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Economic policy of Eastern European countries in the field of energy in the context of global challenges

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ABSTRACT

BACKGROUND AND OBJECTIVES: The crisis in the energy sector of Eastern European countries determines the search for alternative ways to solve the above problem, one of which is the development of economic policy in the field of energy in the context of European integration. The purpose of the article is to develop conceptual, theoretical-methodological and methodical-practical foundations of economic policy in the field of energy.
METHODS: The methodological basis of the paper is a set of techniques, principles, general theoretical, special, interdisciplinary methods of scientific study. The method of metric ranking is used in assessing the levels of energy security in countries with high energy use. Based on the method of system equations, a functional system of critical infrastructure of the country is built.
FINDINGS: A model of compatibility of energy infrastructure with other components of critical infrastructure (institutional and technological) was developed in order to ensure uninterrupted interaction between all key elements of critical infrastructure of the country and increase the level of energy, economic and national security of the country. Based on the content analysis of the legislation of the countries, it has been proven that in the system of critical infrastructure the energy sector is a key factor of national security. The calculated indicators of the level of energy efficiency of the energy system of Ukraine until 2035 based on the use of blockchain technology proved that the level of energy intensity of Gross domestic product should be reduced by more than half (53.57 %).
CONCLUSION: As a conclusion, the developed model of the system of management of distribution of energy resources in the country using blockchain technology will contribute to decentralization of energy transactions, generation and supply of energy based on renewable and traditional sources, will allow to solve the problem of significant distance between renewable energy sources and industrial centers (its main consumers).

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INTRODUCTION

The problem of rational use of energy resources, increasing the level of energy efficiency and energy security is a necessary condition for the harmonious economic and social development of each country. Providing all sectors of the economy of a country with various types of energy and fuel is one of the most important tasks of the management system, the economic policy of a country, a necessary condition for its successful and harmonious development. The formation and implementation of the energy policy of a country is a very important component of the economic policy as a whole. Only successful mutual complementation (complementarity) of economic and energy policies will allow achieving the harmonious development of the country in the context of global challenges. Given the limited energy resources, there is an acute problem of their efficient use, geographical and other types of diversification of energy products by a country. Improving energy supply will help to create conditions for the harmonious development of the economy of a country, will ensure increased levels of energy efficiency, and a high level of economic and national security. A significant number of scientific studies have been devoted to the problems of energy management, in particular, the formation of energy policy. Bauer *et al.*, (2017) describe the experience of developing energy strategies in world countries with the purpose of increasing their energy security. Pollit (2017) studies the problems, prospects of stimulating investment attraction in the energy sector of a country. A study of the energy management processes of individual regions is covered in the papers of Jafarigol *et al.,* (2016); Sadeghi-Pouya *et al.,* (2017); Kemp and Never (2017); Obama, B. (2017). The strategies of regional energy development were analyzed by Nakano *et al.*, (2017); Rogge *et al.*, (2017); Kooij *et al.*, (2018). An analysis of economic approaches to the use of energy resources is given in the papers of Garrett-Peltier (2017); van Veelen (2017); Lyytimäki (2018); Gielen *et al.*, (2019). The motivational function in the energy sector was studied by Keeley and Ikeda (2017); Khan and Singh (2017); Aized *et al.*, (2018); Oh *et al.*, (2018). The problems of forming strategies at energy enterprises are the subject of studies of such scientists as Skiba *et al.,* (2017); Adams *et al.*, (2018). Curran and Spigarelli (2017); Moreau and Vuille (2018) analyzed the implementation of the energy strategy of a specific country. Zandi *et al.,* (2017) reviewed energy security management processes. Shahbaz *et al.*, (2017) examined the problems of increasing the level of energy efficiency of a national economy, etc. A great contribution to the formation of the methodological foundations of the analysis of the energy market of a country was made by economists, namely: Koçak and Şarkgüneşi (2017). The problems of development of global energy, the use of alternative sources in this area, were analyzed by scientists, among which the papers of Jiang *et al.*, (2017), Papageorgiou *et al.*, (2017) Pollitt (2017) and others can be emphasized. However, the conceptual, theoretical-methodological, and methodical foundations of forming a complementary economic and energy policy of the country based on harmonious development remain insufficiently substantiated and formed. The development of a system of compatibility of energy infrastructure with elements of critical infrastructure is required. There is a need to develop a method of cost estimation of the level of the economic effect of the implementation of energy-saving measures within the framework of introduction of renewable energy sources. There is a need to improve energy supply through integrating it with the European Union system by bringing it in line with European regulations. Given the limited energy resources, the reduction of the availability of traditional energy resources in nature, the growing need for diversifying energy resources, increasing the level of energy security, solving the above problems should be carried out on the basis of scientific substantiation and with the help of the most relevant measures. The problems of critical infrastructure protection are related with the rapid development of new approaches to national security in developed countries, which is due to the rapid changes taking place in the security environment in the global, regional and national dimensions. The energy sector is part of the critical infrastructure of the Eastern Europe countries. When studying theoretical-practical principles, the above problems still remain at the level of insufficient substantiation, and the corresponding conceptual, methodological, methodical-practical principles are insufficiently formed, which determines the level of importance of studies in the field of energy. Unpredictable changes in price levels for various types of energy resources, a high level of energy import dependence of the economy of a country cause an increase in the level of uncertainty in the energy sector of a country and risk level, which leads to a decrease in the level of energy and, accordingly, economic and national security. All of the above determined the selection of the subject of the paper, its purposes and its objectives. The purpose of the paper is to develop conceptual, theoretical-methodological and methodical-practical foundations of the formation of economic policies in the energy sector. Achieving the set goal conditioned the solution of such problems: to develop a model of compatibility (coherence) of energy infrastructure with other components of critical infrastructure in Eastern Europe (institutional and technological ones); to develop a method of intellectualization of energy systems of the countries in the conditions of European integration; to substantiate the system of management of distribution of energy resources in Ukraine based on blockchain technology. This study was conducted in the Eastern European countries (Bulgaria, Poland, Ukraine, Slovakia, Russia) during 2015–2020.

