Метою проведених досліджень є моделювання інвестиційного ризику здійснення ресурсозберігаючих технологічних змін на підприємствах та розроблення методу врахування цього ризику при обґрунтуванні проектів впровадження ресурсозберігаючих технологій. Урахування ризику є важливою умовою підвищення обґрунтованості заходів із провадження технологічних змін. Своєю чергою, правильне врахування чинника ризику може підвищити впевненість власників підприємств у доцільності впровадження ресурсозберігаючих технологій, що дасть змогу збільшити масштаби такого впровадження.

Проведене моделювання впливу цін, за якими підприємства купуватимуть виробничі ресурси, на ефективність впровадження ресурсозберігаючих технологій. Результати моделювання показали, що рівень такої ефективності є достатньо високим лише у певному діапазоні цін на ресурси. У зв'язку з цим було побудовано вирази для визначення інтервалів ціни на певний вид ресурсу, які відповідають трьом основним варіантам дій щодо використання існуючого технологічного процесу. Такими варіантами є: продовження експлуатації існуючої технології, припинення її експлуатації із заміною на нову ресурсозберігаючу технологію, припинення експлуатації існуючої технології без заміни її на нову.

Обрунтовано доцільність врахування чинника ризику при обґрунтуванні проектів ресурсозберігаючих технологічних змін на підприємствах шляхом обчислення величини максимально припустимого розміру інвестицій у таке впровадження. Своєю чергою, максимально припустимий обсяг інвестицій пропонується визначати на підставі побудованої множини сценаріїв значень тих показників проекту, які характеризуються низьким рівнем прогнозованості. За такого підходу до врахування чинника ризику зникає необхідність обґрунтовувати величину дисконтної ставки, що часто характеризується високим ступенем суб'єктивності.

Використання розробленого методу обгрунтування проектів ресурсозберігаючих технологічних змін у практиці діяльності підприємств дасть змогу підвищити обґрунтованість відповідних інвестиційних рішень завдяки всебічному врахуванню чинника ризику

Ключові слова: проект, ресурсозберігаючі технологічні зміни, ризик, моделювання технологічних змін, ціни на ресурси

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SUBSTANTIATION OF PROJECTS THAT ACCOUNT FOR RISK IN THE RESOURCE-SAVING TECHNOLOGICAL CHANGES AT ENTERPRISES

V. Lesinskyi
PhD, Assistant
Department of Radio Engineering and Information Security
Yuriy Fedkovych Chernivtsi National University
Kotsiubynskoho str., 2, Chernivtsi, Ukraine, 58012
E-mail: lesynsky@chnu.edu.ua

O. Yemelyanov
PhD, Associate Professor*
E-mail: oleksandr.y.yemelianov@lpnu.ua

O. Zarytska
PhD, Associate Professor*
E-mail: oksana1684@i.ua

A. Symak
PhD, Associate Professor*
E-mail: asimak@ukr.net

O. Koleshchuk
PhD, Associate Professor*
E-mail: orest.y.koleshchuk@lpnu.ua

*Department of Business Economics and Investment
Lviv Polytechnic National University
S. Bandery str., 12, Lviv, Ukraine, 79013

1. Introduction

The problem of resource conservation is emerging in many countries of the world at present, because of limitedness and high costs of many types of resources, and, first of all, energy. The issue of resource conservation for the countries of Eastern Europe and, particularly for Ukraine, is especially relevant, because most enterprises have low level of efficiency of their activities in Ukraine [1]. One of the main factors, which contribute to this situation, is high cost of production resources for production of products, especially labor and energy resources. High resource consumption of production determines insufficient profitability of production and makes it uncompetitive. Accordingly, enterprises, which produce resource-intensive products, often cannot compete with technologically advanced manufacturers of similar products.

Reducing of expenses for productive resources requires implementation of complex of organizational, economic, and technical measures at enterprises. Technological renovation of production takes the central place among them [2].

Obviously, a need for such renovation and its scale will be different for different enterprises. The assessment of a need for technological upgrade of production necessitates an objective need to determine potential of resource-saving technological changes at enterprises. Replacement of technologies requires investment costs from enterprises. Therefore, such replacement requires substantiation of expediency in terms of ensuring of proper efficiency of investments placed in new technologies [3]. Since many owners of enterprises and their managers are not aware of the methodology of such substantiation, enterprises do not use the existing potential of technological upgrading of production fully. For example, in 2015, there were only 458 resource-saving technological processes introduced in the Ukrainian industry, which roughly corresponds to the number of such processes introduced in previous years [4]. There are a number of reasons, in particular, lack of necessary investment in many enterprises, complexity of attraction of funds from external sources, low demand for products, etc. An important factor, which hampers the pace of technological upgrades is a significant risk associated with investments in such an upgrade.

In general, the risk resides in most of investment projects [5–8]. Its presence often causes a negative attitude of owners and managers of enterprises to implementation of investment projects of replacement of existing technologies to resource-saving ones, especially if the existing technology still brings some economic benefits. Therefore, it is necessary to establish if the attitude of owners of enterprises to expediency is substantiated in the process of assessment of the potential of resource-saving technological changes at enterprises and to convince owners in it if necessary. Obviously, solution of this problem requires careful consideration of the investment risk factor in substantiation of investment projects of resource-saving technological changes. A proper consideration of the risk factor may increase confidence of owners of enterprises in expediency of introduction of resource-saving technologies, which will increase a scale of such introduction.

Thus, a well-founded assessment of the expediency of resource-saving technological changes at enterprises requires mandatory consideration of a risk factor. Such consideration should provide owners and managers with trusted information on the most effective means of replacement of existing processes with new resource-saving technologies. Accordingly, these measures should include arrangements, which ensure a proper correlation between their expected profitability and a level of risk of investing in these activities. Consequently, the above considerations confirm the urgency of the question of substantiation of projects of resource-saving technological changes at enterprises taking risk into consideration.

2. Literature review and problem statement

Literature sources propose various methods of substantiation of expediency of implementation of investment projects. Their base is a use of certain well-known indicators. Such indicators are a payback period of a project, an index of profitability, an internal rate of profitability of a project, etc. [6]. However, we should consider a net present value as the most generalized indicator for assessment of the effectiveness of investment projects [7]. As this indicator takes into consideration all projected revenue flows, current expenses, and investment costs of a project. Its calculation includes a factor of time and it is measured in monetary units of measurement.

