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TOOLS FOR ASSESSING OBSTACLES IN IMPLEMENTATION OF ENERGY SAVING MEASURES BY ENTERPRISES

Purpose. To create methodological tools for assessing obstacles to implementation of energy saving measures by enterprises.

Methodology. In the course of the research the following methods were used: economic-mathematical modeling (substantiation of parameters of preferential crediting of energy-saving projects of enterprises on the basis of building models of repayment of loans and obtaining financial and economic results from these projects), classification and generalization (when grouping obstacles to reduction of consumption of non-renewable energy resources), system analysis (in the development of methodological principles for assessing barriers to energy efficiency); economic analysis and technical and economic calculations (when performing empirical studies on barriers to reducing natural gas consumption), questionnaire (when conducting a survey of owners and managers of surveyed enterprises on factors that hinder the implementation of projects), mathematical statistics (to process the results).

Findings. Based on the results of a survey of owners and managers of 74 Ukrainian enterprises belonging to three industries characterized by significant volumes of natural gas consumption, the most significant barriers to reducing the consumption of non-renewable energy resources were identified and grouped. Methods for estimating the level of these barriers by the totality of the studied enterprises and by certain types of financial and economic barriers to reducing the consumption of energy resources are proposed. Models of substantiation of parameters of preferential crediting of energy saving projects which have for the purpose of realization of measures for reduction of consumption of natural gas at the enterprises are constructed.

Originality. Existing methods for grouping barriers to reducing the consumption of non-renewable energy resources have been supplemented by introducing such additional features as the stages of development and implementation of energy saving measures and the factors of occurrence of relevant barriers. The methodological basis for assessing these barriers has been improved by substantiating the approach according to which the height of the barrier is determined by the cost of resources to overcome it. Formalized models of preferential lending for energy-saving projects of enterprises have been built, taking into account the efficiency of budget expenditures for such lending.

Practical value. The obtained results can be used by both enterprises and public authorities and local governments in assessing obstacles to reducing the consumption of non-renewable energy resources and developing a set of organizational and economic measures to overcome them.

Keywords: *non-renewable energy resource, reduction of energy consumption, energy saving project, soft loans*

Introduction. The current state of socio-economic development is defined for many countries as a movement to the post-industrial stage, in which there are radical changes in all spheres of society, from production to ideological processes. The new technical and technological paradigm of development significantly expands the potential for economic growth, pushing the need for traditional resources into the background and requiring economic agents to think innovatively and make non-standard decisions.

If back in the middle of the twentieth century, firms and entire countries were waging a grueling competition for access to energy sources, today, they are increasingly trying to get rid of the need to use them in production processes. This situation, on the one hand, is associated with the emergence of new technologies, and on the other hand, with the disadvantages of continuing to exploit the industrial components of economic

growth. It is known that the main types of fossil fuels are characterized by significant costs for their extraction, transportation and use. Consumption of these energy sources is also associated with a significant risk due to both significant fluctuations in their prices on world markets and the possible cessation of their supply. In addition, the use of fossil energy resources has an adverse effect on the environment and may have negative geopolitical consequences, which are reflected in the political dependence of countries importing these resources on those countries that export them. That is why the governments of many countries are striving for energy security by persuading economic agents to switch to energy-saving technologies. However, in practice, not all companies are highly motivated to implement structural changes. The obvious benefits of modernization in the future are significantly reduced due to current costs and difficulties. First of all, the process of reducing the consumption of non-renewable energy resources requires the implementation of a number of technical and technological measures aimed at improving the effi-

ciency of use of fossil energy resources and the replacement of non-renewable energy sources with renewable ones. Such measures, as a rule, require significant investment costs, they are quite complex in organizational terms and require appropriate experience and skills to implement them. This is very important, especially for countries with economies in transformation, whose business units, as a rule, do not have sufficient technical, human, financial, and other resources for structural adjustment, they are not competent in the direct implementation of energy saving projects, and the projects themselves very often do not allow obtaining the appropriate level of economic and social results from their implementation given the existing institutional environment. According to a number of studies on the post-socialist transformation of Eastern European countries, the economic activity of people in such systems is realized in the context of institutional conflict, which blocks development, often creating insurmountable barriers to progressive initiatives and does not promote innovation [1].

Thus, we can say that on the way to structural modernization of production processes, in particular, reducing the consumption of fossil energy resources, there are technical, economic, social, organizational, and institutional obstacles that slow it down or make it impossible [2]. Such obstacles, which can be described as barriers, are not always on the surface, so we need to have the tools for their identification and assessment in order to develop effective ways for economic agents to overcome them [3].

In particular, this applies to organizational and economic mechanisms, as a significant number of barriers on the way to reduction in the use of non-renewable energy resources is of an organizational and economic nature. At the same time, overcoming barriers of technical and other nature may also require the implementation of appropriate organizational and economic measures. Therefore, it should be noted that organizational and economic mechanisms for overcoming barriers on the way to the reduction in the use of non-renewable energy resources should apply to all groups of their consumers, especially enterprises, households, and budgetary institutions. At the same time, it is in the case of enterprises that the development of such mechanisms can be considered the most difficult task. This is due to the variety of types of enterprises and the purposes of their operation, and the presence of complex patterns that characterize the conducting production, trade, investment and other types of business activities.

