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Recent methods of urban development and the principles of stability and efficient use of energy resources

Anastasiia TSYBULIAK *[1], Nataliia GAVKALOVA [2], Olena SHERSHENIUK [3], Liudmyla SHVORAK [4], Oleksandr SALIUK-KRAVCHENKO [5]

[1] Ukrainian-American Concordia University, Kyiv, Ukraine.
[2] Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine.
[3] Kharkiv National Automobile and Highway University, Kharkiv, Ukraine.
[4] Taras Shevchenko National University of Kyiv, Kyiv, Ukraine.
[5] Interregional Academy of Personnel Management, Kyiv, Ukraine.
*Email: anastasiia.tsybuliak@ujis.in.ua

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ABSTRACT: The article analyzes the role of sustainable economic development in shaping the energy security policy of Central and Eastern European countries, exploring the relationship between stable access to energy resources and economic progress. The issue of energy security is of particular importance in the context of resource depletion, geopolitical instability, and climate change, which exacerbate countries' dependence on energy imports. The aim is to study the peculiarities of forming a flexible energy security policy, assess its impact on sustainable economic development, and develop recommendations for minimizing energy risks. The analytical method is used to decompose the concept of energy security into components and assess their impact on the economy, as well as the comparative method to compare the energy policies of the countries of the region. The least-squares method was used to analyze the financial performance of 20 energy projects, which made it possible to assess the effectiveness of investments. The analysis revealed that the lack of investment, insufficient staff qualifications, and external threats significantly affect energy security, leading to supply disruptions and economic losses. Indicators for assessing the state of energy systems are proposed, which have shown gradual improvement due to diversification and energy efficiency. The regression model confirmed the dependence of project costs on management and resources. Further research could focus on improving energy risk forecasting models, analyzing the impact of digital technologies on energy efficiency, and developing regional strategies for integrating renewable energy sources.
Keywords: sustainable development; energy security; energy policy; Central and Eastern Europe; energy investments; energy efficiency.

Métodos recentes de desenvolvimento urbano e os princípios da estabilidade e da utilização eficiente dos recursos energéticos

RESUMO: Este artigo analisa o papel do desenvolvimento econômico sustentável na formulação da política de segurança energética dos países da Europa Central e Oriental, explorando a relação entre o acesso estável aos recursos energéticos e o progresso econômico. A questão da segurança energética assume particular importância no contexto da escassez de recursos, da instabilidade geopolítica e das mudanças climáticas, que exacerbam a dependência dos países em relação às importações de energia. O objetivo é estudar as peculiaridades da formulação de uma política flexível de segurança energética, avaliar seu impacto no desenvolvimento econômico sustentável e elaborar recomendações para minimizar os riscos energéticos. O método analítico é utilizado para decompor o conceito de segurança energética em componentes e avaliar seu impacto na economia, enquanto o método comparativo é utilizado para comparar as políticas energéticas dos países da região. O método dos mínimos quadrados foi utilizado para analisar o desempenho financeiro de 20 projetos energéticos, permitindo avaliar a eficácia dos investimentos. A análise revelou que a falta de investimento, a qualificação insuficiente da equipe e as ameaças externas afetam significativamente a segurança energética, levando a interrupções no fornecimento e perdas econômicas. São propostos indicadores para avaliar o estado dos sistemas energéticos, que têm demonstrado uma melhoria gradual devido à diversificação e à eficiência energética. O modelo de regressão confirmou a dependência dos custos do projeto em relação à gestão e aos recursos. Pesquisas futuras poderiam se concentrar em aprimorar os modelos de previsão de risco energético, analisar o impacto das tecnologias digitais na eficiência energética e desenvolver estratégias regionais para a integração de fontes de energia renováveis.
Palavras-chave: desenvolvimento sustentável; segurança energética; política energética; Europa Central e Oriental; investimentos em energia; eficiência energética.

1. INTRODUCTION

At the end of the twentieth century, the international community focused on the study of globalization processes, which largely determined the economic and political dynamics of the world community. However, at the beginning of the twenty-first century, there was a significant shift in priorities: the rapid depletion of natural resources, growing instability of energy supplies, and increased competition for access to energy sources made states realize the critical importance of developing an effective energy security policy. From now on, this problem is considered not only within national borders but as a key factor in the global agenda that requires coordinated action by all members of the world community, including governments, international organizations, integration structures, and research institutions (IRENA, 2024).

