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MODELING OF ENERGY-SAVING PROCESSES IN THE CONTEXT OF ENERGY SAFETY AND SECURITY

Tetiana Polozova[1], Viktoriia Musiienko[2], Oleksandra Storozhenko[3], Olena Peresada[4], Nataliia Geseleva[5]

[1, 2,3,4]Kharkiv National University of Radio Electronics, Nauky Ave, 14, Kharkiv, Kharkivs'ka oblast, 61000, Ukraine*
[5] Kyiv National University of Trade and Economics, 19, Kyoto str., Kyiv, 02156, Ukraine
E-mail: [1]koaduep@gmail.com*

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Abstract. The national security strategies in terms of the energy independence of the EU member states were analyzed. It is proved that it is diversification of energy sources that will ensure the reduction of the energy intensity of the gross domestic product of the country. Only the development of energy-saving technologies based on the use of alternative energy sources will improve environmental safety as a component of energy. The evidences of an effective energy system of the country, which is able to protect national security from external and internal threats, were considered. It is clarified that it is advisable to determine the specifics of the implementation of energy saving processes taking into account the temporal determination of the number of potential consumers. This circumstance mediates the dependence of the population on the number of energy generating and energy distribution organizations that serve it. The model of the dynamics of the number of potential consumers who know about energy-saving products allows reflecting the success of the communication activities of organizations in modern energy markets.

Keywords: energy saving; national security; agent; potential consumer; sustainable development

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1. Introduction

The key driving forces and instruments of EU energy security are the completion of building an internal integrated energy market, diversification of energy sources, enhancement of cooperation between countries in the transportation and storage of natural gas, energy efficiency improvement, reducing of harmful emissions into the atmosphere.

The EU implements a systematic and consistent policy of ensuring energy security, an important role in the implementation of which is assigned to the diversification of the energy market as a crucial component of energy security. The EU actively supports activities aimed at promotion of diversification (both of energy types and sources), improving the functioning of European energy markets and assisting their cross-border integration.

The energy security is an important component of national security, and its support is a priority, given the growing global competition for control over energy resources. There are a large number of scientific works on energy security, reflecting the complexity, importance and urgent need to take into account the objective changes that occur in the field of economic and energy security (Ardalan, F.; Almasi, N. A.; Atasheneh, M. (2017); Androniceanu, A., Popescu, C.R. (2017); Rogalev, A., Komarov, I. Kindra, V., Zlyvk, O. (2018), Strielkowski, W., Lisin, E., Astachova, E. (2017); Humbatova, S. I. O.; Garayev, A.I.O.; Tanriverdiev, S.M.O.;

Hajiyev, N.Q-O. (2019); Plenkina, V.V. Osinovskaya, I.V. (2018); Smaliukiene, R., Monni, S. (2019)).

The energy system, in order to ensure an adequate level of energy security, should be, as a rule, characterized by: the diversification of the complex of primary energy sources and types of fuel used with the possibility of their mutual replacement if necessary; the diversification of energy suppliers without excessive dependence on such energy supplies for imports, which may entail the risk of disruptions / violations uncontrolled by the country; the diversification of energy supply routes for imports without over-reliance on specific "supply corridors"; the tendency to reduce the energy intensity of GDP, that is, the amount of energy needed to produce a unit of a national product; the reliable physical energy infrastructure; the stable and affordable energy prices; the commercially viable technology improvement plans for the energy infrastructure.

2. Literature Survey

The energy security strategies can be divided into:
strategies that are directly related to diversification: increase in the number of types of primary energy resources and fuel that make up the complex of energy sources that are used (Hilorme, T., Nazarenko Inna, Okulicz-Kozaryn, W., Getman, O. & Drobyazko, S. (2018)); increase in the number of suppliers of resources and fuel (Nakashydze, L., & Gil'orme, T. (2015)); development of storage facilities for energy resources and fuel and the formation of their strategic reserves (Buzar, S. (2016));
other strategies that are not related or are indirectly related to diversification: conservations, energy efficiency improvement (Goldthau, A. (2016)); (Tvaronavičienė, M.; Mačiulis, A.; Lankauskienė, T.;. Raudeliūnienė, J.; Dzemyda, I. (2015); Tvaronavičienė, M. (2017); Tvaronavičienė, M. (2018); Austvik, O. G. (2016)); use of endogenous energy sources (Aalto, P. (Ed.). (2016)).

