***This study's object is the potential to overcome economic barriers in the design and implementation of energy-saving technologies at enterprises. The task addressed is to devise an effective toolset for assessing this potential.***

***The theoretical foundations for analyzing economic barriers in the design and implementation of energy-saving technologies have been substantiated. A procedure for assessing the potential for overcoming these obstacles was developed. This procedure involves determining the capabilities of enterprises under certain conditions to overcome specified barriers of a subjective and objective nature. In turn, such conditions include enhancing the competence of company personnel and improving the processes of information support for the process that assesses the effectiveness of energy-saving projects, as well as positive changes of an external nature.***

***The designed toolkit was assessed using data from 98 industrial enterprises in the western region of Ukraine. Among other things, it was found that the companies studied have a sufficiently high potential for overcoming economic obstacles that arise when implementing energy-saving technological processes. In particular, the share of energy-saving technology projects that were considered and rejected because of the presence of subjective economic obstacles in the total number of rejected projects varies by industry from 39.29% to 47.54%.***

***The proposed toolkit produces accurate and comprehensive results using a formalized procedure. It could be used by enterprises in various industries to assess the potential for overcoming economic barriers to the design and implementation of energy-saving technologies***

***Keywords: enterprise potential, enterprise potential assessment toolkit, energy-saving technologies, economic obstacles, overcoming obstacles, energy-saving project***

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# ASSESSING THE POTENTIAL TO OVERCOME ECONOMIC BARRIERS IN THE DESIGN AND IMPLEMENTATION OF ENERGY-SAVING TECHNOLOGIES

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## 1. Introduction

The need to reduce energy consumption has taken a principal place among government priorities in many countries over the past decade. This situation was caused by a number of reasons. In particular, these include the deterioration of the environment caused by carbon emissions in the process of energy consumption [1], the negative impact of high energy intensity on the competitiveness of certain sectors of the economy [2], a significant level and high volatility of energy prices [3], etc. In addition, in the context of increasing geopolitical instability and the deployment of military operations in a number of regions of the world, logistics chains have deteriorated while supply risks have increased [4]. This has naturally strengthened the desire of many countries to increase their own energy independence [5], in particular, on the basis of reducing energy consumption [6].

These considerations have caused an objective need in many countries, primarily European ones, to accelerate their technological transition. Such a transition requires the intensification of energy efficiency improvement processes [7] and an increase in the share of renewable sources in energy balances [8]. In turn, an important tool for solving these problems is the design and implementation of progressive energy-saving technological processes. Such implementation should be carried out primarily at enterprises [9] since they, along with households, are the main consumers of energy resources.

However, the implementation of energy-saving technological change projects and other energy-saving measures at enterprises quite often encounters various obstacles. This leads to a slowdown in the process of such implementation [10]. At the same time, the obstacles mentioned can be of quite different nature, that is, have their own specificity. Therefore, each of the types of obstacles that arise during the implementation of energy-saving projects at enterprises requires separate attention. In particular, this applies to the development of tools for assessing the potential for overcoming the corresponding type of obstacle. One of these types is economic barriers that arise due to the insufficient level of economic efficiency of investing in the implementation of energy-saving technological changes at enterprises. Assessment of the potential for overcoming these barriers should

provide important information on the basis of which it would be possible to establish the prerequisites under which such overcoming will be possible. These considerations determine the relevance of the issue of assessing the potential for overcoming economic obstacles that arise on the way to the implementation of energy-saving technological changes at enterprises.

## 2. Literature review and problem statement

Numerous studies consider the task of overcoming barriers that arise during the implementation of energy-saving projects. At the same time, different scientists prefer different types of such barriers. In particular, a number of scientists attribute managerial obstacles to the main barriers that arise on the way to increasing energy efficiency. Thus, in [11], it was established that companies often refuse to implement energy-saving projects that are characterized by a fairly high economic efficiency due to the absence of energy saving among the priority goals, lack of rationality, and insufficient level of information support. The insufficiency of this level as an important factor inhibiting the implementation of energy-saving projects is also noted in [12, 13]. At the same time, the authors of works [11–13] focused on the study of managerial obstacles to increasing energy efficiency, while economic barriers remained outside their consideration. This is probably explained by the fact that the authors of the above works considered managerial obstacles as the most significant.

Special attention from scientists is also paid to obstacles of a resource nature, in particular, the lack of funds needed for the implementation of energy-saving projects. The importance of taking these obstacles into account is proven, in particular, in work [14], which considers the features of financing energy-saving projects from various sources of funds. Although the cited work provides a fairly detailed description of the financial obstacles that arise during the implementation of energy-saving projects, the issue of the low level of economic efficiency of such projects is not considered in the work fully enough. This is largely explained by the fact that this issue went beyond the scope of the study carried out by the authors.

At the same time, quite a few researchers consider economic barriers to be the most important obstacles to the large-scale implementation of energy-saving technological changes. In particular, this opinion is shared by the authors of work [15]. The significant influence of economic barriers on the inhibition of these changes was also established in [16], in which the lack of financial incentives is positioned as one of the decisive factors that negatively affect the implementation of energy-saving measures. However, despite the thoroughness of the studies carried out by the authors of [15, 16], they did not consider the entire set of main factors that cause economic obstacles that arise on the way to the implementation of energy-saving measures. This may be due to the existence of a significant number of such factors. At the same time, the level of formalization of the process of analyzing economic barriers is insufficient since such analysis is largely qualitative in nature.

Therefore, it is necessary to take into account the fact that the height of economic obstacles that arise on the way to energy-saving technological changes depends, in turn, on the influence of various factors. Scientists have attributed the risk of investing in energy saving to these factors [17], as well as the volume of investments required to this end [18], etc. Special attention has also been paid to the factor of insufficiently high prices for energy resources. However, the results of research into the significance of this factor, reported by different scientists, are generally contradictory. For example, whereas in [19] the influence of changes in electricity prices on changes in its consumption was revealed, in [20] the absence of such an influence was established. However, in each study [17–20] only individual factors that influence the implementation of energy saving measures are considered, that is, a comprehensive consideration of these factors was not carried out because of the subject matter of the cited papers.

