The purpose of the study is to develop a toolkit for assessing and overcoming barriers to the implementation of energy-saving projects. The barriers on the way to implementation of energy-saving projects at enterprises were grouped, and general approaches to evaluation of these barriers were determined. Modeling of economic barriers on the way to implementation of energy-saving projects at enterprises was fulfilled. The means of overcoming barriers to implementation of energy-saving projects were substantiated. The need for these studies is due to the need to assess and realize the potential of energy saving in the economies of many countries in Europe and the world. The existence of five main groups of barriers on the way to the implementation of energy-saving projects at enterprises was established. There is a reasonable need to take into consideration the sources of funding energy saving projects when assessing these barriers. It was found that according to the managers of enterprises, for all the studied industries of the Ukrainian economy, the most essential barrier to implementation of the projects of decreasing natural gas consumption is the insufficient level of their implementation. At the same time, the estimated effectiveness of state expenditures for subsidizing the researched enterprises is quite high. Therefore, it is appropriate to extend to cases of enterprises the Ukrainian practice of state subsidization of individuals receiving loans in order to implement projects to decrease the natural gas consumption. The importance of the obtained results is due to the possibility of their use both at the level of enterprises and in the practice of activity of state and municipal authorities in the development of energy-saving strategies and programs

Keywords: energy saving, energy-saving project, project implementation barrier, funding, energy efficiency, state support

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DEVELOPMENT OF A TOOLKIT FOR ASSESSING AND OVERCOMING BARRIERS TO THE IMPLEMENTATION OF ENERGY SAVING PROJECTS

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1. Introduction

An important direction of increasing the efficiency of many enterprises is to reduce their consumption of energy resources. This problem is especially relevant for countries with the high energy intensity of their gross national product, in particular, for most eastern European countries [1]. However, the pace and the scope of implementation of energy-saving measures by enterprises of these countries are generally insufficient in order to achieve a significant reduction in energy resource consumption. This, in turn, adversely affects the level of competitiveness of products and, consequently, the income and profits of business entities. In addition, for the countries, in which the possibilities of own production of certain types of energy carriers are limited, the high energy intensity of gross domestic product can cause an increased level of energy dependence on the countries – energy exporters. At the same time, such dependence can lead to both economic losses in countries that import corresponding types of energy resources and a certain loss of political subjectivity of these countries.

At the same time, many developed countries, particularly Western European countries, have shown a positive example of improving energy efficiency over the past decade and increased the share of renewable energy sources in the energy balance [2]. To a large extent, this result is due to the wide implementation of energy-saving projects by enterprises and households. However, the volume of such implementation differs significantly in different countries, which causes essential differences in the level of energy intensity of gross

national product of countries, in addition to structural, climatic, and some other factors of a country.

The difficulty of realizing the energy-saving potential at enterprises, institutions, and households is caused by the existence of a series of barriers that emerge in the process of the implementation. In this regard, it is important to separate these barriers, group, and quantify them. This, in turn, will make it possible to establish the ways to overcome barriers to implement energy-efficient projects both at the level of enterprises and households and at the state and municipal levels. At the same time, the acuteness of the problem of overcoming barriers to the implementation of energy-saving projects may increase against the background of the general tendency to reduce prices for certain energy resources that have existed for the last years [3]. In particular, we are talking about crude oil and natural gas. In this case, the need to reduce consumption of these energy resources persists, as the issues of improving ecology and reducing energy dependence are still relevant for many countries, particularly, for Eastern European countries.

2. Literature review and problem statement

The development of a toolkit for assessing and overcoming barriers to implementation of energy-saving projects should be preceded by separation and grouping of these barriers. This is due to the need to establish the most significant of them. The results of numerous studies on this matter conducted by many scientists differ from each other and do not provide a clear answer. Thus, in paper [4], the main obstacles to the large-scale implementation of energy-efficient technologies were called economic barriers. The importance of economic barriers was also shown in [5], where it is stated that the implementation of energy-saving measures is hampered by the lack of necessary financial stimuli.

Some scientists point out the crucial role of management barriers in making decisions on refusal to implement energy-saving projects. Thus, [6] states that small and micro-enterprises refuse to implement rather effective energy saving projects due to lack of rationality, the fact that priority goals do not include energy-saving, and imperfection of information support. The existence of significant information barriers to the implementation of energy-saving projects is also noted in [7].

In addition, among the barriers that hamper an increase in energy efficiency, according to the authors of research [8], the risk of implementing projects of energy-saving technological changes takes an important place. At the same time, it should be taken into consideration that technological changes often require significant investment resources [9], which are not possessed by the enterprises and households wishing to implement energy-saving projects. At the same time, it is inappropriate or impossible to attract lent resources to fund these projects, due to unattractive lending conditions [10].

Among the barriers to implementation of energy-saving projects, an insufficient level of process for energy carriers deserves special consideration. However, the results of the study on the significance of this barrier, conducted by various scientists, are contradictory. For example, research [11] revealed the impact of changes in electricity prices on a change in its consumption, while in study [12], it was found that such influence does not exist.

Thus, different authors separate somewhat different types of major obstacles to the implementation of energy-saving projects and proposed different ways of grouping these barriers. In general, as noted in article [13], which mentioned 42 barriers to energy efficiency in the U.S. industry, the issue of drawing up an exhaustible list of such barriers remains open and perhaps not fully addressed at all.

One possible reason for the existing differences between scientists' opinions on the most significant obstacles to the implementation of energy-saving projects is that insufficient attention is paid to the relationship between these obstacles. In this regard, one should mention three types of interactions between barriers to improving energy efficiency, noted in research [14]: cause-and-effect, synergic, and hidden. However, it is also advisable to investigate the patterns of sequential, parallel, and combined arrangement of these barriers, as this would greatly facilitate their grouping.

Regarding the evaluation of barriers to energy efficiency, a significant number of scientists conduct only their qualitative analysis, as it was done in article [15] using the example of the Finnish construction sector. The results of the survey of energy managers were also used for the purpose of such evaluation [16]. However, the results of the qualitative evaluation of barriers to the implementation of energy-saving projects are characterized by a significant level of subjectivism. If we consider more objective ways of assessing energy efficiency barriers, it is worth mentioning the measurement of these barriers with the application of the hierarchical approach and graph-analytical models, conducted in article [17]. However, this approach does not provide an opportunity to link directly the level of barriers to implementation of energy-saving projects to the magnitude of the efforts required to overcome these barriers.

At the same time, it is necessary to take into consideration the existence of different ways of overcoming barriers to the implementation of energy-saving projects. In particular, paper [15] points out the need to provide up-to-date information on energy efficiency. Research [18], using the example of the implementation of Swedish municipal energy efficiency programs of enterprises, emphasized the importance not only of comprehensive information support of these enterprises but also of their ability to process information.

Some authors rightly point out the importance of the access of people who want to implement energy-saving projects to financial resources. Thus, considering the data from 56 states, the authors of paper [19] established the importance of improving the investment climate to enhance energy efficiency. Paper [20] indicates that an important tool for stimulating energy saving and switching to clean energy sources in China is subsidizing programs. According to the authors of article [21], the use of preferential lending can accelerate the scale of implementation of energy-saving measures. Separate proposals concerning the organization of such lending for small enterprises are given in [22]. However, the relationship between the parameters of preferential lending with the level of barriers to implementation of energy-saving projects was not considered by scientists.

In some publications, their authors consider the managerial aspects of overcoming barriers to the implementation of energy-saving projects. Thus, in [23], it is proposed to improve the energy audit procedures for such acceleration. Paper [24] represented an interesting approach to the substantiation of the ways to overcome barriers to the enhancement of energy efficiency in industrial companies. This approach involves finding the weakest link from such four stages – motivation, capacity, implementation, and results.

