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Assessment of the Region's Energy Security Level in the Process of Formation of the Common European Energy Space

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ABSTRACT

Creation of a single European energy space is impossible without proper and rapid assessment of the level of energy supply of the country. Depending on the specifics of regional development, indicators for assessing the level of energy security are different. Therefore, the study of the methodology for assessing the current state of the resource supply of the multifaceted energy system of the country is an important and topical task of the country's management. The proposed methodology for an integrated assessment of the economic security level is characterized by the use of the multiplicative form of the integrated index and contains a number of additional recent indices; simultaneous normalization of indices and their threshold values by a common normalizing function; substantiation of the threshold value vector; as well as by a formalized definition of weighting factors, which allows to compare the dynamics of the integrated index with integrated threshold values on one scale, i.e., correctly identify the state of economic security. The theoretical approaches to the integrated assessment of the country's energy security level have been analyzed and summarized and an evaluation methodology has been proposed that differs from the previous ones in that it allows to assess in detail the energy security level in the regional context. The paper describes the results of developing a methodology for assessing Ukraine's energy security based on an indicative approach. The methodology for predicting threats to the country's energy security has been provided. The numerical values and data sources of Ukraine's energy security indices have been presented.

Keywords: Energy Security, Indicative Analysis, Threats, Prediction, Fuel and Energy Resources, Modeling, Assessment of the Energy Security Level

JEL Classifications: O11, P28, R11, Q43

1. INTRODUCTION

The establishment of the Common European Energy Space (CEES) reinforces the need for objectivity in the process of making managerial decisions to ensure uninterrupted energy supply and management. Given that the national regulatory authorities for energy supply, performing the functions of tariff regulation and oversight and supervision over the energy supply security, publicly manage data on energy resources reserves, region's energy security level, analysis of the largest share of energy resources in the country's energy balance, share of the region's own energy resources, capacity of the region's energy system, level of demand in terms of the structure of energy resources, costs and energy balance programs, this information requires an integrated assessment and continuous monitoring. In the process of formation of the CEES and sustainable development of the country's energy supply, equally important is also information on the level of reduction of dependence on monopolists - fuel and energy resources (FER) suppliers - through the development of local, regional, European energy base, efficient management of energy demand, improvement of energy efficiency and search for varieties and diversification of energy supply routes, structuring of energy balances and priority ways to increase the energy security level. Therefore, the methodology for assessing the integrated index of the country's energy security (ES) and its components should to the greatest possible extent provide adequate and end-to-end prediction of the state of the energy system under investigation in order to promptly respond to the destabilizing factors of the formation of the CEES. Depending on the specific features of the regional development of a particular country, the indices for assessing the energy security level can differ significantly among themselves. Therefore, in order to make effective managerial decisions, it is proposed to carry out a comparative analysis of the ES level among the regions and determine which region has better ES state and which one needs additional resource adjustments to stand up to threats and develop a scope of measures to prevent them.

Since in market conditions the effective performance of the country's energy system is manifested in the presence of a reliable energy security system, in particular at the local regional level, the comparison of the energy security level of regions should determine the current state of the resource provision of the country's multifaceted energy system. Each country defines the concept of energy security in its own way subject to its own geographical location and develops national systems of indices (performance), on the basis of which a quantitative assessment and analysis of the current state and prospective development of the country's energy security are carried out. Despite the particular urgency of energy reforms, Ukraine has no single official document that provides energy security indices. The current methodology for predicting Ukraine's economic security level was approved by Order No. 60 of the Ministry of Economy on March 2, 2007. Therefore, further improvement of methodological approaches to assessing the country's energy security level in searching for additional indices for monitoring the country's energy security that would allow for more complete characterization of the processes taking place in this area at the national and regional levels is relevant and necessary research and can also be used in terms of searching for additional indices for assessing the energy security level of the Polish voivodships.The paper aims at improving the methodological approaches to assessing the country's energy security at the regional level.

2. PROBLEM DEFINITION

In most methodological approaches used to assess the state of energy security, the key element is the energy security (ES) index (or performance). Since the ES indices reflect different directions of the emergence of threats to the ES and are inconsistent, the development of a system of indices, which could be handled appropriately to achieve the desired result, is an essential component of the methodology for assessing the ES state in any and all assessment tasks. The objectives of creating such system of indices are to provide information to the decision maker for:

- The development of activities to increase the ES level in case of a crisis state according to one or several indices and decrease the level of threats to the ES in case of a pre-crisis state (in the presence of threats to the ES),
- The measurement of performance of the implemented measures to increase the ES level, including the assessment of the ES state dynamics over the past period,
- The prediction of the ES state for the future based on potential scenarios for the development of the energy industry or individual energy sectors,
- The selection of alternative solutions for the country's economic development subject to the requirements for ensuring energy security.

