PROBLEMY EKOROZWOJU – PROBLEMS OF SUSTAINABLE DEVELOPMENT
SUBMITTED: 11.11.2024, ACCEPTED: 28.12.2024, PUBLISHED ON-LINE: 10.01.2025
2025, 20(1): 221-235
DOI: 10.35784/preko.6808

Assessing the Level of Energy Security of China: Evidence from TOPSIS-entropy Weight Method

Ocena poziomu bezpieczeństwa energetycznego Chin: dowody z metody wagowej entropii TOPSIS

Li Pan

National Technical University of Ukraine, Igor Sikorsky Kyiv Polytechnic Institute, Kyiv, Ukraine
E-mail: 504564464@qq.com, ORCID: 0000-0001-8520-0842

Abstract
As the economic scale continues to grow, issues related to China's energy supply security have become increasingly severe. Energy security remains a crucial concern in China's development. Especially in the face of the international turmoil in recent years, for China, an economy with high dependence on foreign energy, the risk of energy security stability is inevitably transmitted to other economic fields, causing a series of problems. This study quantitatively evaluates China's energy security over the period from 2013 to 2022. Based on 35 specific indicators of China's energy industry, an index system of energy security, comprising four dimensions – energy production, consumption, environmental impact, and energy supply – and the TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) entropy method, has been adopted. The results show that the overall condition of energy security in China is at an upper-middle level, with notable differences across various dimensions. The coordination of energy production, consumption, environmental impact, and energy supply faces challenges due to multiple factors. In terms of energy production and consumption, China's energy security exhibits relatively higher levels of sustainable development, while the environment and energy supply dimensions face significantly more difficulties, revealing the urgency of sustainable development in China's energy sector: under the dual pressures of maintaining economic growth as well as protecting the environment, increasing policy support for the renewable energy industry and increasing its share of the energy production and consumption structure is a feasible solution. It is recommended to promote reforms in energy technology, international energy cooperation and innovation to provide diversified guarantees for China's energy security.

Key words: energy security, energy supply, energy efficiency, China's economy, multidimensional assessment, TOPSIS-entropy weight

Streszczenie
Wraz ze wzrostem gospodarczym kwestie związane z bezpieczeństwem dostaw energii w Chinach stają się coraz poważniejsze. Bezpieczeństwo energetyczne pozostaje kluczowym problemem w rozwoju Chin. Zwłaszcza w obliczu międzynarodowych zawirowań w ostatnich latach, dla Chin, gospodarki o dużym uzależnieniu od zagranicznej energii, ryzyko stabilności bezpieczeństwa energetycznego jest nieuchronnie przenoszone na inne dziedziny gospodarki, powodując szereg problemów. Niniejsze badanie ilościowo ocenia bezpieczeństwo energetyczne Chin w okresie od 2013 do 2022 roku. Na podstawie 35 konkretnych wskaźników chińskiego przemysłu energetycznego przyjęto system indeksów bezpieczeństwa energetycznego, obejmujący cztery wymiary – produkcję energii, zużycie, wpływ na środowisko i dostawy energii – oraz metodę entropii TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution). Wyniki pokazują, że ogólny stan bezpieczeństwa energetycznego w Chinach jest na poziomie średnio-wyższym, ze znacznymi różnicami w różnych wymiarach. Koordynacja produkcji energii, zużycia, wpływu na środowisko i dostaw energii stanowi wielkie wyzwanie z powodu wielu czynników. Jeśli chodzi o produkcję i zużycie energii, bezpieczeństwo energetyczne Chin wykazuje stosunkowo wyższy poziom zrównoważonego rozwoju, podczas gdy wymiary środowiska i dostaw energii napotykają znacznie więcej trudności, co ujawnia pilną potrzebę zrównoważonego rozwoju w chińskim sektorze energetycznym: pod podwójnym

naciskiem utrzymania wzrostu gospodarczego i ochrony środowiska, zwiększenie wsparcia politycznego dla przemysłu energii odnawialnej i zwiększenie jego udziału w strukturze produkcji i zużycia energii jest wykonalnym rozwiązaniem. Zaleca się promowanie reform w zakresie technologii energetycznych, międzynarodowej współpracy energetycznej i innowacji w celu zapewnienia gwarancji dla bezpieczeństwa energetycznego Chin.

Słowa kluczowe: bezpieczeństwo energetyczne, zaopatrzenie w energię, efektywność energetyczna, gospodarka Chin, ocena wielowymiarowa, waga entropii TOPSIS

1. Introduction

As China's economy continues its rapid growth and the processes of urbanization and industrialization advance swiftly, the landscape of energy resource acquisition and utilization has undergone profound changes. The characteristics of energy resources, particularly their finiteness and scarcity, have become increasingly prominent, drawing widespread attention to issues surrounding the stability and security of energy supply. Meanwhile, under the compounded challenges of rising population pressure, tightening resource constraints, and escalating environmental problems, improving energy efficiency and enhancing its overall development capacity have emerged as pressing issues. This shift not only demands a focus on sustainability in energy development and utilization but also urges a deeper consideration of how to balance economic development and environmental protection in energy strategies and policymaking, aiming to achieve a win-win outcome of energy security and green development.

As a critical factor in economic development, there is a long-term, stable, and inseparable relationship between energy consumption and economic growth. Thus, energy security is directly tied to economic security and national stability (Knox-Hayes et al., 2013). If there is a severe energy supply shortage, a sharp rise in prices, or a temporary disruption, it can lead to significant economic losses. Therefore, at the current time, the policy of diversification of energy supply has been widely carried out in various countries in order to respond to the problem of energy supply (De Rosa et al., 2022; Doğan et al., 2022), and the formulation of provisions on energy dependence can also be observed in China's energy development strategy, which requires that the total domestic energy production account for more than 90% of the to be domestic consumption, of which clean energy production accounts for more than 70% (Zou et al., 2020). But in contrast, the new expansion of the content of energy security in the context of climate issues – the environmental consequences of energy consumption, combined with the requirements of the Sustainable Development Goals (SDGs) (United Nations, 2015) – is becoming an inescapable and imperative concern. In fact, the concept of energy security has been broadened by the SDGs, with specific goals on human health, clean water quality, protection of land and water ecosystems, clean energy, economic growth, responsible production and consumption, and climate change, all of which are related to the production and consumption of energy. In addition, in the context of global economic integration, serious energy supply problems are less frequent and can be solved through trade diversification, but pollution caused by industrialized production persists and can easily be transferred from some regions to the global scale. The ecological pollution accompanying China's rapid economic growth is of particular concern.

Therefore, in order to fulfill the Paris Climate Change Agreement, China has pledged to take the initiative to increase its participation and take more stringent measures to strive to peak carbon dioxide emissions by 2030, and strive to achieve carbon neutrality by 2060. Increasing R&D investment in renewable energy and increasing the share of production and consumption is a response to the requirements of sustainable development, but it also solves the problem of energy supply (Liu et al., 2022).

According to the bp Statistical Review of World Energy 2023 report (Energy Institute, 2023), in 2022, global primary energy consumption increased by 1%, approximately 3% higher than the pre-pandemic level in 2019. Compared to the pre-pandemic level in 2019, the growth in primary energy consumption in non-OECD countries was primarily driven by China's consumption, which accounted for 72% of the increase. Compared with the non-renewable or extremely difficult to regenerate nature of fossil energy reserves, increasing the share of renewable energy consumption is also important in terms of total energy consumption and self-sufficiency in energy consumption. In addition, in light of recent global security crises, such as the COVID-19 pandemic, Russia's invasion of Ukraine, and the conflicts in the Middle East, assessing China's energy security to study the impacts of these crises is both timely and of significant practical importance. It helps track and identify changes in the energy security landscape, addressing an urgent and pressing need.