Recently, there has been observed a moderate recovery in pre-crisis energy consumption in the world. This happens against the background of a rapid change in the institutional structure of energy markets with a predominance of the concept of liberalization, the development of transport infrastructure, countries' transition to energy-saving technologies, as well as against the background of the increasing role and importance of energy supply diversification policies (Sovacool, B. K., Heffron, R. J., McCauley, D., & Goldthau, A. (2016)).

The International Energy Agency (IEA), which central mission since its incorporation is to ensure energy security, has one of its main activities - to ensure the ability to respond collectively in the event of a significant disruption of oil supplies through short-term energy emergency response measures (Doherty, R. (2017)). The long-term aspect of energy security is also included in the incorporation objectives of the IEA, which suggests encouraging the use of alternative energy sources to reduce dependence on oil imports. The IEA works to improve energy security in the long term prospect, promoting energy policies that encourage diversification of both energy types and sources of supply, as well as more efficient functioning and integration of energy markets (Juncos, A. E. (2017)). In general, according to the IEA definition, the following main components of energy security can be identified: acceptable / competitive energy supply (at price factor); reliable / uninterrupted supply of energy (according to the state of the energy infrastructure); available / existing energy supply (according to the physical availability of energy resources). The national security strategy of the United Kingdom among the main risks determines, inter alia, disruptions in oil and gas supply and price instability, which have arisen as a result of war, accidents, actions of political factors or manipulation of suppliers. The UK's energy security system is a system that is able to meet the needs of people and organizations in providing energy services, such as heating, lighting, electricity and transportation, in a reliable and affordable way, both now and in the future. And the energy security itself is to provide access to the necessary energy services (physical security) at prices that are not overly unstable (price security) (Chandler, W. (2018)).

The National Energy Security Strategy of Spain sets forth a definition of energy security, which refers to government activities aimed at ensuring the stability of energy supply in an economically and environmentally sustainable manner through external procurement and using its own resources while respecting international obligations. And the main task in the field of energy security of Spain is to diversify energy sources, ensure the safety of transportation and supply of energy resources, as well as support energy efficiency and reduce the negative impact on the environment (Sperling, J. (2018)).

Considering the conceptual approaches of the EU to the definition of energy security and its components, it should be noted that energy security is the cornerstone of the European energy strategy, the fundamental objectives of which are the security of energy supplies, stability and competitiveness.

In this context, security of energy supply is considered as the most important aspect, since it is associated with a deep interdependence between markets and the economy, often based on political or geopolitical considerations. In the EU, supply security is defined as the state of energy supply, in which the basic future energy needs must be met through the use of domestic energy resources and strategic reserves in an acceptable economic environment and using diversified and stably accessible external sources of energy (Cohen, A. (2017)).

Thus, in the EU, the starting point for understanding the concept of energy security is to ensure the security of the energy supply chain. The problem of ensuring energy supply is primarily associated with the ability to meet the demand of EU member states for energy and energy resources. That is, the security of energy supply (energy resources) occupies a central place in the definition of energy security.

The energy policy has always been and is currently decisive for any country due to the fact that it is through implementation that the conditions necessary for the functioning of any industry are created. Recently, there is a noticeable intensification of the efforts of the EU member states to develop and implement a common energy policy, in particular, considerable attention is paid to the implementation of the energy market diversification policy (Tetiana, H., Chorna M., Karpenko L., Milyavskiy M. & Drobyazko S. (2018)).

The energy security in the EU has traditionally been associated with ensuring access to the supply of oil and fossil fuel. However, over time, the problem of ensuring energy security began to be considered in a broader sense, taking into account many new aspects and factors that could potentially influence the level of energy security. This broader approach covers supply and demand issues, security of supply, energy availability, geopolitical security issues, considerations of political and economic risk factors, as well as technological and environmental factors. However, the concept of energy security cannot fully cover all possible risks and vulnerabilities, although it should provide a basis for their identification, measurement and management. Modern studies of energy security are based on the identification and study of the links between energy systems and important social values and energy security is defined as part of the generally accepted concept of national (economic) security (Von Moltke, A., McKee, C., Morgan, T., & Töpfer, K. (2017)).

The energy security is defined as the ability of energy industries to provide relevant services at a reasonable price in a competitive, fully liberalized European energy market (Bouzarovski, S., & Tirado Herrero, S. (2017); conservations).

