

*This study investigates competence of enterprise personnel in the development and implementation of energy-saving technological change projects. The task addressed is to identify the impact of these competences on energy-saving technological change.*

*A grouping of competences in the implementation of energy-saving technological change projects was advanced. Using the constructed three-level model of assessing the impact of factors on energy-saving technological change at enterprises, the place of personnel competences among these factors was established. The methodological principles of assessing the impact of personnel competence on energy-saving technological change at enterprises were improved by designing a toolkit for indirect and direct assessment of the specified impact. Such an assessment, among other things, provides for the establishment of reserves for reducing obstacles to the implementation of energy-saving technologies by increasing personnel competence.*

*The designed toolkit was tested using data from 34 enterprises in Ukraine. In particular, it was found that the transition of enterprises with a low level of personnel competence to the class of companies with medium and high levels of such competence, respectively, would lead to an expected increase in average energy efficiency by 35.89% and 84.15%. At the same time, eliminating obstacles caused by insufficiently high competence of the personnel could make it possible to reduce the average overall level of such obstacles by type of economic activity for enterprises from 35.48% to 54.17%.*

*The proposed toolkit is suitable for use by enterprises of all types of economic activity when assessing reserves for increasing energy efficiency by improving employee competence*

**Keywords:** *personnel competence, impact of competence on energy saving, obstacles to increasing energy efficiency, reduction of obstacles*

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# REVEALING THE IMPACT OF THE COMPETENCE OF ENTERPRISES' PERSONNEL ON ENERGY-SAVING TECHNOLOGICAL CHANGES

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## 1. Introduction

Given current business conditions when competition in the markets of many goods is intensifying, ensuring the proper efficiency of the functioning of enterprises requires them to implement measures to reduce the cost of production. An important direction for such reduction is the implementation by companies of projects aimed at increasing the energy efficiency of economic activities and replacing non-renewable energy sources with renewable ones [1].

At the same time, the implementation of energy-saving technological changes by enterprises is of exceptional importance not only for increasing the competitiveness of these enterprises. Such implementation, if it is of a large-scale nature, also leads to significant positive consequences at the macroeconomic level, in particular, increasing the energy independence of countries and regions [2]. This is especially

relevant given the conditions of modern geopolitical turbulence, when the stability of supplies of imported goods has significantly decreased, and the risks of disruption of these supplies have significantly increased [3].

As, along with households, enterprises are also among the main consumers of energy resources, their implementation of energy-saving measures should be attributed to the most important areas of reducing energy consumption. At the same time, as the experience of energy-saving activities of many companies shows, various obstacles arise when implementing this activity [4]. Identification and assessment of obstacles that inhibit the process of energy saving at enterprises is of key importance for designing effective mechanisms for activating this process. It is obvious that among such obstacles, an important place is occupied by the limited resources available to companies, primarily financial [5]. Also, quite often, enterprises face a lack of information necessary for

the development and implementation of energy-efficient measures [6].

However, implementing the existing energy saving potential of enterprises requires not only the availability of the necessary amounts of financial, informational, and other resources, but also the ability to effectively manage them. In particular, managers and specialists of enterprises must have sufficient competencies in the development and implementation of energy-saving projects. Such competencies should include the knowledge and skills of personnel, the possession of which allows for the effective implementation of energy-saving measures.

One of the most important types of these measures is energy-saving technological change projects at enterprises [7]. The implementation of such changes requires the identification of the main potential drivers of their acceleration. Given the above, among the specified drivers it is appropriate to consider the improvement of the competencies of managers and specialists of firms in the development and implementation of energy-saving technological change projects. This, in turn, requires the preliminary identification of the impact of such competencies on the scale of energy-saving technological change at enterprises. Therefore, research into the development of effective tools that could be used to detect it is relevant.

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## 2. Literature review and problem statement

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Issues related to the significance of personnel competencies and the assessment of their impact on various aspects of the functioning of companies have been considered in many scientific works. Thus, in [8] it is noted that human competencies are an important factor in the success of organizational strategy and sustainable management of activities by firms. In [9], the competencies of enterprise employees are considered as an important factor in ensuring the competitiveness of companies. At the same time, in [10], the positive impact of managerial competencies on the long-term effectiveness of small and medium-sized enterprises is established. However, in [8–10], insufficient attention is paid to the impact of enterprise personnel competencies on energy-saving activities. A likely reason is that the consideration of this impact went beyond the tasks set by the authors of those works.

At the same time, scientific literature includes a number of studies in which attempts have been made to determine the impact of enterprise employee competencies on the energy efficiency of economic activity. In particular, work [11] established a significant relationship between the level of flexibility of employees' competencies and energy efficiency at enterprises. A similar result was reported in [12], in which it was found that the development of green key competence has a positive effect on the amount of investment made by firms in green research and development. Work [13] indicates the importance of stimulating competencies as a tool for realizing the potential for increasing energy efficiency in the manufacturing sector. A similar opinion is held by the authors of [14] who established the importance of environmental awareness in the context of sustainable energy management at enterprises. Also noteworthy is work [15] whose authors identified, in particular, increasing employees' awareness of energy issues in the organization among the driving forces for increasing energy efficiency. At the same time, papers [11–15] do not detail the competencies

of enterprise personnel on issues of increasing energy efficiency. This may be due to the fact that implementing such detailing is a very laborious process that should be carried out within the framework of a separate study.

However, the detailed analysis of the competencies of company personnel in terms of increasing energy efficiency has been carried out in some other scientific works, in particular in [16]. The results show that candidates for "green" jobs lack technical and mechanical knowledge, IT skills, as well as experience and ability to work independently and in a team to solve emerging problems. At the same time, work [17] considers competencies related to energy literacy and argues that energy literacy training provides an effective approach to promoting responsible energy production and consumption. Paper [18] notes that the base of personnel competencies in terms of increasing energy efficiency is subject to expansion, which is one of the decisive factors for the success of companies. However, papers [16–18] did not carry out a detailed study of each of the studied competencies. This can be explained by the fact that such a study was not included in the list of tasks set in the above scientific works.