MATERIALS AND METHODS

The methodological basis of the paper is a combination of techniques, principles, general theoretical, special, and interdisciplinary methods of scientific study. To achieve the set purpose and solve determined objectives, the following methods were used: method of theoretical generalization for the formation of own approach to understanding the key concepts in the area of economic policy in the energy sector; statistical and comparative analysis for study of the state of the energy sector and identification of trends in the energy sector, setting priorities for the energy sector; method of synthesis when forming individual elements of the structure of an integrated economic policy in the energy sector. As already mentioned, the energy sector is a key sector of critical infrastructure in many countries, including the Eastern Europe countries. Functionally, the system of critical infrastructure can be defined by this system using Eq. 1.

$$\begin{cases} I_k = S^1_{I_k} \cup S^2_{I_k} \cup \ldots \cup S^n_{I_k} \\ S^n_{I_k} = \sum_{l=1}^{p} F_l \end{cases} \qquad (1)$$

Where, I_k — critical infrastructure of a country; $S^1_{I_k}, S^2_{I_k}, S^n_{I_k}$ — critical infrastructure sectors of a country; F_l — factors influencing the relevant sector of the critical infrastructure of a country; n — number of critical infrastructure sectors of a country; l — the number of factors influencing the critical infrastructure sectors of a country. It should be noted that each country has an appropriate system of critical infrastructure (Table 1).

The countries listed in Table 1 were selected in accordance with the following requirements: the US legislation for the first time identified the subjects and objects of the critical infrastructure of a country, China as the fastest growing country, Great Britain as a country that left the EU, Poland and Bulgaria as Eastern European countries that are members of the EU. It can be concluded that the energy sector is a mandatory element of the critical infrastructure of the analyzed countries. Of course, the security of the energy sector is influenced by both global (world scale) and local (for the national level) factors. The importance of protection of the energy infrastructure of a country has grown significantly. This infrastructure is significantly influenced by the following factors (which also apply to the global energy sector as a whole): the need to ensure a high degree of reliability of the public energy supply system; growth in global energy trade; expansion of energy infrastructure, in particular, cross-border grids; the use, by some countries, of energy resources, energy infrastructure for conducting a geopolitical struggle; intensification of the activities of terrorist groups that purposefully destroy the energy infrastructure; growing requirements for the level of protection of the environment and human beings from the results of the activity of the energy sector of the economy. Functionally, the influence of key factors on the energy sector of the critical infrastructure can be determined using Eq. 2.

$$S^E_{I_k} = \sum_{l=1}^{6} F_l = F_1 + F_2 - F_3 + F_4 - F_5 + F_6 \qquad (2)$$

Where, $S^E_{I_k}$ — energy sector of the critical infrastructure of a country; $F_1, F_2, F_3, F_4, F_5, F_6$ — factors influencing the energy sector of the critical infrastructure of a country.

Thus, according to the author's study, based on the content analysis of the legislation of Eastern Europe, the functional impact of the factors on the level of protection of energy infrastructure of the main factors in the energy sector of critical infrastructure can be determined by the following elements: F_1 – The need to ensure the sustainability of the energy system; F_2 – Increase in the volume of world trade in energy; F_3 – Use by countries of energy resources and energy infrastructure as tools for geopolitical struggle; F_4 – Expansion of energy infrastructure, including cross-border networks; F_5 – Intensifying the activities of terrorist groups that steadily destroy the energy infrastructure; F_6 – Strengthening the environmental and human protection requirements of the energy sector.

