Imperatives to improve the efficiency of the energy security system of Ukraine

Olena Pavlova[1], *Kostiantyn* Pavlov[1*], *Liubomyr* Matiichuk[2], *Igor* Kotsan[3], and *Iryna* Perevozova[4]

[1]Lesya Ukrainka Volyn National University, Department of Economics and Trade, 13 Voli Ave., 43025 Lutsk, Ukraine
[2]Ternopil Ivan Puluj National Technical National Technical University, Department of Computer Science, 56 Ruska St., Room 2-80, 46001 Ternopil, Ukraine
[3]AGH University of Krakow, Department of Analytical Chemistry and Biochemistry, Faculty of Materials Science and Ceramics, 30 Mickiewicza Ave., 30-059 Krakow, Poland
[4]Ivano-Frankivsk National Technical Oil and Gas University, Department of Entrepreneurship and Marketing, 15 Karpatska St., 76019 Ivano-Frankivsk, Ukraine

Abstract. The increasing volatility of external and internal factors, emergence of new risks in the global energy market (implementation of sustainable development principles and spread of the green economy), aggravation of political challenges, and intensification of integration processes point to the need to review and supplement existing methods for assessing the levels of energy security of states. Forming a single European energy space increases the requirements for ensuring an uninterrupted sustainable energy supply and efficient energy management that protects the interests of all market participants. In the process of substantiating approaches and creating new models of energy security, national and supranational issues of developing a joint energy base that will form the economic basis for the strategic competitiveness of European national economies are becoming essential. A necessary condition for organizing this process is to ensure adequacy and transparency of energy governance, which should consider the current state and trends of joint and national energy security indicators.

1 Introduction

Increased volatility of external and internal environmental factors, the emergence of new risks in the global energy market (implementation of the principles of sustainable development and spread of the "green economy"), aggravation of political challenges, and intensification of integration processes make it necessary to revise and supplement the existing methodological framework for assessing the levels of energy security of states. In turn, forming a single European energy space increases the requirements for ensuring uninterrupted sustainable energy supply and efficient energy management that protects the interests of all market participants. In the process of substantiating approaches and building the architecture of new energy security models, national and supranational issues of developing a single energy base, which will form the economic basis for the strategic

* Corresponding author: pavlov.kostiantyn@vnu.edu.ua

competitiveness of European national economies, become relevant. An exceptional condition for organizing this process is ensuring adequacy and transparency of energy management, which should consider the current state and trends of the leading indicators of the current standard and national energy security level.

2 Reference background

Domestic theory and practice have already developed a solid methodological basis for assessing the country's energy security. At the same time, the study of the introductory provisions of national methodologies has shown that a significant number of them are based on a systematic approach based on calculating a complex integral indicator.

We fully share the scientific and methodological position of academician Khalatov A.A., as well as Fialko N.M. and Timchenko M.P., that the methodology and models for assessing the level of energy security should be characterized by clear, specific, and maximally identified indicators, normalized by their actual values and definition criteria [1].

The authors support the methodology for determining the level of energy security, which was approved in the past: "Methodological Recommendations for Calculating the Level of Economic Security of Ukraine" of 29.30.2013. All energy efficiency indicators (nine groups of indicators) have a certain threshold: critical, dangerous, unsatisfactory, satisfactory, and optimal [2, 3].

According to this methodology, scientists distinguish three zones of the current state of the country's energy security:

1. The zone of critical security state (the value of the integral index is 0 – 50%).
2. The zone of dangerous security state (the value of the integral index is 50 – 80%).
3. The zone of satisfactory energy security (80 – 100%).

The methodological basis of indicator models is formed by groups (blocks) of indicators similar in functional content, which are transformed into integral indicators based on economic and statistical methods or expert (scoring) assessment. A variation of this methodological approach used in constructing economic and mathematical models is a multiplicative indicator of the energy security level. Several additional indicators help simultaneously normalize the indices and their thresholds [4].

Statistical techniques are particularly important in such economic and mathematical models, giving integral indicators a quantitative value based on normalization methods. Among such statistical methods, V. Kovalchuk proposes to use the procedures of statistical standardization, scalarization, and discriminative economic and statistical data analysis methods. As a result of an integral assessment of the system of energy security indicators, the author comes to its three primary states: normal, pre-crisis, and crisis [5].

The economic and mathematical model of determining the state's energy security level, proposed by Bobrov E.A., is characterized by a similar content. Block groups of indicators are reduced to the value of a single integral indicator, which determines the actual state of energy security within the weak, medium, and firm [6].

By quantifying the parameters of the entire energy system based on economic and mathematical modeling data, the optimal values for each type of fuel and energy resources are determined, taking into account their origin and the variation of the normalized value of the indicator in the range from 0 to 1.

The four-dimensional model of ensuring the country's energy security proposed by S. Pryimeneko is also worthy of attention, which, like most economic and mathematical models, is based on a set of relevant groups of energy security indicators but takes as a basis a qualitative assessment of the ratio of the cost and benefit planes of electricity generating sources. The author's model envisages four options for developing the energy security state: maintenance, stabilization, recovery, and decline. Each state corresponds to the value of an integral indicator determined by a qualitative scoring: the state of "decline" – with a gap in

the value of the integral indicator in the range of 0 – 3; the state of "recovery" – in the range of 3 – 6; the state of "stabilization" – 6 – 9; the state of "maintenance" – the value of the indicator within the statistical scale of 9 – 12 [7].