However, the practice of using of the indicator of net present income faces the problem of taking into consideration a factor of investment risk. We can reduce this problem to two main issues. The first issue is to define the well-substantiated method of quantitative measurement of the riskiness of investment projects. The second issue is to identify the best way to take into consideration the risk factor in the process of project design.

There are various available tools for the assessment of investment risk. The tools include such methods as sensitivity analysis (parameter variation method), stability testing method (critical points calculation), scenario method and simulation modeling [8]. However, the disadvantage of these methods is that their use does not make it possible to obtain a clear quantitative indication of a degree of risk of investing in projects. Therefore, we usually use indicators, which measure the risk of investing as a measure of deviations of expected returns (profits) of a project from their mathematical expectation, along with the above methods in the practice of project analysis. These indicators are indicators of dispersion, average linear deviation, standard deviation, and corresponding variation coefficients for estimation of the relative risk level [9]. The standard deviation indicator is the most used [10]. However, some scientists think that there is no sufficient substantiation for the use of this indicator taken from the apparatus of mathematical statistics to assess the investment risk. In particular, paper [11] notes that the correct use of standard deviation (or dispersion) requires implementation of the indicator of standard deviation exactly and not, for example, a normal low of distribution of random value, and lots of investment projects do not meet this requirement. However, as noted in work [12], the modern theory of investment portfolios uses widely dispersion and standard deviation indicators. Application of the standard deviation rate, and not, for example, the average linear deviation, remains unsubstantiated as a measure of investment risk.

As for the consideration of the risk factor in substantiation of expediency of implementation of investment projects, the most common way of such substantiation is an increase in discount rate for a bonus for risk. However, we can't consider existing methods for calculation of the bonus based on an expert survey [13] and those that require implementation of quantitative analysis [14] as methods, which provide a sufficiently accurate assessment of a discount rate in all cases. Because expert survey methods are subjective significantly, and the results of quantitative analysis depend very much on preset initial conditions. In addition, we should note work [15], which generally calls into question correctness of taking into consideration the risk factor by including a risk bonus of a discount rate. Proceeding from this, authors of paper [16] propose to assess the net present income by a discount rate, which does not take into consideration a bonus for investment risk. They also propose to reduce simultaneously the expected return on a project for the risk bonus in absolute (monetary) terms. However, the authors did not provide a concrete approach to the implementation of their proposed general idea.

The project of technological changes relates to investment projects by type. Therefore, we apply commonly known indicators, particularly, net present income, to assess technological changes projects [17]. It is obvious that the problem of taking into consideration the investment risk factor also relates to technological change projects. However, authors of a paper [18] note it is necessary to take into account specificity of these projects, in particular the fact that changes in specific costs of resources for production of products occur and a share of the technological component of fixed assets of enterprises may increase due to technological changes. Also, technological changes can affect significantly a production yield of enterprises and act as a driving force of economic development [19].

The risks inherent to technological changes determine peculiarities of these changes [20]. Specifically, it is necessary to note the risk of unemployment due to implementation of economically efficient technological changes [21]. However, there are also risks of technological changes from the point of view of an enterprise, which implements these changes by investing in their implementation. The presence of these risks may hinder implementation of appropriate technological changes [22]. In particular, such risks include a risk of lowering of prices for types of resources aimed for cost savings by the implementation of a resource-saving technology [23]. Indeed, for example, a decrease in energy prices is a positive phenomenon from the point of view of an enterprise in general, but such reduction is a risk event from the point of view of implementation of an energy saving technology project. Authors of work [24] indicate also such a specific risk of technological change as the emergence of a significantly more efficient technological process in a relatively short time after introduction of a certain technology. Such an emergence causes moral aging of a newly introduced technology.

The question of an impact of price changes on products manufactured using new technology on the investment risk in such an introduction is more complex. Solution of this question requires consideration of various types of technological changes. Paper [25] presents their classification. If physical volumes of production and its consumer properties remain unchanged due to the new technology, then a value of fluctuations in profits due to changes in prices for its products will not depend on the chosen technological solution. Otherwise, a decrease in prices for products will be a kind of technological risks.

It is also necessary to note the importance of taking into consideration the factor of investment risk in assessment of potential of resource-saving technological changes in enterprises, because this factor has a negative impact on the potential of resource conservation and, accordingly, we should take it into account in assessment of this potential. Despite the generally productive approaches to assessment of the potential of resource conservation in paper [26], and the energy saving potential presented in work [27], the studies do not investigate sufficiently the risk of investing in technological change projects. Authors consider resource conservation in a positive context mainly, and they consider possible losses from implementation of resource conservation projects as hardly probable.

Thus, the problem of taking into consideration the risk factor for substantiation of investment projects in the scientific literature is not completely resolved at present. Moreover, the issue of substantiation of technological changes taking into account investment risk is not finally resolved, as it should additionally take into account the specific risks inherent to these projects exactly.

3. The aim and objectives of the study

The aim of this study is to model the investment risk of implementation of resource-saving technological changes at enterprises and development of a method for taking this risk into account for substantiation of projects of implementation of resource-saving technologies.

We solved the following tasks to achieve the objective:

– definition of principles, information base and sequence of substantiation of projects of resource-saving technological changes at enterprises;

– modeling of an influence of individual factors, in particular, prices on productive resources, on efficiency of implementation of resource-saving technologies;

– development of a method for assessment of expediency of introduction of resource-saving technologies at enterprises taking into consideration the risk factor.

4. Principles, information base and sequence of substantiation of projects of resource-saving technological changes at enterprises

We should base the process of substantiation of projects of resource-saving technological changes at enterprises on several principles. We defined the most important of them below.

1. The principle of taking into consideration peculiarities of the environment where an enterprise operates. Specifically, factors of this environment are prices of resources, capacity of product markets for products of an enterprise and a level of competition on them.

2. The principle of taking into account an existing engineering and technological level of an enterprise. The lower is this level, the greater is effectiveness of replacement of existing technologies with new resource-saving technological processes under other unchanging conditions.

3. Principle of completeness of information necessary for substantiation of resource-saving technological changes at an enterprise. Table 1 presents the detailed content of the array of such information.