The urgency of modern energy challenges is due to several interrelated economic, political and environmental factors, among which a special place is occupied by the problem of individual countries' dependence on energy imports. The shortage of oil, the threat of depletion of easily accessible reserves and, as a result, the intensification of geopolitical struggle for resources lead to growing instability in international energy markets and increased risks to the energy security of states.

This situation forces states to look for new sources of supply, develop hard-to-reach territories, invest in innovative technologies, and revise economic strategies towards energy efficiency, including for Central and Eastern European (CEE) countries (ROSIEK, 2024). In this context, sustainable economic development is not only a concept that combines economic efficiency with social justice, but also a fundamental basis for the formation of a long-term, balanced energy security policy that takes into account both the needs of present and future generations.

2. LITERATURE REVIEW

In the context of studying the country's energy security policy and its impact on sustainable economic development, modern scholarship emphasizes that ensuring stable access to energy resources is critical to maintaining economic growth, social stability, and environmental balance in the face of global challenges such as climate change, geopolitical conflicts, and technological transformation. Leading researchers, in particular Artyushok et al. (2023) and Dirma et al. (2024), draw attention to systemic approaches to energy policy making, emphasizing that its effectiveness depends on the country's ability to adapt to external threats, such as energy supply disruptions or price fluctuations in world markets, as well as on internal factors, including infrastructure readiness and technological progress.

Atstaja et al. (2022), Fortea et al. (2024) and Khan et al. (2024) note that countries that rely on a monoculture of energy resources, such as fossil fuels, become vulnerable to market fluctuations, while the introduction of renewable energy sources, such as solar or wind, contributes not only to economic stability but also to environmental safety, which is the basis for sustainable development.

Infrastructure plays an equally important role in shaping energy security policy, as its development, as Kim et al. (2025) and Wójtowicz (2024) note, is a prerequisite for the efficient distribution of energy resources, business support, and meeting the needs of the population, which directly affects economic productivity and social stability.

Dykha et al. (2024) and Hadfield; Demir (2024), for example, emphasize that energy security is a complex concept that depends on the context, from the geographical location of the country to its economic priorities, which requires flexible approaches to its implementation. The characteristic ambiguity stimulates further research aimed at developing models that would take into account both local and global factors influencing energy policy, in the XX century. Firlej et al. (2024), Idroes et al. (2024) and Kovalko et al. (2022), analyzing the trajectories of energy systems, emphasized that deviations from the planned course, for example, due to external sanctions or natural disasters, can destabilize the economy, emphasizing the importance of redundancy and planning in energy policy.

A different view of energy security is offered by Llorca; Rodriguez-Alvarez (2024), and Zeng et al. (2024), who argue that energy systems are often vulnerable to internal and external shocks, and their mathematical modeling is difficult due to the unpredictability of factors such as terrorist attacks or technological failures, which requires countries to develop adaptive strategies. At the same time, Zahir et al. (2025), studying macroeconomic aspects, identified criteria by which energy security can support economic development, in particular through the integration of renewable sources and reduced dependence on imports. Among the researchers, Gavkalova et al. (2025) and Zakari; Musibau (2023) made a significant contribution to the understanding of energy security by analyzing how quantitative and qualitative factors, such as production volumes or the level of training, affect the ability of the energy sector to support economic processes under external pressure.

Modern authors, such as Borodina et al. (2022) and Mogoș et al. (2024), emphasize that an effective energy policy to form an energy security dome should take into account both external factors, such as sanctions or climate change, and internal factors, such as innovation and risk management, as this affects the country's ability to achieve economic goals in the short and long term. Despite the absence of a single approach, the authors agree that energy security is the foundation of economic progress, requiring continuous improvement of strategies to ensure sustainability in the face of current challenges.

The purpose of the article is to study the peculiarities of formulating and implementing a flexible energy security policy in the countries of Central and Eastern Europe.

