The object of this study is the assessment of the organizational and technological inertia of energy consumption processes at enterprises. The task to design effective toolset for such an assessment was tackled.

The indicators for assessing the organizational and technological inertia of energy consumption processes at enterprises have been determined and systematized. The factors that influence the level of this inertia were highlighted. A method for decomposing the relative level of organizational and technological inertia of energy consumption processes has been developed.

The level of organizational and technological inertia of the processes of natural gas consumption was assessed on the basis of a sample of enterprises. It has been established that this level is quite high. In particular, the duration of lag in the reduction of natural gas consumption, averaged over 2016–2021, ranged from 1.3 to 1.8 years. At the same time, the relative level of organizational and technological inertia of the processes of consumption of natural gas in terms of its natural volumes ranged from 36.5 % to 47.9 %. The empirical results are explained by the presence of significant obstacles to the implementation of organizational and technological measures to save natural gas.

A feature of the designed toolset for assessing the organizational and technological inertia of energy consumption processes is that its use makes it possible to obtain a comprehensive and accurate assessment of the specified inertia. This toolset can be used by enterprises of all types of economic activity in assessing the reserves for reducing the organizational and technological inertia of energy consumption. In addition, the designed tools can be used by state authorities and local governments in the formation of strategies for energy-saving economic development

Keywords: organizational and technological inertia, enterprise, energy consumption, energy saving lag, energy resource, natural gas

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DESIGNING A TOOLSET FOR ASSESSING THE ORGANIZATIONAL AND TECHNOLOGICAL INERTIA OF ENERGY CONSUMPTION PROCESSES AT ENTERPRISES

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

Olexandr Yemelyanov
Doctor of Economic Sciences, Professor*

Oksana Zarytska
PhD, Associate Professor*

Tetyana Petrushka
PhD, Associate Professor*

Nataliia Myroshchenko
PhD, Senior Lecturer*

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

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1. Introduction

Many countries, especially European ones, have faced the problem of providing their economies with adequate amounts of energy resources. To a large extent, this situation was due to the aggravation of hostilities in Ukraine in February 2022 and the various geopolitical and economic consequences to which this aggravation led. At the same time, it is necessary to take into account the fact that the increase in energy independence in recent years has been identified as a priority by the governments of most European countries. Accordingly, both at the level of the European Union and at the level of its member states, as well as other European states, a number of strategies and programs have been adopted to reduce the consumption of fossil energy carriers.

At their core, strategies and programs implied a large-scale energy transition based on improving energy efficiency [1] and a significant increase in the share of renewable energy sources in the structure of energy consumption [2]. As a result, this was supposed to improve the security of energy supply for both economic actors and national economies in general [3].

However, as the experience of implementing energy transition programs has shown, their implementation is usually associated with overcoming a number of obstacles of a financial, organizational, institutional, and other nature. As a result, the energy transition can take a long time [4]. On the one hand, this will exacerbate the environmental situation since it will be necessary to continue to use environmentally harmful energy sources [5]. On the other hand, the delay in the energy transition will leave a high level of risk in the field of energy supply and will contribute to a further increase in prices for fossil energy carriers [6].

Finding out the reasons that hinder the process of energy transition makes it possible, in particular, to highlight the lack in some cases of appropriate technical, technological, and organizational means by which it would be possible to significantly reduce the consumption of non-renewable energy resources. However, quite often there is a situation in which these means have existed for quite some time but remain not implemented by many business entities and households. This situation reflects the phenomenon of organizational and technological inertia of energy consumption processes. This phenomenon manifests itself in the existence of a lag between the moment of the emergence of new progressive technical, technological, and organizational means of reducing energy consumption and the moment of their application in practice.

Studying the laws that form organizational and technological inertia of the processes of consumption of non-renewable energy resources should be defined as an important prerequisite for the development and implementation of measures to accelerate the energy transition. In turn, the implementation of such studies should be based on a preliminary assessment of the existing level of organizational and technological inertia of energy consumption in various sectors of the economy. Such an assessment should be carried out, first of all, in two directions.

The first of them should provide for the quantitative measurement of this property, which is a prerequisite for its effective management. The second direction of assessing the organizational and technological inertia of energy consumption should include the establishment of the influence on it of the main factors, which is also necessary for the development and implementation of measures to accelerate the energy transition. However, it is impossible to implement both described directions for assessing the organizational and technological inertia of fossil energy consumption without developing effective tools for such an assessment. Therefore, such a development must be recognized as an important prerequisite for ensuring the reduction of the use of non-renewable energy resources by their consumers, in particular enterprises.

Therefore, research into the design of tools for assessing the organizational and technological inertia of energy consumption processes at enterprises is relevant.

2. Literature review and problem statement

Considering patterns in the formation of organizational and technological inertia as one of the main properties of energy consumption, it is possible to note that this inertia is caused by obstacles that arise in the way of reducing the use of non-renewable energy sources. Therefore, the assessment of this property requires a preliminary identification of the main barriers to improving energy efficiency. However, there is a problem that is due to the fact that in the modern scientific literature there is no unity about which of these obstacles should be considered the main ones. For example, in [7], preference is given to economic barriers. A similar opinion is expressed by the authors of work [8] who pay attention to the inhibition of the implementation of energy saving measures due to the lack of necessary financial incentives.

At the same time, other scientists point out the significant role played in curbing the growth of energy efficiency barriers associated with shortcomings in the organization of management activities. In particular, [9] states that such shortcomings are the lack of energy saving among the priority goals, the lack of rationality, and the imperfection of information support. The author of [9] argues that, as a result, many companies refuse to implement sufficiently effective energy-saving projects. A similar point of view is held by the authors of [10] who emphasize the lack of proper information as one of the decisive factors in the inhibition of energy-saving processes.