Table 1

Grouping of an array of information necessary for substantiation of expediency of resource-saving technological changes at an enterprise

Information groups	Information on internal environment of an enterprise	Information on external environment of an enterprise
1. Initial information	Information on the available technical and technological level of the investigated enterprise; specific expenses of different types of productive resources for each type of product	Information on the current demand for products, current prices for it and resources used for production of these products; specific expenses of resources for different options of resource-saving technologies
2. Secondary information	Expected profit and expected production volumes of an enterprise by different options of technological changes	Forecasted level of product price fluctuations, resource prices and demand for products after technological changes at an enterprise
3. Summarizing information	List of types of equipment that for replacement; list of types of equipment to be put into operation; an expected relative increase in financial and economic outcomes of an enterprise after introduction of technological changes at an enterprise	Expected share of sales markets of this enterprise after implementation of measures for introduction of resource-saving technological changes; expected price level for products

4. The principle of distinguishing of the main features of resource-saving technological changes under consideration. In particular, such features should include a list of types of resources, a cost of which decreases, possibility of replacement of one type of resources with others, a need for decommissioning of existing equipment, etc. We should note that further, under resource-saving technological change, we will understand such a change in technology, which reduces a cost of one or several types of resources per production unit, i.e. their specific costs.

5. The principle of alternative options to technological changes. Several alternative technologies that can replace existing ones appear quite often when substantiating expediency of replacement of the existing technology of manufacturing products with new ones. It is important to make a well-founded choice of the best possible technological change under such conditions.

6. The principle of taking into consideration the risk factor of investment in projects of resource-saving technological changes, that is, a threat of non-receival or lack of expected (planned) financial and economic indicators due to implementation of measures to replace existing technologies with new resource-saving technological processes of manufacturing of products. It is advisable to distinguish several major options of the risk. First of all, a risk of non-receipt of expected profits due to: reduced prices for products, changes in prices for resources; a decrease in demand for products. We should also note the risk of shortening of duration of operation of a technology compared with the planned duration due to acceleration of physical and moral wear of equipment. Finally, there are risks of an increase in the investments need compared to the planned need for them and a false substantiation of a return rate on investment. Therefore, the task of managers and specialists of an enterprise is to consider correctly and comprehensively the risk factor in assessment of economic efficiency and substantiate expediency of implementation of investment projects for introduction of resource-saving technological changes at an enterprise under such conditions.

Even though that different types of resource-saving technological changes have their own specifics, it is possible to present a general sequence of substantiation of the expediency of implementation of resource-saving technological changes at an enterprise, which will contain the following main stages.

1. Collection of input (initial) information on the internal environment of an enterprise. It is important to analyze the existing level of expenditures of different types of resources (material, energy, labor, technical resources, etc.) per unit of each type of product manufactured or planned for manufacturing at an enterprise. It is convenient to present the results of such an analysis in the form of a matrix. Its lines correspond to the types of resources of an enterprise, and columns – to the types of its products. We should keep in mind that an enterprise can produce several types of products simultaneously using the same equipment. Therefore, it is also advisable to group types of products of an enterprise by an association with specific units of equipment (or groups of the same type of equipment). Then, further, we can determine how an expenditure of certain resources for production of certain types of products will affect replacement of one or another unit of equipment (or a whole group of similar equipment) to new resource-saving equipment.

2. Collection of input (primary) information on the enterprise environment necessary for assessment of the resource potential of technological changes. Particularly, information on possible options of replacement of certain pieces of equipment (or groups of the same type of equipment) to new equipment, which manufactures the same products but at lower costs of certain resources, is necessary.

3. Analysis of the riskiness of various options for replacement of certain types of equipment. The analysis should provide modeling of an impact of the factors, which determine risks of such a change (primarily indicator of resources prices used by an enterprise), on the level of risk.

4. Definition of the best option for replacement of each unit of equipment by the criterion of the ratio between the expected financial results and the risk of such a replacement for each unit of equipment (or group of similar equipment).

5. Substantiation of expediency of implementation of each measure to replace a relevant unit of equipment (or group of similar equipment) taking into consideration necessary volumes of investments for such replacement.

6. Making a general list of equipment units (or groups of the same type of equipment) for replacement with a new one. It is necessary to determine the overall needs of an enterprise in the investment resources for such a substitution at this stage. In addition, there may be a need to adjust a program of measures to replace equipment, taking into account the actual opportunities of an enterprise to attract investment resources.

7. Calculation of general economic indicators to substantiate expediency of implementation of projects of resource-saving technological changes at an enterprise.

5. Development and testing of a method for substantiation of projects of resource-saving technological changes at enterprises taking risk into consideration

5. 1. Modeling of an influence of prices on resources on the expediency of resource-saving technological changes

One of the main factors that influence riskiness of the process of resource-saving technological changes at an enterprise is a price for resources used by an enterprise for production of products. Therefore, it becomes necessary to model an influence of prices for resources used by an enterprise on efficiency and expediency of implementation of projects of resource-saving technologies.

It is important to choose a criterion for such substantiation in the process of substantiating of expediency of implementation of resource-saving technologies. For this, we can use an indicator of excess profit, which is a difference between the actual return on investment and a value of the investment on a rate of profitability:

$$P_s = P - K \cdot N_k, \tag{1}$$

where P_s is the amount of an excess profit from investing; P is the actual value of profit; K is the volume of investments, which led to obtaining the profit; N_k is the rate of return on investments expressed in parts of a unit, that is, the minimum level at which investors will agree to invest in this sector of the economy.

We can take N_k indicator in a risk-free level in formula (1) depending on the level of determinism of profit and investment, and it can contain a risk bonus. We should consider investment profitability of investments in projects, which guarantees the receipt of the set amount of income (profits), as a risk-free level of return.

It is necessary to mark out a case when the investment in new equipment does not require cessation of the operation of other equipment, which still brings certain positive financial and economic results for an enterprise. The criterion of expediency of such acquisition is a positive (or, at least, non-negative) value of the excess profit under such conditions. It is also possible a case when the existing equipment is still able to bring a certain amount of net cash flow (amount of profit and allocations) for an enterprise. In this case, replacement of old equipment with the new one would be appropriate if the amount of excess profits under the new equipment exceeds the amount of net cash flow for the old equipment.