The methodology for determining the level of energy security was developed by a group of scientists, including O. Sukhodol, Y. Kharazishvili, D. Bobro, and others, using a systematic approach and a thorough methodological basis. The method is also based on a system of fundamental indicators normalized by the reference value depending on their functional content and nature of impact. An additional variation range of 5 – 10% was used for the system of stimulant indicators [8].

The organizational and managerial components are essential to ensuring the state's energy security. However, methodological difficulties and subjectivity in measuring its indicators have lower accuracy than the basic ones. This, in turn, affects the reality and objectivity of the country's overall performance indicators of energy security level [9].

3 Research methods

A study of existing methodological approaches and models for determining and assessing the level of energy security in Ukraine and foreign countries has shown that many methodological approaches are used in practice. Almost all of them are closely related to identifying energy security risks and involve calculating indicators and their respective levels.

Among such methodological approaches, the paper identifies systemic, indicative, factor, target-oriented methodological approaches, denotative, resource, and structural approaches, which to varying degrees come to a single integral basis and calculation of the leading (primary) final indicators. The economic and mathematical models were built on several approaches, the most common of which was the systemic approach. At the same time, familiarization with modeling energy security processes at different levels of energy management showed that, in many cases, systems of indicators for auditing the actual state of energy security were understood as "models".

Such an assessment was supplemented by identifying risks and threats and their qualitative and quantitative assessment. In this case, we consider it expedient to distinguish the types of energy security models into two main types: models for diagnosing the energy security of an energy management facility and models for ensuring the energy security of an energy management facility (Fig. 1).

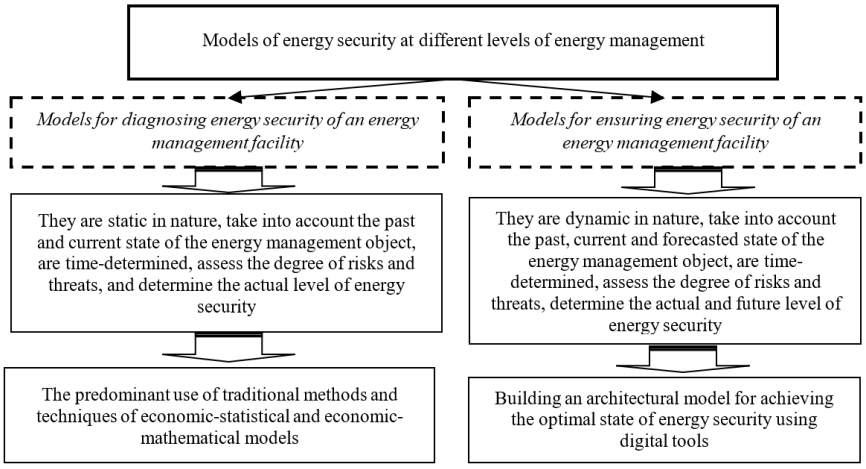

Fig. 1. Types of models for studying the energy security of an energy management facility.

The plane of zoning of energy security levels and the corresponding plane to which the calculated indicators belong is of exceptional importance in the existing methodological approaches to modeling. Such methodological approaches form a robust statistical basis for building the architecture of economic and mathematical models, the main task of which is to find the optimal solution and the value of integral indicators for assessing the state of energy security at different levels of economic management (Fig. 2).

