UDC 621.31:330.322
DOI: 10.15587/1729-4061.2025.321965

DEVISING A COMPREHENSIVE METHODOLOGY FOR ESTIMATING THE ECONOMIC EFFICIENCY OF IMPLEMENTING AN INVESTMENT PROJECT FOR ENSURING ENERGY SECURITY OF ENTERPRISES: ORGANIZATIONAL-ECONOMIC ASPECT

Viktoriia Prokhorova
Doctor of Economic Sciences, Professor*
Mykola Budanov
PhD Student*
Pavlo Budanov
Corresponding author
PhD, Associate Professor
Department of Physics, Electrical Engineering and Power Engineering**
E-mail: pavelfeofanovich@ukr.net
Anna Zaitseva
Doctor of Economic Sciences, Associate Professor
Department of International Economic Relations and Logistics
V. N. Karazin Kharkiv National University
Svobody sq., 4, Kharkiv, Ukraine, 61022
Anzhelika Slastianykova
PhD, Associate Professor*
*Department of Economy and Management**
**Education and Research Institute "Ukrainian Engineering Pedagogics Academy" of V.N. Karazin Kharkiv National University
Universytetska str., 16, Kharkiv, Ukraine, 61003

The subject of this study is the process of assessing the economic efficiency of implementing an investment project aimed at ensuring the energy security of enterprises within the power sector at the microeconomic level.

The task considered was to devise a comprehensive and adaptive approach to assessing the economic efficiency of investments, enabling effective planning, implementation, and adjustment of the investment project for ensuring energy security at enterprises under uncertainty.

The research revealed that conventional approaches, such as cost-benefit analysis, do not adequately account for risks and potential threats that arise during the implementation of investment projects.

An improved comprehensive method for assessing economic efficiency has been proposed, consisting of eight key stages that are interconnected based on calculations and analysis of the economic efficiency indicators of the investment project for the enterprise.

A distinctive feature of this method is the integration of quantitative and qualitative indicators of investment projects, which allows for evaluating their effectiveness and ensuring real-time adaptation to justify management decisions under uncertainty.

The choice of criteria for evaluating investment objects for forming a system of energy security indicators for enterprises has been substantiated.

A computational algorithm was developed to monitor the dynamics of indicator changes, which helps make timely management decisions to minimize energy security risks.

The practical significance of this study is that it provides enterprises with methodological foundations for optimizing investment strategies.

It has been shown that maximum energy security and financial benefits for enterprises are achieved through the complete prevention of accidents, ensuring profitability at the level of 41 %

Keywords: economic efficiency, energy security of enterprises, management decisions, organizational-economic aspect

Received 16.10.2024
Received in revised form 10.12.2024
Accepted 27.12.2024
Published 28.02.2025

How to Cite: *Prokhorova, V., Budanov, M., Budanov, P., Zaitseva, A., Slastyanikova, A. (2025). Devising a comprehensive methodology for estimating the economic efficiency of implementing an investment project for ensuring energy security of enterprises: organizational-economic aspect. Eastern-European Journal of Enterprise Technologies, 1 (13 (133)), 59–68. https://doi.org/10.15587/1729-4061.2025.321965*

1. Introduction

Economic efficiency (EcEf) in the implementation of investment projects (InPrs) in the energy sector is a critically important aspect for ensuring the stability and development of industrial enterprises.

Under current conditions, when energy security (EnS) issues are becoming more and more urgent, investments in energy infrastructure not only increase the competitiveness of enterprises but also ensure the reliability of the supply of energy resources. However, existing approaches to the assessment of EcEf often do not take into account the specific requirements and risks associated with EnS, which can lead to significant economic losses.

Studies show that conventional methods for evaluating the energy efficiency of investments usually focus on financial indicators, leaving out of consideration more complex aspects, such as the consequences of the processes of generation, transmission, distribution, and energy consumption.

The lack of an integrated approach to evaluation can lead to an underestimation of the impact of investments on the level of enterprise's EnS. This emphasizes the need to devise new methods that would allow for an adequate assessment of EcEf of investments taking into account all the factors affecting EnS.

The relevance of this topic relates to the need for a comprehensive analysis of investment projects that contribute to the provision of EnS of enterprises at the microeconomic level.

Devising a methodology that includes organizational and economic aspects will allow enterprises not only to increase the efficiency of resource use but also to reduce the risks associated with energy threats.

Taking into account these aspects is essential for the formation of an effective investment policy under the conditions of a constantly changing energy landscape.

Also, modern methods for evaluating the energy efficiency of investment projects do not always take into account the specificity of the processes of generation, transmission, distribution, and consumption of energy at the level of industrial enterprises. This leads to an underestimation of the real risks and opportunities associated with the provision of EnS at the microeconomic level, which is critically important for the stability and development of the economy as a whole.

Thus, research into this area expands the theoretical understanding of investment activity in the energy sector and contributes to the practical solution of current problems of energy security at the macro-, meso-, and micro-levels of the economy.

2. Literature review and problem statement

In order to improve the accuracy of calculation of EcEf in investment projects, in [1] a decision-making method is proposed for investment optimization for multiple projects of construction of electrical networks of complex construction under a certain investment scale. This investment decision model is based on a combination approach and makes it possible to prevent investment risks. As a drawback of the model, one should note the limitation of data, which determines the dependence of the model on the quality and quantity of available data, which can affect the accuracy of risk assessments and EcEf in investment projects.

Paper [2] proposed an integrated model for evaluating the EcEf of wind energy investment projects, taking into account the knowledge and experience of experts. The main advantages of the proposed model are to provide comprehensive identification of risks in energy investment projects using a modified fuzzy model to improve the risk assessment process taking into account the competence of experts in energy projects. The disadvantage of the model is that the level of expertise varies, and the estimation of EcEf, without taking into account the competence of experts, can lead to distorted results and does not take into account the uncertainty in all parameters of the cash flow.

In [3], a flexible model for evaluating the EcEf of investment projects is proposed, which can help companies evaluate their own investment projects for the development of energy resources with various characteristics of the corresponding technological process. A disadvantage of the model is that it does not take into account changes in market conditions, such as fluctuations in oil prices, which can quickly affect the results of the model, making long-term planning difficult.

Work [4] proposed a model that can be adapted for different types of innovative projects and industrial enterprises, which makes it applicable in different contexts and increases the chances of EcEf. As a drawback worth noting is the implementation of the proposed model, which may require significant resources, time, and expertise, which might be problematic for companies and reduce their EcEf.