Further, we calculate relevant indicators per unit of a particular type of product manufactured by the company. We divide the cost of its unit into two parts: costs that remain unchanged in transition to production of the same products using resource-saving technology, and costs that change in this transition.

Then we can determine the value of net cash flow per unit of a particular type of product under the existing technology by the following formula:

$$F_0 = p_r - c_a - \sum_{i=1}^{m} p_{ri} \cdot N_{0i}, \tag{2}$$

where F_0 is the value of the net cash flow (amount of profit and depreciation) according to the existing technology per unit of product; p_r is the price of a unit of a certain type of manufactured product, with deduction of indirect taxes; c_a is the cost per unit of production without depreciation in that part, which remains unchanged after transition to production of the same product using resource-saving technology; p_{ri} is the cost of a unit of i-th type of resources; N_{0i} is the rate of expenditure of i-th type of resources per unit of this type of product produced by an enterprise, based on the existing technology of its production; m is the number of types of resources used to produce this type of product and a cost of which differ for old technologies and new technologies.

On the other hand, we determine the value of an enterprise's excess profit per unit of product using the new technology of its production by the following formula:

$$P_{s1} = p_r - c_a - a_1 - \sum_{i=1}^{m} p_{ri} \cdot N_{1i} - k_1 \cdot N_k, \tag{3}$$

where P_{s1} is the value of excess profit per unit of this type of product using the new technology of its production; a_1 is the depreciation deductions for new technology per unit of product; N_{1i} is the rate of expenditures of i-th type of resources per unit of this type of product produced by an enterprise using the new technology of its production; k_1 is the volume of investments in introduction of a new technology for production of this product per unit of product (specific capital intensity of products). «1» index refers to the indicators, which characterize the new technology of manufacturing of products.

Then, if the net cash flow of the existing technology determined by formula (2) is positive, then replacement of the old technology with the new one would be appropriate if such inequality is correct:

$$P_{s1} - F_0 = \sum_{i=1}^{m} \left(N_{0i} - N_{1i}\right) \cdot p_i - a_1 - k_1 \cdot N_k > 0. \tag{4}$$

If, however, the net cash flow of the existing technology determined by formula (2), is positive, and inequality (4) is not correct, replacement of the old technology with the new one is inappropriate.

Let us assume the value of the net cash flow for the existing technology determined by formula (2) is zero or negative. Then, introduction of a new technology instead of the old would be expedient if the excess profit of the new technology calculated by formula (3), would prove to be positive.

We should note that a rate of expenditures for the old technology should exceed a rate of expenditures for the new technology at least for one type of resource. Otherwise, introduction of a new technology of products manufacturing instead of old technology will be inappropriate a priori.

Taking into consideration inequalities (4) and the above-described rules of decision-making on replacement of the existing technology of manufacturing of products with new technology, we can assess the expediency of such a substitution and determine its economic effect for different values of resource prices. In particular, Fig. 1 presents the mechanism of substantiation of decisions on replacement of the existing technology of manufacturing of a certain type of production of an enterprise with a new resource-saving technology. The mechanism corresponds to the case when the technology differs in terms of the cost of only one production resource.

We should note that there is a potential situation when there will be several alternatives to new resource-saving technologies that will differ by the rates of expenditures of production resources and the specific capital intensities of products. Then we should resolve of the question of replacement of the existing technology with the new one in two stages:

1) a choice of the best option for a new technology of production according to the maximum excess profit criterion;

2) assessment of the expediency of replacement of the existing technology with the best technology chosen in the previous stage.

We should note that the level of prices on production resources significantly affects not only the expediency of technological changes, but also the choice of the best option of new technology.

Thus, modeling of an influence of price changes on production resources on the decision on the expediency of resource-saving technological changes at an enterprise makes it possible to establish ranges of values of prices for production resources, for which it is expedient to make a corresponding decision. Then, after assessment of the probability of finding prices for resources in those or other ranges of their values, we can determine the level of risk of investing in technology upgrades in relation to the indicator of prices for productive resources.

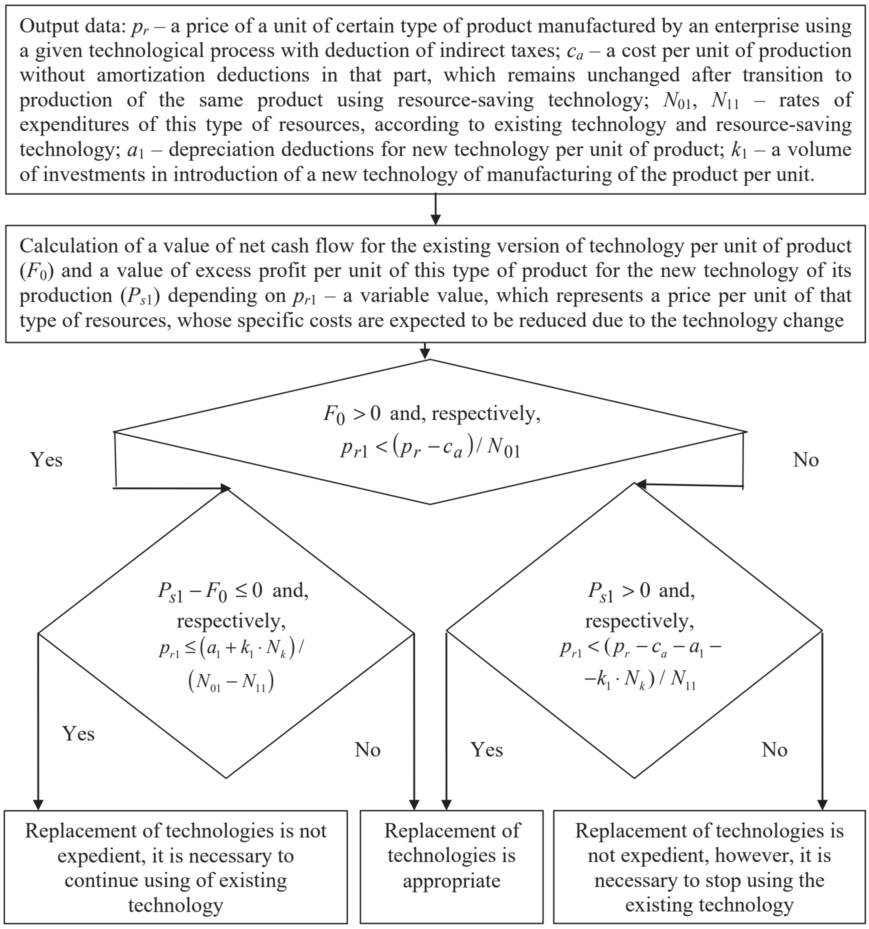

Fig. 1. The mechanism of substantiation for decisions on replacement of the existing technology of manufacturing of a certain type of product of an enterprise with a new resource-saving technology in the case when these technologies differ in terms of costs of one production resource only, depending on a price of this resource