At the same time, there are a number of scientific papers that study in detail certain types of competencies in the field of energy-saving activities of enterprises. In particular, in work [19], its authors identified patterns of formation and designed mechanisms for improving the competencies of enterprise employees in matters of collecting input information necessary for the development of energy-saving technological change projects. In contrast, in [20], it is shown that company personnel must have competencies not only in collecting input information for implementing energy-saving measures but also be able to properly process this information. At the same time, in work [21] it is established that the effectiveness and scale of implementation of energy-saving projects largely depend on the skills of enterprise managers to effectively manage the process of financing these projects. In [22], its authors, among other things, paid attention to other important competencies, namely, in ensuring sustainable energy-saving development of companies on the basis of their implementation of renewable energy projects. At the same time, [23] found that such provision requires the presence of significant amounts of knowledge and skills in assessing and managing the potential of energy-saving economic development of enterprises among the personnel of firms. However, in papers [19–23], a detailed quantitative assessment of the impact of the level of competence of enterprise personnel on their energy-saving activities was not carried out. This may be due to the fact that those works did not set such a goal.

One possible approach to such an assessment is to determine the quantitative possibilities of reducing obstacles to the development and implementation of energy-saving projects at enterprises by increasing the competencies of their personnel. In general, at present there are a number of scientific publications that report studying the role played by improving the competencies of enterprise employees in overcoming obstacles that arise on the way to the implementation of energy-saving measures. Thus, in work [24] it is shown that increasing the awareness of company employees on energy efficiency issues is of crucial importance for ensuring such overcoming. At the same time, in [25], the importance of proper competence of company owners and top managers as a factor that significantly reduces barriers to the implementation of energy-saving measures is proven. However, in papers [24, 25] and other scientific works on obstacles to the

implementation of energy-saving measures at enterprises, the issue of quantitative assessment of the impact of personnel competence on the level of these obstacles was not considered in sufficient detail. A likely reason is that the issue of such an assessment was not within the scope of scientific interests of the authors of those papers.

Thus, scientific literature has not solved the problem of designing a toolkit to identify the impact of personnel competence on energy-saving technological changes in the context of overcoming obstacles that arise on the way to implementing these changes. At the same time, there are reasonable grounds to consider increasing the level of competence of managers and specialists of enterprises as a potential driver that can ensure the acceleration of the implementation of energy-saving technological processes.

The above allows us to argue that it is advisable to conduct a study aimed at designing a toolkit to identify the impact of personnel competence of companies on energy-saving technological changes in them.

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### 3. The aim and objectives of the study

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The purpose of our study is to identify the impact of the competence of enterprise personnel on energy-saving technological changes on them. This will allow us to establish reserves for increasing the energy efficiency of companies' activities by improving the competence of their personnel. The implementation of such reserves, in turn, will have a positive impact on competitiveness and improve the financial condition of enterprises, as well as contribute to the improvement of the environmental situation and energy security.

In order to achieve the goal, the following tasks were set:

- to group the competences of personnel in the development and implementation of projects for energy-saving technological changes, as well as to establish the place of these competences among the factors influencing the implementation of these changes;
- to improve the toolkit for assessing the impact of the competence of enterprise personnel on energy-saving technological changes on them;
- to test this toolkit on a sample of Ukrainian firms.

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### 4. The study materials and methods

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The object of our study is the competence of enterprise personnel in the development and implementation of energy-saving technological change projects. The principal hypothesis assumes the influence of these competences on energy-saving technological change in randomly selected companies.

At the same time, some assumptions were adopted in the process of the study, namely:

- 1) the possibility of dividing the process of implementing energy-saving technological change projects into a limited number of consecutive stages;
- 2) the possibility of matching each of these stages with a certain group of personnel competences in the development and implementation of energy-saving technological change projects.

Also, a number of simplifications were accepted during the study, namely:

- 1) consideration of only those energy-saving technological change projects whose implementation is aimed at increasing the efficiency of natural gas use;

- 2) limited number of companies studied;

- 3) limited number of types of economic activity considered.

The theoretical basis of the study was scientific works that considered the issues of assessing personnel competence, managing the implementation of technological changes, and overcoming obstacles that arise during their implementation.

The information base for conducting empirical analysis was accounting and management accounting data from a number of companies, as well as the results of their survey. All of these companies belong to three energy-intensive industries that manufacture products from metal, glass, and clay, respectively. At the initial stage of the empirical study, a sample of 30 randomly selected companies located in the western region of Ukraine was formed for each of the three industries. At a later stage, a questionnaire was sent to each enterprise. In addition, data from open sources about the selected firms was analyzed. Ultimately, taking into account the completeness of the collected information, as well as the willingness of the companies to share this information, a final sample of 34 companies was formed.

In carrying out our study, a wide range of various methods of scientific knowledge was applied. Thus, in devising a method for directly assessing the impact of personnel competence on energy-saving technological changes at the enterprise, economic and mathematical modeling was used. The need for this modeling is due to the complexity of the formation of obstacles in the implementation of energy-saving technological changes, which requires the formalization of the process of such formation.

When grouping personnel competencies regarding the implementation of energy-saving technological changes, as well as when establishing the place of these competencies among the factors of influence on the specified changes, grouping and generalization methods were used. The use of these methods made it possible to divide personnel competencies into groups, as well as to build a model of the influence of factors on the process of implementing energy-saving technological changes at enterprises.

In addition, the method of system analysis was used when conducting the study. That made it possible to systematize the causes of obstacles in the development and implementation of energy-saving technological change projects at enterprises.

When conducting empirical research, the methods of questionnaire survey, economic analysis, and feasibility studies were used. To process the data obtained, mathematical statistics methods were employed, in particular, one-factor variance analysis [26]. In addition, in the process of conducting empirical research, the methods developed in this work for assessing the impact of enterprise personnel competencies on energy-saving technological changes on them were used.

To visually display the results obtained during this study, graphical and tabular methods were used.

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## 5. Results of investigating the toolkit for identifying the impact of enterprise personnel competence on energy-saving technological changes

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### 5.1. Grouping competencies and establishing their place among the factors of influence on energy-saving technological changes

Assessment of the impact of personnel competencies on energy-saving technological changes should be preceded by

grouping types and determining the place occupied by the specified competencies among other possible factors of this impact. For this purpose, it is advisable to divide the process of developing and implementing energy-saving technological change projects into several stages. At the same time, it is necessary to attach to each of these stages a certain group of competencies of managers and specialists of enterprises in the issues of developing and implementing the specified projects. Then it is possible to distinguish such groups of

the specified competencies as competencies in the issues of collecting input information, processing it, making a preliminary decision, its resource provision, making a final decision, and its implementation (Table 1).