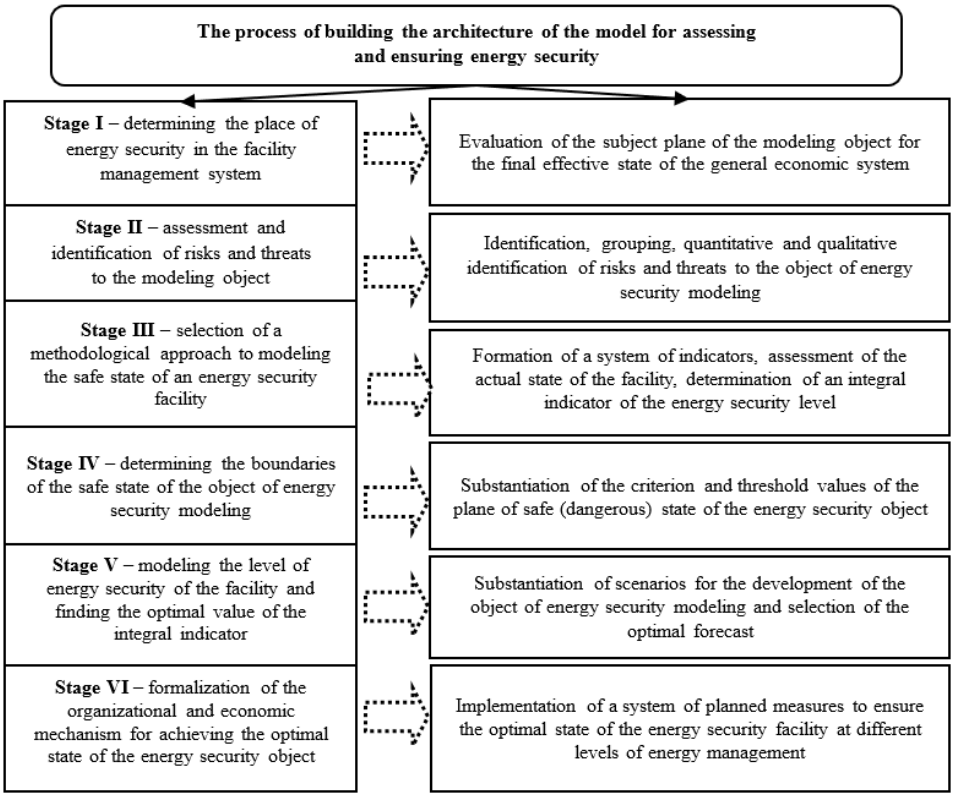

Fig. 2. Stages of building the architecture of the economic and mathematical model of energy security.

Scientists today call the reduction of energy poverty, achievement of environmental sustainability goals, and solving the problems of physical, economic, and social availability of energy resources the critical areas of ensuring the optimal state of energy security of the European market [10].

The methodological basis of indicators of modern models for assessing and ensuring the energy security of the common European market is formed by the strategic priorities of the European Union, based on which Tutak, M. sets the weighting coefficients of the level of significance of a particular indicator.

The group of indicators is evaluated using the statistical methods of Grey Relational Grade (GRG), entropy, and standard deviations. The results show the current state of energy security of individual countries and the European Union. At the same time, this model does not have level limits of the actual state of energy security of countries, which makes it impossible to find its optimal forecast level [11 – 13].

To date, only a tiny part of the scientific works of European scientists is devoted to the substantiation of optimization economic and mathematical models focused on finding the optimal criterion (value) of an integral indicator with a forecast period. Among them, the

economic and mathematical model by Franki et al. should be noted, which resulted in a forecast of the future level of energy security of the countries of Southeast Europe [14].

Most models are focused on the statistical retrospective of aggregate data of the past or current state of energy security. To solve this methodological problem, Ziemba P. proposes using the DMCDM model based on a dynamic multi-criteria decision-making system. In this model, the set of factors (criteria) is not fixed; it is determined by dynamism and considers several main forecast scenarios. The peculiarity of the model is that it is a specific procedure for assessing and weighing various factors (coefficients) that influence the state of energy security [15].

A similar analysis of trends in the country's energy security is provided in the models of Jassbi et al. [16].

Scientists have proven that countries' energy policy is relatively stable on a large scale and does not undergo radical changes in the short term. The Asia-Pacific Energy Research Center has developed a model of energy security based on four basic principles [17]:

– security (availability of energy);
– physical availability of energy resources for consumers;
– financial availability of energy resources for consumers;
– acceptability (by critical conditions of energy consumption).

This model design has been harshly criticized by some scholars Cherp, A.; Jewell, J. (2013), who consider the 4-A model to be limited and capable of showing its effectiveness only if the set of external and internal factors that affect the energy security of the object of management is stable [18, 19].

In turn, Y. Song (2019) attempted to substantiate a model for assessing the level of energy security for national island economies (South Korea, Singapore, Japan, Taiwan), which are not characterized by such close economic ties as the EU member states, but also have poor energy potential [20].

However, these parameters' systematic nature and complexity have led to the widespread development of models that use only a few dimensions to define energy security. The model of L.X. Yao et al. assessed the state of China's energy security based on the quantification of four basic parameters: energy resources, technology, acceptability to society, and energy resource availability [15, 21 – 23].

At the same time, Ang et al. (2015) proved that using a significant number of indicators in models for assessing countries' energy security reduced their overall impact on the integral indicator and distorted the final resultant value [24, 25].

This led to the justification of the optimal number of indicators in the range of 15 – 20.

Realizing the limitations of such statistical models for assessing energy security, an approach that includes three main stages of energy security assessment has become quite common in foreign practice: normalization of a group of selected indicators, weighting of normalized parameters of individual indicators and aggregation into an aggregate integrated index with the definition of security zones [26].

A controversial aspect of these methods is the procedural methods of assessing weighted indicators, which were often based on qualitative expert methods (surveys, interviews, Delphi method), the results of which were somewhat subjective [27, 28].

We consider pretty promising the methodology for assessing the level of energy security used in the research of Sovacool (2018), who used the method of additive aggregation to assess the basic operators (indicators) for each group of which the relevant statistical properties and interval range of data were determined [29 – 31].

In the future, such a methodological approach will be promising in building the architecture of an economic and mathematical model of the optimal state of the energy security object, with the addition of a more detailed and thorough analysis of the sustainability results of the assessment parameters.