2. RESEARCH METHODOLOGY

The article uses an analytical method to decompose the concept of energy security into components (security of supply, diversification, energy efficiency) and assess the level of impact on economic processes, which allowed for the identification of key threats and the development of strategic recommendations. The comparative method focuses on comparing the energy policies of Central and Eastern European countries, analyzing their indicators (production, imports, infrastructure) and identifying best practices that promote sustainable development, ensuring a comprehensive approach to effective energy security. To assess the level of development of energy projects, the least squares method was used as the most reliable and accurate statistical tool, which allowed for a comprehensive analysis of financial indicators obtained from 20 implemented or planned energy projects in CEE countries that are key to regional energy security. This created methodological prerequisites not only for assessing the impact of individual factors on the level of costs, but also for making reasonable forecasts of potential costs in future similar energy initiatives.

4. RESULTS

4.1. Problems of forming energy security of the state

The analysis of scientific sources on energy security in the context of sustainable economic development has made it possible to specify the content of the concept of "energy security", which is now considered an independent component of national security, covering a set of conditions under which the reliability, continuity and stability of the functioning of all participants in the energy system, from producers and transmitters to distributors and end users of energy, is ensured at the micro, meso and macro levels in the context of protection against internal and external threats (Table 1). Particularly noteworthy is the fact that for energy consumers, in particular in the context of dynamic economic development, the main threat is power outages, which can lead not only to disruptions in the daily activities of the population, but also to disruption of the normal functioning of critical infrastructure (EMBER, 2024). In turn, for companies in the fuel and energy sector, energy security risks take the form of increased artificial threats, lower quality of energy supply, increased accidents and disruptions in production processes, which creates a chain reaction of negative consequences for consumers and the economy as a whole (MAKEDON, et. al., 2024).

To timely identify such threats and prevent critical situations in the field of energy supply, we will study the specifics for several Central and Eastern European countries, especially in the context of the implementation of sustainable economic development goals, using an indicative approach to assessing the state of energy security, which involves the identification of several parameters and key indicators characterizing the current level of development of these countries and the stability of their fuel and energy complex, its structural subsystems and individual facilities (ANDRIYIV et al., 2022).

Table 1. Threats to energy security and their impact on sustainable economic development.
Tabela 1. Ameaças à segurança energética e o seu impacto no desenvolvimento económico sustentável.

Threat to energy security	Cause of the threat	Threat to the sustainable operation of fuel and energy sector enterprises	The threat to energy consumers in the context of sustainable development
Lack of investments in the modernization of the main production assets of the fuel and energy sector	Low investment attractiveness of the industry due to the lack of its own financial resources and high debt of fuel and energy companies	Increase in accidents; deterioration of energy quality; increase in energy losses during transportation	Interruptions in power supply, disruption of production stability, and reduced economic efficiency
Limited opportunities to attract financing by FEC organizations, including external financing	An imperfect regulatory framework and peculiarities of the organizational structure	Slowdown in the pace of modernization, replacement and renewal of energy equipment; increase in operating costs	Unstable electricity supply, rising tariffs, which complicate access to energy resources
Insufficient level of training of highly qualified personnel for the FEC	Limited academic exchange of experience with leading experts in the energy sector	Unstable operation of energy facilities due to the human factor, resulting in increased accidents	Power outages and inefficient use of resources contradict the principles of sustainability
Sabotage and terrorist acts (including the use of information technology) at energy facilities	Insufficient system of protection of energy facilities and a low level of training of fuel and energy complex specialists	Disruption of the technological cycle; failure to fulfill obligations to consumers; risk of significant financial losses	Power outages, the threat of energy shortages that undermine energy security

Source: compiled by the author.
Fonte: compilada pelo autor.

Such a model can help not only to quantify changes in security levels, but also to trace the territorial differentiation of threats, the depth of their penetration into the economic system, and the degree of influence on key sectors that are crucial for national development. We can propose a system of eleven basic indicators, grouped into areas that reflect the most important aspects of energy security for Central and Eastern European countries (JĘDRZEJCZAK-GAS et al., 2024). To facilitate analysis and management decisions, all these indicators are classified by threat levels, which are designated as critical (C), pre-critical (PC), and normal (N), which allows for an objective assessment of both the general state of the power system and the dynamics of its changes in the context of the sustainable development strategy (Table 2).

In the current conditions of increasing complexity of global energy processes, the assessment of the investment attractiveness of the energy sector should be based primarily on the analysis of the real conditions for the implementation of large-scale investment projects in the fuel and energy complex (FEC), which, in turn, requires improving methods for assessing investments, risks and efficiency of project implementation in accordance with the strategic objectives of energy security of CEE countries (MAKEDON et al., 2021).

