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REGIONAL CLUSTERING OF FEC ENTERPRISES TO STRENGTHEN THE COUNTRY'S ECONOMIC SECURITY

The object of this work is the process of strengthening the economic security of enterprises of the fuel and energy complex of Ukraine. The work considers the issue of dividing business entities of different forms of ownership into clusters according to their territorial affiliation and features of functioning. A characteristic feature of the territorial organization of the energy complex of Ukraine is not the isolated location of its production facilities, but the functioning of most of them in energy systems and close interconnection. As a result of the proposed methods of cluster analysis, similarity, correlation and Euclidean distance, a division into territorial clusters was carried out according to the studied industry. The results obtained are presented in a matrix representation, which helped to adjust possible cluster similarities and determine them due to territorial proximity and results of financial activity. Further research is devoted to determining the changes in indicators over the past five years regarding such characteristics as: economic growth of the cluster, interconnection with other clusters, financial stability of the cluster and socio-economic development. This helped to generalize the analyzed data and identify the weaknesses and strengths of energy enterprises. It was determined that the leaders among the positive generalized results are the Black Sea cluster (34.88/1) and the Capital (30.34/2) cluster and Podilskyi (27.91/3). And the negative ones are the Central (25.15/9), Prydniprovskyi (26.09/8) and TO Donetsk (27.26/7). The results obtained are explained by the diversity of financial results of companies over a five-year period, as well as the constant change in factors of external influence on critical infrastructure facilities. The proposed measures for dividing enterprises into clusters are aimed at further maintaining the existing level of economic security. They are also aimed at protecting all sources of energy generation by enterprises and further prospects for renewal and/or reconstruction in the chain of energy services from production to the end consumer, which should become a priority area of development for the country.

Keywords: *energy enterprises, energy clusters, regional development, economic security, energy systems, regional management.*

1. Introduction

Ensuring the economic security of economic entities and the integrity of regions is one of the priority areas of Ukraine's national security [1]. In the practice of regional management, there is no single developed system for managing risks and threats to economic security. According to the state and regional strategic documents, the general system of the country's management is formed on their basis, but there are changes of both a global and local nature that have different effects on the socio-economic system as a whole. Ensuring national security, on the one hand, allows to partially reduce the obvious differentiation in development rates [2], but, on the other hand, has an ambiguous effect on economic security [3]. Quantitative achievement of the values specified in strategic documents does not mean qualitative development of the region. A feature of

strengthening the economic security of energy enterprises is the presence of potential, which is not completely lost, but changed under the influence of a number of negative factors. Therefore, the study of economic security in the context of the selection of regional clusters will make it possible to determine for which regions this approach is only an additional tool for improving the development and stabilization of economic security, and for which it remains the only means of minimizing the impact of crisis situations.

Considering the geographical location and climatic conditions of Ukraine, it is important to objectively assess how reliably the quantitative data reflect the real situation in the region. Clustering in order to ensure the economic security of enterprises in the context of regional division is becoming more and more relevant. In the conditions of modern world economic relations [4], the growth of the competitiveness of regions, and especially in the conditions of

martial law in Ukraine, should be carried out at the expense of the introduction of market mechanisms that compensate for various destructive natural processes.

This task should be solved on the basis of flexible forms of cooperation, coordination and integration of joint actions of individual business entities. Global economic changes and war have led to the growing popularity of a new production innovation model, within which all production participants seek to unite in clusters in order to successfully conduct economic activity, and a special need for this approach is observed for energy enterprises [5]. As world experience shows [6], significant changes in the organization of production both at the national and international levels contribute to the creation of territorial-industry and integration associations – clusters.

The aim of research is to identify factors that affect the economic security of energy enterprises, taking into account the processes of regional clustering. To achieve the aim of research, it is necessary to justify the chosen methods of assessing the economic security of regions, analyze the economic security of regions in terms of their clustering and identify significant factors of positive and negative influence based on the results of algorithmic-hierarchical cluster analysis, form general recommendations for the regions of Ukraine included in the clusters obtained during analysis. The object of analysis is the regions of Ukraine, united into clusters under the conditions of their division within the economic activity of energy enterprises. The recommendations defined in the work should contribute to strengthening the economic security of enterprises of the selected industry.

Quite a large number of scientific works are devoted to the issues of economic security of the region [7]. In this study conducted on the basis of a sample of scientific papers from 2016 to 2021, rightly note that during the analysis of publications devoted to the topic of economics security, the following feature can be traced: modern scientists in their research works practically do not use the category "economic security" [8]. However, the term "security" itself is used separately when analyzing the state of food [9, 10], energy [11, 12], environmental [13], national security [14], personal security [15, 16]. The authors of the article understand economic security as a state of security of the national economy, which ensures stable development, reliability and sustainability of economic systems, as well as protection of the interests of the state and citizens from external and internal threats.

However, some scientists in Ukraine consider that consider the listed types of security, with the exception of national security, to be components of economic security. Modern approaches to the study of the category "economic security of the region" are based on the definition of the region as a subject of the country [17], and the substantive part of economic security itself is considered from the perspective of sustainable development [18], as well as the theory of regional economics [19]. Features of a regional approach to managing the economic security of an enterprise, taking into account strategic development approaches, are considered in the studies [8, 20, 21].