4 Research results and discussion

Among most of the models for assessing the level of energy security that we have reviewed, it is worthwhile to focus on those that represent a generalization of partial coefficients or indices into intermediate components that should be considered components of the model based on which the integral value of the coefficient of the level of energy security of the state is calculated. Taking the above works as a basis, we have developed and proposed a model for assessing the level of energy security that includes five components, each of which is calculated from separate partial indicators or coefficients [30, 31].

The paper uses a convolution model of partial indicators into components based on factor correlations using threshold values and the proposed target values using the tools of the homeostatic plateau of indicators. From our point of view, the calculated threshold values of the proposed coefficients, some of which we also used in our calculations, as they qualitatively reflect the processes under study, can be used to obtain ranges of coefficient values, each of which we have classified accordingly. The thresholds allow us to propose ranges of values accordingly: "Shallow level of the energy security coefficient or component", "Low level of the energy security coefficient or component", "Medium level of the energy security coefficient or component", "High level of the energy security coefficient or component" and "Very high level of the energy security coefficient or component".

Similar thresholds were calculated for the indicators we developed and proposed to obtain ranges for qualitative interpretation of energy security indicators. Based on a generalization of existing approaches to the allocation of energy security components, we have identified and substantiated five key blocks that, by their importance, form a comprehensive, integrated coefficient of the state's energy security:

– the strategic component of energy security (SCES);
– socio-economic component of energy security (SECES);
– energy sector efficiency (ESE);
– environmental and economic component of energy security (EECES);
– socio-economic component of energy security (SECES);

To calculate the integral value for individual components and the overall energy security, we propose to use a fuzzy inference model, the algorithm of which will be presented below.

Let us describe each component and its indicators. The indicators for the strategic component of energy security are presented in Table 1.

Table 1. Indicators of the strategic component of the state's energy security.

Indicators
Meeting the needs with own fuel and energy resources
The cost of energy imports for the country
Share of coal and peat in the energy balance
Share of crude oil and oil products in the energy balance
Share of natural gas in the energy balance
Share of nuclear energy in the energy balance
Share of hydropower in the energy balance
Share of biofuels and waste in the energy balance
Share of wind and solar energy in the energy balance

It is worth noting that only those resources with indicators that differ from 0% or 100% were included in the chart. Because of this scattering of component values, the integral value for all components does not show such strong dynamics, i.e., the multidirectional trends in changes in individual components were "canceled out" by each other.

Throughout the entire period under study, the value of the indicator of satisfaction of needs with own fuel and energy resources is in the range of the average level of energy security. The next critical indicator for energy security is the cost of energy imports for the state – Fig. 3.

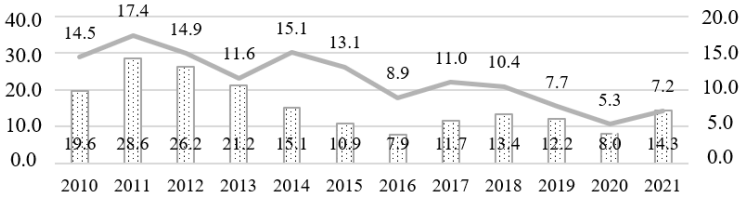

Fig. 3. Dynamics of fuel imports and their share in GDP, columns – fuel imports (USD bn); line – share of fuel imports in GDP.

Unlike the previous one, it is worth noting that a better trend characterizes this indicator – there are positive dynamics both in absolute and relative terms.

The situation with individual energy resources is generally unsatisfactory. The coefficient is very low for 3 out of seven resources, low for 2, medium for biofuels and waste, and high for nuclear energy. This indicates a relatively favorable situation in nuclear energy and significant problems in all other energy production sectors. Ukraine needs to catch up in indicators characterizing the development level of alternative energy sources, which indicates the impossibility of an energy transition to new energy security standards based on them.

The next component combines indicators that characterize the socio-economic component of the state's energy security, which are presented in Table 2. The first indicator in this group that should be considered is the cost of energy resources consumed by the state, calculated as a percentage of GDP (Fig. 4).

Table 2. Indicators of the socio-economic component of the state's energy security.

Indicators
Cost of consumed energy resources for the state
Annual energy consumption per person
Energy intensity of GDP
Share of the fuel and energy sector in GDP
Level of losses of the fuel and energy complex in the energy balance
Consumption and conversion rates

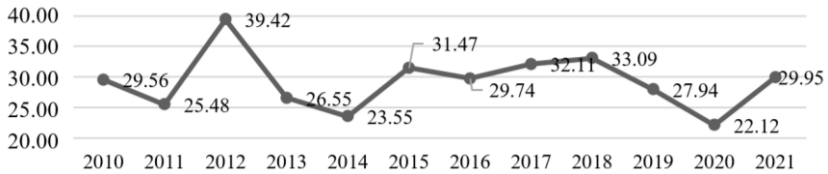

Fig. 4. Cost of energy resources consumed for the state (% of GDP).

The next indicator is the annual energy consumption per capita, the dynamics of which are shown in Fig. 5. Unlike the previous one, this indicator is characterized by a downward trend, which is a negative trend, as its authors refer to it as a stimulant and, accordingly, the higher it is, the better it is for the state's energy security. Unlike the previous one, this indicator is also characterized by specific dynamics, represented by a trend.