In work [5], a study was conducted on devising a methodology for the assessment of EcEf and the interaction of enterprises in the innovation cluster for the further planning of measures to improve its functioning. To achieve this goal, the following methods of scientific research were used: the method of comparison and synthesis; econometric method; abstract logical method; graphical method. Such a technique should be used in forming directions for the development of new members of the cluster, in adjusting the existing strategy of existing clusters of enterprises, and in the development of measures aimed at increasing the efficiency of their interaction. The disadvantage of this approach is the complexity of its implementation since the development of the methodology for evaluating EcEf may require significant time and resource costs, as well as the availability of reliable and up-to-date data.

Paper [6] proposed a method for evaluating the EcEf of an investment project, which consists in collecting data for a business case within the framework of production using digital information technologies, intelligent technical systems, and smart devices. A disadvantage of this approach worth noting is that the business case is only a support for decision-making and, therefore, does not provide immediate benefits, which may limit its practical use under the conditions of a changing market.

In work [7], a method for estimating EcEf based on a multiple linear regression model was developed, which provides an average quadrature payback error of 0.48 years and allows determining EcEf using dimensionless parameters. The disadvantage of the model is that for an accurate estimation of EcEf, it is necessary to have reliable and up-to-date data, which can be difficult to provide.

In paper [8], a comprehensive methodology for evaluating EcEf is proposed, emphasizing the interdependence between economic, social, and environmental aspects. The integration of the assessment methodology for the collection and monitoring of data on energy consumption and emissions allows for the development of an intelligent management model aimed at optimizing resources and increasing the efficiency of processes. The shortcoming of the methodology is that for an accurate estimate of the energy efficiency, it is necessary to take into account the total amount of electricity at energy enterprises, as well as the energy efficiency of green energy.

In works [9, 10], the model of convergence of the dominant forms of the investment project depending on the stages of industrial development is considered. It is indicated that one of the indicators characterizing the efficiency of investment projects is its mobility or immobility, which is influenced by a number of macroeconomic factors. Considering the structure of direct foreign investments, the main directions of their use are indicated. The need for forecasting: investment projects often depend on forecasts of market, technology, and economic conditions, which may turn out to be incorrect. The disadvantage of the model is that it requires forecasting because investment projects often depend on forecasts of market, technology, and economic conditions, which may turn out to be wrong.

In [11, 12], a model for estimating the cost of products is proposed, but it is not specified which specific goods are considered. An assessment of the innovative and investment security component of the development of industrial enterprises was also carried out, but it was not specified with which methods the assessment was carried out, as well as there is no information about the results obtained and recommendations for improving the security mechanism.

In work [13, 14], the algorithm for optimizing the influence of risk factors on the potential management system of enterprises is considered, but it is not indicated by which methods the effectiveness of the organizational and economic mechanism of their activity was evaluated, and there is no specific information about the evaluation results.

Thus, our review of the literature [1–14] demonstrates that there is a part of the unsolved problem of evaluating the energy efficiency of the implementation of investment projects, in relation to the provision of environmental protection of an industrial enterprise, namely:

– lack of uniform methodical approaches to the evaluation of EcEf implementation of investment projects, regarding the provision of EnS of the industrial enterprise;

– opacity of investment management processes (for example, it is often unclear how investment decisions are made, which leads to risks and costs);

– insufficient adaptation to the specificity of the industry, i.e., existing methods do not always take into account the peculiarities of the levels of the electric power system (macro, meso, and micro level), which can reduce their effectiveness;

– failure to take into account the specificity of energy processes, such as generation, transmission, distribution, and consumption of energy, which leads to difficulties in the formation of objective criteria for evaluating the effectiveness of investments;

– limited use of modern technologies, i.e., not all studies include the latest technologies for monitoring and evaluation of EcEf;

– incompleteness of current and detailed information to justify the indicators of EcEf of investment projects;

– failure to take into account the integrated indicators of EcEf of investment projects;

– the specific risks associated with the implementation of investment projects are not taken into account, which may lead to an underestimation of the threats to the enterprise's safety and security.

These factors underline the need for further research aimed at improving the methods for evaluating the economic efficiency of investment projects in the energy sector.

Thus, the problem of EcEf in the implementation of investment projects, regarding the provision of EnS of enterprises is multifaceted and requires a comprehensive approach.

First, energy security becomes an integral component of strategic management of enterprises, as its level directly affects the stability of their activities and competitiveness. Investment projects aimed at increasing EnS require significant financial resources, and their EcEf is often uncertain due to unpredictable changes in market conditions.

Secondly, there is a problem of insufficient integration of economic, ecological, and social aspects in the implementation of investment projects. Many businesses focus on short-term economic benefits, ignoring the potential environmental and social consequences that can affect their EcEf.

Thirdly, the methodological approaches to the evaluation of EcEf of investments in EnS remain insufficiently developed.

Fourthly, the organizational and economic aspect of the implementation of investment projects also requires a separate analysis. Effective organization of management processes and rational use of resources are key factors for achieving set goals. Non-transparency in decision-making, lack of clear procedures, and insufficient coordination between various structural divisions of enterprises can significantly reduce the EcEf of investments.

Thus, the problem of EcEf in the implementation of investment projects in terms of ensuring the EnS of enterprises is multifaceted and requires a comprehensive approach to its solution. To achieve sustainability and competitiveness of enterprises, it is necessary to take into account not only economic indicators but also environmental and social consequences, as well as improve organizational structures and management methodologies. This will allow for a more in-depth and objective assessment of the economic efficiency of investments in the field of energy security.

3. The aim and objectives of the study

The purpose of our study is to devise a methodology for assessing the economic efficiency of implementing an investment project aimed at ensuring the energy security of industrial enterprises, with an emphasis on the organizational-economic aspect. This will make it possible to identify and take into account threats and risks that affect the economic efficiency of investments, for the timely development of management decisions and the development of recommendations for increasing the level of energy security of enterprises.

To achieve this goal, the following tasks were set:

– to define stages of a comprehensive methodology for assessing the energy efficiency of investment projects based on determining the criteria and indicators for evaluating the energy efficiency of investments in the context of energy security, taking into account the impact of external and internal threats to energy security;

– to develop a computational algorithm that integrates the devised methodology for evaluating the energy efficiency in the software-computing systems (SCS) for the technological process automated control systems (TP ACS) to automate the energy efficiency assessment process of an investment project;

– to investigate results of the practical application of the proposed EcEf assessment methodology on the example of an investment project, regarding the implementation of an accident prevention module (APM) as part of TP ACS at the Zaporizhzhia Nuclear Power Plant (ZNPP) power unit.

4. The study materials and methods

The object of our study is the process of evaluating the economic efficiency of implementing an investment project aimed at ensuring the energy security of electric power system enterprises at the microeconomic level.

The hypothesis of the study assumes that if the selection and calculation of the indicators of the evaluation of energy efficiency of investment projects are carried out on the basis of an integrated methodology using the computational algorithm of TP ACS of the power unit, then this will allow for the following:

– to quickly identify external (internal) threats and energy security risks;

– to improve the economic efficiency of the investment project.