A key stage in the process of formulating strategic scenarios for the development of the energy sector, which should be focused on achieving a high level of energy security, should be the development of a set of management measures aimed at minimizing the negative impact of energy threats on the living standards of the population, since ensuring stable access to energy resources of high quality and at an affordable price is the foundation for achieving social welfare and economic stability (United Nations Department of Economic and Social Affairs, 2024).

Table 2. Energy Security Indicators in the Context of Sustainable Economic Development and Their Dynamics for Central and Eastern Europe.
Tabela 2. Indicadores de segurança energética no contexto do desenvolvimento económico sustentável e da sua dinâmica na Europa Central e Oriental.

Name of the indicator	Retrospective		The nearest future		Perspective	
	2010	2015	2025	2027	2030	2035
Energy independence						
Ratio of primary energy production to total primary energy consumption	C	C	PC	PC	PC	PC
Share of renewable energy sources in the structure of primary energy consumption	C	C	PC	PC	PC	PC
Diversification of suppliers and types of energy resources						
Share of the dominant supplier in total energy imports	C	C	C	PC	PC	PC
Share of one type of fuel in the structure of total energy consumption	PC	PC	PC	PC	PC	N
Reliability of supply, reserves, processing and distribution of fuel and energy resources						
The ratio of the total installed capacity of power plants to the maximum load in the power system (reserve level)	PC	PC	N	N	N	N
The share of accumulated depreciation in the initial cost of fixed assets of the fuel and energy complex	PC	PC	N	N	N	N
The amount of investments in the development of the fuel and energy sector, relative to the initial cost of fixed assets	N	N	N	N	N	N
Share of the dominant energy resource (natural gas) in heat and electricity generation	C	C	PC	PC	N	N
The ratio of the number of power outages to the total number of settlements	N	N	N	N	N	N
Energy efficiency of final consumption in the fuel and energy sector and economic sustainability of the fuel and energy sector						
Energy intensity of GDP, kg of fuel equivalent/million euros	PC	PC	PC	PC	PC	PC
Share of energy imports in the GDP structure, %.	PC	PC	PC	PC	PC	N

Source: compiled by the author.
Fonte: compilada pelo autor.

4.2. Priorities and peculiarities of energy security in Central and Eastern Europe

An analysis of current research and official documents shows that the issue of energy security is currently at the forefront of political discourse and strategic planning in the European Union, including in Central and Eastern Europe, as it directly affects the pace and sustainability of their economic development. The global challenges of recent years, in particular the COVID-19 pandemic and Russia's full-scale war against Ukraine, have significantly exacerbated the existing vulnerabilities in the energy policies of the countries of the region and emphasized the urgent need to develop effective mechanisms to ensure energy sustainability at all levels - from national to regional and supranational.

Given the EU's high dependence on imported energy, which currently accounts for about 50% of total consumption and, if current trends continue, could increase to 70% by 2030, Central and Eastern European countries are in an extremely vulnerable position, forcing them to rethink traditional energy consumption patterns and develop long-term approaches to reducing dependence on one supplier or one type of energy (UNITED NATIONS REGIONAL COMMISSIONS, 2024). It should be emphasized that the security of supply policy does not necessarily aim at full energy autonomy or complete independence from external sources, but rather aims to reduce the associated risks by diversifying geographical and technological sources of supply, developing renewable energy sources, and integrating innovative solutions into the energy infrastructure (KOVAL et al., 2023).

A review of the national energy and climate strategic plans of EU countries has shown that, despite the difference in priorities, most Central and Eastern European countries share common goals, among which the key ones are to increase the reliability of energy supply, stimulate the development of domestic energy potential, and gradually introduce energy-efficient solutions (EURELECTRIC, 2024; ROBERTS; BOWDEN, 2024). Based on the results of the classification of approaches to energy security, three dominant areas can be distinguished: the diversification approach, the interdependence approach, and the institutional approach (Figure 1).