Among the reasons that slow down the energy transition, the modern literature also indicates the risk of implementing energy-saving investment projects [11]. Special attention is paid to the need for significant amounts of financial resources needed for the implementation of these projects while many enterprises and households do not have such resources [12]. At the same time, the use of borrowed sources to finance investment projects is often impractical or impossible since lending conditions are not attractive [13].

The barriers that arise with the introduction of energy-saving measures, in some cases, include an insufficiently high level of prices for fossil energy resources. This can cause a significant return on investment in the implementation of energy-saving projects. However, this barrier is hardly decisive as fossil energy prices are at a fairly high level. In addition, it is worth noting the differences in the results of research conducted by various scientists on the impact of the level of energy prices on the volume of their consumption. Thus, the author of [14] revealed the influence of electricity prices on the volume of its consumption. At the same time, the authors of [15] did not find the presence of this influence.

Consequently, different researchers distinguish different types of the most significant obstacles to the energy transition. In general, we can agree with the statement made in [16] about the impossibility of compiling a complete list of these obstacles. At the same time, in [16], 42 types of barriers have been identified, which arise in the process of improving energy efficiency in the US industry.

Summarizing the analysis of approaches to identifying obstacles to the growth of energy efficiency, it seems expedient to divide these obstacles into three types. The first type of interference is caused by the insufficient level of efficiency of energy saving projects. Obstacles to the growth of energy efficiency of the second type are due to the lack of energy consumers of the necessary amounts of resources necessary for the implementation of energy-saving projects, primarily financial resources. The same group of obstacles contains barriers caused by the difficulty of obtaining these resources from their external sources. Finally, the third group of obstacles includes those barriers that are formed due to the insufficient level of competence of energy consumers in managing their consumption and shortcomings in the information support of the process of such management. Accordingly, these groups of obstacles can be represented as factors that form the organizational and technological inertia of energy consumption.

Since little attention has been paid to the issue of assessing this inertia in the scientific literature, it is advisable to consider ways to assess the obstacles indicated above that cause this inertia. In this regard, it should be noted that many scientists are limited only to qualitative methods of such assessment. In particular, this approach for the Finnish construction sector is used in [17]. In addition, in order to assess obstacles to the energy transition, expert survey methods are often used. In particular, this was done in work [18], which shows the results of a survey of energy managers.

Of course, the results obtained in this case are characterized by a certain degree of subjectivity. As for more objective ways of assessing barriers to the implementation of energy-saving projects, these methods include a hierarchical approach and graph-analytical models given in [19]. It is also worth noting the method of such assessment, which is based on the identification of the level of barriers to improving energy efficiency with the minimum amount of the efforts that are required to overcome them [20].

It should be noted that the process of assessing the barriers that arise in the process of the energy transition is complicated by the existing relationships between them. In this regard, it is worth noting the existence of causal, synergistic, and hidden types of such relationships [7]. Also of particular note is the sequential, parallel, and combined arrangement of these barriers presented in [20].

Obviously, the assessment of the organizational and technological inertia of the processes of consumption of non-renewable energy resources should ultimately involve the establishment of opportunities to reduce the level of this inertia. In turn, as follows from the above, this requires the establishment of existing reserves to overcome obstacles to reducing energy consumption.

In modern scientific literature, various ways of ensuring such overcoming have been proposed. In particular, in [17] much attention is paid to improving the information support for energy saving management, in particular, increasing the level of relevance of information on energy efficiency. In [21], the experience of implementing Swedish municipal programs aimed at improving the energy efficiency of companies was analyzed. Based on the results of this analysis, the authors established not only the importance of comprehensive information support but also the acquisition by the staff of firms of the proper skills in the ability to process information about energy efficiency.

A number of scientists emphasize the importance of providing persons who intend to implement energy-saving investment measures with adequate amounts of financial resources. In particular, such scientists include the authors of work [22], who, based on data analysis from 56 states, established the importance of improving the existing investment climate to reduce energy consumption. Work [23] substantiates the importance of subsidy programs as an effective tool to stimulate energy efficiency and increase the use of clean energy sources in China. The authors of [24] show the role that preferential lending plays to accelerate the scale of implementation of energy saving measures. Some recommendations for establishing rational parameters of such lending for small enterprises are given in [25]. However, the issue of studying the impact of the lack of necessary amounts of financial resources on the level of obstacles to energy saving remains unresolved. Moreover, this concerns the study of this impact on the degree of organizational and technological inertia of energy saving processes.

In addition, scientists are considering the management aspects of overcoming the barriers that arise in the process of implementing energy-saving measures. Thus, in [26] it is proposed to carry out such overcoming on the basis of improving the methodology of an energy audit. In [27], where the possibilities of reducing the energy intensity of industrial products were studied, the search for the weakest link of the four successive stages of the energy-saving management process is proposed. At the same time, these stages include motivation, ability, as well as implementation, and results.

In general, as evidenced by the review of literary sources, the issues of assessing and overcoming barriers to improving energy efficiency are the focus of many scientists. They provide a number of scientifically based proposals for solving these issues. At the same time, the relationship between these barriers and the level of organizational and technological inertia of energy consumption processes in the scientific literature has not yet been investigated. There is also a need to develop a toolkit for assessing such inertia since this will provide an opportunity to identify opportunities for its reduction. The reasoning expressed predetermines the need for research on the topic of this work.

3. The aim and objectives of the study

The aim is to develop tools for assessing the organizational and technological inertia of energy consumption processes at enterprises. Such development will enable owners and managers of enterprises to obtain reliable information about existing and promising reserves for accelerating the implementation of energy-saving measures.