It is impossible to develop a unified framework for ensuring the economic security of energy enterprises for all regions of Ukraine due to the fact that active military operations, annexation and front-line regions have distinctive features that determine differentiation. A significant role is played by the realization of self-development potential,

which is directly related to the type of region. There are different approaches to classifying types of regions, but there is no universal typology. Classification according to target typology has become widespread, in such works as [22–24]. According to this classification, there are a number of difficulties in defining clusters on a regional basis. Therefore, a clarification for the classification of such regions is the typology proposed in [25], according to which in the structure of regions it is necessary to distinguish them by the state of economic stability, integrity and security.

A significant feature of the regions of Ukraine and, at the same time, their distinctive feature from the backward EU countries is the lack of integrity and complete control of the domestic government, which is associated with military aggression [26]. But this fact does not mean that previously the regions also experienced significant difficulties in terms of development. Therefore, the resource potential in the annexed regions has been changed, but not completely lost. The unsatisfactory dynamics of the socio-economic indicators of the regions indicates the presence of risks and threats, but, at the same time, modern conditions not only give rise to challenges to economic security, but also create opportunities for the development of innovation.

The introduction of innovations in annexed regions after liberation is a promising method aimed at improving socio-economic development, which can contribute, for example, to the transition of regions to highly specialized status, as for example, this was done in the USA [27], China [28] and Indonesia [29]. Moreover, the development of innovation in the regions is based on high-quality digitalization processes, which mean the introduction of modern digital technologies into various spheres of life and production. It is important to create conditions for the positive impact of digitalization on the economic security of enterprises. Guided by the fact that the economic security of business entities is a set of characteristics of the socio-economic system of the region, ensuring its sustainable development, high competitiveness and social stability, certain digitalization processes are associated with negative influences (an increase in the unemployment rate during the automation of a number of processes, an increase in cybercrime, etc.). Therefore, there is a clear need to develop regional governance mechanisms. The approach to determining the mechanism for ensuring the economic security of enterprises is not a single tool, since it is based on the achieved socio-economic parameters of a particular region.

As a result of the review of the latest scientific developments, it becomes obvious that the clustering of the regions of Ukraine, taking into account its integrity according to legislative norms, is an urgent issue and needs further development. After all, the unification and strengthening of the positions of energy enterprises in the conditions of the creation of clusters is an encouraging factor in improving and strengthening the economic security of enterprises in this industry.

2. Materials and Methods

As a scientific problem, ensuring the economic security of enterprises has been studied widely and in detail, however, this category is poorly implemented in the practice of regional management. The currently available scientific and methodical apparatus does not have a unified evaluation system [30]. The transition to indicators for assessing the economic security of enterprises, on the one hand, is justified,

since, in most cases, the criteria corresponding to the level of vulnerability of their security, affecting the state of the social and economic system in this industry, are comprehensively taken into account [31]. On the other hand, when conducting an analysis of several enterprises, which are noticeably different from each other in terms of typical affiliation and degree of development [32] evaluation using indicators does not always allow to systematize the results for the further development and recommendations. Including a large number of indicators in the analysis does not yet mean obtaining reliable results, as well as conducting an assessment for energy enterprises of different types according to the same criteria. We consider it reasonable to conduct an analysis of the economic security of energy enterprises in dynamics, with the aim of excluding the influence of short-term positive or, on the contrary, negative factors.

Due to the fact that all regions of Ukraine selected for the study, which are under different state subordination (due to temporary annexation) and belong to relatively different natural and climatic zones, the study of the economic security of energy enterprises in these regions should not be based on comparison, but should be is aimed at obtaining results that allow one to form an idea of the factors of both positive and negative influence. In order to develop recommendations aimed at bringing regions out of the state of annexation, it is important to divide the regions under study in accordance with similar socio-economic parameters. Therefore, it is possible to analyze the indicators recommended by the Economic Security Strategy of Ukraine until 2025 (Resolution for National Security and Defense of Ukraine, 2021) [33].

Indicators that are recorded only at the national level are excluded from the calculation. To calculate indicators, they need to be normalized. If an increase in the indicator is desired, the significance level is calculated using the formula:

$$K_i = \frac{Y_f}{Y_{av}}, \qquad (1)$$

where K_i – normalization of the indicator; Y_f – actual value of the indicator; Y_{av} – average value of the indicator.

If it is necessary to reduce the indicator, it is carried out according to the following formula:

$$K_i = \frac{Y_{av}}{Y_f}. \qquad (2)$$

All indicators of economic security of energy enterprises at the standardization stage are correlated with average values, so it is possible to obtain an indicator value exceeding one. Taking into account the obtained normalized values, summation is performed for each region and a rating score is assigned.

When identifying groups of enterprises that form a cluster, let's use the technique of cluster analysis, the main stages of which include [34].

Stage 1. Establishing the degree of similarity between objects-enterprises and members of the cluster. The correlation coefficient is calculated:

$$r = \sum (x_i - x_m)(y_i - y_m) \sqrt{\sum (x_i - x_m)^2 \sum (y_i - y_m)^2}, \qquad (3)$$

where x_i – criterion data for the 1st object-enterprise under study; x_m – average value for this criterion; y_i – criterion data for the next object-enterprise under study; y_m – average value for a given criterion.

Additionally, the correlation coefficient between objects is calculated based on a set of characteristics:

$$d_{k1} = |1 - r_{k1}|, \qquad (4)$$

where r_{k1} – correlation coefficient between objects based on a set of characteristics; d_{k1} – degree of similarity between the kth and 1st objects – enterprises.