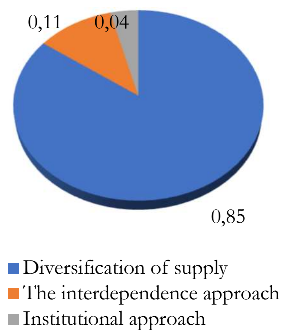

Figure 1. Approaches to solving energy security problems in the European Union.
Source: crested by the author based on EMBER (2024)
Figura 1. Abordagens para resolver os problemas de segurança energética na União Europeia.
Fonte: elaborado pelo autor com base em EMBER, (2024)

The most common among them is the approach of diversifying supply sources, which is used by 85% of EU member states, including most of the Central and Eastern European countries (DOUGLAS et. al., 2024). This approach involves active work on finding alternative energy sources, modernizing the technological base, deregulating the market, attracting international investment, and integrating energy market players to achieve a common goal to reduce energy risks and ensure system resilience. The other two approaches - interdependence (professed by only 11% of countries) and institutional (only 4%) – are less actively used, which indicates a reorientation of the strategic focus from institutional consolidation to the practical implementation of infrastructure and market transformations (KOUKOUFIKIS et al., 2024). In particular, the low interest in the institutional approach is due to the fact that the EU's organizational and legal framework has already been formed, and further complication of management procedures may slow down the efficiency of crisis response.

4.3. Modeling and evaluation of the efficiency of prospective energy projects in the territory of Central and Eastern Europe

As part of a study focused on sustainable economic development and its key role in shaping an effective energy security policy, the analytical focus was shifted to real-world statistical materials covering a wide range of infrastructure and technological energy initiatives implemented in Central and Eastern Europe (Hobhouse, 2025). All projects, which differ in their scale, level of technological implementation, sectoral specialization, and geographic location, cover both new construction of energy facilities, including renewable energy sources, and modernization of existing infrastructure, including reconstruction of power grids, development of LNG terminals, expansion of storage facilities, and introduction of digital control systems (Table 3) (OSUMA; YUSUF, 2025).

Table 3. Promising energy projects (EUR million) in Central and Eastern Europe to increase energy security
Tabela 3. Projetos energéticos promissores (em milhões de euros) na Europa Central e Oriental para aumentar a segurança energética.

№	Energy project	Current selling expenses	Management expenses	Additional operating expenses	Core collateral resources	Expected revenues from implementation	Available provisions	Total economic efficiency	Long-term investment needs
		Y	*X1*	*X2*	*X3*	*X4*	*X5*	*X6*	*X7*
1	Construction of a wind power plant in Poland	1200	300	150	800	2000	500	1250	1000
2	Modernization of hydropower plants in Romania	950	250	100	600	1800	400	1100	850
3	Expansion of a solar power plant in Bulgaria	800	200	120	500	1500	350	950	700
4	Construction of an LNG terminal in Croatia	1500	400	200	1000	2500	600	1600	1300
5	Biogas complex in Hungary	600	150	80	400	1100	250	700	500
	Nuclear power plant in the Czech Republic	5000	1200	600	3000	8000	2000	5200	4500
7	Modernization of networks in Slovakia	700	180	90	450	1300	300	850	650
8	Geopower plant in Slovenia	900	220	110	600	1600	400	1050	800
9	Electric charging stations in Lithuania	500	130	70	350	900	200	600	450
10	Wind farm in Latvia	1100	280	140	750	1900	450	1200	950
11	Modernization of a thermal power plant in Estonia	850	210	100	550	1700	380	1020	780
12	Solar power plant in Ukraine	1300	340	170	900	2200	550	1400	1100
13	Gas storage facility in Moldova	750	190	95	500	1400	320	880	700
14	Wind farm in Romania	1000	260	130	700	1800	420	1150	900
15	Hydroelectric power plant in Serbia	950	250	125	600	1750	400	1100	850
16	Solar power plant in Montenegro	700	180	90	450	1300	300	850	650
17	Power grids in Albania	600	150	80	400	1100	250	700	500
01	LNG terminal in Estonia	1400	370	185	950	2400	580	1550	1200
19	Geothermal plant in North Macedonia	880	220	110	550	1500	320	980	760
20	Wind farm in Bosnia and Herzegovina	1150	270	135	700	1950	440	1250	1000

Source: created by authors based on European Environment Agency (2024).
Fonte: criada pelos autores com base na Agência Europeia do Ambiente (2024).

Based on the collected data, we built a multiple regression equation that allows us to quantify the impact of each of the factors (X_1-X_7) on current costs (Y). Mathematically, the equation is written in the form:

$$Y = \beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\beta_7X_7+\varepsilon \quad (01)$$

where: β_0 – constant; β_1-β_7 – regression coefficients for the relevant model variables; ε – model error.

