The object of this study is the evaluation and implementation of the potential of energy-saving economic development of enterprises. The task to design an effective toolkit for evaluating and implementing the specified potential was resolved.

The theoretical principles of formation and measurement of the level of energy-saving economic development of enterprises have been substantiated. A procedure for assessing the potential of energy-saving economic development of companies has been devised. This procedure involves determining the possibilities of enterprises to ensure simultaneous growth of economic results and the level of energy efficiency through the development and implementation of an optimal program of measures for such growth. The mechanism for implementing the potential of energy-saving economic development of enterprises on the basis of identifying and overcoming the main obstacles that appear on the way to such development has been improved.

The proposed theoretical and methodological approaches to the assessment and implementation of the potential of energy-saving natural gas economic development of enterprises was verified on a sample of 110 enterprises in the western region of Ukraine. In particular, it was established that the estimated potential of energy-saving natural gas economic development of the studied enterprises is very high. In particular, for more than 50 % of enterprises in all three industries, the value of this potential exceeds 6 %. At the same time, enterprises with a higher level of energy-saving economic development in the reporting period were characterized by a smaller value of this potential at the end of that period.

The toolkit proposed in this study could be used by enterprises of all types of economic activity when assessing the potential of their energy-saving economic development and when devising measures to implement the specified potential. This would help improve the economic efficiency of companies

Keywords: energy-saving economic development, development potential, energy efficiency, obstacle to energy saving, gas saving

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DESIGNING A TOOLSET FOR ASSESSING AND IMPLEMENTING THE POTENTIAL OF ENERGY-SAVING ECONOMIC DEVELOPMENT OF ENTERPRISES

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1. Introduction

One of the most important tasks faced by governments, enterprises, and households in many countries of the world is to reduce the consumption of non-renewable energy resources. The need to solve this problem is caused by a whole range of reasons. The most important of them are the significant level of carbon emissions [1], the instability of prices for fossil energy resources [2], the low competitiveness of certain sectors of the economies of a number of countries due to the high level of energy intensity [3], etc. After all, a strong reason that prompts the governments of many countries to implement energy-saving policies is the desire to increase energy independence [4]. This aspiration has especially intensified against the background of large-scale military operations in Ukraine, which, among other things, have led to the destruction of a significant number of logistics chains and significantly reduced the economic stability of many importing countries [5].

Therefore, the need to solve the problem of energy transition seems indisputable. Such a solution requires, in particular, the implementation of measures to increase energy efficiency [6] and the replacement of non-renewable energy sources with renewable ones [7]. Among the main objects for the implementation of these measures, worth mentioning are enterprises, especially those of them that belong to energy-intensive types of economic activity [8].

At the same time, in addition to reducing the consumption of energy resources by enterprises, the economies of many countries face other important tasks. One of these tasks is ensuring economic growth and, as a result, improving the welfare of the population. Solving this task requires an increase in the scale of enterprises' activities, which, quite likely, can lead to an increase in the consumption of

non-renewable energy resources by companies. Thus, there is a problem of a contradiction between the need to reduce the consumption of fossil energy resources and the need to observe the appropriate rates of economic growth. Solving this problem should involve decoupling economic growth from the process of energy consumption at enterprises. Such disconnection is possible only on the basis of the transition of business entities to energy-saving economic development. Under this type of development, the economic growth of enterprises is accompanied by a gradual reduction in their consumption of certain types of non-renewable energy resources.

The complexity of the task of transition to energy-saving economic development at the level of enterprises predetermines the objective need to devise scientifically based theoretical and methodological foundations for solving this task. In the process of such development, it is necessary to investigate, in particular, two issues. First, it is necessary to find out the possibility of devising an effective method for assessing the potential of energy-saving economic development of enterprises. Secondly, it is necessary to form an effective mechanism for the implementation of technical and technological, organizational, and other measures to implement the energy-saving economic development potential of enterprises. This implies that both solving the issue of evaluating the potential of energy-saving economic development of companies and solving the task of forming a mechanism for implementing this potential require researchers to design appropriate tools.

Therefore, it is a relevant task to carry out studies on designing the tools for evaluating and implementing the potential of energy-saving economic development of enterprises.

2. Literature review and problem statement

Issues of assessment and management of various types of economic potential of enterprises were considered in a significant number of scientific works. In particular, work [9] considered the regularities of the formation of investment opportunities of enterprises in relation to the means of implementation of these opportunities. Study [10] presents a toolkit for evaluating the innovative potential of enterprises using mathematical modeling methods. In [11], the ability of enterprises to implement advanced technological processes was studied and evaluated. However, in works [9–11] insufficient attention is paid to the issue of energy saving potential formation at enterprises. This may be due to the fact that the specified question was beyond the scope of relevant research. At the same time, this issue is studied in sufficient detail in [12, 13]. Worth noting is work [14], which identified and analyzed the potential of sustainable technologies in synergy with Industry 4.0 innovations and renewable energy initiatives in production and logistics. At the same time, works [12–14] did not set the goal of designing a toolkit for evaluating and managing the potential of energy-saving economic development of enterprises. Therefore, accordingly, the problem of such development is not solved in those works.

However, the relationship between economic growth and energy consumption is considered in sufficient detail in current scientific works. It should be noted that the results of such consideration, obtained by different authors, are to some extent contradictory. For example, in [15], based on a sample of member states of the Organization for Economic Cooperation and Development, it was established that relationships between economic growth and energy consumption exist both in the short-term and in the long-term. At the same time, according to the results reported in [16], in which the impact of natural gas consumption on the economic development of twelve European countries was assessed, the presence of this impact was found only in the long term. On the other hand, analysis of the processes of natural gas consumption and economic development in China and Japan performed in [17] demonstrated the ambiguity of the dependence between these processes. Moreover, in [18], for some countries of the Persian Gulf, an inverse relationship between the volumes of natural gas consumption and the growth rates of the gross domestic product was found. At the same time, in all four papers described above, insufficient attention was paid to evaluating the impact of replacing renewable energy sources with non-renewable ones on indicators of economic dynamics. This may be due to the fact that the authors of those works did not set a task for such an assessment. However, the specified task was solved in some other scientific studies. At the same time, both the nature and the scale of the impact of replacing renewable energy sources with non-renewable ones on economic dynamics currently remain incompletely established. In part, this can be explained by the fact that predicting trends in the amount of consumption of renewable energy sources is not an easy task [19]. At the same time, only for some countries and regions was the presence of a statistically significant influence of renewable energy on the rate of economic growth found. In particular, the authors of work [20] found the presence of the specified influence only for 57 % of the 38 considered states. Similar results were reported in [21]. The authors of the work, in which the countries of the Black Sea and Balkan regions were studied, found that the impact of renewable energy on economic growth is inherent only to some of these countries, in particular, to Ukraine. However, in all the works reviewed above, the task of establishing the conditions under which energy-saving economic development can take place was not solved. In part, this can be explained by the fact that the authors of those works did not introduce the concept of such a development.