To achieve this goal, the following issues are to be addressed:

- Analysis of components of Ukraine's energy market,
- Review of the list of available energy security indices and preparation of an authoritative list of indices that would allow to characterize in greater detail the processes taking place in Ukraine's energy market,
- Conduct of a regional analysis of energy security indices,
- Calculation of the regional index for assessing the country's energy security level,
- Determination of de-stimulators for the development of the energy market in order to overcome threats in the formation of the CEES.

3. LITERATURE REVIEW

Review of scientific literature on the issues under investigation allowed to single out the following authors' proposals on the study and assessment of the country's energy security level. Thus, Arūnas (2011) carries out a risk analysis for the energy security of the Baltic States. His research is aimed at developing methods for assessing the intensity of risks for energy security of the Baltic States. The analysis carried out by the author is indicative of the presence of at least two major risks of unstable intensity of energy security of the Baltic States: Dependence on the unified energy sources supplier and wrong (in terms of transparency, competence and expertise) decision-making process. Augutis (2012) argues that the assessment of energy supply security is based mainly on mixed conditions and usually limits considerations of possible alternatives to energy supplies due to politically motivated conclusions. Such research efforts made in different countries are kept confidential and unpublished in the scientific press. Lithuanian scientists proposed an alternative methodology based on an expert review of 68 indices on a 15-point scale. It allows to identify the most vulnerable aspects of supply, covers the most dangerous scenarios and assesses the probability of their occurrence. Benjamin (2013) has assessed the energy security index from 20 indices for 18 countries from 1990 to 2010. He concluded that overall energy security level has deteriorated over the past 20 years in all countries, although he identifies three groups of countries in terms of energy security level deterioration.

Chentouf and Allouch (2017) assess the energy security level for the countries of the Mediterranean region. They found a great dependence of these countries (except Libya, Algeria and Egypt) on imported energy resources despite considerable prospects for the region's solar energy. Cherp and Jewell (2013) consider two methodological approaches for assessing the energy security level - The International Energy Agency's Model of Short-term Energy Security and The Global Energy Assessment. The first approach is based on 35 indices and applies to 28 countries, and the second one is based on 30 indices and used for calculation in 134 countries. The authors (Honorata and Eliza, 2017) presented a study of the relationship between the country's energy security and its international competitiveness based on export levels. For this, a linear regression model was used covering 23 countries from 1995 to 2014. The author (Kisel et al., 2016) believe that it is the energy security matrix that should be used to assess energy security, rather than any single integrated index. They carry out the corresponding calculations by the example of Estonia.

The author (Yamanishi et al., 2017) used the Fuzzy-DEMATEL (Fuzzy Decision-Making Trial Evaluation Laboratory) method to assess energy security in Japan after the accident at the Fukushima Nuclear Power Plant, as well as the impact of this accident using fuzzy logic methods. The author (Senderov et al., 2017) propose a convolution method for quantitative assessments of energy security for all energy facilities at the federal level in Russia. The author (Szulecki, 2017) examines three different approaches to determining energy security - deductive, abductive and inductive.

The above scientific works consider the methodological framework of the ES analysis in modern conditions, concepts and models for ensuring the most important components, as well as review threats and identify the developed measures to increase the ES level. However, insufficient attention is paid to the definition of the ES index at the regional level given the importance of research. It is clear that for a small country such an assessment does not make sense. But it becomes relevant for big countries with regions having different economic development. This forms the basis of this paper. The number of indices taken into account is based mainly on the scope of statistical data. Each country has its own approaches to gathering various statistical data; therefore, there is no consistent versatile approach to calculating the energy security level.

4. RESEARCH METHODOLOGY

To address such issues, an indicative approach to the analysis of systems is used to identify indices that reflect the degree of development of threats to energy security. The list of indices includes threshold (maximum permissible) values, with which the actual values of indices are compared. A set of 12 indices has been developed and proposed as indicative indices used to compare the assessment of Ukraine's energy security. The general list of indicative indices for assessing Ukraine's energy security in the context of its regions includes the following:

1. Economy energy intensity level (I_1):

$$I_1 = \frac{Fuel\ used,\ TFOE}{GRP}, \tag{1}$$

2. Energy supply level (I_2):

$$I_2 = \frac{Electricity\ production,\ mil.\ kWh}{Total\ energy\ consumption,\ mil.\ kWh}, \tag{2}$$