Special attention is paid to the issue of assessing the potential of enterprises to overcome economic obstacles that arise on the way to the implementation of energy-saving technological processes. In this case, one should take into account the methodological principles of assessing various types of potential of companies, since these principles can be extrapolated to the case of assessing the potential of enterprises to overcome the above-mentioned obstacles. In this context, worth noting, is in particular, work [21], which reports a scientifically sound toolkit for assessing the innovative potential of firms, based on the use of mathematical modeling. The ability of enterprises to implement advanced technological processes is studied and assessed in detail in [22]. However, in papers [21, 22], insufficient attention is paid to the energy-saving potential. This is likely explained by the fact that the consideration of such potential went beyond the scope of the research carried out in [21, 22]. At the same time, energy-saving potential was the subject of research in [23, 24]. In addition, it is appropriate to note work [25]. It analyzed the potential of sustainable technologies, in particular in the context of renewable energy initiatives. However, studies [23–25] left out of consideration the assessment of the potential for enterprises to overcome economic barriers to energy saving. Therefore, the issue of designing tools for such an assessment was not considered in those papers.

At the same time, the problem of overcoming obstacles in the implementation of energy-saving measures is in the focus of attention of many scientists. In particular, the authors of [26] substantiated the importance of proper information support for the full and timely implementation of energy-saving projects. The authors of [13] structured this support on the example of energy-saving technological changes. The authors of [27] convincingly proved the need for the development of energy-saving projects not only to provide proper input information but also to have the skills to process such information. However, the issue of overcoming economic obstacles in the implementation of energy-saving technologies was not studied in detail in [13, 26, 27]. This is explained by the fact that the authors of those papers did not consider the economic obstacles that arise in the implementation of energy-efficient projects.

One of the possible ways to overcome these obstacles is to reduce the need for investments in the implementation of energy-saving projects, which automatically leads to an increase in the economic efficiency of these investments. In this regard, studies on preferential lending [28] and subsidy programs [29], which can act as forms of financial support for the implementation of energy-saving measures, are particularly noteworthy. An important direction for overcoming economic obstacles that arise on the way to the implementation of energy-saving technologies at enterprises is also the reduction of the riskiness of investing in such implementation [30].

This is explained by the fact that such a reduction causes a decrease in discount rates, which, in turn, increases the present value of the flow of income from the implementation of energy-saving technological change projects at enterprises.

Thus, current scientific literature includes papers, in particular the above-mentioned works [28–30], related to the issue of overcoming economic obstacles to increasing energy efficiency. At the same time, the task to design a tool for assessing the potential for such overcoming has not yet been resolved by scientists. One reason for this may be that scientists pay insufficient attention to identifying this potential as a separate component of the potential for increasing the energy efficiency of companies.

Therefore, although there are quite a large body of research into obstacles in the implementation of energy-saving projects, there are no comprehensive studies on the factors that cause economic barriers that arise on the way to such implementation. The process of analyzing these barriers is also not formalized enough. As a result, even those scientists who consider the potential for increasing energy efficiency do not proceed to assessing the potential for overcoming economic obstacles that arise on the way to such an increase. In particular, this applies to measures for the design and implementation of energy-saving technologies. Thus, there is a need to formalize the analysis of economic obstacles in the implementation of these measures, systematize the factors influencing these obstacles, and establish a sequence and devise indicators for assessing the potential for overcoming these obstacles.

## 3. The aim and objectives of the study

The purpose of our study is to devise and apply a toolkit for assessing the potential for overcoming economic barriers in the design and implementation of energy-saving technologies at enterprises. This will make it possible to establish reserves for increasing the energy efficiency of companies by eliminating at least some of the economic barriers that arise on the way to such an increase. This, in turn, will contribute to improving the competitiveness and financial condition of enterprises, increasing the energy efficiency of their activities, as well as improving the environmental situation.

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

– to substantiate the theoretical principles of analyzing economic barriers in the design and implementation of energy-saving technologies at enterprises;

– to determine the factors and sequence of assessing the potential for overcoming economic barriers that arise in the design and implementation of energy-saving technologies at enterprises;

– to test the toolkit for assessing the potential for overcoming economic obstacles in the design and implementation of energy-saving technologies at enterprises based on a sample of Ukrainian companies.

## 4. The study materials and methods

The object of research in our work is the potential for overcoming economic obstacles in the design and implementation of energy-saving technologies at enterprises. The principal hypothesis of this study assumes that a significant number of enterprises have the specified potential.

Some other assumptions were also accepted, namely:

– the generally low level of implementation of energy-saving technologies that were considered by enterprises for such implementation;

– the existence of a statistically significant impact of the level of economic obstacles that arise on the way to the implementation of energy-saving technologies at enterprises on the overall level of these obstacles.

At the same time, a number of simplifications were adopted in the research process, namely:

– the invariance over time of energy resource consumption standards and values of other technical and economic indicators with the invariance of the technologies used;

– the limited nature of the types of economic activity considered;

– the limited number of companies studied and the time period during which the course of the process of energy-saving technological changes was considered.

The theoretical basis of our research is scientific literature that considers the issues of assessing the potential for overcoming economic obstacles in the design and implementation of energy-saving technologies by business entities.

To conduct empirical analysis, a significant volume of materials was collected and processed, obtained from the accounting, statistical, and management accounting data on a number of enterprises. In addition to the reporting data of the firms, the results of a questionnaire survey of the enterprises under study were used to obtain input information. These companies belong to three rather energy-intensive types of economic activity (manufacture of metal, glass, and clay products). For each of these three types of activity, at the initial stage of the empirical study, a sample of 60 randomly selected firms located in the western region of Ukraine was formed. After that, questionnaires were sent to each enterprise and, in addition, data on the selected companies from open sources was analyzed. In the end, taking into account the completeness of the collected information and the willingness of the companies to share it, a final sample of business entities was formed, which in total (i.e., for all three types of economic activity) included 98 companies. Next, the indicators of the general level of obstacles and the level of economic obstacles that arose on the way to the implementation of energy-saving technological processes at the enterprises studied were calculated. After that, the impact of the level of economic obstacles that arose on the way to the implementation of energy-saving technologies at the enterprises studied on the general level of these obstacles was assessed. At the next stage of empirical research, an assessment of the potential for overcoming economic obstacles of a subjective and objective nature when implementing energy-saving technologies was performed.

A wide range of various methods of scientific knowledge was used in carrying out our study. Thus, when substantiating the theoretical principles of analyzing economic obstacles when designing and implementing energy-saving technologies at enterprises, economic and mathematical modeling was used. The need for such modeling is due to the complexity of the formation of the specified obstacles, which requires a formalized approach to analyzing the process of such formation.

In the process of devising a procedure for assessing the potential for overcoming economic obstacles in the implementation of energy-saving technologies at enterprises, generalization and grouping methods were used. The use of these

methods made it possible to group factors that cause economic obstacles to the implementation of energy-saving technologies at enterprises, as well as to build a system of indicators for assessing the potential for overcoming these obstacles.

The method of system analysis was also used in the research process. This made it possible to systematize the factors of obstacles that arise on the way to the implementation of projects for the implementation of energy-saving technologies at enterprises. In particular, the connections between these factors as components of a certain system were established.