2. Literature review

The industrial development of modern society is inseparable from energy, and crises and upheavals centered around energy issues frequently occur – an expression of security challenges that were unprecedented in agrarian societies. Early research on energy security primarily focused on the security of oil resources, driven directly by the oil crises of the 1970s (Yergin, 1988; Winzer, 2012; Cherp & Jewell, 2014). Therefore, it might be a complex of security concerns, but the issue of energy supply threats has been a primary consideration in energy security research. According to J. Bielecki (2002), energy security is commonly defined as reliable and adequate supply of energy at reasonable prices. However, as argued by Azzuni & Breyer (2018), that the definition of supply security is clearly misleading, as supply security is only one part of the broader concept of energy security, excluding other important dimensions. Chester (2010) criticized that discussions on energy security are overwhelmingly centered around themes of energy supply and geopolitics. In fact, under the influence of these factors, such as global climate change (Bang, 2010; Kim, 2014), which is closely linked to energy efficiency (Ozturk, 2013; Selvakkumaran & Limmeechokchai, 2013; Baublys et al., 2015), energy infrastructure development (Skea et al., 2012; Burgherr et al., 2015), impacts related to food security(Larson, 2013; Pasqualino et al., 2019; Ogbolumani & Nwulu, 2022), and having been considered as part of national security (Downs, 2004; Wang & Zhou, 2017), a growing interest around broaden conception of energy security has been arised. With the concept of sustainable development being widely accepted, the SES (Sustainable Energy Security) concept that refers to the *provisioning of uninterrupted energy services in an affordable, equitable, efficient, and environmentally benign manner* (Radovanović et al., 2017), addresses the problem of diversifying the conceptualization of energy security by integrating the coherence and sustainability of energy, economic, social and environmental development, as well as the efficiency and diversity of energy systems.

In short, as global energy, social-economic, and geopolitical landscapes continue to evolve, the focus, priorities, and perspectives of various countries on energy security are also constantly shifting. As researchers uncover additional dimensions to consider, the understanding and definition of energy security have become progressively more nuanced and precise. For instance, Chang & Yong (2007) proposed a theoretical framework incorporating the availability of resources, the applicability of technology, and societal acceptability, thereby demonstrating their perspective on energy developments and projections of future energy potential. Similarly, Kruyt et al. (2009) categorized energy security into four key dimensions: availability, accessibility, affordability, and acceptability, utilizing these metrics to evaluate Western Europe's energy security over the coming decades. Ren & Sovacool (2014) used four dimensions and twenty four metrics for assessing energy security and determined the most meaningful and important metrics of energy security of China – the availability and affordability dimensions.

Nevertheless, the trend of increasing energy security dimensions and diversified definitions has also brought troubles to subsequent research. Chester (2010) described the concept of energy security as *polysemic* and *slippery*, referring to its tendency to symbolise multiple dimensions at the same time. Moreover, some scholars have criticized energy security research, arguing that the concept of energy security is ubiquitous—either too narrow to provide a comprehensive understanding of energy challenges, or too broad, lacking precision and coherence (Sovacool & Brown, 2010). In these definitions and corresponding studies, while Yergin (2006) stated that energy security discussion should be expanded to include more dimensions, and Ang et al. (2015) advocated for the following seven energy security themes or dimensions: energy availability, infrastructure, energy prices, social impact, environment, governance, and energy efficiency, Winzer (2012) reviewed several definitions of energy security, arguing that energy security should be defined separately from other policy objectives as *the continuity of energy supply relative to demand*.

From the perspective of international relations, literature on global energy politics can be divided into two categories: on one hand, there are realist and geopolitical viewpoints regarding *energy security*; on the other hand, there are liberal and institutionalist perspectives concerning *energy governance* (Van de Graaf & Colgan, 2016). Then the securitization tendency in energy security research (Nyman, 2012; Heinrich & Szulecki, 2018) has also garnered significant attention, as it involves an overemphasis on energy issues and an exaggeration of potential risks, thereby elevating the prominence of energy security topics and attracting more resources for addressing them. Powerful actors inclined to interpret the problem so that it fits their preferred solution (Leung et al., 2014). Thus, in the context of energy security, the initial subjective perspective and approach adopted by scholars significantly influence the outcomes of their research. Gasser (2020) noted that the existence of multiple definitions is not surprising, as countries face different geographical and natural conditions and economic development, and their energy security priorities may also be different. Therefore, this paper complements the exploration of China's energy security from the perspective of the environmental consequences of energy consumption by focusing on the issue of ecological challenges in China's economic development.

Nevertheless, the fluctuations and upheavals in the global geopolitical and economic situation have consistently drawn the attention of scholars, leading to evolving perspectives on energy security. For this reason, the study of energy security in specific countries at specific times is the mainstream trend recently. Adun (2023) conducted a study to estimate the energy security index over a span of 20 years across West African countries, categorizing the results into *dangerous* or *safe* levels. Several scholars (Zou et al., 2023) used the entropy-weighted TOPSIS method to calculate and analyze the energy green consumption revolution in China for the Chinese government to update related policies in this field. Al-Saidi (2023) evaluated the influencies of the ongoing geopolitical issues, that is, Ukraine war and Middle East conflicts, on Europe's future energy security, concluding that while the Ukraine war has increased the strategic importance of the Middle East for Europe's energy security, it is unlikely that the Middle East will become an emergency energy supplier for Europe. Considering the relevance of research

in energy security on the background of international geopolitical intentions, the purpose of this research is to study, reveal and understand the impact of these contradictions and crises on China's energy security.
Therefore, rather than merely stating that energy security is an important topic that necessitates a suitable, widely accepted, and precise definition – often noted as absent in the literature – it is more appropriate to assert that the core essence of this concept is closely aligned with the research methodologies employed. Rather than conducting research at the theoretical level, it seems that a better direction is to conduct empirical analysis and interpret energy security through the results of large-scale data calculations. In fact, some scholars have a more firm attitude towards this view, believing that future research in the field of energy security measurement methods should transition from a rigid scientific approach to practical application (Cherchye et al., 2011). The *four As (categories or dimensions) of energy security*, namely availability, accessibility, affordability, and acceptability, that proposed by the Asia Pacific Energy Research Center (Asia Pacific Energy Research Centre, 2007), remains to be a widely used methodology in research works. In order to measure energy security more specifically and accurately, the TOPSIS method combined with the entropy weight method (Cai et al., 2024) is widely used in this field. In light of the above research methodology for assessing China's energy security from a comprehensive perspective, this paper introduces a series of specific indicators addressing environmental dimensions, along with countermeasures such as renewable energy production and consumption, energy efficiency, and other relevant factors, considering environmental concerns within the framework of sustainable development goals. Conducting research within the framework of sustainable development mitigates common issues in the assessment process, such as a lack of focus or an overly narrow emphasis on energy supply. More importantly, this approach aligns closely with China's current economic development and enables a comprehensive evaluation of energy security to support carbon neutrality goals and inform policy formulation.

3. Methodology

This study assesses the conditions of China’s energy security using a wide range of official statistic data from National Bureau of Statistics of China. In accordance with the objective of developing a system of assessment indices, taking into account their completeness and scientific validity, as well as the availability and comparability of data, the following assessment dimensions were developed in this study: energy production, energy consumption, energy supply and environmental impacts, in turn, each of these dimensions includes several indicators, which leads to the formation of a three-level assessment system (below in Table 1). Thus, in this study, energy security is defined as a stable supply, acquisition and production of sufficient energy to meet the needs of economic development through efficient consumption and reduction of environmental impacts. And the specific dimensions of energy security that linked to the concept of sustainable development include: energy production, energy consumption, energy environmental consequences and energy supply. Specific indicators include total production and consumption of traditional fossil energy sources, production and consumption efficiency, data on renewable energy sources, data on pollutants associated with the consumption of energy from various industrial processes, and data on the international price of energy reflecting the international situation. The use of traditional fossil energy is accompanied by concerns about the depletion of reserves and has a direct impact on the carrying capacity of the environment, while the efficiency of energy use affects the rate of consumption of non-renewable energy sources and the level of pollutant emissions, and the development of renewable energy sources is another effective way to face the environmental and climate problems and to realize the requirements of sustainable development, and in addition to increasing the level of renewable energy use can be a response to the traditional fossil energy sources. In addition, increasing the level of utilization of renewable energy can also address the problem of international price volatility of traditional fossil energy sources, which is particularly urgent in a climate of increased uncertainty.