The literature review showed that scientists have made a significant contribution to solving the issue of evaluation and overcoming barriers to the implementation of energy-saving projects. However, these issues are not yet completely closed. In particular, it is required to develop a procedure for assessing the impact of possible overcoming certain barriers on the way to the implementation of energy-saving projects on the level of such implementation. In addition, modern scientific literature did not establish a clear enough relationship between the magnitude of the respective barriers and the level of efforts to be made to overcome these barriers. This may be due to the fact that such a problem statement has not spread sufficiently. Finally, the issue of assessing the level of barriers on the way to implementation of energy-saving projects depending on the chosen source of project funding remained beyond the scientists' attention. The reason for this may be that the traditional indicators of estimation of effectiveness of investment projects, in particular, their current net value, do not involve direct consideration of the specificity of sources of investment funding. At the same time, such consideration is appropriate since there are quite a few possible projects' funding sources. The above-mentioned speculations determine the need for further research on the topic of this work.

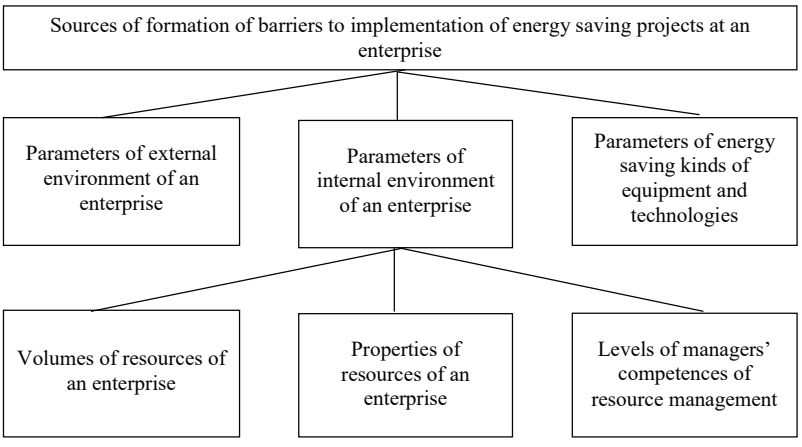

Fig. 1. Types of sources of formation of barriers to implementing energy-saving projects at an enterprise

3. The aim and objectives of the study

The aim of this study is to develop a toolkit for assessing and overcoming barriers to the implementation of energy-saving projects.

To accomplish the aim, the following tasks have been set:

– to group barriers on the way to the implementation of energy-saving projects at enterprises and to determine general approaches to evaluation of these barriers;

– to model economic barriers to the implementation of energy-saving projects at enterprises depending on the chosen source of funding these projects;

– to substantiate the measures to overcome barriers to implementation of energy-saving projects at enterprises;

– to perform approbation of the obtained theoretical and methodological results according to the sample of enterprises.

4. Grouping and general approaches to the assessment of barriers to implementation of energy-saving projects

In the process of grouping barriers to the implementation of energy-saving projects, it is important to ensure identifying all major obstacles. To do this, it is essential to establish the criterion for their division into groups. This criterion can be the source of barriers formation. Specifically, there are three sources: parameters of the external environment of an enterprise, parameters of its internal environment, as well as technical and economic characteristics of energy-saving types of equipment and technologies that are planned to be implemented. In turn, the internal environment of any enterprise is characterized by the scope of its resources, the properties of these resources, and the competencies of managers regarding their management (Fig. 1).

Thus, in general, it is possible to separate five groups of barriers on the way to the implementation of energy-saving projects by the nature of possible causes that determine the existence of corresponding barriers. This grouping makes it possible to detail the factors that cause the existence of appropriate barriers to the implementation of investment measures on energy saving (Table 1).

The barriers to the implementation of energy-saving projects by enterprises listed in Table 1 can be called partial. In addition, it is possible to separate a group of the most general barriers to the implementation of energy-saving projects at enterprises. Their list is shown in Table 2, in which these barriers are presented in a clear sequence. Thus, the general barriers to the implementation of energy-saving projects at enterprises can be shown in the form of a certain chain, as shown in Fig. 2. It follows from Fig. 2 that generalizing barriers are directly determined by partial ones (except for the second generalizing barrier caused mainly by subjective reasons). In this case, the designation of barriers in Fig. 2 correspond to their designations in Tables 1, 2.

The existence of a large number of barriers to the implementation of energy-saving projects at enterprises and a complex mechanism of interconnection between these barriers determine the possibility of different approaches to assessing their level. It is advisable to separate three of the following approaches:

1. Evaluation of barriers to the implementation of energy-saving projects at enterprises in absolute terms. The indicator, in this case, will be a minimum required change in the magnitude of a certain barrier, at which it will be overcome. In particular, the barrier caused by the insufficient economic efficiency of a particular energy-saving project can be estimated as the minimum magnitude of reduction in the need for investments in the implementation of this project, at which this implementation becomes appropriate. Under these conditions, it is possible to evaluate the efforts necessary to overcome barriers (in this example, the magnitude of external financial support for the project implementation, specifically, by the state or local authorities).

2. Evaluation of barriers to implementation of energy-saving projects at enterprises in relative terms. The indicator at the same time will be the ratio of the maximum required magnitude of a certain barrier to the actual value of this barrier. In particular, the barrier, which arose from the lack of financial resources of an enterprise, can be assessed

by the ratio of their minimum required volume to the available magnitude of financial resources.

3. Evaluation of the average level of barriers on the way to the implementation of energy-saving projects by the sampling of enterprises that implemented or tried to implement such projects. Since the generalizing barriers to the implementation of energy-saving projects form a certain sequence, the magnitude of each such barrier will be determined in this case from the following formula:

$$B_i = 1 - \frac{L_{1i}}{L_{0i}}, \quad (1)$$

where B_i is the level of the i-th barrier on the way to implement energy-saving projects by the sampling of enterprises that implemented or tried to implement such projects, fractions of unity; L_{1i} is the number of studied enterprises that overcame the i-th barrier; L_{0i} is the number of studied enterprises that approached the i-th barrier, having overcome the previous barriers.

Let the actual level of implementation of energy-saving projects be measured by the share of those enterprises that ultimately successfully implemented these projects, in the total number of studied enterprises. Then, given that $L_{0i+1}=L_{1i}$, the dependence between the actual level of implementation of energy-saving projects and indicators of the form (1) will be displayed in the following formula:

$$L = \prod_{i=1}^{n_d} \left(L_{1i} / L_{0i} \right) = \prod_{i=1}^{n_b} \left(1 - B_i \right), \quad (2)$$

where L is the actual level of energy-saving project implementation by the studied enterprises, the fraction of unity; Π is the designation of a product; n_b is the number of sequential barriers on the way to implement energy-saving projects at enterprises.