The calculation of Euclidean distance is used in the case of measuring and evaluating pries with the same dimensions:

$$d_{k1} = \sqrt{\sum (x_{kj} - x_{1j})^2}, \qquad (5)$$

where d_{k1} – degree of similarity between the kth and 1st objects; k and 1 – numbers of enterprises included in the cluster; j – number of the characteristic being studied.

The definition of the normalized Euclidean distance is used further to analyze the relationship of any features:

$$d_{k1} = \sqrt{\frac{\sum (x_{kj} - x_{1j})^2}{S_j}}, \qquad (6)$$

$$S_j = \frac{\sum (x_{kj} - x_{1j})^2}{(j-1)}. \qquad (7)$$

Stage 2. Recording the calculated similarity measures in a special matrix (Table 1).

Table 1

Matrix of similarity measures of energy enterprises

Object-enterprise	1	2	3	4
1	1	–	–	–
2	0.75	1	–	–
3	0.30	0.05	1	–
4	0.48	0.06	0.70	1

Note: improved and refined by the authors based on [34]

Table 1 is compiled on the basis of data obtained from the country's energy enterprises and is a cluster in which interconnected objects are collected that have minimal values of the degree of similarity in relation to one of the clusters.

To establish factors for ensuring the economic security of energy enterprises in the context of digital transformation, it is important to correlate the data obtained on the final result of assessing economic security with individual selected indicators of digital transformation (the share of mass socially significant services available in electronic form and the share of households that are provided with broadband access to information – telecommunication network Internet). Of course, the inclusion of only two indicators of digital transformation will not provide objective results, so it was decided to conduct a cluster analysis in order to identify similar trends in the regions, as well as to simplify the development of recommendations for each selected cluster. Cluster analysis is possible using the IBM SPSS Statistics 19 program, the type of clustering tool is hierarchical clustering, the method is "squared Euclidean distance". Variables included in the cluster analysis: a final assessment of the economic security of the regions and two indicators of digital transformation.

3. Results and Discussions

A characteristic feature of the territorial organization of the energy complex of Ukraine is not the isolated location of its production facilities, but the operation of most of them in energy systems. Thus, in the electric power industry, power systems are a complex of large power plants of various types, interconnected by high-voltage power lines. Energy systems contribute to the territorial location of production and population, allow to significantly reduce the required total power of power plants. Therefore, within the framework of our research and with the aim of determining the level of economic security of energy enterprises, the regions of Ukraine and their main energy enterprises were divided into clusters (Fig. 1).

It is worth noting that in connection with the aggression against Ukraine from February 24, 2022 to the present, the data on the temporarily occupied territories (AR Crimea, Donetsk, Luhansk and Kherson regions) were calculated in accordance with the data received by the State Statistics Service of Ukraine and are not fully reflected on the presented geographical maps.

In the future, to determine the general state of the level of economic security of energy enterprises, it was chosen to determine the dynamics of changes in the components of economic security, namely: economic growth, energy interconnection of clusters with each other, financial stability, socio-economic development.

At the same time, the calculation of the indicator of economic growth of the cluster gave the following results (Table 2).

The distribution of rating places by the group under consideration does not exactly repeat the results based on assessments of all selected indicators of economic security. This is not a contradiction of the conducted calculations, but means the possibility of identifying factors influencing the processes related to economic growth on the state of economic security of the enterprises of the cluster as a whole. Among the studied energy regions, significant changes in dynamics are characteristic only for the North-Western cluster, for the period from 2022 to 2023.

The explanation for such changes is the sharp growth of the index of industrial production (above the average value by 27.8 %), the most significant increase was provided by the mining industry, agriculture and the service sector. This event is directly related to the internal migration of the population to this cluster due to the relatively stable state of providing regional security from military operations. Based on the obtained data, let's calculate the average value of the economic growth indicator by clusters for the period 2018–2023 (Fig. 2).
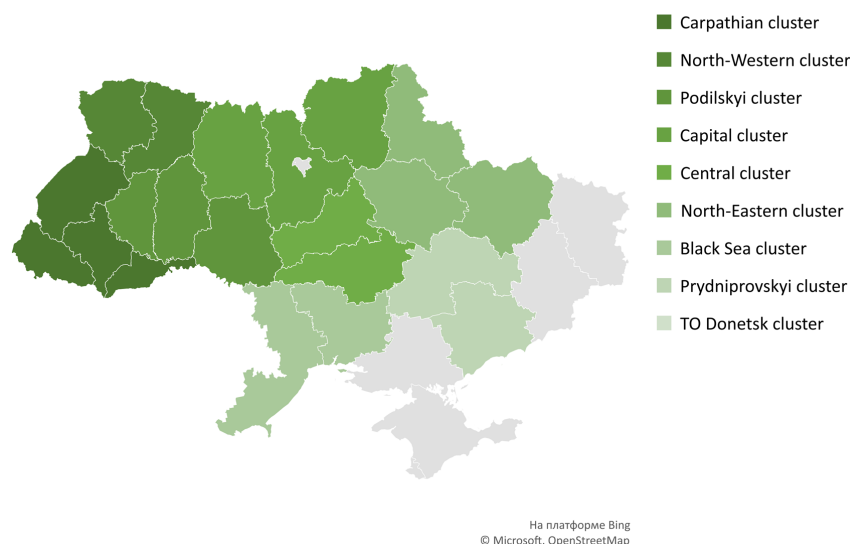

- Carpathian cluster
- North-Western cluster
- Podilskyi cluster
- Capital cluster
- Central cluster
- North-Eastern cluster
- Black Sea cluster
- Prydniprovskyi cluster
- TO Donetsk cluster

