate of the eigenvalue $(j = 1,2, \dots, m)$ $\lambda_j$ call:

$$b_j = \frac{\lambda_j}{\sum_{k=1}^{m} \lambda_k}, (j = 1,2, \dots, m),$$

Information contribution rate of the main component $y_j$;

$$\alpha_p = \frac{\sum_{k=1}^{p} \lambda_k}{\sum_{k=1}^{m} \lambda_k}.$$

The cumulative contribution rate of the main component $y_1, y_2, \dots, y_p$, when $\alpha_p$ close to 1 $\left(\alpha_p = 0.85, 0.90, 0.95\right)$, then select the first p indicator variables $y_1, y_2, \dots, y_p$ as $p$ principal components. Instead of the original m indicator variables, this enables a comprehensive analysis of $p$ principal components.

(2) Calculate the composite score

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$$Z = \sum_{j=1}^{p} b_j y_j.$$

where $b_j$ is the information contribution rate of the $j$th principal component, evaluations can be made based on the overall score value.

## 3.3. Evaluation and Analysis of Energy Security Transition Level in Some Parts of China

SPSS27.0 is used to analyze the principal component analysis of the energy security transition and development level in some parts of China, and the principal component coefficient matrix of the variance decomposition chart is obtained. See Table 2 for details.

**Table 2.** Principal Component Analysis Variance Exploded Plot

| Principal component | Original variable | | | Extraction of principal components | | |
|---|---|---|---|---|---|---|
| | eigenvalue | Variance contribution rate (%). | Cumulative contribution rate (%). | eigenvalue | Variance contribution rate (%). | Cumulative contribution rate (%). |
| 1 | 4.081 | 40.007 | 40.007 | 4.081 | 40.007 | 40.007 |
| 2 | 2.501 | 20.839 | 60.847 | 2.501 | 20.839 | 60.847 |
| 3 | 1.475 | 12.292 | 73.139 | 1.475 | 12.292 | 73.139 |
| 4 | 1.376 | 11.464 | 84.603 | 1.376 | 11.464 | 84.603 |

According to Table 2, the first four principal component characteristic values are greater than 1. Therefore, according to the principal component analysis, four principal components are selected to describe the development level of energy security transition.SPSS27.0 is used to obtain the coefficient matrix of four principal components, and then according to the principal component calculation formula and comprehensive score evaluation function, the principal component score and comprehensive score of the energy security transition and development level in some parts of China are obtained. See Table 3 for details.

**Table 3.** Principal component scores and comprehensive scores of energy security transition and development level in some regions in China

| region | F1 score | F2 score | F3 score | F4 score | Comprehensive score | ranking |
|---|---|---|---|---|---|---|
| domestic | 3.242 | 1.832 | 0.009 | 1.431 | 2.015 | |
| Inner Mongolia | 6.023 | 2.421 | 0.325 | 1.458 | 3.442 | 1 |
| Xinjiang | 4.765 | 2.428 | 0.028 | 1.125 | 2.898 | 2 |
| Hebei Province | 4.805 | 2.138 | 0.042 | 0.544 | 2.760 | 3 |
| Shanxi Province | 4.059 | 2.051 | 0.019 | 1.512 | 2.525 | 4 |
| Jiangsu Province | 3.846 | 2.557 | 0.166 | 0.982 | 2.511 | 5 |
| Anhui Province | 3.894 | 1.752 | -0.004 | 0.310 | 2.235 | 6 |
| Shandong Province | 2.851 | 2.861 | -0.452 | 1.625 | 2.120 | 7 |
| Yunnan Province | 2.385 | 3.021 | 0.820 | 0.864 | 2.021 | 8 |
| Sichuan Province | 2.886 | 1.866 | -0.325 | 0.571 | 1.781 | 9 |
| Hubei Province | 2.415 | 2.032 | 0.369 | 1.341 | 1.763 | 10 |
| Heilongjiang Province | 1.759 | 3.015 | 0.258 | 1.165 | 1.693 | 11 |
| Gansu Province | 1.952 | 3.023 | -0.345 | 0.913 | 1.679 | 12 |
| Qinghai Province | 2.443 | 1.500 | 0.354 | 1.354 | 1.667 | 13 |
| Jilin Province | 1.752 | 2.762 | -0.123 | 1.381 | 1.587 | 14 |

It can be seen from Table 3 that on the whole, Inner Mongolia has the highest comprehensive score in the analysis of the energy security transformation and development level of the selected domestic regions, with a comprehensive score of 3.442, Jilin Province had the lowest overall score of 1.587, the variance fluctuates significantly, see table 4 for details. Among the 14 regions evaluated, Inner Mongolia, Xinjiang and Hebei have obtained a high level of energy transition regional evaluation with huge wind power generation and photovoltaic power generation output. At the same time, each region is affected by geographical location, historical influence, economic factors and scientific and technological level, and the comprehensive score of six provinces, Sichuan, Hubei, Heilongjiang, Gansu, Qinghai and Jilin provinces, is lower than the overall comprehensive score, accounting for 42.9%.This shows that there is a slight imbalance in the level of development of domestic energy security transition[8], but the gap is small and the overall level is high. Analysis of variance was performed based on the principal component scores in Table 3, as shown in Table 4.

**Table 4.** Analysis of the difference in the score of domestic energy security transition development level

| | minimum | maximum | variance |
|---|---|---|---|
| The first principal component | 1.752 | 6.023 | 1.597 |
| The second principal component | 1.5 | 3.023 | 0.240 |
| The third principal component | -0.452 | 0.82 | 0.163 |
| The fourth principal component | 0.31 | 1.625 | 0.149 |
| Comprehensive score | 1.587 | 3.442 | 0.296 |

It can be seen from Table 4 that the variance fluctuation of the score of the first principal component is the most obvious, followed by the second principal component, indicating that the first principal component has the greatest impact on the development level of energy transition. That is, there are obvious differences in the exploration, development and utilization levels of new energy in the study of energy transition speed[9]; third, the scores of the four principal components did not fluctuate significantly, indicating that the impact of policies and institutions on the development level of energy transition in different regions is not significant, and all need to be improved.