Table 1

Grouping barriers to the implementation of energy-saving projects at enterprises

Groups of barriers	Kinds of barriers	Designation of barrier
1. Unfavorable external environment, in which enterprises exist	1. 1. Limited available capabilities of an enterprise to obtain information about the state of their external environment, in particular, information about: volumes of energy saving of competitor enterprises, new types of energy-saving equipment, costs for its manufacture, etc.	B.1.1
	1. 2. Variability and unpredictability of the parameters of the external environment, in which enterprises exist, in particular, prices of energy carriers, cost of insulating materials, cost of energy-saving equipment, prices for products manufactured using it, etc.	B.1.2
	1. 3. Insufficient demand for products manufactured using energy-saving machinery and technologies	B.1.3
2. Insufficient volume of resources of an enterprise to implement energy-saving projects	2. 1. Lack of information required to make a reasonable decision on the implementation of energy-saving projects, in particular, information about expected savings in costs of energy carriers, the rate of return on investments in the implementation of energy-saving projects, etc.	B.2.1
	2. 2. Lack of information required to manage the implementation of energy-saving projects, in particular, information about possible suppliers of energy-saving equipment, about firms that provide commissioning, etc.	B.2.2
	2. 3. Lack of financial resources for the implementation of energy-saving projects by enterprises	B.2.3
	Including those caused by:	
	2. 3. 1. Insufficient volumes of internal sources of financial resources of enterprises (profit, depreciation deductions, etc.)	B.2.3.1
	2. 3. 2. Insufficient investment attractiveness of enterprises, which makes it difficult to receive contributions of third parties to equity of these enterprises to finance energy-saving projects	B.2.3.2
	2. 3. 3. Insufficient creditworthiness of enterprises, which makes it difficult for them to obtain loans to finance energy-saving projects	B.2.3.3
	2. 4. Lack of human resources, specifically, skilled workers who can operate energy-saving equipment	B.2.3.4
	2. 5. Lack of other types of resources, specifically, components, repair units, communications, etc., necessary for the functioning of energy-saving equipment	B.2.3.5
3. Insufficient level of properties of enterprises' resources for the implementation of energy-saving projects	3. 1. Lack of relevance, accuracy, completeness, other properties of information resources necessary for the implementation of energy-saving projects	B.3.1
	3. 2. Lack of qualification and other business qualities of production workers of enterprises that could work with energy-saving equipment	B.3.2
	3. 3. The irrationality of the structure of financial resources, namely, too high loan capital share	B.3.3
	3. 4. Lack of properties of other types of resources, namely, components, repair units, communications, etc., necessary for the functioning of energy-saving equipment	B.3.4
4. Lack of competence of managers and owners of an enterprise in the field of energy-saving projects management	4. 1. Lack of competence in gathering information necessary to implement energy-saving projects	B.4.1
	4. 2. Lack of competence in processing information necessary to implement energy-saving projects	B.4.2
	4. 3. Lack of competence on the involvement of resources necessary to implement energy-saving projects	B.4.3
	4. 4. Lack of competence in the organization of energy-saving projects	B.4.4
	4. 5. Lack of competence to predict the outcomes of the implementation of energy-saving projects	B.4.5
5. Insufficient consumer properties of energy-saving kinds of equipment and technologies, which are expected to be implemented	5. 1. Insufficient estimated level of consumer properties of energy-saving types of equipment and technologies, the introduction of which is expected (in particular, insufficient estimated savings of energy consumption as a result of such implementation)	B.5.1
	5. 2. The insufficient actual level of consumer properties of energy saving, the implementation of which is envisaged. (specifically, insufficient actual energy saving due to this implementation)	B.5.2

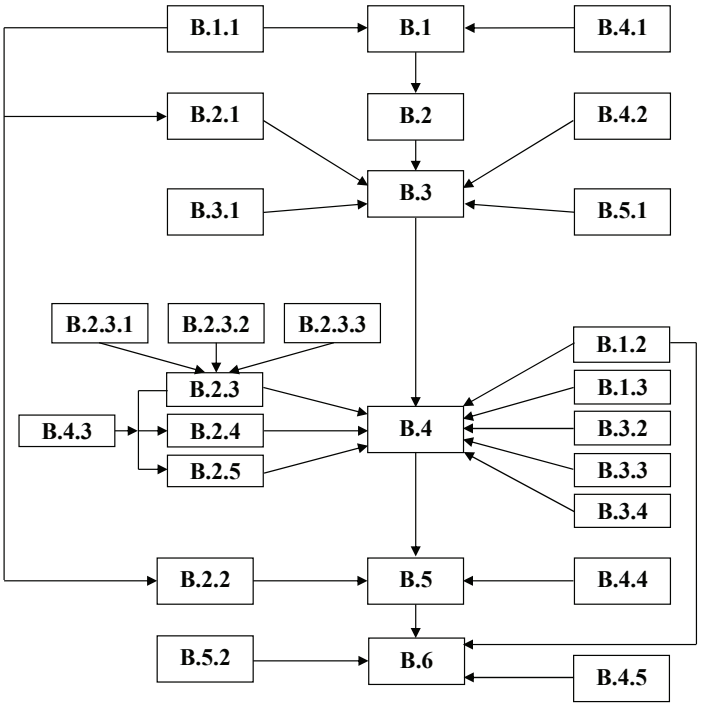

Fig. 2. The relationship between barriers to the implementation of energy-saving projects at enterprises

Table 2

Generalizing barriers to the implementation of energy-saving projects at enterprises

Kinds of barriers	Designations of barriers
1. Lack of input information necessary to make a decision on the implementation of energy-saving projects	B.1
2. Non-acceptance of input information, which is expressed in the lack of attention to it, rejecting the opportunities given by this information, without detailed consideration	B.2
3. Obtaining a conclusion on the economic inappropriateness of implementation of energy-saving projects	B.3
4. Lack of resource provision to implement energy-saving projects	B.4
5. Failure to implement energy-saving kinds of equipment and technologies	B.5
6. Refusal to operate the implemented energy-saving kinds of equipment and technologies	B.6

Using formula (2), it is possible to assess the impact of the magnitude of the expected decrease in a certain barrier on the way to the implementation of energy-saving projects at enterprises to the level of such implementation. This assessment will have, first of all, a retrospective nature, however, its results may also be applied for predictive purposes.

5. The toolkit for assessing and overcoming barriers to the implementation of energy-saving projects at enterprises

5. 1. Modeling economic barriers to the implementation of energy-saving projects at enterprises

Assessment of barriers to the implementation of energy-saving projects at enterprises requires preliminary construction of models of such barriers. In particular, this applies to the models of economic barriers. These barriers can be divided into two groups, namely:

1) barriers caused by an insufficient level of economic efficiency of energy-saving projects;

2) barriers caused by the complexities associated with the use of certain types of funding sources for these projects.

However, for both types of barriers, their existence is caused by too large volumes of investment in energy-saving projects. If it were possible to reduce the amount of investments in an energy-saving project by a certain amount, its implementation would become economically feasible and possible, that is, economic barriers would be absent. Based on this statement, one can express the basic idea of constructing the relative indicators for quantitative evaluation of barriers to the implementation of energy efficiency projects. This idea is to establish the minimum required volumes of reducing the need for investments in these projects, at which they become attractive to enterprises. Then the share of these minimum required volumes of reducing the need for investments in their general actual value will quantify economic barriers to the implementation of corresponding projects. At this stage of the study, a specific mechanism for reimbursement of a part of investments in the implementation of energy-saving projects is not considered (it will be proposed in the next section of the research).

The simplest case of economic barriers to the implementation of energy-saving projects at enterprises is the barrier caused exceptionally by insufficient economic efficiency of investments in a particular project. At the same time, we will assume that a company has its own funds for the implementation of this project. Then the condition for the proper level of economic efficiency of a particular energy-saving project can be represented in the form of such inequality:

$$\frac{\Delta P_r}{I\cdot(1-b)}\geq p, \qquad (3)$$

where ΔP_r is the magnitude of the expected increase in the profit of an enterprise due to its implementation of an energy-saving project, monetary units;

I is the volume of investments in a project, monetary units;

b is the variable characterizing a possible reduction of the whole volume, fractions of unity;

p is the investment return that is minimally permissible for owners and managers of an enterprise, at which they agree to invest, fractions of unity.

Thus, the left-hand side of formula (3) characterizes the profitability of an energy-saving project, depending on what share of investments in a project will be reimbursed by outside parties. If inequality (3) at a certain value of variable b turns into equality, this value will provide a quantitative assessment of the corresponding economic barrier to the implementation of an energy-saving project. At the same time, the profit growth rate can be calculated from the following formula:

$$\Delta P_r = \Delta E \cdot p_e + \sum_{k=1}^{s} \Delta E_k \cdot p_{ek} + C_o, \quad (4)$$

where ΔE is the estimated decrease in the volume of consumption of a certain energy resource, saving of which is expected due to the implementation of an energy-saving project at an enterprise, natural units;

p_e is the price of a unit of this energy resource, monetary units;

s is the number of other kinds of energy resources, consumption of which will change as a result of the implementation of an energy-saving project at an enterprise, natural units;

ΔE_k is the estimated change of the volume of consumption of the k-th energy resource due to the implementation of an energy-saving project at an enterprise, natural units;

p_{ek} is the price of a unit of the k-th energy resource, monetary units;

C_o is the magnitude of other expenses and losses due to the implementation of an energy-saving project at an enterprise (specifically, a possible increase in the magnitude of depreciation deductions, if the energy-saving equipment is expensive and the losses of under-depreciation of the equipment, which will be decommissioned early after the implementation of an energy-saving project), monetary units.