3. Level of energy losses before its consumption (I_3):

$$I_3 = \frac{Energy\ losses\ in\ electric\ energy\ systems,\ thous.\ kWh}{Total\ energy\ consumption,\ thous.\ kWh}, \tag{3}$$

4. Level of the largest share of energy resources in the energy balance (I_4):

$$I_4 = \frac{Fuel\ consumed,\ TFOE}{MAX_{cons}\begin{pmatrix} coal,\ gas,\ peat,\ firewood, \\ fuel\ oil,\ LNG,\ diesel\ fuel, \\ gasoline, nuclear\ energy \end{pmatrix},\ TFOE}, \tag{4}$$

5. Share of produced own fuel in the consumption balance (I_5):

$$I_5 = \frac{Produced\ own\ fuel,\ TFOE}{Total\ fuel\ consumption,\ TFOE}, \tag{5}$$

6. Level of power plant capacity to the greatest load (I_6):

$$I_6 = \frac{Power\ plant\ installed\ capacity,\ thous.\ kWh}{Total\ fuel\ consumption,\ TFOE}, \tag{6}$$

7. Gas storage supply level (I_7):

$$I_7 = \frac{Active\ gas\ storage\ capacity,\ mil.\ cu\ m}{Natural\ gas\ utilization,\ thous.\ cu\ m}, \tag{7}$$

8. Share of emergency undersupply of energy (I_8):

$$I_8 = \frac{Share\ of\ emergency\ undersupply\ of\ energy}{Electricity\ production\ by\ regions,\ mil.\ kWh}, \tag{8}$$

9. Number of outages per 100 km of network (I_9):

   I_9=*Taken form the Power Distribution Network Developerment Plant 2016-2025 [19]*

10. Share of dilapidated and emergency heat and steam supply networks (I_{10}):

   I_{10}=*Courtesy of the State Statistics Service of Ukraine. Economic statistics. Economic activity. Industry. Length of dilapidated and emergency heat and steam supply networks at the year-end in two-pipe terms [20]*

11. Share of heat losses (I_{11}):

$$I_{11} = \frac{Heat\ losses\ in\ electric\ energy\ systems,\ Gcal}{Heat\ energy\ output,\ Gcal}, \tag{9}$$

12. Level of heat plant capacity to the average load per day (I_{12}):

$$I_{12} = \frac{Established\ heat\ output,\ Gcal/h}{Heat\ energy\ output,\ Gcal \cdot 24 \cdot 182} \tag{10}$$

The list of ES components is not a dogma and can be supplemented or refined both by components and by individual indices of each component based on the research objectives. Knowledge of the weighting factors of the energy security index components is important data for exercising the control impact on Ukraine's ES state in order to identify the degree of impact of individual components and provide the necessary information for the development of priority enforcement actions.

The next step is the procedure for the normalization of indices, which is a necessary step in calculating the integrated index since all indices have different dimensions. Moreover, they can be multidirectional: There are indices, the increase of which is desirable (S), whereas the reduction of other indices is not desirable (D). Firstly, the normalization procedure converts indices with different dimensions to non-dimensional values to the range [0.1]. Secondly, it allows to compare multidirectional indices, without which it would be impossible to form an energy security assessment index.

Various normalization methods are put into practice. All of them are based on comparing empirical values of index x with a certain reference value: Norm K_{norm} - the normalizing factor. The maximum, minimum, average value of the aggregate $[x_1, x_2, \ldots x_n]$, or the reference (threshold) value of the index is used as such a value.

The simplest to use is the following normalization method:

$$S: z_i = \frac{x_i}{k_{norm}}, k_{norm} \geq x_{\max}, D: z_i = \frac{k_{nprm}}{x_i}, k_{norm} \leq x_{\min} \quad (11)$$

If an average value of the aggregate is used as the normalizing factor, the values of indices can assume values greater than "1" following the normalization, which violates the rules of normalization - maintenance of the normalized indices within the range [0.1]. Both indices and threshold values are subject to normalization. This allows to determine the integrated indices of the ES components and their threshold values in common scale range for their comparison and is the major task of identifying the ES state. A comprehensive assessment of Ukraine's energy security in the context of regions was carried out on the basis of the energy market analysis for the respective regions with the view of timely identifying negative trends and ensuring prompt managerial decisions.

The region's energy security level cannot be assessed using any single integrated index. It is a "weighted average assessment" of the cumulative effect of multiple indices; therefore, it is necessary to select primary statistical indices and calculate generalized indices (indices for the development of the region's energy market). To characterize the energy security level, it is essential to select the statistical data for the development of the region's energy market. As follows from the analysis of numerous indices, 12 indices were selected, 7 de-stimulators and 5 stimulants.