Table 1. Input indicators for the entropy weight TOPSIS model of energy security of China, source: developed by the author

Level I indicator	Level II indicator	Level III indicator	Description of indicators and their impact (+: positive, -: negative)
1. Energy Production	1.1 Volume	Total primary energy production	(10 thousand tons of coal equivalent); **x1; +**
		Energy production per capita	x1 / Average annual population (1 kilogram of coal equivalent); **x2; +**
		Installed generating capacity of electricity	Heat, hydro, wind, nuclear and solar energy, etc. 10 thousand kilowatts (kW); **x3; +**
	1.2 Ability	Development of the energy industry	Investments in fixed assets of the Energy Industry (0.1 billion yuan); **x4; +**
		Elasticity Coefficient of Energy Production	Average annual growth rate of total energy production / average annual growth rate of GDP; **x5; -**
		Overall Energy Processing and Conversion Efficiency	Energy Obtained from Processing and Transformation / Energy Consumed (%); **x6; +**

Level I indicator	Level II indicator	Level III indicator	Description of indicators and their impact (+: positive, -: negative)
	1.3 Structure	Share of run-of-mine coal production	Share of run-of-mine coal in total primary energy production (%); **x7; +**
		Share of crude oil production	Share of crude oil in total primary energy production (%); **x8; +**
		Share of natural gas production	Share of natural gas in total primary energy production (%); **x9; +**
		Share of electricity and other clean energy	Share of total primary energy production (%); **x10; +**
2. Energy Consumption	2.1 Structure	Share of coal consumption	Share of coal in total energy consumption (%); **x11; -**
		Share of oil consumption	Share of oil in total energy consumption (%); **x12; +**
		Share of natural gas consumption	Share of natural gas in total energy consumption (%); **x13; +**
		Share of electricity and other types of energy	Share in total energy consumption (%); **x14; +**
	2.2 Efficiency	Elasticity Coefficient of Energy Consumption	Average annual growth rate of energy consumption/average annual GDP growth rate; **x15; -**
		Share of industrial electricity consumption	Industrial Electricity Consumption / Total Electricity Consumption (%); **x16; -**
		Energy consumption for per Unit of GDP	Energy consumption / GDP (tons / 10 thousand yuan); **x17; -**
	2.3 Volume	Total energy consumption	(10 thousand tons of coal equivalent); **x18; +**
		Energy consumption per capita	x17 / Average annual population (1 kilogram of carbon equivalent); **x19; +**
		Self-assurance of energy consumption	Energy Production / Energy Consumption (%); **x20; +**
3.Environmental impacts	3.1 Emissions	Sulphur dioxide emissions SO_2	(10 thousand tons); **x21; -**
		Chemical Oxygen Demand in Wastewater	(10 thousand tons); **x22; -**
		Particulate matter in the air	(10 thousand tons); **x23; -**
		Pollution Load per Unit of GDP	Total Three Pollutants / GDP (kg/10 thousand yuan); **x24; -**
	3.2 Pollution Treatment Measures	Investments in the treatment of industrial pollution	(0.1 billion yuan); **x25; +**
		Investments in environmental protection	(0.1 billion yuan); **x26; +**
4. Energy supply	4.1 International Market	Dependence on external energy markets	Crude Oil Imports / Oil Consumption; **x27; -**
		Coal imports	(10 thousand tons); **x28; +**
		Crude Oil Imports	(10 thousand tons); **x29; +**
		Natural Gas Imports	(0.1 billion cubic meters); **x30; +**
	4.2 Domestic Reserves	Technically recoverable coal reserves	(0.1 billion tons); **x31; +**
		Technically recoverable oil reserves	(0.1 billion tons); **x32; +**
		Technically recoverable natural gas reserves	(0.1 billion cubic meters); **x33; +**
	4.3 International Prices	International oil prices	Crude oil spot price averaged across multiple markets; (USD/bbl); **x34; -**
		International prices for natural gas	Based on the import price of liquefied natural gas to Japan; (USD/MMU); **x35; -**

All the indicators described above and their values used in the empirical study were obtained from the following sources: China Statistical Yearbook and the database of the official website of the National Bureau of Statistics (*National Bureau of Statistics of China*), China Energy Statistics Yearbook (*中国能源统计年鉴*), and World Energy Yearbook 2023 published by the Energy Research Institute (Statistical Review of World Energy, 2023). The length of the analysis period is 10 years. The empirical analysis procedure using the TOPSIS-entropy weight methodology to assess the state of the energy and economic system is given below.

The TOPSIS method (full name: Technique for Order Preference by Similarity to an Ideal Solution) is an effective multi-faceted decision-making method that has been widely used in economic disciplines in recent years. As more and more problems related to multi-faceted and multi-level decision-making arise in scientific research, and the indicators involved in economic systems become more complex and multi-criteria, the use of the TOPSIS method demonstrates more and more advantages in data analysis. This method was first proposed by K. L. Hwang and K. Yoon in 1981 in the book *Multiple Attribute Decision Making* (Hwang & Yoon, 1981) as a method for making multi-objective decisions, which is known as a ranking method that is closest to the *ideal solution* in decision analysis. The procedure for implementing the TOPSIS-entropy weight method (Kaynak et al., 2017; Zheng et al., 2018) is directly proposed below. The main stages are:

(1) Formation of the decision matrix: at the initial stage, a decision matrix is formed, where the rows represent the alternatives, and the columns are the criteria by which these alternatives are evaluated. Assuming that there are m provinces and each province has n evaluation indicators, the evaluation value of indicator j for province i is X_{ij}. The decision matrix for all provinces is. Thus, the matrix X is formed:

$$\mathrm{X} = X_{ij} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

or

$$\mathrm{X} = \left[X_{ij}\right]_{m\times n} \tag{2}$$

where X_{ij} is the value of alternative or sample i for indicator j.

(2) Matrix Normalization: A necessary step in the TOPSIS-Entropy Weight method is the normalization or standardization of the data, since the units of measurement for different metrics may vary significantly.

Positive indicators. For positive indicators, the increase of the value of which is associated with improvement, standardization is performed according to the formula:

$$X'_{ij} = \frac{X_{ij} - min\{X_{1j},\ X_{2j}, X_{3j}, \dots . X_{mj}\}}{max\{X_{1j},\ X_{2j}, X_{3j}, \dots . X_{mj}\} - min\{X_{1j},\ X_{2j}, X_{3j}, \dots . X_{mj}\}} \tag{3}$$

Negative indicators. For negative indicators, the decrease of which is associated with improvement, standardization is performed according to the formula:

$$X'_{ij} = \frac{max\{X_{1j},\ X_{2j}, X_{3j}, \dots . X_{mj}\} - X_{ij}}{max\{X_{1j},\ X_{2j}, X_{3j}, \dots . X_{mj}\} - min\{X_{1j},\ X_{2j}, X_{3j}, \dots . X_{mj}\}} \tag{4}$$

(3) Weighting of the matrix of indicators: each indicator is weighted according to its importance. The weights of the indicators can be determined by experts or using various weighting methods. In our study, the entropy weighting method is used, which allows us to objectively determine or change the weighting coefficients depending on the specific situation, with high accuracy and high adaptability. First of all, it is necessary to calculate the probability value of each indicator P_{ij} using the formula:

$$P_{ij} = \frac{X'_{ij}}{\sum_{i=1}^{m} X'_{ij}} \tag{5}$$

(4) Then the entropy of each indicator E_j is calculated using the formula:

$$E_j = -k \sum_{i=1}^{m} P_{ij} \ln P_{ij} \tag{6}$$

where $k = \frac{1}{\ln m} > 0$ is a normalization coefficient that ensures that the entropy E_j lies in the range from 0 to 1. The lower the entropy value, the more informative the indicator will be.

(5) Calculate the attribute weight by the following equation:

$$W_j = \frac{1 - E_j}{\sum_{j=1}^{n}(1 - E_j)} \tag{7}$$

where W_j is the weight of the j-th attribute; n is the number of attributes.

To apply the TOPSIS method after using the entropy weighting method, the following steps must be performed:

(6) Construction of the weighted normalized decision matrix. This calculation is performed by multiplying the normalized decision matrix by the weight coefficients obtained by the entropy weighting method:

$$V_{ij} = W_j \times X'_{ij} \tag{8}$$

where V_{ij} is the weighted normalized decision matrix.

(7) Determination of ideal-optimal and ideal-negative solutions: the ideal solution is formed on the basis of the best values for each criterion, and the anti-ideal one is formed on the basis of the worst values. Ideal (V^+) and negative ideal (V^-) solutions are determined for each indicator:

$$V^+ = \{\, max(V_{ij}) \mid j \in J_1; min(V_{ij}) \mid j \in J_2 \,\} \tag{9}$$

$$V^{-} = \{min(V_{ij}) \mid j \in J_1; max(V_{ij}) \mid j \in J_2\} \quad (10)$$

where J_1 is a set of positive indicators for which higher values indicate better results, and J_2 is a set of negative indicators for which, conversely, lower values indicate better results.