Obviously, at any positive values of ΔP_r, I and p, there are such values of indicator b, at which inequality (3) is true. In this case, the value of indicator b can range from zero to one. In order to establish its minimum possible value, at which inequality (3) is true, we transform this inequality into equality and determine b_1 from it:

$$b_1 = 1 - \frac{\Delta P_r}{p \cdot I}, \quad (5)$$

b_1 is the level of a barrier on the way to implementation of an energy-saving project at the expense of currently available own resources of funds, fractions of unity.

At the same time, if the value of the level of the barrier b_1 turns out to be negative, we will assume that b_1 is equal to zero. This condition will be accepted for all other economic barriers considered in the future.

In addition to using currently available sources of funds at an enterprise, there are also other ways to finance energy-saving projects. The use of each of them is associated with certain conditions (restrictions). The general condition that is characteristic of any source of funds is the proper level of economic efficiency of their use from the enterprise's point of view. As for partial conditions, they should primarily include the following:

– for a bank loan – the timeliness of its repayment. We will assume that there is a limit (maximum possible) period, within which a company should return the loan it has taken;

– for reinvestment of the profits of an enterprise – the duration of accumulation of necessary funds for the project implementation at the expense of profit should not be too large, because it will negatively affect the long-term dividend payments;

– for contributions of third-party investors to the authorized capital of the enterprise – the amount of these contributions should not be too large, since otherwise, the present owners of an enterprise may lose control over it.

Taking into consideration the above mentioned, it is advisable to perform a generalized assessment of the level of economic barriers on the way to the implementation of energy-saving projects using the minimax principle:

$$b = \min \begin{pmatrix} \max\left(b_{11},...,b_{1j},...,b_{1n_1}\right),..., \\ \max\left(b_{i1},...,b_{ij},...,b_{in_j}\right),..., \\ \max\left(b_{m1},...,b_{mj},...,b_{mn_m}\right) \end{pmatrix}, \quad (6)$$

where b is the general level of economic barriers to the implementation of an energy-saving project;

b_{ij} is the level of the i-th economic barrier for the j-th way of project funding;

n_j is the general number of economic barriers for the j-th way of project funding;

m is the number of ways of project funding.

Thus, according to expression (6), the general level of economic barriers to the implementation of an energy-saving project is determined at two stages. At the first stage, the maximum level of existing economic barriers to the implementation of this project is established for each way of funding. Then at the second stage, among the established values of barriers, a minimal barrier, which will correspond to the best way of funding a certain energy-saving project, is chosen from the established values of barriers.

In the future, we will pay the main attention to the first two of the three ways of project funding, as these two methods are the most common in economic practice.

In particular, with regard to such a source of project funding as a bank loan, as it is initially important to establish the condition for full repayment of its main amount and accrued interest. This condition is that the flow of repayment discounted by loan interest must be equal to its principal amount:

$$\sum_{t=1}^{T_L} \frac{P_l}{(1+c)^t} = \frac{P_l \cdot \left((1+c)^{T_l} - 1\right)}{c \cdot (1+c)^{T_l}} = I, \quad (7)$$

where T_l is the general term of repayment of the loan, taken with the aim of project funding. time intervals;

P_l is the magnitude of repayment of a loan and loan interest within the corresponding period, monetary units;

c is the loan interest rate, the fraction of unity;

t is the designation of the time interval.

From equation (7), one can determine the formulas for calculating indicators T_l and P_l. These formulas take the following form:

$$P_l = \frac{I \cdot (1+c)^{T_l} \cdot c}{(1+c)^{T_l} - 1}; \quad (8)$$

$$T_l = \log_{1+c}\left(\frac{P_l}{P_l - I \cdot c}\right). \quad (9)$$

Now consider the conditions limiting the possibilities of using a bank loan as a source of funding energy-saving projects at enterprises. The first such condition is the growth of the discounted magnitude of the profit flow at an enterprise due to the project implementation, which will be funded by a bank loan. This condition can be formalized as follows:

$$\sum_{t=1}^{T_{\max}} \frac{P_r + \Delta P_r - P_l}{(1+d)^t} + \frac{P_r + \Delta P_r}{d \cdot (1+d)^{T_{\max}}} > \frac{P_r}{d}, \quad (10)$$

or

$$\frac{\left(P_r+\Delta P_r-P_l\right)\cdot\left(\left(1+d\right)^{T_{\max}}-1\right)}{d\cdot\left(1+d\right)^{T_{\max}}}+\frac{P_r+\Delta P_r}{d\cdot\left(1+d\right)^{T_{\max}}}>\frac{P_r}{d}, \quad (11)$$

$T_{\max}$ is the maximum possible term of repayment of a loan taken to fund an energy-saving project, time intervals;

P_r is the profit of an enterprise before the implementation of an energy-saving project, monetary units;

d is the discount rate, the fraction of unity.

Thus, the left-hand side of inequality (10) and, consequently, inequality (11) represents the sum of two expressions. The first expression describes the discounted flow of the company's profit during the repayment period of the loan taken in order to finance an energy-saving project. The second expression describes the discounted flow of the company's profits in the next period, that is when the loan is fully repaid. At the same time, the duration of this period is unlimited, since in general, the company can function as long as possible.

Having put formula (8) instead of P_l into expression (11), we obtain:

$$\left(\begin{array}{l}P_r+\Delta P_r-\\-\frac{I\cdot\left(1+c\right)^{T_{\max}}\cdot c}{\left(1+c\right)^{T_{\max}}-1}\end{array}\right)\cdot\frac{\left(\left(1+d\right)^{T_{\max}}-1\right)}{d\cdot\left(1+d\right)^{T_{\max}}}+\frac{P_r+\Delta P_r}{d\cdot\left(1+d\right)^{T_{\max}}}>\frac{P_r}{d}. \quad (12)$$

Now we substitute I with a product of I by coefficient $1-b_{11}$ in expression (12), we convert inequality (12) into equality and express b_{11} from it. Consequently, we get a formula for determining the level of the first economic barrier on the way to implementation of an energy-saving project by an enterprise, which will be funded by a bank loan:

$$b_{11}=1-\frac{\Delta P_r}{I\cdot d}\cdot\frac{\left(1+d\right)^{T_{\max}}}{\left(1+c\right)^{T_{\max}}}\cdot\frac{\left(1+c\right)^{T_{\max}}-1}{\left(1+d\right)^{T_{\max}}-1}. \quad (13)$$

As for the second economic barrier on the way to the implementation of an energy-saving project, which will be funded by a bank loan, it is determined by the need for timely loan repayment. This condition can be formalized in the form of such inequality, which follows directly from formula (9):

$$\log_{1+c}\left(\frac{P_r+\Delta P_r}{P_r+\Delta P_r-I\cdot c}\right)\le T_{\max}. \quad (14)$$

Now we substitute I with a product of I by coefficient $1-b_{12}$ in expression (14), we convert inequality (14) into equality and express b_{12} from it. As a result, we get a formula to determine the level of the second economic barrier on the way to implementation of an energy-saving project at an enterprise, which will be funded by a bank loan:

$$b_{12}=1-\frac{P_r+\Delta P_r}{I\cdot c}\cdot\frac{\left(1+c\right)^{T_{\max}}-1}{\left(1+c\right)^{T_{\max}}}. \quad (15)$$

Regarding such a source of project funding as reinvestment of profits of an enterprise, its important parameter is the time, during which a company will be able to accumulate the necessary amount of funds. In the case, where the reinvestment rate is equal to the discount rate, this parameter can be determined from the following inequality:

$$\sum_{t=1}^{T_a}\left(P_r\cdot\left(1+d\right)^{T_a-t}\right)=\frac{P_r}{d}\cdot\left(\left(1+d\right)^{T_a}-1\right)=I, \quad (16)$$

where T_a is the duration of the period, during which a company will be able to accumulate the necessary amount of funds for the project implementation at the expense of its own profit, time intervals.