The following methods of economic efficiency assessment, which have scientific justification and practical application, were chosen for the study of economic efficiency assessment of investment projects in the field of energy security of enterprises:

– net present value (*NPV*);

– internal rate of return (*IRR*);

– payback period ($\mathbf{T}_{so}$).

A combination of EcEf indicators (*NPV*, *IRR*, $\mathbf{T}_{so}$) provides a comprehensive assessment of investment projects, allowing us to make informed management decisions.

We have considered requirements for the selection of criteria for evaluating economic efficiency:

– project cash flow forecasting;

– selection of an adequate discount rate that reflects project risk and alternative costs of capital;

– considering that money is worth more today than in the future.

The main criteria for evaluating the economic efficiency of investment projects:

– net profit, which reflects the overall profitability of the project, showing how much money is left after covering all costs;

– the profitability ratio, which determines how much hryvnia of profit accrues for each hryvnia invested, which helps to assess how profitable the project is;

– the rate of return on investment, which indicates how much profit was received from the investment in percentage terms, which makes it possible to understand the efficiency of investments.

Together, these criteria make it possible to comprehensively assess investment projects and make informed decisions.

5. Results of devising a comprehensive methodology for assessing the economic efficiency of investment projects

5. 1. Defining stages in the methodology for assessing the economic efficiency of investment projects.

Devising a comprehensive methodology for evaluating the EcEf of investment projects includes several stages (Fig. 1), each of which has its specific characteristics:

– stage No. 1: determination of goals and objects of evaluation of EcEf of investments in the context of EnS (for example, new technologies, modernization of equipment, management decisions);

– stage No. 2: identification and analysis of external and internal threats and risks that may affect EcEf (for example, accidents during the generation, transmission, distribution, and consumption of electricity);

– stage No. 3: determination of criteria for assessing the EcEf of investments, including return on investment; net reduced income; internal rate of return; payback period, as well as a system of indicators: energy consumption; CO_2 emissions, availability of reserve capacity;

– stage No. 4: collection of data necessary for the calculation of the evaluation of investments EcEf (for example, financial reports, technical characteristics of technological equipment of facilities of generation, transmission, distribution, and consumption of electricity);

– stage No. 5: carrying out calculations of return on investment (NPV), net REDUCED income (IRR), and payback period (T) with the help of derived calculation formulas to determine the indicators of EcEf;

– stage No. 6: evaluation and analysis of the results, by comparing the obtained indicators with the initial criteria and indicators in order to assess the overall effectiveness of the investment;

– stage No. 7: determination of management decisions regarding optimization of investment costs; risk reduction; increase of EcEf in the use of resources;

– stage No. 8: conducting continuous monitoring of EcEf of investment indicators, as well as analyzing the results and making corrections to the assessment methodology, based on new data and changes in the environment of the energy enterprise.

The development of stages in the formation of the assessment of EcEf of the investment project in the context of EnS is a systemic process consisting of eight key stages.

Each one fulfills its unique role in the comprehensive analysis of economic efficiency, providing a comprehensive approach to solving the problem of evaluating the energy efficiency of an investment project at energy enterprises.

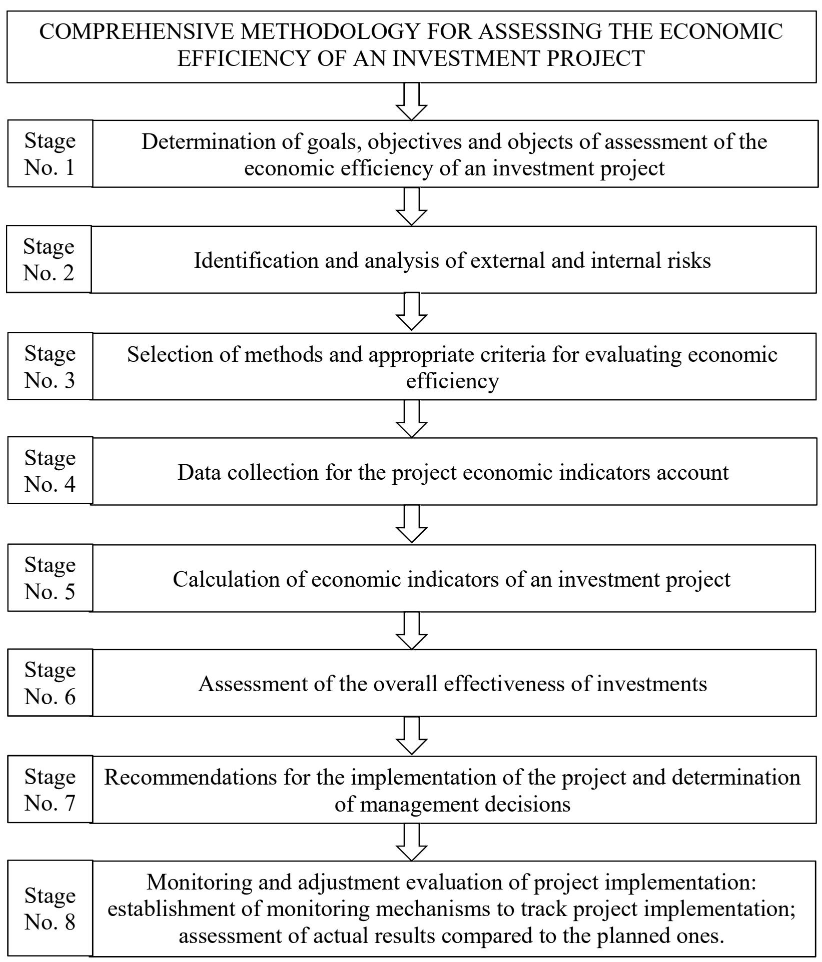

Fig. 1. Block diagram of stages in the methodology for assessing the economic efficiency of investment projects

Defining the goals and objects of evaluation makes it possible to focus efforts on the most critical aspects, such as new technologies and management decisions.

Identification of risks is a critically important stage, as risks can significantly affect the economic indicators of the project. This stage helps identify potential problems in the early stages, which helps to reduce negative consequences in the future.

Defining evaluation criteria is important for standardization of evaluation, provides clear indicators for comparison and analysis, which makes it possible to formalize evaluation approaches and make them transparent to stakeholders.

The collection of qualitative data ensures the reliability and accuracy of calculations and is the basis for further analyses, and the effectiveness of the assessment depends on their collection.

Calculation of economic indicators is a key stage at which the collected data are transformed into quantitative indicators.

This stage demonstrates the economic viability of the project and its profitability.

Estimating the overall economic efficiency of investments makes it possible to compare the results with predefined indicators, and also makes it possible to identify weak points and adjust the strategy in time.