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Fig. 1. Division of Ukraine's regions into energy clusters

Table 2

Results of the evaluation of the component of economic security – economic growth of clusters of energy clusters of Ukraine for 2018–2023

Cluster	Place according to rating assessment (sum of points)					
	2018	2019	2020	2021	2022	2023
Carpathian	6 (4.239)	2 (4.672)	3 (4.688)	3 (4.732)	1 (4.987)	2 (5.063)
North-Western	2 (4.414)	1 (4.931)	2 (4.734)	2 (4.801)	2 (4.654)	4 (4.801)
Podilskyi	8 (6.674)	7 (4.048)	5 (4.313)	6 (4.373)	9 (4.048)	1 (5.260)
Capital	3 (4.658)	3 (4.624)	1 (4.890)	1 (4.864)	3 (4.586)	3 (4.909)
Central	9 (3.943)	9 (3.951)	8 (4.116)	8 (4.178)	7 (4.138)	9 (4.168)
North-Eastern	7 (4.416)	8 (4.030)	9 (4.038)	9 (4.051)	8 (4.126)	7 (4.262)
Black Sea	5 (4.305)	6 (4.196)	4 (4.501)	5 (4.496)	6 (4.302)	5 (4.440)
Prydniprovskyi	1 (6.454)	5 (4.317)	7 (4.138)	4 (4.509)	4 (4.443)	8 (4.224)
TO Donetsk	4 (4.436)	4 (4.388)	6 (4.200)	7 (4.285)	5 (4.427)	6 (4.359)

Note: Own development based on data from the State Statistics Service of Ukraine (2018–2023) [35]

The average value economic growth of energy clusters of Ukraine

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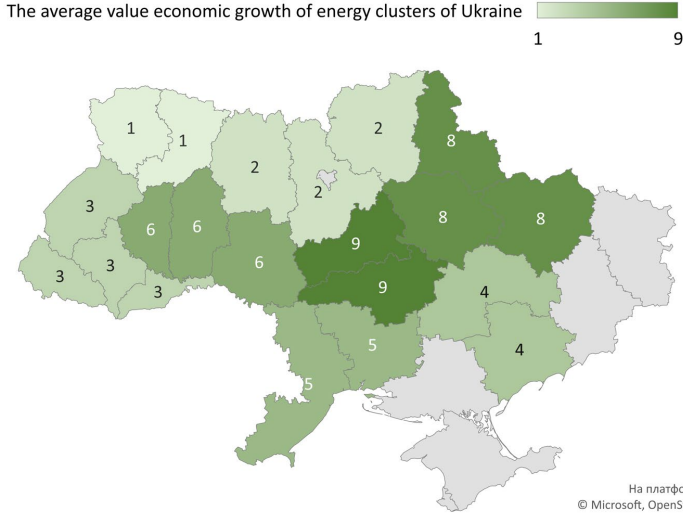На платформе Bing
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Fig. 2. Average value of economic growth of energy clusters of Ukraine
for the period 2018–2023

The lowest values in the ranking are occupied by the following clusters: Podilskyi, Capital, Carpathian and Prydniprovskyi. The Podilskyi cluster is part of industrial complexes, which corresponds to high electricity consumption, and the Capital cluster is characterized by high population density, which contributes to obtaining these indicators. The lowest rates of economic growth are observed in the Prydniprovskyi cluster, which is due to the close demarcation

line of the war front. The basis of the economy of this cluster is heavy industrial production, but a significant barrier to development is high energy dependence. In the Carpathian cluster, differentiated development of industries has been more typical in recent times than before 2022, but this does not allow achieving an average value in economic growth rates.

Middle positions in the rating are occupied by clusters that do not achieve stable economic growth over the entire period under study. For example, the TO Donetsk cluster is only due to the actual threefold increase in the share of the investing country – the aggressor in fixed capital compared to the average value and the decrease in the depreciation of fixed assets to 41.1 % of the average value in the rating of energy clusters. For the entire subsequent period of the study, the region is characterized by consistently low values. The central cluster is the leader in the rating of economic growth.

It is possible to believe that these indicators of economic growth are related to the stable growth of the regional economy and the redirection of the main capacities to safer places.

The results of the rating assessment of indicators of the energy interconnection of clusters are presented in Table 3.

On the basis of the obtained data, the average value of the indicator of energy interconnection of clusters for the period 2018–2023 was calculated (Fig. 3).

Table 3

Results of the assessment of the component of economic security – the interconnection of energy clusters of Ukraine for the years 2018–2023

Cluster	Place according to rating assessment (sum of points)					
	2018	2019	2020	2021	2022	2023
Carpathian	3 (1.225)	2 (1.224)	2 (2.095)	5 (3.907)	8 (0.656)	8 (0.633)
North-Western	4 (1.160)	5 (1.143)	5 (1.114)	2 (7.221)	1 (15.570)	1 (15.396)
Podilskyi	8 (0.523)	9 (0.521)	9 (0.302)	9 (1.143)	9 (0.090)	9 (0.090)
Capital	2 (1.270)	3 (1.180)	4 (1.629)	6 (2.570)	5 (6.024)	5 (5.935)
Central	9 (0.523)	8 (0.555)	6 (0.739)	7 (2.522)	6 (3.649)	7 (3.653)
North-Eastern	6 (0.687)	6 (0.676)	3 (2.014)	4 (5.283)	2 (8.492)	3 (8.341)
Black Sea	7 (0.636)	7 (0.645)	8 (0.348)	8 (2.030)	3 (7.566)	4 (7.408)
Prydniprovskyi	5 (1.128)	4 (1.152)	7 (0.568)	3 (7.566)	7 (1.128)	6 (1.103)
TO Donetsk	1 (2.820)	1 (2.952)	1 (8.056)	1 (8.056)	4 (6.410)	2 (6.262)

