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INNOVATIVE APPROACHES TO EVALUATING ENERGY EFFICIENCY POTENTIAL AT ENTERPRISES

Purpose. To highlight the factors of formation and development of indicators for assessing the potential for increasing energy efficiency at enterprises.

Methodology. In the research process, the following methods were used: economic-mathematical modeling (when developing indicators for assessing the potential for increasing energy efficiency at enterprises); grouping and generalization (when classifying factors for the formation of the potential for increasing the energy efficiency of companies' activities); system analysis (when establishing the characteristic features of the potential for increasing energy efficiency and research mechanism of its formation).

Findings. Characteristic features were established and the content of the energy efficiency improvement potential was defined. Grouping of the factors of formation of this potential was carried out. The methodological principles of its assessment are proposed, in particular, a number of indicators have been developed, with the help of which it is possible to get a complete and comprehensive picture of the possibilities of enterprises to increase their energy efficiency. Based on a sample of 110 Ukrainian enterprises, the potential for increasing energy efficiency using natural gas was assessed. The impact of certain factors on the value of this potential has been established.

Originality. The concept of "energy efficiency improvement potential" has been clarified. The methods for grouping factors that affect the potential for increasing energy efficiency at enterprises have gained further development by highlighting new classification features, namely: by location; by the nature of the impact; according to the possibility of management; by place in the hierarchy; depending on the type of potential caused by the relevant factors; by content; by sphere of influence; by areas of increasing the energy efficiency of enterprises; according to the degree of variability. Methodological principles for assessing the potential for increasing the energy efficiency of enterprises have been improved, which, unlike the existing ones, provide for solving two tasks simultaneously in the process of such an assessment, namely: 1) formation of an optimal program of energy-efficient measures in relation to individual energy consumption processes; 2) determination of the optimal intensity of each of these processes.

Practical value. The obtained results can be used by enterprises in assessing the potential of increasing the energy efficiency of their activities and in the formation of information support for energy saving management.

Keywords: *enterprise, potential, energy efficiency, energy efficiency measure, energy saving, natural gas*

Introduction. In recent years, there has been a growing need to reduce energy consumption, primarily the consumption of fossil energy resources. This is due to many reasons, including high energy prices, threats of disruptions in their supplies, the need to reduce environmental pollution, etc. The influence of these reasons became even stronger after the start of large-scale military operations in Ukraine and the sharp complication of the geopolitical situation caused by them and the deepening of the crisis in interstate relations. Under such conditions, many countries, in particular the states of the European Union, set the task of significantly increasing energy independence on the basis of accelerating the energy transition.

At the same time, reducing the consumption of non-renewable energy resources is a rather difficult task that requires significant amounts of investment resources. On the other hand, such a reduction may conflict with another important goal of sustainable development, namely, with the need to ensure permanent economic growth. The resolution of this contradiction is possible only on the basis of increasing the ratio between the volume of economic results and the expenditure of energy resources incurred to obtain these results. In other words, ensuring sustainable economic growth with a simultaneous reduction in the consumption of non-renewable energy resources is possible only under the condition of constantly increasing the level of efficiency in the use of these resources.

It should be noted that the problem of increasing energy efficiency can be considered at different levels, in particular at the national, sectoral, individual enterprise and household

levels. The level of enterprises is especially important, since it is at this level that decisions are made regarding the implementation of energy-efficient measures for commercial energy consumers. At the same time, it is important for each of these consumers to establish reserves for increasing the energy efficiency of their activities. In turn, if one seeks to cover the entire possible range of energy-efficient measures, then the determination of the possibilities of increasing the energy efficiency of enterprises should be based on the assessment of the potential of such an increase.

However, the assessment of the potential for increasing the energy efficiency of companies' activities requires the presence of a significant amount of input data and scientifically based methods of its processing. For such an assessment, it is important to take into account the main factors that influence the level of energy efficiency of economic activity. It is also necessary to have an effective toolkit, primarily a system of indicators, with the help of which it is possible to carry out a complete and comprehensive assessment of the potential for increasing the energy efficiency of enterprises. Therefore, determining the potential for increasing the energy efficiency of business entities requires preliminary establishment of the main factors that influence this potential, and the construction of a system of indicators for its evaluation.