Regarding energy security in terms of the availability of energy, the concept of energy security takes into account the relevant safety (reliability) and diversification of energy sources and energy services. Ensuring the availability of energy provides for an adequate and uninterrupted supply and minimization of dependence on energy resources of foreign origin. Related aspects of the availability of energy are the diversification of energy supply and the prevention of physical damage to critical energy infrastructure (power plants, pipelines, distribution networks) so that the services provided would be uninterrupted (Gariup, M. (2017)).

At the same time, in general, diversification covers three main aspects (Tocci, N. (2017)): diversification of energy sources (energy resources); diversification of energy suppliers; diversification of locations of individual energy facilities on a spatial (geographical, territorial) principle. Diversification of energy sources requires the use of a combination of different energy sources, types of energy resources, fuel cycles (relying not only on nuclear energy or natural gas, but also on other types of energy resources, such as coal, oil, wind, biomass, geothermal energy sources, etc.). Diversification of energy suppliers involves the use of several points of energy production, so that one company or energy supplier cannot fully control the energy market. Spatial (geographical, territorial) diversification implies spatial distribution of locations of individual energy facilities in such a way that their functioning cannot be disrupted / destabilized as a result of a single event, malfunction or failure.

3. Methods

Ensuring the diversity of energy sources by investing in many alternatives serves the interests of both consumers and producers, because it guarantees the independence of the energy supply chain from any single energy source.

The geographical distribution of locations of individual energy facilities not only increases their overall safety and reliability of operation, but also makes the entire energy distribution network safer and more resistant to accidental failures and power system failures or deliberate actions. Geographic diversification contributes to the creation of several conditional goals that can not be violated at the same time, and thus prevents the possibility of a general collapse of the energy system (Kaunert, C. (2018)).

Diversification of sources and routes of energy supply is a determining factor in ensuring energy security, and its implementation is aimed at: reducing risks and minimizing the consequences of accidents at energy infrastructure facilities; development of competitive relations between exporters through the formation of a single liberalized energy market; reducing political influence of monopoly or large supplying and / or transit countries.

Since security of supply is only one of the many aspects covered by the EU's energy policy, identifying energy security with security of energy supply (energy resources) can be viewed as a very simplified approach that has certain limitations. However, it should be noted that the security of supply is given the most attention due to the fact that it is in fact the basis for ensuring all other elements of energy security. Only continuous access to energy resources can guarantee energy security from the national level to the level of households, which means its sustainability and competitiveness. Since energy security can be ensured with the help of national instruments, and security of supply is based at least on regional cooperation, the diversification of energy suppliers (energy resources) depends on many external factors (Zemlickiene, V., Mačiulis, A., Tvaronavičienė, M. (2017); Tetiana, H., Karpenko, L., Fedoruk, O., Shevchenko, I., & Drobyazko, S. (2018)).

The EU's energy security is understood as a process of reducing dependence on external energy suppliers (energy resources) by development of own energy production, diversification of the domestic energy portfolio and diversification of energy supplies (energy resources) from external sources, creation of sufficient strategic energy reserves, energy efficiency improvement, decarbonization as a means of coping with climate change and environmental pollution minimization. A necessary condition for the existence of any country of the modern world is the use of energy. Energy is extremely important for the economy and has a great influence on its other industries, since their normal functioning depends on it. Energy is the basis of almost all spheres of life in the modern world and plays a crucial role not only in the economic development of the country, but also serves as a basis in ensuring the sustainable development of society.

All the processes of extraction and processing of fuel, production, transportation and distribution of energy resources covers one of the most important interbranch complexes - fuel and energy (FEC) (Gil'orme, T., Ryzhyk, Y., & Yaresko, A. (2016)). The social and economic development of the country is inseparably linked with the level of development of all sectors of the FEC, improving the energy balance with the obligatory account of the achievements of scientific and technological progress. Comprehensive intensification of production sets new tasks for the fuel and energy complex, increases its role in accelerating economic growth rates and increasing labor productivity. The fuel and energy complex is a large inter-sectoral territorial system, an integral part of a single national economic complex of the country; basic complex of the entire heavy industry. The ultimate goal of its operation is the reliable provision of the entire economic complex and the needs of the population in fuel and electricity. The fuel and energy complex is a complex system - a set of industries, processes, material devices for the extraction of energy resources, their conversion, transportation, distribution and consumption of both primary fuel and energy resources and transformed types of energy carriers.