When conducting empirical studies on the potential for overcoming economic obstacles in the design and implementation of energy-saving technologies at enterprises, the methods of technical and economic calculations and economic analysis were applied. When collecting data from enterprises, the questionnaire survey method was used. To process the obtained data, mathematical statistical methods were used, in particular, the one-way analysis of variance method [31]. In addition, in the process of carrying out empirical research, the procedure devised in our work for quantitative assessment of the potential for overcoming economic obstacles in the implementation of energy-saving technologies in companies was applied.

In order to clearly display the results obtained in the course of this study, tabular and graphical methods were used.

When discussing the results and generalizing them in the process of drawing conclusions, an abstract-logical method was used. The application of this method has made it possible to highlight the most significant results of our study, to establish the main reasons that determined these results, and to describe possible areas for further study of the issues considered in our study.

## 5. Toolkit for assessing the potential for overcoming economic barriers in the design and implementation of energy-saving technologies

### 5. 1. Substantiation of the theoretical principles for analyzing economic barriers in the design and implementation of energy-saving technologies

Assessing the potential for overcoming economic barriers in the implementation of energy-saving technologies requires a preliminary analysis of these barriers. It can be performed at least at two levels, namely:

– for a set of projects for implementing energy-saving technologies at a particular enterprise or group of enterprises;

– for a single project for implementing energy-saving technologies.

In the first case, to establish the height of economic obstacles that arise when implementing energy-saving technologies, one should use indicators such as:

1) the number of projects for the implementation of energy-saving technological processes that were considered by the enterprise (enterprises) under study during a certain period and were rejected due to the economic inexpediency of their implementation;

2) the share of such projects in the total number of projects for the implementation of energy-saving technological processes that were considered by the enterprise (enterprises) under study;

3) the share of such projects in the total number of projects for the implementation of energy-saving technological processes that were considered by the enterprise (enterprises) under study and were rejected for various reasons;

4) the number of rejected projects for the implementation of energy-saving technological processes that were considered by the enterprise (enterprises) under study due to insufficient economic efficiency, distributed by the estimated level of this efficiency. The following gradation of this level can be proposed: very low (less than 0.33 of the minimum allowable); low (from 0.33 to 0.67 of the minimum allowable); and insufficiently high (more than 0.67 of the minimum allowable). In this case, the specified level should be assessed by the indicator of the project profitability index. Then its minimum allowable value will be one.

For a separate project for the implementation of energy-saving technology, the level of economic obstacles that arise on the way to such implementation can be assessed using the profitability index. Since a project can be considered reasonably effective if its present value is not less than the investment made in it, the profitability index of the project should be not less than one. If this condition is not met, this will mean that there is a certain level of economic obstacles that stand in the way of designing and implementing energy-saving technology. At the same time, the greater the difference between one and the profitability index, the greater the specified level, which can thus be estimated by the following formula

$$R = 1 - I_r = 1 - \frac{W}{I}, \quad (1)$$

where $R$ is the level of economic obstacles that arise in the way of designing and implementing energy-saving technology;

$I_r$ is the profitability index of the project for such implementation;

$W$ is the expected present value of the net cash flow from the implementation of energy-saving technology, monetary units;

$I$ is the required investment in the implementation of the project for the implementation of energy-saving technology, monetary units.

In this case, the expected value of the net cash flow from the implementation of the energy-saving technology implementation project at the enterprise in a certain year of operation of this project can be calculated in the following sequence:

1) determining the annual amount of savings on the purchase of a certain type of energy resources after the enterprise implements the energy-saving technological change project;

2) subtracting from the result obtained at the first stage of calculations the possible amount of additional expenses and losses of the enterprise as a result of its implementation of the energy-saving technology. For example, such expenses may be the costs of purchasing another type of energy resources if one type of energy carrier is replaced by another;

3) deducting income tax from the expected amount of the enterprise's profit increase as a result of its implementation of energy-saving technology;

4) adding to the obtained result the amount of depreciation deductions for the project since this amount is a component of the net cash flow.

The described sequence of actions can be formalized in the form of the following formula

$$F = \left( p \cdot \sum_{i=1}^{m} \left( n_{0i} - n_{1i} \right) \cdot V_i - C \right) \cdot \left( 1 - k \right) + A, \quad (2)$$

where $F$ is the net cash flow from the implementation of the energy-saving technology implementation project at the enterprise in a certain year of operation of this project, monetary units;

$p$ is the price of a unit of the energy resource, the savings of which are provided for by this project, in the corresponding year;

$m$ is the number of types of products of the enterprise that will be manufactured in the corresponding year using this energy resource, monetary units;

$n_{0i}$, $n_{1i}$ are the norms of expenditure of this type of energy resources for the production in the corresponding year of a unit of the $i$-th type of product of the enterprise according to and after the implementation of energy-saving technology;

$V_i$ is the planned (forecast) physical volume of production in the corresponding year of the $i$-th type of product of the enterprise after the implementation of energy-saving technology;

$C$ is the possible amount of additional expenses and losses of the enterprise in the corresponding year as a result of its implementation of energy-saving technology, monetary units;

$k$ is the corporate income tax rate in fractions of a unit;

$A$ – amount of depreciation deductions for the project in the corresponding year, in monetary units.

If we consider the case where the values of the indicators in expression (2) do not change significantly during the life of the energy-saving technology, then the present value of the project for implementing this technology can be calculated using the well-known formula for discounting a uniform net cash flow, used in particular in [30]

$$W_1 = \sum_{t=1}^{T} \frac{F}{(1+e)^t} = \frac{F}{e} \cdot \left(1 - \frac{1}{(1+e)^T}\right), \quad (3)$$

or

$$W_1 = \frac{\left(p \cdot \sum_{i=1}^{m} (n_{0i} - n_{1i}) \cdot V_i - C\right) \cdot (1-k) + A}{e} \times \times \left(1 - \frac{1}{(1+e)^T}\right), \quad (4)$$

where $W_1$ – present value of net cash flow under the project of implementing energy-saving technology if the values of indicators in expression (2) do not change significantly during the operation period of this technology, monetary units;

$T$ – forecast duration of the operation period of energy-saving technology, years; $e$ – discount rate in fractions of a unit.

Taking into account expressions (3) and (4), formula (1) is transformed into the following

$$R_1 = 1 - \frac{F}{I \cdot e} \cdot \left(1 - \frac{1}{(1+e)^T}\right), \quad (5)$$

or

$$R_1 = 1 - \frac{\left(p \cdot \sum_{i=1}^{m} (n_{0i} - n_{1i}) \cdot V_i - C\right) \cdot (1-k) + A}{I \cdot e} \times \times \left(1 - \frac{1}{(1+e)^T}\right), \quad (6)$$

where $R_1$ is the level of economic obstacles that arise on the way to the implementation of energy-saving technology if the values of the indicators in expression (1) do not change significantly during the life of this technology.