To assess the region's energy security level, we will use the following system of the above described indices: I_1, I_2, I_3, I_4, I_5, I_6, I_7, I_8, I_9, I_{10}, I_{11}, I_{12}.

Each energy security index is formed on the basis of two sets - a set of stimulants and a set of de-stimulators:

$$I_{dj} = M_{vd_j} \cup N_{vd_j} \quad (12)$$

$$M_{vd_j} = (i_{vdm_j} \mid i = \overline{1 m_{vd_j}}) \quad (13)$$

$$N_{vd_j} = (i_{vdm_j} \mid i = \overline{1 n_{vd_j}}) \quad (14)$$

Where M_{vd_j} is a set of stimulants of j-th region; N_{vd_j} is a set of de-stimulators of j-th region; i_{vdm_j} is m stimulant of j-th region; i_{vdm_j} is n de-stimulator of j-th region.

These formulas are used to calculate the integrated indices of the country's energy security level. These indices are interpreted as follows: The closer the level of the corresponding component to unity, the better the situation in the region. The resulting vectors of indices of each type enable the comparison of regions by levels of each of the region's energy market development components.

The necessary procedure for measuring energy security of Ukraine's regions is the preliminary unification of the selected target indices, i.e the application of such conversion to them, as a result of which all of them will be measured by a one-point scale. However, the zero value of the converted index will correspond to the lowest energy security level, and the maximum value of 1 will correspond to the highest energy security level.

For stimulants, the growth of which contributes to an increase in the energy security index, the value of the corresponding unified variable was calculated by the formula:

$$x_{ij} = \frac{\tilde{x}_{ij} - \tilde{x}_{j\min}}{\tilde{x}_{j\max} - \tilde{x}_{j\min}}, \quad (15)$$

where x_{ij} is i-th value of j-th target unified energy security index; $x_j (i = \overline{1, n}, j = \overline{1, m}$, n is the number of observations for the initial index; x_j, m is the number of the target energy security assessment indices that were considered; $\tilde{x}_{ij}$ is the i-th value of j-th target non-unified energy security index; $\tilde{x}_{j\min}$ is the minimum value of the j-th target non-unified energy security index; $\tilde{x}_{j\max}$ is the maximum value of the j-th target non-unified energy security index; for de-stimulators, the calculations were carried out by the following formula:

$$x_{ij} = \frac{\tilde{x}_{\max} - \tilde{x}_{ij}}{\tilde{x}_{j\max} - \tilde{x}_{j\min}} \quad (16)$$

Calculations of integrated index Y, which characterizes the aspects of energy security of the j-th region selected by authors, were carried out by the formula:

$$Y = \sum_{j=1}^{m} w_j x_j \quad (17)$$

where w_j is the weighting factor with which the j-th index of the r-th aspect of energy security is taken into account in calculating the integrated index.

Weighting factors w_j were calculated by the following methods: Were determined as the fraction of variance $D(x_j)$ of index x_j in the total variance of all the fraction criteria:

$$w_j = \frac{D(x_j)}{\sum_{j-1}^{m} D(x_j)} \quad (18)$$

The implementation of the method for predicting threats to address the issue of optimization consists in optimally substantiating the quantitative and qualitative requirements for the organization of the country's energy security system and provides for the following stages:

- Collection and processing of expert information on the characteristics of threats and their elimination: Frequency of

occurrence, degree of damage, threat face-off level for each threat;
- Assessment of the cost of organization of the country's energy security system for a particular option of implementation subject to the allowable amount of expenditures;
- Elaboration of an algorithm for selecting a sustainable option of building the country's energy security system.

The calculation of generalized indices of energy security of Ukraine's regions for 2016 was carried out using Excel. It was assumed that n = 24. The numerical values of the existing indices for Ukraine for 2016 are given in Table 1. Some indices were calculated according to the data of the State Statistics Service of Ukraine, whereas others were derived from official statistical data and calculated using economic models. In calculations using the modified first major component method, the variance explained by the first major component was more than 50% for all aspects concerned of the energy security assessment, i.e., the method's performance criterion was fulfilled in all cases. Tables 1 and 2 give the calculation of the integrated energy security index.