From equation (16), we obtain:

$$T_a=\log_{1+d}\left(1+\frac{I\cdot d}{P_r}\right). \quad (17)$$

Taking into consideration the above mentioned, it is possible to formalize the conditions, under which a company can use profit reinvestment as a source of funding an energy-saving project. The first of these conditions is the growth of the magnitude of the discounted profit of an enterprise after the project implementation. This condition can be represented in the form of such inequality:

$$\frac{P_r+\Delta P}{d\cdot\left(1+d\right)^{T_a}}=\frac{P_r\cdot\left(P_r+\Delta P\right)}{\left(P_r+I\cdot d\right)\cdot d}>\frac{P_r}{d}. \quad (18)$$

Thus, the left side of inequality (18) characterizes the magnitude of the discounted profit of an enterprise after the implementation of an energy-saving project. At the same time, the right part of this inequality contains a formula for capitalizing the profits of an enterprise in case of refusal to implement a project.

Now we substitute I with a product of I by coefficient $1-b_{22}$ in expression (18) and convert inequality (14) into equality and express b_{22} from it. As a result, we get a formula to determine the level of the first economic barrier on the way to implementation of an energy-saving project at an enterprise, which will be funded by profit reinvestment:

$$b_{21}=1-\frac{\Delta P_r}{p\cdot I}. \quad (19)$$

It is possible to see that formula (19) is the same as formula (5), meaning the level of the corresponding barrier in both cases is the same.

Regarding the second economic barrier to the implementation of an energy-saving project, which will be funded by enterprise's profit reinvestment, this barrier is caused by the limitation to the total duration of fund accumulation:

$$\log_{1+d}\left(1+\frac{I\cdot d}{P_r}\right)\le T_{e\max}, \quad (20)$$

where $T_{e\max}$ is the maximum (maximum admissible) duration of funds accumulation by reinvesting the enterprise's profit, established by its owners (managers), time intervals.

It should be noted that formula (20) follows directly from expression (17).

Now we substitute I with a product of I by coefficient $1-b_{22}$ in expression (20) and convert inequality (14) into equality and express b_{22} from it. As a result, we get a formula to determine the level of the second economic barrier on the way to implementation of an energy-saving project at an enterprise, which will be funded by profit reinvestment:

$$b_{22} = 1 - \frac{P_r}{I \cdot d} \cdot \left((1+d)^{T_{e\max}} - 1 \right). \quad (21)$$

Thus, in the case when two alternative sources of funding an energy-saving project at an enterprise are considered, each of which has two restrictions to their application, expression (6) takes the following form:

$$b_g = \min\left(\max(b_{11}, b_{12}), \max(b_{21}, b_{22}) \right), \quad (22)$$

where b_g is the generalizing level of economic barriers to the implementation of an energy-saving project in case two alternative sources of its funding, each of which has two restrictions to their application, are considered.

Expression (22) can be applied in the development of state programs of financial support for enterprises seeking to implement energy-saving projects.

5. 2. Substantiation of measures to overcome barriers to implementation of energy-saving projects of enterprises

Overcoming barriers to the implementation of energy-saving projects at enterprises requires taking certain measures that may have an organizational, economic, and technological nature. At the same time, the subjects introducing these measures can be both the management of enterprises and the state and/or municipal authorities (Table 3).

Preferential lending should be called one of the most effective means of state stimulation of the implementation of energy-saving projects at enterprises. Three main mechanisms of such lending are possible, namely:

1) when the state reimburses a portion of the interest (or its full amount) of the loan that enterprises receive in order to finance energy-saving projects;

2) when the state reimburses a part of the main amount (or its full amount) of the loans that are received by enterprises in order to finance energy-saving projects;

3) when there is a combination of the previous two mechanisms.

At the same time, the main parameters of state programs of preferential lending are the necessary shares of reimbursement by the state of interest and /or the basic amount of loans taken by enterprises for the implementation of energy-saving projects. The substantiation of these parameters requires a certain sequence of actions shown in Fig. 3.

It should be noted that the sequence of substantiation of the main parameters of state programs of preferential lending shown in Fig. 3 concerns the case of a separate project on energy saving. However, the final values of the respective parameters should be set by a sufficiently large sampling of such projects. At the same time, it should be taken into consideration that the efficiency of public expenditures for subsidizing enterprises planning to implement energy-saving projects can vary significantly for different enterprises. In particular, this may be caused by industry differences.

Table 3

Grouping the measures to overcome barriers to implementation of energy-saving projects at enterprises by types of barriers and subjects who realize these measures

Types of barriers to the implementation of energy-saving projects at enterprises	Measures to overcome barriers according to subjects of their implementation (indicating partial barriers, which are overcome in accordance with their designations given in Table 1)	
	Management of enterprises (owners, top management)	State and (or) municipal authorities
1. Lack of input information required to make a decision on the implementation of energy-saving projects	Software and databases improvement (B.1.1); improvement of competences of employees in the field of information support (B.4.1)	Generation of up-to-date, accurate and complete information about economic, environmental and other consequences of implementation by enterprises of various energy-saving projects in terms of economy and industry sectors (B.1.1)
2. Rejection of input information expressed in disinterest in it, rejecting the opportunities offered by this information without its detailed consideration	Developing the employees' desire for energy saving, motivating them to consider the possible implementation of energy-saving projects	Substantiation of the importance of energy-saving, the propaganda of measures related to it, presentation of the existence of a large number of potential energy-saving measures
3. Obtaining a conclusion on the economic impracticality of the implementation of energy-saving projects	An increase in the volumes and improving the quality of information support required to evaluate the effectiveness of energy-saving projects (B.2.1; B.3.1); implementation in the enterprises' activity of scientifically grounded methods for assessing the economic efficiency of energy-saving projects (B.1.1; B.4.2)	Granting the enterprises that implement energy-saving projects certain economic preferences (tax, financial and loan, etc.) (B.5.1)
4. Lack of resource provision to implement energy-saving projects	Improvement of competencies of employees of enterprises in the field of organization of resource support of their activities (B.2.3; B.2.4; B.2.5; B.3.2; B.3.3; B.3.4)	Coverage (at least partial) of the needs of enterprises that implement energy-saving projects for appropriate resources (B.2.3; B.2.4; B.2.5)
5. A failure to implement energy-saving kinds of equipment of technologies	An increase in the volumes and improvement of the quality of information support required to manage the implementation of energy-saving projects (B.2.2); improvement of competences of employees of enterprises in the field of implementation of energy-saving types of equipment and technologies (B.4.4)	Conducting appropriate trainings, implementing other ways of informing employees of enterprises about the effective organization of the implementation of energy-saving types of equipment and technologies (B.4.4)
6. Refusal to operate implemented energy-saving types of equipment and technologies	Improvement of the competences of employees of enterprises in the field of forecasting the consequences of implemented energy-saving types of equipment and technologies (B.4.5)	Granting the enterprises that implement energy-saving projects certain economic preferences (tax, financial and loan, etc.) (B.5.2)