5. 2. Development of a method for assessment of the expediency of introduction of resource-saving technologies taking risk into consideration

We should base the consideration of the risk factor in assessment of the expediency of implementation of resource-saving technologies at enterprises on the allocation of different scenarios for obtaining of financial results from such implementation in dependence on possible values of indicators-factors, which determine values of these results. The main factors include resource prices and prices for finished products, which will be produced using resource-saving technology. Also, factors that may affect effectiveness of resource-saving technological changes are natural volumes of production and sales of products and duration of use of new technology.

We can estimate probability of each possible scenario of obtaining of financial and economic results from introduction of resources-saving technologies at enterprises by assessment of the probability of acquiring of each indicator-factor of one or another value and considering possible combinations of these values. We can carry out determination of the probability of acquiring of a certain indicator-factor of its certain value both directly by managers and specialists of enterprises and by experts invited by them. It is expedient to provide a qualitative gradation of values of each indicator-factor for the convenience of calculations. For example, we can distinguish low, medium and high levels, and estimate the probability of achieving an appropriate indicator for each of these levels.

It is important to choose an indicator, which will characterize financial results of implementation of resource-saving technology at an enterprise. Further in this study, such an indicator will be an increase in the annual operating profit of an enterprise due to replacement of the existing technology of manufacturing products to a new resource-saving technology. We should note that this indicator indirectly takes into account not only prices for resources and finished products and natural volumes of its production, but also duration of operation of the new technology. Such accounting occurs due to substantiation of depreciation deductions: the lower the expected operating duration of the equipment under the new technology is, the higher should be the rate of depreciation and, accordingly, the expected amount of operating profit will be lower.

Let us model different combinations of levels of factors, which determine a value of annual operating profit of an enterprise after implementation of the resource-saving technology. As a result, we obtain a set of possible values of the increase in this profit due to the replacement of an existing technological process with a new one:

$$V_1 = (I_1, \ldots, I_j, \ldots, I_n), \quad (5)$$

where V_1 is the vector of possible values of the indicator of an increase in the annual operating profit of an enterprise in the order of growth of these values; I_j is the value of an increase in the annual operating profit of an enterprise due to the replacement of existing technology with the new one by j-th scenario for obtaining of this value; n is the number of scenarios.

Each I_j value has a certain probability of its achievement. Consequently, we can construct a vector of probabilities of different scenarios for an increase in the enterprise's profit:

$$V_2 = (r_1, \ldots, r_j, \ldots, r_n), \quad (6)$$

where V_2 is the vector of probabilities of different scenarios of growth of annual operating profit of an enterprise due to replacement of the existing technology of manufacturing of products with a new resource-saving technology; r_j is the probability of j-th scenario (in this case, the sum of all probabilities is equal to one).

Finally, we can match the following vector with vector (5):

$$V_3 = (I_1, I_2 - I_1, \ldots, I_j - I_{j-1}, \ldots, I_n - I_{n-1}) = (d_1, \ldots, d_j, \ldots, d_n), \quad (7)$$

where V_3 is the difference of values the growth rates of the enterprise's annual operating profit; d_j (if $j>1$) is the difference between an increase in the annual operating profit of an enterprise by j-th scenario and by an increase in this profit by $j-1$ scenario ($d_1=I_1$; $d_j=I_j-I_{j-1}$ if $j>1$).

We should note that the elements of vector (5) have numbers in the order of their growth, so all elements of the vector (7) are integral.

The combined consideration of vectors (6) and (7) makes it possible to describe the expected distribution of probabilities of an increase of an enterprise's annual operating profit. If the probability is 1, an enterprise receives a profit increase of d_1, if the probability is $1-r_1$, an enterprise receives, in addition, a profit increase of d_2, if the probability is $1-r_1-r_2$, an enterprise receives, in addition, a profit increase in the amount of d_3, etc. Thus, each d_j value matches a certain level of risk – the probability of not receiving of this value: the risk level is zero for d_1, the risk level is r_1 for d_2; the level of risk is r_1+r_2 for d, etc.

In general, despite the variety of indicators of investment risk measurement used in its assessment valuation practice, the most generalized indicator of this risk is the risk bonus part in the mathematical expectation of return on investment project:

$$R=\frac{E-K\cdot N_k}{E}, \tag{8}$$

where R is the level of risk; E is the mathematical expectation of project profit; K is the value of investment in a project; N_k is the risk-free rate of return on investment in parts of unit.

With information on values of R, E and N_k, from equation (8), it is possible to determine the maximum acceptable investment in a project expedient for an investor to implement it. We determine this investment by the following formula:

$$K_{\max}=\frac{E\cdot(1-R)}{N_k}=E\cdot k_{cap}, \tag{9}$$

where $K_{\max}$ is the maximum acceptable amount of investment in a project expedient for an investor to implement it; k_{cap} is the capitalization coefficient of a value of the mathematical expectation of profit ($k_{cap}=(1-R)/N_k$).