To achieve the set aim, the following tasks have been solved:

– to determine the indicators for assessing the organizational and technological inertia of energy consumption processes at enterprises;

– to develop a method of decomposition of the relative level of organizational and technological inertia of energy consumption processes at enterprises;

– to test the obtained theoretical and methodological results of the performed research on a sample of enterprises.

4. The study materials and methods

The object of the study is the assessment of the organizational and technological inertia of energy consumption processes at enterprises. The main hypothesis of this study is the statement about the possibility of developing tools, the use of which will make it possible to assess the organizational and technological inertia of energy consumption processes in full and with high accuracy.

The theoretical basis for our research included available studies on energy-saving management, evaluation of the effectiveness of investment programs, and rational use of energy resources [28–30].

During the empirical analysis, materials of accounting, statistical, and management accounting of a number of industrial enterprises were collected and processed. In addition to company reporting, the results of the questionnaire survey were used to obtain incoming information.

To build indicators for assessing the organizational and technological inertia of energy consumption processes at enterprises, the method of system analysis was applied. The need to use this method is due to the presence of relationships between different indicators for assessing the organizational and technological inertia of energy consumption processes. There is also a complex mechanism for the influence of factors on the level of this inertia. These circumstances determine the need for a systematic consideration of these connections.

To develop a method of decomposition of the relative level of organizational and technological inertia of energy consumption processes at enterprises, the method of economic and statistical modeling was applied. The need to apply this method is caused by the need to assess the influence of factors at the specified level.

The implementation of empirical research, among other things, required the use of methods of economic analysis and the implementation of technical and economic calculations. These techniques make it possible to perform a detailed assessment of the organizational and technological inertia of energy consumption processes at enterprises, as well as to establish the influence of individual factors on the level of this inertia.

In order to visualize the results of the study, graphic and tabular methods were used.

When discussing the results and while drawing conclusions from the study performed, an abstract-logical method was used. This made it possible to determine the most significant results of the research, to establish the reasons that led to these results, and to identify directions for further study of the issues under consideration.

5. Results of investigating the toolset for assessing the organizational and technological inertia of energy consumption processes at enterprises

5. 1. Determining indicators for assessing the organizational and technological inertia of energy consumption processes at enterprises

Since the inertia of energy consumption is its multifaceted property, it is advisable to measure this property using a certain set of indicators. It seems possible to identify three groups of such indicators.

The first group of indicators for assessing the organizational and technological inertia of energy consumption processes at enterprises will be based on the establishment of the time characteristics of this property. First of all, it concerns determining a lag between the moment of appearance at a certain enterprise of the opportunity to reduce the consumption of certain types of energy resources and the moment of actual realization of these opportunities. In the future, this lag will also be called a lag of energy saving (reduction of energy consumption). At the same time, for a sufficiently long period, there can be quite a lot of such lags at enterprises. The presence of some of them can exert a greater impact on energy consumption, while others – less. With this in mind, to assess the time parameters of the organizational and technological inertia of energy consumption processes at the enterprise, indicators of the averaged values of these lags can be applied. These indicators can be calculated using the following formulas:

$$l_{a1} = \sum_{i=1}^{n} l_i / n; \quad (1)$$

$$l_{a2} = \left(\sum_{i=1}^{n} l_i \cdot k_i \right) / n, \quad (2)$$

where l_{a1} – averaged for a certain period, the duration of lags between the moments of appearance at the enterprise of opportunities to reduce energy consumption and the moments of actual realization of these opportunities, time units;

n is the number of specified lags;

l_i is the duration of the i-th lag, time units;

l_{a2} is averaged over a certain period, the weighted durations of lags between the moments of appearance at the enterprise of opportunities to reduce energy consumption and the moments of actual realization of these opportunities, time units;

k_i is the level of significance of the i-th lag, which is calculated from the following formula.

$$\beta_i = V_{ei} / \sum_{i=1}^{n} V_{ei}, \quad (3)$$

where V_{ei} is the expected decrease in energy consumption during the studied period, provided that the duration of the i-th lag would be zero.

Thus, the indicator V_{ei} in formula (3) corresponds to the case in which the implementation of a certain energy saving measure is carried out without delay.

The second group of indicators for assessing the organizational and technological inertia of energy consumption processes at enterprises involves measuring the relative level of this inertia. First of all, it is possible to attribute two indicators to this group, which are calculated using the following formulas:

$$I_1 = \left(E_{f0} - E_{f1} \right) / E_{f0}; \quad (4)$$

$$I_2 = \left(E_{w0} - E_{w1} \right) / E_{w0}, \quad (5)$$

where I_1 is the relative level of organizational and technological inertia of energy consumption processes at the enterprise by natural volumes of such consumption;

E_{f0} – the actual amount of energy consumption at the enterprise during the studied time period in the corresponding physical units of measurement;

E_{f1} – the minimum possible amount of energy consumption at the enterprise during the studied time interval in the appropriate physical units of measurement, which could be achieved by implementing all possible energy-saving measures;

I_2 – the relative level of organizational and technological inertia of energy consumption processes at the enterprise at the cost incurred by it for the purchase of energy resources;

E_{w0} – the actual amount of expenses of the enterprise for energy consumption during the studied time period, monetary units;

E_{w1} – the minimum possible amount of expenditures of the enterprise for energy consumption during the studied time period, which could be achieved by implementing all possible energy-saving measures, monetary units.