5. RESULTS AND DISCUSSION

The weighting factors determined reflect the current state of Ukraine's ES at the end of 2016 and may vary in time as a function of the level of economic development. According to the calculations, a high level of economy energy intensity has the greatest impact on Ukraine's ES level in the current period. In Donetsk and Lugansk regions, however, these values indicate low energy efficiency even after the loss of a major industrial complex. The low energy security level in Ukraine and its regions is caused by a large number of outages per 100 km of network (I_9), high share of dilapidated and emergency heat and steam supply networks (I_8), as well as low energy supply level (I_2). Gas and coal (I_4) account for the greatest share in Ukraine's energy balance, which is indicative of a low level of differentiation of energy resources. Heavy heat losses (I_{11}) and high share of dilapidated and emergency heat and steam supply networks (I_{10}) indicate the depletion of energy system.

The application of the methodology allows to single out the integrated threshold values of each ES component to identify their state and determine the stimulants and de-stimulators influencing the country's energy security level (Table 2). Among the prospects for the development of Ukraine's energy market, it is worth mentioning the high level of domestic fuel production in the consumption balance, high electricity production in Ukraine, high capacity of power plants, availability and large capacity of oil and gas storage in the fuel and energy sector, which allows to provide a reserve stock of fuel in the event of unforeseen conditions.

The rating of the generalized region's energy security level assessment has been calculated on the basis of procedures for reducing the dimension and building generalized indices. The rating of Ukraine's regions has been prepared for each calculated integrated index (Figure 1).

According to the calculation data in Tables 1 and 2, Ukraine's ES level teeters at the level of the lower threshold - 0.4. As of 2016, 7 indices out of 12 were below the lower threshold. The rest teeter on the brink of the lower threshold or between the lower threshold and the lower optimum one. All this is indicative of the inefficient development of the energy system and requires the introduction of a new market approach to the management of economic processes

Table 1: Ukraine's energy security monitoring indices

Ukrainian REGIONS Indices	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	I_{11}	I_{12}
Ukraine	48.14	1.13	0.07	0.33	0.34	2.66	0.92	0.40	20.00	18.60	0.10	12.25
Vinnytsia	43.92	1.06	0.11	0.52	0.00	2.81	0.00	0.36	79.90	25.30	0.08	4.31
Volyn	31.21	0.04	0.13	0.58	0.13	0.07	0.00	6.31	4.40	24.10	0.06	4.50
Dnipropetrovsk	86.62	0.33	0.00	0.60	1.08	1.56	1.02	0.21	8.50	8.90	0.04	7.57
Donetsk	149.5	1.66	0.01	0.84	0.81	6.67	0.00	0.82	30.10	9.90	0.10	82.31
Zhytomyr	29.39	0.01	0.15	0.62	0.00	0.07	0.00	98.30	7.70	17.50	0.05	5.19
Transcarpathian	30.01	0.07	0.19	0.57	0.00	0.04	0.00	0.05	7.60	10.40	0.01	1.79
Zaporizhya	87.19	3.06	0.06	0.70	0.25	6.96	0.00	0.04	5.20	24.60	0.12	5.86
Ivano-Frankivsk	104.2	2.16	0.08	0.67	0.00	5.17	1.99	0.32	30.00	17.40	0.09	28.50
Kyiv	32.82	0.61	0.16	0.47	0.00	2.16	0.00	2.19	87.20	13.70	0.06	5.65
Kirovograd	26.33	0.33	0.08	0.47	0.00	1.44	0.00	0.61	26.50	27.90	0.06	7.70
Lugansk	167.4	1.00	0.01	0.75	0.99	8.34	0.00	0.00	0.00	10.10	0.10	7.83
Lviv	35.37	0.59	0.12	0.54	0.30	0.69	12.4	0.22	11.50	27.20	0.14	8.67
Mykolayiv	29.99	3.14	0.00	0.78	0.27	6.48	0.00	0.19	19.60	5.00	0.04	7.75
Odessa	23.45	0.07	0.16	0.69	0.00	3.97	0.00	31.50	0.00	39.10	0.10	4.42
Poltava	57.07	0.15	0.08	0.73	0.00	0.41	0.55	0.10	8.30	14.40	0.08	4.59
Rivne	38.15	3.56	0.00	0.80	0.28	5.44	0.00	0.03	26.10	11.30	0.06	5.44
Sumy	36.62	0.15	0.10	0.74	0.00	0.43	0.00	0.59	17.10	39.50	0.15	5.76
Ternopil	36.13	0.03	0.18	0.71	0.00	0.17	0.00	12.36	40.40	28.40	0.00	5.76
Kharkiv	53.47	0.55	0.11	0.72	0.00	1.98	0.15	0.16	4.30	26.60	0.12	4.58
Kherson	22.67	0.51	0.17	0.58	0.00	0.93	0.00	2.43	21.80	9.20	0.15	5.01
Khmelnytskyi	33.49	3.85	0.10	0.72	0.25	3.94	0.00	0.02	3.50	18.40	0.10	5.18
Cherkasy	57.26	0.42	0.11	0.74	0.00	1.38	0.00	0.54	18.10	21.20	0.13	5.24
Chernivtsi	33.05	1.24	0.20	0.62	0.00	7.28	0.00	0.36	5.90	10.90	0.07	9.76
Chernihiv	39.56	0.52	0.02	0.52	0.00	0.60	0.44	0.44	5.50	27.10	0.14	4.20
Kyiv	8.97	0.48	0.09	0.73	0.00	0.72	0.00	0.00	0.20	10.90	0.18	3.37

