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SECTION 1
Mathematical Models of Objects and Processes

Modelling the Level of Energy Security at Enterprises in the Context of Environmentalization of Their Innovative Development

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Abstract **The paper justifies the need to promote the environmentalization of production that will create innovative opportunities for the economy. It highlights the issue of preventing climate through ensuring energy security. It shows that the level of energy security should be modelled based on the scenario method since it can analyze the priority of components of the integrated indicator of energy security. It suggests the classification system of components of energy security at enterprises which form a set of indicators subject to quantification (resources and energy, equipment and technologies, organization and management, finances and economics, environment and society). It gives grounds for a reasonable selection of priority criteria of energy security at enterprises. The paper employs the following research methods: graphic methods – to demonstrate the dynamics of levels of energy security at enterprises based on relevant scenarios; analysis – to determine the role of energy security in the system of enterprise functioning; theoretical generalization – to justify the list of scenarios for achieving energy security. The paper suggests introducing an optimal scenario for promoting energy security at enterprises, based on the respective weight coefficients of components of energy security for each of the five possible scenarios determined using expert assessment. The paper presents optimal conditions of functioning of the enterprises under study to achieve the maximum possible level of energy security.**

Keywords: energy security, environmentalization, modelling, energy efficiency, enterprise.

I. INTRODUCTION

The whole world witnesses and experiences the changes in approaches to elaborating energy policies in different countries. There occurs a transition from an outdated model of functioning, which encompasses major producers, traditional types of energy resources, inefficient networks, ineffective competition, to a new model balancing the possibilities for the environmentalization of production, the use of alternative and renewable energy sources, thus creating the most innovative opportunities for economic development. However, it is preferable to prevent and adapt to climate change, energy efficiency and ensure energy security at mega, macro-, meso- and micro- levels. At the same time, the unsatisfactory conditions of industrial enterprises are caused by moral and physical ageing of fixed assets, many of which are worn-out and ineffective [1-3].

Efficient use of fuel and energy resources by economic entities is recognized as a priority of state development. This is confirmed by the legislative initiatives of Parliament and the adoption of relevant legislative, institutional and organizational initiatives.

Aggressive challenges and threats arising under the current economic circumstances are related to the need to increase the production of primary energy resources, diversify external sources of supply of fuel and energy resources, ensure national energy independence through overcoming monopoly power and developing competition, as well as ensuring energy-efficient production.

Therefore, threats to environmentalization have put new economic, environmental and technological challenges on enterprises regarding elaborating a strategic model of the necessary and sufficient level of energy security, as well as implementing environmental and energy-efficient measures and achieving the set goals.

The connection between enterprise development and energy security lies in the use of modern environmentally friendly and energy-efficient production technologies that will contribute to economic growth, reduce the anthropogenic impact on the environment and strengthen the competitive positions of socio-economic systems.

In this regard, there is a need to study the components that most affect the energy security of enterprises. Under such circumstances, energy security cannot be reasonably justified in a generalized way since threats to energy security at enterprises may arise both outside and at the level of the energy efficiency policy of the enterprise itself. Given these features, it is advisable to formulate a methodical approach taking into account the impact on energy security which can reflect the qualitative and quantitative level of meeting the needs of the enterprise regarding the most critical energy resources [4-6].

The author of the paper believes that the essence of energy security at enterprises is most fully revealed through the system of functional components, which act as a set of essential areas for ensuring energy security. It must be acknowledged that the functional components differ significantly in content and goals and represent a specific unit (sub-system) to achieve an adequate level of energy security of economic entities.

II. LITERATURE REVIEW

The issue of ensuring energy security is addressed by [7], who identifies the need to understand the concept of energy security and analyzes the future energy-related paths and scenarios that may form the basis for increasing its level. [8] considers the issue of improving energy efficiency, as well as the ongoing global recession and global warming. The authors focus on the challenges of sustaining continued economic growth and reducing pollutant emissions, as well as using a tool for modelling the impact of implementing new and anticipated energy and environmental policy. [9] suggests five aspects of energy security (availability, accessibility, affordability, acceptability and develop-ability) to build a model for assessing sustainable energy security (SES) index. The paper proves that accessibility and develop-ability are of paramount importance in the system of SES index. [10] justifies the need and expediency of implementing a strategy which can coordinate the actions of senior management of enterprises in solving the issues of reducing the energy intensity of production, as well as energy consumption and energy dependence.

M. Asaul [11] considers transformations related to building an innovative environmental and energy-efficient model of economy oriented towards high-tech scientific production, sustainable development and creating an infrastructure for creating an intellectualized information space. O. Mykoliuk & V. Bobrovnyk [12] prove that the primary tool for ensuring energy security at the enterprise is the increased use of renewable energy. E. Oro [13] has built dynamic models for a correct understanding and quantification of energy consumption and identified the benefits of using energy efficiency strategies and renewable energy sources.