An important direction in the analysis of economic obstacles that arise when implementing energy-saving technologies at enterprises is to establish the significance of these obstacles. For this purpose, the sequence of assessing the impact of the level of economic obstacles that arise on the way to the implementation of energy-saving technologies at enterprises on the overall level of these obstacles can be used, shown in Fig. 1.

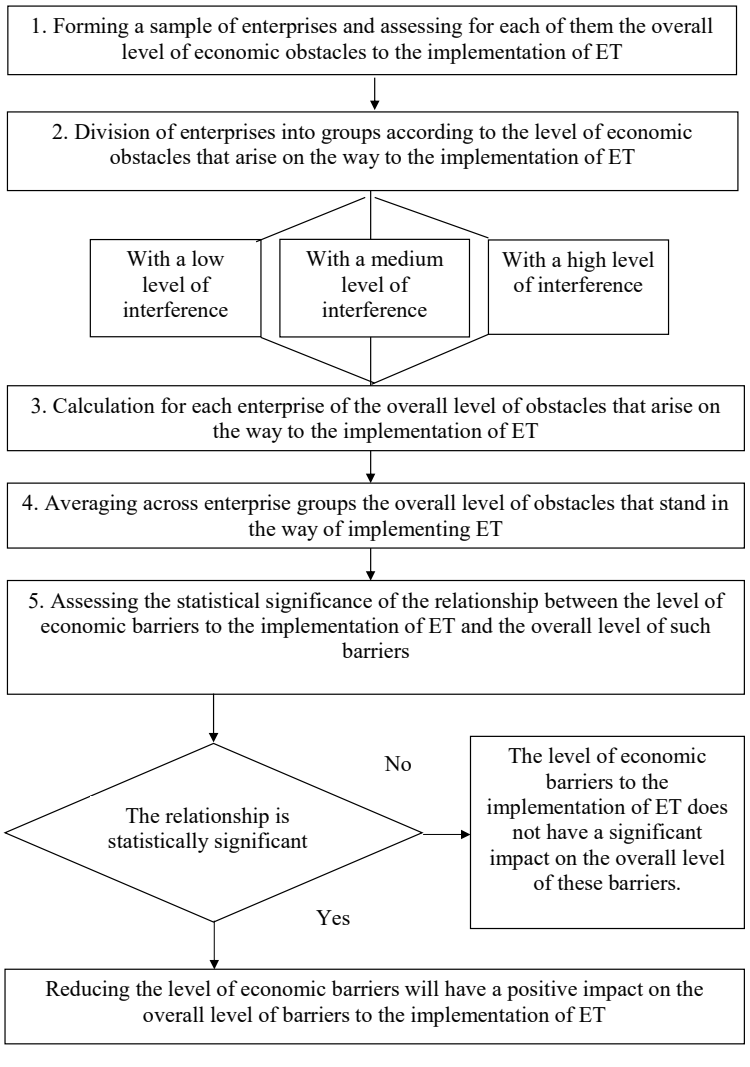


Fig. 1. The sequence of assessing the impact of the level of economic obstacles that arise on the way to the implementation of energy-saving technologies (ETs) at enterprises on the overall level of these obstacles

At the same time, the overall level of obstacles to the implementation of energy-saving technologies can be assessed by the share of such implementation projects that were not implemented in the total number of such projects that were considered for their implementation.

**5. 2. Determining the factors and sequence of assessing the potential for overcoming economic barriers**

When designing and implementing energy-saving technologies, it is necessary to take into account the presence of two

types of such barriers, namely, obstacles of a subjective and objective nature. The first type is barriers caused by erroneous or inaccurate calculations of the level of economic efficiency of projects for the implementation of energy-saving technologies, as a result of which this level was unreasonably underestimated. The emergence of such barriers is a consequence of insufficient competence of relevant officials of companies and (or) unsatisfactory information provision for them in the process of assessing projects for the implementation of energy-saving technologies. As for economic barriers of an objective nature, as follows from data in Fig. 2, the main reasons for their occurrence are exogenous in nature, that is, they are not susceptible or are weakly susceptible to managerial influences from enterprises.

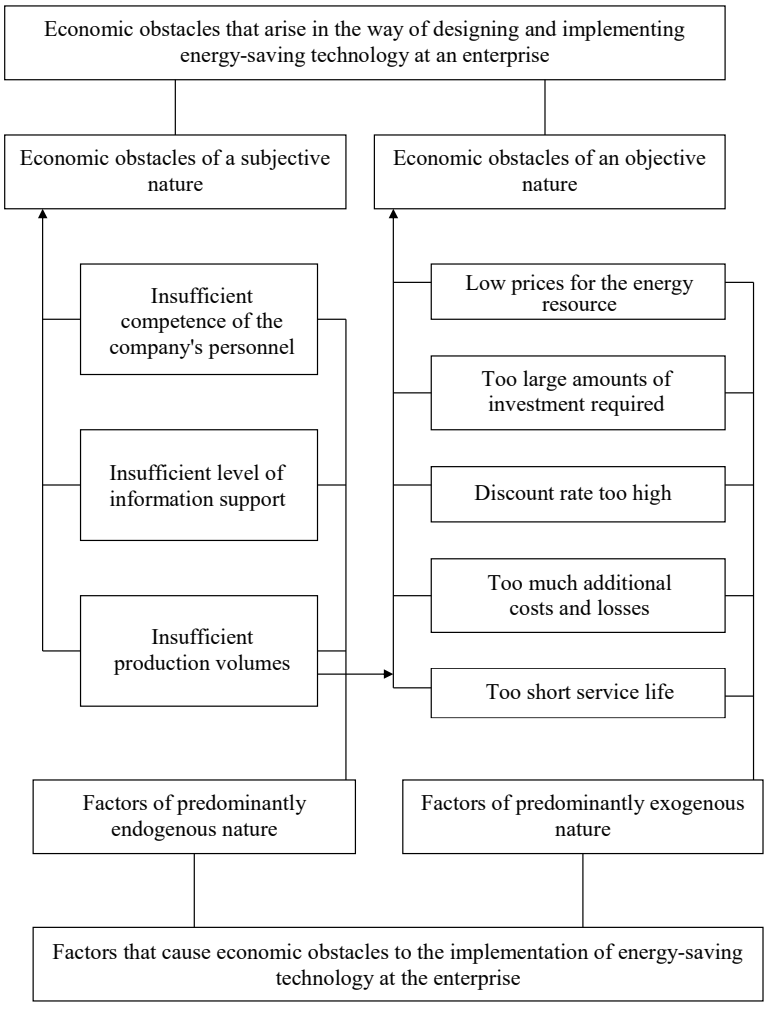


Fig. 2. Grouping of factors that cause economic obstacles to the design and implementation of energy-saving technology at an enterprise