As for determining the place of personnel competencies among the factors influencing energy-saving technological changes, for this purpose a three-level model of such influence is proposed, a schematic representation of which is shown in Fig. 1.

Table 1

Grouping of competencies of enterprise personnel in the development and implementation of energy-saving technological change (ETC) projects

Names of the stages of the process of developing and implementing energy-saving technological changes	Names of competencies for the development and implementation of energy-saving technological change projects	Competency labels
1. Collection of input information necessary for the development and implementation of ETC projects	1. 1. The ability to find sources of input information about the internal environment of the enterprise	C.1.1
	1. 2. The ability to find sources of input information about the external environment of the enterprise	C.1.2
	1. 3. Ability to use all legal methods of obtaining input information about the internal environment of the enterprise	C.1.3
	1. 4. Ability to use all legal methods of obtaining input information about the external environment of the enterprise	C.1.4
	1. 5. Ability to ensure the relevance, completeness, and accuracy of data on the internal environment of the enterprise, necessary for the development and implementation of ETC	C.1.5
	1. 6. Ability to ensure the relevance, completeness, and accuracy of data on the external environment of the enterprise, necessary for the development and implementation of the ETP	C.1.6
2. Processing of input information necessary for the development and implementation of ETC projects	2. 1. Ability to successfully use modern methods of analyzing incoming information	C.2.1
	2. 2. The ability to successfully use modern forecasting methods, including establishing the probability of various scenarios for the further development of the situation	C.2.2
	2. 3. Ability to successfully identify alternative solutions in the field of ETC implementation	C.2.3
	2. 4. The ability to obtain, with an appropriate degree of accuracy, forecast values of expected profits and other indicators on the basis of which the effectiveness of ETC projects is assessed	C.2.4
	2. 5. Ability to obtain with an appropriate degree of accuracy forecast values of the effectiveness of ETC projects	C.2.5
3. Adoption of a preliminary decision on the implementation of ETC projects	3. 1. Ability to take into account existing resource constraints	C.3.1
	3. 2. Ability to choose criteria for decision-making regarding the implementation of ETC projects	C.3.2
	3. 3. Ability to choose the best options for implementing ETC projects	C.3.3
	3. 4. Ability to use optimization methods to form a program of ETC projects	C.3.4
4. Formation of resource support for the implementation of ETC projects	4. 1. Ability to determine the best ways to obtain resources for implementing ETC projects	C.4.1
	4. 2. The ability to determine a rational structure of resource (primarily financial) support for the implementation of ETC projects	C.4.2
	4. 3. Ability to obtain the resources necessary for the implementation of ETC projects	C.4.3
	4. 4. Ability to provide acceptable conditions for the enterprise to obtain the resources necessary for the implementation of ETC projects	C.4.4
5. Adoption of the final decision on the implementation of ETC projects	5. 1. The ability to adjust the previous decision on the implementation of ETC projects taking into account real opportunities and conditions for attracting the resources necessary for such implementation	C.5.1
	5. 2. Ability to draw up calendar plans for the implementation of ETC projects at the enterprise	C.5.2
	5. 3. Ability to assess the economic and other consequences for the enterprise of implementing ETC projects there	C.5.3
6. Implementation of ETC projects	6. 1. The ability to create organizational mechanisms for implementing decisions on the implementation of ETC projects at the enterprise	C.6.1
	6. 2. Ability to enter into contracts related to obtaining the necessary types of resources for the implementation of ETC projects	C.6.2
	6. 3. Ability to conclude contracts related to the acquisition of energy-saving equipment, materials, etc., the implementation of which is provided for in the ETC projects	C.6.3
	6. 4. Ability to organize the procurement of energy-saving equipment, materials, etc., the implementation of which is provided for in the ETC projects	C.6.4
	6. 5. Ability to organize commissioning work	C.6.5