Thus, in the conditions of energy transition there is an important problem of the development of organizational and economic mechanisms of overcoming obstacles on the way to reduction in consumption of non-renewable energy resources at the enterprises. However, tackling this problem requires a preliminary assessment of the level of such barriers, as both the nature and scale of the measures to overcome the relevant barriers depend on it.

Literature review. The issue of identifying, assessing and overcoming barriers to reducing the consumption of non-renewable energy resources is the focus of many scientists. However, it should be noted that the results of research on these issues obtained by different scientists differ significantly. In particular, it concerns the identification of those obstacles that should be considered as the major barriers and, accordingly, on which the greatest efforts should be concentrated. Thus, A. Trianni, E. Cagno, E. Worrell & G. Pugliese (2013) pay special attention to economic barriers to the implementation of energy saving measures, and Z. Zhang, X. Jin, Q. Yang, & Y. Zhang (2013) emphasize that among all economic components, the lack of financial resources is one of the determining factors that hinder the implementation of such measures. Some authors pay considerable attention to management barriers to increasing the energy efficiency. These barriers are reflected, in particular, in the lack of rationality, inability to de-

termine the target implementation [4], as well as inadequate information support of the management decision-making process for energy efficiency programs and projects [5]. Also, among the factors that have a negative impact on the pace of implementation of energy-saving technologies and other measures to improve energy efficiency, scientists single out a significant risk of such implementation [6]. In addition, a possible reason for the reluctance of owners and managers of individual enterprises to implement energy-saving projects is insufficiently high prices for energy resources, which are expected to be saved. On the other hand, there are conflicting views in the literature on the role of rising energy prices as a factor in reducing energy consumption. For instance, R. Nesbakken (1999) established the existence of the influence of changes in electricity prices on the volume of its consumption. At the same time, Y.-T. Chen (2017) did not find this relationship in their empirical studies [7].

One of the important factors that under certain conditions can reduce the effectiveness of the implementation of energy saving projects at enterprises is the rebound effect in energy consumption, when increasing energy efficiency causes an increase in energy consumption in absolute terms. At the same time, the results of different researchers regarding the manifestations of this effect are contradictory. For example, in the well-known study by R. Howarth (1997) the rebound effect was not detected while L. Orea, M. Orea, M. Filippini (2015) established its presence, but its effect was considered insignificant [8].

In general, the identification of the most important barriers to the implementation of measures to reduce energy consumption requires further empirical research and consideration of the relationship between different types of these barriers (E. Cagno, E. Worrell, A. Trianni & G. Pugliese, 2013). At the same time, according to the researchers, it is necessary to assess the level of certain barriers that arise in the implementation of energy saving measures at enterprises, and, in turn, in ensuring the energy-saving type of development of companies [9]. The modern scientific literature presents a number of methodological approaches to such assessment. In particular, the work by H. Kangas, D. Lazarevic & P. Kivimaa proposes a method of qualitative analysis of obstacles to improving energy efficiency [10]. To this end, a number of researchers recommend conducting a survey of energy managers [11]. The tools for assessing obstacles in the implementation of energy saving measures presented in [12] are more complex as they involve the use of a hierarchical approach and graph-analytical models. In [13], the analysis of these obstacles focuses mainly on assessing the lack of necessary information, and in [14], it centers on the shortcomings of existing energy audit techniques. However, these methods do not take into account the level of effort and resources (organizational, financial and others) that need to be spent to overcome the relevant barriers. Also noteworthy is the approach outlined by K. Chai & C. Yeo (2012) to assess barriers to energy efficiency of enterprises, which involves finding the weakest link among the following: motivation, ability, implementation, and results [15]. However, these methods and approaches do not take into account the level of effort and resources (organizational, financial and others) that need to be spent to overcome the relevant barriers. In particular, with regard to financial barriers to the implementation of energy saving measures, such overcoming may involve the need for soft loans for enterprises. It should be borne in mind that soft loan programs, especially if they involve government support, require careful justification [16]. This justification requires consideration of a number of different interrelated factors that determine the effectiveness and feasibility of implementing appropriate energy saving measures, in particular, the level of their riskiness [17], the cost of these measures, and the motivation to implement them [18]. However, at present, the methodological principles of substantiation of the state financial support of the enterprises concerning overcoming of ob-

stacles on the way of realization of energy saving measures remain not completely formed.

Thus, the issues of grouping types, identifying factors, and developing tools for assessing barriers to reducing the consumption of non-renewable energy resources by enterprises are not definitively resolved and, given their relevance, require further research.

Purpose. Creation of methodological tools for assessing obstacles to the implementation of energy saving measures by enterprises.