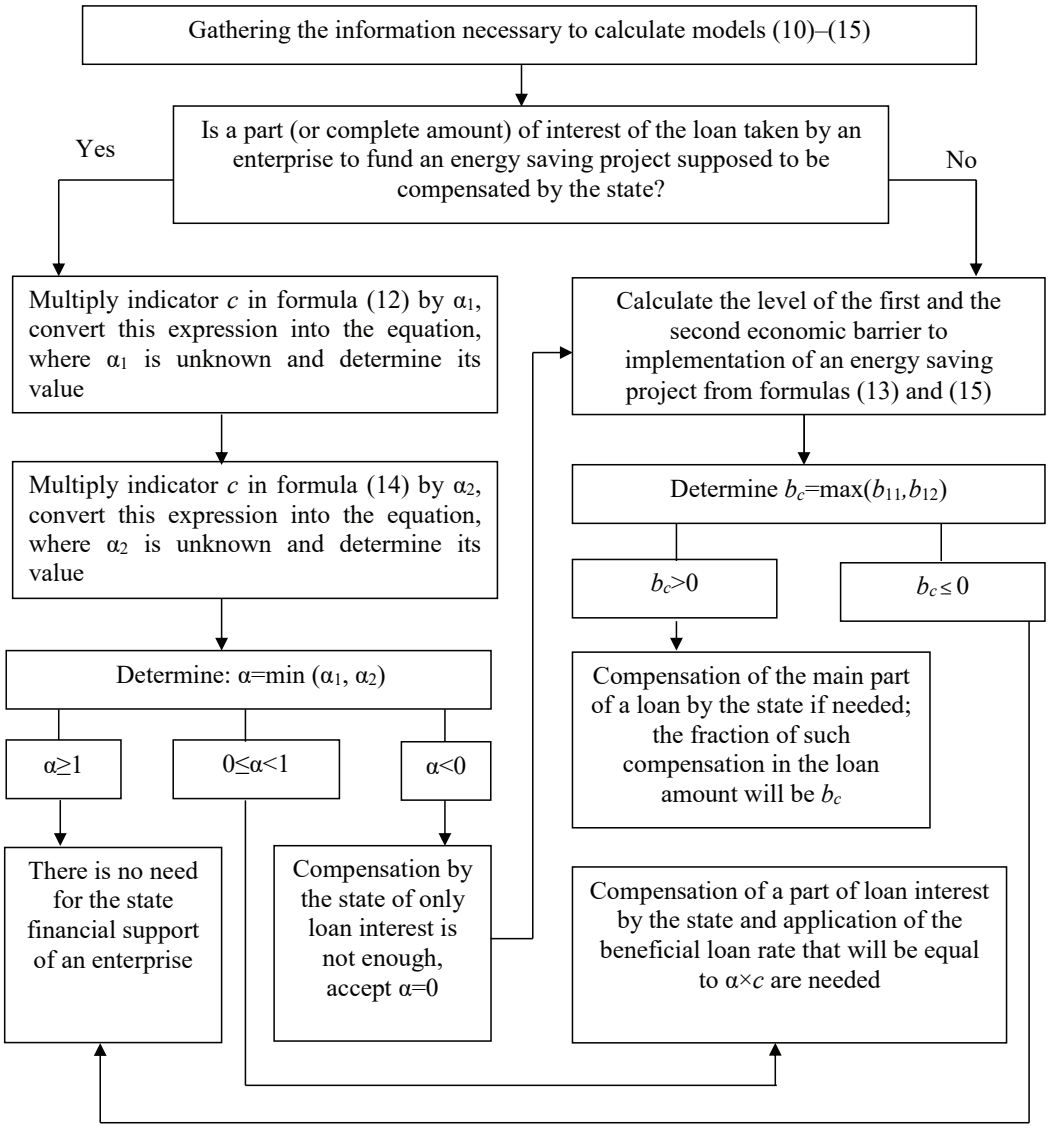

Fig. 3. The sequence of substantiation of the main parameters of state preferential lending programs for enterprises seeking to implement energy-saving projects

In order to evaluate the effectiveness of public expenditures for subsidizing enterprises that plan to implement energy-saving projects, it is advisable to use the following indicator:

$$e_g = \frac{\Delta E}{I \cdot b}, \tag{23}$$

e_g is the indicator of the efficiency of state expenditures for subsidization of enterprises that plan to implement energy-saving projects (saving the corresponding energy resources per one monetary unit of budget expenditures);

ΔE, I, b are the indicators contained accordingly in formulas (4), (3), and (6).

The expression (23) implies that the effectiveness of budget expenditures to stimulate energy saving depends significantly on the types of economic barriers to the implementation of energy-saving projects and the level of these barriers. In particular, if the magnitude of barrier b is determined from formula (5), expression (23) takes the following form:

$$e_{g1} = \frac{\Delta E}{I \cdot \left(1 - \frac{\Delta P_r}{p \cdot I}\right)} = \frac{\Delta E \cdot p}{I \cdot p - \Delta P_r}, \tag{24}$$

where e_{g1} is the indicator of the effectiveness of public expenditures for subsidizing enterprises planning to implement energy-saving projects, in case the barrier to such implementation is evaluated by expression (5).

Having put expression (4) in formula (23) instead of ΔP_r, we finally get:

$$e_{g1} = \frac{\Delta E \cdot p}{I \cdot p - \left(\Delta E \cdot p_e + \sum_{k=1}^{s} \Delta E_k \cdot p_{ek} + C_o\right)}, \tag{25}$$

It should be noted that a specific mathematical model of the indicator (23) depends significantly on what economic barriers to the implementation of energy-saving projects appear on a case-by-case basis. However, under all conditions, indicator (23) is an important tool for identifying the

most effective areas of state financial support for enterprises that plan the implementation of energy-saving projects under conditions of budgetary restrictions.

5. 3. Approbation of the obtained theoretical and methodological results on the example of Ukrainian enterprises

The problem of energy saving is relevant for many countries of the world, in particular, for eastern European countries. These countries include Ukraine. One of the priority directions of its energy strategy is to reduce the consumption of natural gas. In this regard, we conducted a survey of managers of 150 enterprises, which implemented or tried to implement during projects related to reducing natural gas consumption within 2016–2019. Data on the sectoral affiliation of these enterprises are shown in Table 4.

Fig. 5 shows the data on the number of enterprises that, according to the survey, overcame the corresponding type of barriers to the implementation of projects on reducing natural gas consumption.

Using the data shown in Tables 4, 5, it is possible to evaluate the actual level of implementation of projects on reducing the consumption of natural gas at the studied enterprises. This level will be determined as the ratio of enterprises that have passed the sixth barrier to the total number of enterprises. In particular, this level for enterprises that produce food, beverages and tobacco products is 0.190. For enterprises that manufacture wood products, produce paper and are engaged in printing activities, the level of implementation of projects on reducing natural gas consumption is 0.298. At the same time, for enterprises producing machinery and equipment, this level is 0.389; for enterprises of other industries – 0,296; for the entire set of studied enterprises – 0,267.

Using formula (1), it is possible to assess the level of barriers to the implementation of projects on reducing natural gas consumption for the studied enterprises. The corresponding indicators are shown in Table 6.

As it follows from the information shown in Table 6, for all industries, and insufficient, in the opinion of managers of enterprises, level of efficiency of the implementation of natural gas-saving projects is the highest among the studied barriers. The level of this barrier ranges from 0.308 for enterprises producing machinery and equipment to 0.548 for enterprises producing food, beverages, and tobacco products. At the same time, the removal of the specified barrier. according to formula (2), would make it possible to increase the level of implementation of energy-saving technologies for the whole totality of enterprises from 0.267 to 0.267/(1–0.474)=0.508 (Fig. 4). At the same time, for the studied enterprises, some barriers to the implementation of projects on reducing the consumption of natural gas were quite low or absent at all. The latter includes the refusal to use implemented energy-saving technologies and equipment.

Table 4

Sectoral affiliation of enterprises, the managers of which were interviewed about barriers to the implementation of projects on reducing natural gas consumption

Kinds of economic activity	Number of enterprises
1. Production of food, beverages, and tobacco products	58
2. Manufacture of wood products, paper products and printing activities	47
3. Production of machines and equipment	18
4. Other kinds of economic activity	27
Total	150

Many of the studied enterprises did not implement the projects on reducing natural gas consumption due to insufficient economic efficiency of these projects and/or lack of adequate financial resources. To do this, we calculated the levels of the corresponding barriers: b_{11} from formula (13); b_{12} from formula (15); b_{21} from formula (19); b_{22} from formula (21). The results of the calculations are shown in Table 7.