Literature review. The problem of assessing the potential of energy efficiency was considered in many scientific works. At the same time, scholars have considered this problem at different levels. In particular, John, A. conducted a nationwide assessment of energy efficiency potential using the US economy as an example, showing that there are enough cost-effective

energy efficiency options to cut total US energy needs in half [1]. A similar study for the USA was carried out, in particular, by Wilson E.J., at al., which identified a number of untapped cost-effective ways to achieve energy efficiency, roughly equivalent to 250 billion barrels of oil [2]. At the same time, Feng, C. & Wang, M. assessed the potential for energy efficiency improvement at the sectoral level, showing the crucial role of technological progress in such improvement using the example of China's industrial sector [3]. Zhou, N., at al. also paid attention to energy consumption in China, but the object of the study was the building sector, in which it was established that there is a significant potential for improving energy efficiency [4].

Also, the presence of a significant potential for energy efficiency growth was revealed in a number of scientific works devoted to individual sectors of the economy of European countries. In particular, this applies to the metallurgical and food industries of Great Britain [5], the building environments of Greece [6], the wood and cork industries, food and metal products of Sweden [7], and so on. It should be noted that in a significant number of publications, the assessment of the potential for increasing energy efficiency is carried out through the prism of identifying factors that contribute to and inhibit the process of such an increase. In particular, as established by Wang, J., at al., there are quite a lot of such factors and they differ for different subjects and for different stages of implementation of energy-saving measures [8].

Scientists pay special attention to the study of obstacles that stand in the way of implementing energy-efficient measures. G. Kostka, U. Moslener & J. Andreas established, in particular, the presence of a significant number of types of such obstacles [9]. A number of researchers have identified the most important of such obstacles. In particular, A. Trianni, at al. attributed to them, among other things, the insufficient level of economic efficiency of energy-efficient measures [10]. Z. Zhang, at al. established that the lack of financial incentives for the implementation of energy-saving measures is one of the main barriers that inhibit such implementation [11]. At the same time, F. Backman attributed to the mentioned barriers an insufficient level of rationality, which is often inherent in making energy saving investment decisions [12]. Also worthy of attention is the opinion of V. Lesinskyi, at al., who attributed the high riskiness of energy-saving projects [13] and the organizational and technological inertia of energy consumption at enterprises to the obstacles on the way to energy saving [14].

Some researchers, including L. G. Giraudet, found a significant impact of information barriers on the process of energy saving at enterprises [15]. As established by J. Palm & F. Backman, these obstacles are usually associated with a lack of input information and low competence of company managers in its processing [16].

Since there are many obstacles in the implementation of energy-saving measures by enterprises, the methods for overcoming them, proposed in the literature, are quite diverse. In particular, H. L. Kangas, at al. draw attention to the importance of increasing the relevance of input information [17]. D. Chiaroni, at al. propose improvement of energy audit mechanisms [18]. L. G. Giraudet considers it necessary to improve the competence of managers and specialists of companies in matters of energy management [15].

At the same time, scientists offer different approaches to measuring obstacles that stand in the way of increasing energy efficiency. In particular, H. Kangas, D. Lazarevic & P. Kivimaa proposed a method of qualitative analysis of such obstacles [17]. Herrera B., at al. recommend using the results of a survey of energy managers for this purpose [19]. Bhandari, D., Singh, R. K. & Garg, S. K. draw attention to the expediency of using a hierarchical approach and grapho-analytical models [20]. Measuring the barriers that appear when enterprises implement energy efficiency measures can be considered as one of the components of the general procedure for assessing the potential for increasing energy efficiency. Another important

direction of such assessment is the determination of the economic efficiency of the implementation of energy-efficient projects. In this regard, it is worth noting the methods of such determination considered in the work by E. Szafranko [21]. Scientists have also presented an information base for evaluating energy-efficient projects [22, 23], substantiated their selection criteria [24], developed theoretical principles for the formation of programs of energy-efficient measures [25], determined the conditions for their successful implementation in the context of ensuring energy security [26], etc. At the same time, the appropriate level of intellectualization of enterprise development management processes [27, 28], the use of advanced technological processes and innovativeness [29, 30] becomes important.

However, the issue of identifying a sufficiently complete set of factors that determine the potential for increasing energy efficiency at the enterprise level has not yet been fully resolved. Also, the issue of developing a system of indicators for evaluating this potential remains unresolved. These questions are very relevant to ensure the long-term economic development of companies under the conditions of reducing their consumption of non-renewable energy resources. Therefore, there is a need to research the issues of identifying factors of formation and developing indicators for assessing the potential for increasing energy efficiency at enterprises.

The purpose of this article is to highlight the factors of formation and development of indicators for assessing the potential for increasing energy efficiency at enterprises. Achieving the set goal presupposes the need to solve a number of tasks, the main of which are the following:

- to clarify the concept of the potential for increasing the energy efficiency of enterprises;
- to build a typology of the factors of formation of this potential;
- to develop indicators for assessing the potential for increasing energy efficiency at enterprises;
- to evaluate the specified potential based on a sample of natural gas consumer enterprises and determine the factors that have a significant impact on the value of this potential.