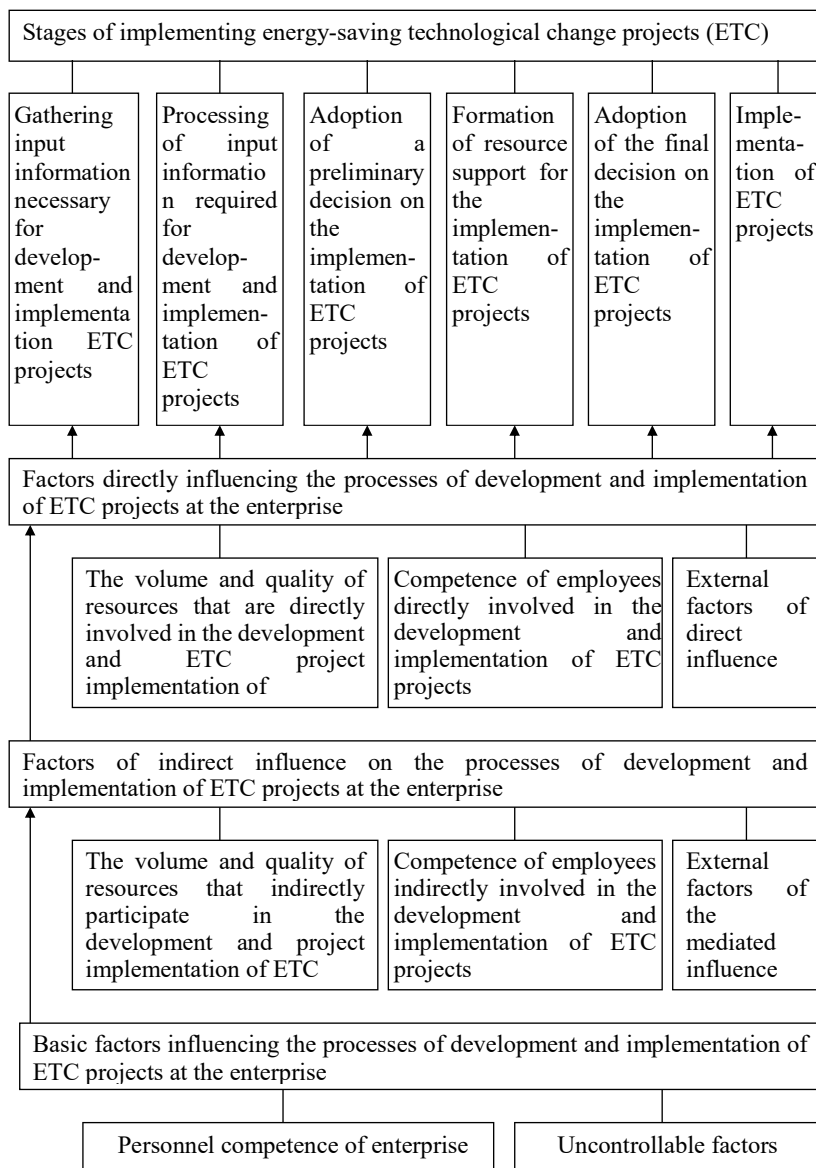


Fig. 1. Three-level model for assessing the impact of factors on energy-saving technological changes at enterprises

According to the model shown in Fig. 1, all factors influencing the scale of energy-saving technological changes at enterprises can be located at three levels, namely:

1) factors of direct influence. These factors include the volume and quality of resources that are directly involved in the development and implementation of energy-saving technological change projects at enterprises; competence in these matters and external environmental factors. The latter, for example, include prices for those energy resources whose consumption is expected to be reduced as a result of technological changes;

2) factors of indirect influence. These factors influence the factors of direct influence. For example, insufficient amounts of human or technical resources required to develop energy-saving technological change projects may be due to insufficient amounts of financial resources available to enterprises. Thus, financial resources belong to both direct influence factors, if these resources are considered from the point of view of purchasing equipment for projects, and indirect influence factors, if financial resources are considered as a tool for obtaining other types of resources;

3) basic factors. These factors have an impact on indirect influence factors. They should be divided into only two groups, namely – the competence of managers and specialists of enterprises and uncontrollable factors (which the enterprise cannot influence). Returning to the example of financial resources, it can be noted that their shortage can be caused by various factors. These factors can be both an insufficient level of competence of managers in managing these resources, in particular, their involvement from external sources, and objective restrictions on such involvement. Then the second factor has an irresistible influence and, accordingly, belongs to uncontrollable factors.

Therefore, according to the proposed model of the influence of factors on the scale of energy-saving technological changes at enterprises, these changes can ultimately be divided into two large groups. These groups are the competencies of managers and specialists at enterprises and uncontrollable factors.

**5.2. Improving the toolkit for assessing the impact of personnel competence on energy-saving technological changes at enterprises**

The toolkit for assessing the impact of personnel competence on energy-saving technological changes at enterprises includes two methods of such assessment, namely:

1) the method of indirect impact assessment. This method allows us to establish the presence of the impact of personnel competence on energy-saving technological changes, but does not provide for determining the extent of such impact;

2) the method of direct impact assessment. The application of this method allows us to establish the extent of such impact. In addition, this method makes it

possible to identify those stages of the process of developing and implementing energy-saving technological change projects where there is the greatest lack of relevant competencies.

Regarding the first method, it should involve the formation of a sample of enterprises with subsequent assessment in points of the level of each of the competencies, the list of which is given above in Table 1. In particular, such an assessment can be carried out on a five-point scale. Accordingly, on this scale, each of the competencies will have five levels: very low (1 point), low (2 points), medium (3 points), high (4 points) and very high (5 points). Then, for each group of competencies, their average level for a particular enterprise can be estimated using the arithmetic mean formula. At the same time, the influence of the averaged group levels of competencies on the generalized level of competencies is multiplicative. Therefore, to assess this level, it is worth using the following formula

$$L = \sqrt[6]{\prod_{i=1}^6 l_{i/5}}, \tag{1}$$

where  $L$  – generalized level of competence of the enterprise personnel in the development and implementation of energy-saving technological change projects, points;  $l_i$  – average level of the specified competencies for their  $i$ -th group.

Having calculated the generalized level of competence of the personnel in the development and implementation of energy-saving technological change projects according to formula (1) for each studied enterprise, it is possible to divide these enterprises into classes according to the specified level. In particular, it is possible to distinguish enterprises with a low level of competence (generalized level does not exceed 2), with an average (generalized level takes on a value from 2 to 3.5) and high (generalized level exceeds 3.5) levels.

At the next stage of applying the method of indirect assessment of the impact of personnel competence on energy-saving technological changes at enterprises, it is necessary to estimate the energy efficiency values for each studied enterprise and average them by enterprise classes. Then, using the method of variance analysis, it is possible to assess the statistical significance of the differences between the average values of energy efficiency of activities by enterprise classes. If these differences turn out to be statistically significant, this will mean that the level of personnel competence affects the energy efficiency of enterprises (Fig. 2). In other words, under such conditions, a change in the specified level has a statistically significant effect on the change in the energy efficiency of economic activity. Accordingly, if energy efficiency is determined primarily by the technologies used, then the level of competence will be a factor influencing the scale of energy-saving technological changes.

Thus, using the indirect assessment method, the scale of energy-saving technological changes in relative terms will be determined by the value of energy efficiency of economic activity. At the same time, using the direct assessment method of the impact of personnel competence on energy-saving technological changes at enterprises, the scale of such changes should be characterized by the number of their implemented projects (or the amount of investment invested in them).

At the same time, using the direct assessment method of the impact of personnel competence on energy-saving technological changes, it is first necessary to form an array of data on the number of considered projects of such changes at the enterprises under study for the reporting period. Subsequently, the number of projects that have overcome each of the stages of the development and implementation of these projects shown above in Fig. 1 are determined. Then the level of obstacles to such implementation will be estimated by the ratio of the

number of projects that have not overcome the corresponding stage to the number of projects at the beginning of the stage

$$f_i = \frac{\Delta f_i}{F_i}, \tag{2}$$

where  $f_i$  – level of obstacles to the  $i$ -th stage of development and implementation of energy-saving technological change projects;  $\Delta f_i$  – number of projects that have passed the  $i$ -th stage of their development and implementation process;  $F_i$  – number of energy-saving technological change projects at the beginning of the  $i$ -th stage.