A certain formalization of the conditions under which energy-saving economic development can occur at the level of national economies is presented in [22]. At the same time, in this work, as in [15–21], the relationship between energy consumption and economic growth was considered in an aggregated form, that is, the level of individual consumers of energy resources, in particular the level of individual companies, was not investigated. Regarding the level of individual enterprises, the conditions of their energy-saving economic development are presented in sufficient detail in [23]. However, there are practically no results of assessing the potential of such development. This, in turn, is largely due to the lack of effective tools for such assessment.

In general, assessing the potential of energy-saving economic development of companies should be considered a prerequisite for the development and implementation of measures to implement this potential. In turn, the formation of a program of these measures can be carried out, aiming at overcoming obstacles that appear on the way to energy-saving economic development of enterprises. At the same time, special attention should be paid to the obstacles that stand in the way of increasing the energy efficiency of economic activity [24].

It should be noted that the scientific literature presents a number of different approaches to overcoming obstacles in the implementation of energy-saving measures. In particular, [25] notes the importance of proper information support for the implementation of these measures. In [26], a detailed structuring of this provision of the specified provision for the case of implementation of energy-saving technological changes at enterprises is carried out. In [27], it was proved that in order to increase the energy efficiency of enterprises, it is necessary not only to properly provide them with input information but also to have company managers have the skills to process information. However, the subject matter of the works reviewed above [24–27], which tackle the problem of overcoming obstacles in the implementation of energy-saving measures, did not involve a detailed study of the laws of overcoming such obstacles as financial ones.

At the same time, some other scientists pay attention to such a means of overcoming obstacles that stand in the way of energy saving at enterprises, such as providing companies with the appropriate amount of financial resources, in particular credit [28]. Also, as noted in [29], subsidy programs can play an important role in financial support for the implementation of energy-saving measures. However, the authors of works [28, 29], within the scope of the research questions outlined by them, did not foresee a detailed study of the technical and organizational means of overcoming the barriers to increasing the energy efficiency of enterprises. At the same time, these tools are considered in sufficient detail in other scientific publications. Thus, in [30], to ensure the acceleration of the energy saving process, it is suggested to improve energy audit techniques. In [31], among other things, the importance of digitalization for stimulating energy-saving technological changes in enterprises is substantiated. An interesting approach to justifying the mechanisms for overcoming obstacles that arise during the implementation of energy-saving projects in industrial firms is presented in [32]. This approach aims to find the weakest link of the four elements of energy management, which are motivation, capability, implementation, and results.

In general, in modern scientific literature, quite a lot of publications address the issue of overcoming obstacles that appear on the way to increasing energy efficiency, and the proposed mechanisms for such overcoming are quite effective and well-founded. At the same time, the influence of the recommendations developed by them regarding overcoming the barriers that arise during the implementation of energy-saving projects on ensuring the implementation of the potential of energy-saving economic development of enterprises remains outside the consideration of scientists. One of the reasons for this may be that researchers have not paid enough attention to establishing the place of this potential in the aggregate economic potential of companies.

So, in the literature there are quite a lot of works reporting studies into the relationship between energy consumption and economic growth. On the other hand, scientists have devised a number of mechanisms for increasing the energy efficiency of enterprises, which, as noted in particular in [22, 23], is an important condition for achieving energy-saving economic development of business entities. However, the problem of assessing and implementing the potential of such development remains unsolved. Considering the significant relevance of this issue, the solution of which will contribute to the combination of economic growth of companies with a reduction in their consumption of non-renewable energy resources, there is a need for further research into this area.

3. The aim and objectives of the study

The goal is to design a toolkit for assessing and implementing the potential of energy-saving economic development of enterprises. This will make it possible to identify reserves for ensuring the economic growth of companies in combination with a reduction in their use of fossil energy resources, which, in turn, will contribute to increasing energy efficiency and improving the environmental situation.

To achieve the goal, the following tasks were set:

– to substantiate the theoretical principles of formation and measurement of the level of energy-saving economic development of enterprises;

– to devise a procedure for quantitative assessment of the potential of energy-saving economic development of enterprises;

– to propose a mechanism for implementing the potential of energy-saving economic development of enterprises on the basis of overcoming obstacles that appear on the way to such development;

– to verify the designed toolkit for assessing and implementing the potential of energy-saving economic development of enterprises based on a sample of Ukrainian companies.

4. The study materials and methods

The object of our study is the assessment and implementation of the potential of energy-saving economic development of enterprises. The main hypothesis of this study assumes the presence of this potential in a significant number of enterprises.

The theoretical basis of this study was the works tackling the assessment of the economic potential of enterprises, the implementation of energy-saving measures and ensuring the economic development of business entities.

During the empirical analysis, statistical, accounting and management accounting materials of a number of industrial enterprises were collected and processed. In addition to the reporting of companies, the results of a questionnaire survey of owners and managers of enterprises were used to obtain input information. These enterprises belong to three rather energy-intensive branches of industry (production of products from metal, glass, and clay, respectively). For each of these three types of economic activity, a preliminary sample of 80 randomly selected companies in the western region of Ukraine was formed. 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.

Various methods of scientific knowledge were used in the research process. In particular, when devising a method for assessing the potential of energy-saving economic development of business entities, economic and mathematical modeling was applied. The need for such modeling is due to the complexity of the formation of the specified potential, which requires the formalization of the influence of the factors that determine its value.

When justifying the theoretical foundations of formation and measurement of the level of energy-saving economic

development of enterprises, methods of grouping and generalization were used. The application of these methods made it possible to identify the types of relationship between the dynamics of the economic results of enterprises and changes in their energy consumption, as well as to establish an indicator of the level of energy-saving economic development of business entities.

In order to design a mechanism for implementing the potential of energy-saving economic development of enterprises, the method of system analysis was used. The expediency of using this method is due to the need to systematize ways to overcome obstacles that arise when business entities transition to energy-saving economic development.

When carrying out empirical studies on the potential of energy-saving economic development of enterprises, the methods of economic analysis and technical and economic calculations were applied. The questionnaire survey method was used to conduct the survey at enterprises. In order to process the results, the methods of mathematical statistics are used, in particular, one-factor variance analysis [33]. In addition, the method of quantitative assessment of the potential of energy-saving economic development of enterprises, devised in this work, was used when conducting empirical research.