Methods. Various methods of scientific knowledge were used in the research process. In particular, economic-mathematical modeling was used when constructing indicators for assessing the potential for energy efficiency improvement at enterprises. Grouping and generalization methods were used when classifying factors influencing the value of this potential. In order to establish the characteristic features of the energy efficiency improvement potential and to study the mechanism of its formation, the system analysis method is used. The methods of economic analysis and techno-economic calculations were applied when performing empirical studies of the potential for increasing energy efficiency based on a sample of enterprises – consumers of natural gas. A survey method was used to survey owners and managers of enterprises regarding their implementation of energy-efficient measures. The apparatus of mathematical statistics was used to process the obtained results.

The results. The potential for increasing the energy efficiency of enterprises, as well as any other type of their potential, is characterized, in particular, by the following features:

- 1) the magnitude of this potential is not constant over time. It changes under the influence of various factors. Therefore, when assessing the potential for energy efficiency improvement, it is always necessary to fix in advance the time point at which this potential is assessed;
- 2) the magnitude of the energy efficiency improvement potential is determined, first of all, by the available and expected resources of the enterprise necessary for such improvement, as well as by the existing and expected future competences in managing these resources.
- 3) although the magnitude of the energy efficiency improvement potential is determined, first of all, by the factors of

Grouping of factors that affect the potential for increasing the energy efficiency of enterprises

Signs of grouping	Names of groups of factors
1. By location	1.1. Factors of the internal environment of enterprises
	1.2. Factors of the external environment of enterprises
2. By the nature of the influence	2.1. Factors that have a positive effect on the magnitude of the energy efficiency improvement potential
	2.2. Factors that negatively affect the potential for energy efficiency improvement
3. By the possibility of managing factors	3.1. Managed
	3.2. Uncontrolled
4. By place in the hierarchy	4.1. Factors of direct influence
	4.2. Factors determining the expected economic feasibility of implementing energy efficiency measures
	4.3. Factors characterizing the resource possibilities of implementation of measures to increase energy efficiency and restrictions on such implementation
5. Depending on the type of potential caused by the relevant factors	5.1. Factors determining the existing potential for increasing the energy efficiency of enterprises
	5.2. Factors determining the strategic (perspective) potential of increasing the energy efficiency of enterprises
6. By content	6.1. Technical and technological
	6.2. Production
	6.3. Economical
	6.4. Management
7. By sphere of influence	7.1. Factors affecting the potential for increasing the energy efficiency of the main activity of enterprises
	7.2. Factors that influence the magnitude of the energy efficiency improvement potential of auxiliary activities
	7.3. Factors affecting the potential for increasing the energy efficiency of service processes
8. By areas of increasing energy efficiency of enterprises	8.1. Factors affecting the potential for increasing energy efficiency by reducing energy consumption rates
	8.2. Factors affecting the potential for increasing energy efficiency by reducing specific constant (conditionally constant) energy consumption
	8.3. Factors affecting the potential for energy efficiency improvement due to changes in the structure of the company's production program
9. By the degree of variability over a certain period of time	9.1. Fixed factors (unchanged over a certain period of time)
	9.2. Partially variable (moderately changing over a certain period of time)
	9.3. Variable (changes a lot over a certain period of time)

the internal environment of the enterprises, the external environment of the companies' functioning can also have a significant impact on this magnitude. For example, under other constant conditions, a change in energy prices can affect the feasibility of implementing energy efficiency measures by enterprises and, accordingly, the potential for increasing energy efficiency of companies;

4) the implementation of the potential for increasing the energy efficiency of enterprises should ensure the maximum possible amount of financial and economic results from the implementation of relevant energy efficiency measures. In particular, such a result can be the net present value of the net cash flow of income from the implementation of energy-efficient projects.

Taking into account the above, the potential for increasing the energy efficiency of an enterprise should be understood as the ability it has at some point in time to implement such an increase, based on existing and expected future resources and competencies, as well as external environmental conditions, ensuring the maximum possible amount of financial and economic results from implementation of relevant energy-efficient measures. At the same time, the formation of the specified potential takes place under the influence of a significant number of various factors, which can be divided according to the following characteristics: by location; by the nature of the impact; according to the possibility of management; by place in the hierarchy; depending on the type of potential caused by the relevant factors; by content; by sphere of influence; by areas of increasing the energy efficiency of enterprises; according to the degree of variability over a certain period of time (Table 1).