(8) Calculation of distances to ideal and anti-ideal solutions: for each sample object, distances to ideal (D_i^+) and negative ideal (D_i^-) solutions are calculated.

$$D_i^+ = \sqrt{\sum_{j=1}^{m} (V_{ij} - V_j^+)^2} \quad (11)$$

$$D_i^- = \sqrt{\sum_{j=1}^{m} (V_{ij} - V_j^-)^2} \quad (12)$$

(9) Calculation of relative proximity to the ideal solution: the relative proximity of the object to the ideal solution (C_i^*) is calculated as:

$$C_i^* = \frac{D_i^-}{D_i^+ + D_i^-} \quad (13)$$

Based on the number of calculated relative proximity of objects to the ideal solution C_i^*, a ranking is carried out, among which the best one will have the smallest distance to the ideal solution and the largest distance to the anti-ideal one.

4. Results & discussion

Before conducting empirical calculations, descriptive statistics of the data set are required to understand the overall information and structure of the indicator data and to check whether there are any missing values. The following Table 2 is the descriptive statistics of the data set used in this paper. All calculation procedures in our research are carried out in Stata program.

Table 2. Descriptive statistics of the variables (indicators) of energy security of China, source: developed by the author

VarName	Obs	Mean	SD	Min	Median	Max
x1	10	386459.60	37909.411	345954	370535.5	466000
x2	10	2767.70	241.127	2493	2670.5	3284
x3	10	186473.46	43040.519	125768	183860.2	256794
x4	10	33344.72	3805.482	29008.91	32419.19	42598.69
x5	10	0.81	0.856	.14	.56	3.07
x6	10	73.22	0.266	72.8	73.2	73.7
x7	10	69.98	2.853	66.7	69.4	75.4
x8	10	7.50	0.825	6.3	7.4	8.5
x9	10	5.34	0.564	4.4	5.4	6
x10	10	17.18	3.032	11.8	17.8	20.6
x11	10	60.55	4.112	55.9	59.8	67.4
x12	10	18.36	0.690	17.1	18.65	19
x13	10	7.09	1.314	5.3	7.25	8.8
x14	10	14.00	2.403	10.2	14.05	17.5
x15	10	0.54	0.271	.19	.495	1
x16	10	0.69	0.027	.649774	.6926222	.7305713
x17	10	0.61	0.113	.4780708	.5703417	.7944179
x18	10	470130.20	42337.472	416913	463876	541000
x19	10	3368.50	264.195	3058	3314.5	3831
x20	10	0.82	0.028	.783602	.8161877	.8613678
x21	10	1026.40	704.530	243.52	875.4	2043.92
x22	10	1995.26	686.560	1021.94	2259.045	2636.76
x23	10	1131.27	452.287	493.38	1205.2	1740.75
x24	10	5.79	3.167	2.945075	4.227753	10.81316
x25	10	643.34	230.299	285.7	651.45	997.7

VarName	Obs	Mean	SD	Min	Median	Max
x26	10	9346.15	523.026	8806.3	9185.85	10638.9
x27	10	0.19	0.025	.1529092	.198521	.2261135
x28	10	28507.20	3578.621	20406	29221	32702
x29	10	42567.90	9446.907	28174	44067.5	54201
x30	10	1057.50	424.038	525	1096	1674
x31	10	2446.42	231.839	2070.12	2466.18	2746
x32	10	35.58	1.253	33.7	35.45	38.06
x33	10	56675.70	6323.286	46428.84	56578.5	65690.12
x34	10	69.31	23.756	41.4525	65.9475	106.0175
x35	10	8.60	5.873	4.06	6.68	24.17

In Table 2 the VarName represents the energy security indicators, the details of which are presented in Table 1; Obs represents the study period, which covers 10 years from 2013 to 2022. Mean - average value of each indicator, Min - minimum value, Max - maximum value, Median - median of the indicator; for example, for the indicator x1 - total energy production, the maximum value is 466,000 (unit: 10 thousand tons of coal equivalent, that is, a total of 4.66 billion tons of coal equivalent) in 2022, the minimum is 345,954 (3.46 billion tons of coal equivalent) in 2013. The average value is 386,459.6, the median value - 370,535.5, indicating a uniform increase in energy production in China over 10 years. A similar trend can be observed with the data of energy consumption (x18), from 4.17 billion tons of coal equivalent in 2013 to 5.41 billion tons of coal equivalent in 2022.

For this study, the actual values of energy production and consumption are treated as positive indicators, while the ratio of energy production to consumption (i.e., x1/x18), representing energy self-sufficiency, is treated as a negative indicator, indicating that energy supply must rely on external sources or that investment is required in energy infrastructure to enhance the efficiency of the energy sector (x17). The development and utilization of new energy sources such as wind power have been steadily increasing (x3 and x6), meaning that there is a greater proportion of non-fossil fuel being harnessed to meet primary energy demand and having great positive impacts on environment conditions.

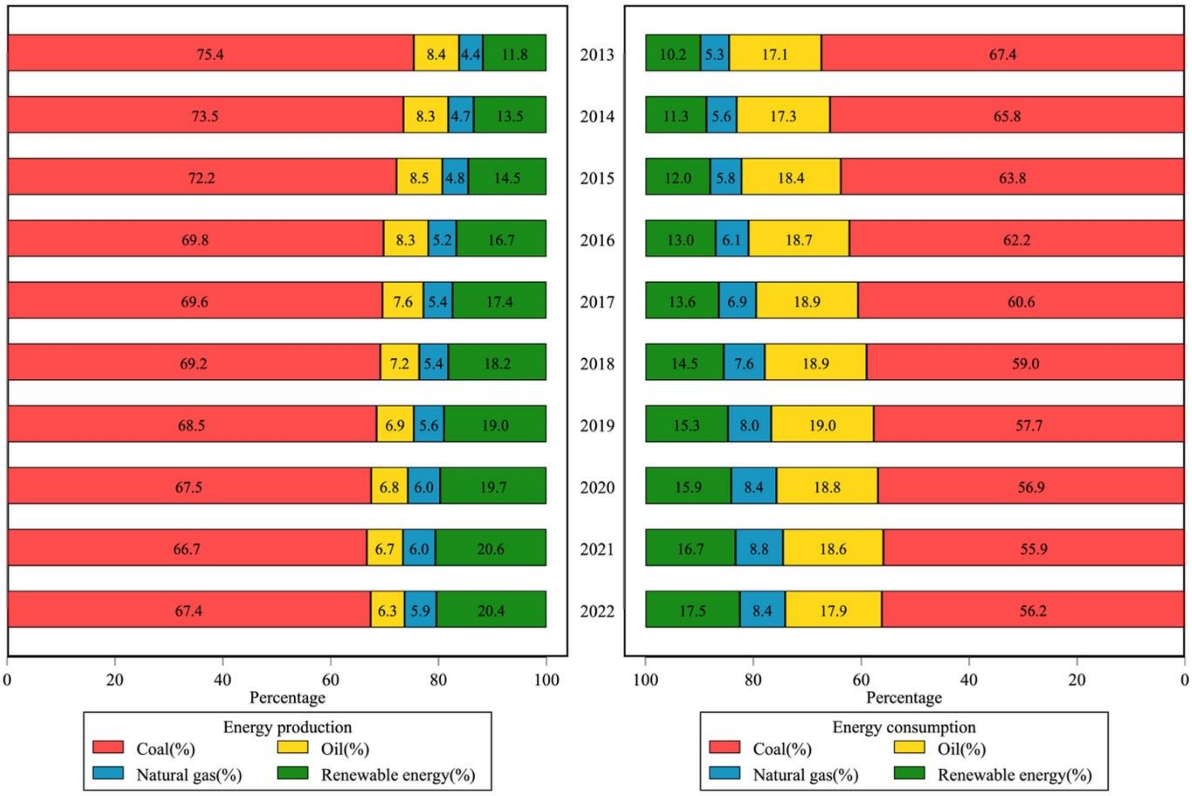

Figure 1. Structure of energy production and consumption in China, source: developed by the author