MATERIALS AND METHODS

Given a rather unstable environment, the company needs to solve complex and sometimes contradictory problems. The scenario method is an effective strategic planning tool since it allows one to solve the problems of multivariate development, including choosing the scenario under which the enterprise will reach the maximum level of energy security.

The scenario method implies conduct a study which can help to builds several alternatives for the future. It aims to interpret the current conditions of the enterprise with respect to future events, as well as find effective ways to avoid future hazards.

According to the research, the author of the paper has identified and proposed five components of energy security at enterprises: resources and energy, equipment and technologies, environment and society, finances and economy, organization and management [14-22].

Also, they have constructed scenarios based on which they can demonstrate changes in the priority of components by the actual value of the integrated indicator of energy security to model the level of energy security at the enterprises under study. Given the volatility of the internal environment, enterprises operate under constant changes, including limited energy and fuel resources. Using the scenario method, it is possible to determine the impact of each component of energy security at enterprises and achieve the optimal level of energy security under certain conditions.

Thus, this paper considers five scenarios of the possible level of energy security at the enterprises under study and analyzes the dynamics of changes in the integrated indicator. The weight coefficients of components of energy security at the enterprises under each of the five possible scenarios are determined based on expert assessment (see Table 1). It must be noted that highly qualified specialists in relevant fields were involved in expert assessment; the opinions of these specialists are presented in a form that allows one to systematize them; a large number of the expressed ideas include certain innovative ideas; following the law of large numbers, the opinions of many specialists were considered as accurate characteristics of the problem under study; the systematic responses received the specialists were provided in the context of clearly defined tasks and specific questions; after obtaining new information, the specialists used it creatively and refined the answers to increase the credibility and accuracy of the estimates. Within the framework of the study, each specialist created his or her intuitive model of the phenomenon under study, which allowed him or her to form approximate quantitative estimates under certain conditions.

III. RESULTS AND DISCUSSION

The normalization procedure should be realized to bring the qualitative and quantitative indicators characterizing the energy security of the enterprise into a comparable form. It means the transition from absolute to normalized values, characterizing the level of approximation to the optimal value. It is necessary to have an aggregate index, namely, an integral index that is not directly measured but integrates the primary indicators and is calculated based on their statistical values, to analyze the indicators and assess the level of energy security at enterprises. The normalization of indicators implies moving to such a scale of measurement, when “the best” value of the indicator corresponds to 1 and “the worst” – to 0.

Each of these components is endowed with energy content indicators that are specific to its content, which have been determined from the set of indicators by expert assessment. They should be given the weighting factors (expert assessment). Besides, the priority of each of them should be considered as an individual scenario to achieve the maximum level of energy security at enterprises, taking into account the calculated integral index. If the priority of the energy security component changes (depending on its weighting factor), the integral index of the energy security level will change. The maximum calculated value of the integral index will indicate the optimistic scenario of reaching the highest value of the energy security level at a particular enterprise, the minimum value – the pessimistic scenario. Respectively, the average value of the energy security level for one or another component will indicate the pessimistic scenario. Based on the questionnaires, a summary matrix of ranks was compiled; the significance of the investigated factors was analyzed; the level of concordance of the opinions of all specialists was evaluated; the indicators of the importance of the considered parameters were calculated.

Thus, Table 1 shows that resources and energy (P_1) and equipment and technologies (P_2) become the most important components under the conditions of scenario 1 – 0.352 and 0.242, respectively. According to scenario 2, equipment and technologies (P_2) is more important than resources and energy (P_1), whereas organization and management (P_5) is valued more than environment and society (P_3) – 0.187 and 0.121. Scenario 3 attaches more importance to environment and society (P_3) and finances and economy (P_4) and less importance to organization and management (P_5) – 0.099.

TABLE I. WEIGHT COEFFICIENTS OF COMPONENTS OF ENERGY SECURITY BY SCENARIOS

Components of the integrated indicator	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Resources and energy (P_1)	0.352	0.242	0.187	0.121	0.099
Equipment and technologies (P_2)	0.242	0.352	0.121	0.187	0.242
Environment and society (P_3)	0.187	0.121	0.352	0.099	0.187
Finances and economy (P_4)	0.121	0.099	0.242	0.352	0.121
Organization and management (P_5)	0.099	0.187	0.099	0.242	0.352

According to scenario 4, finances and economy (P_4) and organization and management (P_5) are at top positions, which means the highest importance among all the components. Scenario 5 emphasizes the strong position of organization and management (P_5). Thud, the presented scenarios make it possible to analyze changes in the level of energy security at the enterprises under study depending on the change in the weight coefficients of each component.