Results. The development of organizational and economic mechanisms for overcoming obstacles to reducing the consumption of non-renewable energy resources should be preceded by the identification and assessment of the main ones of such obstacles. To this end, it is necessary to group all the main types of barriers that arise at enterprises during the implementation of measures aimed to save fossil energy. It seems appropriate to group the types of such barriers according to two main features: the stages of development and implementation of measures to save fossil energy and the sources of the relevant obstacles. In particular, with regard to obstacles to reducing the consumption of non-renewable energy resources at the stages of development and implementation of appropriate measures for such reduction, the following types of obstacles should be identified: those that arise when setting goals for the development and implementation of energy-saving measures; those that arise during the collection of input information necessary for the development and implementation of energy-saving measures; those that arise in the process of processing this information; those that arise during the preparation of the final program of measures to reduce the consumption of non-renewable energy resources; those that arise in the process of

forming the necessary amount of financial resources for the implementation of planned energy-saving measures, as well as the acquisition of other types of necessary resources, if such acquisition does not require investment; those that arise in the process of investing financial resources in the implementation of planned energy-saving measures; those that occur during commissioning; those that arise in the process of obtaining financial, economic and(or) social results from the implementation of planned energy-saving measures.

Regarding the classification of obstacles to reducing the consumption of non-renewable energy resources by the factors of the corresponding obstacles, it is advisable to identify the following types: obstacles caused by the lack of certain amounts, available and possible to attract, of resources of enterprises; obstacles caused by the insufficient level of certain existing and possible properties to attract types of resource provision of enterprises; obstacles caused by the qualities possessed by business owners; political and institutional obstacles; obstacles caused by insufficient level of financial and economic and(or) social results of implementation of energy-saving measures at enterprises. These groups of types of obstacles to reducing the consumption of non-renewable energy resources can be divided into a number of subgroups, as presented in Table 1.

As follows from the data given in Table 1, there are a number of different barriers that arise in the development and implementation of energy-saving measures by enterprises. In this case, some of the subgroups of these barriers can be divided into new, more detailed subgroups. For example, obstacles caused by insufficient levels of certain properties available and possible to attract human resources of the enterprise may include barriers driven by low competence of employees, lack of motivation to save energy, personal traits, and others.

Table 1

Classification of obstacles in the implementation of energy-saving measures by enterprises

Names of obstacle groups	Names of obstacle subgroups
1. Obstacles caused by the lack of certain amounts of enterprises' resources available and possible to attract	Obstacles caused by the lack of amounts, available and possible to attract, of: 1.1. Human resources. 1.2. Technical resources and other means of labor. 1.3. Material resources and other objects of labor. 1.4. Information resources. 1.5. Financial resources
2. Obstacles caused by the insufficient level of certain existing and possible properties to attract types of resource provision of enterprises	Obstacles caused by insufficient level of certain properties available and possible to attract: 2.1. Human resources. 2.2. Technical resources and other means of labor. 2.3. Material resources and other objects of labor. 2.4. Information resources. 2.5. Financial resources
3. Obstacles caused by the qualities possessed by business owners	Obstacles caused by such qualities possessed by business owners as: 3.1. Insufficient competence in the field of implementation of energy-saving projects. 3.2. Insufficient level of entrepreneurial skills. 3.3. Inappropriate personal qualities. 3.4. Insufficient level of material well-being
4. Obstacles of political and institutional nature	4.1. Shortcomings in the legal framework for implementing measures to reduce the consumption of non-renewable energy resources. 4.2. Shortcomings in the state energy saving policy. 4.3. Difficulty in obtaining loan financing for projects to reduce the consumption of non-renewable energy resources. 4.4. Underdeveloped stock market
5. Obstacles caused by insufficient level of financial and economic and(or) social results of implementation of energy saving measures at enterprises	Obstacles caused by insufficient level of such results of implementation of energy saving measures at enterprises: 5.1. Profit and net cash flow. 5.2. The growth of the market value of the enterprise. 5.3. Physical sales volumes of the enterprise products. 5.4. Cost sales volumes of the enterprise products. 5.5. Social, environmental and other results

Having identified the types of major obstacles to the implementation of energy-saving measures by enterprises, we can proceed to address the issue of assessing the level of these obstacles, taking into account the main factors of their formation.

It is advisable to identify two main directions of such assessment:

1) assessment of a sample of enterprises in a particular industry (type of economic activity);

2) assessment of individual energy-saving measures that were planned or are being planned to be implemented at a particular enterprise.

Let us first consider the first direction of assessing the level of obstacles to energy-saving at enterprises. First of all, it should be noted that if the sample of enterprises is large enough, it is possible to assess all the above types of barriers. In particular, with regard to obstacles to reducing the consumption of non-renewable energy resources at the stages of development and implementation of appropriate measures for such reduction, the assessment of these obstacles can be performed according to the formula

$$L_{bi} = \frac{N_{bi-1} - N_{bi}}{N_{bi-1}}, \quad (1)$$

where L_{bi} is the level of the i^{th} obstacle at the stages of development and implementation of energy saving measures, N_{bi} is the number of energy saving measures that were developed in the reporting period by enterprises for which the i^{th} obstacle was overcome; and N_{b0} is the initial number of energy saving measures, which in the reporting period were considered by the surveyed enterprises for their implementation.