In general, the statistical data of the indicators in the table reveal the following problems:1) the increase in China's economic size is inevitably accompanied by an increase in energy demand, and the energy threat caused by insuf-

ficient energy supply is intensifying. 2) the structure of energy production and consumption is unbalanced. China is rich in coal resources but relatively scarce in oil and natural gas resources. The significant reliance on energy imports affects the level of energy security (Figure 1). 3) the technological level of the energy industry directly determines the efficiency of energy use and the burden of environmental pollution. 4) the turbulent international situation impacts macroeconomic development through its influence on the energy supply chain and price stability.
Figure 1 specifically illustrates the structure of China's energy production and consumption during the study period. Insufficient oil and gas resources pose a significant risk to China's energy security, primarily reflected in excessive total energy consumption and large oil and gas consumption gaps. Consequently, coal extraction and consumption remain the dominant components of China's energy structure. Despite a 10% decrease in coal use and an 8% reduction in production share during 2013-2022, coal remains the primary energy source. At the same time, the share of renewable energy in production has risen by 10% and consumption by 7%, emerging as the second-largest energy category after coal. Nevertheless, it still falls short of half the share of coal. In addition, the use of coal has a direct impact on the data of the environmental impact dimension of the energy security evaluation system in this paper, and the realization of the sustainable development goals is also closely related to it.
Since multidimensional and complex data can more comprehensively reflect the development of the energy industry and influence robustness assessments, simplistic data are limited to explaining specific areas, underscoring the necessity of a comprehensive assessment approach. It is worth noting that the multidimensional data used in Tables 1 and 2 may also increase the complexity of the study, necessitating the use of a multidimensional integrated evaluation method for data processing and analysis. Then, according to the calculation steps of formula (1) to (6), by using stata software, the objective weights of the 35 indicators, that is, the impact of the 35 indicators on overall energy security can be obtained in table 3.

Table 3. Objective weights of indicators influencing China's energy security, source: developed by the author

1: Energy Production									
x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
0.0412	0.0364	0.0285	0.0345	0.0120	0.0228	0.0379	0.0273	0.0225	0.0207
Energy Production Weight: 0.2838									
2: Energy Comsuption									
x11	x12	x13	x14	x15	x16	x17	x18	x19	x20
0.0230	0.0211	0.032	0.024	0.0242	0.0284	0.0237	0.0339	0.0375	0.0305
Energy Comsuption Weight: 0.2785									

3: Environment Impacts					
x21	x22	x23	x24	x25	x26
0.0315	0.0572	0.0306	0.0285	0.0259	0.0399
Environment Impacts Weight: 0.2137					

4: Energy Suply								
x27	x28	x29	x30	x31	x32	x33	x34	x35
0.0331	0.0143	0.0267	0.0372	0.0264	0.0244	0.0231	0.0269	0.0119
Energy Suply Weight: 0.2241								

In Table 3, the underlined indicators represent negative factors, where larger values indicate a greater negative impact. In the production dimension of the table, the four indicators – x1 (total energy production), x2 (total energy production per capita), x4 (investment in the energy sector), and x7 (share of coal production) – have the largest weights, reflecting their importance and influence. The economic development of modern countries is inseparable from energy production. The growth rate of this indicator compared with the growth rate of the per capita index allows for the derivation of the elasticity coefficient of energy production growth, and other indicators can also be used to calculate the production elasticity coefficient. x4 encompasses various aspects of energy production, including its relation to production volume and its influence on production efficiency, which is crucial for achieving sustainable development. x7 (coal production) highlights the significant role of this energy type in China's economic growth. This paper considers coal a positive indicator within the production dimension to reflect its supply capacity. In coal-producing provinces, coal production is a key economic driver. However, coal data within the energy consumption dimension are treated as a negative indicator due to the significant impact of carbon emissions, which contradicts sustainable development goals and hinders progress toward carbon neutrality policy and goals.
In the energy consumption dimension, the weights of some indicators are small because they are treated as negative indicators, thus affecting the final score of this dimension. These indicators include x11 (coal consumption), x15

(energy consumption elasticity coefficient), x16 (share of industrial electricity consumption), and x17 (energy consumption per unit of GDP). The elasticity coefficient of energy consumption most intuitively reflects changes in the quantity and quality of energy consumption; a value greater than 1 signifies that the consumption growth rate exceeds economic growth, indicating inefficiency in energy use. The proportion of total electricity consumed by industry and energy consumption per unit of GDP also reflect energy efficiency. These indicators further highlight the level of sustainable development. The presence of negative indicators can reduce the final scoring result. In addition, the data of total energy consumption and per capita consumption have large weights, which also affect the final results as positive indicators.

In the environmental impact dimension, all indicators are central to this study, reflecting the quality of China's energy consumption and economic growth, while directly influencing the achievement of the SDGs and carbon neutrality goals. x21 (sulfur monoxide emissions, a gaseous pollutant), x22 (chemical oxygen demand, a liquid pollutant), and x23 (airborne solid particulate matter emissions) are all associated with the SDGs. Meanwhile, x26 represents investments by the Chinese government and companies in environmental governance. The high dimensionality of both positive and negative indicators in this dimension underscores the importance of these factors in energy security research.

In the energy supply dimension, both data on energy imports and information on various domestic fossil energy reserves are included. x27 (crude oil external dependence) is treated as a negative indicator to underscore the significance of domestic production sources. x29 (absolute value of crude oil imports) is a positive indicator of stable access to energy sources, as is x30 (natural gas imports). x31 (China's coal reserves) represents the primary energy source in the current energy structure. Achieving sustainable development and carbon neutrality does not require the complete abandonment of coal but rather increased investment in its efficient and cleaner use. x34 (international oil trading price) is sourced from the *World Energy Statistical Yearbook*; its stability and acceptability serve as key indicators of the current energy supply's reliability.

Then, according to equations (1) to (13), we obtained the relative closeness (TOPSIS score C_i^*) for 35 indicators in China's energy sector over the decade from 2013 to 2022, reflecting the level of energy security throughout these years. Next, the TOPSIS calculation is applied to the corresponding variables within each of the four dimensions, and the score for each dimension is derived by dividing by 4, resulting in equal weights of 0.25 for each dimension. This process ensures that, while the sum of these dimension-specific scores closely approximates the total score calculated across all dimensions and variables, it more effectively captures the distinctions between the dimensions. All results are demonstrated in table 4.

Table 4. Total TOPSIS score and scores of every dimension of energy security in China, source: developed by the author

Year	**Total TOPSIS Score**		**TOPSIS Score of Energy Production**	**TOPSIS Score of Energy Consumption**	**TOPSIS Score of Environment Impacts**	**TOPSIS Score of Energy Supply**
2013	0.32671858		0.098503895	0.074600733	0.064281445	0.080948375
2014	0.34186391		0.097498168	0.075340318	0.078756633	0.089275035
2015	0.37650239		0.102017085	0.090590513	0.062029438	0.118108528
2016	0.45848473		0.09185357	0.093373885	0.14845431	0.123175843
2017	0.48965313		0.083210193	0.10774821	0.16666338	0.130686735
2018	0.51298955		0.084623258	0.133565523	0.153945238	0.14015957
2019	0.51234659		0.106432098	0.157244153	0.108821798	0.146834498
2020	0.55566914		0.124951358	0.156548515	0.12704737	0.15740413
2021	0.55656921		0.13230648	0.185977033	0.11139611	0.143316743
2022	0.57617556		0.154838543	0.189151233	0.106436505	0.13658107

It can be seen from the table that the total score of China's energy security index calculated by the TOPSIS entropy weight method has shown a relatively stable upward trend in the past 10 years, increasing from 0.327 in 2013 to 0.577 in 2022. However, due to the influences of multidimensional factors, the overall scores of energy security index did not reach a high level, and the data change trend shows that the rate of security growth has started to slow down since the beginning of 2018. In addition, the scores at the dimension level do not consistently exhibit an upward trend. For example, some data in the environmental and supply dimensions from 2018 to 2022 demonstrates fluctuations. Among them, the environmental dimension score reached its highest level in 2017–2018, indicating that by this time, China's energy security in the environmental dimension maintained an upward trend, characterized by declining pollutant levels and increased investment in environmental governance, despite the influence of negative indicators. However, the score began to decline after 2018, and the overall environmental dimension score remained relatively low. As for the supply dimension, the 2020 score reached its peak, followed by a decline, although it remained consistently higher than the environmental dimension score. An evident conclusion that can be drawn from the table is that the scores of the first two dimensions of China's energy security have increased significantly and exhibited only slight fluctuations, rising by 0.05-0.1 points during the 10-year observation period. In contrast, the scores of the last two dimensions have experienced modest growth alongside substantial fluctuations, with the score in 2022 increasing by only 0.05 points compared to 2013. Therefore, in connection with the theme of sustainable development, for China, the key object of attention in energy security should be the environmental dimension of energy, followed by the supply dimension.