Table 2 shows the change in the level of energy security for enterprise 1, taking into account the proposed scenarios. The study of dynamics in the level of energy security between 2014 and 2018 reflects the priority of enterprise development according to scenario 2 since, under such conditions, enterprise 1 can show a dynamic growth of energy security.

TABLE II. THE DYNAMICS OF THE INTEGRATED INDICATOR OF ENERGY SECURITY AT ENTERPRISE 1 ACCORDING TO THE PROPOSED SCENARIOS

Scenarios of the level of energy security at enterprises	The level of energy security				
	2014	2015	2016	2017	2018
Scenario 1: priority (P_1)	0.155	0.149	0.158	0.152	0.196
Scenario 2: priority (P_2)	0.163	0.159	0.16	0.162	0.165
Scenario 3: priority (P_3)	0.156	0.15	0.159	0.149	0.182
Scenario 4: priority (P_4)	0.158	0.152	0.159	0.154	0.188
Scenario 5: priority (P_5)	0.165	0.159	0.166	0.161	0.202

However, one can see the highest level of energy security under scenario 5 in 2018. In the same year, the high level of the indicator under study can be achieved under scenario 1. Thus, the focus of senior management on the development and improvement of equipment and technologies (P2), as well as the enhancement of its indicators (f_5 – extent of using innovative technologies; f_6 – the deterioration level of the main fixed assets; f_7 – the level of energy efficiency; f_8 – the level of power supply capacity) will enable the enterprise under study to achieve the highest level of energy security under the given conditions.

A graphical representation of energy security scenarios at enterprise 1 in dynamics is shown in Fig. 1.

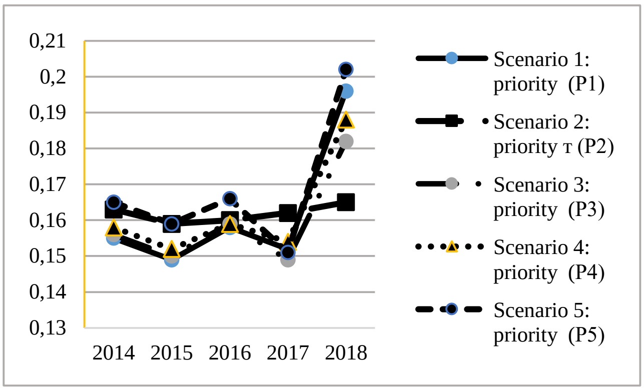

Fig. 1. The level of energy security at enterprise 1 by scenarios between 2014-2018

As evidenced by Fig. 1, one can see the lowest level of energy security under scenarios 3 and 1, which is reflected in the fluctuation of the energy security indicator within almost the same range. The highest level of energy security under scenario 2 is observed in 2018, which is explained by the increase in the integrated indicator of the energy security level. The dynamics of the integrated indicator of the energy security level at enterprise 2 is shown in Table 3.

TABLE III. THE DYNAMICS OF THE INTEGRATED INDICATOR OF ENERGY SECURITY AT ENTERPRISE 2 ACCORDING TO THE PROPOSED SCENARIOS

Scenarios of the level of energy security at enterprises	The level of energy security				
	2014	2015	2016	2017	2018
Scenario 1: priority (P_1)	0.095	0.097	0.091	0.088	0.102
Scenario 2: priority (P_2)	0.108	0.109	0.106	0.101	0.104
Scenario 3: priority (P_3)	0.097	0.101	0.097	0.09	0.093
Scenario 4: priority (P_4)	0.115	0.114	0.112	0.112	0.113
Scenario 5: priority (P_5)	0.111	0.112	0.112	0.109	0.107

According to the conducted calculations, the dynamics in the integrated indicator of the energy security level at Enterprise 2 is reflected in priority under scenario 4. In 2014, the highest indicator of the energy security level is observed under component P4 (scenario 4) and the lowest one – under priority component P3 (scenario 3). Between 2015 and 2016, the priority trend under scenario 5 continues and peaks at 0.112 in 2016 and 0.111 in 2015. In 2017, the lowest level of energy security was under scenario 1 and in 2018 – under scenario 3 (P3). A graphical representation of the dynamics of the integrated indicator of energy security at enterprise 2 by scenarios is shown in Fig. 2.

As can be seen from Fig. 2, the level of energy security at enterprise 2 under the proposed scenarios between 2014 and 2018 fluctuates and reflects the current indicators of the enterprise's performance. In this case, the integrated index reflects both upward and downward trends. The lowest level of the integrated indicator of energy security is observed under scenario 3, which characterizes the insignificant impact of the component P_3 within the research period.