RESULTS AND DISCUSSION

The issue of energy security is becoming increasingly acute in the world since it is both an integral component of national security and a determining condition for the formation of the economic and political independence of each country. There is a high level of energy hazards in the world economy. Dynamic and substantive approaches are fully tied to a single project and do not allow for comprehensive and holistic energy security management. Energy security management based on a functional approach is built on the implementation of basic management functions. An approach that identifies 5 key management functions is effective: planning, organization, motivation, control, and regulation. Based on literature review, an energy security management for an enterprise, region, country, which is based on the principles of a functional approach, was developed (Fig. 1).

Energy security management using a functional approach is carried out by planning (development, making investment plans, forecasting, etc),

Table 1: Critical infrastructure sectors of some countries

Item No.	Sector	Country				
		USA	China	Great Britain	Poland	Bulgaria
1.	Information and communication	+	+	+	+	+
2.	Emergency services	+	-	+	-	-
3.	Energy	+	+	+	+	+
4.	Financial and banking	+	+	+	+	+
5.	Food (and agriculture)	+ (+)	+	+	-	+
6.	State administration	+	+	+	+	+
7.	Health care	+	+	+	+	+
8.	Transport	+	+	+	-	+
9.	Water supply (and treatment)	+ (+)	+	+	+	+
10.	Defense	+	-	+	-	-
11.	Nuclear	+	-	+	-	-
12.	Space	-	-	+	-	-
13.	Chemical	+	-	+	-	-
14.	Security	-	+	-	-	+
15.	Industrial	+	-	-	-	+
16.	Air	-	-	-	+	-
17.	Railway	-	-	-	+	-
18.	Electricity	-	-	-	+	-
19.	Fuel	-	-	-	+	-
20.	Logistics	-	-	-	+	-
21.	Waste disposal and water treatment	-	+	-	-	-
22.	Commercial	+	-	-	-	-
23.	Communications	+	-	-	-	-
24.	Hydrotechnical	+	-	-	-	-