Accordingly, the overall level of obstacles to the implementation of these projects will be estimated by the ratio of the total number of projects that have not passed a particular stage to the number of projects at the beginning of the first stage

$$F = \frac{\sum_{i=1}^6 f_i}{F_1}, \tag{3}$$

where  $F$  is the general level of obstacles to the implementation of energy-saving technological change projects at enterprises.

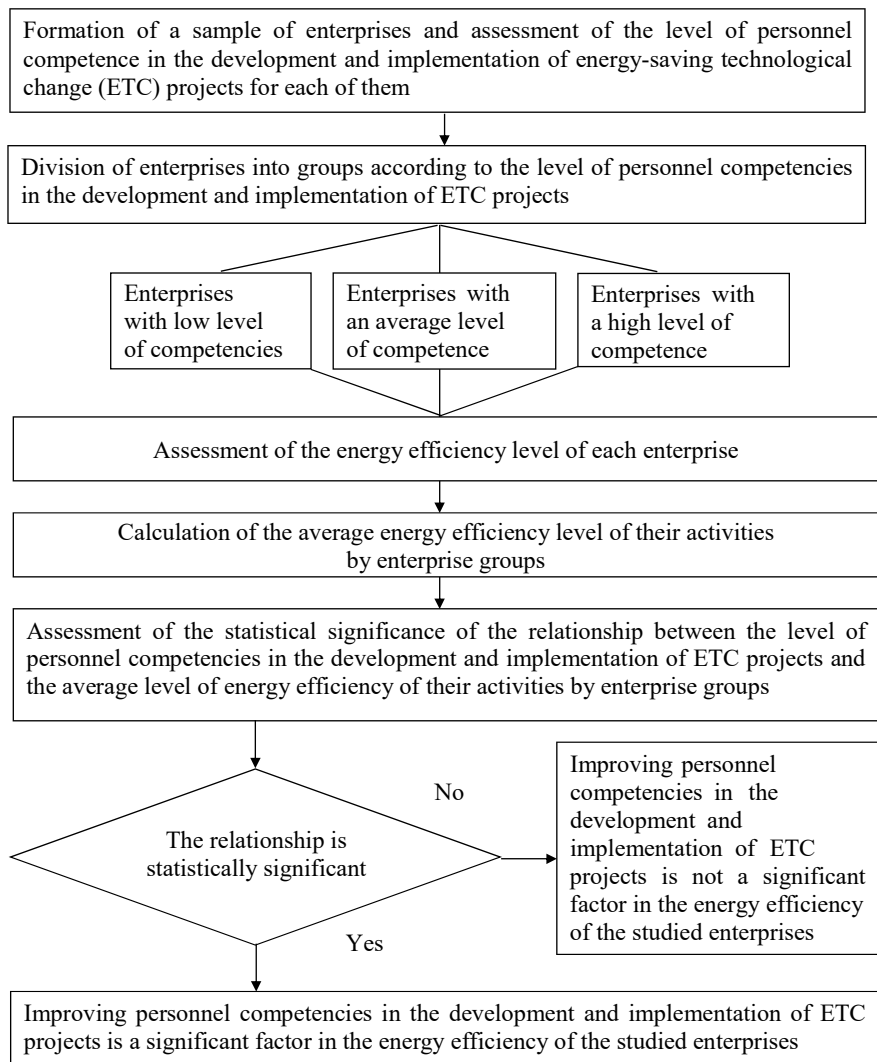


Fig. 2. The sequence of assessing the impact of the competencies of enterprise personnel in the development and implementation of energy-saving technological change projects on the level of energy efficiency of these enterprises

It should be noted that there is the following relationship between the general and partial (i.e., at the corresponding stages) levels of obstacles

$$F = 1 - \prod_{i=1}^6 (1 - f_i), \tag{4}$$

Using dependence (4), it is possible to estimate the influence of each obstacle on their overall level. To do this, it is necessary to assume that the values of all obstacle levels, except for one, are equal to zero.

Similarly to formula (3), it is possible to construct an expression for determining the overall level of obstacles in the development and implementation of energy-saving technological change projects due to insufficient level of personnel competences

$$E = \frac{\sum_{i=1}^6 e_i}{F_1}, \tag{5}$$

where  $E$  is the total level of obstacles in the development and implementation of energy-saving technological change projects due to the insufficient level of personnel competencies;  $e_i$  is the number of projects that did not pass the  $i$ -th stage due to the insufficient level of personnel competencies.

Then the impact of the lack of personnel competencies on the total level of obstacles in the development and implementation of energy-saving technological processes can be assessed by comparing expressions (3), (5)

$$I = \frac{F - E}{F} \cdot 100, \tag{6}$$

where  $I$  is an indicator of the impact of insufficient personnel competence on the overall level of obstacles in the development and implementation of energy-saving technological processes, %.

Thus, using formula (6), it is possible to estimate the share of insufficient personnel competence in the total amount of obstacles that arose in the development and implementation of energy-saving technological processes at enterprises.

Using formula (6), it is possible to estimate how much the number of implemented energy-saving technological change projects at the studied enterprises would increase if their personnel had the appropriate competencies at a high level.

It should be noted that in the case where the projects under consideration differ significantly in investment costs for their implementation, instead of the number of projects in the above formulas, it is more appropriate to take the amount of investment in the implementation of these projects.

### 5. 3. Using the toolkit for assessing the impact of personnel competence on energy-saving technological changes at enterprises

In the process of empirical analysis, attention was focused on one type of energy resources, namely natural gas. This is due to two main circumstances. First, the need to

reduce the consumption of this type of energy carrier is currently acutely faced by many countries [27], including Ukraine, whose enterprises were analyzed in this study. Second, these enterprises belong to those types of economic activity that are characterized by fairly high volumes of natural gas consumption.

Therefore, in the future, only those energy-saving technological changes that relate to increasing the efficiency of natural gas use will be considered. First of all, a survey was conducted of the owners and top managers of the companies under study regarding the level of competencies available to their personnel as of the end of 2024 in the development and implementation of energy-saving technological change projects. The results of data processing from such a survey are given in Table 2.