Taking into account the above, the assessment of the potential for overcoming subjective economic obstacles in the implementation of energy-saving technologies can be performed using the following indicators:

– the number of projects for the implementation of energy-saving technological processes that were considered by the studied enterprises over a certain period of time and were rejected due to the presence of subjective economic obstacles;

– the share of such projects $k_1$ in the total number of projects considered

$$k_1 = N_1 / N_2, \quad (7)$$

where $N_1$ is the number of projects for the implementation of energy-saving technological processes, which were considered by the studied enterprises during a certain period of time and were rejected due to the presence of subjective economic obstacles; $N_2$ is the total number of projects for the implementation of energy-saving technological processes considered by the enterprises during this period of time;

– the share of such projects $k_2$ in the total number of rejected projects

$$k_2 = N_1 / N_3, \quad (8)$$

where $N_3$ is the total number of projects for the implementation of energy-saving technological processes rejected by enterprises for various reasons during a given period of time.

Therefore, the realization of the potential for overcoming economic obstacles of a subjective nature in the design and implementation of energy-saving technologies at enterprises should provide, first of all, for improving the competence of company personnel and improving the information support of their activities in the field of energy saving. At the same time, there is another way to overcome economic obstacles of a subjective nature, namely, seeking help from specialists in assessing the economic efficiency of energy-saving programs and projects. Such an appeal can take the form of purchasing the relevant services from consulting or engineering firms.

Regarding the assessment of the potential for overcoming economic obstacles of an objective nature, since the factors of the formation of this potential are not subject to or are weakly subject to managerial influence, such an assessment should be based on forecast estimates. In particular, for this purpose, it is worth identifying a set of scenarios for improving the effects of factors that cause economic obstacles of an objective nature (Fig. 3). Then, an assessment of the potential for overcoming these obstacles can be performed for each of the selected scenarios, as well as, if necessary, for combinations of such scenarios.

Taking into account the above, the assessment of the potential for overcoming objective economic obstacles in the design and implementation of energy-saving technologies can be performed using the following indicators:

– the number of projects for the implementation of energy-saving technologies rejected due to objective economic obstacles that would not arise when implementing a certain scenario for improving the action of the relevant factor(s);

– the share of such projects $k_3$ in the total number of projects considered

$$k_3 = N_4 / N_2, \quad (9)$$

where $N_4$ is the number of projects for the implementation of energy-saving technologies rejected due to economic obstacles of an objective nature that would not arise when implementing a certain scenario for improving the action of the relevant factor(s);

– the share of such projects $k_4$ in the total number of rejected projects

$$k_4 = N_4 / N_3; \quad (10)$$

– the share of such projects $k_5$ in the total number of projects that were rejected for objective reasons

$$k_5 = N_4 / \left(N_3 - N_1\right). \quad (11)$$

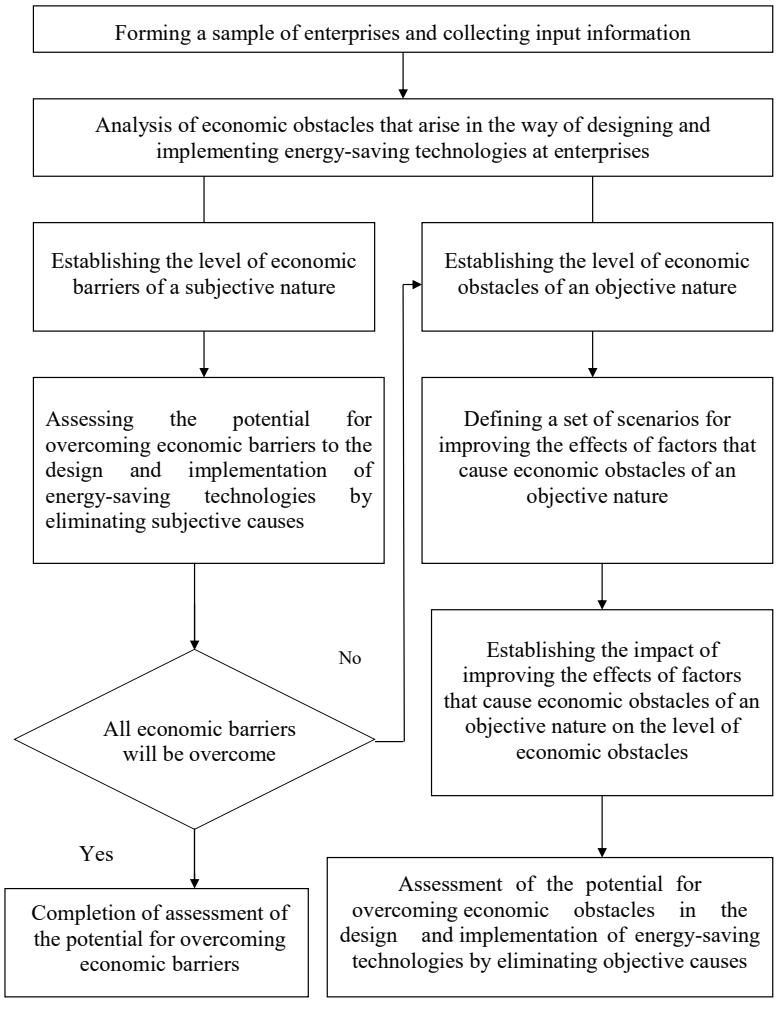


Fig. 3. Sequence of assessing the potential for overcoming economic obstacles in the design and implementation of energy-saving technologies at enterprises

Therefore, the realization of the potential for overcoming economic obstacles of an objective nature when implementing energy-saving technologies at an enterprise should involve, first of all, improving the action of those factors that cause the presence of these obstacles.

**5. 3. Testing the toolkit on a sample of industrial enterprises**

In order to test the theoretical and methodological approaches described above to assessing the potential for overcoming economic obstacles in the implementation of energy-saving technologies at enterprises, a sample of 98 industrial companies in the western region of Ukraine was built. The selected enterprises belong to three industries that are characterized by a fairly high level of natural gas consumption. At the same time, the sample included only those companies that during 2020–2024 considered the possibility of implementing at least one energy-saving technology.