4. Results

The fuel and energy complex is the most important structural component of the economy, one of the key factors for ensuring the vital activity of the productive forces and the population. Reliable, stable, sufficient, cost-effective, environmentally friendly provision of the country's economy with energy resources is the key to its energy security and, consequently, sustainable development. Therefore, ensuring energy security becomes a priority in the economic and public policies of countries.

Economic phenomena and processes are interconnected, finding dependencies and relationships between them through the construction of statistical models and their quantitative description allows a deeper understanding of existing patterns. Energy saving is one of the main problems for the EU. Considering the importance of the problem of energy saving on a global scale, various measures are being taken in the EU to reduce the amount of energy consumed in both industrial and social spheres. High consumption of fuel and energy resources in the EU and, as a result, a high level of energy intensity of GDP determine the need for a statistical assessment of the relationship between the consumption of energy resources and economic factors that have a significant impact on the level of its formation. The continuous rise in prices for fuel and energy resources (FER), the reserves of which can be exhausted in the near historical perspective, as well as significant environmental pollution by emissions from their combustion, leads people to understand the need for more rational and economical consumption, as well as the transition to the use of alternative energy sources, which include secondary energy resources (SER) and renewable energy sources (RES). The use of renewable forms of energy, in particular solar and wind energy, has gained tangible scales and a steady upward trend. The state policy in the field of introducing innovative technologies in the energy sector and energy consumption is implemented through targeted investment, a system of benefits and "Green" tariffs on the resources produced.

High capital spending creates uncertainty for investments in renewable energy sources, creating a barrier to their development. The policy of using renewable energy sources is changing, and it also increases the lack of trust for investors. Therefore, a predictable and stable policy should be maintained for long periods to ensure continuity of investment in renewable energy technologies. It is extremely important that the design of modern systems takes into account not only the direct economic indicators and the instant effect, but the comprehensive result of the introduction of technologies, taking into account the environmental component, the trends of depletion of certain resources. In recent years, alternative energy has become the subject of keen interest and heated discussions. The reason for this can be called both climate change and the fact that average world temperatures continue to grow every year, and according to numerous findings of scientists in the field of geology, the exhaustion of traditional energy resources in the form of oil, gas and coal in nature. The fossil resources that we use as fuel belong to non-renewable sources of energy, eventually leading to complete depletion. During the processing and combustion of hydrocarbons, a large amount of greenhouse gases is emitted, which adversely affect the climate of the entire planet. The desire to find forms of energy that will reduce dependence on fossil fuels, coal, and other polluting processes has naturally grown. Scientific thought and progress do not stand still, and today there are clear prospects for the widespread use of alternative energy sources by humans. Due to improved technology and production, the cost of most forms of alternative energy has decreased, while efficiency has increased.

The technologies that make it possible to convert thermal energy into electrical energy include: magnetohydrodynamic energy conversion; use of the fast neutron breeder energy; use of the thermonuclear reaction energy; thermoelectric technology; thermophotovoltaic technology; thermionic technology; zirconium technology. Unconventional fuels include: hydrogen and hydrogen energy; methane from coal deposits and landfills, synthesis gas, energy of gases of geothermal waters, energy of bioyl treatment plants.

Secondary energy resources can be divided into three groups: combustible - this is the chemical energy of the waste of technological processes of chemical and thermochemical processing of raw materials; thermal - is the heat of waste gases from fuel combustion, the heat of water and air, which are used to cool process units, the heat of products and waste products (for example, metallurgy); excessive pressure - is the potential energy of gases, liquids, and loose bodies that leave process units with overpressure (pressure).

The large-scale use of innovative energy generation technologies leads to an increase in the energy efficiency of the energy supply systems of buildings. That is, a significant reduction in the use of traditional organic energy sources is possible due to the development of new technological and technical solutions. The problems of energy saving are solved by engineering means, which are aimed at converting the energy of alternative sources (energy of solar radiation, heat of the environment, energy of wind flow), increasing the indicators of thermal resistance, redistributing energy flows, etc. Taking into account the analysis performed, it is advisable to use the methodology of economic modeling in the distribution of energy-saving technologies based on the temporal determination of the number of potential consumers. This methodology is an integral part of the proposed methodology for determining the environmental conditions for the formation of the thermal regime of a structure based on calculated economic models (Hilorme T. et al. (2018)).