Then, for each element of vector (7), it is possible to match a certain $K_{\max}$ value, which we calculate by formula (9), that is, the calculation employs the following formula:

$$K_{\max J}=\frac{E_J\cdot(1-R_j)}{N_k}=E_j\cdot k_j, \tag{9}$$

where $K_{\max j}$, E_j, R_j are the maximum acceptable investment amount, the mathematical expectation of profit and the level of risk, which characterize j-th element of the vector (7), respectively; k_{capj} is the coefficient of capitalization of a value of the mathematical expectation of profit E_j ($k_{capj}=(1-R_j)/N_k$). We calculate E_j and R_j indicators from the following formulas:

$$E_j=d_j\cdot\sum_{l=j}^{n}r_j; \tag{10}$$

$$R_j=1-\sum_{l=j}^{n}r_j. \tag{11}$$

For example, an enterprise receives a profit increase in the amount of d_1 if the probability is 1. So, in this case, E_1 mathematical expectation is equal to d_1, and R_1 risk level is zero. As for the profit in the amount of d_2, an enterprise receives it if the probability is $1-r_1$. So, E_2 mathematical expectation is equal to:

$$E_2=d_2\cdot\sum_{j=2}^{n}r_j=d_2\cdot(1-r_1), \tag{12}$$

and the following formula determines the risk level:

$$R_2=1-\sum_{l=2}^{n}r_j=r_1. \tag{13}$$

It is possible to assess the expediency of implementation of an investment project of replacement of the existing technology of manufacturing of products to a new resource-saving technology of their production by calculation of all $K_{\max j}$ values according to formula (9). We can represent the criterion of such expediency in the form of inequality:

$$\sum_{j=1}^{n}K_{\max j}\geq K_f, \tag{14}$$

where K_f is the actual amount of investment required for implementation of an investment project of replacement of the existing technology of manufacturing of products with a new resource-saving technology for their production.

If there are several options of technology for replacement of an existing technology of manufacturing of products, then, the best of these options is the one, in which the difference between the maximum acceptable volume of investment and the actual need for them is maximal.

We can submit a general indicator of the risk of implementation of an investment project based on the suggested indicator of the maximum acceptable volume of investments. Previously, we should note that the market value of a risk-free asset with a certain mathematical expectation of income on it will always be greater than the market value of a risk asset with this mathematical expectation of income. The indicator of the maximum acceptable volume of investment reflects the maximum market value of assets purchased under an investment project. Taking into account the above considerations, we can determine the level of risk of implementation of the project by the following formula:

$$R_s=1-\sum_{j=1}^{n}K_{\max j}/K_b, \tag{15}$$

where R_s is the generalizing indicator of the riskiness of a particular investment project; K_b is the market value of a risk-free asset with the same value of the mathematical expectation of income as in this investment project (we determine it by division of the mathematical expectation of a risk-free rate of profitability).

Taking into account the above, it is possible to distinguish the main economic indicators for substantiation of projects of resource-saving technological changes at enterprises. It is appropriate to divide these indicators into three groups. The first group includes indicators of the expected absolute increase in the operating profit of an enterprise as a result of the introduction of resource-saving technologies and the necessary investments in such implementation. The second group of indicators characterizes the relative increase in operating profit and assets of an enterprise. Finally, the third group of economic indicators for substantiation of projects of resource-saving technological changes at enterprises includes indicators, which finally determine expediency of such changes. First of all, such indicators include the difference between the maximum acceptable volume of investment and the actual need for them, as well as the correlation between these two indicators.

5. 3. Testing the method of assessment of the expediency of resource-saving technologies projects taking risk into consideration

We developed the method of substantiation of projects of resource-saving technological changes taking risk into consideration was developed in the study. We tested it on the data of six enterprises of the western region of Ukraine. In particular, we used the method to substantiate the project of energy saving at Zakhid Budservice LLC (Lviv). The project provided for replacement of existing technology for the manufacture of building materials (ceramic tiles) with a new energy-saving technology for their production. We determined an increase in operating profit of the enterprise due to the replacement of the existing technology of manufacturing with energy saving technology based on the initial information on technical and economic indicators of existing and new technological processes. We considered different scenarios for the level of prices for products and energy (Table 2) and the probabilities of each of the scenarios (Table 3).

Table 2

Value of an increase in operating profit of the enterprise due to the replacement of the existing manufacturing technology with energy-saving technology

Scenarios of the level of prices for energy resources	Value of the increase growth in annual operating profit of the enterprise in dependence on the scenario of the level of prices for its products, USD thousand		
	Low level of prices	Medium level of prices	High level of prices
Low level of prices	17	23	29
Medium level of prices	14	18	23
High level of prices	9	12	15

Table 3

Probability of different scenarios for the level of prices for products and energy resources

Scenarios of the level of prices for energy resources	Scenarios of the level of prices for products		
	Low level of prices	Medium level of prices	High level of prices
Low level of prices	0.07	0.10	0.03
Medium level of prices	0.15	0.35	0.10
High level of prices	0.03	0.10	0.07

We can give a graphic representation of the distribution function of the profit probability of the proposed replacement of the technology under consideration (Fig. 2) based on the data presented in Tables 2, 3. The area of the corresponding figures in Fig. 2 is equal to the corresponding values of the mathematical expectation of profit E_j.

We calculated the maximum acceptable investment amount for replacement of existing technology with energy saving one for different scenarios of prices for products and energy resources (Table 4) according to Tables 2, 3. We accepted the risk-free rate of return on investments at the level of 15 % per annum, which approximates the current rate of deposit interest.

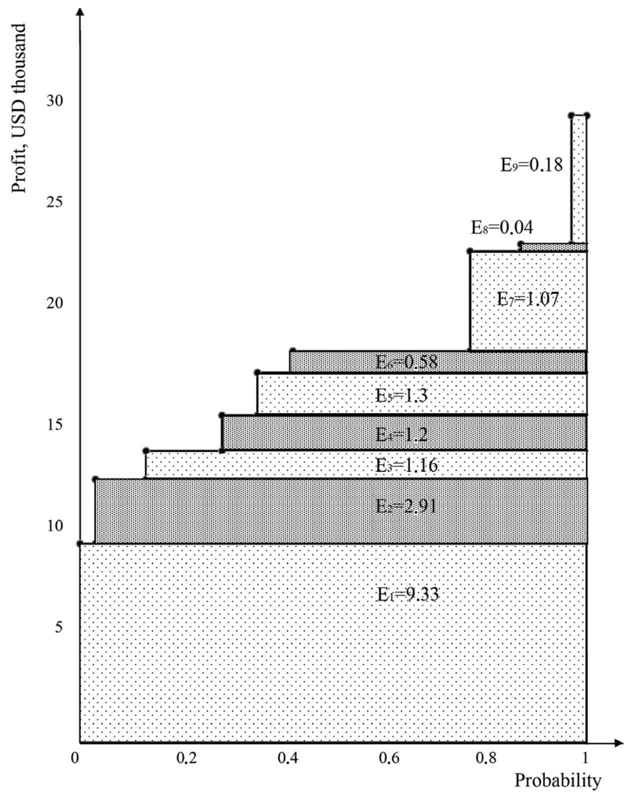

Fig. 2. Graphic representation of the probability distribution function of the value of an increase in the enterprise's annual operating profit due to the replacement of the existing technology of manufacturing with energy saving technology