Graphical and tabular methods were used to visually display the results obtained in the course of the research.

When discussing these results, as well as for the purpose of their generalization, the abstract-logical method was used in the process of forming conclusions. That made it possible to highlight the most significant results of our research, to identify the reasons that led to the specified results, and to outline possible directions for further study of the issues under consideration.

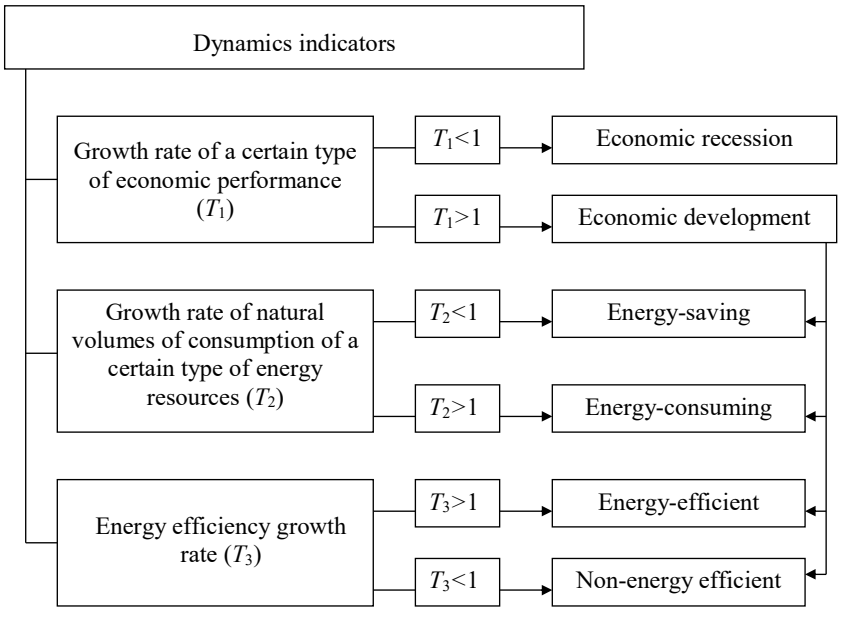

Fig. 1. Types of correlations between the dynamics of the economic results of the company's activity and the change in its consumption of a certain type of energy resources

5. Results of investigating the toolkit for assessing and implementing the potential of energy-saving economic development of enterprises

5. 1. Justification of the theoretical foundations of formation and measurement of the level of energy-saving economic development of enterprises

Considering the regularities in the formation of energy-saving economic development of enterprises, it is worth establishing the place of this type of economic development among other types of correlations between the dynamics of the economic results of the enterprises and the change in their energy consumption. For this purpose, the following indicators should be identified: the rate of growth of a certain type of economic results of enterprises, the rate of growth of natural volumes of their consumption of a certain type of energy resources, and the rate of growth of the energy efficiency indicator. Comparing the values of these indicators with unity, it is possible to identify the types of relationships between the dynamics of the economic results of the subjects' activities and the change in their energy consumption (Fig. 1).

Thus, as follows from Fig. 1, in order for energy-saving economic development to take place at some enterprise, two conditions must be met, namely:

1. The growth rate of a certain type of economic results of the enterprise must be greater than unity, i.e.:

$$T_1 = \frac{R_1}{R_0} > 1, \quad (1)$$

where T_1 is the rate of growth of a certain type of economic results of the enterprise; R_1, R_0 – the value of this type of results at this enterprise, respectively, in the reporting and base periods.

2. The rate of growth of natural volumes of consumption by an enterprise of a certain type of energy resources must be less than unity, i.e.:

$$T_2 = \frac{E_1}{E_0} = \frac{T_1}{T_3} = \frac{R_1 / R_0}{e_1 / e_0} < 1, \quad (2)$$

where T_2 is the growth rate of natural volumes of consumption by the enterprise of a certain type of energy resources; E_1, E_0 – natural volumes of consumption by the enterprise of this energy resource, respectively, in the reporting and base periods; T_3 – the rate of growth of the energy efficiency indicator of the enterprise's activity by the corresponding type of energy resources; e_1, e_0 – energy efficiency of the enterprise's activity by the corresponding type of energy resources, respectively, in the reporting and base periods (the ratio of the value of a certain type of economic results to the natural volumes of consumption of a certain energy resource).

From expressions (1) and (2), the following chain of inequalities is derived, which describes the necessary and sufficient conditions for ensuring the energy-saving economic development of the enterprise according to the corresponding type of energy resources:

$$1 < T_2 < T_3. \quad (3)$$

Thus, in order for energy-saving economic development to take place at the enterprise, the growth rate of a certain type of economic results of activity must exceed unity but be less than the growth rate of energy efficiency.

In addition to knowing the conditions for ensuring energy-saving economic development of enterprises, assessing the potential of such development requires a method for assessing the level of this development. Then the task of assessing the potential of energy-saving economic development of companies can be reduced to forecasting the level of this development. In turn, it is worth highlighting the methods of qualitative and quantitative assessment of the specified level.

Qualitative assessment of energy-saving economic development of enterprises requires preliminary construction of scales for two indicators, namely:

1) for the relative growth of a certain type of economic results of the enterprise. The value of this indicator is the difference between the rate of growth of the value of these results and unity;

2) for a relative reduction in the company's consumption of a certain energy resource. The value of this indicator is the difference between unity and the growth rate of the company's consumption of this energy resource.

At the same time, each of the scales must be divided into the same number of ranges. For example, for the first of the indicators listed above, cases of low, medium, and high growth of economic results can be distinguished. On the other hand, for the indicator of the relative decrease in energy resource consumption, it is possible to distinguish cases of low, medium, and high decrease in these volumes. Then the qualitative level of energy-saving economic development of a certain enterprise (low, medium, or high) will be determined by the qualitative characteristic of the one of these two indicators according to which this characteristic is the smallest.

It should be noted that the length of the ranges for one and the same qualitative level of these indicators may differ by them. For example, let this length be greater for the rate of growth of economic results of activity. Then this means that the significance of an increase by a certain percentage of the value of this indicator is less than the significance of a decrease by the same percentage of the energy resource consumption. Therefore, it is possible to introduce into consideration the coefficient of significance of the indicator of the relative decrease in energy consumption in comparison with the relative indicator of the growth of the economic results of the enterprises. Using this coefficient, it is possible to establish a quantitative assessment of the energy-saving economic development of a certain enterprise. For this purpose, it is worth applying the following formula:

$$l = \min\left\{T_1 - 1, (1 - T_2)\cdot\alpha\right\}, \quad (4)$$

where l is the level of energy-saving economic development of a certain enterprise; α is the coefficient of significance of the indicator of the relative decrease in energy consumption in comparison with the relative indicator of the growth of economic results of enterprises.