Table 2: Levels of Stimulants (S) and De-stimulators (D) of Ukraine's energy security in terms of regions

Normalization	Economy energy intensity D	Share of energy losses before its consumption D	Share of the largest energy resource in the balance D	Share of emergency undersupply of energy D	Number of outages per 100 km of network D	Share of dilapidated and emergency heat and steam supply networks D	Share of heat losses D	Electricity production to consumption ratio S	Share of produced own fuel in the consumption balance S	Power plant capacity to the greatest load S	Gas storage capacity for consumption S	Heat plant capacity to the average load per day S
Ukraine	0.753	0.664	1.000	0.996	0.771	0.606	0.447	0.292	0.317	0.316	0.074	0.130
Vinnytsia	0.780	0.447	0.639	0.996	0.084	0.412	0.600	0.275	0.000	0.333	0.000	0.031
Volyn	0.860	0.373	0.507	0.936	0.950	0.446	0.678	0.007	0.124	0.003	0.000	0.034
Dnipropetrovsk	0.510	0.993	0.466	0.998	0.903	0.887	0.775	0.083	1.000	0.183	0.082	0.072
Donetsk	0.113	0.944	0.000	0.992	0.655	0.858	0.467	0.430	0.749	0.799	0.000	1.000
Zhytomyr	0.871	0.258	0.441	0.000	0.912	0.638	0.767	0.000	0.000	0.004	0.000	0.042
Transcarpathian	0.867	0.081	0.542	0.999	0.913	0.843	0.979	0.016	0.000	0.000	0.000	0.000
Zaporizhya	0.507	0.707	0.267	1.000	0.940	0.432	0.350	0.795	0.228	0.834	0.000	0.050
Ivano-Frankivsk	0.399	0.611	0.328	0.997	0.656	0.641	0.542	0.561	0.000	0.618	0.160	0.332
Kyiv	0.850	0.229	0.732	0.978	0.000	0.748	0.710	0.158	0.000	0.255	0.000	0.048
Kirovograd	0.890	0.617	0.731	0.994	0.696	0.336	0.684	0.084	0.000	0.168	0.000	0.073
Lugansk	0.000	0.978	0.180	1.000	1.000	0.852	0.484	0.259	0.913	1.000	0.000	0.075
Lviv	0.833	0.408	0.588	0.998	0.868	0.357	0.262	0.151	0.279	0.078	1.000	0.085
Mykolayiv	0.867	1.000	0.112	0.998	0.775	1.000	0.782	0.814	0.253	0.776	0.000	0.074
Odessa	0.909	0.233	0.295	0.680	1.000	0.012	0.457	0.015	0.000	0.473	0.000	0.033
Poltava	0.697	0.592	0.207	0.999	0.905	0.728	0.586	0.037	0.003	0.044	0.044	0.035
Rivne	0.816	0.998	0.072	1.000	0.701	0.817	0.692	0.925	0.260	0.650	0.000	0.045
Sumy	0.826	0.495	0.203	0.994	0.804	0.000	0.170	0.036	0.001	0.046	0.000	0.049
Ternopil	0.829	0.099	0.256	0.874	0.537	0.322	1.000	0.005	0.000	0.015	0.000	0.049
Kharkiv	0.719	0.449	0.239	0.998	0.951	0.374	0.348	0.142	0.001	0.233	0.012	0.035
Kherson	0.914	0.154	0.509	0.975	0.750	0.878	0.195	0.132	0.000	0.106	0.000	0.040
Khmelnytskyi	0.845	0.504	0.236	1.000	0.960	0.612	0.491	1.000	0.233	0.470	0.000	0.042
Cherkasy	0.695	0.448	0.193	0.995	0.792	0.530	0.293	0.108	0.000	0.162	0.000	0.043
Chernivtsi	0.848	0.000	0.432	0.996	0.932	0.829	0.655	0.320	0.000	0.872	0.000	0.099
Chernihiv	0.807	0.900	0.634	0.996	0.937	0.359	0.238	0.134	0.000	0.067	0.035	0.030
Kyiv	1.000	0.581	0.213	1.000	0.998	0.829	0.000	0.122	0.000	0.082	0.000	0.020