Indeed, the impact of global crisis events that have occurred over the past five years, including the COVID-19 pandemic, the Russia-Ukraine war, and the turmoil in the Middle East, cannot be ignored. These crises have directly affected China at the energy supply chain level and indirectly placed considerable strain on the security of the energy sector by influencing economic development. Therefore, the overall score may obscure certain critical realities, making dimensional scoring indispensable. The content in the table can be displayed in the following two figures through data visualization to present the results more intuitively.

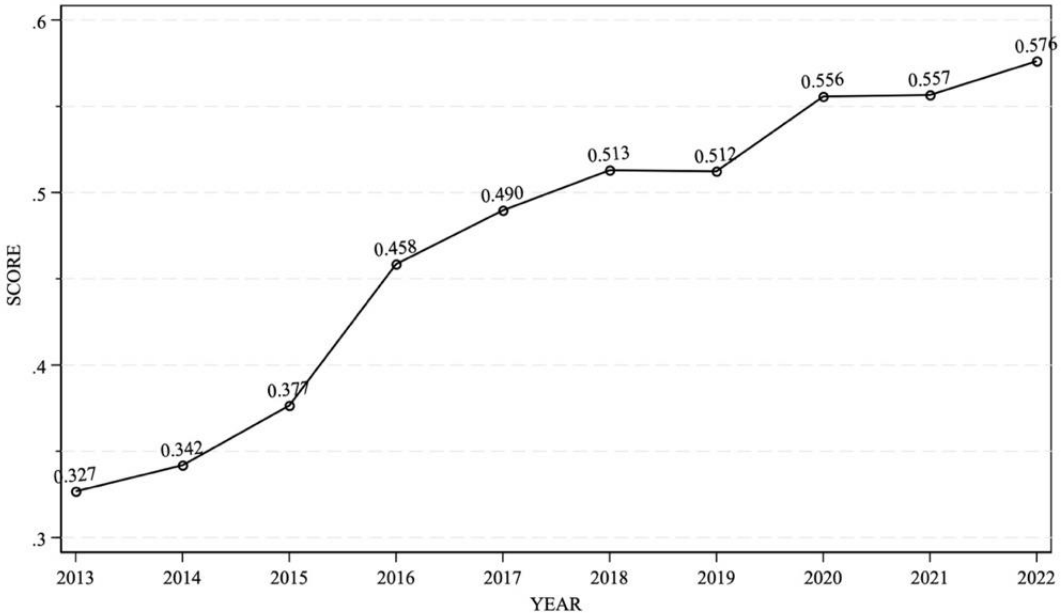

Figure 2. Energy Security TOPSIS Scores of China, 2013-2022 years, source: developed by the author

As shown in Table 4 and Figure 2, since 2013, China's energy security situation has shown an overall upward trend. Since 2018, the growth rate of energy security has slowed down, and the overall security level has been at a medium level throughout the period. After 2019, various factors such as the global economic downturn, the intensification of Sino-US frictions, and the spread of the COVID-19 epidemic have caused the international environment to deteriorate, affecting energy security. The specific trend of energy security levels in the four dimensions is shown in the Figure 3.

The energy security situation at the dimensional level is more specific and more closely linked to the world situation. In terms of energy production, the decline in energy production (x1) and energy industry investment (x4) led to a decline in the security level from 2015 to 2017. In this dimension, the impact of changes in the international situation is not significant. Some indexes are related to economic indicators, which leads to fluctuations in the security level: the production elasticity coefficient (x5) shows the changes in the relationship between macro supply and macro demand. The supply maintains an upward trend, while the total social demand decreases, resulting in the elasticity coefficient value being particularly significant during the crisis; however, the optimization of the energy structure: the proportion of coal production has decreased (x7), and clean energy has continued to develop (x10), ensuring that even if the international situation deteriorates since 2018, the energy security level remains on an upward trend. In recent years, centered on the goals of sustainable development and carbon neutrality, the Chinese government has actively formulated policies to increase the share of renewable energy in energy production and consumption, and has encouraged new energy projects and increased investment in renewable energy through a variety of effective measures, which has led to a large increase in the share of renewable and clean energy in China's energy mix. However, according to the results of this paper, coal has always been in the first place in China's energy structure, which makes China face an extremely strict choice between economic development and environmental protection. Therefore, the Chinese government should formulate further renewable energy policies according to the local financial and economic development level to promote the development of the renewable energy industry to bring more benefits.

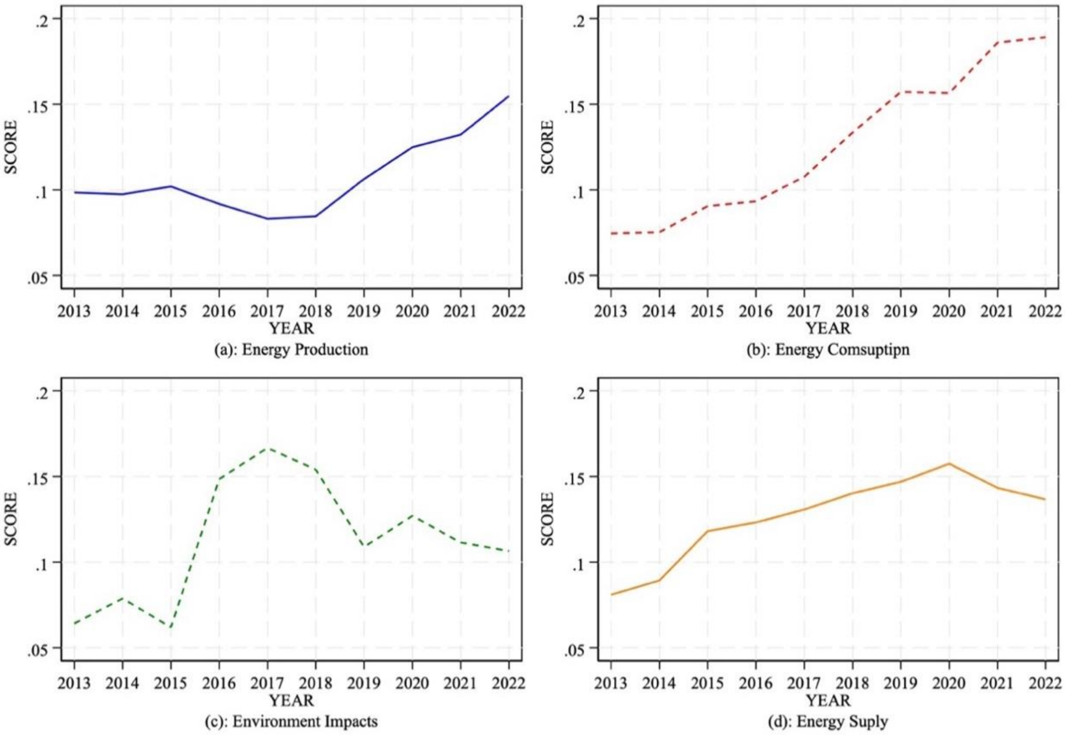

Figure 3. The 4 Dimensions of Energy Security TOPSIS Scores of China, 2013-2022 years, source: developed by the author

As for the security level of energy consumption, under the background of the steady increase in the total consumption of traditional fossil energy and new energy (x18), the optimization of consumption structure (x11 and x14), and the improvement of energy efficiency (x16 and x17), the economic fluctuations caused by the international situation also affect the energy consumption elasticity coefficient (x15), thus affecting the energy security level.