Table 2

Results of processing data from a survey of enterprises regarding the level of competencies available to their staff as of the end of 2024

Names of the stages of the process of implementing energy-saving technological changes	Competency labels	Number of enterprises where the level of relevant competencies was					Average level of competencies, points
		Very low	Low	Average	Quite high	High	
1. Collection of input information necessary for the development and implementation of ETC projects	C.1.1	0	14	12	8	0	2.824
	C.1.2	0	12	15	7	0	2.853
	C.1.3	0	13	13	8	0	2.853
	C.1.4	0	16	12	6	0	2.706
	C.1.5	0	14	13	7	0	2.794
	C.1.6	0	15	10	9	0	2.824
2. Processing of input information necessary for the development and implementation of ETC projects	C.2.1	0	13	16	5	0	2.765
	C.2.2	0	14	12	8	0	2.824
	C.2.3	0	15	14	5	0	2.706
	C.2.4	0	12	15	7	0	2.853
	C.2.5	0	16	11	7	0	2.735
3. Adoption of a preliminary decision on the implementation of ETC projects	C.3.1	0	10	14	10	0	3.000
	C.3.2	0	9	17	8	0	2.971
	C.3.3	0	11	16	7	0	2.882
	C.3.4	0	10	15	9	0	2.971
4. Formation of resource support for the implementation of ETC projects	C.4.1	0	8	16	10	0	3.059
	C.4.2	0	9	17	8	0	2.971
	C.4.3	0	7	17	10	0	3.088
	C.4.4	0	9	18	7	0	2.941
5. Adoption of the final decision on the implementation of ETC projects	C.5.1	0	8	18	8	0	3.000
	C.5.2	0	10	18	6	0	2.882
	C.5.3	0	7	19	8	0	3.029
6. Implementation of ETC projects	C.6.1	0	10	17	7	0	2.912
	C.6.2	0	8	16	10	0	3.059
	C.6.3	0	7	19	8	0	3.029
	C.6.4	0	11	15	8	0	2.912
	C.6.5	0	8	17	9	0	3.029

As follows from the data given in Table 2, the averaged levels of various competencies across the studied enterprises differ. The highest are these levels for most competencies related to the formation of resource provision and project implementation. At the same time, the averaged levels of competencies for information collection and processing are lower.

At the next stage of the empirical study, the generalized levels of personnel competencies in the development and implementation of energy-saving technological changes were assessed using formula (1). That made it possible, using the

sequence of actions shown above in Fig. 2, to indirectly assess the impact of personnel competencies on energy-saving technological changes at the studied enterprises. The results of such assessment are given in Table 3. At the same time, it was taken into account that the sample included enterprises belonging to three different types of economic activity. Therefore, the relative value of the energy efficiency indicator was assessed for each enterprise. This indicator was determined by dividing the actual energy efficiency value of the relevant enterprise for 2024 by the maximum energy efficiency value among all enterprises in a certain industry under study. In turn, energy efficiency was defined as the ratio of the company's annual net income to its annual natural gas consumption.

As can be seen from the data in Table 3, with an increase in the level of personnel competence, the level of energy efficiency of enterprises increases. The use of the one-factor analysis of variance method showed that this dependence is statistically significant (since the actual value of the Fisher test exceeds the critical one). At the same time, as was additionally established, enterprises with medium and high levels of personnel competence during 2014–2024 were quite actively implementing energy-saving technological changes. Therefore, it can be concluded that the competence of the personnel of the studied companies had a positive effect on these changes.

The expected impact of increasing the level of personnel competence in the development and implementation of ETC projects is particularly significant for those studied enterprises in which this level is low. In particular, the transition of such enterprises after implementing appropriate measures, primarily specialized training for personnel, to the class of enterprises with an average level of the specified competence

will lead to an expected increase in average energy efficiency by 35.89%. At the same time, the transition of enterprises with a low level of personnel competence to the class of companies with a high level of such a level will lead to an expected increase in average energy efficiency by 84.15%.

Information was also collected on energy-saving technological change projects that were considered for their implementation at the studied enterprises in 2019–2024. This information is summarized in Tables 4 and 5. Based on this information and using formula (2), the level of partial obstacles to the development and implementation of energy-saving technological changes at the studied enterprises was calculated. As can be seen from the data given in Table 6, the highest level of such obstacles for all three types of economic activity considered is characteristic of the stages of collecting input information and resource provision for project implementation.

At the next stage of the study, the level of partial obstacles to the development and implementation of energy-saving technological change projects at the studied enterprises due to the insufficient level of personnel competence was assessed. The results of such an assessment are given in the last three columns of Table 6. As follows from these data, for all three types of economic activity, the highest level of these obstacles was inherent in the stage of collecting input information.

Subsequently, using expression (3), for each of the three types of economic activity, the total level of obstacles to the development and implementation of energy-saving technological change projects was calculated. Also, using formula (5), this same level was calculated, but only in terms of obstacles caused by a lack of competence. The corresponding results are given in Table 7.

Table 3

Indicators of the impact of the level of competencies on the energy efficiency of enterprises

Indicator ID	Definition of indicators by groups of enterprises with a level of competence in the development and implementation of ETC projects		
	Low	Medium	High
1. Number of enterprises	11	12	11
2. Average level of energy efficiency of enterprises in 2024	0.457	0.621	0.759
3. The difference between the average energy efficiency levels of enterprises in their neighboring groups	–	0.164	0.138
4. Expected increase in average energy efficiency in enterprises with low staff competence when moving to a class of enterprises with a higher level of competence, %	–	35.89	84.15

Table 4

Data on the number of energy-saving technological change (ETC) projects at the beginning and end of the corresponding stages of the process of developing and implementing these projects at the studied enterprises

Names of the stages of development and implementation of ETC projects	Number of ETC projects at the beginning of the corresponding stage by enterprises that manufacture products			Number of ETC projects at the end of the corresponding stage by enterprises that manufacture products		
	from metal	from glass	from clay	from metal	from glass	from clay
1. Collection of input information necessary for the development and implementation of ETC projects	46	53	39	31	37	29
2. Processing of input information necessary for the development and implementation of ETC projects	31	37	29	31	37	29
3. Adoption of a preliminary decision on the implementation of ETC projects	31	37	29	28	34	26
4. Formation of resource support for the implementation of ETC projects	28	34	26	20	26	17
5. Adoption of the final decision on the implementation of ETC projects	20	26	17	19	24	16
6. Implementation of ETC projects	19	24	16	18	22	15