Note: Own development based on data from the State Statistics Service of Ukraine (2018–2023) [35]

The average value of energy interconnection of clusters of Ukraine

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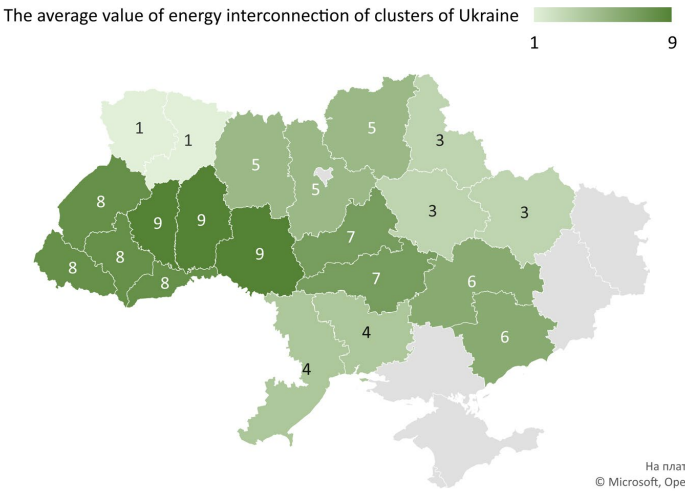

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Fig. 3. The average value of the interconnection of energy clusters of Ukraine for the period 2018–2023

A common characteristic of the energy enterprises selected for the study is their sufficient level of interconnection, but it is worth noting that this only applies to territories controlled by Ukraine. As a result, the calculation established that the TO Donetsk cluster does not have a close energy connection with other territories of the occupied government. This is due to the historical rationale, which dates back to the construction of the energy networks of Ukraine and, accordingly, it is not possible to reconfigure the flows of produced electricity in the shortest possible time. It should also be noted that government support and reforms, on the contrary, contributed to the fact that Ukraine has a European integration direction in development and the results of the energy interconnection of the Carpathian and Podilskyi clusters have the highest average indicators (9 and 10, respectively).

Table 4 presents the results of the rating assessment of the group of indicators of financial stability of the energy cluster of Ukraine.

The results of calculating the average value of the indicator of economic security financial stability for the research period 2018–2023 are presented in Fig. 4.

Of all the studied groups of economic security indicators, the values of financial stability are the lowest. The logical explanation is the conduct of military operations in Ukraine, and consequently a decrease in business activity, the solvency of the population and a decrease in the standard of living of the population. In this case, one can observe high average values for the years of study in the Pridneprovskyi (10), North-Western (9) and Podilskyi (8) clusters. For the first, this is directly related to subsidies from the state in order to maintain the front-line cluster; for the second and third, this is due to increased internal migration of the population.

Subsequently, let's calculate the indicators of the largest group – the socio-economic development of energy clusters in Ukraine (Table 5).

The results of calculating the average value of the indicator of socio-economic development of economic security for the studied period of 2018–2023 are presented in Fig. 5.

A significant decrease in the number of officially registered economic crimes by 2023 allowed the Black Sea and Podilskyi clusters to take first place in the presented ranking. But, along with positive changes, these energy clusters are characterized by the following problems: low level of average per capita cash income, sharp declines in the electricity consumption index among legal entities (enterprises), and low levels of innovation activity. For the clusters that close the rankings – North-Western, Central and Carpathian – more than 50 % of the analyzed indicators showed values below average.

Summarizing the results obtained for all indicators of economic security of energy clusters, let's calculate the general indicators (Table 6) and present the ranking distribution by cluster (Fig. 6).

Table 4

Results of the assessment of the component of economic security – financial stability of energy clusters of Ukraine for 2018–2023

Cluster	Place according to rating assessment (sum of points)					
	2018	2019	2020	2021	2022	2023
Carpathian	4 (1.980)	7 (1.061)	7 (0.548)	7 (1.115)	8 (1.216)	3 (1.207)
North-Western	9 (−1.833)	3 (2.587)	4 (1.458)	9 (0.361)	3 (2.037)	5 (0.989)
Podilskyi	5 (1.839)	8 (0.998)	8 (0.471)	5 (1.274)	9 (1.138)	9 (0.118)
Capital	1 (4.494)	4 (1.706)	5 (1.197)	3 (1.897)	5 (1.414)	6 (0.892)
Central	2 (4.178)	9 (0.964)	3 (1.939)	6 (1.118)	6 (1.367)	1 (1.432)
North-Eastern	7 (0.818)	6 (1.117)	6 (1.159)	8 (1.019)	7 (1.282)	2 (1.397)
Black Sea	3 (3.224)	2 (3.234)	1 (4.358)	2 (3.116)	2 (3.208)	8 (0.623)
Prydniprovskyi	8 (0.455)	5 (1,615)	9 (−0.435)	4 (1.326)	4 (1.700)	7 (0.629)
TO Donetsk	6 (1.696)	1 (3.573)	2 (3.929)	1 (4.852)	1 (6.672)	4 (1.232)