It should be noted that if the coefficient α is less than unity, it means that the relative indicator of the growth of economic results of enterprises is more significant than the indicator of the relative decrease in energy consumption. And, conversely, if the coefficient α is greater than unity, it means that the relative indicator of the growth of the economic results of enterprises is less significant than the indicator of the relative decrease in energy consumption. At the same time, the value of the coefficient can be estimated both on the basis of an expert survey and by analyzing empirical data for previous periods. In the latter case, it is necessary to compare the average values of the indicators of the growth of the economic results of the companies under study and the relative decrease of their energy consumption for a sample of enterprises.

5. 2. Procedure for assessing the potential of energy-saving economic development of enterprises

Qualitative and quantitative assessment of the potential of energy-saving economic development of companies can be performed both on the basis of retrospective data of previous periods and on future time periods. In particular, in relation to the second case, we may be talking about assessing the potential of energy-saving economic development of enterprises. At the same time, it is necessary to take into account the presence of a number of varieties of the specified potential. Among these varieties worth highlighting first of all are the following:

– by changing the types of products manufactured by the enterprise: current and prospective potential. When evaluating the prospective potential of energy-saving economic development, unlike the current one, the possibility of new types of products appearing in the company's product range and the withdrawal of some existing types of products from production is assumed;

– by the maximum number of energy-saving projects, which can be implemented at the enterprise, if necessary, for each type of product: single-project and multi-project. In particular, the multi-project potential refers to the case when a number of separate technological processes need to be performed for the production of a certain type of product by an enterprise, each of which is possible in principle to carry out an energy-saving upgrade;

– by the number of energy resources of the enterprise under consideration: energy-saving potential for one type of energy resources of economic development and energy-saving potential for several types of energy resources of economic development.

At the same time, the assessment of the energy-saving economic development potential of economic entities should be based on the application of an optimization approach. This approach requires the application of a model that includes an objective function and resource constraints. Such a function can be the expected value of the excess profit of the enterprise (the difference between the expected profit and the profit of the required investments at the rate of their profitability) after the implementation of measures to improve energy efficiency and increase economic results. As for resource restrictions, the most important of them is the restriction on the total amount of investment resources that the company can use to finance the mentioned measures [34].

Taking into account the above, the model for evaluating the potential of energy-saving economic development of a current single-project energy-saving enterprise based on a certain type of energy resources will take the following formalized form:

$$W = \sum_{i=1}^{n}\left(\left(n_{0i} - n_{1i}\right)\cdot\left(Q_{0i} + \sum_{j=1}^{m}\Delta Q_{ij}\right) - C_i\right) +$$
$$+\sum_{j=1}^{m}\Delta Q_{ij}\cdot p_i - C_{ij} - N\cdot\sum_{i=1}^{n}\left(Q_{0i} + \sum_{j=1}^{m}\Delta Q_{ij}\right)\cdot k_i -$$
$$-N\cdot\sum_{j=1}^{m}\Delta Q_{ij}\cdot k_{ij} \to \max; \quad (5)$$

$$\sum_{i=1}^{n}\left(Q_{0i}+\sum_{j=1}^{m}\Delta Q_{ij}\right)\cdot k_i+\sum_{j=1}^{m}\Delta Q_{ij}\cdot k_{ij}\le I, \quad (6)$$

where W is the expected excess profit from the implementation of measures to increase energy efficiency and increase the economic results of the enterprise; n – the number of types of products of the enterprise; n_{0i}, n_{1i} – the rate of expenditure of this type of energy resources for the production of a unit of the i-th type of product in accordance with and after the implementation of energy efficiency improvement measures; Q_{0i} – basic volume of production by the enterprise of the i-th type of products; m – the number of types of measures to increase production and sales of the company's products; ΔQ_{ij} – the expected increase in production and sales volumes of the i-th type of product after the implementation of the j-th event; C_i – additional current expenses related to the implementation of energy efficiency improvement measures for the i-th type of product; p_i – profitability of the i-th type of production; C_{ij} – additional current expenses and losses associated with the implementation of the j-th measure to increase production and sales of the ith type of enterprise products; N is the rate of return on investments in units; k_i – specific investments in the implementation of energy efficiency improvement measures for the i-th type of product; k_{ij} – specific investments in the implementation of the j-th measure to increase production and sales of the i-th type of the company's products; I is the general limit of the amount of investment resources of the enterprise for the implementation of measures to increase energy efficiency and increase the volume of production and sales of the enterprise's products.

With regard to the measures to increase the volume of production and sales of the company's products, data about which appear in expressions (5) and (6), these measures should include, first of all, the following:

1) optimization of the volume of production of each type of product, which maximizes the amount of operating profit from the sale of this product;

2) increasing the volume of production and sales of products on the basis of entering new markets for such sales;

3) formation and improvement of sales channels;

4) stimulation of product sales.

Thus, assessing the potential of energy-saving economic development of enterprises is a rather complex task, the solution of which requires the implementation of a certain sequence of actions. The indicated sequence is shown in Fig. 2.

As can be seen from the diagram shown in Fig. 2, assessing the potential of energy-saving economic development of the enterprise requires a preliminary determination of the value of two varieties of this potential. These varieties are the potential for growth in the volume of production and sales of products, as well as the potential for increasing energy efficiency. Then, at the final stage, a joint consideration of the possibilities of increasing sales and production of the company's products and its ability to increase energy efficiency is required. This need is caused both by the presence of resource limitations and by the possible impact of increasing energy efficiency on the size of the company's sales opportunities. Then the final result of the sequence of actions shown in Fig. 2 will be the quantitative value of the energy-saving economic development potential of the enterprise, calculated according to expression (4) taking into account the developed programs of measures. At the same time, performing such calculations based on a sample of enterprises of a certain type (types) of economic activity will make it possible to obtain information about the size of the opportunities of the relevant industry (industries) to ensure their energy-saving economic development. The specified information will be valuable not only for the owners and managers of the investigated enterprises but also for the state authorities and local governments. In particular, the results of the assessment of the potential of energy-saving economic development will be important for the development of national and regional programs and strategies in the field of energy saving.