The next indicator is the energy intensity of the gross domestic product. Here, we will use the trend value based on the analysis of the dynamics of energy consumption over the study period, as shown in Fig. 6.

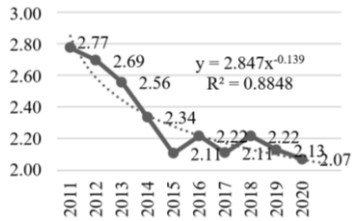

Fig. 5. Dynamics of annual energy consumption per capita with a trend line.

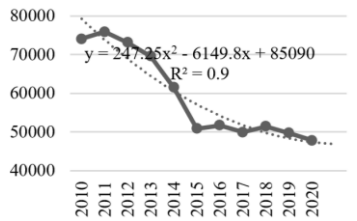

Fig. 6. Energy consumption (tons of oil equivalent) in dynamics.

Based on the forecasted value of energy consumption along the trend line in 2021 and considering the actual value of GDP for the same year, we calculated the level of energy intensity of GDP, the dynamics of which is shown in Fig. 7. This indicator is a discourager; the lower it is, the better for energy security.

These results indicate a steady downward trend in the energy intensity of Ukraine's GDP. Despite the positive dynamics, the value of this coefficient is very low.

The next indicator is the share of the fuel and energy sector in the country's GDP, the dynamics of which are shown in Fig. 8.

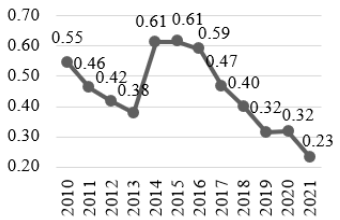

Fig. 7. Energy consumption (tons of oil equivalent) in dynamics per 1000 $.

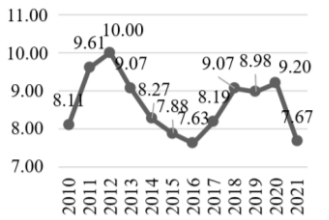

Fig. 8. Dynamics of the indicator "Share of the fuel and energy sector in GDP".

This indicator is considered a discourager: the lower it is, the better. During the period under study, there were noticeable dynamics that differed from the general trends of the indicators that had been discussed previously. Such dynamics, by the thresholds, allowed this indicator to ensure high energy security.

According to the threshold values, the indicator of losses in the energy balance is at the average level of energy security, and the indicator of consumption for transformation is very low. These two indicators are related to the state of the energy system in the country, which, regardless of the degree of its utilization, is characterized by its parameters of losses and energy conversion costs, which require the maximum level of its utilization to reduce their share.

A generalization of the indicators of the socio-economic component of energy security is shown in Fig. 9. Generally, the considered component's indicators are characterized by a higher level of energy security by the values that fell into the corresponding ranges than in the previous component. Thus, the strategic orientation of the energy sector, which ensures the desired level of energy security, is inferior to its socio-economic aspects. The next component is the efficiency of the energy sector, the set of indicators presented in Table 3.

By the thresholds, all values of the indicator were at most a shallow level for the entire period under study, which indicates insufficient investment by fuel and energy sector enterprises.

Table 3. Set of indicators of the energy sector performance component.

Indicators
The level of investment in the fuel and energy sector
Renewal rate of fixed assets of the fuel and energy sector
The serviceability of fixed assets in the fuel and energy sector
Share of electricity losses in the grid, %
Share of heat losses in heating networks, %
Utilization rate of the Ukrainian gas transportation system

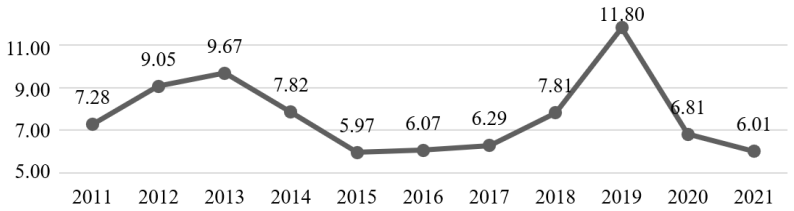

Fig. 9. Dynamics of the indicator "Level of Investment of Fuel and Energy Sector Enterprises".

Considering the threshold values of the fixed assets serviceability ratio and the renewal rate, the serviceability ratio falls into the low energy security values and renewal rate range. However, in 2019, it was high. The following two indicators illustrate the efficiency of the electricity and heat supply systems.

Unfortunately, both indicators have a steady upward trend, which indicates the inefficiency of the functioning of these systems, which generates losses. Based on the constructed trend lines, we predicted the values of these indicators, which, according to their thresholds, fall into the range of low levels for electricity losses and deficient levels for heat losses. The latter indicator of this component is represented by the load factor of Ukraine's gas transportation system.

Summarizing the values of the indicators of the energy sector efficiency component, it should be noted that, compared to the previous ones, these values have the worst levels: 2 are very low, and three are low. This makes it necessary to focus maximum efforts on improving these systems to increase energy security. The next component among the aggregate components of the energy security index is the environmental and economic component. The set of indicators of this component is presented in Table 4.