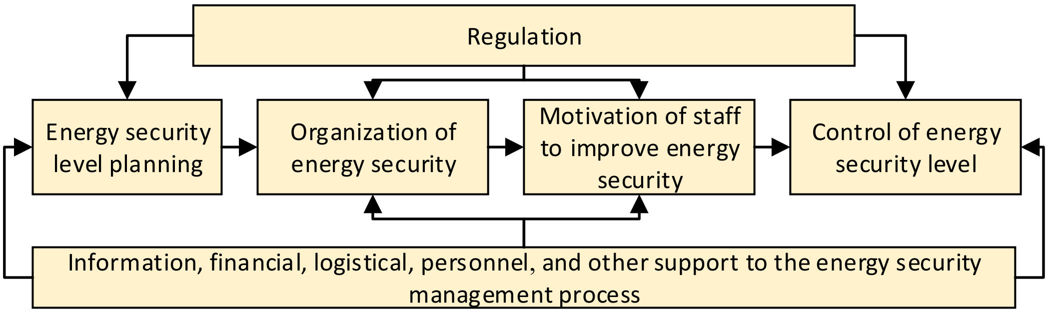

Fig. 1: Energy security management based on a functional approach

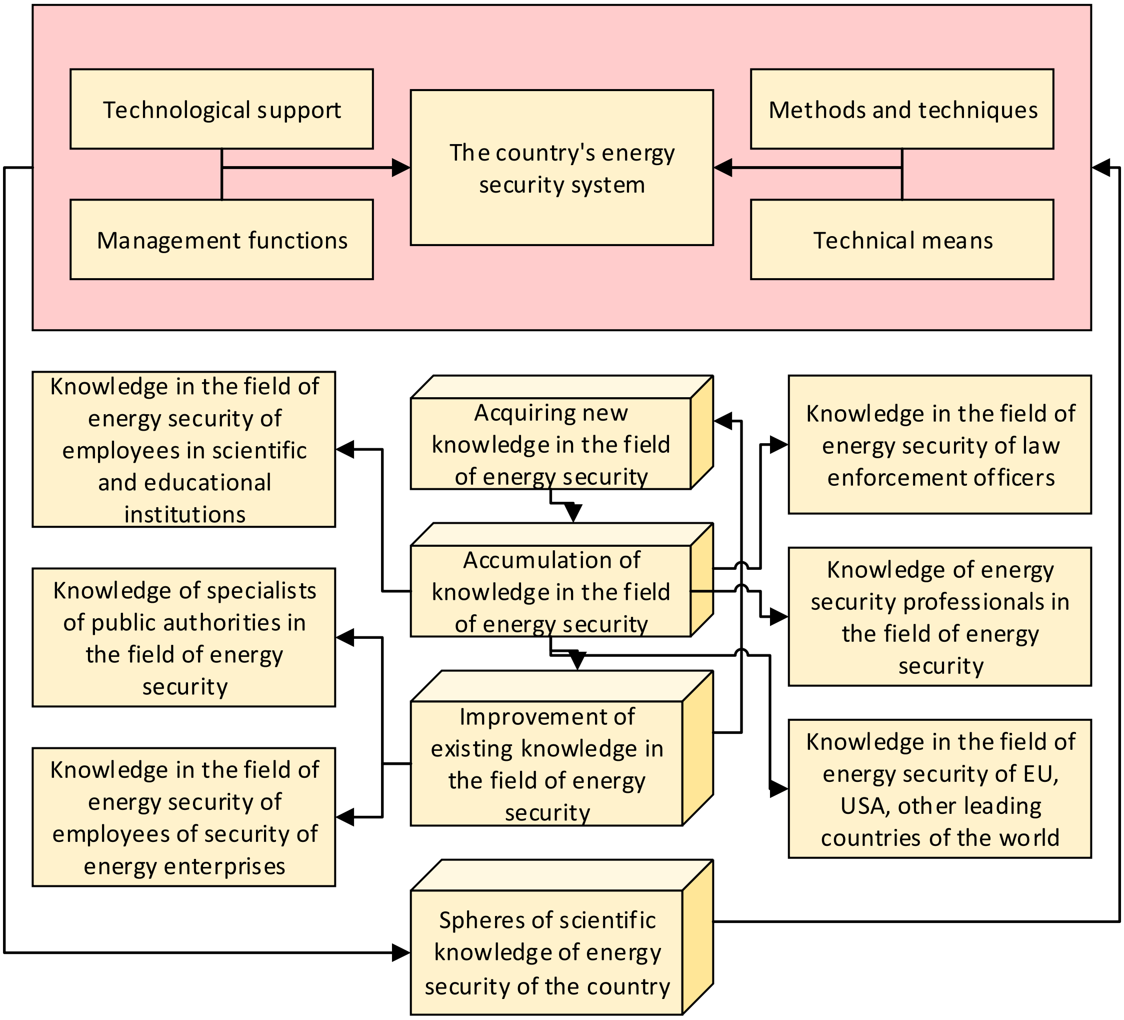

Fig. 2: System of knowledge management in the field of energy security of the country

organization (creating the necessary units for the implementation of investment activity), motivation (stimulating the increase of the level of the investment component of economic security), control (ensuring verification of the obtained results of the investment activity with the planned ones, evaluation of the effectiveness of the investment activity, achievement of the goals), regulation (elimination of deviations and deficiencies found in the process of controlling investment activity, implementation of corrective actions). It should be noted that energy security and its investment component (since capital investments are required to increase energy security, which are quite large in volume) must be ensured not only by economic methods (without denying their priority) but also by other methods (non-economic): political, military, information, etc. These resources can be used for approximately another 100 years for energy use. That is why the development of alternative (renewable) energy is a relevant (although not profitable in the first stages) timely direction for the development of the world energy sector, and, in particular, of each country, as it will help reduce the consumption of fossil fuels. In Fig. 2, the suggested system of knowledge management in the field of energy security of the country is considered.

The suggested model for the formation of knowledge in the area of energy security will enable the entities of the energy security system of a country to accumulate developments when performing their functions, as well as international (including European) experience, which will allow obtaining new knowledge in the area of the energy security of a country, improving existing one, effectively using it in the activities of energy security systems of business entities, government agencies and other

Table 2: Ranking of energy security levels in the world countries with high energy use (IIESR, 2018)

Countries	Risk level of energy security of the country	Ranks of the countries, which are the largest energy consumers
Norway	774	1
Mexico	802	2
Denmark	819	3
New Zealand	866	4
Great Britain	885	5
USA	893	6
Canada	912	7
France	942	8
Germany	944	9
Australia	962	10
Poland	987	11
Spain	1037	12
Italy	1043	13
Turkey	1087	14
Japan	1088	15
Netherlands	1106	16
Russia	1115	17
India	1164	18
Indonesia	1164	18
China	1172	20
South Africa	1175	21
South Korea	1306	22
Brazil	1307	23
Thailand	1616	24
Ukraine	2009	25