As can be seen from the data given in Table 1, for all types of economic activity studied, the majority of projects for the implementation of energy-saving technologies that were considered by enterprises during 2020–2024 were not implemented. At the same time, the share of unimplemented projects ranges from 62.89% for companies that manufacture metal products to 70.64% for companies that make glass products.

It should be noted that among the reasons that led to a significant share of rejected projects, a significant role is played by the low estimated level of economic efficiency of these projects. This conclusion directly follows from the data presented in Table 2. As can be seen from these data, the share of rejected for economic reasons projects of energy-saving technological changes in the total number of such projects that were considered varies by type of economic activity from 46.34% to 52.29%. At the same time, the share of rejected for economic reasons projects of energy-saving technological changes in the total number of such projects that were rejected for various reasons varies by type of economic activity from 67.86% to 75.41%. However, as follows from the data in Table 2, for most projects rejected for economic reasons, the level of their economic efficiency was not very low, but only not high enough. This may indicate that at least some of the companies studied have some potential to overcome economic obstacles to implementing energy-saving technologies.

Based on the diagram shown above in Fig. 1, an assessment of the impact of the level of economic obstacles that arise on the way to the implementation of energy-saving technologies at the enterprises studied on the overall level of these obstacles was performed. At the same time, all enterprises were divided into three groups by the level of economic obstacles, namely:

– with a low level, in which the share of energy-saving technology projects not implemented for economic reasons in the total number of such projects that were considered for their implementation during 2020–2024 does not exceed 0.33;

– with an average level, in which the share of energy-saving technology projects not implemented for economic reasons in the total number of such projects that were considered for their implementation during 2020–2024 is from 0.33 to 0.67;

– with a high level, in which the share of energy-saving technology projects not implemented for economic reasons in the total number of such projects that were considered for their implementation during 2020–2024 exceeds 0.67.

As follows from the data given in Table 3, with an increase in the level of economic obstacles that arise on the way to the implementation of energy-saving technologies at the enterprises studied, the overall level of these obstacles also increases. At the same time, this dependence for all three types of economic activity is statistically significant since the actual values of the *F*-test are greater than critical.

Table 1

Indicators of the general level of obstacles that arose on the way to the implementation of energy-saving technological processes at the enterprises studied

| Indicator ID | Values of indicators by groups of enterprises that manufacture products | | |
|---|---|---|---|
| | Metal | Glass | Clay |
| 1. Number of enterprises under study, units | 29 | 32 | 27 |
| 2. Number of projects for the implementation of energy-saving technological processes, which during 2020–2024 were considered by the enterprises under study for the possibility of implementation, units | 97 | 109 | 82 |
| 3. Share of projects for the implementation of energy-saving technological processes that were not implemented in the total number of such projects considered during 2020–2024, % | 62.89 | 70.64 | 68.29 |
| 4. Share of required investments in projects for the implementation of energy-saving technological processes that were not implemented in the total amount of required investments in the implementation of such projects considered during 2020–2024, % | 64.07 | 69.12 | 71.43 |

Table 2

Indicators of the level of economic obstacles that arose on the way to the implementation of energy-saving technological processes at the enterprises studied

| Indicator ID | Values of indicators by groups of enterprises that manufacture products | | |
|---|---|---|---|
| | Metal | Glass | Clay |
| 1. Number of projects for the implementation of energy-saving technological processes, which during 2020–2024 were considered by the enterprises under study and were rejected due to the economic inexpediency of their implementation: | 46 | 57 | 38 |
| 1. 1. Total, units | 47.42 | 52.29 | 46.34 |
| 1. 2. Share in the total number of projects, % | 75.41 | 74.03 | 67.86 |
| 1. 3. Share in the total number of rejected projects, % | 3 | 5 | 2 |
| 2. Number of projects for the implementation of energy-saving technological processes rejected due to insufficient economic efficiency, which during 2020–2024 were considered by the enterprises under study, in which the estimated level of this efficiency was: | 6 | 9 | 5 |
| 2. 1. Very low | 37 | 43 | 31 |

Table 3

Input data and results of variance analysis of the impact of the level of economic obstacles that stood in the way of the implementation of energy-saving technologies at the studied enterprises on the overall level of these obstacles

| Indicator ID | Values of indicators by groups of enterprises that manufacture products | | |
|---|---|---|---|
| | Metal | Glass | Clay |
| 1. The number of enterprises in which the level of economic obstacles that arose during 2020–2024 on the way to the implementation of energy-saving technologies was:<br>1. 1. Low | 8 | 9 | 7 |
| 1. 2. Medium | 11 | 12 | 11 |
| 1. 3. High | 10 | 11 | 9 |
| 2. Averaged by enterprise groups, the total level of obstacles that arose in the way of the implementation of energy-saving technologies during 2020–2024:<br>2. 1. For enterprises with a low level of economic obstacles | 0.22 | 0.19 | 0.28 |
| 2. 2. For enterprises with medium level of economic barriers | 0.59 | 0.53 | 0.63 |
| 2. 3. For enterprises with high level of economic barriers | 0.93 | 0.89 | 0.95 |
| 3. Estimated value of *F*-test | 6.87 | 6.13 | 7.35 |

As follows from the data in Table 4, the enterprises studied have, on average, sufficiently high potential for overcoming economic obstacles of a subjective nature that arise when implementing energy-saving technological processes. In particular, the share of projects for the implementation of energy-saving technologies, which were considered by the studied enterprises during 2020–2024 and were rejected due to the presence of economic obstacles of a subjective nature, in the total number of rejected projects ranges from 39.29% to 47.54%.

It is also worth noting that at least some of the companies studied have a fairly significant potential to overcome in the future economic obstacles of an objective nature that arise when implementing energy-saving technological processes. This conclusion follows from the data presented in Table 5. In particular, as can be seen from the data in Table 5, even under fairly moderate scenarios of improving the action of factors, there is a significant decrease in the number of projects that face economic obstacles of an objective nature. At the same time, the simultaneous implemen-

tation of two scenarios leads to a certain synergistic effect. This effect is manifested in the fact that the reduction in the number of projects that will face economic obstacles of an objective nature, with the simultaneous implementation of two scenarios, is greater than the total value of such a decrease under these scenarios. It should be noted that the reason for the aforementioned synergistic effect is due to the fact that the model of the influence of factors on the profitability index of energy-saving projects is multiplicative, which can be seen in particular from the construction of expressions (5) and (6).