Table 4

Calculation of the maximum acceptable investment in replacement of the existing production technology with energy saving technology

Scenario number	Profit increase for scenarios, USD thousand	Probability of scenarios	Indicators for the value of the difference between profit increases compared to the previous scenario				
			Value, USD thousand	Mathematical expectation, USD thousand	Risk level	Capitalization ratio	Maximum acceptable volume of investments, USD thousand
1	9	0.03	9	9.33	0.00	6.67	62.22
2	12	0.10	3	2.91	0.03	6.47	18.82
3	14	0.15	1	1.16	0.13	5.80	6.73
4	15	0.07	2	1.20	0.28	4.80	5.76
5	17	0.07	2	1.30	0.35	4.33	5.63
6	18	0.35	1	0.58	0.42	3.87	2.24
7	23	0.10	5	1.07	0.77	1.53	1.65
8	23	0.10	0	0.04	0.87	0.87	0.04
9	29	0.03	6	0.18	0.97	0.20	0.04
Total	–	–	–	–	–	–	103.12

The capitalization coefficient contained in formula (9) and the calculation results of which are given in Table 4, is linearly dependent on the project risk level (Fig. 3). Specifically, this coefficient is equal to 1/0.15=6.67 at zero risk. Under such conditions, we can represent schematically the amount of the maximum acceptable investment in replacement of the existing production technology with the energy-saving technology of its production as the sum of the areas of the figures depicted in Fig. 4.

Table 4 shows that the total value of the maximum acceptable volumes of investments in implementation of energy saving technology is USD 103.12 thousand. Given that the actual investment need for such an implementation in this case is USD 83.3 thousand, we can consider the introduction of energy saving technology as appropriate. In addition, based on the data given in Table 4, it is possible to calculate the expected increase in operating profit of the enterprise due to its implementation of energy saving technology. This increase, which represents the sum of products of increases of profit for scenarios for their probability, is USD 17.78 thousand in our case. Consequently, the investigated enterprise has the potential of resource-saving technological changes in terms of the introduction of energy-saving technology of manufacturing of products.

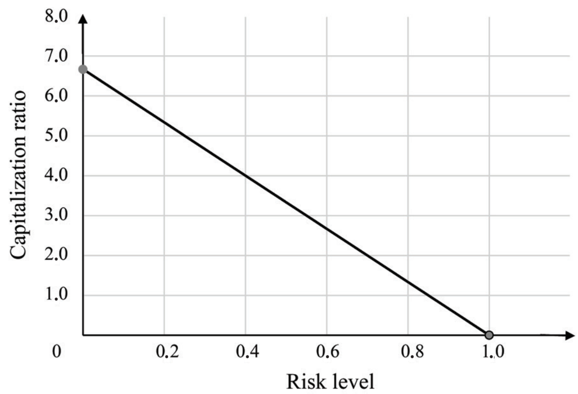

Fig. 3. Dependence of the coefficient of capitalization of profit on the level of risk at the risk-free rate of return on investment equal to 0.15 per year

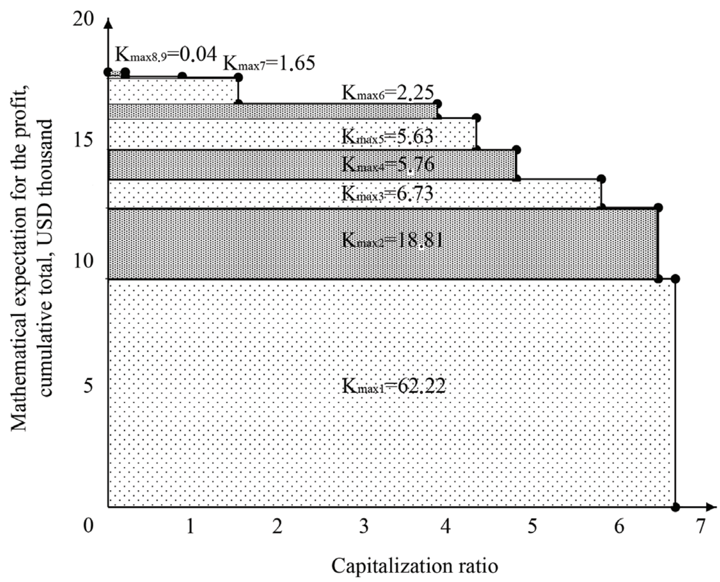

Fig. 4. Geometric interpretation of the process of determination of the value of the maximum acceptable investment in replacement of the existing production technology with the energy-saving technology of its production

Table 5 presents the results of calculation of the economic indicators for the substantiation of energy saving technological changes projects at «ZakhidbudService» Ltd, as well as at five other enterprises of Ukraine, which were investigated.

As it follows from the data in the Table 5, all enterprises listed in the Table have rather high level of potential of energy-saving technological changes. In particular, the expected relative growth of operating profit due to the implementation of these changes varies from 10.50 % to 30.18 % for the enterprises under investigation. We should also note that for all these enterprises, the difference between the maximum acceptable volume of investment in the introduction of energy saving technologies and the actual need for these investments is positive. This indicates the expediency of such implementation. The ratio of the maximum acceptable volume of investments to the actual need for them for all investigated enterprises exceeds 1.2. This indicates that the efficiency of investments in the implementation of energy-saving technologies at these enterprises is sufficiently high.