Presented in Table 1, the classification of factors that affect the potential for increasing the energy efficiency of enterprises makes it possible to improve the processes of assessment and management of the specified potential. This is achieved both by choosing the most important factors included in each of their groups, and by establishing relationships between these factors. For this purpose, it is worth considering the double grouping of factors influencing the potential of energy efficiency improvement according to two features, namely, according to the place of the factors in their hierarchy and according to the content of the factors. As can be seen from the data given in Table 2, the process of forming the potential for increasing the energy efficiency of enterprises has a hierarchical nature. At the highest level of this hierarchy are factors that directly affect the value of the specified potential. These factors, in turn, are influenced by factors that determine the expected economic feasibility of implementing energy efficiency measures. The need to take these factors into account is due to the fact that for realizing the potential of energy efficiency improvement, it is important not only to have potential reserves for such an increase, but also the condition of proper economic efficiency of such implementation. After all, at the basic level of the hierarchy of factors for the formation of the potential for energy efficiency improvement, there are factors characterizing resource opportunities to implement measures to increase energy efficiency and restrictions on such implementation.

An overview of the factors that form the potential for increasing the energy efficiency of enterprises makes it possible to establish the conceptual basis for assessing the value of this potential. These principles are reflected, first of all, in the sequence of such an assessment, which for any enterprise should include the following actions:

1. Division of the energy consumption process at the enterprise into separate, relatively autonomous processes, each of which is affected separately by the implementation of energy-efficient measures. At the same time, such a division should be carried out both by the main types of enterprise activity (that is, by types of its products or by their groups), and in relation to auxiliary and service processes, the course of which takes place at this enterprise.

2. Collection of input information. At the same time, one should take into account the fact that the assessment of the

Division of factors affecting the magnitude of the energy efficiency improvement potential of the enterprise, by place in the hierarchy and by content

Groups of factors by place in their hierarchy	Examples of factors grouped by their content			
	Technical and technological factors	Production factors	Economic factors	Management factors
1. Factors of direct influence	Correlation between the existing rates of consumption of energy resources at the enterprise and optimal ones	The ratio between the actual and optimal natural volumes of production of the enterprise's products by its types, as well as between the actual and optimal volumes of auxiliary and service processes	Selling prices for the company's products by type	The level of competence of managers and specialists of the enterprise in matters of managing its operational activities
2. Factors determining the expected economic feasibility of implementing energy efficiency measures		Actual and optimal natural volumes of production of the company's products by its types; actual and optimal volumes of auxiliary and service processes	Current and forecast prices for energy resources, volumes of necessary investments in the implementation of energy-saving measures, the level of risk of the implementation of these measures	The level of competence of managers and specialists of the enterprise in matters of forming and implementing a program of measures to increase energy efficiency
3. Factors characterizing the resource possibilities of implementation of measures to increase energy efficiency and restrictions on such implementation	Energy consumption standards existing at the enterprise	The presence of the enterprise or the possibility of attracting the necessary personnel to work with energy-efficient types of equipment, technologies, etc	The presence of the enterprise or the possibility of additional attraction of the necessary amounts of financial resources; restrictions in demand for the company's products	The level of competence of managers and specialists of the enterprise in matters of resource provision for the implementation of measures to increase energy efficiency

potential for increasing the energy efficiency of the business entity should involve the solution of two interrelated tasks, namely: 1) formation of an optimal program of energy-efficient measures in relation to isolated autonomous processes of energy consumption; 2) determining the optimal intensity of each of these processes. In particular, with regard to the processes of the main activity of the enterprise, the intensity of their flow will be determined by the natural volumes of production per unit of time (for example, per year).

3. Construction of the objective function of energy consumption optimization. The specified function can describe the expected value of the net present value of the additional net cash flow received by the enterprise as a result of realizing the potential of increasing its energy efficiency. In this case the variables that this function should contain can be divided into three groups, namely: the level of intensity of each energy consumption process, energy efficiency measures and options for implementing these measures.

4. Building a system of resource restrictions, as well as other possible restrictions on the enterprise's implementation of energy-saving measures and on increasing the intensity of energy consumption processes. In particular, the restrictions of the second group may include both restrictions on the size of the enterprise's production capacity and the sales volumes of its products.

5. The solution of the corresponding model, which makes it possible to solve both the tasks set above in the second stage of actions. At the same time, such a solution makes it possible to optimize some other variables that directly affect the potential for increasing the energy efficiency of economic activity, in particular, the norms of energy consumption and the structure of the production program.