participants of energy markets. The knowledge in the area of energy security is formed in various scientific fields, it is somewhat disparate by nature and doesn't allow to effectively implement comprehensive ensuring energy security. It is necessary to develop theoretical-methodological tools for energy security management, as well as to form a scientific school. Not only energy but also economic and national security will largely depend on it. The suggested model of knowledge management in the area of energy security of a country will contribute to the acquisition of new knowledge in the area of energy security, which will become the basis for the formation of innovative energy security systems of a country, which are capable of responding adequately, timely and highly effectively to all dangers/threats to the activity of economic entities and the country as a whole. The above circumstances require a substantial revision of the economic policy of a country in the energy sector regarding increasing the level of protection of important energy facilities (that is, critical energy infrastructure) and reflection of corresponding priorities in the national legislation. So, when creating a clear system for protecting the critical energy infrastructure of the country it is necessary at the legislative level to determine the functions and objectives of state authorities, energy economic entities of various forms of ownership. The establishment of joint responsibility for ensuring the necessary level of protection of the critical

Table 3: Metric ranking of energy security levels in countries with high energy use (IIESR, 2018)

Market and price indicators				Energy consumption intensity levels			
No	Level of energy expenditures from the country's budget	No	GNP per capita	No	Energy consumption per capita	No	Energy consumption intensity level
1.	Norway	1.	Norway	1.	India	1.	India
2.	Germany	2.	Denmark	2.	Indonesia	2.	Indonesia
3.	Great Britain	3.	USA	3.	Brazil	3.	Brazil
4.	Mexico	4.	Netherlands	4.	Mexico	4.	Mexico
5.	USA	5.	Germany	5.	Turkey	5.	Turkey
6.	Denmark	6.	Great Britain	6.	Thailand	6.	Thailand
7.	New Zealand	7.	Canada	7.	China	7.	China
8.	France	8.	Australia	8.	Poland	8.	Poland
9.	Netherlands	9.	Japan	9.	South Africa	9.	South Africa
10.	Turkey	10.	France	10.	Ukraine	10.	Ukraine
11.	Italy	11.	New Zealand	11.	Italy	11.	Italy
12.	South Korea	12.	Italy	12.	Spain	12.	Spain
13.	Spain	13.	Spain	13.	Great Britain	13.	Great Britain
14.	Canada	14.	South Korea	14.	Denmark	14.	Denmark
15.	Australia	15.	Poland	15.	Japan	15.	Japan
16.	Japan	16.	Turkey	16.	France	16.	France
17.	Poland	17.	Mexico	17.	Germany	17.	Germany
18.	India	18.	Russia	18.	New Zealand	18.	New Zealand
19.	Russia	19.	South Africa	19.	Russia	19.	Russia
20.	China	20.	Brazil	20.	South Korea	20.	South Korea
21.	South Africa	21.	China	21.	Netherlands	21.	Netherlands
22.	Indonesia	22.	Thailand	22.	Australia	22.	Australia
23.	Thailand	23.	Ukraine	23.	USA	23.	USA
24.	Brazil	24.	Indonesia	24.	Canada	24.	Canada
25.	Ukraine	25.	India	25.	Norway	25.	Norway

infrastructure of a private sector of the country at the level of corresponding state authorities should be an important element. Table 2 shows the ranking of energy security levels in countries with high energy use.

In the energy sector, the EU is strict with regulation of safety standards. Member countries must adhere to the "Emergency Preparedness and Response Plan", i.e., the plan of preparation, actions in emergency situations (Eurostat, 2018). The energy component of critical infrastructure is faced with certain risks. In particular, when transporting energy, lightning problems are most likely to occur, followed by fires/other natural disasters, equipment problems, or human error, followed by problems caused by strong wind. Table 3 shows the metric ranking of energy security levels in countries with high energy use. In terms of intensity of use, developing countries such as India, Indonesia, China, Brazil and others are ahead of us.

A high level of implementation of the latest technologies is a sign of the level of development of the country and a determining factor of its competitiveness (a necessary condition for achieving the goals of national interests). However, with innovative advantages, technological progress also leads to a high level of dependence of a person and society on systems (systems providing energy, communication, information, transportation, financial, and other types of services). Given the impossibility of simultaneously protecting all of these infrastructure systems (primarily due to limited resource potential), the concept of "critical infrastructure" is being implemented in developed countries. At the same time, the results of such studies make it possible to more efficiently distribute the resources allocated to ensure the stable operation of critical infrastructures. The analysis allows