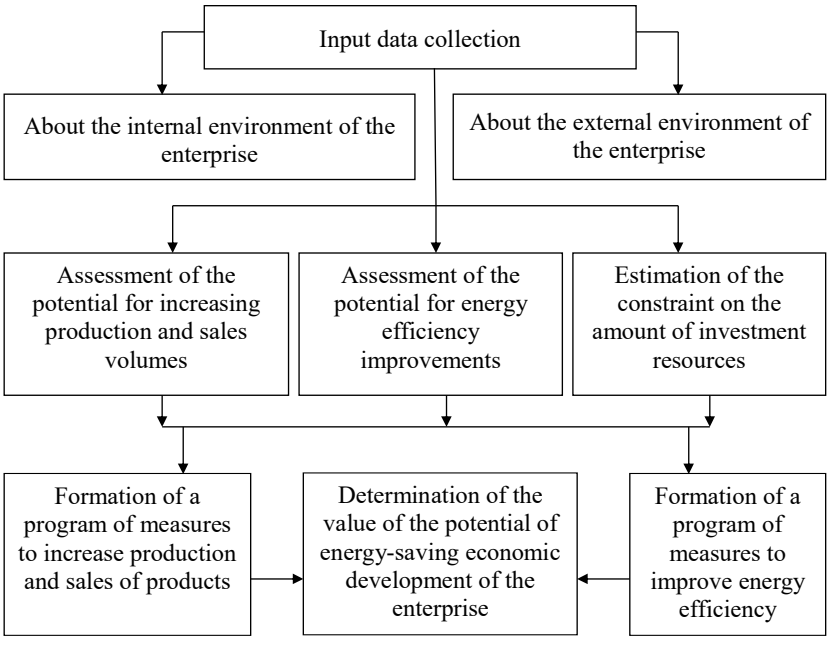

Fig. 2. The sequence of assessing the potential of energy-saving economic development of the enterprise

5. 3. Mechanism for implementing the potential of energy-saving economic development of enterprises

Conducting an assessment of the company's energy-saving economic development potential is the initial stage of devising a program to implement this potential. At the same time, the presence of an unimplemented part of the specified potential at the moment is largely due to the presence of various obstacles that stand in the way of energy-saving economic development. Therefore, it is expedient to build the mechanism for implementing the potential of this development on the basis of overcoming the obstacles that stand in the way of such development.

It is necessary to take into account the presence of a significant number of types of obstacles that arise in the process of energy-saving economic development of economic entities. In particular, according to the content, these obstacles can be divided into those that arise in the process of increasing the economic results of activities, and those that arise during

the implementation of measures to increase energy efficiency at enterprises. Also, the barriers that appear on the way to energy-saving economic development of companies can be grouped according to the stages of implementation of measures to enable this development. In particular, according to this feature, four groups of these barriers can be distinguished, namely:

1) obstacles that arise when collecting the necessary information for the development of a program of measures;

2) obstacles that arise when processing incoming information and making decisions about the implementation of measures;

3) obstacles that arise during the formation of resource support for the implementation of measures;

4) obstacles that arise during the implementation of measures.

In addition, it is expedient to group obstacles that stand in the way of energy-saving economic development of companies by the reasons for their formation. On this basis, worth distinguishing are the following groups of the specified obstacles:

1) obstacles caused by insufficiently effective activities of enterprise managers;

2) obstacles caused by insufficient quality of enterprise resources (in particular, insufficient level of competence of their personnel);

3) obstacles caused by insufficient amounts of enterprise resources;

4) obstacles caused by reasons external to the enterprise. This type of obstacles includes, in particular, the low profitability of investments in the implementation of relevant measures.

One of the main tasks in devising a mechanism for implementing the potential of energy-saving economic development of enterprises is to determine priority measures for such implementation. For this purpose, it is necessary, first of all, to quantitatively assess the number of obstacles that stand in the way of energy-saving economic development of business entities. At the same time, the level of these obstacles can be set separately for each of the stages of implementation of measures to ensure this development. For this purpose, the following formula can be applied:

$$B_k = 1 - \frac{M_k}{M_{k-1}}, \tag{7}$$

where B_k is the level of barriers that appear at the k-th stage of the process of implementing measures; M_k is the number of events that have passed the k-th stage.

At the same time, indicator (7) should be calculated separately for each of the two types of obstacles to energy-saving economic development according to their content.

Therefore, indicator (7) characterizes the share of activities that did not pass the corresponding stage in the total number of activities that were available at the beginning of this stage (that is, passed the previous stages).

Expression (7) can be represented in the following more detailed form:

$$B_k = \frac{M_{k-1} - M_k}{M_{k-1}} = \frac{\sum_{l=1}^{r} M_{kl}}{M_{k-1}} = \sum_{l=1}^{r} m_{kl}, \tag{8}$$

where r is the number of reasons, as a result of which companies may not overcome the appropriate stage of implementation of measures; M_{kl} is the number of measures that did not pass the k-th stage for the l-th reason; m_{kl} is the share of activities that did not pass the k-th stage for the l-th reason in the total number of activities that were available at the beginning of this stage.

If there are several reasons why some measures did not overcome a certain stage, when calculating M_{kl}, the number of these measures should be distributed among the values of M_{kl}, taking into account the significance of each of these reasons.

In general, equation (8) can be extended to the entire process of implementation by business entities of each of the two types of obstacles to energy-saving economic development according to their content. Then the corresponding indicator will take the following form:

$$B = 1 - \frac{M_r}{M_0}, \tag{9}$$

where B is the general level of a certain type of obstacles in terms of their content, which stand in the way of implementing measures to ensure energy-saving economic development of enterprises; M_r is the number of those measures at the investigated enterprises that have overcome the last stage of implementation; M_0 is the number of measures for the studied business subjects as of the beginning of the first stage of the implementation of these measures.

The following identity is valid:

$$\frac{M_r}{M_0} = \prod_{k=1}^{r} \frac{M_k}{M_{k-1}}, \tag{10}$$

where r is the total number of stages of implementation of measures to ensure energy-saving economic development of enterprises.

Taking into account (10), it is possible to build a model of the dependence between the general level of barriers that arise during the implementation of measures to ensure energy-saving economic development of enterprises, and the level of the specified barriers at each stage of such implementation:

$$B = 1 - \prod_{k=1}^{r} (1 - B_k) = 1 - \prod_{k=1}^{r} \left(1 - \sum_{l}^{d} m_{kl} \right). \tag{11}$$

Model (11) makes it possible to establish the influence of certain factors on the general level of the investigated obstacles. To this end, it is necessary to assume that the values of the level of individual partial obstacles appearing in formula (11) are equal to zero. Then it is possible to determine how the total level of interference B will decrease under the hypothetical conditions of the absence of corresponding partial interference. This, in turn, makes it possible to determine a list of the main partial obstacles, the development of measures to eliminate which should be considered a priority. It is this idea that underlies the mechanism for implementing the potential of energy-saving economic development of enterprises, the diagram of which is shown in Fig. 3.