## 4. Based on K-means Cluster Analysis, the Domestic Energy Security Transformation and Development Level is Classified

### 4.1. Research Thought

Based on the above comprehensive score of the development level of energy security transformation in some regions of China Comprehensive score, K-means cluster analysis algorithm is used to classify the selected domestic regions according to the regional energy development level, so as to study the spatial heterogeneity of the energy security transformation and development level in some domestic regions.

### 4.2. Research Method

They were analyzed into different categories by K-means clustering.

According to the clustering results of Table 4, the development level of energy security transformation in some regions in China is divided into four categories, namely high levels energy transformation, high level energy transformation, general level energy transformation and low-level energy transformation. Its overall development level is relatively balanced.

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**Table 5.** Cluster results of energy security transformation and development level in some regions of China

| Level of the transformation and development of energy security | Regional name | Average composite score |
|---|---|---|
| High-level energy transition areas | Inner Mongolia Autonomous Region, Xinjiang, Hebei Province | 3.033 |
| Higher level of energy transition areas | Shanxi, Jiangsu, Anhui and Shandong provinces | 2.348 |
| General level of energy transition area | Yunnan, Sichuan, and Hubei Province | 1.855 |
| Low-level energy transition areas | Jilin, Gansu, Qinghai and Heilongjiang Province | 1.657 |

## 5. Conclusion and Suggestion

Based on SPSS27 software, this paper uses data collection to comprehensively evaluate the risk identification and optimization level of domestic energy security transformation under the background of double carbon. It can be seen that the risk identification and optimization level of domestic energy security transformation is high. Overall, the principal component analysis method and K-means clustering analysis model adopted in this paper are very practical to solve the problem in this paper, solving the problem we need to solve [13]. This paper uses K-means cluster analysis to divide parts of China into the following four categories: Inner Mongolia Autonomous Region, Xinjiang, Hebei Province are the high level energy transition region; Shanxi Province, Jiangsu Province, Anhui Province are the high level energy transition region; Yunnan Province, Sichuan Province is the general level energy transition region; Qinghai Province, Heilongjiang Province, Jilin Province, Gansu Province are the low level energy transition region. Including regional development still exist many problems: urban development, energy security transformation level and the city overall economic gap is bigger, according to the above constructed the comprehensive evaluation model, analysis and influence the domestic energy security transformation risk identification and optimization level of related factors, and for the future domestic parts of energy security transformation risk identification and optimization of further improve the level put forward the following Suggestions:

(1) Step up technological innovation to promote high-quality development in energy security transformation

Technological innovation plays a major role in identifying and optimizing the risks of the regional energy security transformation, Not only is it necessary to ensure that analytical studies of potential hazards in a two-carbon context, But also to optimize and improve the effect of transformation, For the Inner Mongolia Autonomous Region and other regions with certain regional advantages in economic development, We should integrate maintaining steady and orderly economic growth, technological progress and environmental protection, Reduce the water, atmospheric, and soil pollutants, Improve resource utilization efficiency and reduce energy consumption, To further develop and expand the new and high-tech industries, Improve the transition level of energy security, Optimize the transformation, We will increase investment in and subsidies for scientific and technological research and development, Create a high-quality scientific research environment, Attract high-tech talent, Encourage scientific and technological progress and innovation, we will work hard to promote the commercialization of scientific and technological achievements, build strategic emerging industrial clusters, we will achieve high-quality development in regional energy security transformation.

(2) Ensure the coordinated development of regional energy security transformation in accordance with local conditions

We should focus on the gradient of investment in the energy industry in different regions, increase investment in new energy sources, increase input in energy technology reform, strengthen technical exchanges and migration between regions. According on the geographical location of each region, environmental factor, income level and other factors to effectively select a good plan to ensure the smooth progress of the energy security transformation. In the implementation process, it needs to constantly coordinate its transformation risks and benefits, for the security of the supply, use security, economic security, comprehensive assessment of the four aspects of environmental safety according to local conditions. To ensure the coordinated development of the eastern and western regions, to minimize differences in development, continue to promote the transformation and development of the overall regional energy security in China, identify its risk of transformation. We will ensure the transformation and optimization of domestic energy security[14].

(3) Ensure the development of new energy and its enterprise application

In the process of research, we found that in the absence of carbon emission reduction policy, technological progress and improvement of energy efficiency can drive economic growth, but it can’t have a good effect on emission reduction and has a rebound effect. Therefore, under the influence of China's dual carbon target, the intervention of carbon emission reduction policy is very necessary [15]. In addition, on the basis of the existing research, it is found that the Chinese government provides strong support for the development of new energy enterprises through low-carbon transformation policies; Low-carbon transformation policy can be applied on the value of new energy enterprises through various ways; The low-carbon transformation policy under the "double-carbon" target has significantly enhanced the value of new energy enterprises. In the future development, we should ensure that on the basis of safe and reliable alternative of new energy. Each region should accord to its own characteristics, we should vigorously research and develop new technologies and new products, vigorously promote the development and development of new energy sources such as hydropower, nuclear energy, wind energy, solar energy and biomass energy. To improve the current energy production structure dominated by fossil fuels and extract the excellent part of the traditional energy for comprehensive creation of new energy and ensure its steady development and application. To conduct a risk assessment, optimize its performance, further establish new energy enterprises. Ensuring energy security in this process, we will develop versatile and complementary new energy sources.

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