Table 4. Indicators of the environmental and economic component.

Indicators
CO_2 emissions per unit of GDP
Level of CO_2 emissions generated by the fuel and energy complex per TSEP unit
CO_2 emissions per 1 exajoule
Methane emissions per TSEP unit
Share of renewable sources in the total volume

Unlike the previous components, this one was developed entirely from the proposed indicators, which requires determining the law of distribution of the values of the calculation coefficients and setting thresholds and ranges of values based on this law. To solve this problem and to comply with a single methodological approach to determining the threshold values of the calculated primary indicators, we used the method of setting thresholds proposed in the same paper, which was investigated within the environmental and economic components. This value results from the level of CO_2 emissions per unit of GDP [32].

In turn, to determine the overall assessment, it is necessary to obtain values for each of the five components of the aggregate level, which in turn are formed by the corresponding set of initial primary indicators. As noted above, using threshold values, we proposed interval ranges for classifying the values of the coefficient that fall within it, which allowed us to form 5 linguistic terms:

– shallow level of the value of the coefficient or component of energy security;
– low level of the value of the coefficient or component of energy security;
– medium level of the value of the coefficient or component of energy security;
– high level of the value of the coefficient or component of energy security;
– very high level of the value of the coefficient or component of energy security;
– very high level of the value of the coefficient or component of energy security.

It is proposed to use a symmetric Gaussian membership function as a function:

$$f(x,\ \sigma,\ c) = e^{\frac{-(x-c)^2}{2\sigma^2}}. \quad (1)$$

where c is the maximum coordinate (membership function); σ is the concentration coefficient (membership function).

The output data (variables) for processes are set by the same function.

To implement the phasing and defuzzification of input/output variables, it is necessary to form a rule base, which is formed by developing rules for determining the level of each component of energy security and the overall level of the integral coefficient. Levels are described by n number of terms. Let us consider this on the example of the socio-economic component, in which case the rules look like this:

If “the share of total household income spent on utilities” is level A_1, “annual electricity consumption per capita” is level A_2, “accounts receivable turnover ratio” is level A_3, “the share of household debts in the amount of accounts receivable for the supply of electricity, gas, steam and air conditioning” is level A_1, “the share of environmental protection costs in GDP” is level A_3, then “the value of the socio-economic component” is level A_n.

Thus, rules that take on the specified Mamdani form within the “Fuzzy Logic Toolbox” package of the “MatLab” software are formed. As a result, the fuzzy logic inference system will have the following form (Table 5).

Table 5. Parameters of the fuzzy system for assessing the level of energy security (on the example of the socio-economic component).

Parametric	Explanation
Input variables	Indicators of the socio-economic component that determine their level
Output variables	The importance of the socio-economic component of management
Type of membership function	U-shape, for input and output parameters
Number of terms	5: very low level of the energy security coefficient or component; low level of value of the coefficient or component of energy security; medium level of value of the coefficient or component of energy security; high level of the energy security coefficient or component; very high level of the energy security coefficient or component.
Fuzzy knowledge base	Results of calculations
Knowledge base rules	“Mamdani” rules of type
Method of defuzzification	Center of gravity – the method

The results of the assessment of the values of the aggregate components and the resulting value of the integral coefficient are presented in Table 6.

Table 6. Results of estimating the values of the energy security model components and the integral coefficient.

Strategic component of energy security (SCES)	Middle level	Middle level
Public, economic component of energy security (PECES)	Middle level	
Energy sector efficiency (ESE)	Low level	
Environmental and Economic Component of Energy Security (EECS)	Low level	
Socio-Economic Component of Energy Security (SECES)	Middle level	

The analysis of energy security indicators reveals significant concerns, particularly in the efficiency and environmental-economic components. Despite a brief period of improvement in 2019, the energy sector's efficiency remains low, with both electricity and heat systems showing inefficiencies that contribute to losses. Predictions indicate that these inefficiencies will persist, necessitating urgent efforts to enhance system performance. The environmental-economic component, defined by indicators such as CO_2 and methane emissions, also reflects low levels of security. Overall, the energy security index reveals critical areas in need of improvement, particularly in efficiency and environmental impact, to ensure a more secure and sustainable energy system.

5 Conclusions

Thus, using the developed fuzzy inference model, we have determined the qualitative level of each of the proposed aggregated components and the generalized integral coefficient of energy security. An unfavorable situation has developed about the efficiency of the energy sector and the environmental and economic components of energy security, the level of which is low compared to the average level of other components.

The architectural composition of the author's proposed economic and statistical model of energy security provides four main scenarios for its development: maintenance, stabilization, recovery, and decline. Based on the generalization of existing models for calculating the integral coefficient of energy security, it was found that most often, it is planned to use the methods of additive or multiplicative convolution of primary partial indicators, which were previously combined into intermediate aggregate components.

Based on these approaches, we have proposed an assessment model that includes several aggregated energy security components: SCES, PECES, EFES, EECS, and SocEES.

As a result, threshold ranges were determined for a set of indicators, which allowed us to interpret the obtained values in the very low, low, medium, high, and very high levels of the value of the coefficient or component of energy security.