Determination of management decisions – based on the analysis, this stage focuses on decision-making, on optimizing investments, reducing risks, and increasing the efficiency of resource use.

Recommendations are also formed here, which can significantly affect the success of the investment project.

Monitoring and adjustment ensures the dynamism of the EcEf of assessment process, makes it possible to adapt the strategy under the conditions of a changing external environment, which is especially important in the field of energy where risk factors can change quickly.

Thus, these stages are interrelated and provide a holistic view of the process of evaluating EcEf, which allows for the formation of a comprehensive methodology for evaluating the economic efficiency of investment projects in the field of energy security.

5. 2. Development of a computational algorithm for calculating the integral indicator of economic efficiency

In order to implement a comprehensive methodology for evaluating the EcEf of an investment project to ensure the level of EcEf of an enterprise, an algorithm for calculating the integral indicator of EcEf is proposed, which combines various aspects of EcEf (Fig. 2):

This algorithm allows for a comprehensive approach to assessing the economic efficiency of investment projects, ensuring consideration of all important factors and risks in the field of energy security [15].

The algorithm developed to assess economic efficiency and ensure energy security has several key features:

– the algorithm ensures continuous collection and updating of data on indicators of energy security threats, which allows prompt response to changes in the environment, such as fluctuations in energy prices, technical failures;

– the algorithm adapts to the detected threats, allowing regular adjustment of management decisions, which means that when new risks arise, the algorithm automatically suggests changes in the company's EnS management strategy;

– the algorithm uses statistical and machine learning methods to predict possible threats, which makes it possible to identify potential problems in advance and take preventive measures;

– the algorithm includes a multi-level approach to analysis, which allows taking into account both internal and external factors that affect EnS, and also provides a deeper understanding of risks;

– the algorithm is equipped with automated notification functions, which makes it possible to quickly inform the responsible person about the occurrence of threats or deviations from the norms, and also minimizes the reaction time to potential risks;

– the algorithm provides intuitive visualizations of current indicators and threats, which simplifies the decision-making process for experts;

– the algorithm collects data on the results of decisions made and their consequences, which allows for constant improvement of algorithms for various investment projects;

– the algorithm can be integrated with already existing management and automated monitoring systems.

Adding functionality to the algorithm for monitoring EcEf indicators to track threats and risks in real time is critically important for timely decision-making [16].

This algorithm not only optimizes management processes but also provides a systematic approach to the analysis of risks and threats arising in the dynamic environment of the energy sector

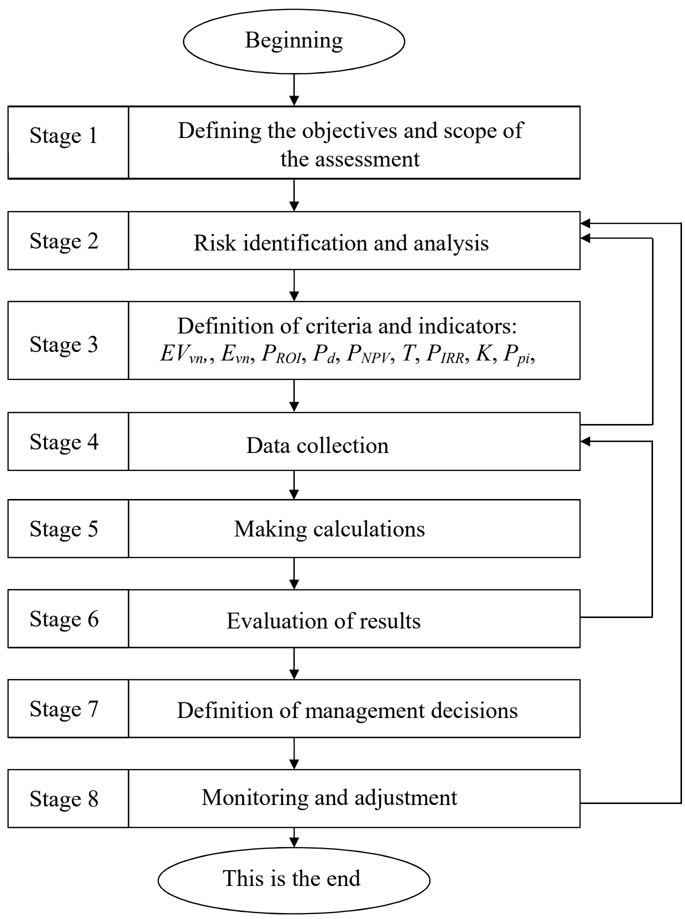

Fig. 2. Structural diagram of the algorithm for calculating indicators of the economic efficiency of an investment project

The integration of this algorithm in the software-computing systems of technological process automated control systems (TP ACS) at electricity generation facilities is an important step for increasing the economic efficiency of investment projects that ensure the energy security of electric power enterprises [17].

5. 3. Investigating results of the practical application of the comprehensive methodology for assessing the economic efficiency of an investment project

An assessment of the economic efficiency of the investment project was carried out, regarding the implementation of the accident prevention module (APM) as part of TP ACS at ZNPP power unit.

For this purpose, one can use the following initial data of the investment project:

– the average cost of one accident at ZNPP power unit: S_{avar}=150,000 USD;

– the frequency of accidents before the introduction of APM in TP ACS: N_{god}=10 accidents/year;

– the total number of accident prevention variations: N_{pr}=0÷10 accidents per year;

– investments regarding the implementation of APM in TP ACS: I_0=1500000 USD;

– discount rate: r=10 %;

– project term: n=5 years.

In accordance with the comprehensive methodology for evaluating EcEf, the selection of indicators for EcEf assessment of the investment project on the implementation of APM in TP ACS at ZNPP power unit was carried out. For this purpose, a unified calculation of the determination of costs before the implementation of APM in TP ACS is considered, according to expression (1):

$$\sum S_{avar} = S_{avar} \cdot N_{avar}, \tag{1}$$

where $\sum S_{avar}$ is the total economic costs of accidents per year (USD);

S_{avar} – average cost of one accident (USD);

N_{avar} – number of accidents per year (accident/year);

We have determined economic costs after the implementation of APM in TP ACS, according to expression (2):

$$\sum S_{avar/vn} = S_{avar/vn} \cdot N_{avar/vn}, \tag{2}$$

where $\sum S_{avar/vn}$ – total economic costs of accidents per year after the implementation of APM in TP ACS (USD);

$S_{avar/vn}$ – average cost of one accident after the implementation of APM in TP ACS (USD);

$N_{avar/vn}$ – number of accidents per year after the implementation of TP ACS APM (accidents/year);

We have determined savings from accident costs after the implementation of APM in TP ACS, according to expression (3):

$$E_{vn} = \left(S_{avar/vn} \cdot N_{avar/vn}\right) - \left(S_{avar} \cdot N_{avar}\right), \tag{3}$$

where E_{vn} is an indicator of savings from accident costs after the implementation of APM in TP ACS.