Thus, the use of (1) makes it possible to determine the share of energy saving measures, the development or implementation of which has stopped due to overcoming the i^{th} obstacle, in the total number of measures that have successfully overcome all previous barriers to their development (implementation).

Regarding the obstacles to reducing the consumption of non-renewable energy resources by the factors of the emergence of appropriate barriers, it is advisable to assess them according to the following formula

$$L_{bj} = \sum_{i=1}^n (L_{bi} \cdot v_{ij}), \quad (2)$$

where L_{bj} is the level of the j^{th} obstacle on the way to reducing the consumption of non-renewable energy resources due to the factors of the occurrence of the corresponding obstacles at the i^{th} stage of development and implementation of appropriate energy-saving measures; n is the number of barriers to reducing the consumption of non-renewable energy resources at the stages of development and implementation of appropriate measures for such reduction; v_{ij} is the coefficient of significance of the j^{th} obstacle in relation to the creation of conditions for the impossibility of overcoming part (or all) of barriers at the i^{th} stage of development and implementation of energy saving measures (determined on the basis of expert survey of owners and managers).

Thus, the application of (2) makes it possible to simultaneously take into account the following: first, the level of all barriers that arise to reduce the consumption of non-renewable energy resources at the stages of development and implementation of appropriate measures for such reduction; second, the significance of each of the factors that determine the emergence of these barriers.

If we consider the procedure for assessing obstacles to reducing the consumption of non-renewable energy resources at enterprises for individual energy saving measures, such an assessment may be more detailed. However, its implementation can be carried out only for certain types of these obstacles. In particular, this applies to financial and economic barriers as-

sociated with the lack of adequate financial resources for enterprises and the insufficient level of economic efficiency of energy-saving projects that these enterprises intend to implement. In this case, as mentioned above, it seems appropriate to link the degree of these obstacles with the efforts that should be made to overcome them. Among other things, a possible method for overcoming them will be soft loans for energy-saving projects of enterprises.

Considering the financial and economic barriers to reducing the consumption of non-renewable energy resources and soft loans as a way to overcome these barriers, it is appropriate to assess three main parameters, namely:

1) the ability of a certain enterprise to timely and fully repay the loan received for financing energy-saving projects;

2) the level of economic efficiency of energy-saving projects in terms of enterprises that provide for their implementation;

3) the level of economic efficiency of measures to provide financial support for the implementation of energy-saving projects by enterprises from the point of view of institutions that provide such support (primarily from the point of view of public authorities and local governments).

Regarding the first parameter, its assessment should be based on the following formalized condition of timely repayment of the loan taken by the enterprise for the purpose of implementing an energy-saving project (projects)

$$\begin{aligned} (P_{r0} + P_{r1}) \cdot \left(\sum_t^T \frac{1}{(1+r_c)^t} \right) = \\ = \left(\frac{P_{r0} + P_{r1}}{r_c} \right) \cdot \left(1 - \frac{1}{(1+r_c)^T} \right) \leq I \cdot (1-\alpha), \end{aligned} \quad (3)$$

where P_{r0} is the amount of initial profit of the enterprise (i. e., profit, the receipt of which is not related to the implementation of energy-saving projects), which is expected to be used to repay the loan; P_{r1} is the expected increase in the enterprise's profit from the implementation of its energy-saving project (projects); T is the maximum loan term for the enterprise; r_c is loan interest rate expressed as a fraction of a whole number; I is the total amount of investments required for the implementation of energy-saving project (projects); α is the share of their own sources of funds in the total amount of investments, that is, available own funds of the enterprise at the time of the energy-saving project (projects) implementation.

Thus, the economic meaning of inequality (3) follows from the following rule: the enterprise will be able to timely and fully repay the loan, provided that the discounted cash flow aimed at such repayment (in our case $P_{r0} + P_{r1}$) does not exceed the initial amount of the taken loan; in this case, the discount rate should be the loan interest at which the loan was received.

If inequality (3) is not satisfied, it will mean that there is an obstacle for the enterprise to implement an energy-saving project (projects), caused by the inability to repay the loan taken for such implementation in a timely manner. To quantify the magnitude of this obstacle, it is necessary to convert inequality (3) to equality, multiply the index I by $(1 - \beta_1)$ and express β_1 from the obtained equation. As a result, we obtain the following

$$\beta_1 = 1 - \frac{1}{I \cdot (1-\alpha)} \cdot \left(\frac{P_{r0} + P_{r1}}{r_c} \right) \cdot \left(1 - \frac{1}{(1+r_c)^T} \right), \quad (4)$$

where β_1 is the level of the barrier caused by the inability of the enterprise to timely repay the loan taken to implement an energy-saving project (projects), fraction of a whole number.