To summarize and obtain a qualitative value of the aggregated components and the overall index of the integral indicator, the fuzzy logic method was used, which was implemented in the environment of the relevant software (“Fuzzy Logic Toolbox” of the MatLab program). It was found that a low level of security is inherent in the subsystem of energy sector efficiency and the environmental and economic component, which should be considered sources of potential risks. The strategic, socio-economic, and socio-economic components of energy security are characterized by an average level, which results in an average level of energy security for the entire system. The obtained value is a limit value since if any component moves from the medium to the low level, the resulting coefficien’s integral value will change, allowing us to interpret the obtained value as an average with an adverse scenario to the low level. This method has advantages over others, as it allows the use of the current actual values and forecast parameters obtained based on the analysis of previous data using a trend line.

Achieving the forecast indicators of the author's economic and statistical energy security model objectively requires substantiation of the relevant organizational and economic principles for implementing its critical tasks and compliance with the recommended

parameters. To mitigate the short- and long-term risks and threats in the practical implementation of the proposed energy security model, it is necessary to identify and structure the level of risk factors in energy management. The risk support of the energy security model, according to the author's approach, should include three primary levels according to the criterion of their potential manageability: Level 1 – risks that cannot be controlled; Level 2 – controlled risks; Level 3 – managed risks in the system of anti-crisis energy management. The organizational and economic mechanism of energy risk management should be built based on unity and joint action of administrative, economic, organizational, managerial, and socio-psychological measures.

References

1. Khalatov, A.A., Fialko N.M., & Tymchenko M.P. (2020). Enerhetychna bezpeka Ukrainy: metodolohichni zasady otsinky rivnia bezpeky ta porivnialnyi analiz potochnoho stanu. *Teplofizyka ta Teploenerhetyka*, *42*(2), 18-30.
2. MRCLE. (2013). *Methodological recommendations for calculating the level of economic security of Ukraine*: Approved by Order of the Ministry of Economic Development and Trade dated 10/29/2013 No. 1277. Verkhovna Rada of Ukraine. Legislation of Ukraine. Retrieved from https://zakon.rada.gov.ua/rada/show/v1277731-13#Text
3. Pavlov, K., Pavlova O., Haliant, S., Perevozova, I., Shostak, L., Begun, S., & Bortnik, S. (2022). Determination of the level of innovative activity of gas distribution enterprises of the Western Region of Ukraine. *AD ALTA: Journal of Interdisciplinary Research*, *12*(01), 130-134. http://www.doi.org/10.33543/1201
4. Pysar, N. (2019). Assessment of the Region's Energy Security Level in the Process of Formation of the Common European Energy Space. *International Journal of Energy Economics and Policy*, *9*(4), 149-157. https://doi.org/10.32479/ijeep.7679
5. Kovalchuk V.M. (2010). Kontseptualni pidkhody do otsinky ta klasyfikatsii terytorii za rivnem enerhetychnoi bezpeky. *Finansova Systema Ukrayiny*, (15), 475-479.
6. Bobrov, Ye.A. (2013). *Enerhetychna bezpeka derzhavy*. Kyiv, Ukraina: Universytet ekonomiky ta prava "KROK", 308 s.
7. Pryymenko, S.A. (2014). Stratehiia rozvytku enerhetychnoi haluzi Ukrainy yak skladova enerhetychnoi bezpeky. *Mekhanizm Rehulyuvannya Ekonomiky*, (2), 167-172.
8. Pavlova, O., Pavlov, K., Horal, L., Novosad, O., Korol, S., Perevozova, I., Obelnytska, K., Daliak, N., Protsyshyn, O., & Popadynets, N. (2021). Integral estimation of the competitiveness level of the western Ukrainian gas distribution companies. *Accounting*, 1073-1084. https://doi.org/10.5267/j.ac.2021.3.001
9. Polyanska, A., Pazynich, Y., Mykhailyshyn, K., Babets, D., & Toś, P. (2024). Aspects of energy efficiency management for rational energy resource utilization. *Rudarsko-Geološko-Naftni Zbornik*, *39*(3), 13-26. https://doi.org/10.17794/rgn.2024.3.2
10. Iddrisu, I., & Bhattacharyya, S.C. (2015). Sustainable energy development index: A multi-dimensional indicator for measuring sustainable energy development. *Renewable and Sustainable Energy Reviews*, (50), 513-530. https://doi.org/10.1016/j.rser.2015.05.032
11. Lukic, M., & Ninkovic, P. (2016). Testing and verification of a novel single-channel IGBT driver circuit. *Zbornik Radova, Elektrotehnicki Institut Nikola Tesla*, *26*(26), 53-68. https://doi.org/10.5937/zeint26-12304
12. Brodny, J., & Tutak, M. (2021). The comparative assessment of sustainable energy security in the Visegrad countries. A 10-year perspective. *Journal of Cleaner Production*, (317), 128427. https://doi.org/10.1016/j.jclepro.2021.128427
13. Yakymchuk, A., Valyukh, A., Irtyshcheva, I., Yakubiv, V., Popadynets, N., Hryhoruk, I., Pavlov, K., Pavlova, O., Maksymiv, Y., Boiko, Y., Hryshyna, N., & Ishchenko, O. (2021). Economic diagnostics and management of eco-innovations: conceptual model of taxonomic analysis.