The quantitative indicator of net present value was calculated according to expression (4):

$$P_{NPV} = \sum_{t=1}^{n} \frac{E_{vn}}{(1+r)^t} - I_{in}, \tag{4}$$

P_{NPV} is a quantitative indicator of net present value;

r – discount rate;

n is the term of the project.

The return on investment indicator was calculated according to expression (5):

$$P_{ROI} = \frac{E_{vn} - I_{in}}{I_{in}} \cdot 100\,\%, \tag{5}$$

where P_{ROI} is the indicator of return on investment;

I_{in} – investments for the implementation of APM in TP ACS.

The net income indicator can be calculated using formula (6):

$$P_d = E_{vn} - I_{in}. \tag{6}$$

The cost reduction coefficient (K) was calculated according to expression (7):

$$K = \frac{E_{vn}}{S_{avar}}. \tag{7}$$

The profitability index (P_{pv}) was calculated according to expression (8):

$$P_{ip} = \frac{N_{pr} \cdot S_{avar} \sum_{t=1}^{n} \frac{1}{(1+r)^t}}{I_{iv}}, \tag{8}$$

where P_{ip} is the indicator of the project's profitability index.

Calculation of the payback period (this time required for the total savings to cover the cost of implementing APM in TP ACS is carried out in accordance with expression (9):

$$T_{so} = \frac{I_{in}}{E_{vn}}. \tag{9}$$

On the basis of analytical expressions (1) to (9), for the calculation of EcEf indicators, it is possible to draw a conclusion about how economically beneficial it was to implement APM in TP ACS to ensure the power unit's state of EnS.

The final results of calculations of EcEf indicators, which are performed according to expressions (1) to (9), are given in Table 1.

Table 1 shows how indicators of EcEf change depending on the number of accidents prevented (note: the data are presented in USD at the following exchange rate: USD equals UAH 40.0).

Based on the results of calculating the indicators of the economic efficiency of the innovative project (Table 1), plots (Fig. 3) of the dependence of these indicators on the number of accidents prevented ($N_{god/vn}$) were constructed after the implementation of APM in TP ACS at ZNPP power unit.

Fig. 3, *a* shows the plot of dependence of the internal rate of return (P_{IRR}) on the number of accidents prevented ($N_{god/vn}$). From the plot (Fig. 3, *a*), it can be seen that the profitability of the project begins to decrease sharply after ($N_{god/vn}$=4) accident prevention and is 5 %, which leads to an increase in losses, which means that the project becomes ineffective.

Fig. 3, *b* shows the plot of dependence of the net income indicator (P_d) on the number of accidents prevented ($N_{god/vn}$), where it can be seen that the net income of the project becomes positive only when 0 accidents are prevented. In all other cases, it is negative, which indicates that the costs of implementing the module exceed the savings from accident prevention.

Fig. 3, *c* shows the plot of dependence of the indicator of the net indicated value of the project (P_{NPV}) on the number of accidents prevented ($N_{god/vn}$). The plot (Fig. 3, *c*) demonstrates that for 43,264<P_{NPV}<289,314 USD, the project becomes inefficient and unprofitable.

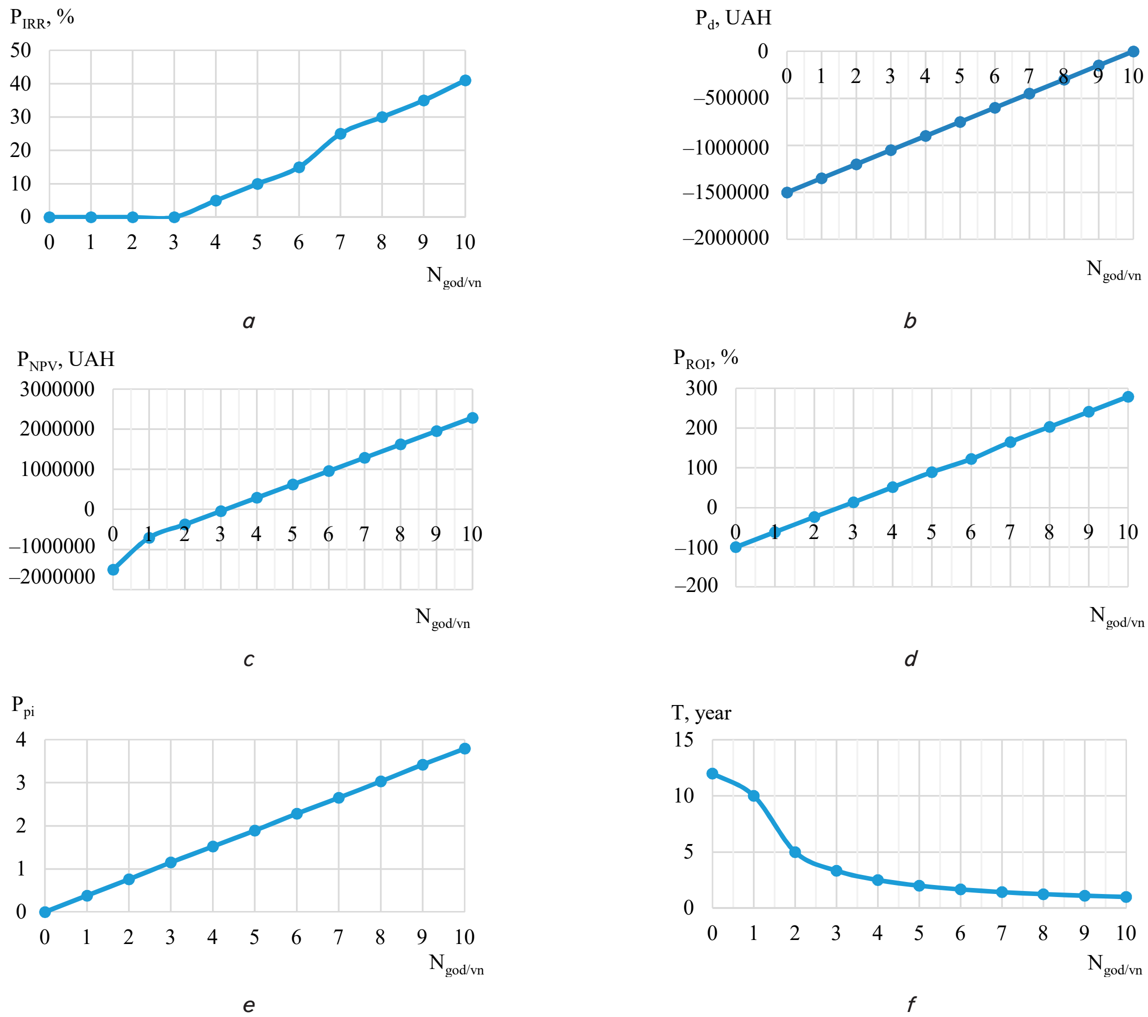

Fig. 3. Plots of dependence of economic efficiency indicators on the number of accidents prevented: *a* — indicator of the internal rate of return (P_{IRR}) on the number of accidents prevented ($N_{god/vn}$); *b* — indicator of net income (P_d) on the number of accidents prevented ($N_{god/vn}$); *c* — indicator of the net stated value of the project (P_{NPV}) on the number of accidents prevented ($N_{god/vn}$); *d* — the rate of return on investment (P_{ROI}) on the number of accidents prevented ($N_{god/vn}$); *e* — indicator of the profitability index (P_{pi}) on the number of accidents prevented ($N_{god/vn}$); *f* — indicator of the payback period (T) on the number of accidents prevented ($N_{god/vn}$)