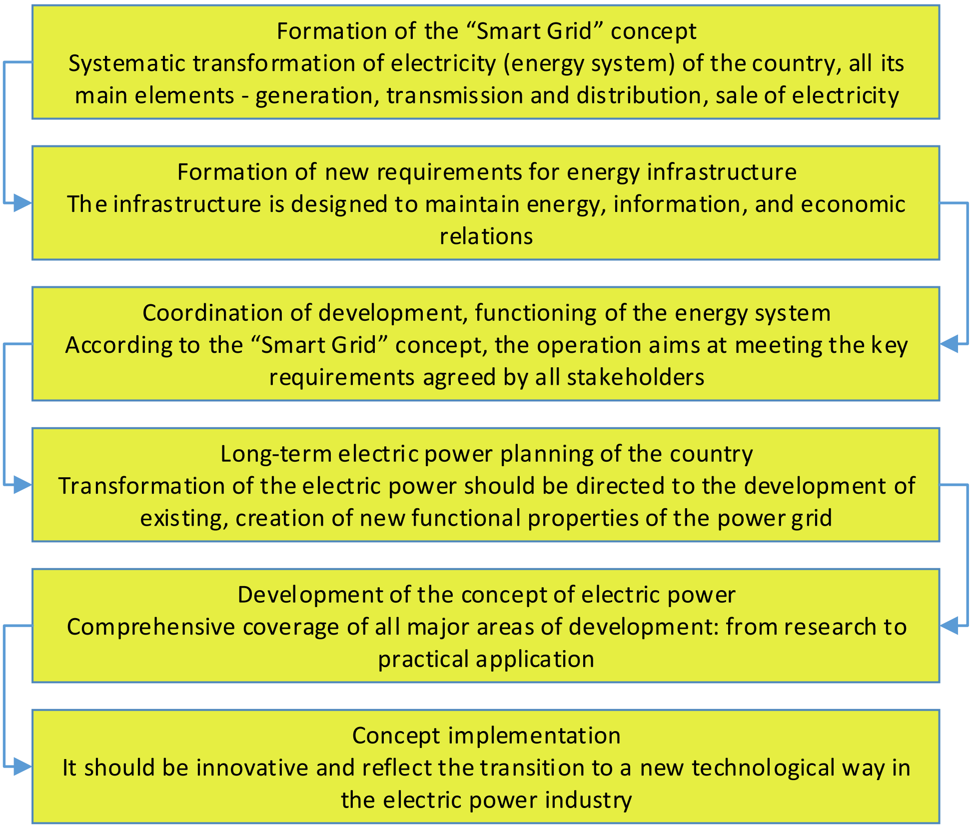

Fig. 3: Stages of "Smart Grid" implementation in the electric system of a country

forming a sequence of basic postulates, blockchain, development stages, and development of the “Smart Grid” concept in the country (Fig. 3).

In developed countries, to solve new problems, considerable attention is paid to the problems of introducing “smart” technologies, such as “Smart Grid”, “Smart Metering” in the energy industry, in particular in the electrical energy industry. Globally, obsolete metering devices are being replaced by the “smart” energy metering system “Smart Metering”, which is able to provide at a qualitatively new level of reliability: measurement of energy resources; management and control of their supply, transportation and consumption; automated transmission, processing and provision of information on resource consumption; creation of situational databases on energy consumption with elements of information support of tasks of management of consumption of energy resources and a number of other tasks. Smart Metering technologies allow to evaluate the efficiency of energy saving technologies, make transparent payments for used energy resources, promptly receive data on current electricity consumption and its modes, to monitor the state of meters, to draw the balance for groups of meters (which helps to identify unaccounted consumption and the facts of action on meters). The introduction of smart metering technology is a key element in the creation of intelligent energy systems with an active-adaptive grid (“Smart Grid”), thanks to which the reliability and efficiency of energy supply is taken to a new level. Table 4 gives a comparative description of the functional characteristics of the current (existing) energy system in the country and the energy system created on the basis of the implementation of the “Smart Grid” concept.

That is, an innovative energy system, which is based on the “Smart Grid” concept has significant advantages over the current one. The main advantage is the cost-effectiveness, efficiency, and operational controllability (adjustability) of the system. The development and implementation of functional capabilities (Table 4) will significantly increase the level of efficiency of the electrical energy industry and provide the expected benefits for all interested parties. It should be noted that for each individual stakeholder implementation of the concept of “Smart Grid” in the energy sector will have different economic effects. This method is based on a comparison of the efficiency of the existing energy systems of Eastern Europe countries (without elements of “Smart Grid”) and the suggested one (with elements of “Smart Grid”). For example, for consumers this will be provision of minimum operating costs provided that sufficiently comfortable conditions are created. For their own needs, consumers of electricity will

Table 4: Comparative characteristics of the functional characteristics of the current energy system and the energy system based on the concept of “Smart Grid”