Table 5

Data on the number of energy-saving technological change (ETC) projects that did not pass the appropriate stages of the development and implementation process of these projects at the studied enterprises

Names of the stages of development and implementation of ETC projects	Total number of ETC projects that have not passed the appropriate stage, by enterprises that manufacture products			Number of ETC projects that did not pass the appropriate stage due to lack of competence, by enterprises that manufacture products		
	from metal	from glass	from clay	from metal	from glass	from clay
1. Collection of input information necessary for the development and implementation of ETC projects	15	16	10	11	13	8
2. Processing of input information necessary for the development and implementation of ETC projects	0	0	0	0	0	0
3. Adoption of a preliminary decision on the implementation of ETC projects	3	3	3	2	3	1
4. Formation of resource support for the implementation of ETC projects	8	8	9	1	2	2
5. Adoption of the final decision on the implementation of ETC projects	1	2	1	0	1	0
6. Implementation of ETC projects	1	2	1	0	1	0
Total	28	31	24	14	20	11

Table 6

Data on partial levels of obstacles in the development and implementation of energy-saving technological change (ETC) projects at the studied enterprises

Names of the stages of development and implementation of ETC projects	Average overall level of obstacles at the appropriate stage of development and implementation of ETC projects by enterprises that manufacture products			Number of ETC projects that did not pass the appropriate stage due to lack of competence, by enterprises that manufacture products		
	from metal	from glass	from clay	from metal	from glass	from clay
1. Collection of input information necessary for the development and implementation of ETC projects	0.326	0.302	0.256	0.239	0.245	0.205
2. Processing of input information necessary for the development and implementation of ETC projects	0.000	0.000	0.000	0.000	0.000	0.000
3. Adoption of a preliminary decision on the implementation of ETC projects	0.097	0.081	0.103	0.065	0.081	0.034
4. Formation of resource support for the implementation of ETC projects	0.286	0.235	0.346	0.036	0.059	0.077
5. Adoption of the final decision on the implementation of ETC projects	0.050	0.077	0.059	0.000	0.038	0.000
6. Implementation of ETC projects	0.053	0.083	0.063	0.000	0.042	0.000

Table 7

Results of assessing the impact of personnel competence on energy-saving technological changes (ETC) at the studied enterprises

Indicator ID	Average values of indicators by enterprises that manufacture products		
	from metal	from glass	from clay
1. General level of obstacles in the development and implementation of ETC projects at enterprises	0.609	0.585	0.615
2. The overall level of obstacles in the development and implementation of ETC projects due to the insufficient level of competence of enterprise personnel	0.304	0.377	0.282
3. Expected relative change in the overall level of obstacles in the development and implementation of ETC projects as a result of ensuring a high level of competence of enterprise personnel, %	50.00	35.48	54.17

From the data given in Table 7, it follows that the elimination of obstacles caused by an insufficiently high level of personnel competence would make it possible to reduce the average level of such obstacles by type of economic activity for enterprises by 35.48% to 54.17%. Thus, the level of personnel competence had a rather significant impact on the scale of energy-saving technological changes for

a significant number of enterprises under study. At the same time, this impact was negative in the sense that the necessary competencies were lacking. Therefore, improving these competencies should be considered an important reserve for intensification of the process of energy-saving (for natural gas) technological changes in some of the enterprises under study.

## 6. Discussion of the designed tool for assessing the impact of personnel competence on energy-saving technological changes

Our study showed that the assessment of the impact of personnel competence on energy-saving technological changes at enterprises should be based on properly substantiated theoretical principles. This is explained, in particular, by the complex mechanism of such an impact, the model of which is shown in Fig. 1. It is also important to structure the sequence of implementation of energy-saving technological change projects at enterprises. Such structuring made it possible to group the studied competencies by the stages of the process of such implementation, as was done in Table 1.

The method of indirect assessment of the impact of the level of personnel competence on the scale of implementation of energy-saving technologies at enterprises, developed in the course of this study, also deserves special attention. As follows from Fig. 2, for this purpose, it is necessary to divide enterprises into groups according to the level of competence in the development and implementation of energy-saving technological change projects. This makes it possible to assess the statistical significance of the relationship between the level of these competencies and the energy efficiency of activities, which, in turn, is largely determined by the scale of implementation of energy-saving technologies at enterprises.

Regarding the method of direct assessment of the impact of personnel competencies on energy-saving technological changes, this method makes it possible not only to establish the presence of such an impact but also assess its extent. In addition, this method makes it possible to identify those stages of the process of developing and implementing energy-saving technological change projects at which there is the greatest lack of relevant competencies. These opportunities are largely due to the constructed economic and mathematical models of obstacles to the implementation of energy-saving technological change projects at enterprises (expressions (2) to (6)).

The use of the designed toolkit on a sample of 34 companies in the western region of Ukraine showed its effectiveness. In particular, data from a survey of enterprises regarding the level of competencies available to their personnel as of the end of 2024 were processed (Table 2). These results, in particular, showed that the averaged levels of various competencies across the studied enterprises differ from each other. These levels are the highest for most competencies related to the formation of resource provision and project implementation. At the same time, the average levels of competence in information collection and processing are lower. At the next stage of the empirical study, using formula (1), the generalized levels of personnel competence in the development and implementation of energy-saving technological changes were estimated (Table 3). That made it possible to establish that with an increase in the level of personnel competence, the level of energy efficiency of enterprises increases. It was also found that the transition of enterprises with a low level of personnel competence to the class of companies with medium and high such levels, respectively, would lead to an expected increase in average energy efficiency by 35.89% and 84.15%. Using the method of one-factor analysis of variance showed that this dependence is statistically significant. At the same time, as was additionally established, enterprises with medium and high levels of personnel competence during 2014–2024 quite actively implemented energy-saving technological changes. This allowed us to conclude that the competence of the personnel of the companies studied had a positive impact on these changes.