Table 1

Final results of calculating the economic efficiency indicators

$N_{god/vn}$	EV_{vn} (UAH/year)	E_{vn} (UAH)	P_{ROI} (%)	P_d (UAH)	P_{NPV} (UAH)	T_{so} (year)	P_{IRR} (%)	K	P_{pi}
10	0	1,500,000	279	0.0	2,284,784	1.00	41 %	1.0	3.79
9	150,000	1,350,000	241	–150,000	1,952,206	1.11	35 %	0.9	3.42
8	300,000	1,200,000	203	–300,000	1,619,627	1.25	30 %	0.8	3.03
7	450,000	1,050,000	165	–450,000	1,287,049	1.43	25 %	0.7	2.65
6	600,000	900,000	122	–600,000	954,470	1.67	15 %	0.6	2.28
5	750,000	750,000	89	–750,000	621,892	2.00	10 %	0.5	1.89
4	900,000	600,000	51	–900,000	289,314	2.50	5 %	0.4	1.52
3	1,050,000	450,000	13	$-1.05\cdot10^6$	–43,264	3.33	0 %	0.3	0.96
2	1,200,000	300,000	–24	$-1.20\cdot10^6$	–375,842	5.00	0 %	0.2	0.76
1	1,350,000	150,000	–62	$-1.35\cdot10^6$	–708,421	10.00	0 %	0.1	0.38
0	1,500,000	0	–100	$-1.50\cdot10^6$	$-1.5\cdot10^6$	∞	0 %	0.0	0

Fig. 3, *d* shows the plot of dependence of the return on investment indicator (PROI) on the number of accidents prevented ($N_{god/vn}$). When $N_{god/vn}$=0, P_{ROI}=100 %, which means total loss. The rate of return on investment (P_{ROI}) becomes positive at $N_{god/vn}$=3, which indicates the feasibility of the investment. With an increase in the number of accidents prevented ($N_{god/vn}$), the P_{ROI} increases, reaching 279.12 % at $N_{god/vn}$=10, which indicates a high EcEf of the investment in the project. Fig. 3, *d* shows the plot of dependence of the profitability index indicator (P_{pi}) on the number of accidents prevented ($N_{god/vn}$). When $N_{god/vn}$=0, the profitability index is equal to P_{pi}=0. When $N_{god/vn}$=3, the index becomes less than 1 (P_{pi}=0.96), which indicates the feasibility and unprofitability of investments. As the number of accidents prevented increases, the profitability index increases, reaching a maximum of 3.79 ($N_{god/vn}$=10 accidents). Dependence of the payback period (T) on the number of accidents prevented ($N_{god/vn}$) is shown by the plot in Fig. 3, *f*.

Based on the data in Table 1, a diagram of the generalized integrated indicator of the economic efficiency of the investment project was drawn up (Fig. 4), which helps us draw several important conclusions:

– the biggest factor that affects the integrated indicator of EcEf of the investment project is the accident prevention number ($N_{god/vn}$). So, for the value of $N_{god/vn}$<4, the indicator of the net stated value of the project has a negative value (P_{NPV}=–43,264 USD), therefore, it can be concluded that the project becomes inefficient and unprofitable, and also indicates the impracticality of investments;

– the possibility of identifying critical points where EcEf begins to noticeably increase or decrease (for example, point 4.4 of the year, where the indicator of the net stated value of the project sharply drops from P_{NPV}=289,314 to P_{NPV}=–43,264 USD.

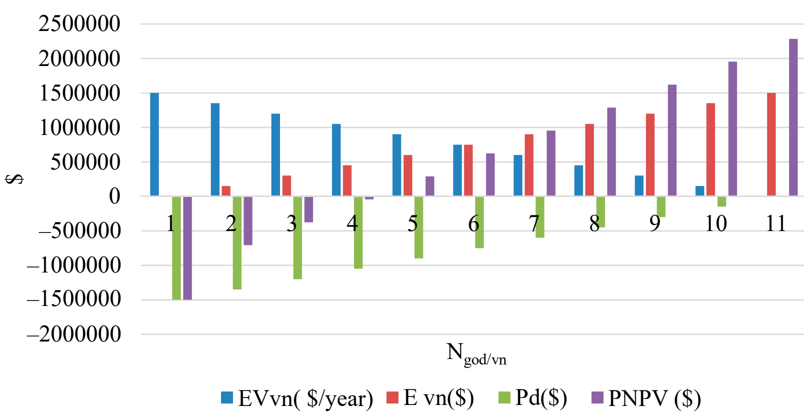

Fig. 4. Diagram of the integrated indicator of the economic efficiency of an investment project

In accordance with the devised methodology, an assessment of the overall efficiency of investments was carried out. To this end, an analysis of the results of the calculation of the energy efficiency indicators of the investment project (Table 1, plots in Fig. 3) and their impact on energy security was carried out, taking into account the variation of the total number of accidents prevented (N=0÷10) at ZNPP power unit:

1. At $N_{god/vn}$=10, the project prevents 100 % of accidents, while ensuring maximum energy security and significant financial benefits. High economic efficiency was achieved due to the profitability of the project equal to 41 %.

2. With $N_{god/vn}$=9, the project reduces the number of accidents by 90 %, and also significantly reduces costs and risks. Energy security remains at a high level. A good EcEf was achieved due to the profitability of the project, which is equal to 35 %.

3. At $N_{god/vn}$=8, the project prevents 80 % of accidents, which ensures a high level of EnS, but with lower profits. EcEf at project profitability equals 30 %.

4. At $N_{god/vn}$=7, the project prevents 70 % of accidents, which increases the cost of eliminating risks. Low EcEf, as the profitability of the project is equal to 25 %.