At the same time, as can be seen from Fig. 3, the final list of measures to implement the potential of energy-saving economic development of enterprises should provide for an assessment of the economic efficiency of the investments that will be invested in these measures.

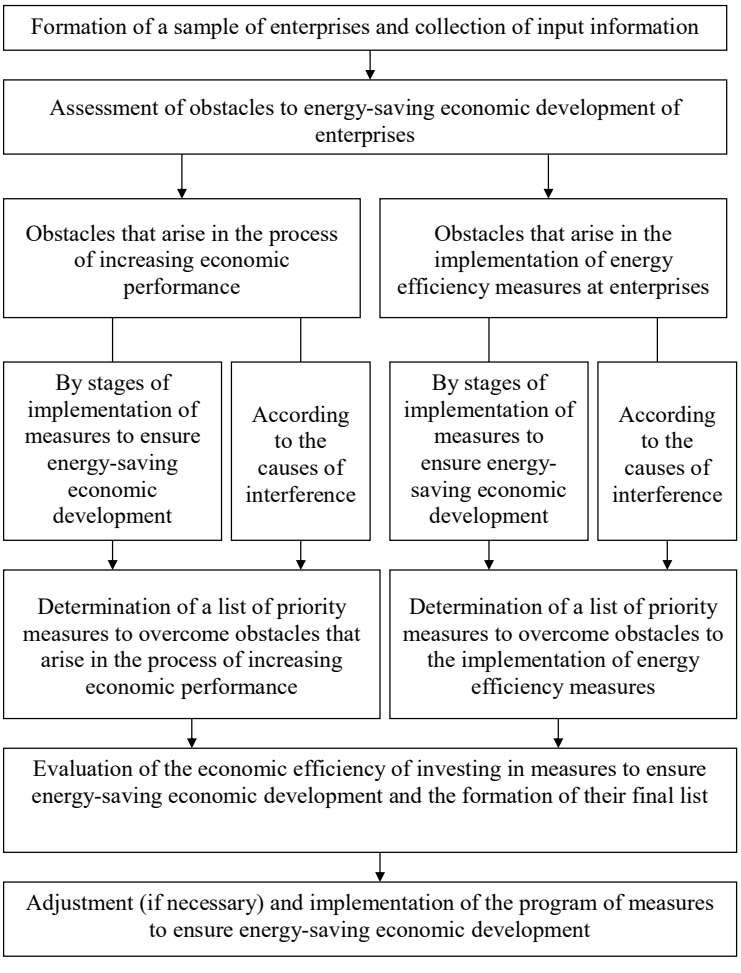

Fig. 3. Mechanism for implementing the potential of energy-saving economic development of enterprises

5. 4. Verifying the toolkit for assessing and implementing the potential of energy-saving economic development of enterprises

A sample of 110 industrial enterprises in the western region of Ukraine was formed in order to test the above-presented theoretical and methodological approaches to assessing the implementation of the potential of energy-saving economic development of enterprises. The main evaluation procedures related to data as of the beginning of 2022. At the same time, natural gas was chosen as the studied energy resource, the problem of reducing its consumption is very relevant both for Ukraine and for a number of other countries. Accordingly, enterprises up to three branches of industry with a fairly high level of natural gas consumption were selected.

As can be seen from the data given in Table 1, for all types of economic activity that were considered, the vast majority of enterprises during 2019–2021 did not experience energy-saving natural gas economic development. In particular, the share of companies in which this type of economic development was identified did not exceed 32.5 %. At the same time, more than 70 % of the studied enterprises in each industry were characterized by economic growth and an increase in the level of energy efficiency of natural gas activities.

In order to qualitatively assess the level of energy-saving economic development, three gradations of this level are distinguished: high, medium, and low. As can be seen from the data given in Table 2, for most of the studied enterprises, which during 2019–2021 were characterized by energy-saving natural gas economic development, the level of this development turned out to be low.

However, as follows from the data in Table 3, the estimated potential of energy-saving natural gas economic development of the studied enterprises is very high. In particular, for more than 50 % of enterprises in all three industries, the value of indicator (4) exceeds 6 %. At the same time, from the data in Table 4, it can be seen that enterprises with a higher level of energy-saving economic development in the reporting period are characterized by a smaller value of this potential at the end of this period. The use of the one-factor variance analysis method proved the statistical significance of this dependence since the actual value of the *F*-criterion exceeds its critical value with a significance level of $\alpha=0.05$ for all groups of enterprises.

Table 1

Distribution of the studied enterprises according to the ratio between the dynamics of economic results of activity (their net income) and the change in the volume of natural gas consumption during 2019—2021

Names of the correlation between the change in net income and the change in the volume of natural gas consumption	Data on enterprises engaged in the manufacture of articles					
	Made of metal		Made of glass		Made of clay	
	Number of enterprises	%	Number of enterprises	%	Number of enterprises	%
Economic decline	6	18.75	10	20.83	8	20.00
Economic growth	26	81.25	38	79.17	32	80.00
Energy-efficient economic development	25	78.13	34	70.83	28	70.00
Energy-saving economic development	10	31.25	14	29.17	13	32.50
Total	32	100.00	48	100.00	40	100.00

Table 2

Distribution of the investigated enterprises, which during 2019—2021 were characterized by energy-saving natural gas economic development, by the level of this development

Qualitative level of energy-saving natural gas economic development	Data on enterprises engaged in the manufacture of articles					
	Made of metal		Made of glass		Made of clay	
	Number of enterprises	%	Number of enterprises	%	Number of enterprises	%
Low	5	62.50	6	54.55	6	60.00
Average	2	25.00	3	27.27	3	30.00
High	2	25.00	2	18.18	1	10.00
Total	8	100.00	11	100.00	10	100.00

The results of our assessment of the obstacles that stand in the way of energy-saving natural gas economic development of the studied enterprises are given in Tables 5, 6. The specified evaluation was carried out according to formulas (7) to (11). As can be seen from the data given in Table 5, the highest level of obstacles is those obstacles that arise when collecting the necessary information to devise a program of measures to ensure energy-saving economic development of companies. Therefore, enterprises do not actively collect initial information on the basis of which appropriate measures can be devised. Regarding the division of the studied obstacles by the reasons for their occurrence, as can be seen from the data in Table 6, the greatest impact on the overall level of obstacles was such a factor as the insufficient quality of resources of enterprises (in particular, the insufficient level of competence of their personnel). In second place in terms of the power of influence is such a factor as the insufficient amounts of resources at enterprises. At the same time, it should be noted that model (11) has a multiplicative nature. Therefore, simultaneously overcoming the impact of several factors on the overall level of obstacles that stand in the way of energy-saving economic development of enterprises should ensure the achievement of a synergistic effect.