Taking into account the temporality, the method of economic assessment and the procedure of consumer support for the basic circuit design of an integrated energy supply system should contain formal analytical dependencies on the definition and assessment of the economic efficiency of a set of energy saving measures based on the use of alternative energy sources.
λ part of the population is interested in the energy-saving products of an enterprise (λ =0,0082), that is:

$$Q(n) = \lambda \cdot N(n) \quad (1)$$

where *N(n)* – total count of population (the amount of population associated with each city), persons.

Equation (1) determines the model on the basis of which optimization of the enterprise's work can be carried out with the introduction of energy-saving technology.

That is, significant is the modeling of the delivery and installation of energy-saving technologies in the final consumers. Given the formula (1), the value of *Q(n)* will be considered the number of consumers interested in energy-saving products.

But it should be understood that, taking the present time as the initial moment of time $t = 0$, the share $(\gamma 0)$ of the total number of interested consumers (potential product buyers), which reflects the number of already informed about the availability and benefits of energy-saving products of the enterprise, at $t = 0$, in absolute values, has the value $\gamma 0Q\ (n)$.

The increase in this indicator is possible due to the exchange of information between members of a specific target segment of the energy market and through advertising campaigns aimed primarily at uninformed potential consumers.

The model of the dynamics of the number of potential consumers *X(t)*, who know about energy-saving products, has the form:

$$\frac{dX(t)}{dt} = k_1 X(t)(Q(n) - X(t)) + k_2 (Q(n) - X(t)), \quad (2)$$

where k_1 – index of proportionality, which determines the efficiency of the exchange between informed and uninformed members of the target segment of the energy market;
k_2 – index of proportionality, which determines the effectiveness of the advertising campaign of energy generating and energy distribution organizations.

The model of the dynamics of the share of potential consumers *γ(t)*, who know about the product, has the form:

$$\frac{d\gamma(t)}{dt} = k_1\gamma(t)(1-\gamma(t)) + k_2(1-\gamma(t)). \tag{3}$$

The initial conditions for equation (3) are equality:

$$\gamma(t) = \gamma_0. \tag{5}$$

The dynamics of the share of potential consumers is represented by the function:

$$\gamma(t) = \frac{Ce^{(k_1+k_2)t} - k_2}{k_1 + Ce^{(k_1+k_2)t}}, \tag{6}$$

where: *C* – arbitrary constant, determined on the basis of (5) and given by the expression:

$$C = \frac{k_1\gamma_0 + k_2}{1-\gamma_0} \tag{7}$$

Function (6), together with expression (7), determine the model on the basis of which the organization of events can be optimized during an advertising campaign in order to promote energy-saving technologies in the regional market.

In particular, under the conditions of $k_1 = 0.05$, $k_2 = 0.1$, $\gamma_0 = 0.1$, after 9 months, informed consumers will account 70% of the total number.

Thus, in order that informed consumers account 80% under the conditions of $k_1 = 0.05$, $\gamma_0 = 0.1$ for 9 months, it is necessary to organize an advertising campaign, the effectiveness of which is characterized by the value of $k_2 = 0.14$.

5. Discussion

The competitiveness of such facilities is ensured by the synchronization and redistribution of energy costs and greater productivity of generating energy flows. The energy and economic security of the functioning of business entities and large industry associations is ensured precisely through the use of the achievements of progressive innovative technologies in the field of electric power industry. The social and economic efficiency of introducing innovative energy and information technologies is to save social labor and save important resources.

In this case, in our opinion, it is possible to conduct an economic assessment of the effects of the implementation of the model for determining potential consumers of energy-saving technologies in such directions as:
1. Environmental effects – allow reducing carbon emissions.
2. Effects of reducing operating and working costs of energy companies - reducing losses in the distribution of electricity by optimization of the performance of power plants and the balance of the power system.
3. Reducing the cost of industrial consumers.
4. Effects of improving the quality of business customer service based on interactive communication with consumers.
5. Increased efficiency and quality of power supply.
6. Effects of increasing the share of renewable energy and distributed generation.

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At the same time, the expected effects from the implementation of the model for identifying potential consumers of energy-saving technologies depend on the group of stakeholders: energy companies (electricity wholesalers, energy service retailers, electricity transmission companies, distribution network companies), end-users (industrial, commercial, public), regulatory authorities (government regulators, wholesale electricity market operator, reliability regulators), the state and society as a whole.