In the context of the study of sustainable economic development and its decisive role in the formation of a strategically oriented energy security policy in Central and

Eastern Europe, each coefficient within the regression model serves as an important analytical indicator, which reflects the degree of influence of the relevant factor on the amount of current costs, demonstrating how much the value of these costs changes when the value of a particular factor varies by one conditional unit, provided that all other variables remain fixed (HACIIMAMOĞLU; SUNGUR, 2024).

$$Y = -1059.72+0.387X_1+0.805X_2+1.6397X_3+ 0.9068X_4+ 0.6739X_5+0.1973X_6+0.0714X_7 \quad (02)$$

It has been found that management costs (X1) play a significant role in shaping the overall budget of energy projects: a positive coefficient value of 0.3870 indicates that an increase in administrative costs by €1 million is accompanied by an increase in total project costs by €0.387 million. This is because effective governance in the energy sector, especially in the context of economic transformation towards sustainable development, requires careful coordination, institutional capacity building, and a strong mechanism for monitoring the use of resources, which inevitably affects the financial architecture of projects (AGBAKWURU et al., 2024). At the same time, additional operating costs (X2) show the opposite dynamics, which is manifested in a negative coefficient of -0.8050; that is, with an increase in these costs by EUR 1 million, the current costs of project implementation decrease by EUR 0.805 million. This may indicate that additional resources are often invested in the implementation of innovative processes, such as digitalization, automation, or supply chain improvements, which, in the long run, provide cost savings and operational efficiency in the implementation of energy initiatives.

The largest positive impact in the model was found for the variable "basic support resources" (X3), which includes the cost of materials, equipment, technical support and human capital: a coefficient of 1.6397 means that an increase in the volume of such resources by 1 million euros leads to an increase in current costs by 1.6397 million euros. This dependence is logical, as large-scale energy projects, especially those aimed at strengthening the energy independence of states, usually require significant investments in technical and engineering infrastructure (MAKEDON, et. al., 2025).

Expected revenues from project implementation (X4) also have a pronounced positive effect on financing, as the coefficient of 0.9068 indicates that with an increase in projected revenues by EUR 1 million, the corresponding increase in current costs is EUR 0.9068 million. The final result demonstrates that projects with high expected returns usually require significant upfront investments, such as the introduction of renewable energy sources, the construction of LNG terminals, or the development of smart grid systems.

Additionally, it was found that available financial reserves (X5) also have a positive impact on costs, albeit less intense: an increase in reserves by EUR 1 million leads to an increase in current expenses by EUR 0.6739 million. This trend is explained by the fact that reserve funds are often activated during the implementation of additional project phases, in particular for the purchase of equipment or expansion of the scope of work, which in turn increases the overall financial burden. Instead, the overall cost-effectiveness of the project (X6) shows an inverse relationship with current costs, and then, with an increase of €1 million, there is a decrease in costs by €0.1973 million, which indicates the critical importance of effective resource planning, reducing losses, increasing productivity, and rational use of funding at all stages of the project.

As for the long-term investment needs (X7), they have a slight negative impact, which is reflected in a decrease in current expenses by EUR 0.0714 million, while capital needs increase by EUR 1 million. This effect is likely due to the fact that capital investments are directed to strategic upgrades and modernization, which can reduce operating costs at the early stages of implementation. In this context, the regression equation not only allows us to estimate the cost factors but also forms the basis for making strategic decisions on resource planning, which is extremely important in the context of the energy transformation of Central and Eastern European countries (Figure 2).