Note: Own development based on data from the State Statistics Service of Ukraine (2018–2023) [35]

Fig. 4. The average value of the indicator of financial stability of energy clusters of Ukraine for the period 2018–2023

To highlight the main conclusions based on the results obtained, let's highlight the most problematic groups for each energy cluster of Ukraine. According to the criterion of social growth, the North-Western (1), Central (2) and Carpathian (3) energy clusters have positive indicators. Let's believe that this is primarily due to the development of the social sphere in connection with internal migration. At the same time, the Central (9), North-Eastern (8) and TO Donetsk (7) energy clusters have the worst performance. The reason is also a decrease in the population, greater risks to the lives of the population and, accordingly, the inability to fully ensure the normal social development of the population. According to the criterion of the relationship between energy clusters, the leading positive indicators are the North-Western (1), TO Donetsk (2) and North-Eastern (3). The first has a strong connection in connection with the construction of energy networks with the European Union as part of the development of Ukraine in the European integration direction. The second – for reasons of occupation, has a connection with the relevant authorities and is configured to provide energy. And the latter has a stable connection with the Central (7) cluster, although it is among the worst in terms of indicators. Podilskyi (9) and Carpathian (8) are also considered bad.
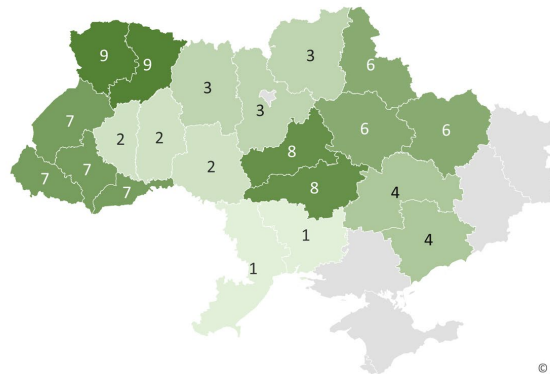
Table 5

Results of the assessment of the component of economic security – socio-economic development of energy clusters of Ukraine for 2018–2023

Cluster	Place according to rating assessment (sum of points)					
	2018	2019	2020	2021	2022	2023
Carpathian	4 (20.205)	7 (20.401)	8 (17.512)	8 (18.690)	6 (20.251)	2 (2.153)
North-Western	9 (17.901)	9 (19.742)	6 (19389)	9 (18.035)	9 (17.531)	9 (16.665)
Podilskyi	3 (20.467)	2 (23.786)	2 (23.786)	5 (19.803)	2 (22.867)	3 (20.905)
Capital	6 (19.571)	4 (22.397)	3 (22.230)	4 (19.850)	4 (20.336)	6 (19.387)
Central	8 (18.736)	5 (20.696)	5 (19.980)	7 (18.877)	8 (19.077)	8 (17.387)
North-Eastern	5 (20.073)	8 (19.841)	7 (19.190)	3 (20.233)	5 (20.322)	5 (20.485)
Black Sea	2 (21.443)	3 (22.634)	1 (34.946)	1 (21.807)	1 (23.272)	1 (22.518)
Prydniprovskyi	7 (18.844)	1 (29.943)	9 (14.490)	2 (20.981)	7 (19.270)	7 (19.270)
TO Donetsk	2 (21.321)	6 (20.506)	4 (20.259)	6 (19.295)	3 (20.646)	4 (20.857)

Note: Own development based on data from the State Statistics Service of Ukraine (2018–2023) [35]

The average value of the indicator of socio-economic development

Fig. 5. The average value of the indicator of socio-economic development of energy clusters of Ukraine for the period 2018–2023

Table 6

Generalized results of assessing the economic security of energy clusters in the regions of Ukraine for the period 2018–2023

Cluster	Place according to rating assessment (sum of points)					
	2018	2019	2020	2021	2022	2023
Carpathian	4 (27.703)	6 (27.358)	8 (25.142)	7 (28.776)	9 (26.790)	6 (27.818)
North-Western	9 (21.902)	5 (28.297)	6 (26.157)	5 (30.280)	1 (39.730)	1 (31.851)
Podilskyi	6 (26.973)	4 (29.340)	3 (29.804)	8 (27.468)	6 (28.398)	9 (25.486)
Capital	2 (29.993)	3 (29.899)	4 (29.445)	6 (29.218)	5 (32.398)	5 (31.079)
Central	5 (27.381)	7 (26.152)	7 (25.784)	9 (16.675)	7 (28.200)	7 (26.716)
North-Eastern	8 (25.783)	8 (25.621)	5 (26.330)	4 (30.761)	4 (34.120)	3 (34.274)
Black Sea	3 (29.607)	2 (30.708)	1 (43.954)	3 (31.393)	2 (38.547)	2 (35.045)
Prydniprovskyi	7 (26.881)	9 (21.573)	9 (19.065)	2 (36.562)	8 (26.945)	8 (25.511)
TO Donetsk	1 (30.273)	1 (31.419)	2 (30.954)	1 (36.562)	3 (37.928)	4 (32.635)

Note: Own development based on data from the State Statistics Service of Ukraine (2018–2023) [35]