Current energy system	Energy system based on the concept “Smart Grid”
One-way communication between elements or its complete absense	Two-way communication
Centralized generation - distributed generation with a complex integration process	Distributed generation
Radial topology prevails	Grid topology prevails
Responding to the consequences of an accident	Responding to predicting and preventing (avoidance) an accident
Operation of the equipment until complete failure (breakdown)	Continuous monitoring, self-diagnosis, which help to extend the life of the equipment
Manual recovery in the case of errors, crashes, etc.	Automatic grid recovery (“self-healing grids”)
High level of system crashes	Forecasting of the development of system crashes, predicting their occurrence
Manual, fixed grid allocation	Adaptive grid allocation
Checking the equipment on site	Remote monitoring of equipment
Limited power flow control	General power flow control
End-user price level information is not available or too late	End-user price level is displayed in real time

be able to convert it into other types of energy (for example, thermal, mechanical, etc.). When a consumer receives different types of energy, energy redistribution will be carried out, which will increase the volume of electricity consumption. It is advisable to present the total volumes of electricity (W) received by a consumer in a simplified form using the mathematical Eq. 3.

$$W = \begin{bmatrix} A_1 \\ A_2 \\ A_3 \end{bmatrix} = \sum_{1}^{3} A_i \tag{3}$$

Where, A_1, A_2, A_3 — volumes of electric, thermal energy, thermal energy of hot water supply, respectively.

The volumes of energy will depend on the corresponding parameters, which are the arguments for the function A_i. The values A_1, A_2, A_3 in the energy supply of consumers of the combined energy supply system are presented in the form of the function $A_i = f(A_1, A_2, A_3, ..., A_r)$ from the variable parameters A_i as: Electrical energy using Eq. 4.

$$A_1 = f(c_1, U, I, k, t_1) \tag{4}$$

Thermal energy using Eq. 5.

$$A_2 = f(c_2, m, g, \Delta Q, t_2) \tag{5}$$

Thermal energy of hot water supply using Eq. 6.

$$A_3 = f(c_3, m, g, \Delta Q, t_3) \tag{6}$$

Moreover, if there are other types of energy (A_r), one can also introduce them into the suggested model. The designations of the constituent elements in the dependences (4–6) mean the following: U - voltage (phase or line) in the power supply system; I - load current; k - load factor, which characterizes the ratio of active energy to total energy; m - heating mass; g - specific heat capacity; ΔQ - difference between the final (maximum permissible) and initial temperature of the substance; c_1, c_2, c_3 - coefficients that include constants characteristic of the corresponding type of energy; t_1, t_2, t_3 - time of production, use of the corresponding type of energy. These functional dependencies (4–6) allow to proceed to the implementation of the stage of making sound management decisions on the design of components for automatic control devices, their interactions and/or selection (modernization, improvement of its technical and economic parameters) of existing power plants, devices, etc. of the local energy supply system using renewable energy sources. It is expedient to put substantiation of functional dependence of the sizes of consumption of types of energy as a basis at designing of components of the device of automatic control of a smart electrical grid. The beginning for the development of the "Smart Grid" concept in industrialized countries was the formation of a clear strategic vision of the goals and objectives of the development of the electrical energy industry, which would meet the constantly growing requirements of society, stakeholders, namely: the state, science, manufacturers, economy, business, consumers, and so on (Table 5).

Thus, the structure of smart electrical grids is promising (Fig. 4) since to connect renewable energy sources to the electrical grid of a country in the context of the development of the electricity market, it is necessary to use the appropriate "Smart Grid" systems for the purpose of automated control of energy flows, timely performance regulation of power flows, consumption of electricity by the system maneuvering capacities, and the like. It is also associated with the level of development of electric transport in the country.

Since 2010, the process of activating the introduction of systems based on Smart Grid technology has been started. The first step in this direction is the integration of the smart measuring equipment such as "Smart Meters". In accordance with it, "Smart Grid" acts as a concept of a fully integrated, self-regulating, self-sufficient, self-healing electrical energy system, which has a grid topology, including all generation sources, bulk and distribution grids, all varieties of electricity consumers, which are controlled by a unified network of information and control devices, real-time systems. The low speed of information exchange hindered the achievement of the goals of harmonious development (converting the global energy system to the green one, combining the interests of all participants in energy market relations). It is the blockchain system that can solve this problem. The blockchain system in the energy sector will also help to create the conditions for the accumulation,

Table 5: Requirements of stakeholders for implementing the "Smart Grid" concept in the energy industry (systematized by the author)