Finally, the third group of indicators for assessing the organizational and technological inertia of energy consumption processes at enterprises involves its measurement on the basis of determining the magnitude of the corresponding barriers that arise in the way of implementing energy-saving measures. As noted above, the most important such barriers include insufficient efficiency of energy-saving measures, lack of necessary financial resources, and insufficient level of competence and amount of information necessary for energy saving management. All these obstacles can be assessed through the amount of investment needed to overcome them. Taking into account these considerations, it seems expedient to propose the following indicators that belong to the third group of indicators for assessing the organizational and technological inertia of energy consumption processes at enterprises:

$$b_1 = \left(I_p + I_c \right) / D; \quad (6)$$

$$b_2 = \left(I_p + I_c\right) / I_f; \qquad (7)$$

$$b_3 = \max\left\{b_1, b_2\right\}, \qquad (8)$$

where b_1 is the level of organizational and technological inertia of energy consumption processes at the enterprise, due to the low efficiency of energy-saving measures, and insufficient competencies and amounts of information necessary for energy saving management;

I_p – the total need for investments in the implementation by the enterprise of energy-saving measures, monetary units;

I_c – the general need for investments for the implementation of measures at the enterprise to increase competencies in energy saving management and improve the information support of the process of such management, monetary units;

D – the present value of the projected net cash flow from the implementation by enterprises of energy-saving investment measures, monetary units;

b_2 – the level of organizational and technological inertia of energy consumption processes at the enterprise, due to the lack of necessary financial resources and insufficient competencies and amounts of information necessary to manage energy saving;

I_f – the amount of financial resources that are available to the enterprise and which it can attract additionally for the implementation of energy-saving investment measures, monetary units;

b_3 – a generalized level of organizational and technological inertia of energy consumption processes at the enterprise, due to the barriers that arise in the way of implementing energy saving measures.

It should be noted that in the case when the values of indicators (6) to (8) are greater than one, this indicates that it is not profitable for the enterprise to fully implement energy-saving measures. Another reason may be the lack of means necessary for the implementation of energy saving measures of financial resources.

5. 2. Development of a method of decomposition of the relative level of organizational and technological inertia of energy consumption processes at enterprises

There are certain relationships between different groups of indicators for assessing the organizational and technological inertia of energy consumption processes at enterprises. In particular, it is possible to note the relationship between indicators (2) and (4) since the last indicator can be represented as follows:

$$I_1 = \frac{E_{f0} - E_{f1}}{E_{f0}} = \frac{\Delta E_{f1} + \Delta E_{f2} + \Delta E_{f3}}{E_{f0}} = \frac{\Delta E_{f1} + l_{a2} \cdot n + \Delta E_{f3}}{E_{f0}}, \qquad (9)$$

where ΔE_{f1} is the physical volume of energy consumption by the enterprise in the reporting period, due to the presence of energy saving lags, the beginning of which falls on previous periods;

ΔE_{f2} – the physical volume of energy consumption by the enterprise in the reporting period, due to the presence of energy saving lags, the beginning and completion of which falls on this period;

ΔE_{f3} – the physical amount of energy consumption by the enterprise in the reporting period, due to the presence of energy saving lags, the completion of which does not fall on this period.

With an increase in the duration of the reporting period, the impact of ΔE_{f1} and ΔE_{f3} on the value of indicator (9) (and, accordingly, indicator (4)) will decrease. Consequently, with a sufficient duration of the reporting period, the relationship between indicators (2) and (4) will approach a directly proportional one.

Taking into account the foregoing, it is possible to propose a method of decomposition of the relative level of organizational and technological inertia of energy consumption processes at enterprises. This method is based on the preliminary formation of a sample from enterprises of a certain type of economic activity, which at the beginning of the reporting period were characterized by a high level of energy intensity of products. At a further stage of research, these enterprises were divided into four groups, as given in Table 1. For each group of enterprises, the average duration of the energy saving lag in the reporting period was determined (Fig. 1). Then the statistical significance of the differences in the average values of the energy saving lag by groups was estimated. If this significance is significant, then it is possible to establish how the above-mentioned barriers to improving energy efficiency on average affect the duration of the energy saving lag. To this end, it is necessary to calculate the differences between the average values of energy saving lags for enterprises of different groups (Table 2). This is especially true for enterprises that have all three barriers (that is, group D enterprises). For such enterprises, based on formula (9), it is possible to estimate a possible decrease in the relative level of organizational and technological inertia of energy consumption processes in the reporting period if a certain barrier did not exist.

Thus, the sequence of the proposed actions would make it possible to perform a decomposition of the relative level of organizational and technological inertia of energy consumption processes at enterprises. This would make it possible to assess the impact of each of the barriers on the way to improving energy efficiency on the value of this level.

In turn, such an assessment makes it possible to establish the potential for reducing the consumption of a certain energy resource by eliminating one or another barrier to such a decrease. This can be done in terms of a set of types of economic activity, if sufficiently representative samples of enterprises engaged in these activities are considered. In the latter case, the impact of eliminating one or another barrier to reducing the consumption of a certain energy resource should be determined using the following formula:

$$I_b = \sum_{s=1}^{m} I_{bs} \cdot \alpha_s, \qquad (10)$$

where I_b is the total relative decrease in the reporting period of natural volumes of energy consumption for the entire set of economic activities that are considered, subject to the elimination of a certain barrier to such a decrease, the share of a unit;

m – the number of economic activities that are considered;

I_{bs} – expected for the s-th type of activity reduction of the relative level of organizational and technological inertia of the processes of consumption of natural volumes of energy resources in case of elimination of a certain barrier to such a decrease, the share of one;

α_s – the share of energy consumption by enterprises belonging to the s-th type of activity, in the total amount of such consumption for all types of activities under consideration, the share of the unit.