Thus, the indicator β_1 characterizes the share of the loan taken by the enterprise for the purpose of implementation of the energy-saving project (projects), which requires to reduce the loan amount so that the enterprise could repay it in due

time. However, there may be another way to reimburse the enterprise's expenses associated with repaying the loan, namely, reducing the interest rate. This method of repayment is a priori sufficient if the enterprise is able to repay the loan at a zero credit rate – i.e., when the following inequality is satisfied

$$\frac{I \cdot (1 - \alpha)}{P_{r0} + P_{r1}} \leq T. \quad (5)$$

If inequality (5) is not satisfied, then it is impossible to overcome this barrier only by reducing the loan interest rate, and the loan principal should also be partially repaid.

Let us now consider the methodological principles of assessing the level of economic efficiency of energy-saving projects in terms of enterprises that provide for their implementation. Such an assessment requires the calculation of the net present value of the future profit flow of the enterprise, obtained as a result of its implementation of energy-saving project (projects). Assume that the barrier caused by the inability of the company to repay the loan taken for implementing an energy-saving project (projects) in time is absent or will be overcome through external financial support. Then the specified net present value will be calculated by the following formula

$$\begin{aligned} V &= -I \cdot (1 - \alpha) \cdot (1 - \beta_1) - P_{r0} \cdot \sum_{t=1}^{T_c} \left(\frac{1}{(1 + r_e)^t} \right) + \\ &+ P_{r1} \cdot \sum_{t=1}^{T_p - T_c} \left(\frac{1}{(1 + r_e)^t} \right) = \\ &= -I \cdot (1 - \alpha) \cdot (1 - \beta_1) - \left(\frac{P_{r0}}{r_e} \right) \cdot \left(1 - \frac{1}{(1 + r_e)^{T_c}} \right) + \\ &+ \left(\frac{P_{r1}}{r_e} \right) \cdot \left(1 - \frac{1}{(1 + r_e)^{T_p - T_c}} \right), \end{aligned} \quad (6)$$

where V is the present value of future cash flow of the enterprise obtained as a result of its implementation of energy-saving project (projects); T_c is the forecast period for the full repayment by the enterprise of a loan taken for the purpose of implementing an energy-saving project (projects); r_e is the discount rate the enterprise accepts to reduce different costs, it is expressed as a fraction of a whole number; T_p is the total duration of the forecast period.

It should be noted that in the case where the total duration of the forecast period is unlimited, expression (6) takes the following form

$$\begin{aligned} V' &= -I \cdot (1 - \alpha) \cdot (1 - \beta_1) - \\ &- \left(\frac{P_{r0}}{r_e} \right) \cdot \left(1 - \frac{1}{(1 + r_e)^{T_c}} \right) + \left(\frac{P_{r1}}{r_e} \right) \cdot \left(\frac{1}{(1 + r_e)^{T_c}} \right), \end{aligned} \quad (7)$$

where V' is the present value of future cash flow of the enterprise obtained as a result of its implementation of energy-saving project (projects) in the case of unlimited forecast period.

If the value of expression (7) is negative, it means that there is an obstacle for the enterprise to implement an energy-saving project (projects) caused by insufficient level of economic efficiency of such implementation. To quantify the magnitude of this obstacle, multiply the index I by $(1 - \beta_2)$, equate expression (7) to zero and express β_2 from the obtained equation. As a result, we obtain

$$\beta_2 = 1 - \frac{\left(\frac{P_{r1}}{r_e} \right) \cdot \left(\frac{1}{(1 + r_e)^{T_c}} \right) - \left(\frac{P_{r0}}{r_e} \right) \cdot \left(1 - \frac{1}{(1 + r_e)^{T_c}} \right)}{I \cdot (1 - \alpha) \cdot (1 - \beta_1)}, \quad (8)$$

where β_2 is the level of the barrier caused by the insufficient level of economic efficiency of the enterprise's implementation of the energy saving project (projects) is expressed as a fraction of a whole number.

Thus, knowing the value of the indicator (8), it is possible to estimate the required amount of reimbursement of invest-

ment costs of the enterprise associated with the implementation of energy saving project (projects) to ensure the appropriate (from the point of view of enterprises) level of economic efficiency of such implementation.

Let us now consider the peculiarities of establishing the level of economic efficiency of measures to financially support the implementation of energy-saving projects by enterprises from the point of view of institutions that provide such support. To estimate this level in the general case, it is advisable to use the following formula

$$L_e = \frac{E}{C_b - \sum_{t=1}^{T_n} \left(\frac{P_t}{(1 + r_d)^t} \right)}, \quad (9)$$

where L_e is the level of economic efficiency of financial support for the implementation of a certain enterprise energy-saving project (projects) from the point of view of the institution providing such support; E is the physical volume of expected energy savings due to the implementation of a certain enterprise energy saving project (projects); C_b is the volume of financial support for this enterprise; T_n is the number of time periods when the enterprise is provided with the financial support in the form of cash flows; P_t is the amount of cash flows from the financial support provided to the enterprise in the t^{th} period; r_d is the discount rate the enterprise accepts to reduce different costs, it is expressed as a fraction of a whole number.