Intelligent Human Systems Integration 2021, 573-579. https://doi.org/10.1007/978-3-030-68017-6_84

14. Franki, V., & Višković, A. (2021). Multi-criteria decision support: A case study of Southeast Europe power systems. *Utilities Policy*, (73), 101286. https://doi.org/10.1016/j.jup.2021.101286
15. World Energy Council. (2021). *World Energy Trilemma Framework*. Retrieved from https://www.worldenergy.org/transition-toolkit/world-energy-trilemma-framework
16. Jassbi, J.J., Ribeiro, R.A., & Varela, L.R. (2014). Dynamic MCDM with future knowledge for supplier selection. *Journal of Decision Systems*, *23*(3), 232-248. https://doi.org/10.1080/12460125.2014.886850
17. García-Verdugo, J., San-Martín, E., Muñoz, B. (2012). Global energy needs and resources: geographical imbalances and energy security. *Energy Security for the EU in the 21st Century*, 29-47. https://doi.org/10.4324/9780203153291-11
18. Cherp, A., & Jewell, J. (2013). Energy security assessment framework and three case studies. *International Handbook of Energy Security*, 146-173 https://doi.org/10.4337/9781781007907.00018
19. Polyanska, A., Pazynich, Y., Mykhailyshyn, K., & Buketov, V. (2023). Energy transition: the future of energy on the base of smart specialization. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, (4), 89-95. https://doi.org/10.33271/nvngu/2023-4/089
20. Song, Y., Zhang, M., & Sun, R. (2019). Using a new aggregated indicator to evaluate China's energy security. *Energy Policy*, (132), 167-174. https://doi.org/10.1016/j.enpol.2019.05.036
21. Siksnelyte, I., & Zavadskas, E.K. (2019). Achievements of the European Union Countries in Seeking a Sustainable Electricity Sector. *Energies*, *12*(12), 2254. https://doi.org/10.3390/en12122254
22. Yao, L., & Chang, Y. (2014). Energy security in China: A quantitative analysis and policy implications. *Energy Policy*, (67), 595-604. https://doi.org/10.1016/j.enpol.2013.12.047
23. Polyanska, A., Savchuk, S., Dudek, M., Sala, D., Pazynich, Y., & Cicho, D. (2022). Impact of digital maturity on sustainable development effects in energy sector in the condition of Industry 4.0. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, (6), 97-103. https://doi.org/10.33271/nvngu/2022-6/097
24. 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
25. Pavlov, K., Pavlova, O., Kotsko, T., Novosad, O., Matiychuk, L., Tomashevska, A., Shabala, O., & Pylypiv, N. (2023). Functioning efficiency of the electricity market of the western region of Ukraine. *Polityka Energetyczna – Energy Policy Journal*, *26*(2), 47-64. https://doi.org/10.33223/epj/163195
26. Augutis, J., Krikstolaitis, R., Martisauskas, L., & Peciulyte, S. (2012). Energy security level assessment technology. *Applied Energy*, (97), 143-149. https://doi.org/10.1016/j.apenergy.2011.11.032
27. Sala, D., & Bieda, B. (2022). Stochastic approach based on Monte Carlo (MC) simulation used for Life Cycle Inventory (LCI) uncertainty analysis in Rare Earth Elements (REEs) recovery. *E3S Web of Conferences*, (349), 01013. https://doi.org/10.1051/e3sconf/202234901013
28. Wu, G., Liu, L.-C., Han, Z.-Y., & Wei, Y.-M. (2012). Climate protection and China's energy security: Win–win or tradeoff. *Applied Energy*, (97), 157-163. https://doi.org/10.1016/j.apenergy.2011.11.061
29. Gitelman, L., Magaril, E., & Kozhevnikov, M. (2023). Energy Security: New Threats and Solutions. *Energies*, *16*(6), 2869. https://doi.org/10.3390/en16062869
30. Sala, D., Pavlov, K., Pavlova, O., Dychkovskyi R., Ruskykh, V., & Pysanko, S. (2023). Determining the level of efficiency of gas distribution enterprises in the Western Region of Ukraine. *Inżynieria Mineralna*, *2*(*2*(52)), 109-122. https://doi.org/10.29227/im-2023-02-64

31. Sala, D., Bashynska, I., Pavlova, O., Pavlov, K., Chorna, N., & Chornyi, R. (2023). Investment and innovation activity of renewable energy sources in the electric power industry in the South-Eastern Region of Ukraine. *Energies*, *16*(5), 2363. https://doi.org/10.3390/en16052363
32. SukhodoliaO.M., Kharazishvili, Yu.M., Bobro, D.H., Riabtsev, H.L., & Zavhorodnia, S.P. (2021). *Vyznachennia rivnia enerhetychnoi bezpeky Ukrainy*: analitychna dopovid. Kyiv, Ukraina: NISD, 71 s. https://doi.org/10.53679/NISS-analytrep.2022.02