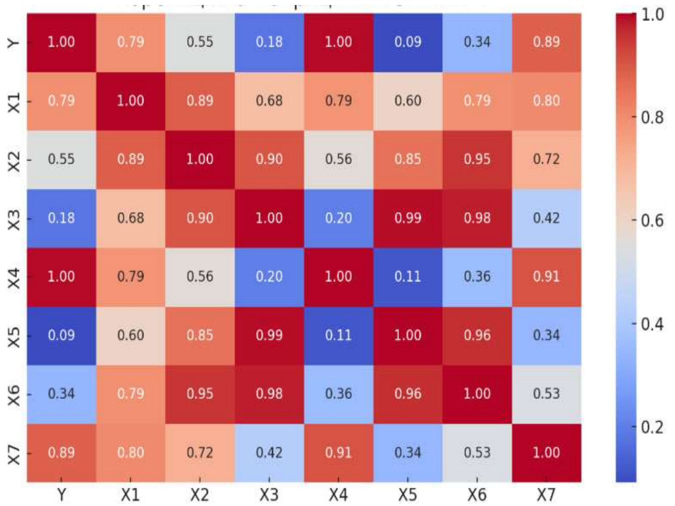

Figure 2. Multiple linear regression matrix for a selected set of 20 energy projects in CEE countries.
Source: developed by the authors.
Figura 2. Matriz de regressão linear múltipla para um conjunto de 20 projetos energéticos selecionados dos países da Europa Central e Oriental.
Fonte: desenvolvida pelos autores.

It was found that long-term investment needs (X7) demonstrate a significant level of correlation with the current costs of implementing energy projects, which is 0.76. This indicates that there is a fairly strong link between the scale of investments aimed at infrastructure, technological and organizational improvements in the energy sector and the level of current financial commitments to implement relevant initiatives, particularly in the context of the high cost of modern energy technologies and rising equipment prices.

At the same time, expected project revenues (X4), which typically reflect projected profitability and economic returns in the medium and long term, show a moderate correlation with current expenditures (Y), which is 0.65. This means that although the potential profitability of projects does affect their cost side, this impact is less pronounced than in the case of direct investment or the amount of resources. This phenomenon may be because when making investment decisions in the energy sector, the key role is played not so much by potential profits as by feasibility studies, the degree of risk, and the need for energy diversification and security (ALI; RAISSI, 2024).

In contrast, the variable characterizing available financial reserves (X5) shows a weak correlation with current expenditures, only 0.30, indicating their limited role in directly financing the implementation of energy initiatives. This may be due to the fact that reserves mostly act as buffer or insurance funds that are activated only in exceptional cases, such as force majeure or deviations from the plan, and are not the main source of current financing.

The study also found a deep interdependence between the individual factors used in the model, in particular between management costs (X1), additional operating costs (X2), and core resources (X3), which showed almost perfect correlations: X1 and X2 - 0.98, X1 and X3 - 0.99, X2 and X3 - 1.00. Such a tight correlation shows that these variables function as a single interdependent system in which an increase in one element logically leads to an increase in the others, which is especially true for complex energy projects that require clear coordination of administrative, resource, and logistics units.

In addition, overall economic efficiency (X6) also showed significant integration with other financial indicators: its correlation coefficients with management costs (0.97), operating costs (0.99), and support resources (0.98) indicate a systemic linkage of efficiency with key management and material factors.

The study focused on analyzing the relationship between the current costs of implementing energy projects (Y) and the indicator of overall economic efficiency (X6) This relationship is clearly represented in the form of a scatter plot (Figure 3), which demonstrates the dynamic interaction between the amount of project funding and the level of their efficiency, which together reflects the general logic of building an energy security strategy in the CEE countries. The graph illustrating the relationship between the current costs of implementing energy projects and the level of their overall economic efficiency, with a demonstrated coefficient of determination of R2 = 0.9935, indicates a strong relationship between these two variables.

In this regard, there is a logical need to reorient the strategic management of the energy projects group towards systematic optimization of not only economic efficiency as such, but also towards consistent improvement of management processes, rational use of available resources, and active implementation of modern technological solutions that reduce costs without compromising overall performance. Such measures may include digitalization of management procedures, automation of operations, introduction of energy-saving practices, and increased investment in green innovations. In the long run, this not only reduces the cost of the project budget but also ensures its compliance with the principles of sustainable development and enhances energy security for CEE countries.

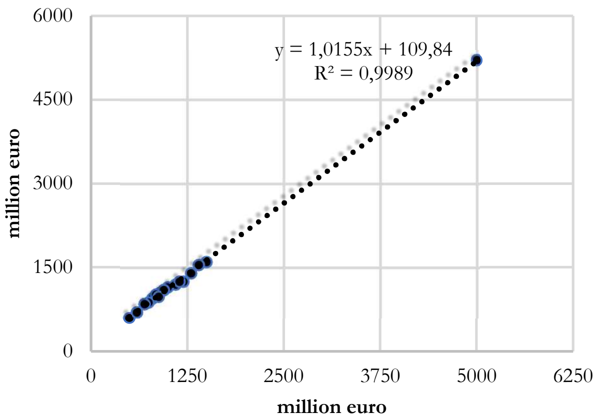

Figure 3. Scatterplot and linear regression line showing the relationship between current implementation costs (Y) and overall economic efficiency (X_6) in CEE energy projects
Source: built by the authors.
Figura 3. Gráfico de dispersão e linha de regressão linear mostrando a relação entre os custos atuais de implementação (Y) e a eficiência económica global (X_6) em projetos energéticos da CEE
Fonte: elaborado pelos autores.