It should be noted that the amount of cash flow from financial support provided to the enterprise, which appears in (9), relates primarily to the amount of interest paid and the principal loan repayment granted on concessional terms by a particular institution (e.g., state bank) for the enterprise that seeks to implement energy saving measures.

Thus, (9) can be used to assess the economic efficiency of budget expenditures to support enterprises seeking to implement energy saving measures. Thus, having worked out a large enough sample of enterprises of different sectors of the economy and knowing the available financial capabilities of the budgets of the respective levels, it is possible to establish a standard for such efficiency. This standard will be the minimum allowable efficiency of budget expenditures to support energy saving measures at enterprises, for which it is advisable to provide this support.

It is also important to note the fact that the implementation of these measures may cause a rebound effect in energy consumption. This effect should be taken into account when calculating the economic efficiency of budget expenditures according to (9). However, the rebound effect does not always reduce the level of this efficiency as it can lead to an increase in budget revenues (due to increased production and sales). With this in mind, formula (8) should be modified to look like this

$$L_{er} = \frac{E + \Delta E}{C_b - \sum_{t=1}^{T_n} \left(\frac{P_t}{(1 + r_d)^t} \right) - \Delta P_T}, \quad (10)$$

where L_{er} is the level of economic efficiency of financial support for the implementation of a certain enterprise energy saving project (projects) from the point of view of the institution providing such support, taking into account the rebound effect; ΔE is the increase in energy consumption due to the rebound effect; ΔP_T is the increase in budget revenues due to the rebound effect.

The described above theoretical and methodological principles of assessing obstacles to the implementation of measures by enterprises to reduce the consumption of fossil energy resources can be used for each type of such resources. In particular, this applies to natural gas that is an energy source, the consumption of which the governments of many countries are trying to limit significantly.

For the purpose of empirical analysis, data were collected on 74 Ukrainian enterprises belonging to three industries characterized by significant volumes of natural gas consumption. As

shown in Table 2, during 2018–2020, these enterprises considered 133 measures to save natural gas consumption, of which 46 measures were successfully implemented (i. e., about a third).

Based on the data presented in Table 2 and using formula (1), it is possible to estimate the level of obstacles to the reduction of natural gas consumption by the stages of development and implementation of measures for such reduction by the surveyed enterprises. The corresponding assessment results are presented in Table 3.

As shown in Table 3, the most formidable are the obstacles that arise in the process of forming the necessary amount of financial resources for the implementation of planned energy saving measures, as well as the acquisition of other types of necessary resources. There are also significant barriers to the collection of input information needed to develop and implement energy saving measures. Thus, these findings are valid for all three industries under consideration.

Table 2

Data on overcoming obstacles to reducing natural gas consumption

Names of indicators	The value of indicators by type of economic activity		
	Metal product manufacturing	Production of bricks, tiles and other clay building materials	Manufacture of glass and glass products
1. The number of enterprises surveyed (a whole number)	24	19	31
2. The number of measures to save natural gas consumption, which during 2018–2020 were considered at enterprises for the possibility of their implementation (a whole number)	37	41	55
3. The number of implemented measures from those considered (a whole number)	12	15	19
4. The share of successfully implemented measures from those considered (a fraction of a whole number)	0.324	0.366	0.345
5. The number of measures for which in the process of their development and implementation the relevant obstacles have been overcome (a whole number):			
5.1. Obstacles that arise when setting goals for the development and implementation of energy saving measures	35	39	52
5.2. Obstacles to the collection of input information needed to develop and implement energy saving measures	29	33	47
5.3. Obstacles in the processing of input information	26	30	43
5.4. Obstacles that arise during the preparation of the final program of measures to reduce the consumption of non-renewable energy resources	25	29	41
5.5. Obstacles that arise in the process of forming the necessary amount of financial resources for the implementation of planned energy saving measures, as well as the acquisition of other types of necessary resources	14	17	24
5.6. Obstacles to the process of investing financial resources in the implementation of planned energy saving measures	13	16	22
5.7. Obstacles that arise during commissioning works	13	16	21
5.8. Obstacles that arise in the process of obtaining financial, economic and (or) social results from the implementation of planned energy saving measures	12	15	19

Table 3

The level of obstacles in the implementation of measures to save natural gas at the stages of their development and implementation