It was also possible to perform an analysis of obstacles to the implementation of energy-saving technological change projects at the studied enterprises, the input data for the implementation and the results of which are given in Tables 4–7. In particular, it turned out that the highest level of such obstacles for all three types of economic activity considered is characteristic of the stages of collecting input information and resource provision for project implementation. Ultimately, it was found that the elimination of obstacles caused by the lack of personnel competence will make it possible to reduce the average level of such obstacles by type of economic activity for enterprises by a relative value from 35.48% to 54.17%.

Thus, the proposed toolkit makes it possible to assess the impact of the competence of enterprise personnel on energy-saving technological change. In particular, a positive feature of the designed toolkit should be considered the ability to obtain accurate and comprehensive results using a formalized procedure for processing input information. The proposed toolkit is suitable for use by companies of all types of economic activity, which will have a positive impact on their competitiveness and the level of economic efficiency of operation.

Given these positive features of the results of our study, it was possible to close some gaps in scientific literature. In particular, although the issue of assessing the impact of personnel competencies on energy-saving activities of enterprises has been considered in many works, in particular in [11–15], in the process of this study it was possible to increase the degree of formalization of such assessment. Also, despite the existence in the literature, in particular in [16–23], of various ways of distinguishing competencies regarding energy saving, the method of grouping these competencies proposed based on the results of this study allowed us to increase their detailing. Finally, although the role of competencies in overcoming obstacles in the implementation of energy-saving measures has already been established in previous works, in particular in [24, 25], in this study it was possible to obtain a quantitative assessment of this role.

Taking into account the above, the tools formed in the process of this study sufficiently fully cover the problem of determining the extent of the impact of personnel competencies on energy-saving technological changes at enterprises. This is achieved due to the fact that the application of the developed methods and models makes it possible to perform such an assessment with due accuracy. In this regard, the information obtained through such application provides an opportunity to properly substantiate the directions of improving personnel competencies.

At the same time, our research has some limitations. In particular, when conducting an empirical analysis, only the first-level competencies were considered according to the three-level model proposed in Fig. 1. It is also worth noting the possibility of using, in addition to variance analysis, other methods of statistical analysis, in particular regression.

In addition, it is appropriate to note the disadvantage of the proposed procedure for assessing the impact of personnel competence on energy-saving technological changes at enterprises, which somewhat limits the level of accuracy of the results obtained through the application of this procedure. The essence of the aforementioned disadvantage is in the fact that a significant part of the input information consists of survey results, which are a priori characterized by a certain subjectivity. Therefore, further research, among other things, should include the search for opportunities to use more objective approaches to assessing the level of personnel competence.

It should also be noted that part of the time period considered in this study fell on the time of large-scale military operations on the territory of Ukraine. These actions had significantly negative consequences for the investment activity of business entities in Ukraine, including investments in energy-saving technological change projects. Therefore, in further research, it would be worth assessing this impact in more detail.

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## 7. Conclusions

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1. The grouping of personnel competencies in the development and implementation of energy-saving technological change projects has been carried out, and the place of these competencies among the factors influencing the implementation of these changes was also established. For this purpose, the process of developing and implementing energy-saving technological change projects was divided into several stages. A certain group of competencies of managers and specialists of enterprises in the issues of such development and implementation was tied to each of these stages. This made it possible to develop existing methods of grouping the specified competencies, highlighting such competencies as collecting input information, processing it, making a preliminary decision, its resource provision, making a final decision, and its implementation. At the same time, all factors influencing the scale of energy-saving technological change at enterprises were located at three levels, namely: factors of direct influence, factors of indirect influence and basic factors. Thus, according to the proposed model of the influence of factors on the scale of energy-saving technological changes at enterprises, these changes can ultimately be divided into two large groups. Such groups are the competencies of managers and specialists of enterprises and uncontrollable factors. This is due to the fact that if some factors are subject to managerial influence, but such influence is absent, which negatively affects energy efficiency, there is a lack of relevant managerial competencies. This approach to identifying factors of influence on energy-saving technological changes at enterprises does not reduce the significance of controllable factors, in particular the volume and quality of resources required for the implementation of energy-saving measures. However, this approach makes it possible to identify the most profound, basic factors of this influence.

2. A toolkit has been proposed for assessing the impact of enterprise personnel competence on energy-saving technological changes on them. The first method of such assessment (indirect impact assessment) makes it possible to establish the presence of the impact of personnel competence on energy-saving technological changes but does not provide for determining the extent of such impact. The application of the second method of the method (direct impact assessment) makes it possible to establish the extent of such impact. In addition, this method makes it possible to identify those stages of the process of developing and implementing projects of energy-saving technological changes at which there is the greatest lack of relevant competencies. The proposed toolkit, compared to those existing in modern scientific literature, provides for obtaining a more accurate quantitative

assessment of the impact of enterprise personnel competence on energy-saving technological changes.

3. The proposed tool for assessing the impact of enterprise personnel competence on energy-saving technological changes in them was tested on a sample of Ukrainian firms. For this purpose, a sample of 34 enterprises located in the western region of Ukraine was formed. These enterprises belonged to three types of activity, which are characterized by a fairly significant consumption of natural gas. The analysis revealed, in particular, that the elimination of obstacles caused by the lack of personnel competence would reduce the average level of such obstacles by type of economic activity for enterprises by an amount from 35.48% to 54.17%. Thus, the level of personnel competence had a fairly significant impact on the scale of energy-saving technological changes for a significant number of enterprises under study. At the same time, this impact was negative in the sense that the necessary competencies were lacking. Therefore, improving these competencies should be considered an important reserve for intensification of the process of energy-saving (for natural gas) technological changes at some of the enterprises under consideration.

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## Conflicts of interest

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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 and the results reported in this paper.

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## Funding

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## Data availability

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All data are available in the main text of the manuscript.

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## Use of artificial intelligence

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

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## Authors' contributions

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**Valentyn Lesinskyi:** Conceptualization, Software, Validation, Funding acquisition; **Olexandr Yemelyanov:** Conceptualization, Methodology, Formal analysis, Funding acquisition; **Oksana Zarytska:** Investigation, Data Curation, Writing – review & editing, Funding acquisition; **Tetyana Petrushka:** Investigation, Supervision, Visualization, Funding acquisition; **Nataliia Myroshchenko:** Formal analysis, Data Curation, Project administration, Funding acquisition.

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