5. DISCUSSION

The results of the study empirically confirm the existence of a deep systemic relationship between energy security indicators and parameters of sustainable economic development, which is especially evident in the context of Central and Eastern European countries, which are traditionally characterized by increased energy vulnerability due to historical dependence on energy imports and insufficient diversification of energy sources. The patterns identified in the course of econometric modeling find their theoretical confirmation in the works of leading modern energy security researchers, in particular in the researchs of Dirma et al. (2024) and Zakari; Musibau (2023), where special emphasis is placed on the critical importance of such strategic directions for increasing energy sustainability as systemic diversification of energy sources, large-scale infrastructure investments, and gradual reduction of dependence on energy imports through the development of domestic energy potential.

The scientific novelty of the presented study lies in the unique combination of quantitative methods for assessing the economic efficiency of energy projects with a qualitative analysis of political practices in energy policy making, which allowed the development of a comprehensive analytical toolkit for assessing energy security. In particular, the application of the multiple regression method made it possible to identify the key factors that have a decisive impact on the structure of the current costs of energy projects, which is consistent with the findings of Fortea et al. (2024) on the importance of considering technological complexity and potential returns when planning energy investments.

However, the findings differ significantly from certain provisions of the current scientific debate, in particular, from the theses of Agbakwuru et al. (2024) on the dominant role of administrative management in shaping the cost structure of energy projects.

Particularly noteworthy is the phenomenon of deep systemic interdependence between the individual components of energy projects identified in the study, which is conceptually consistent with the scientific positions put forward by Kim et al. (2025) and Llorca; Rodriguez-Alvarez (2024) on the need for an integrated approach to energy project management that takes into account the organic relationship between the administrative, logistical and material aspects of their implementation, which actualizes the need to develop integrated models for planning measures aimed at national energy security.

6. CONCLUSIONS

The study of threats and indicators of energy security confirmed the feasibility of using an indicative method of assessment, which allows for the quantification of the degree of stability of the energy system, tracking changes in threats and assessing their impact on national economies. The study developed a classification of key indicators that can serve as a tool for forecasting critical changes in the fuel and energy complex and shaping the energy policy of the countries of the region.

The analysis of the national energy and climate plans of the EU countries allowed us to identify three main areas of policy formation: diversification of energy sources, interdependence and institutional regulation. The most effective and widespread approach among the countries of the region is diversification, which reduces geopolitical risks and increases the flexibility of the energy system. However, further policy improvement requires a shift from declarative institutional initiatives to active investment in infrastructure development, innovation, and integration of regional energy markets.

An economic and statistical analysis of the factors influencing the current costs of implementing 20 energy projects in Central and Eastern Europe, conducted using a multiple linear regression model, has revealed the key determinants of energy initiative management. In particular, management costs (X1), basic support resources (X3), and expected revenues (X4) have the greatest positive impact on cost growth. On the contrary, additional operating costs (X2), overall economic efficiency (X6), and long-term investment needs (X7) contribute to cost reduction through productivity and technological development. The developed model can be used for cost forecasting and strategic decision-making in the field of energy investments, taking into account their impact on sustainability. The revealed almost perfect correlations between individual variables (X1, X2, X3) confirm the need for a systematic approach to optimizing management, operational and resource decisions in the energy sector. Based on the study, proposals are made to improve the financial strategy of energy projects aimed at ensuring resource efficiency, economic sustainability and technological upgrading.

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Authors' contributions: A.T.: conceptualization, methodology, investigation and data collection, writing (original draft), writing (review & editing), administration; N.G.: conceptualization, methodology, supervision, validation, writing (review & editing); O.S.: methodology, investigation and data collection, statistical analysis, validation, writing (original draft); L.S.: investigation and data collection, statistical analysis, writing (original draft); O.S.-K.: conceptualization, methodology, supervision, validation, writing (review & editing). All authors have read and agreed to the published version of the manuscript.

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