However, China's energy security level fluctuates greatly in terms of the environmental dimension and supply dimension compared with the first two. In the context of China's continued industrialization, energy consumption demand is still in a period of growth and is expected to continue growing at a significant rate for the foreseeable future. The carbon neutrality goal also requires China to accelerate its low-carbon energy transition and reduce its total energy consumption and carbon emissions. Additionally, China must expedite the optimization of its energy structure and actively promote replacing traditional fossil fuels like coal with renewable energy at an accelerated pace. However, given China's longstanding high reliance on coal and its limited reserves of relatively clean oil and natural gas resources, the withdrawal of traditional fossil energy sources during energy restructuring—particularly aggressive carbon reduction strategies—may directly affect energy supply security and economic growth. Therefore, from the perspective of energy consumption, the path to sustainable development involves investing in scientific and technological research to enhance the efficiency of traditional fossil fuel use while identifying optimal strategies for gradually transitioning to renewable energy sources.

In terms of the environmental dimension, the energy security level has maintained a downward trend since 2017. Only in 2019-2020, due to the COVID-19 pandemic, the large-scale quarantine and epidemic prevention measures taken affected economic production activities, resulting in a short-term improvement in the environmental level. On the other hand, when faced with economic growth pressures, some countries, especially developing economies, may choose between economic growth and environmental protection, scaling back investments in infrastructure development or upgrading in the energy sector, and environmental protection investments or expenditures. During the research period, the downward trend in the second half of the period may be caused by the following reasons: 1. In the context of strong support for environmental governance, the overall level of China's environmental energy security has transformed from a low level and high growth rate in the first half to a higher level, and the growth rate has declined, and the emissions of several major pollutants have decreased significantly; 2. The slowdown in economic growth has led to a reduction in support for industrial pollution investment; 3. The impact of the data itself on the results may require an increase in the number of indicators. Therefore, in the environmental protection dimension, the advantages of renewable energy will be limited by the impact of the downturn in economic growth. In addition, although the global energy transition is accelerating and renewable energy is developing rapidly, no energy source can really replace the strategic position of oil and gas so far. Under the constraints of carbon neutrality targets, the consumer demand for oil and gas will decline, but even by 2060, oil and gas will remain irreplaceable strategic resources.

Finally, energy security in the supply dimension is especially influenced by the international situation. On the one hand, the increase in imports of the three major conventional fossil fuels can be interpreted as an improvement in the ability to obtain energy in the international market. On the other hand, the external dependence on oil (imports divided by consumption) has maintained an upward trend in recent years and can also be regarded as an area of vulnerability. In addition, given that domestic energy reserves are relatively stable, fluctuations in international energy prices, especially oil and natural gas prices, significantly affect China's energy security. For instance, the price drop in 2014-2015 led to an increase in China's energy supply security, while the price rise starting in 2020 has inevitably weakened this score. As a result, a reasonable and efficient increase in the share of renewable energy could improve China's hydrocarbon energy dependence and reduce the frequent international price fluctuations and possible supply chain risks. More importantly, as an alternative energy source, the efficient exploitation of geographic potential for renewable energy is also expanding the country's potential energy reserves, which is crucial for energy security in the narrow sense of the term.

The ongoing regional turmoil will undoubtedly have an impact on China, a major energy-consuming nation, and directly affect the supply chain and the output of energy suppliers. The panic caused by uncertainty will influence the international energy market for an extended period. Energy diversification strategies and technological advancements in the energy industry are key factors in ensuring energy security. However, in the new context, the harmonious development of energy, the economy and the environment has become the main goal of China's energy security. Therefore, during the assessment period, due to the structural adjustment of China's energy production and consumption, the development of renewable energy sources, the increase in the efficiency of energy consumption, and the investment in environmental governance of energy consumption, China's energy security level has maintained an upward trend in general, but the results of the assessment of specific dimensions demonstrate different problems.

5. Conclusions

Amid recent global instability and the pursuit of sustainable development, this study investigates China's energy security through a multidimensional and holistic lens. This paper employs a scientific and methodological approach, specifically the TOPSIS-entropy weight method, to assess and determine China's level of energy security. Based on 35 indicators of China's energy industry during the 2013-2022 period, an integral system consisting of four dimensions has been developed, allowing the distinction between internal and external factors. The primary findings suggest that China's energy security situation is generally on an upward trend but faces challenges and fluctuations over time. The empirical evidence demonstrates the decisive role of new energy resource production and consumption, energy technologies that improve utilization efficiency and reduce environmental emissions, and international energy supply. Therefore, energy security will remain a key component of China's economic stability for the foreseeable future.

In addition, the problem that this paper solves at the theoretical level is that most definitions of energy security are similar and do not go beyond the scope of 4AS. Therefore, from an empirical perspective, by selecting a large number of energy indicators, dividing them into multiple dimensions, and measuring them based on the objective TOPSIS-entropy weight method, we can find out which specific dimensions are more important for a country. As a large energy-consuming country with relatively scarce resources, foreign energy cooperation has always been an important part of China's foreign economic and trade activities and its guarantee of energy resource supply. Actively participating in global energy governance is another necessary way to proactively seek solutions to challenges.

However, it should be noted that although the indicators in this paper are selected comprehensively and the variety is sufficiently diverse, the indicators for some dimensions are still not perfect. The indicators and their associated data directly influence the results of the analysis. Therefore, in future research, comparative studies should be conducted – examining China's energy security index alongside other countries using the same data – and further discussions and analyses should focus on the indicators themselves, incorporating expert opinions. Additionally, another research direction is to enhance the granularity of the data: specifically, evaluating data from various regions in China and exploring the regression relationship between a specific calculated energy security index and economic growth.

References

1. KNOX-HAYES J., BROWN M.A., SOVACOOL B.K., WANG Y., 2013, Understanding attitudes toward energy security: Results of a cross-national survey, *Global Environmental Change* 23(3): 609-622, https://doi.org/10.1016/j.gloenvcha.2013.02.003.
2. ENERGY INSTITUTE, 2023, *Statistical Review of World Energy 2023*, https://www.energyinst.org/statistical-review.