5. At $N_{god/vn}$=6, the project reduces the number of accidents by 60 %, which leads to an increase in losses, which means that the project becomes ineffective. In addition, it leads to an increase in risks and the threat of EnS. Low EcEf, as the profitability of the project is 15 %.

6. At $N_{god/vn}$=5, the project reduces the number of accidents by 50 % but becomes unprofitable and ineffective. At the same time, the costs and threats of EnS are increasing. Low EcEf, as the project's profitability is 10 %.

7. At $N_{god/vn}$=4, the project reduces the number of accidents by 40 %, but does not make a profit, and the risk of accidents remains high. Critically low economic efficiency, as the profitability of the project is 5 %.

8. At $N_{god/vn}$=3, the project reduces the number of accidents by 30 %, but becomes critically inefficient, which creates serious risks for energy security.

9. At $N_{god/vn}$=2, the project reduces the number of accidents by 20 %, but it is not expedient. Damages are increasing and energy security is under threat.

10. When $N_{god/vn}$=1, the project reduces the number of accidents by 10 %, the System does not provide sufficient EnS, which can lead to serious incidents.

11. When $N_{god/vn}$=0, the project is completely ineffective, as it does not provide accident prevention, which leads to serious financial losses and threatens energy security.

Thus, the economic efficiency of the investment project regarding the implementation of APM in TP ACS, even with the prevention of two accidents out of ten, is profitable in five years. This follows from the data reported in [18–20], which indicate that the average cleanliness of accidents that occur at NPP is 2<$N_{god/vn}$<3 per year, which makes this project feasible.

6. Discussion of results related to devising a comprehensive methodology for assessing the level of economic efficiency of an industrial energy enterprise

A comprehensive methodology for assessing the level of energy efficiency of an investment project of energy enterprises has been devised, which, unlike previous studies [21–24], in which the assessment of economic efficiency was reduced to fixed indicators, allows for an adaptive response to changes in energy security.

We have developed eight stages of a comprehensive methodology for assessing the economic efficiency of an investment project, the block diagram of which is shown in Fig. 1. These stages are interconnected and allow for the following:

– provide a holistic view of the process of comprehensive evaluation of EcEf of investment projects in the field of energy security of enterprises;

– focus efforts on the most critical aspects, such as management decisions;

– ensure the reliability and accuracy of calculations of economic indicators for the evaluation of EcEf;

– to optimize investments by reducing risks and increasing the efficiency of resource use;

– adapt the strategy under the conditions of a changing external environment, which is especially important for energy companies, where risk factors can change quickly.

In order to implement a comprehensive methodology for evaluating EcEf of an investment project and ensuring the level of EnS of the enterprise, an algorithm for calculating the integral indicator of EcEf is proposed, the structural block diagram of which is shown in Fig. 2.

This algorithm made it possible to ensure:

– continuous collection and updating of data on indicators of energy security threats, which allows prompt response to changes in the environment, such as fluctuations in energy prices, technical failures;

– monitoring of threats and risks in real time, which is critically important for energy security management processes of enterprises;

– the integration of this algorithm in software-computing systems of the automated system for managing technological processes of power generation, transmission, and distribution facilities.

In our work, an evaluation of EcEf of the investment project was performed, regarding the implementation of an accident prevention module as part of TP ACS at ZNPP power unit, on the basis of the proposed comprehensive methodology for evaluating the investment project's energy efficiency. Based on the results of the calculation of EcEf indicators (Table 1), which was performed according to expressions (1) to (9), plots (Fig. 3) of the dependence of these indicators on the number of accidents prevented were drawn. Analysis of the plots revealed that the implementation of the investment project is appropriate when the number of accidents decreases from 100 % to 40 %, as costs and risks are significantly reduced. With the number of accident prevention $N_{god/vn}$=3, the project reduces the number of accidents by 30 %, but becomes critically inefficient, which creates serious risks for the energy security of enterprises.

With the help of the diagram of the integrated indicator EcEf (Fig. 4), it is possible to identify critical points where EcEf begins to noticeably increase or decrease (for example, point 4.4 of the year, where the P_{NPV} indicator drops sharply).

The assessment of the economic efficiency of an investment project may be limited by insufficient accuracy of the initial data, especially under difficult or unstable market conditions. In addition, the proposed methodology may be somewhat universal, and in some cases may not fully take into account the specificity of specific energy enterprises, their technological process (for example, generation, transmission, and distribution of electricity). Rapid changes can complicate the process of adapting strategies and calculating indicators of economic efficiency of an investment project.

During the implementation of an investment project, problems with initial calculations may arise, due to which energy resources may be used inefficiently in the first stages of the project, which leads to additional costs. These shortcomings may limit the effectiveness and practical application of the proposed methodology under real conditions, and they should be taken into account during its implementation and further improvements.

As a disadvantage, it is possible to note the difficulty of integrating the proposed algorithm into existing ACSs of energy companies. Real integration into the software-computing systems of TP ACS at enterprises may require considerable effort and time.

7. Conclusions

1. Eight stages of a comprehensive methodology for the formation of an assessment of the economic efficiency of an investment project have been defined, which made it possible to identify and analyze risks, determine criteria and indicators, as well as perform calculations of key economic indicators, which made it possible to objectively evaluate the investment project. The resulting stages of economic efficiency assessment ensure not only the systematization of approaches but also form the basis for making management decisions. Detection of accidents in real time significantly reduces the probability of serious incidents, which, in turn, leads to a reduction in financial losses and threats to energy security.

2. A computational algorithm has been developed, which is integrated into the economic efficiency assessment system, by implementing a comprehensive methodology for assessing the economic efficiency of the investment project to ensure the level of energy security of the enterprise. The algorithm adapts to the detected threats, which makes it possible to regularly adjust management decisions, optimizing the company's energy security management strategies. This not only increases the accuracy of performance evaluation but also makes the management process more flexible and adaptive. This algorithm makes it possible to identify potential problems in advance and implement preventive measures, which increases the overall economic efficiency of the investment project. Thus, the algorithm becomes an important tool for assessing risks and opportunities arising in the process of project implementation.

3. As part of the study of the results of the practical application of the comprehensive methodology for evaluating EcEf of investment projects regarding the implementation of APM in the control system at ZNPP power unit, it was found that the level of EcEf directly depends on the frequency of power unit accidents. The implementation of APM in TP ACS at ZNPP has a significant positive impact on the enterprise's economic indicators. According to our calculations, after returning the investment of USD 1,500,000, the profit is expected to increase to USD 900,000 per year. This indicates a positive financial effect from the implementation of the module, which makes the investment worthwhile.

Conflicts of interest

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

Funding

The study was conducted without financial support.