in Ukraine's energy system. The strategy of ensuring Ukraine's energy security should primarily be aimed at improving the state of the negative components of energy security subject to certain weighting factors of influence. In this connection, there is a task of scientific substantiation of the strategic ES objectives in the midterm subject to the non-linearity of economic processes, delayed influence and varying sensitivity at the level of indices of each ES component. This task is adequate to the issue of synthesizing the values of ES components, i.e., what their value should be, in order to ensure the finding of the integrated ES index at a given level.

As can be seen from Figure 1, Ukraine's eastern regions feature the highest energy security level. Ukraine's western and central regions are quite sensitive to the proposed integrated indices for assessing the region's energy security level and demonstrated lower values and also the need for applying state resource regulation in terms of establishing a market-based energy system. The findings can be used to determine the management impact on a specific factor (e.g., energy efficiency of region's industrial enterprises characterized by significant specific consumption of FER, etc.). To this end, a complete list of interrelated management activities representing a holistic management process has been compiled, with leverage summarized in Table 3. Firstly, it is necessary to determine the significance of the share of each management impact V on a given factor (Delphi approach: For V_1 it will be 0.35, for V_2 - 0.327, for V_3 - 0.23, for V_4 - 0.18). Secondly, it is necessary to measure the weight of common factors $V_i=V_j/N_j$ for each management impact, which is included in the corresponding priority group. This means that all management impacts within the priority group have the same weights. If no priorities are established from management impacts, they have equal weight, i.e., $V_i = 1/n$. The calculation data on the share of management impact in the whole aggregate of management impacts are summarized in Table 3. Further, an assessment of significance of the relevant management impact on the procedure in question has been conducted (Delphi approach, polling). Each expert working separately should be furnished with a list of management impacts and invited to assess the significance of their impact on energy security factors subject to the following assessment system:

0 - This management impact most likely does not affect the energy security factor; 25 - the effect of this management impact cannot be determined exactly;

50 - The effect of this management impact can cause occasional minor changes in energy security;

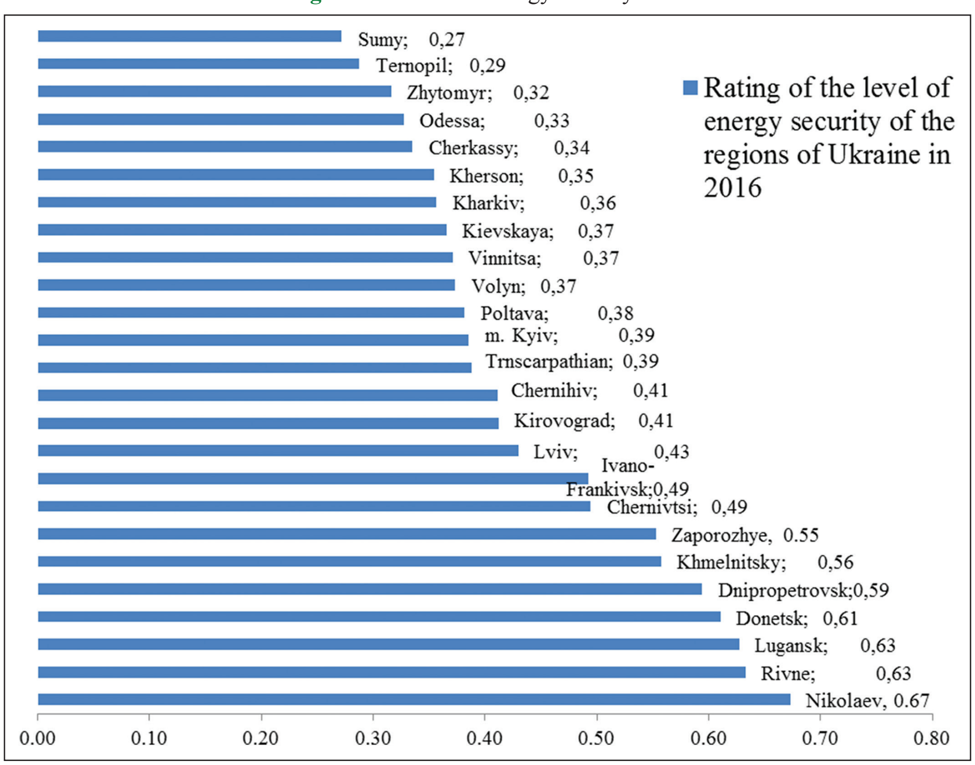
75 - This management impact always entails minor changes in energy security;

100 - This management impact always entails fundamental changes in energy security. The final assessment of the significance of all management impact is made by the formula $I=V_iR_i$, where R_i is the weight of i-th effect (Table 3).