3. YERGIN D., 1988, Energy security in the 1990s, *Foreign Affairs* 67: 110.
4. WINZER C., 2012, Conceptualizing energy security, *Energy Policy* 46: 36-48, https://doi.org/10.1016/j.enpol.2012.02.067.
5. CHERP A., JEWELL J., 2014, The concept of energy security: Beyond the four As, *Energy Policy* 75: 415-421, https://doi.org/10.1016/j.enpol.2014.09.005.
6. BIELECKI J., 2002, Energy security: Is the wolf at the door?, *The Quarterly Review of Economics and Finance* 42(2): 235-250, https://doi.org/10.1016/S1062-9769(02)00137-0.
7. AZZUNI A., BREYER C., 2018, Definitions and dimensions of energy security: A literature review, *WIREs Energy and Environment* 7(1): e268, https://doi.org/10.1002/wene.268.
8. CHESTER L., 2010, Conceptualising energy security and making explicit its polysemic nature, *Energy Policy* 38(2): 887-895, https://doi.org/10.1016/j.enpol.2009.10.039.
9. BANG G., 2010, Energy security and climate change concerns: Triggers for energy policy change in the United States?, *Energy Policy* 38(4): 1645-1653.
10. KIM J.E., 2014, Energy security and climate change: How oil endowment influences alternative vehicle innovation, *Energy Policy* 66(C): 400-410.
11. OZTURK I., 2013, Energy dependency and energy security: The role of energy efficiency and renewable energy sources, *The Pakistan Development Review* 52(4): 309-330.
12. SELVAKKUMARAN S., LIMMEECHOKCHAI B., 2013, Energy security and co-benefits of energy efficiency improvement in three Asian countries, *Renewable and Sustainable Energy Reviews* 20: 491-503, https://doi.org/10.1016/j.rser.2012.12.004.
13. BAUBLYS J., MIŠKINIS V., KONSTANTINAVIČIŪTĖ I., LEKAVIČIUS V., 2015, Energy efficiency as precondition of energy security, *Journal of Security and Sustainability Issues* 4(3): 197-208.
14. SKEA J., CHAUDRY M., WANG X., 2012, The role of gas infrastructure in promoting UK energy security, *Energy Policy* 43: 202-213, https://doi.org/10.1016/j.enpol.2011.12.057.
15. BURGHERR P., GIROUX J., SPADA M., 2015, Accidents in the energy sector and energy infrastructure attacks in the context of energy security, *European Journal of Risk Regulation* 6(2): 271-283, https://doi.org/10.1017/S1867299X00004578.
16. LARSON R.B., 2013, Reconciling energy and food security, *University of Richmond Law Review* 48: 929.
17. OGBOLUMANI O.A., NWULU N.I., 2022, A food-energy-water nexus meta-model for food and energy security, *Sustainable Production and Consumption* 30: 438-453, https://doi.org/10.1016/j.spc.2021.12.019.
18. PASQUALINO R., MONASTEROLO I., JONES A., 2019, An integrated global food and energy security system dynamics model for addressing systemic risk, *Sustainability* 11(14): 14, https://doi.org/10.3390/su11143995.
19. DOWNS E.S., 2004, The Chinese energy security debate, *The China Quarterly* 177: 21-41, https://doi.org/10.1017/S0305741004000037.
20. DE ROSA M., GAINSFORD K., PALLONETTO F., FINN D.P., 2022, Diversification, concentration and renewability of the energy supply in the European Union, *Energy* 253: 124097.
21. WANG Q., ZHOU K., 2017, A framework for evaluating global national energy security, *Applied Energy* 188: 19-31, https://doi.org/10.1016/j.apenergy.2016.11.116.
22. CHANG Y., YONG J., 2007, Differing perspectives of major oil firms on future energy developments: An illustrative framework, *Energy Policy* 35(11): 546605480.
23. KRUYT B., VAN VUUREN D.P., DE VRIES H.J.M., GROENENBERG H., 2009, Indicators for energy security, *Energy Policy* 37(6): 216602181, https://doi.org/10.1016/j.enpol.2009.02.006.
24. REN J., SOVACOOL B.K., 2014, Quantifying, measuring, and strategizing energy security: Determining the most meaningful dimensions and metrics, *Energy* 76: 838-849, https://doi.org/10.1016/j.energy.2014.08.083.
25. SOVACOOL B.K., BROWN M.A., 2010, Competing dimensions of energy security: An international perspective, *Annual Review of Environment and Resources* 35: 77-108, https://doi.org/10.1146/annurev-environ-042509-143035.
26. YERGIN D., 2006, Ensuring energy security, *Foreign Affairs* 85(2): 69-82, https://doi.org/10.2307/20031912.
27. ANG B.W., CHOONG W.L., NG T.S., 2015, Energy security: Definitions, dimensions and indexes, *Renewable and Sustainable Energy Reviews* 42: 1077-1093, https://doi.org/10.1016/j.rser.2014.10.064.
28. KILINÇ-PALA P.B., 2021, Approaches in energy exclusive security: Theories of energy security and the dominance of realism, *Politics & Policy* 49(3): 771-794.
29. VAN DE GRAAF T., COLGAN J., 2016, Global energy governance: A review and research agenda, *Palgrave Communications* 2(1): 1-12, https://doi.org/10.1057/palcomms.2015.47.
30. NYMAN J., 2013, *Securitization theory*, *Critical Approaches to Security*, Routledge: 51-62.
31. HEINRICH A., SZULECKI K., 2018, Energy securitisation: Applying the Copenhagen School's framework to energy, *Energy Security in Europe: Divergent Perceptions and Policy Challenges,* ed. Szulecki K., Springer International Publishing: 33-59, https://doi.org/10.1007/978-3-319-64964-1_2.
32. LEUNG G.C.K., CHERP A., JEWELL J., WEI Y.-M., 2014, Securitization of energy supply chains in China, *Applied Energy* 123: 316-326, https://doi.org/10.1016/j.apenergy.2013.12.016.
33. GASSER P., 2020, A review on energy security indices to compare country performances, *Energy Policy* 139: 111339, https://doi.org/10.1016/j.enpol.2020.111339.
34. CHERCHYE L., MOESEN W., ROGGE N., PUYENBROECK T., 2011, Constructing composite indicators with imprecise data: A proposal, *Expert Systems with Applications* 38: 10940-10949, https://doi.org/10.1016/j.eswa.2011.02.136.
35. ASIA PACIFIC ENERGY RESEARCH CENTRE, 2007, *A quest for energy security in the 21st century: Resources and constraints*, Institute of Energy Economics, Japan.
36. CAI Q., CHEN H., ZHENG N., CHEN H., SHI P., LI Y., ZHENG Y., 2024, Quantifying energy security and influencing factors based on entropy weighted TOPSIS and machine learning, *Advances in Energy Resources and Environmental*

Engineering, eds. Abomohra A., Harun R., Wen J., Springer International Publishing: 245-256, https://doi.org/10.1007/978-3-031-42563-9_25.
37. YANG Y., ZHENG X., SUN Z., 2020, Coal resource security assessment in China: A study using entropy-weight-based TOPSIS and BP neural network, *Sustainability* 12(6): 2294.
38. AN Y., TAN X., GU B., ZHU K., SHI L., DING Z., 2023, An assessment of renewable energy development in Belt and Road Initiative countries: An entropy and TOPSIS approach, *Energy Reports* 10: 3545-3560.
39. ZHAO D., LI C., WANG Q., YUAN J., 2020, Comprehensive evaluation of national electric power development based on cloud model and entropy method and TOPSIS: A case study in 11 countries, *Journal of Cleaner Production* 277: 123190.
40. ADUN H., 2023, Sustainability energy security: 20 years assessment of the West African nations using a comprehensive entropy-TOPSIS analysis, *Environmental Science and Pollution Research* 30(33): 81093-81112, https://doi.org/10.1007/s11356-023-28116-5.
41. ZOU T., GUO P., WU Q., 2023, Applying an entropy-weighted TOPSIS method to evaluate energy green consumption revolution progressing of China, *Environmental Science and Pollution Research* 30(14): 42267-42281, https://doi.org/10.1007/s11356-023-25175-6.
42. AL-SAIDI M., 2023, White knight or partner of choice? The Ukraine war and the role of the Middle East in the energy security of Europe, *Energy Strategy Reviews* 49: 101116, https://doi.org/10.1016/j.esr.2023.101116.
43. NATIONAL BUREAU OF STATISTICS OF CHINA, 2024, https://www.stats.gov.cn/english/ (3.10.2024).
44. 中国能源统计年鉴 (China Energy Statistics Yearbook), http://www.zgtjcbs.com/books/booksdetail.jsp?id=5661&no-deid=461&siteid=2 (23.07.2024).
45. STATISTICAL REVIEW OF WORLD ENERGY, 2023, https://www.energyinst.org/__data/assets/pdf_file/0007/1408075/5456af7ed79ea2b1943197dce2f0b019e78f3ee2.pdf (23.07.2024).
46. HWANG C.-L., YOON K., 1981, Methods for multiple attribute decision making, *Multiple Attribute Decision Making: Methods and Applications A State-of-the-Art Survey*, eds. Hwang C.-L., Yoon K., Springer: 58-191, https://doi.org/10.1007/978-3-642-48318-9_3.
47. KAYNAK S., ALTUNTAS S., DERELI T., 2017, Comparing the innovation performance of EU candidate countries: An entropy-based TOPSIS approach, *Economic Research-Ekonomska Istraživanja* 30(1): 31-54, https://doi.org/10.1080/1331677X.2016.1265895.
48. ZHENG H., SI D., WANG W., WANG R., 2018, Quantitative entropy weight TOPSIS evaluation of sustainable Chinese wind power developments, *Mathematical Problems in Engineering* 2018: 1-12, https://doi.org/10.1155/2018/6965439.
49. DOĞAN B., FERRAZ D., GUPTA M., HUYNH T.L.D., SHAHZADI I., 2022, Exploring the effects of import diversification on energy efficiency: Evidence from the OECD economies, *Renewable Energy* 189: 639-650.
50. ZOU C., PAN S., HAO Q., 2020, On the connotation, challenge and significance of China's 'energy independence' strategy, *Petroleum Exploration and Development* 47(2): 449-462.
51. UNITED NATIONS, 2015, *The 17 goals of sustainable development*, https://sdgs.un.org/goals (4.12.2024).
52. LIU Z., DENG Z., HE G., WANG H., ZHANG X., LIN J., …, LIANG X., 2022, Challenges and opportunities for carbon neutrality in China, *Nature Reviews Earth & Environment* 3(2): 141-155.
53. RADOVANOVIĆ M., FILIPOVIĆ S., PAVLOVIĆ D., 2017, Energy security measurement – A sustainable approach, *Renewable and Sustainable Energy Reviews* 68: 1020-1032.