Names of obstacles	The level of obstacles by type of economic activity (a fraction of a whole number)		
	Metal product manufacturing	Production of bricks, tiles and other clay building materials	Manufacture of glass and glass products
1. Obstacles that arise when setting goals for the development and implementation of energy saving measures	0.054	0.049	0.055
2. Obstacles to the collection of input information needed to develop and implement energy saving measures	0.171	0.154	0.096
3. Obstacles in the processing of input information	0.103	0.091	0.085
4. Obstacles that arise during the preparation of the final program of measures to reduce the consumption of non-renewable energy resources	0.038	0.033	0.047
5. Obstacles that arise in the process of forming the necessary amount of financial resources for the implementation of planned energy saving measures, as well as the acquisition of other types of necessary resources	0.440	0.414	0.415
6. Obstacles to the process of investing financial resources in the implementation of planned energy saving measures	0.071	0.059	0.083
7. Obstacles that arise during commissioning works	0.000	0.000	0.045
8. Obstacles that arise in the process of obtaining financial, economic and (or) social results from the implementation of planned energy saving measures	0.077	0.063	0.095

Using (2), it is possible to estimate the level of barriers to reducing natural gas consumption by the factors of the occurrence of the corresponding barriers for the surveyed enterprises. The results of this assessment are presented in Table 4.

As follows from the data presented in Table 4, for all industries the most formidable are the obstacles that are caused by the insufficient amounts of certain types of enterprises' resource provision available and possible to attract. Also, a significant degree is inherent in the obstacles caused by the insufficient level of financial, economic and (or) social results of the implementation of energy saving measures at enterprises. Finally, the third largest group of obstacles are those that are caused by the insufficient level of certain properties of existing and possible types of resource provision of enterprises.

According to Tables 3 and 4, it can be concluded that the main directions of overcoming obstacles to reducing natural gas consumption in the surveyed enterprises should be the following: increasing the level of information support for the process of making and implementing management decisions on such reduction; improving the competence of employees in energy saving; simplification of opportunities for enterprises to attract additional amounts of economic resources, including financial, etc. For overcoming the obstacles to the implementation of measures to reduce natural gas consumption in the surveyed enterprises, it is also important to increase the economic efficiency of these measures. Thus, financial and economic barriers are some of the most important obstacles to improving the use of natural gas in the surveyed enterprises.

Using formulas (4, 8), it is possible to assess the level of financial and economic barriers to reducing natural gas consumption by the surveyed enterprises. The results of this assessment are presented in Table 5.

As follows from Table 5, according to the surveyed enterprises, the average level of the barrier caused by the inability of enterprises to repay the loan taken for implementing energy-saving projects in time is quite high and ranges from 0.297 to 0.389. As for the average level of the barrier caused by insufficient economic efficiency of the implementation of energy-saving projects by enterprises, this barrier is less significant than the previous one. This is because the level of the second barrier is calculated based on the fact that some effort has been made to overcome the first barrier.

Using formulas (9, 10), it is possible to assess the level of economic efficiency of budget financial support for the implementation of measures by the surveyed enterprises in order to reduce natural gas consumption. The results of this assessment are presented in Table 6.

As shown in Table 6, the forecast level of economic efficiency of budget financial support for the implementation of measures by the surveyed enterprises to reduce natural gas consumption is quite high. In particular, the average value of this level for all measures to reduce the use of this energy source ranges from 0.197 to 0.223 m³ of natural gas per year per 1 UAH of discounted budget expenditures. Thus, government soft loan programs for the implementation of measures to reduce natural gas consumption for at least some of the surveyed enterprises can be quite effective.

Conclusion. Existing approaches to grouping the types of barriers that arise at enterprises during the implementation of fossil energy saving measures should be supplemented by grouping these barriers by stages of development and implementation of fossil energy saving measures and by the factors of the occurrence of relevant barriers. The study shows that it is possible to build indicators for assessing each of the types of

Table 4

The level of obstacles in the implementation of measures to save natural gas by the factors of the occurrence of the corresponding obstacles

Names of obstacles	The level of obstacles by type of economic activity (a fraction of a whole number)		
	Metal product manufacturing	Production of bricks, tiles and other clay building materials	Manufacture of glass and glass products
1. Obstacles caused by the lack of certain amounts of enterprises' resources available and possible to attract	0.132	0.127	0.140
2. Obstacles caused by the insufficient level of certain existing and possible properties to attract types of resource provision of enterprises	0.113	0.091	0.084
3. Obstacles caused by the qualities possessed by business owners	0.032	0.040	0.026
4. Obstacles of political and institutional nature	0.093	0.082	0.107
5. Obstacles caused by insufficient level of financial and economic and (or) social results of implementation of energy saving measures at enterprises	0.128	0.111	0.125

Table 5

The level of financial and economic obstacles in the implementation of measures to save natural gas

Names of indicators	The value of indicators by type of economic activity		
	Metal product manufacturing	Production of bricks, tiles and other clay building materials	Manufacture of glass and glass products
1. The number of measures to reduce natural gas consumption at enterprises that have not been implemented due to financial and economic barriers (a whole number)	13	16	20
2. The average level of the barrier caused by the inability of enterprises to repay the loan in time that was taken to implement energy-saving projects (a fraction of a whole number)	0.352	0.297	0.389
3. The average level of the barrier caused by the insufficient degree of economic efficiency of the implementation of energy-saving projects by enterprises (a fraction of a whole number)	0.108	0.135	0.086