Table 3: Rating value of management impacts on energy security factors

Leverage	Priority Group, Q_j	Value, V_i	Value, R_i	Value Factor, V_iR_i
Legal	Q_1	0.113	91	10.3
Economic		0.110	89	9.7
Financial		0.111	86	9.5
Technical		0.100	85	8.5
Organizational	Q_2	0.090	84	7.6
Marketing		0.089	73	6.5
Social	Q_3	0.075	64	4.8
Environmental		0.075	64	4.8
Psychological	Q_4	0.062	56	3.5

Figure 1: Ukraine's energy security level



The results of the quantitative analysis carried out according to the proposed methodology allow to identify the most significant management impacts for this factor. The calculation data show that economic and legal management impacts (1st rating) are of greatest importance, with psychological ones (10th rating) being of lowest importance for the factor under consideration.

Thus, the development of measures aimed at increasing the energy efficiency of Ukraine's industrial enterprises characterized by significant specific consumption of FER is expedient due to intensification of management impacts being of greatest importance and having the highest rating (financial, technical, organizational). This involves the creation of conditions for financial support that is required to implement an active policy of modernizing deteriorated energy equipment of the region's fuel and energy sector; adequate deconcentration of energy production and intensification of an active energy-saving policy, which should result in growth in the region's alternative energy use, reduced demand for energy supplies and reduced tension in the energy balance, stimulation of energy saving and energy efficiency at enterprises, offering economically sound behavior strategies for efficient use of the stock of available FER.

6. CONCLUSION

The scientific and practical results obtained in the research allow to make the following conclusion:

1. Energy security is an integral part of the country's economic security achieved by such energy market development level at which the market is able to meet the country's needs for FER and ensure the continuity of supply of various energy types in full at affordable prices, as well as guarantee access to energy sources.
2. The review of official approaches to the integrated assessment of the country's energy security level found that the lack of an assessment of energy security in terms of Ukraine's regions necessitates the improvement of methodological approaches. The defined shortcomings concern both the scope of indices and the methodology of integrated assessment (normalization of indices, determination of weighting factors, substantiation of the vector of threshold values), which brings about incorrect results of the integrated assessment.
3. The proposed methodology for an integrated assessment of Ukraine's energy security level is characterized by the use of the multiplicative form of the integrated index and contains a number of additional indices, without regard to which the assessment is not correct; simultaneous normalization of indices and their threshold values by a common normalizing function; substantiation of the threshold value vector; as well as by a formalized definition of weighting factors, which allows to compare the dynamics of the integrated index with integrated threshold values on one scale, i.e correctly identify the state of energy security.
4. Practical approval of the proposed methodology by the example of Ukraine's economic security indices suggests an unfavorable state of Ukraine's energy security due to the fact that a number of components and their energy security indices are below the threshold values and serve as de-stimulators of energy security.
5. In general, the methodology for an integral assessment of Ukraine's energy security level allows to assess the energy security level, which is a prerequisite for the development of a targeted strategy for the development of Ukraine's energy market, as well as deploy a system of energy security components and indices with their weighting factors to identify bottlenecks, direction of improvement and development of appropriate measures due to the impact on structural elements.
6. The indicative method has been proposed to assess Ukraine's energy security. A list of 12 energy security indices has been compiled, data sources have been identified, and a methodology for identifying index values has been developed. The numerical values of the current indices for Ukraine for 2016 have been provided.
7. The system of indices has been developed to provide an accurate model for assessing the current region's energy security level, as well as a model for assessing the country's energy security level as a whole, which allow to improve the efficiency of management behavior to ensure country's energy security through the organization of early detection and prevention of threats.
8. The major task of state authorities responsible for the current assessment of the economic security level and the development of long-term and indicative plans for social and economic development is the need to monitor macroeconomic performance with a view of an integrated assessment of the economic security level both in the country and in regions.
9. The issues of domestic reforming of Ukraine's energy industry in the process of integration of Ukraine's energy market into the global energy space and the establishment of a liberal model for the development of the energy market with increased openness for the dynamic global economic space, increased industry's competitive potential in the global market under the influence of constant market changes contributed to the need for investment measures to improve Ukraine's energy security level. Prospects for further research consist in the development of strategic priorities for Ukraine's entry into the CEES.

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