Table 5

Results of calculation of economic indicators for the substantiation of projects of energy saving technological changes for the investigated enterprises

Names of indicators, measurements units	Values of indicators by enterprises					
	«Zakhidbud-sevis»Ltd	«Kva-tega»Ltd	«Avtotekhbud-servis» PE	«Vamir-gal» Ltd	«Modul» Ltd	«Zavod Elektron-butprylad» Ltd
1. Expected absolute increase in annual operating profit, USD thousand	17.78	7.06	10.25	5.89	2.47	26.75
2. Volume of necessary investments, USD thousand	83.33	35.33	45.87	27.17	11.60	132.73
3. Expected relative increase in annual operating profit, %	18.17	16.22	21.36	10.50	15.37	30.18
4. Expected relative increase in total assets, %	11.23	13.44	15.25	7.61	11.96	18.14
5. Difference between the maximum acceptable volume of investments and the actual need for them, USD thousand	19.80	7.60	11.77	9.77	5.27	56.73
6. Ratio of the maximum acceptable volume of investment to the actual need of them, times	1.237	1.215	1.256	1.360	1.454	1.427

6. Discussion of results of studying the regularities of assessment of the potential of resource-saving technological changes

In the study, we obtained three main results at development of the method for substantiation of projects of resource-saving technological changes at enterprises taking into consideration risks in this study. Firstly, we identified the factors, which determine the risk of investing in technological change. Secondly, we defined a new method to take into account the risk in assessment of the economic effect of introduction of resource-saving technological changes at enterprises. Thirdly, we proposed a new generalized indicator of risk assessment of an investment project.

The study showed that there are three main risk factors for investment in resource-saving technological changes. These factors are: a decrease in prices for products by the project compared with their planned level; reduction of prices for resources, the saving of which is anticipated, in comparison with the planned amount; a decrease in demand for products in comparison with planned volume. The factor of reducing of the price for products determines the risk of investing in resource-saving technological changes only if the technology introduced involves a change (growth) in physical volumes of products. Otherwise, the economic effect of implementation of resource-saving technologies appears solely due to reducing of the cost of production.

The study showed that there is a certain range of prices for these resources, for which implementation of resource-saving technology is appropriate. At the same time, in order to make such an introduction attractive from the point of view of owners of enterprises, the owners should expect that a high level of prices for resources keep for a long period. Consequently, if prices for resources increase insufficiently high or if there are expectations of owners of enterprises that the period of high prices will be short, owners will not have an interest in resource-saving technological changes. This thesis partly explains the fact the pace of implementation of energy saving technologies in Ukraine is rather low despite of the growth of energy prices.

We should perform consideration of the risk factor in substantiation of the projects of resource-saving technological changes at enterprises by calculation of the value of the maximum acceptable amount of investment in implementation of these changes. If the maximum acceptable value of investment in the implementation of resource-saving technology project is greater than the actual investment need, then we should consider the implementation of this project as appropriate. In case of several options of technology replacement, the best option would be the one where the difference between the maximum acceptable volume of investments and the actual need for them is maximal. We should determine the maximum acceptable volume of investments based on the constructed set of scenarios of values of those indicators of the project, which have low level of their predictability. We should assess probability of each of the scenarios, as well as the expected increase in the enterprise's annual operating profit due to the replacement of the existing technology with the new resource-saving technology.

The proposed method to take risks into consideration in substantiation of projects, unlike the existing ones, does not require the prior determination of the risk bonus at the discount rate. This significantly simplifies the procedure for assessment of the effectiveness of projects and eliminates the factor of erroneous determination of the bonus. Also, the presentation of the risk-taking method enabled us to propose a generalized risk score. This indicator is simpler than the dispersion and standard deviation rates, since it does not require estimation of random variable dispersion. In addition, the proposed general risk indicator, in contrast to the above indicators, has a transparent economic content.

The results of application of the proposed approach to consideration of the risk in substantiation of projects of resource-saving technological changes strongly depend on the forecast values of the increase in operating profit of an enterprise in different scenarios and on the correct establishment of their probabilities. We can consider these moments as a disadvantage of the developed method. On the other hand, these disadvantages are inherent to available methods for assessment of investment risk by using indicators of the degree of dispersion of a random variable.

It is necessary to note that we can apply the proposed approach to consideration of the risks in substantiation of projects to other tasks, in particular, in assessment of property that generates revenue. In addition, the developed method has prospects for application in optimization of an investment portfolio. Then, the optimal structure of this portfolio will be the structure, which will maximize the difference between the total maximum acceptable volume of investments in various financial assets that will be included in the portfolio and the total actual amount of investments in the acquisition of these assets. At the same time, application of the proposed risk consideration method for optimization of an investment portfolio may be complicated by the need to take into account time fluctuations in the return on assets included in the portfolio.

7. Conclusions

1. The conducted research has defined the principles, information base and consequence of substantiation of projects of resource-saving technological changes at enterprises. We established that the sequence, among other things, should include the analysis of the risk of different options of replacement of certain types of equipment. A base of such analysis should be the modeling of an impact of indicators-factors that determine riskiness of replacement of technologies (in particular, the price index of resources used by the enterprise) on the level of the risk.

2. The modeling of the impact of prices for productive resources on the efficiency of implementation of resource-saving technologies showed that the level of such efficiency is rather high only within a certain range of the prices. Consequently, at substantiation of implementation of resource-saving technological changes, it is necessary to assess thoroughly the expected forecasting price range for those types of production, savings of which are expected as a result of the implementation of the corresponding technological changes. In this study, we constructed the expressions to determine price intervals for a particular type of resource, which correspond to the three main options of action regarding the use of an existing technological process. Such options are: continuation of exploitation of existing technology; termination of its operation with replacement of a new resource-saving technology; stop of the operation of existing technology without replacing it with a new one.

3. A base of the method of assessment of the expediency of introduction of resource-saving technologies at enterprises taking into account the risk factor is the construction of a set of scenarios of for values of those indicators of a project of such implementation, which have the greatest unpredictability.

It is possible to set the maximum acceptable investment in implementation of resource-saving technology by assessment of the probability of each of these scenarios and increasing of the profit of an enterprise for them using the procedure described in this study. Comparison of this value with the actual need for investments in such an introduction is a criterion for substantiation of the expediency of the investments. The conducted research shows that the method of consideration of the risk factor developed in the study has a higher degree of objectivity than the approaches applied in practice to the investment analysis of such an account. Because the proposed method does not require a prior substantiation of the discount rate, which always has significant methodological difficulties and is not sufficiently precise. The use of the developed method of substantiation of projects of resource-saving technological changes at enterprises in the practice of their activities will enable to increase validity of the corresponding investment decisions through the comprehensive consideration of the risk factor.

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