Table 1

Grouping enterprises by existing barriers to improving energy efficiency

Designation of groups	Characteristics of enterprises	Designation of average values of energy saving lags	Factors for the presence of energy saving lags
A	The level of financial support for the implementation of energy-saving measures is appropriate. The level of competence in energy saving management and information support of this management is appropriate	L_A	1) insufficient level of efficiency of energy saving measures; 2) other factors, in particular the lack of adequate resources required for the implementation of energy saving measures (except financial)
B	The level of financial support for the implementation of energy-saving measures is appropriate. The level of competence in energy saving management and information support of this management is inadequate	L_B	1) factors characteristic of group A enterprises; 2) inadequate level of competence in energy saving management and information support of this management
C	The level of financial support for the implementation of energy-saving measures is inadequate. The level of competence in energy saving management and information support of this management is appropriate	L_C	1) factors characteristic of enterprises of group A; 2) inadequate level of financial support for the implementation of energy-saving measures
D	The level of financial support for the implementation of energy-saving measures is inadequate. The level of competence in energy saving management and information support of this management is inadequate	L_D	1) factors characteristic of enterprises of group A; 2) inadequate level of financial support for the implementation of energy-saving measures; 3) inadequate level of competence in energy saving management and information support of this department

Table 2

Formalization of the assessment of the influence of factors on the average duration of the energy saving lag according to a sample of enterprises

Groups of factors of influence	Formalization of the influence of relevant factors
1. Insufficient level of efficiency of energy saving measures; other factors, including the lack of adequate resources needed to implement energy saving measures (except financial)	L_A
2. Inadequate level of competence in energy saving management and information support of this department	$L_A - L_B$
3. Inadequate level of financial support for the implementation of energy-saving measures	$L_A - L_C$
4. Inadequate levels of competence in energy saving management and information support of this management, as well as financial support for the implementation of energy-saving measures	$L_A - L_B - L_C$

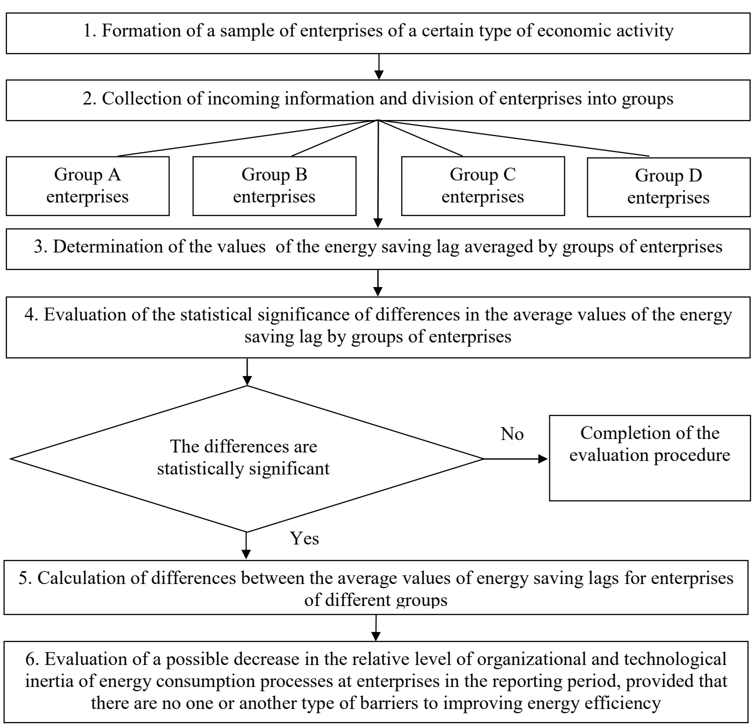

Fig. 1. The sequence of implementation of the method of decomposition of the relative level of organizational and technological inertia of energy consumption processes at enterprises

It should be noted that, in principle, there are opportunities to form representative samples of enterprises from all types of economic activity that consume a certain energy resource. Then the use of formula (10) makes it possible to assess the influence of organizational and technological inertia of the processes of such consumption on its volumes according to the national economy as a whole.

5. 3. Approbation of the obtained theoretical and methodological results

Among the types of non-renewable energy resources, the need to reduce the consumption of which is currently particularly acute, natural gas occupies an important place. Therefore, the use of this type of energy resources in three industries of Ukraine was analyzed. These industries are characterized by significant specific volumes of natural gas consumption.

In the process of research, a sample of 66 enterprises was formed. For these enterprises, in particular, the main indicators of the implementation of organizational and technological measures to save natural gas were determined (Table 3). As follows from the data in Table 3, for all types of economic activity, the average level of implementation of organizational and technological measures to save natural gas at the studied enterprises during 2016–2021 was low. In particular, the average number of implemented organizational and technological measures to save natural gas per enterprise ranged from 2.04 to 3.1. The studied enterprises had a rather low average share of investments in the acquisition of patents and licenses for technologies involving natural gas savings in the structure of non-current assets. This share ranged in terms of economic activity from 0.009 % to 0.014 %. In addition, it is necessary to note the low level of license fees for the use of technologies involving the saving of natural gas inherent in the studied enterprises. The value of these payments per 1 monetary unit of operating income ranged from 0.006 % to 0.009 % by type of economic activity. Thus, the level of updating the technological processes of natural gas consumption at the studied enterprises during 2016–2021 was low. This was especially true of enterprises engaged in the manufacture of clay products, according to which the average values of the listed indicators are the lowest compared to the other two types of economic activity.

In addition, in the process of the performed research, a certain amount of additional information was obtained from each of the enterprises that were considered, which can be divided into the following blocks:

1. Information on the affiliation of each enterprise to one of the four groups presented above in Table 1. These data are obtained on the basis of a survey of managers of the studied enterprises.

2. Information on measures to save natural gas, which were implemented at enterprises during the reporting period. In particular, this concerns the moments of implementation of measures, the volume of savings in natural gas as a result of such implementation, the amount of investment in such implementation, etc.

3. Information on natural gas saving measures that the studied enterprises could and (or) tried to implement during the reporting period. In particular, this concerns the possible moments of implementation of measures, the expected volumes of savings in natural gas, the required amount of investment in such implementation, etc.