Based on the data in Table 5, it is possible to assess the level of potential for overcoming economic obstacles of an objective nature when implementing energy-saving technologies at the enterprises under study. Such an assessment should be carried out in accordance with the selected scenario for improving the action of a certain factor (factors). Of particular interest is the scenario of moderate improvement in the action of such a factor as the natural volumes of production of enterprises. This is due to the fact that this factor is mostly subject to managerial influences (although it is under the influence of such a predominantly exogenous factor as demand for products). The values of the corresponding indicators of the potential for overcoming economic obstacles of an objective nature when implementing energy-saving technologies, provided that the natural volumes of production increase by 10%, are given in Table 6.

Comparing the data in Table 4 and Table 6, we can see that the level of potential for overcoming economic obstacles of an objective nature is significantly lower than obstacles of a subjective nature. At the same time, it should be noted that Table 6 provides data only for the case of improving the impact of only one factor. However, as follows from the above Fig. 2, there are quite a lot of such factors for obstacles of an objective nature. In this case, it is worth taking into account the synergistic effect described above from the joint impact of such factors.

Table 4

Indicators of the level of potential for overcoming subjective economic obstacles in the implementation of energy-saving technologies

| Indicator ID | Values of indicators by groups of enterprises that manufacture products | | |
|---|---|---|---|
| | Metal | Glass | Clay |
| Number of projects for the implementation of energy-saving technological processes that were considered by the studied enterprises during 2020–2024 and were rejected due to the presence of economic obstacles of a subjective nature: 1. Total, units | 29 | 34 | 22 |
| 2. Share in the total number of projects, % | 29.90 | 31.19 | 26.83 |
| 3. Share in the total number of rejected projects, % | 47.54 | 44.16 | 39.29 |

Table 5

Expected change in the number of projects for the implementation of energy-saving technologies that were considered by the studied enterprises during 2020—2024 and will encounter economic obstacles of an objective nature, due to the improvement of the impact factors

| Scenarios for improving the action of factors | Reducing the number of projects that will encounter economic obstacles of an objective nature, by enterprises – manufacturers of products | | | | | |
|---|---|---|---|---|---|---|
| | Metal | | Glass | | Clay | |
| | Absolute change | % | Absolute change | % | Absolute change | % |
| 1. 10% increase in physical production volumes (scenario A) | 6 | 35.29 | 7 | 30.43 | 5 | 31.25 |
| 2. 10% increase in energy prices (scenario B) | 5 | 29.41 | 6 | 26.09 | 5 | 31.25 |
| 3. 10% decrease in investment needs (scenario C) | 6 | 35.29 | 8 | 34.78 | 6 | 37.50 |
| 4. Simultaneous implementation of scenarios A and B | 13 | 76.47 | 14 | 60.87 | 12 | 75.00 |
| 5. Simultaneous implementation of scenarios B and C | 12 | 70.59 | 15 | 65.22 | 13 | 81.25 |
| 6. Simultaneous implementation of scenarios A and C | 14 | 82.35 | 16 | 69.57 | 13 | 81.25 |

Table 6

Indicators of the level of potential for overcoming objective economic obstacles when implementing energy-saving technologies at the enterprises studied, provided that the natural volume of production increases by 10%

| Indicator ID | Values of indicators by groups of enterprises that manufacture products | | |
|---|---|---|---|
| | Metal | Glass | Clay |
| Number of projects for the implementation of energy-saving technologies rejected due to economic obstacles of an objective nature that would not arise in the implementation of a certain scenario: 1. Total, units | 6 | 7 | 5 |
| 2. Share in the total number of projects, % | 6.19 | 6.42 | 6.10 |
| 3. Share in the total number of rejected projects, % | 9.84 | 9.09 | 8.93 |
| 4. Share in the total number of projects rejected due to objective reasons, % | 35.29 | 30.43 | 31.25 |

## 6. Discussion of the devised tool for assessing the potential for overcoming economic barriers in the design and implementation of energy-saving technologies

Our study showed that the assessment of the potential for overcoming economic barriers in the design and implementation of energy-saving technologies should be based on properly substantiated theoretical principles for analyzing these barriers. This is explained, in particular, by the complex mechanism of formation of these barriers, which is modeled using expressions (1) to (6). It is also important to establish a sequence for assessing the impact of the level of economic barriers that arise in the design and implementation of energy-saving technologies at enterprises on the overall level of these barriers. As follows from Fig. 1, for this purpose, it is necessary to divide enterprises into groups according to the level of economic barriers that appear on the way to implementation. This will make it possible to assess the statistical significance of the relationship between the level of economic barriers that arise on the way to the implementation of energy-saving technologies at enterprises and the overall level of such barriers.

The procedure for assessing the potential for overcoming economic barriers in the design and implementation of energy-saving technologies, devised in the course of this study, also deserves special attention. The use of this procedure makes it possible to obtain a fairly accurate estimate of the magnitude of the specified potential. This is explained, in particular, by the fact that the devised procedure fully takes into account the influence of the main factors listed in Fig. 2 that cause economic barriers to the implementation of energy-saving technologies at the enterprise. In addition, the proposed procedure for assessing the potential for overcoming economic barriers in the implementation of energy-saving technologies, the general sequence of which is shown in Fig. 3, is based on a quantitative method for assessing the studied potential. For the purpose of such an assessment, the research process identified economic obstacles of a subjective and objective nature and proposed a system of indicators for assessing the potential for overcoming these obstacles. These indicators include, among others, coefficients calculated using formulas (7) to (11).

The use of the proposed devised toolkit for assessing the potential for overcoming economic obstacles in the design and implementation of energy-saving technologies in a sample of 98 companies in the western region of Ukraine showed the effectiveness of this toolkit. In particular, this is explained by the fact that it was possible to perform an analysis of the indicated obstacles, the results of which are given in Tables 1–3. On this basis, a quantitative assessment of the potential for overcoming economic obstacles in the implementation of energy-saving technologies was carried out at the enterprises under study. The results of such an assessment are given in Tables 4–6. At the same time, our study revealed the existence of a fairly significant number of enterprises with significant potential for overcoming economic obstacles in the implementation of energy-saving technologies. However, the implementation of this potential requires the implementation of a set of organizational and economic measures. The content of this set, in general, is the same for all three types of economic activity under study (production of products from metal, glass, and clay, respectively). Thus, it is necessary to improve the competence of enterprise personnel in assessing the economic efficiency of projects for the implementation of energy-saving technologies and to improve information support for the process of such assessment. In addition, public authorities can play an important role in realizing the potential of overcoming economic obstacles to the implementation of energy-saving technologies. In particular, this concerns measures to reduce the cost of energy-saving technologies (primarily through the provision of grants) and reduce loan interest rates, which will positively affect the level of discount rates.