General results of assessing the economic security of energy clusters
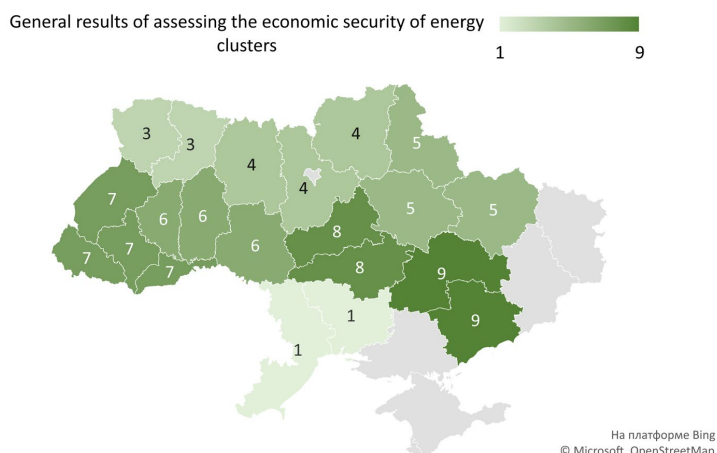
1   9

Fig. 6. General results of assessing the economic security of energy clusters in the regions of Ukraine

Their poor relationship is due to low performance of fixed assets and high wear and tear. The next indicator – financial stability, which is characterized by the presence of positive indicators of the financial performance of energy industry entities, showed good results in the TO Donetsk (1), Black Sea (2) and Capital (3) energy clusters. For the first, this is a sacrifice from the occupier and a contribution of large financial resources. For the other two, this is confirmed, in our opinion, by the growth and development of small and medium-sized businesses. It is these groups of legal entities that form the main flow of results from the sale of electricity. At the same time, Podilskyi (9), North-Western (8) and Central (7) have the worst results. The financial results of the activities of energy enterprises in this region have the least positive results. And the last component – socio-economic development – the Black Sea (1), Podilskyi (2) and Capital (3) energy clusters have a high level, while the North-Western (9), Central (8) and Carpathian (7) clusters have minimal values. In this case, this is due to the development of social spheres that have commercial justifications and contribute to the development of regions.

The field of electricity is key in the activities of all subjects, regardless of its type and subordination. From a technological point of view, a large number of consumers participate in the production – transportation – energy consumption chain. Therefore, the issue of dividing into clusters of enterprises in this industry is quite relevant. And first of all, research on these issues is directly caused by military aggression on the territory of the state. Competent, qualified, timely and sustainable development of Ukraine as a whole depends on critical infrastructure facilities (which primarily includes electricity). In the current realities, the management and strengthening of the economic security of electric power enterprises is a key factor in the further development of statehood as a whole. In our opinion, focusing attention on the management of economic security by enterprises of this industry is currently the basis for further modernization and reconstruction. Unfortunately, the disappointing consequences of the destruction indicate that the majority of electricity production and transportation facilities cannot be restored. And this means that decisive management decisions must be made now to strengthen economic security in the future. Yes, according to [36], it is the state

administration within the framework of subsidies and support by normative legal acts that is able to support the development of enterprises, and within the framework of ensuring their security in particular. An in-depth study by scientists for the period from 1996 to 2023 using the regression method of least squares (LSM) shows that the continuity of support actions from the state has a correlational nature and a significant impact. In our opinion, the totality of these achievements can serve as a good perspective for ways to fill the gaps in the management of economic security of energy enterprises. In the paper [37], it is also noteworthy that scientists rely on demographic components using the method of statistical analysis and conclude that there is a relationship between food and demographic components. In confirmation of this, it is worth noting the work [38] with a tangential analysis in the field of bioeconomy.

Accordingly, in the context of our research, these are components of socio-economic development and directly affect the state of economic security of enterprises. In the case of a general collective definition of controversial issues regarding the presented material, it is worth paying attention to the paper [39], who in their work considered the formation of clusters by regional division as a basis for improving the development of small and medium-sized businesses on the example of Asian countries. Researchers who use the method of separation and application of the discriminant with the selection of at least three groups of enterprises believe that their relationship is homogeneous and improves the performance of each of them. But such a case is accompanied by a lack of competition on the market in this regional cluster and the formation of an artificial oligopoly, which can cause violations of the law. This approach is quite relevant, but in our work, we did not consider the formation of energy clusters according to the principle of division by the number of enterprises, but formed them based on the specified methodology and formed them according to regional distribution. This is primarily due to the close interconnection of energy networks and their auxiliary function, which encouraged not to separate various market representatives from the electricity production chain. And in the light of future forecasts, it is worth paying attention to the paper [40], in which scientists fairly widely substantiate the criteria for the development of enterprises and, with the help of statistical analysis tools, the coefficient of sensitivity and ratings of enterprises, determine their place in the matrix of relationships. This approach can expand the research presented by us within the framework of the analysis of end consumers and changes in the distribution of aggregate energy consumption by clusters.

In general, the issue of regional clustering covers different countries. So, in particular, in Poland, scientists in [22, 41] analyze the problems of creating and expanding clusters on the example of their country. They distinguish clusters as separate territorial units that contribute to the deepening of economic ties. In this context, it is important to note various spheres of economic activity, as well as bioenergy. That is, the works have a wider spectrum of manifestation and, accordingly, the results of these works can significantly affect the development of Ukrainian energy as an alternative, including green energy.

As a result of the studies, there is the basis for the further development of the research topic in the following directions: improvement of the components for the analysis of economic security, selection of tools for managing energy enterprises divided into regional clusters, defining and applying a more in-depth methodical approach to the statistical analysis of data on the financial performance of state-grant entities, to analyze the future interaction of the formed clusters in the process of restoring the energy industry of Ukraine.