Forecast level of efficiency of budget financial support for the implementation of measures to reduce natural gas consumption

Names of indicators	The value of indicators by type of economic activity		
	Metal product manufacturing	Production of bricks, tiles and other clay building materials	Manufacture of glass and glass products
1. The average level of economic efficiency of budget financial support for the implementation of measures by enterprises to reduce the consumption of natural gas, m ³ of natural gas per year by 1 UAH of discounted budget expenditures	0.223	0.209	0.197
2. The average level of economic efficiency of budget financial support for enterprises to implement measures to reduce natural gas consumption by 30 % of the most effective of such measures, m ³ of natural gas per year per 1 UAH of discounted budget expenditures	0.354	0.319	0.284
3. The number of measures to reduce the consumption of natural gas, according to which the average level of economic efficiency of budget financial support for the implementation of these measures by enterprises exceeds 0.15 m ³ of natural gas per year by 1 UAH of discounted budget expenditures (expressed as a whole number)	6	7	9
4. The part of measures to reduce natural gas consumption, according to which the average level of economic efficiency of budget financial support for the implementation of these measures by enterprises exceeds 0.15 m ³ of natural gas per year per 1 UAH of discounted budget expenditures, in the total number of such measures (expressed as a fraction of a whole number)	0.462	0.438	0.450

obstacles from both groups. At the same time, certain types of obstacles to improving the energy efficiency of enterprises can be estimated by the share of investment in energy saving measures, which should be reimbursed to enterprises to make the implementation of these measures possible and appropriate for them. This result relates to the obstacles associated with the lack of adequate financial resources for enterprises and the insufficient level of economic efficiency of energy-saving projects that economic entities intend to implement. However, the level of economic efficiency of measures to financially support enterprises to implement energy saving projects should also be taken into account from the point of view of institutions that provide such support (primarily from the point of view of public authorities and local governments). Thus, the most reasonable way to assess the level of barriers to reducing non-renewable energy consumption by enterprises is to establish the amount of effort that needs to be made in order to overcome these barriers. In particular, with regard to financial and economic barriers, one of the main tools for overcoming them is providing soft loans for energy-saving projects of enterprises.

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Інструментарій оцінювання перешкод при реалізації підприємствами енергозберігаючих заходів

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Мета. Створення методологічного інструментарію оцінювання перешкод при реалізації підприємствами енергозберігаючих заходів.

Методика. У процесі дослідження використані методи: економіко-математичного моделювання (при обґрунтуванні параметрів пільгового кредитування енергозберігаючих проектів підприємств на засадах побудови моделей погашення узятих позик і отримання підприємствами фінансово-економічних результатів від реалізації цих проектів); класифікації та узагальнення (при проведенні групування перешкод на шляху до скорочення споживання невідновних енергоресурсів); системного аналізу (при розробленні методичних засад оцінювання бар'єрів підвищення енергоефективності); економічного аналізу й техніко-економічних розрахунків (при виконанні емпіричних досліджень бар'єрів на шляху зниження споживання природного газу); анкетного опитування (при проведенні опитування власників і менеджерів підприємств щодо чинників, які перешкоджають реалізації проектів); математичної статистики (для обробки результатів).

Результати. На основі результатів опитування власників і менеджерів 74 українських підприємств, які належать до трьох галузей промисловості, що характеризуються значними обсягами споживання природного газу, виявлені найбільш значимі бар'єри на шляху до скорочення споживання невідновних енергоресурсів і здійснене їх групування. Запропоновані методи оцінювання рівня цих перешкод за сукупністю досліджуваних підприємств і за окремими видами фінансово-економічних бар'єрів на шляху до скорочення споживання енергоресурсів. Побудовані моделі обґрунтування параметрів пільгового кредитування енергозберігаючих проектів, що мають на меті реалізацію заходів зі скорочення споживання природного газу на підприємствах.

Наукова новизна. Доповнені існуючі способи групування перешкод на шляху до скорочення споживання невідновних енергоресурсів шляхом уведення таких додаткових ознак, як етапи розроблення й реалізації енергозберігаючих заходів і чинники виникнення відповідних перешкод. Удосконалені методичні засади оцінювання цих перешкод через обґрунтування підходу, згідно з яким висота бар'єру визначається витратами ресурсів на його подолання. Побудовані формалізовані моделі пільгового кредитування енергозберігаючих проектів підприємств з урахуванням ефективності бюджетних видатків на здійснення такого кредитування.

Практична значимість. Отримані результати можуть бути використані як підприємствами, так і органами державної влади й місцевого самоврядування при оцінюванні перешкод на шляху до скорочення споживання невідновних енергоресурсів і розробленні комплексу організаційно-економічних заходів, спрямованих на їх подолання.

Ключові слова: невідновний енергоресурс, скорочення енергоспоживання, енергозберігаючий проект, пільгове кредитування

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