Table 5

The number of enterprises that, according to the survey, overcame the correspondent type of barriers to the implementation of projects on reducing the natural gas consumption

Types of barriers to the implementation of energy-saving projects at enterprises	Kinds of economic activity				
	Production of food, beverages, and tobacco products	Manufacture of wood products, paper products and printing activities	Production of machines and equipment	Other	Total
1. Lack of input information required to make a decision on the implementation of energy-saving projects	47	40	13	19	119
2. Rejection of input information expressed in disinterest in it, rejecting the opportunities offered by this information without its detailed consideration	42	40	13	19	114
3. Obtaining a conclusion on the economic impracticality of the implementation of energy-saving projects	19	22	9	10	60
4. Lack of resource provision to implement energy-saving projects	14	17	7	8	46
5. A failure to implement energy-saving kinds of equipment of technologies	11	14	7	8	40
6. Refusal to operate implemented energy-saving types of equipment and technologies	11	14	7	8	40

Table 6

The level of barriers to the implementation of projects on reducing the natural gas consumption for the considered enterprises, the fraction of unity

Types of barriers to the implementation of energy-saving projects at enterprises	Kinds of economic activity				
	Production of food, beverages, and tobacco products	Manufacture of wood products, paper products and printing activities	Production of machines and equipment	Other	Total
1. Lack of input information required to make a decision on implementation of energy saving projects	0.190	0.149	0.278	0.296	0.207
2. Rejection of input information expressed in disinterest in it, rejecting the opportunities offered by this information without its detailed consideration	0.106	0.000	0.000	0.000	0.042
3. Obtaining a conclusion on the economic impracticality of the implementation of energy-saving projects	0.548	0.450	0.308	0.474	0.474
4. Lack of resource provision to implement energy saving projects	0.263	0.227	0.222	0.200	0.233
5. A failure to implement energy-saving kinds of equipment of technologies	0.214	0.176	0.000	0.000	0.130
6. Refusal to operate implemented energy saving types of equipment and technologies	0.000	0.000	0.000	0.000	0.000

Table 7

Results of calculations of economic barriers on the way to the implementation of projects on reducing the natural gas consumption

Designation of barriers	Characteristics of barriers	Kinds of economic activity			
		Production of food, beverages, and tobacco products	Manufacture of wood products, paper products and printing activity	Production of machines and equipment	Other
b_{11}	Minimal level	0.327	0.378	0.411	0.251
	Maximal level	0.378	0.414	0.469	0.301
	Average level	0.356	0.398	0.448	0.274
	Variance factor	0.214	0.209	0.195	0.202
b_{12}	Minimal level	0.256	0.294	0.350	0.206
	Maximal level	0.304	0.331	0.400	0.253
	Average level	0.280	0.316	0.377	0.225
	Variance factor	0.184	0.199	0.187	0.174
b_{21}	Minimal level	0.359	0.388	0.424	0.249
	Maximal level	0.411	0.437	0.503	0.315
	Average level	0.378	0.416	0.467	0.288
	Variance factor	0.151	0.168	0.173	0.159
b_{22}	Minimal level	0.307	0.319	0.360	0.213
	Maximal level	0.379	0.389	0.419	0.272
	Average level	0.342	0.360	0.398	0.247
	Variance factor	0.251	0.192	0.178	0.209

As one can see from the data of Table 7, for most of the economic barriers studied, the level of fluctuations in their levels for enterprises within each industry is relatively small. This is proved by the fact that the variance factors are mainly from 0.15 to 0.25. Therefore, the use of average values of barrier levels can be considered correct enough. According to the results, in all sectors, the level of corresponding economic barriers for the case of project funding by a bank loan is lower than in the case of project funding by the profits of enterprises. In turn, in the case of using a bank loan, the highest barrier is the barrier caused by insufficient economic efficiency of projects. However, as it follows from Fig. 5, this conclusion is fair at the basic natural gas price for industrial consumers, that is, the one laid down in the calculation. This price was accepted by us at USD 145.5 per 1,000 m^3. However, at a significant increase in the price of natural gas, this barrier becomes the key one due to the inability of enterprises to repay loans timely (since they will have too little profit). Thus, there is such a level of prices for natural gas, in which the generalizing magnitude of barriers to the implementation of gas-saving projects is the smallest.

Using the minimax principle (expression (22)), we calculated the generalizing level of economic barriers on the way to the implementation at the studied enterprises of the projects on reducing natural gas consumption. According to the data shown in Table 8, this level ranges from 0.274 to 0.448 for various industries.

Based on the calculated values of the generalizing level of economic barriers to the implementation of projects on reducing the consumption of natural gas, the efficiency of state expenditures on the subsidization of enterprises was calculated. To this end, formula (23) was used. According to the data shown in Table 8, the estimated effectiveness of state expenditures on subsidizing enterprises ranges from 4.235 to 9.790 m^3/USD. It should be noted that as of today in Ukraine such subsidizing is performed mainly for house-

holds receiving targeted loans. At the same time, according to the State Agency on Energy Efficiency and Energy Saving of Ukraine, the efficiency of public expenditures on subsidized households ranges from 2.750 to 9.625 m^3/USD [25]. Thus, the estimated level of this efficiency for the industry is almost the same. That is why it is advisable to extend to enterprises the Ukrainian practice of state subsidization of individuals receiving loans in order to implement projects to reduce natural gas consumption.

Table 8

Generalizing level of economic barriers to implementation of projects on reducing natural gas consumption and efficiency of state expenditures for subsidization of enterprises

Indicators	Kinds of economic activity				
	Production of food, beverages, and tobacco products	Manufacture of wood products, paper products and printing activities	Production of machines and equipment	Other	Total
1. Generalizing level of economic barriers on the way to implementation of projects on reducing the natural gas consumption at enterprises	0.356	0.398	0.448	0.274	0.367
2. Effectiveness of state expenditures to subsidize enterprises that plan to implement the projects on reducing the natural gas consumption, m^3/USD	8.003	5.913	4.235	9.790	6.545

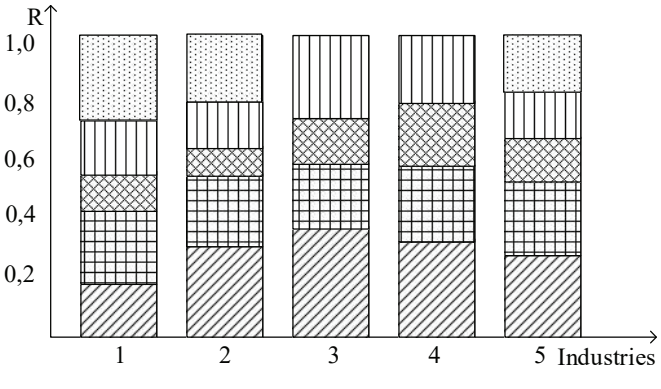

Fig. 4. The influence of the measures to overcome the barriers on the way to implementing the projects on reducing the natural gas consumption on the level of this implementation (R) for enterprises that belong to: 1 — food and taste industry; 2 — wood processing and printing industries; 3 — machine-building; 4 — other industries; 5 — all studied industries, where: ▨ — actual level of project implementation; ▦ — increase in the level of project implementation due to overcoming low economic effectiveness of projects; ▩ — increase in the level of project implementation due to overcoming the lack of input information; ▥ — increase in the level of project implementation due to overcoming the lack of resource provision; ⁘ — increase in the level of project implementation due to overcoming other kinds of barriers