6. Calculation of generalizing indicators for assessing the potential for increasing the energy efficiency of the enterprise under study.

7. Identifying the possibilities of increasing the potential for increasing energy efficiency in the future. Such an increase can occur, in particular, due to the growth of the relevant production, financial and informational resources, as well as due to the improvement of the competence of the company's employees in matters of energy management.

Thus, one of the results of the implementation of the above sequence of actions should be the general value of the energy efficiency improvement potential of the enterprise under study. The specified value can be displayed both in absolute and relative terms. Accordingly, the following two generalizing indicators for assessing the potential for energy efficiency improvement can be distinguished

$$L_1 = R_1/E_1 - R_0/E_0; \quad (1)$$

$$L_2 = \frac{R_1 \cdot E_0}{R_0 \cdot E_1}, \quad (2)$$

where L_1 is the absolute value of the energy efficiency improvement potential of the enterprise under study; R_1, R_0 – the total value of the company's income for a certain period of time (for example, for a year), respectively, expected after the realization of the potential for increasing energy efficiency and the base; E_0, E_1 – the amount of consumption by the enterprise of a certain type of energy resources (or a set of such resources), respectively, basic and expected after realizing the potential for energy efficiency improvement; L_2 – the relative value of the energy efficiency improvement potential of the enterprise under study.

In addition to generalizing indicators for assessing the potential for increasing the energy efficiency of enterprises, it is advisable to distinguish two more groups of such indicators, namely: indicators for assessing the degree of influence of individual tools on the amount of energy efficiency potential and partial indicators characterizing individual factors of the formation of this potential. At the same time, it is possible to single out three main tools that ensure the realization of the potential of increasing energy efficiency: reducing the norms of direct consumption of energy resources, changing the structure of the production program of the enterprise, as well as changing specific constant (conditionally constant) energy costs. Therefore, it is possible to decompose the absolute value of the energy efficiency potential of the enterprise under study using the following formulas

$$L_1 = \Delta L_1 + \Delta L_2 + \Delta L_3; \quad (3)$$

$$\Delta L_1 = L_{11} - R_0/E_0; \quad (4)$$

$$\Delta L_2 = L_{12} - R_0/E_0; \quad (5)$$

$$\Delta L_3 = L_1 - \Delta L_1 - \Delta L_2, \quad (6)$$

where ΔL_1 , ΔL_2 , ΔL_3 are part of the absolute value of the energy efficiency potential of the enterprise under study, due to a decrease in the norms of direct consumption of energy resources, a change in the structure of the enterprise's production program, and a change in the specific constant (conditionally constant) energy consumption; L_{11} – the level of energy efficiency, calculated based on the basic values of all input indicators, except for data on the norms of direct consumption of energy resources, which are taken at the optimal level; L_{12} – the level of energy efficiency, calculated based on the basic values of all input indicators, except for data on the structure of the company's production program, which is taken at the optimal level.

It should be noted that each of the above-considered parts of the absolute value of the energy efficiency potential of the enterprise can be presented in relative terms, as a share of this value.

With regard to partial indicators for assessing the potential for energy efficiency improvement, these indicators should include the following:

1) the average level of the ratio between the optimal and actual value volumes of the company's products (I_1), which can be calculated according to the following formula

$$I_1 = R_1/R_0; \quad (7)$$

2) the average level of the ratio between the optimal and available amounts of energy consumption at the enterprise (I_2), which can be calculated according to the following formula

$$I_2 = E_1/E_0; \quad (8)$$

3) the share of energy-saving investment measures, the implementation of which turned out to be economically feasible, in the total number of such measures considered for the feasibility of implementation (I_3). This share can be calculated using the following formula

$$I_3 = N_2/N_1, \quad (9)$$

where N_2 is the number of energy-saving investment measures, the implementation of which turned out to be economically feasible; N_1 – the total number of energy-saving investment measures considered for feasibility of implementation;

4) the share of energy-saving investment measures, the implementation of which turned out to be possible (taking into account the available resource provision) in the total number of such measures, the implementation of which is economically feasible (I_4). This share can be calculated using the following formula

$$I_4 = N_3/N_2, \quad (10)$$

where N_3 is the number of energy-saving investment measures, the implementation of which turned out to be possible (taking into account the available resource provision);

5) the level of competence of managers and specialists of the enterprise in matters of forming and implementing a program of measures to increase energy efficiency (I_5). This level can be calculated using the following formula

$$I_5 = C_f/C_m, \quad (11)$$

where C_f is the actual level of competence of managers and specialists of the enterprise in matters of forming and implementing a program of measures to increase energy efficiency, determined in points based on the conducted survey; C_m – the maximum possible level of competence of managers and specialists of the enterprise in matters of forming and implementing a program of measures to increase energy efficiency in points.