4. Data on the dynamics of natural gas consumption during the reporting period.

Obtaining the listed arrays of information made it possible to group the studied enterprises (Table 4) and calculate the indicators of organizational and technological inertia of natural gas consumption processes at these enterprises (Table 5). In particular, with regard to the division of enterprises into groups, it is possible to note a relatively small proportion of group A enterprises, that is, those that have the best conditions for the implementation of energy saving measures. This share ranges from 18.18 % for enterprises engaged in the manufacture of metal products, to 25 % for enterprises producing glass products. At the same time, the share of group D enterprises (that is, enterprises with the least favorable conditions for the implementation of energy-saving measures) is larger and ranges from 30 % to 33.33 %.

Regarding the level of organizational and technological inertia of the processes of natural gas consumption at the studied enterprises, then, as can be seen from the data of Table 5, it is quite high. In particular, averaged over 2016–2021, the duration of the lag in reducing the consumption of natural gas ranges from 1.3 to 1.8 years. Even longer is the duration of the weighted lag. This is due to the higher level of importance of measures for the conservation of natural gas, which are characterized by longer durations of lags to reduce the consumption of natural gas. This situation naturally caused a significant relative level of organizational and technological inertia of the processes of natural gas consumption at the enterprises under consideration. In particular, in terms of natural energy consumption, this level ranges from 36.5 % to 47.9 %, that is, enterprises during 2016–2021 had significant untapped opportunities to reduce natural gas consumption. At the same time, the studied enterprises could not fully implement all the projects of such a reduction. This is evidenced by the excess of the unit of averaged values of the third group of indicators for assessing the organizational and technological inertia of energy consumption processes at enterprises. Particularly significant (from 1.38 to 1.64) is the level of organizational and technological inertia of natural gas consumption due to the lack of financial resources, as well as insufficient competencies and amounts of information necessary to manage the reduction of energy consumption.

Table 3

The basic indicators of the implementation of organizational and technological measures to save natural gas at the studied enterprises during 2016–2021

Names of indicators	The value of indicators by type of economic activity		
	Manufacture of metal products	Manufacture of glass products	Manufacture of clay products
1. Number of studied enterprises	22	20	24
2. The total number of organizational and technological measures implemented at the enterprises to save natural gas	57	62	49
Including – energy-saving technological processes	41	44	32
3. The average number of organizational and technological measures implemented at enterprises to save natural gas per enterprise	2.59	3.10	2.04
Including – energy-saving technological processes	1.86	2.20	1.33
4. The average share of investments in the acquisition of patents and licenses for technologies that provide for saving natural gas in the structure of non-current assets, %	0.011	0.014	0.009
5. Value of license payments for the use of technologies that provide for saving natural gas by 1 monetary unit of income from operating activities, %	0.008	0.009	0.006

Averaged by the enterprises under consideration, the values of lags for reducing natural gas consumption are presented in Table 6. Note that these lags are weighted taking into account the importance of the relevant measures to reduce the use of this energy resource. As can be seen from the above data in Table 6, the complication of the conditions for the implementation of energy-saving measures leads to an increase in the duration of the lag. The use of the method of analysis of variance showed that this dependence is statistically significant since for all industries the calculated value of the *F*-criterion is greater than its critical value with a significance level of α=0.05.

Using the methodological principles presented above in Table 2, according to the data given in Table 6, an assessment of the influence of factors on the average duration of the lag of reduction in natural gas consumption was carried out. Such an assessment, the results of which are summarized in Table 7, was carried out according to the group of studied enterprises with the longest such duration (group D). As follows from the data in Table 7, among the identified factors, the most significant are the insufficient level of effectiveness of energy saving measures and other factors (except for the factors contained in their subsequent groups). However, factors from the other three groups also have a significant impact on the average duration of the lag to reduce natural gas consumption. At the same time, their joint influence is about the same as the influence of the factors of the first group.

Table 4

Distribution of the studied enterprises – consumers of natural gas by their groups

Groups of enterprises	The number of enterprises by type of economic activity			Share of enterprises, % to their total number		
	Enterprises that manufacture metal products	Enterprises that make glass products	Enterprises that make clay products	Enterprises that manufacture metal products	Enterprises that make glass products	Enterprises that make clay products
A	4	5	4	18.18	25.00	16.67
B	6	4	7	27.27	20.00	29.17
C	5	5	5	22.73	25.00	20.83
D	7	6	8	31.82	30.00	33.33
Total	22	20	24	100.00	100.00	100.00

Table 5

Indicators for assessing the organizational and technological inertia of natural gas consumption processes at enterprises during 2016–2021

Names of indicators	Averaged values of indicators by type of economic activity		
	Manufacture of metal products	Manufacture of glass products	Manufacture of clay products
1. Averaged over 2016–2021, the duration of lag reduction of natural gas consumption, years	1.4	1.2	1.6
2. Averaged over 2016–2021, the weighted lag durations reducing natural gas consumption, years	1.5	1.3	1.8
3. Relative level of organizational and technological inertia of natural gas consumption processes by natural volumes of such consumption, %	40.9	36.5	47.9
4. Relative level of organizational and technological inertia of natural gas consumption processes at the costs incurred for the purchase of this type of energy resources, %	41.7	38.0	49.1
5. The level of organizational and technological inertia of natural gas consumption processes is due to the low efficiency of energy-saving measures, as well as insufficient competencies and amounts of information necessary to manage the reduction of consumption of this type of energy resources	1.22	1.14	1.34
6. The level of organizational and technological inertia of natural gas consumption processes is due to the lack of necessary financial resources, as well as insufficient competencies and amounts of information necessary to manage the reduction in consumption of this type of energy resources	1.38	1.65	1.54
7. The generalized level of organizational and technological inertia of the processes of natural gas consumption, due to the barriers that arise in the way of implementing measures to reduce the consumption of this type of energy resources	1.38	1.65	1.54