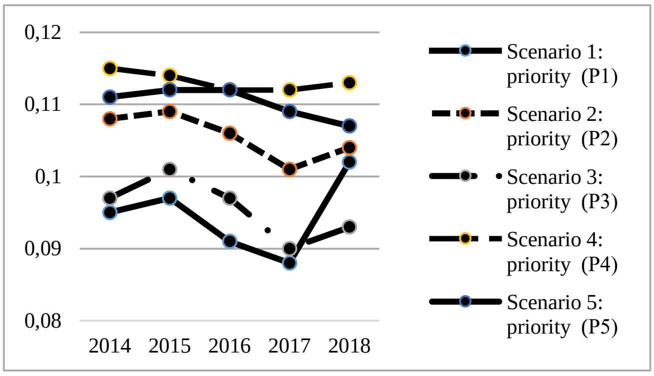

Fig. 2. The level of energy security at enterprise 2 by scenarios between 2014-2018

The results of the research on modelling the level of energy security at the enterprises under study under all the scenarios show the optimal conditions for their functioning to achieve the maximum possible level of energy security.

According to the chosen scenario, the impact of each component on the level of energy security at enterprises can be assessed using a particular measurement scale. Therefore, each scenario can present evidence proving or denying the impact of any component on the level of energy security at enterprises. The paper employs the following scale to assess the results according to a desirability scale based on exponential transformation. It also suggests changing the boundaries of the levels of the universal scale (see Table 4) to eliminate inaccuracies and ensure a clear and unambiguous interpretation of the results.

TABLE IV. GRADING THE LEVEL OF ENERGY SECURITY BASED ON AN OPTIMAL SCENARIO

Grade	The level of energy security
LVLes≤0.01	crisis-ridden
0.011≤ LVLes ≥0.038	critical
0.039≤ LVLes ≥0.06	pre-critical
0.061≤ LVLes ≥0.089	ambiguous
0.09≤ LVLes ≥0.10	unstable
0.11≤ LVLes ≥0.199	standard
LVLes ≥0.2	absolute

Thus, the revealed dependencies between the level of energy security at enterprises and the appropriate scenarios to achieve the maximum possible level of energy security at the enterprises under study prove that economic entities can choose one or the other scenario and strengthen those components of energy security which have the most significant impact on maximizing the level of the integrated indicator in each case and under appropriate conditions.

IV. CONCLUSION

Therefore, the constant changes in competitive conditions, the environment and the positions of enterprises in the market, complicated by adverse political, environmental and socio-economic changes in society, show that it is essential to identify the most critical factors in the security of modern enterprises and suggest relevant measures to ensure their status at the proper level. Ensuring the proper level of security at enterprises and, above all, its energy security involves choosing priority areas of activity and developing tactical mechanisms for their implementation. Given the growing uncertainty in the environment of the enterprise's functioning, it is crucial to employ forecasting tools, identify potential hazards and prepare for not one but several possible alternatives in the future.

The successful practice of international business proves that the scenario method is useful in medium- and long-term perspectives, with a medium or high degree of uncertainty. This method makes the modelling of the management strategy more flexible, which allows the enterprise to remain successful under various circumstances in the future.

The scenario method, as a management method, contains specific tools that can be used to interpret the current conditions of the object concerning future events and avoid the dangers of future economic relations.

The author of the paper believes that this method can be used in such a context to manage and ensure energy security at enterprises and determine its optimal level under the implementation of a particular scenario. Therefore, the use of the scenario method can help to predict the possible variants (scenarios) under which the enterprise can achieve the maximum possible level of energy security.

Each component is characterized by the indicators of energy efficiency specific to its content, which have been determined based on a set of indicators by expert assessment. The results of the research show that these indicators are given specific weight coefficients (expert assessment).

At the same time, the research determines the specific priority of each scenario for achieving the maximum possible level of energy security at enterprises, taking into account the calculated integrated index. If the priority of the energy security component changes (depending on its weight coefficients), the integrated indicator of the energy security level will change. The maximum calculated value of the integrated indicator indicates the optimistic scenario of achieving the highest value of the energy security level at a particular enterprise, whereas the minimum calculated value – the pessimistic scenario. The average calculated value of the energy security level for one or another component indicates a pessimistic scenario, too.

Further research should focus on assessing the level of energy security at enterprises for each component, conducting an energy audit of the consumption of fuel and energy resources and analyzing the identified threats. This can become the basis for modelling an optimized system of energy security at enterprises, which will involve discovering ways to minimize and neutralize the impact of negative factors, selecting the tools and means of protection, appointing responsible persons, preparing proposals for improving the energy security system, defining all types of necessary resources, planning the costs of ensuring the functioning of such a system, as well as implementing the existing system at enterprises and assessing its effectiveness.

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