In order to test the developed methodological principles for assessing the potential of increasing the energy efficiency of

enterprises, materials from the accounting, statistical and management records of a number of industrial companies in the western region of Ukraine were collected and processed. In addition to enterprise reporting, the results of a questionnaire survey of company managers were used to obtain input information. These firms belong to three rather energy-intensive types of economic activity (production of products from metal, glass, and clay, respectively). A preliminary sample of 80 randomly selected companies was formed for each of these three industries. After that, questionnaires were sent to each enterprise, and data from open sources were analyzed. In the end, taking into account the completeness of the collected data and the willingness of enterprises to provide them, the final sample of researched companies was formed, which consisted of 110 enterprises in all three industries.

At the same time, natural gas was chosen as an energy resource whose consumption efficiency was considered, since this type of energy carrier is quite intensively used by enterprises of the considered industries.

At the first stage of the empirical analysis, all studied enterprises were divided into three groups, namely, enterprises with a high level of energy efficiency (in which this level was in the range from 80 to 100 % of the maximum possible for each type of economic activity); those with an average level of energy efficiency (in which this level was in the range from 50 to 80 % of the maximum possible for each type of economic activity) and with a low level of energy efficiency (in which this level was less than 50 % of the maximum possible for each type of economic activity). As follows from the data presented in Table 3, for all types of economic activity, more than half of the enterprises are characterized by a low level of energy efficiency for natural gas.

In order to find out the reasons for the low energy efficiency of most of the studied companies, data on the number of energy-efficient natural gas investment projects implemented by enterprises in previous years was collected and processed. As can be seen from the data presented in Table 4, the number of such projects per enterprise was: for enterprises producing metal products – 0.75; for enterprises producing glass products – 0.69; for enterprises producing clay products – 0.78. Therefore, the average value of this ratio is quite low.

Using the sequence proposed above for assessing the potential for increasing the energy efficiency of enterprises and applying formulas (1–11), a number of indicators were calculated, the averaged numerical values of which are presented in Table 5.

As can be seen from the data in Table 5, according to most indicators, the average level of potential for increasing energy efficiency for natural gas of the studied enterprises is quite high. In particular, the average relative value of this potential is: for enterprises producing metal products – 1.46; for enterprises producing glass products – 1.34; for enterprises producing clay products – 1.59. At the same time, as follows from the data in Table 6,

Table 3

Division of the studied enterprises according to the level of energy efficiency of their activities for natural gas in 2023

Energy efficiency levels of enterprises	Data on enterprises that manufacture products					
	Made of metal		Made of glass		Made of clay	
	Number of enterprises	%	Number of enterprises	%	Number of enterprises	%
Low	20	62.50	28	58.33	25	62.50
Average	9	28.13	12	25.00	10	25.00
High	3	9.38	8	16.67	5	12.50
Total	32	100.00	48	100.00	40	100.00

Table 4

Data on the implementation of energy-efficient natural gas investment projects during 2018–2022

Indicator names	Data on enterprises that manufacture products		
	Made of metal	Made of glass	Made of clay
1. The total number of energy-efficient natural gas investment projects that were reconsidered for their implementation	58	81	87
2. Actually implemented projects	24	33	31
3. The share of projects that were implemented in the total number of projects that were considered, %	41.38	40.74	35.63
4. The average number of implemented projects per enterprise	0.75	0.69	0.78

for all three types of economic activity, most of the studied companies are characterized by a high relative level of the potential for increasing energy efficiency (the division of companies into groups according to this level took place on the same scale as their division according to current energy efficiency).

Of particular interest may be the results of the study of the influence of individual factors on the relative value of the potential for increasing energy efficiency by natural gas at the studied enterprises. Two such factors were considered: the price of natural gas and the level of competence of managers and specialists of enterprises in matters of forming and implementing a program of measures to increase energy efficiency. The results of the assessment of the impact of these two factors on the relative value of the potential for increasing energy efficiency by natural gas at the studied enterprises are presented, respectively, in Tables 7 and 8.

As can be seen from the data in Table 7, with the increase in natural gas prices to a certain limit, the average relative value of the energy efficiency improvement potential increases. At the same time, after reaching this limit, the specified potential begins to decrease. This is explained by the fact that the too strong increase in natural gas prices does not make it possible to fully offset the costs of energy consumption through the implementation of energy efficiency measures. Accordingly, the operating costs of enterprises are increasing and profits are decreasing, which negatively affects the ability of companies to finance energy-efficient investment projects.