Table 6

Enterprise-averaged values of lags for reducing natural gas consumption and *F*-criteria

Names of indicators	The value of indicators by type of economic activity		
	Manufacture of metal products	Manufacture of glass products	Manufacture of clay products
1. Averaged by enterprises values of lags to reduce natural gas consumption: 1. 1. For group A enterprises	0.9	0.8	1.1
1. 2. For group B enterprises	1.2	1.0	1.4
1. 3. For group C enterprises	1.5	1.3	1.6
1. 4. For group D enterprises	1.9	1.7	2.0
2. Actual values of the *F*-criterion	5.61	6.79	6.33

According to the data given in Table 7, the influence of factors on the relative level of organizational and technological inertia of natural gas consumption processes of group D enterprises was evaluated. The results of such an assessment are summarized in Table 8.

As follows from the data in Table 8, the elimination of obstacles to the implementation of measures to save natural gas could lead to a significant decrease in the relative level of inertia of the processes of its consumption by the studied enterprises. In particular, ensuring an adequate level of competence in energy saving management and information support of this management would reduce the degree of inertia by a value that varies in various industries from 4.29 % to 7.19 %. At the same time, achieving an adequate level of financial support for the implementation of energy-saving measures would reduce the degree of organizational and technological inertia by an amount that varies in various industries from 10.74 % to 12.92 %. The level of efficiency of energy saving measures and other factors, in particular the lack of adequate resources (except for financial ones), have an even greater impact on organizational and technological inertia. However, the effectiveness of energy-saving measures is largely exogenous in relation to enterprises, that is, the possibilities of managing it by enterprises are limited. At the same time, there is a synergistic effect of the influence of the level of competence in energy saving management and information support of this management, as well as the level of financial support for the implementation of energy-saving measures. Indeed, the joint influence of these two factors on the organizational and technological inertia of natural gas consumption exceeds the sum of their separate effects on it.

It should be noted that the shares of natural gas consumption by type of economic activity in the total volume of such consumption by all studied enterprises of group D during 2016–2021 were:

– for the manufacture of metal products – 43.7 %;
– for the manufacture of glass products – 21.9 %;
– for the manufacture of clay products – 34.4 %.

Taking into account these data, it is possible to assess the impact of eliminating a certain barrier to reducing the consumption of natural gas on the volume of its consumption for the entire set of activities under consideration. In particular, the barriers that are easiest to manage include an inadequate level of competence in energy saving management and information support for this management. Based on the data in Table 8, which relate to the specified barrier, and using formula (10), we obtain:

$$I_b = \frac{6.46}{100} \cdot \frac{43.7}{100} + \frac{4.29}{100} \cdot \frac{21.9}{100} + \frac{7.19}{100} \cdot \frac{34.4}{100} = 0.0624.$$

Therefore, the absence of this barrier in the reporting period would lead to a decrease in the volume of natural gas consumption by group D enterprises for the entire set of economic activities under consideration by 6.24 %.

Table 7

Results of the assessment of the influence of factors on the average duration of the lag of reduction in natural gas consumption by the group of enterprises with the longest such duration (group D)

Names of factors	The influence of factors by type of economic activity, years		
	Manufacture of metal products	Manufacture of glass products	Manufacture of clay products
1. Insufficient level of efficiency of energy saving measures; other factors, including the lack of adequate resources needed to implement energy saving measures (except financial)	0.9	0.8	1.1
2. Inadequate level of competence in energy saving management and information support of this management	0.3	0.2	0.3
3. Inadequate level of financial support for the implementation of energy-saving measures	0.6	0.5	0.5
4. Inadequate levels of competence in energy saving management and information support of this management, as well as financial support for the implementation of energy-saving measures	1.0	0.9	0.9

Table 8

Results of assessment of the influence of factors on the relative level of organizational and technological inertia of natural gas consumption processes of group D enterprises

Names of factors	Reduction of the relative level of organizational and technological inertia of natural gas consumption processes, which could be achieved by eliminating the effect of relevant factors, %		
	Manufacture of metal products	Manufacture of glass products	Manufacture of clay products
1. Insufficient level of efficiency of energy saving measures; other factors, including the lack of adequate resources needed to implement energy saving measures (except financial)	19.37	17.18	26.35
2. Inadequate level of competence in energy saving management and information support of this management	6.46	4.29	7.19
3. Inadequate level of financial support for the implementation of energy-saving measures	12.92	10.74	11.98
4. Inadequate levels of competence in energy saving management and information support of this management, as well as financial support for the implementation of energy-saving measures	21.53	19.32	21.56

6. Discussion of the designed tools for assessing the organizational and technological inertia of energy consumption processes at enterprises

The study showed that it is possible to assess the organizational and technological inertia of energy consumption processes at enterprises only with the help of a system of indicators. This is explained by the fact that organizational and technological inertia is a complex and multifaceted characteristic of energy consumption processes. Accordingly, using (1) to (8), it is possible to provide an estimate of this inertia from different angles of view. Then the set of results obtained as a result of the application of (1) to (8) will make it possible to obtain a comprehensive description of the organizational and technological inertia of energy consumption.

It is possible to assess the influence of factors on the level of organizational and technological inertia of energy consumption processes using the developed method of decomposition of this level. The effectiveness of this method, the characteristic of which is shown in Fig. 1 and Table 2, is explained by a clear and unambiguous distribution of the level of organizational and technological inertia of energy consumption into groups of obstacles to energy saving.