Thus, the proposed toolkit allows one to assess the level of economic barriers to the design and implementation of energy-saving technologies, establish the potential for overcoming these barriers and identify priority areas for implementing this potential. In particular, the positive feature of the devised toolkit is the ability to obtain accurate and comprehensive results using a formalized procedure for processing input information. The proposed toolkit is suitable for use by enterprises in various fields of production when assessing the potential for overcoming economic barriers to the implementation of energy-saving technologies and when designing measures to realize this potential. This will have a positive impact on the competitiveness and level of economic efficiency of companies.

Taking into account these positive features of the results of our study, it was possible to close some gaps in the scientific literature. Although it, in particular in [21–25], pays considerable attention to various types of potential of companies, there are no methodological principles for assessing the potential for overcoming economic obstacles in the implementation of energy-saving technologies. Similarly, in the related works, in particular [13, 26, 27], which consider obstacles in the implementation of energy-saving measures, little attention is paid to economic barriers that arise in the process of such implementation. At the same time, in those papers in which these barriers are considered in more detail, in particular [15–18, 28–30], the issue of comprehensive assessment of the possibilities of overcoming the specified barriers was not studied.

Taking into account the above, the proposed toolkit fully enough resolves the task of assessing the potential for overcoming economic obstacles in the implementation of energy-saving technologies at enterprises. This is achieved due to the fact that the use of the devised toolkit provides sufficient opportunity to fully and with due accuracy carry out the specified assessment. In this regard, the information obtained through the use of the specified toolkit provides the opportunity to substantiate the directions of implementation of the studied potential.

At the same time, our research has some limitations. In particular, the proposed model (3) to (6) applies only to the case when the values of the indicators in expression (2) do not change significantly over the life of energy-saving technology. It is also worth noting the possibility of identifying other scenarios for improving the action of factors along with those scenarios described in Table 5. In particular, such a scenario may be a decrease in the value of discount rates for projects for the implementation of energy-saving technologies at enterprises.

In addition, it is necessary to note the disadvantage of the proposed procedure for assessing the potential for overcoming economic obstacles in the design and implementation of energy-saving technologies, which somewhat limits the level of accuracy of the results obtained through the application of this procedure. The disadvantage is that when forming a set of scenarios of the action of factors that determine economic obstacles, an assessment of the probability of each of

these scenarios is not provided. Therefore, further research, among other things, should provide for the establishment of such a probability. Taking this circumstance into account will make it possible to increase the accuracy of determining the magnitude of the potential for overcoming economic obstacles in the implementation of energy-saving technologies at enterprises.

It is also worth noting that part of the period considered in this study coincided with the period of large-scale military operations on the territory of Ukraine, which began on February 24, 2022. These activities had significantly negative consequences for the general macroeconomic situation in the country, in particular, for the level of investment activity, including investment in energy-saving measures. At the same time, in further studies on the formation and assessment of energy-saving potential at Ukrainian enterprises, it would be worth assessing this impact in more detail.

## 7. Conclusions

1. The theoretical principles of analyzing economic barriers to the design and implementation of energy-saving technologies at enterprises have been substantiated. In particular, it was established that such analysis could be performed at least at two levels, namely: for the set of projects for the implementation of energy-saving technologies and for a single project for the implementation of energy-saving technologies. In the first case, to establish the level of economic barriers to the implementation of energy-saving technologies, it is necessary to estimate the number of projects for such implementation that were considered and rejected due to the economic inexpediency of their implementation. In addition, it is worth assessing the shares of such projects in the total number of projects and in the number of projects for the implementation of energy-saving technologies rejected for various reasons. As for the case of considering a separate project, the level of economic barriers that arise on the way to such implementation can be estimated as the result of subtracting the profitability index of this project from one unit.

2. The factors have been identified and the sequence of assessing the potential for overcoming economic obstacles that arise when designing and implementing energy-saving technologies at enterprises has been defined. In this case, two types of such obstacles have been identified, namely, subjective and objective. The first type is obstacles caused by erroneous or inaccurate calculations of the level of economic efficiency of projects for the implementation of energy-saving technologies, as a result of which this level was unreasonably underestimated. The emergence of such barriers is a consequence of insufficient competence of relevant officials at companies and (or) unsatisfactory information provision for them in the process of evaluating projects for the implementation of energy-saving technologies. As for economic obstacles of an objective nature, the main reasons for their occurrence are exogenous, that is, they are not susceptible or are weakly susceptible to managerial influences from enterprises. It was established that the assessment of the potential for overcoming economic obstacles of a subjective nature requires determining the number of projects for the implementation of energy-saving technological processes that were rejected due to the presence of economic obstacles of a subjective nature. It is also proposed to assess the specified potential by the shares of such projects in the total number of projects considered and in the total number of projects rejected. To assess the potential for overcoming economic obstacles of an objective nature, it is recommended to determine the number of projects rejected for objective economic reasons that would not arise when implementing a certain scenario for improving the action of the relevant factor (factors). It is also proposed to assess the specified potential by the shares of the specified projects in the total number of projects considered, in the total number of projects rejected, and in the total number of projects that were rejected for objective reasons.

3. The toolkit for assessing the potential for overcoming economic obstacles in the design and implementation of energy-saving technologies at enterprises was tested. For this purpose, a sample of 98 industrial companies in the western region of Ukraine was formed. The selected enterprises belong to three industries that are characterized by a fairly high level of natural gas consumption. The analysis, in particular, revealed that for all studied types of economic activity, the majority of projects for the implementation of energy-saving technologies that were considered by enterprises during 2020–2024 were not implemented. At the same time, the share of unimplemented projects ranges from 62.89% for companies that manufacture metal products to 70.64% for companies that manufacture glass products. It was also found that with an increase in the level of economic obstacles that arise on the way to the implementation of energy-saving technologies at the enterprises studied, the overall level of these obstacles also increases. In addition, it was found that the companies studied have, on average, a fairly high potential for overcoming economic obstacles of a subjective nature that arise when implementing energy-saving technological processes. In particular, the share of projects for the implementation of energy-saving technologies that were considered by the enterprises studied during 2020–2024 and were rejected due to the presence of economic obstacles of a subjective nature in the total number of rejected projects ranges from 39.29% to 47.54%. It was also found that at least some of the companies studied have a fairly significant potential for overcoming economic obstacles of an objective nature that arise when implementing energy-saving technological processes in the future. This conclusion follows from the fact that even under fairly moderate scenarios of improving the action of factors, there will be a significant decrease in the number of projects that face economic obstacles of an objective nature. At the same time, the simultaneous implementation of the scenarios leads to a certain synergistic effect. This effect is manifested in the fact that the reduction in the number of projects that will encounter economic obstacles of an objective nature, when two scenarios are simultaneously implemented, is greater than the total value of such a reduction under these scenarios.

## 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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