With regard to the impact on the relative value of the potential for increasing energy efficiency, the level of competence of managers and specialists of enterprises, as follows from the data in Table 8, the specified level is lower at enterprises with a higher relative value of this potential. Therefore, with an increase in the level of competence, the potential for increasing energy efficiency decreases, that is, the presence of qualified and experienced management personnel is a factor that positively affects the realization of this potential in previous periods. At the same time, it should be noted that the use of the one-factor variance analysis method proved the statistical significance of the described dependence, since the actual value of the F-criterion for all groups of enterprises exceeds its critical value with a significance level of $\alpha = 0.05$.

Conclusions. As the research has shown, under the potential of increasing the energy efficiency of an enterprise's activity, it should be understood as the ability it has at some point in time to achieve such an increase, based on existing and expected future resources and competencies, as well as external environmental conditions, ensuring the maximum possible amount of financial and economic results from the implementation of appropriate energy-efficient measures.

The formation of the specified potential occurs under the influence of a significant number of various factors, which can be

Table 5

Values of indicators for assessing the potential for increasing energy efficiency for natural gas averaged by enterprises of each industry as of the end of 2023

Indicator names	Averaged values of indicators by enterprises that manufacture products		
	Made of metal	Made of glass	Made of clay
1. The absolute value of the energy efficiency improvement potential, hryvnias/m ³	0.35	0.28	0.41
2. The relative value of the energy efficiency improvement potential	1.46	1.34	1.59
3. The share in the absolute value of the energy efficiency improvement potential is caused by:			
3.1. By reducing the norms of direct consumption of energy resources, %	78.12	74.25	81.44
3.2. By changing the structure of the company's production program, %	19.31	22.65	17.13
3.3. Change in specific constant (conditionally constant) energy consumption, %	2.57	3.10	1.43
4. The average level of the ratio between the optimal and actual production volumes of the company's products	1.12	1.09	1.15
5. The average level of the ratio between the optimal and available volumes of energy consumption at the enterprise	0.61	0.68	0.55
6. The share of energy-saving investment measures, the implementation of which turned out to be economically feasible in the total number of such measures considered for the feasibility of implementation, %	66.49	59.12	70.57
7. The share of energy-saving investment measures, the implementation of which turned out to be possible (taking into account the available resource provision) in the total number of such measures, the implementation of which is economically expedient, %	75.43	81.94	71.50
8. The level of competence of managers and specialists of the enterprise in matters of forming and implementing a program of measures to increase energy efficiency	0.57	0.64	0.59

Table 6

Division of the studied enterprises by the level of potential for increasing the energy efficiency of their natural gas activities as of the end of 2023

Levels of energy efficiency improvement potential	Data on enterprises that manufacture products					
	Made of metal		Made of glass		Made of clay	
	Number of enterprises	%	Number of enterprises	%	Number of enterprises	%
Low	5	15.63	7	14.58	6	15.00
Average	8	25.00	11	22.92	7	17.50
High	19	59.38	30	62.50	27	67.50
Total	32	100.00	48	100.00	40	100.00

Table 7

The results of the assessment of the impact of the change in the price of natural gas on the relative value of the potential for increasing the energy efficiency of natural gas at the studied enterprises

Possible values of the index of changes in the price of natural gas compared to its value as of the end of 2023	Averaged values of the relative potential of increasing energy efficiency for natural gas by enterprises that manufacture products		
	Made of metal	Made of glass	Made of clay
1.00	1.46	1.34	1.59
1.25	1.51	1.43	1.72
1.50	1.53	1.47	1.76
1.75	1.49	1.40	1.68
2.00	1.31	1.18	1.33

Table 8

The results of evaluating the influence of the competence of managers and specialists of enterprises on the relative value of the potential for increasing energy efficiency by natural gas at the enterprises under study

Indicator names	Averaged values of indicators by enterprises that manufacture products		
	Made of metal	Made of glass	Made of clay
1. The level of competence of managers and specialists in matters of forming and implementing a program of measures to increase energy efficiency for those enterprises that have a relative potential for increasing energy efficiency:			
1.1. Low	0.79	0.85	0.82
1.2. Average	0.69	0.78	0.75
1.3. High	0.51	0.57	0.54
2. Actual F-test values	5.93	6.14	6.45

divided according to the following characteristics: by location; by the nature of the impact; according to the possibility of management; by place in the hierarchy; depending on the type of potential caused by the relevant factors; by content; by sphere of influence; by areas of increasing the energy efficiency of enterprises; by the degree of variability over a certain period of time.