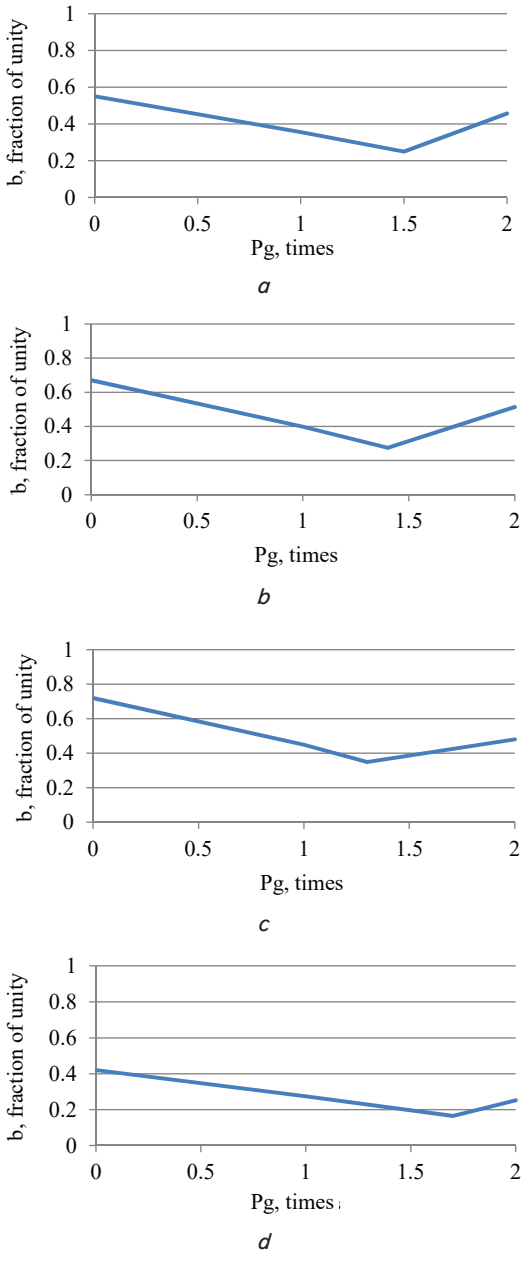

Fig. 5. Dependence of the generalizing level of economic barriers on the way to implement the projects on decreasing the natural gas consumption (b) at enterprises on its price growth rate (p_g) for enterprises that belong to: a — food and taste industry; b — wood processing and printing industries; c — machine-building; d — other industries

6. Discussion of the developed toolkit for assessing and overcoming barriers to the implementation of energy-saving projects

The results obtained in this paper showed the possibility and proved the need to quantify barriers to the implementation of energy-saving projects at enterprises. At the same time, some gaps that exist at this stage in studying the measurement and overcoming barriers to energy efficiency were closed. In particular, the new scientific results presented in the research should include the proposed method of grouping barriers to the implementation of energy-saving projects. This grouping

is based on the proposed division of the respective barriers into partial and generalizing, shown above in Tables 1, 2, and on establishing the relationship between them, shown in Fig. 2. In addition, the procedure for assessing the impact of possible overcoming certain obstacles on the way to the implementation of energy-saving projects on the level of such implementation was developed. This procedure was developed based on the principles of construction of a mathematical model described by formula (2), which takes into consideration the sequential nature of the barriers studied.

In addition, the procedure for assessing barriers to the implementation of energy-saving projects was improved. This was achieved by establishing a clear link between the magnitude of economic barriers to improving energy efficiency and the level of effort to be made to overcome these barriers. The reimbursement of a part of the investment costs of enterprises for energy-saving projects was considered as such efforts and models of substantiation of the minimum required amount of such reimbursement were constructed. These models are based on the minimax principle, which is reflected in formulas (6) and (22). Accordingly, the proposed approach to assessing the level of barriers to the implementation of energy-saving projects, compared to existing approaches, makes it possible to obtain more probable quantitative assessments of these barriers.

In addition, the models for assessing the level of barriers on the way to the implementation of energy-saving projects depending on the chosen source of funding for these projects were constructing in this research. The corresponding models are represented by expressions (5), (13), (15), (19), and (21). They were obtained on the basis of taking into consideration the conditions of using various funding sources and determining their impact on the required share of additional external reimbursement of a part of investments in energy-saving projects.

The grouping of barriers on the way to the implementation of energy-saving projects, performed in the research, made it possible to systematize the measures for their overcoming in Table 3. In turn, the constructed models of evaluation of these barriers allowed establishing the sequence of substantiation of the main parameters of state preferential lending programs for enterprises involving the implementation of energy-saving projects. This sequence is shown in Fig. 3. In addition, when applying expression (23), these models can be used to evaluate the effectiveness of state expenditures on subsidizing enterprises planning to implement energy-saving projects.

Most of the theoretical developments obtained in the study were tested on a sampling of enterprises. Collected and processed data, shown in Tables 4–8 and in Fig. 2, 4, 5, should be considered objective enough. This is due, in particular, to a sufficiently large volume of the sampling. In addition, the empirical results on the level of economic barriers to the implementation of energy-saving projects do not differ significantly within the framework of the studied types of economic activity, as it follows from the data in Table 7. In the end, in all sectors, the level of the corresponding economic barriers to funding energy-saving projects through a bank loan was lower than in the case of financing projects by profits of enterprises.

The results of this study can be used both at the enterprise level and in the practice of activities of state and municipal authorities. In particular, the use of the results, first of all, of model (6), at the enterprises will enable their managers and specialists to increase the degree of validity of management decisions on the implementation of energy-saving projects. As for the state and municipal authorities, the results presented, in particular, in Table 3 and in Fig. 3, make it possible to formalize the process of setting parameters of state programs of financial support for enterprises seeking to implement energy-saving projects. These parameters are characterized by a higher level of validity compared to those offered by other researchers. This is due to the formalization of the process of calculating the fractions of external reimbursement of investment expenditures for energy-saving projects. In addition, the proposed approaches make it possible to choose the most effective directions of state financial support for the implementation of energy-saving projects under conditions of budgetary restrictions through the use of expression (23). Consequently, the results provide additional opportunities for development by the authorities.

At the same time, the shortcomings of the research performed in this work are that a range of the parameters of the constructed models were considered as exogenous, that is, their substantiation was not considered. In particular, this applies to indicators of minimum allowable return on investments and discount rates. In addition, funding sources for energy-saving projects were explored only as alternatives. At the same time, it is quite common to use several sources of investment to finance projects at the same time. Elimination of these shortcomings should be considered as promising areas of further research on the topic of this work. However, there may be difficulties in collecting empirical data along the way, as information about the funding structure of energy-saving projects is difficult to obtain from open databases.

7. Conclusions

1. It is advisable to separate five main groups of barriers on the way to the implementation of energy-saving projects at enterprises. These include, in particular, barriers caused by unfavourability of the external environment, in which the enterprises are located, and the lack of resources of enterprises. In addition, it is advisable to separate barriers determined by an insufficient level of resource properties, lack of competence of managers and owners of an enterprise regarding the management of energy-saving projects and the lack of consumer properties of energy-saving equipment and technologies. In this case, it was established that barriers to the implementation of energy-saving projects can be evaluated both at the level of a separate project (in absolute and relative measurement units) and for a totality of enterprises. For the latter case, within this research, we developed a model of the influence of overcoming certain barriers on the way to the implementation of energy-saving projects on the level of such implementation.

2. When modeling the level of barriers on the way to the implementation of energy-saving projects at enterprises, it is necessary to take into consideration possible sources of funding these projects. At the same time, it is appropriate to perform the generalized assessment of the level of economic barriers on the way to the imple-

mentation of energy-saving projects using the minimax principle. According to this principle, first, the maximum value of the level of economic barriers within each possible source of project funding is chosen. Then from the selected values, one chooses the minimum value, which is accepted as a generalized assessment of the level of all economic barriers on the way to the implementation of energy-saving projects.

3. Overcoming barriers to the implementation of energy-saving projects at enterprises requires taking certain measures that may have organizational, economic, and technological character. These measures should be grouped by types of barriers on the way to the implementation of energy-saving projects, as well as by the subjects of these measures. At the same time, one of the main means of overcoming these barriers is the implementation of state programs of preferential lending for enterprises planning to implement energy-saving projects. The proposed approach to the substantiation of the parameters of these programs can be used in the practice of the activity of state institutions responsible for the development and implementation of state policy in the field of energy-saving.

4. It was found that for all types of economic activity of enterprises that have implemented or tried to implement projects to reduce the consumption of natural gas, in the opinion of managers of enterprises, an insufficient level of efficiency of such implementation is the highest among the barriers to implementation. The level of this barrier ranges from 0.308 for enterprises producing machinery and equipment to 0.548 for enterprises producing food, beverages, and tobacco products. At the same time, the estimated efficiency of state expenditures for subsidizing enterprises ranges from 4.235 to 9.790 m^3/USD. The level of this efficiency is high enough. That is why it is appropriate to extend to enterprises the Ukrainian practice of state subsidization of individuals receiving loans in order to implement projects on reducing natural gas consumption.

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