Data availability

All data are available, either in numerical or graphical form, in the main text of the manuscript.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

References

1. Chang, Y., Liu, C., Liu, M., Liu, W., Liu, Z., Zhang, H., Zheng, Y. (2019). Differentiation degree combination weighting method for investment decision-making risk assessment in power grid construction projects. Global Energy Interconnection, 2 (5), 465–477. https://doi.org/10.1016/j.gloei.2019.11.022
2. Erfani, A., Tavakolan, M. (2020). Risk Evaluation Model of Wind Energy Investment Projects Using Modified Fuzzy Group Decision-making and Monte Carlo Simulation. Arthaniti: Journal of Economic Theory and Practice, 22 (1), 7–33. https://doi.org/10.1177/0976747920963222
3. Wei, Y.-M., Qiao, L., Jiang, S.-M., Lv, X. (2020). A decision-making approach considering technology progress for investment in oil sands projects: An empirical analysis in Canada. Journal of Petroleum Science and Engineering, 195, 107741. https://doi.org/10.1016/j.petrol.2020.107741
4. Camanho, A. S., Silva, M. C., Piran, F. S., Lacerda, D. P. (2024). A literature review of economic efficiency assessments using Data Envelopment Analysis. European Journal of Operational Research, 315 (1), 1–18. https://doi.org/10.1016/j.ejor.2023.07.027
5. Sassanelli, C., Rosa, P., Rocca, R., Terzi, S. (2019). Circular economy performance assessment methods: A systematic literature review. Journal of Cleaner Production, 229, 440–453. https://doi.org/10.1016/j.jclepro.2019.05.019
6. Joppen, R., Kühn, A., Hupach, D., Dumitrescu, R. (2019). Collecting data in the assessment of investments within production. Procedia CIRP, 79, 466–471. https://doi.org/10.1016/j.procir.2019.02.126
7. Fuster-Palop, E., Prades-Gil, C., Masip, X., Viana-Fons, J. D., Payá, J. (2021). Innovative regression-based methodology to assess the techno-economic performance of photovoltaic installations in urban areas. Renewable and Sustainable Energy Reviews, 149, 111357. https://doi.org/10.1016/j.rser.2021.111357
8. Gong, Y., Gu, W., Ren, W. (2022). Green Energy Economic Efficiency and Enterprise Environmental Cost Control Based on the Internet of Things. Security and Communication Networks, 2022, 1–12. https://doi.org/10.1155/2022/6824493
9. Pylypenko, Y., Pylypenko, H., Prokhorova, V. V., Mnykh, O. B., Dubiei, Yu. V. (2021). Transition to a new paradigm of human capital development in the dynamic environment of the knowledge economy. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 6, 170–176. https://doi.org/10.33271/nvngu/2021-6/170
10. Prokhorova, V., Protsenko, V., Abuselidze, G., Mushnykova, S., Us, Yu. (2019). Safety of industrial enterprises development: evaluation of innovative and investment component. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 5. https://doi.org/10.29202/nvngu/2019-5/24
11. Prokhorova, V., Protsenko, V., Bezuglaya, Y., Us, J. (2018). The optimization algorithm for the directions of influence of risk factors on the system that manages the potential of machine-building enterprises. Eastern-European Journal of Enterprise Technologies, 4 (1 (94)), 6–13. https://doi.org/10.15587/1729-4061.2018.139513
12. Shibaeva, N., Baban, T., Prokhorova, V., Karlova, O., Girzheva, O., Krutko, M. (2019). Methodological bases of estimating the efficiency of organizational and economic mechanism of regulatory policy in agriculture. Global Journal of Environmental Science and Management, 5, 160–171. https://doi.org/10.22034/gjesm.2019.05.SI.18
13. Pylypenko, H. M., Prokhorova, V. V., Mrykhina, O. B., Koleshchuk, O. Y., Mushnykova, S. A. (2020). Cost evaluation models of R&D products of industrial enterprises. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 5, 163–170. https://doi.org/10.33271/nvngu/2020-5/163
14. Babenko, V., Baksalova, O., Prokhorova, V., Dykan, V., Ovchynnikova, V., Chobitok, V. (2021). Information And Consulting Service Using In The Organization Of Personnel Management. Studies of Applied Economics, 38 (4). https://doi.org/10.25115/eea.v38i4.3999
15. Hendren, N. (2020). Measuring economic efficiency using inverse-optimum weights. Journal of Public Economics, 187, 104198. https://doi.org/10.1016/j.jpubeco.2020.104198
16. Lv, L., Chen, Y. (2024). The Collision of digital and green: Digital transformation and green economic efficiency. Journal of Environmental Management, 351, 119906. https://doi.org/10.1016/j.jenvman.2023.119906
17. Prokhorova, V., Budanov, M., Budanov, P. (2024). Devising an integrated methodology for energy safety assessment at an industrial power-generating enterprise. Transfer of Technologies: Industry, Energy, Nanotechnology, 4 (13 (130)), 118–131. https://doi.org/10.15587/1729-4061.2024.308056
18. Cui, X., Zou, P. X. W., Arena, M. (2024). An innovative methodology for assessing the safety of logistics infrastructure considering carrying capacity and catastrophe property of accidents. Transport Policy, 159, 178–189. https://doi.org/10.1016/j.tranpol.2024.10.015
19. Qian, X., Dai, J., Jiang, W., Cai, H., Ye, X., Shahab Vafadaran, M. (2024). Economic viability and investment returns of innovative geothermal tri-generation systems: A comparative study. Renewable Energy, 226, 120396. https://doi.org/10.1016/j.renene.2024.120396
20. De Pascale, A., Arbolino, R., Szopik-Depczyńska, K., Limosani, M., Ioppolo, G. (2021). A systematic review for measuring circular economy: The 61 indicators. Journal of Cleaner Production, 281, 124942. https://doi.org/10.1016/j.jclepro.2020.124942
21. Brockway, P. E., Sorrell, S., Semieniuk, G., Heun, M. K., Court, V. (2021). Energy efficiency and economy-wide rebound effects: A review of the evidence and its implications. Renewable and Sustainable Energy Reviews, 141, 110781. https://doi.org/10.1016/j.rser.2021.110781
22. Sadeghi, S., Ghandehariun, S., Rosen, M. A. (2020). Comparative economic and life cycle assessment of solar-based hydrogen production for oil and gas industries. Energy, 208, 118347. https://doi.org/10.1016/j.energy.2020.118347
23. Ahmad, M., Ahmed, Z., Majeed, A., Huang, B. (2021). An environmental impact assessment of economic complexity and energy consumption: Does institutional quality make a difference? Environmental Impact Assessment Review, 89, 106603. https://doi.org/10.1016/j.eiar.2021.106603
24. Zakari, A., Khan, I., Tan, D., Alvarado, R., Dagar, V. (2022). Energy efficiency and sustainable development goals (SDGs). Energy, 239, 122365. https://doi.org/10.1016/j.energy.2021.122365