Regarding the assessment of the potential for increasing the energy efficiency of enterprises, it is necessary to ensure the simultaneous solution of two tasks, namely: 1) to form an optimal program of energy-efficient measures in relation to individual energy consumption processes; 2) determine the optimal intensity of each of these processes. With regard to indicators for evaluating the potential for energy efficiency improvement, they form a certain system consisting of three groups of indicators: general indicators, indicators of the influence of individual factors on the potential for energy efficiency improvement, and partial indicators. The last indicators give quantitative characteristics to individual factors that determine the value of the specified potential.

In order to carry out an empirical analysis, data was collected at 110 Ukrainian enterprises that produce metal, glass and clay products. The conducted research showed, in particular, that for all types of economic activity, more than half of the enterprises are characterized by a low level of energy efficiency for natural gas. At the same time, according to most indicators, the average level of the potential for increasing en-

ergy efficiency for natural gas of the studied enterprises is quite high. In particular, the average relative value of this potential is: for enterprises producing metal products – 1.46; for enterprises producing glass products – 1.34; for enterprises producing clay products – 1.59. Also, for all three types of economic activity, most of the studied companies are characterized by a high relative level of energy efficiency improvement potential. In addition, it was established that with the increase in natural gas prices up to a certain limit, the average relative value of the potential for increasing energy efficiency by enterprises increases. At the same time, after reaching this limit, the specified potential begins to decrease. With regard to the impact on the relative value of the energy efficiency improvement potential of the level of competence of managers and specialists of enterprises, the specified level is lower in enterprises with a higher relative value of this potential. Therefore, with an increase in the level of competence, the potential for increasing energy efficiency decreases, that is, the presence of qualified and experienced management personnel is a factor that positively affects the realization of this potential in previous periods.

Further research on the topic of the article should include an assessment of the impact of resource provision on the formation and realization of the potential for increasing energy efficiency at enterprises. Such an assessment would make it possible to identify additional reserves for intensifying the implementation of energy-saving measures by companies.

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Інноваційні підходи до оцінювання потенціалу енергоефективності на підприємствах

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Мета. Виділення чинників формування й розроблення показників оцінювання потенціалу підвищення енергоефективності на підприємствах.

Методика. У процесі дослідження використані методи: економіко-математичного моделювання (при розробленні показників оцінювання потенціалу підвищення енергоефективності на підприємствах); групування та узагальнення (при здійсненні класифікації чинників формування потенціалу підвищення енергоефективності діяльності компаній); системного аналізу (при встановленні характерних рис потенціалу підвищення енергоефективності й дослідженні механізму його формування).

Результати. Встановлені характерні риси й визначено зміст потенціалу підвищення енергоефективності. Здійснене групування чинників формування цього потенціалу. Запропоновані методологічні засади його оцінювання, зокрема розроблена низка показників, за допомогою яких можливо отримати повне і всебічне уявлення про можливість підприємств підвищувати свою енергоефективність. За вибіркою 110 українських підприємств оцінено наявний у них потенціал підвищення енергоефективності за природним газом. Встановлено вплив окремих чинників на величину цього потенціалу.

Наукова новизна. Уточнене поняття «потенціал підвищення енергоефективності». Набули подальшого розвитку способи групування чинників, що впливають на величину потенціалу підвищення енергоефективності на підприємствах шляхом виділення нових класифікаційних ознак, а саме: за місцем розташування; за характером впливу; за можливістю керування; за місцем у ієрархії; залежно від виду потенціалу, який обумовлюють відповідні чинники; за змістом; за сферою впливу; за напрямками підвищення енергоефективності діяльності підприємств; за ступенем мінливості. Удосконалені методичні засади оцінювання потенціалу підвищення енергоефективності діяльності підприємств, які, на відміну від існуючих, передбачають вирішення у процесі такого оцінювання одночасно двох завдань, а саме: 1) формування оптимальної програми енергоефективних заходів у прив'язці до виокремлених процесів енергоспоживання; 2) визначення оптимальної інтенсивності перебігу кожного з цих процесів.

Практична значимість. Отримані результати можуть бути використані підприємствами при оцінюванні потенціалу підвищення енергоефективності їхньої діяльності та при формуванні інформаційного забезпечення управління енергозбереженням.

Ключові слова: підприємство, потенціал, енергоефективність, енергоефективний захід, енергозбереження, природний газ

The manuscript was submitted 15.06.24.