Thus, end users can expect such effects from the implementation of this model: the ability to control energy consumption, increase the overall level of service, increase the reliability of energy supply, access to information on energy supply in real time, the ability to participate in demand management, optimize the distribution of generation and the like. Whereas, for energy organizations, the expected effects are as follows: reduction of electricity losses, transparent accounting and billing system, optimization of asset management, maintenance and monitoring in real time, etc.

Conclusions

The proposed model can be applied to optimize the operation of energy generating and energy distribution organizations operating in a regional market with significant turbulent changes in the energy expectations of economic agents. Transportation costs have a secondary impact on economic efficiency in this case, however, great importance should be given to the calculation of logistics costs.

The economic efficiency of innovative renewable energy sources implementation is largely determined by research, in particular, it is necessary to carefully establish the purchasing ability of potential consumers, the degree of their intentions to establish new energy-saving technologies.

The methodology of economic modeling for the distribution of energy-saving technologies is improved, taking into account the temporal determination of the number of potential consumers. It is an integral part of the proposed methodology for determining the environmental conditions for the formation of the thermal regime of a structure based on calculated economic models.

In general, it can be said that the diversification of energy supplies is one of the defining elements of ensuring security of supplies, namely, it can be stated that the diversification of energy supplies is: a component of energy policy aimed at improving energy security in the long term prospect; one of the key areas of energy security; a characteristics of the energy security condition (the condition is considered to be satisfactory if the supply of energy resources is diversified); one of the ways to ensure the protection in the energy sector from existing and potential threats of internal and external nature; one of the foundations of the European energy strategy; a component of energy security, which covers reduce in dependence on suppliers through import diversification; one of the main directions to reduce energy dependence; an instrument to achieve standards for uninterrupted power supply; one of the key driving forces of energy security; a fundamental factor of energy security and independence of the EU as one of the largest energy importers in the world; a defining component of energy supply security; a means of reducing risks and minimizing the consequences of accidents at energy infrastructure facilities; a means of developing competitive relations between exporters.

Thus, energy security can be provided on the basis of strategies that are directly related to diversification (strategies for increasing the number of types of primary energy resources and fuel that make up a complex of energy sources; strategies for increasing the number of suppliers of energy and fuel (especially for imports); strategies for developing energy and fuel repositories and forming their strategic reserves) and / or other strategies that are indirectly related to diversification (strategies for improving energy efficiency; conservation strategies; strategies for using endogenous energy sources).

Thus, energy security is defined as one of the most important components of national security, a necessary condition for ensuring the sustainable development of the state. It implies the achievement of a technically reliable, stable, cost-effective and environmentally safe provision of the economy and social sphere of the country with energy resources.

Despite the fact that at present there is no effective instrument that would be able to completely solve the problem of changing the development path towards rational environmental management, it is the concept of sustainable development that deserves the most attention, since it offers realistic approaches and instruments to overcome the threat. But, the longer the economic crisis is, the more serious its social and environmental consequences can be. Thus, in the context of global economic crisis increasing, issues of sustainable development of economic and socio-ecological systems do not lose their relevance, but, on the contrary, acquire a special strategic character on the scale of economic entities, regions, state and, in general, on a global scale.

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Tetiana POLOZOVA, Doctor of Economic Sciences, Head of Department of Economic Cybernetics and Management of Economic Security, Kharkov National University of Radio Electronics, Ukraine
ORCID ID: orcid.org/0000-0001-9956-8816

Viktoriia MUSIIENKO, Candidate of Technical Sciences, Associate Professor of Department of Economic Cybernetics and Management of Economic Security, Kharkov National University of Radio Electronics, Ukraine
ORCID ID: orcid.org/0000-0003-0882-0487

Oleksandra STOROZHENKO, Candidate of Technical Sciences, Associate Professor of Department of Economic Cybernetics and Management of Economic Security, Kharkov National University of Radio Electronics, Ukraine
ORCID ID: orcid.org/0000-0003-1674-9350

Olena PERESADA, Senior lecturer of Department of Economic Cybernetics and Management of Economic Security, Kharkov National University of Radio Electronics, Ukraine
ORCID ID: orcid.org/0000-0003-0388-975X

Nataliia GESELEVA, Candidate of Technical Sciences, Associate Professor of Department of Cybernetics and System Analysis, Kyiv National University of Trade and Economics, Ukraine
ORCID ID: orcid.org/0000-0001-9188-9738

Register for an **ORCID ID:**
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