Approbation of the obtained theoretical and methodological results for the sample of enterprises showed that many of them have a high level of organizational and technological inertia of natural gas consumption. This is explained by the fact that, as evidenced by the data presented in Tables 5–8, the studied enterprises do not fully use their capabilities to save this energy resource. The realization of these opportunities should, among other things, include increasing the level of competence of owners and managers of enterprises in matters of energy saving management and information support of this management.

A positive feature of the designed toolset for assessing the organizational and technological inertia of energy consumption processes is that its use makes it possible to obtain a comprehensive and accurate assessment of this characteristic. Therefore, this toolkit is a definite contribution to the general developments that will contribute to solving the problem of determining ways to improve the energy efficiency of enterprises. In the scientific literature, in particular [7–10], such a solution is based mainly on the identification and evaluation of various types of obstacles that arise on the way to the implementation of energy-saving investment projects by business entities. However, the concept of organizational and technological inertia of energy consumption processes is significantly broader than the content of these obstacles, investigated, among other things, in [16–20]. This is explained by the fact that the obstacles that arise on the way to the implementation of energy-saving measures are factors influencing the organizational and technological inertia. Thus, from these positions, organizational and technological inertia represents a generalizing characteristic of the obstacles that slow down the process of improving energy efficiency. Therefore, the proposed approaches to measuring organizational and technological inertia are a step forward in solving the problem of energy saving compared to [16–20] methods of assessing the barriers that arise on the way to it.

At the same time, the establishment of a link between these barriers and the level of organizational and technological inertia made it possible to solve a number of partial problems. Firstly, the main types of such barriers are highlighted, which determine the value of the absolute and relative levels of organizational and technological inertia of energy consumption processes. Secondly, a method has been developed to determine the impact of each of the selected barriers on the specified value. In the end, this made it possible to quantify the possibilities of reducing the absolute and relative levels of organizational and technological inertia, provided that certain obstacles to improving energy efficiency are overcome.

Taking into account the foregoing, the designed toolset quite fully closes the problem of assessing the organizational and technological inertia of energy consumption processes at enterprises. This is achieved due to the fact that the use of this toolkit makes it possible to perform such an assessment fully and with proper accuracy.

At the same time, certain limitations are inherent in this study. In particular, when dividing enterprises into four groups, their possible differences in terms of financial condition, size, etc. were not taken into account. However, it is possible that these differences will have a certain impact on the organizational and technological inertia of energy consumption. In addition, the issue of justification of rational volumes of investments directed by enterprises to the implementation of energy-saving investment projects remained out of consideration. At the same time, a situation is possible in which, with relatively small volumes of such volumes, the organizational and technological inertia of energy consumption will be absent.

In the end, natural gas consumption was investigated to sample enterprises that belong to only three types of economic activity. Accordingly, the results obtained cannot characterize the national economy as a whole. On the other hand, the possibilities of conducting an appropriate analysis at the national level exist since formula (10) is adapted for this. However, this requires large amounts of incoming information, the acquisition of which will require significant costs.

It is also possible to single out two shortcomings of the study. Firstly, the relationship between the lags in reducing energy consumption and the relative level of its organizational and technological inertia is not fully described. Secondly, industry differences in the energy intensity of products are not taken into account.

The elimination of these limitations and shortcomings should be considered as directions for further research on this topic. In particular, this concerns the assessment of the impact of organizational and technological inertia on the consumption of non-renewable energy resources for the entire set of types of economic activity and, accordingly, on the development of the national economy as a whole.

7. Conclusions

1. A system of indicators for assessing the organizational and technological inertia of energy consumption processes at enterprises has been developed. This system contains three groups of indicators. The first group of indicators is based on the establishment of the time characteristics of this property. The second group of indicators for assessing the organizational and technological inertia of energy consumption processes at enterprises involves measuring the relative level of this inertia. Finally, the third group of indicators for assessing the organizational and technological inertia of energy consumption processes at enterprises involves its measurement on the basis of determining the magnitude of the

corresponding barriers that arise in the way of implementing energy-saving measures. The use of these indicators makes it possible to carry out an accurate and comprehensive measurement of the organizational and technological inertia of energy consumption processes.

2. The method of decomposition of the relative level of organizational and technological inertia of energy consumption processes at enterprises is proposed. This method is based on the preliminary formation of a sample of enterprises of a certain type of economic activity, which at the beginning of the reporting period were characterized by a high level of energy intensity of products. At a further stage of research, these enterprises are divided into four groups according to certain criteria. For each group of enterprises, the average duration of the energy saving lag in the reporting period is determined. Then the statistical significance of the differences in the average values of the energy saving lag by groups is estimated. If this difference exists, then it is possible to identify how the above-mentioned barriers to improving energy efficiency on average affect the duration of the energy saving lag. This, in turn, makes it possible to assess the possible decrease in the relative level of organizational and technological inertia of energy consumption processes in the reporting period, if a certain barrier did not exist.

3. The obtained theoretical and methodological results of the study based on the sample of enterprises – consumers of natural gas were tested. The assessment of the level of organizational and technological inertia of the processes of natural gas consumption at the studied enterprises showed that it is quite high. In particular, averaged during 2016–2021, the duration of the lag reduces the consumption of natural gas in the ranges from 1.3 to 1.8 years. At the same time, the relative level of organizational and technological inertia of the processes of natural gas consumption at the enterprises under consideration was also significant. In particular, in terms of natural energy consumption, this level ranged from 36.5 % to 47.9 %, that is, enterprises during 2016–2021 had significant untapped opportunities to reduce natural gas consumption. It was also found that the implementation of these opportunities should include an increase in the level of competence in energy saving management and information support for this management, as well as the level of financial support for the implementation of energy-saving measures.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data availability

Manuscript has no associated data.

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