Based on the results obtained from assessing the economic security of energy enterprises and conducting a cluster division of the regions of Ukraine, taking into account the main components, it was revealed that such energy clusters as the North-Western, Capital and Black Sea have more developed resource potential.

To further develop our scientific research, it is possible to formulate the main directions of development for all energy clusters.

For the Prydniprovskyi cluster, a clear limiting factor for improving the tools for managing economic security is the decline in indicators of the working population, the increase in the percentage of the population with a cash income below the subsistence level, the energy intensity of the gross domestic product and, as a consequence, the low level of socio-economic development of the cluster territory. The Prydniprovskyi cluster, in terms of the types of economic activity and, accordingly, the costs of electricity consumption, has the largest resource in heavy industry. This cluster is characterized by the presence and concentration of ferrous and non-ferrous metallurgy, which are the most energy-intensive in terms of their costs (for example, electrolysis furnaces, electric arc production of non-ferrous metals, production of alloying additives, etc.).

In the TO Donetsk cluster, the primary problem remains the low level of per capita cash income of the population. The creation of technology parks is the most realistic way to solve socio-economic problems, as well as a catalyst for digital processes within the framework of improving energy networks.

Agricultural complexes in the Podilskyi energy cluster are already serving as a platform for the development of digital processes and improvement of energy networks through the use of alternative generation sources – solar and wind. It is possible to believe that a significant stage can be the development of technology parks, which gradually, over time, transform into system-forming clusters. In the long term, it is also possible to create a technopolis based on energy clusters.

It should be noted that the implementation of the Smart City project is taking place in the Capital energy cluster, which is important for the high-quality implementation of digital processes in the training and retraining of personnel with digital competencies at a sufficient level in the electric power industry.

For the Black Sea cluster, as well as for the Central one, the Smart City project has only theoretical justification and has not yet been put into use with a mass effect. But this kind of action can significantly increase the level of management of the economic security of energy enterprises united in clusters, following the example of Central cluster.

On the basis of existing production enterprises in the Carpathian energy cluster, it is possible to organize the production of microelectronics, which constitutes a significant link in the restoration of lost capacity from the southern and eastern regions of the country. This is also a technically important element on the path of digitalization of this energy cluster and, accordingly, the development of management. Moreover, a special economic zone of industrial production type has been created in the region since February 2022, which is a positive factor for economic growth.

Despite the geographical and sectoral differences between the regions: the Carpathian, North-Eastern and TO Donetsk regions, a general recommendation for the development of power supply and energy transmission networks can be identified for them. In recent years, these regions are in significant need of restoring generating capacity, both qualitatively and quantitatively. These clusters are highly specialized in their field, so it is necessary to qualitatively increase their capacity capabilities.

Based on the analysis, predict future changes in the energy industry for Ukraine, where its main tasks at the moment are to maintain positions in the existing conditions at the expense of preserving the position of economic security of energy enterprises, and in the future – to restore all lost elements of the energy chain within the framework of improved management of the economic security of enterprises in the conditions of the functioning of energy clusters according to regional division.

A promising direction for further research is to conduct an econometric analysis of the identified factors within regional clusters.

Digital transformation processes are closely related to the emergence of completely new products and, accordingly, the emergence of economic practices that are not similar to those that existed before. The high-quality implementation of digitalization in the energy industry depends on human resources and available technologies.

In addition to the analysis of quantitative data, it is necessary to formulate the main directions for improving digital transformation processes in the regions. Among these areas are: the phased implementation of digital processes in accordance with existing programs at the regional and state levels; consideration of the possibility of developing the urban infrastructure of individual regions based on the Smart City project. A more complex and comprehensive direction is the development of technopolises. However, not every region has the necessary and sufficient resource base to implement this direction. The very creation of a technopolis implies the unification of science, technology and entrepreneurship. Moreover, the basis of the technopolis is the research complex of enterprises and industries developing in it. In fact, in the technopolis, radical breakthroughs in technology are being prepared on the basis of fundamental scientific research. The Technopolis is created in such a way as to facilitate and strengthen the interaction of the research and industrial sectors to the greatest extent, to ensure the speedy development and commercialization of scientific research results. They also carry out close cooperation between academic science, entrepreneurs, local and central authorities.

A significant limitation in the use of digital technologies, or more precisely, in the impossibility of using uniform technologies, is industry specificity, which is characterized by the peculiarities of technical means of monitoring the applied infrastructure of enterprises and the software used, due, among other things, to the difference in business processes. Therefore, the creation of a technopolis in the region should be based on developed industries.

4. Conclusions

Based on the study, it was established that, when dividing the regions of Ukraine into clusters, it is possible to generalize factors that can improve the economic security of energy enterprises. The principle of factor separation is based on the existing regional potential. For regions with a higher level of socio-economic development, such as North-Western (rating result 1), Central (rating result 2) and Capital (rating result 3), digital transformation is also necessary, but is not the only basis for bringing the region out of the crisis. Here, digital transformation acts more as an additional tool for improving the socio-economic situation of the cluster. Regions with low socio-economic development need digital transformation as an alternative to the existing resource base. These include the following – North-Eastern (rating result 9), Prydniprovskyi (rating result 8) and TO Donetsk (rating result 7). Accordingly, the generalized result reflects the development of Ukraine's fuel and energy complex over the past five years and should serve as a basis for further improvement and strengthening of economic security.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, including financial, personal, authorship or other, which could affect the study and its results presented in this article.

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Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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