Therefore, the main ways of ensuring energy-saving natural gas economic development of the studied enterprises are to improve the quality and increase the volume of their resources, which are involved in the development and implementation of measures for such provision. In particular, it is important to increase the competences of those employees of companies that participate in these processes.

Table 3

Distribution of the investigated enterprises according to the estimated level of the potential of energy-saving natural gas economic development as of the beginning of 2022

The level of potential of energy-saving economic development for natural gas	Data on enterprises engaged in the manufacture of articles					
	Made of metal		Made of glass		Made of clay	
	Number of enterprises	%	Number of enterprises	%	Number of enterprises	%
Less than 0 %	0	0.00	0	0.00	0	0.00
From 0 % to 2 %	6	18.75	10	20.83	11	27.50
From 2 % to 4 %	2	6.25	7	14.58	3	7.50
From 4 % to 6 %	4	12.50	6	12.50	4	10.00
Exceeding 6 %	20	62.50	25	52.08	22	55.00
Total	32	100.00	48	100.00	40	100.00

Table 4

Indicators of dependence between the level of energy-saving natural gas economic development of enterprises during 2019—2021 and the value of the potential of this development at the beginning of 2022

Indicator ID	Data on enterprises engaged in the manufacture of articles		
	Made of metal	Made of glass	Made of clay
1. Number of enterprises in which during 2019–2021: 1. 1. Energy-saving economic development for natural gas was lacking	24	37	30
1. 2. The level of energy-saving economic development for natural gas did not exceed 3 %	5	8	7
1. 3. The level of energy-saving economic development for natural gas exceeded 3 %	5	6	6
2. The average level of the potential of energy-saving economic development for natural gas as of the beginning of 2022 by groups of enterprises in which during 2019–2021, %: 2. 1. Energy-saving economic development for natural gas was lacking	4.67	5.01	4.28
2. 2. The level of energy-saving economic development for natural gas did not exceed 3 %	3.32	3.54	3.03
2. 3. The level of energy-saving economic development for natural gas exceeded 3 %	1.06	1.27	1.40
3. Actual *F*-test values	6.22	5.34	5.95

Table 5

Results of the assessment of obstacles that stand in the way of energy-saving natural gas economic development of the studied enterprises, according to the stages of implementation of measures to enable such development

Obstacle groups according to their content	Groups of obstacles by stages of implementation of measures	The level of obstacles for enterprises engaged in the manufacture of articles		
		Made of metal	Made of glass	Made of clay
Obstacles that arise in the process of increasing economic performance	Obstacles encountered in gathering the necessary information for the development of an action program	0.568	0.523	0.605
	Obstacles encountered in the processing of incoming information and decision-making on the implementation of measures	0.255	0.364	0.279
	Obstacles that arise in the formation of resource support for the implementation of measures	0.438	0.487	0.513
	Obstacles encountered in the implementation of measures	0.175	0.153	0.098
Obstacles that arise in the implementation of energy efficiency measures at enterprises	Obstacles encountered in gathering the necessary information for the development of an action program	0.473	0.498	0.446
	Obstacles encountered in the processing of incoming information and decision-making on the implementation of measures	0.166	0.203	0.184
	Obstacles that arise in the formation of resource support for the implementation of measures	0.365	0.411	0.424
	Obstacles encountered in the implementation of measures	0.121	0.097	1.135

Table 6

Results of the assessment of obstacles that appear in the way of energy-saving natural gas economic development of the studied enterprises, according to the reasons for the occurrence of these obstacles

Obstacle groups according to their content	Groups of obstacles by stages of implementation of measures	The level of obstacles for enterprises engaged in the manufacture of articles		
		Made of metal	Made of glass	Made of clay
Obstacles that arise in the process of increasing economic performance	Obstacles caused by ineffective activities of enterprise managers	0.128	0.146	0.153
	Obstacles caused by the insufficient quality of enterprises' resources (in particular, the insufficient level of competence of their personnel)	0.251	0.275	0.188
	Obstacles caused by insufficient resources of enterprises	0.176	0.190	0.157
	Obstacles caused by external causes to enterprises	0.088	0.094	0.071
Obstacles that arise in the implementation of energy efficiency measures at enterprises	Obstacles caused by ineffective activities of enterprise managers	0.109	0.124	0.131
	Obstacles caused by the insufficient quality of enterprises' resources (in particular, the insufficient level of competence of their personnel)	0.219	0.243	0.208
	Obstacles caused by insufficient resources of enterprises	0.165	0.171	0.148
	Obstacles caused by external causes to enterprises	0.076	0.082	0.064

6. Discussion of the designed toolkit for assessing and implementing the potential of energy-saving economic development of enterprises

Our research showed that the assessment and implementation of the potential of energy-saving economic development of enterprises should be based on properly substantiated theoretical principles of formation and measurement of the level of such development. This is explained, in particular, by the significant number, as shown in Fig. 1, of types of relationships between the dynamics of the economic results of the enterprise and the change in its consumption of a certain type of energy resources. It is also important to establish conditions for energy-saving economic development at enterprises. As follows from (3), in order for this type of development to take place at the enterprise, the growth rate of a certain type of economic results of activity must exceed unity but be less than the growth rate of energy efficiency.

The method of assessing the potential of energy-saving economic development of enterprises devised in the course of this research also deserves special attention. The use of this method makes it possible to obtain an accurate enough estimate of the value of the indicated potential. This is explained by the fact that the devised method, the sequence of use of which is shown in Fig. 2, is based on a quantitative method for assessing the level of energy-saving economic development of companies, the proposed model of which is represented by expression (4). At the same time, the assessment of the energy-saving economic development potential of economic entities should be based on the application of an optimization approach. This approach requires the application of a model that includes an objective function and resource constraints. Such a function can be the expected value of the excess profit of the enterprise (the difference between the expected profit and the profit of the required investments at the rate of their profitability) after the implementation of measures to improve energy efficiency and increase economic results. As for resource restrictions, the most important of them is the restriction on the total amount of investment resources that the company can use to finance the mentioned measures.

Also, this study found that assessing the company's energy-saving economic development potential is the initial stage of devising a program to implement this potential. At the same time, the presence of an unimplemented part of the specified potential at the moment is largely due to the presence of various obstacles that stand in the way of energy-saving economic development. Therefore, it is expedient to build the mechanism for implementing the potential of this development on the basis of overcoming the obstacles that stand in the way of such development. Taking into account this circumstance, quantitative indicators were determined to assess the obstacles that stand in the way of energy-saving economic development of economic entities. These indicators take the form of formulas (7) to (11). The use of these indicators, in turn, makes it possible to identify the most priority measures for implementing the energy-saving economic development potential of enterprises. The specified circumstances explain the effectiveness of the mechanism proposed in this study (and depicted in Fig. 3) for implementing the potential of energy-saving economic development of enterprises.

The use of the proposed theoretical and methodological principles of assessment and implementation of the potential of energy-saving natural gas economic development of enterprises based on a sample of 110 enterprises in the western region of Ukraine showed the effectiveness of these principles. In particular, this is explained by the fact that it was possible to perform a quantitative assessment of this potential, the results of which are given in Tables 1–4, and based on the data in Table 5, to compile recommendations for implementing the specified potential. At the same time, our research showed the presence of a significant number of enterprises that have significant current potential for energy-saving economic development, but its implementation requires the implementation of a set of certain measures. The content of this set of measures, in general, is the same for all three studied types of economic activity (production of products from metal, glass, and clay, respectively). For all these types, it is necessary, first of all, to improve the quality and increase the amounts of resources that are involved in ensuring energy-saving natural gas economic development of the companies under study. However, the need for these measures is most acute for enterprises that manufacture glass products since the corresponding obstacles are the highest for these companies. At the same time, for companies that make products from clay, these barriers are the lowest, but still quite high.

Therefore, the proposed toolkit makes it possible to assess the level of energy-saving economic development of enterprises, to establish the value of the potential of such development

and to identify the priority directions for the implementation of this potential. In particular, a positive feature of the designed toolkit is that its application makes it possible to obtain accurate and comprehensive results using an optimization approach. The proposed toolkit could be used by enterprises of all types of economic activity when assessing the potential of their energy-saving economic development and when devising measures to implement the specified potential. This will help increase the economic efficiency of companies.

Given the above-described positive features of the results of our study, it was possible to address some of the existing gaps in the literature. Although in the scientific literature, in particular in [9–14], considerable attention is paid to various types of economic potential of enterprises, there is no assessment of the potential of their energy-saving economic development. Similarly, in particular in [15–23], in which the relationship between energy consumption and economic growth is considered, little attention was paid to the assessment of the prospects for ensuring energy-saving economic development in the respective countries. Accordingly, the toolkit designed in this study makes it possible to devise measures to overcome obstacles that arise when implementing the potential of energy-saving economic development of enterprises, which is not implemented in [25–32].

Taking into account the above, the designed toolkit reasonably solves the problem of assessing and implementing the potential of energy-saving economic development of enterprises. This is achieved due to the fact that the use of such a toolkit makes it possible to perform the specified assessment completely and with due accuracy. Therefore, the information obtained as a result of the use of the specified toolkit makes it possible to substantiate the ways of implementation of the researched potential.

At the same time, this study has certain limitations. In particular, the proposed model (5), (6) applies only to the case of evaluating the potential of the energy-saving economic development of the current single-project energy-saving enterprise based on a certain type of energy resources. Also worth noting is the possibility of using criteria indicators other than excess profit to assess the value of the specified potential. In particular, such an indicator can be the market value of enterprises.

In addition, it is necessary to note a certain shortcoming of the proposed model for evaluating the energy-saving economic development of enterprises, which limits the accuracy of the results obtained as a result of the application of this model. The noted drawback is that the procedure for setting the value of the significance coefficient in expression (4) is characterized by a certain subjectivity. Therefore, further research should, among other things, involve the development of a more objective method of such determination. Taking this circumstance into account will make it possible to increase the accuracy of estimating the potential of energy-saving economic development of enterprises.

It is also worth noting that our research took place at the beginning of 2022 and was completed before the onset of large-scale military operations that began on the territory of Ukraine on February 24 of the same year. In this regard, an important area of further research is the testing of the methodological principles devised in this paper for the period after the declaration of martial law in Ukraine. Such a study should take into account the impact of military actions both on the volume of sales of enterprises' products and on their financial capabilities regarding the implementation of energy-saving measures. It should also be taken into account that during the war, enterprises may face a shortage not only of financial but also of production resources needed both for the production of articles and for the implementation of energy-saving projects.

7. Conclusions

1. The theoretical principles of formation and measurement of the level of energy-saving economic development of enterprises have been substantiated. Among other things, the place of this type of economic development among other types of correlations between the dynamics of economic results of enterprises and changes in their energy consumption was determined. This made it possible to identify the necessary and sufficient conditions for ensuring such development. In particular, it was determined that in order to enable energy-saving economic development at the enterprise, the growth rate of economic results of activity should exceed unity but be lower than the growth rate of energy efficiency.

2. The procedure for assessing the potential of energy-saving economic development of enterprises has been devised. The use of this procedure makes it possible to carry out a qualitative and quantitative assessment of the capabilities of enterprises to enable the simultaneous growth of economic results and the level of energy efficiency. At the same time, the specified assessment is based on the development of a program of measures for such growth using an optimization approach, taking into account the possible presence of resource limitations. Therefore, the implementation of the estimated value of the potential of energy-saving economic development of enterprises should ensure the growth of financial and economic results of their economic activity.

3. The mechanism for implementing the potential of energy-saving economic development of enterprises was improved. It is shown that such improvement should involve the development and implementation of recommendations for overcoming obstacles that appear on the way to the specified implementation. In turn, such obstacles were grouped and indicators for their quantitative assessment were defined. Such evaluation is proposed to be performed by determining the share of energy-saving economic development measures that have not passed the appropriate stage of their implementation in the total number of measures that have passed all previous stages. This made it possible to increase the degree of validity of proposals regarding the implementation of the potential of energy-saving economic development of business entities.

4. The proposed theoretical and methodological approaches to the assessment and implementation of the potential of energy-saving economic development of enterprises based on natural gas were verified based on a sample of 110 enterprises in the western region of Ukraine. In particular, it was established that for all types of economic activity that were considered, the vast majority of enterprises during 2019–2021 did not experience energy-saving natural gas economic development. In particular, the share of companies in which this type of economic development was identified did not exceed 32.5 %. At the same time, the estimated potential of energy-saving natural gas economic development of the studied enterprises is very high. In particular, for more than 50 % of enterprises in all three industries, the value of this potential exceeds 6 %. At the same time, it

was established that the main ways to ensure energy-saving natural gas economic development of the studied enterprises are to improve the quality and increase the volume of their resources, which are involved in the development and implementation of measures for such provision. In particular, it is important to increase the competences of those employees of companies that participate in these processes.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

All data are available, either in numerical or graphical form, in the main text of the manuscript.

Use of artificial intelligence

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

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