Groups of stakeholders	Stakeholders	Requirements/expected effects
Energy companies	Wholesale sellers of electrical energy Retail sellers of energy services Electricity transmission companies Distribution grid companies	Operational improvements. Transparent metering and billing system. Outage management in real time. Improving energy management processes. Decrease in the level of electricity losses. Optimization of asset management. System planning. Maintenance, real-time monitoring.
Regulatory authorities	State regulation bodies of the country Wholesale electricity market operator Reliability regulators	Improvement of the reliability of electrical supply Transparent system of supply and metering of electric energy. Improvement of the energy management processes. Decrease in the level of electricity losses. Lower electricity tariffs.
End users	Industrial Commercial	Improvement of the reliability of electrical supply; increase in the overall level of service. Access to real-time electrical supply information. Ability to control power consumption levels. The opportunity to participate in the demand management process.
	Population	Optimized distributed generation relationship. The possibility of selling electricity to the market. The potential for a significant reduction in the cost of electrical supply.
	State and society as a whole	Reducing the level of electricity prices due to increased levels of operating, market efficiency, attracting new consumers. Reducing the level of consumer costs by increasing the level of reliability. Improving the grid security level by increasing its level of stability. Reducing emissions through the integration of renewable energy sources, reducing costs. New jobs and GDP growth. The possibility of innovative development of the transmission and distribution of electrical energy.

processing, and analysis of huge arrays of non-financial information. This information is contained in the agreements and is unified, which makes it important for both participants in energy markets and representatives of the financial sector of the economy. This applies to the physical characteristics of energy resources: fuel, electricity, etc. The model of a system for managing the distribution of energy resources using blockchain technology is suggested. Its use will contribute to the decentralization of energy transactions, generation and supply of energy based on renewable and traditional sources (Fig. 5).

The system is based on the characteristics of the product - electricity (the production and consumption processes do not coincide in time (it is impossible to determine in advance the volumes of its consumption and generation with a high degree of probability (accuracy)); the inability to accumulate electricity in the required volume and place; it is impossible to connect a specific producer and electricity consumer; and it takes into account the possibilities of technological development of the electrical energy industry (decentralized production (generation) of electricity on the basis of renewable/traditional sources; accumulation of produced (generated) electricity where it is necessary to align load schedules and improve the quality of electricity; supply of excess capacity to the grid for other consumers while controlling the grid operating conditions, monitoring it, etc). Distributed registry or blockchain technology is a data structure distributed between all network nodes in the form of

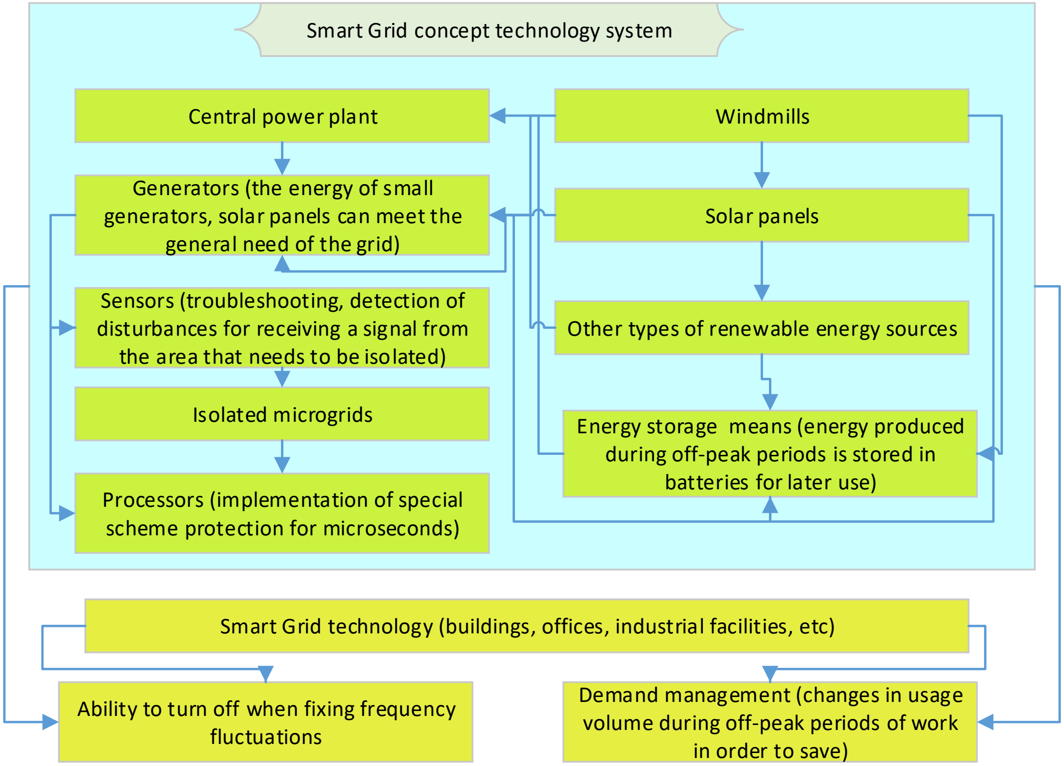

Fig. 4: “Smart electrical grid” structure

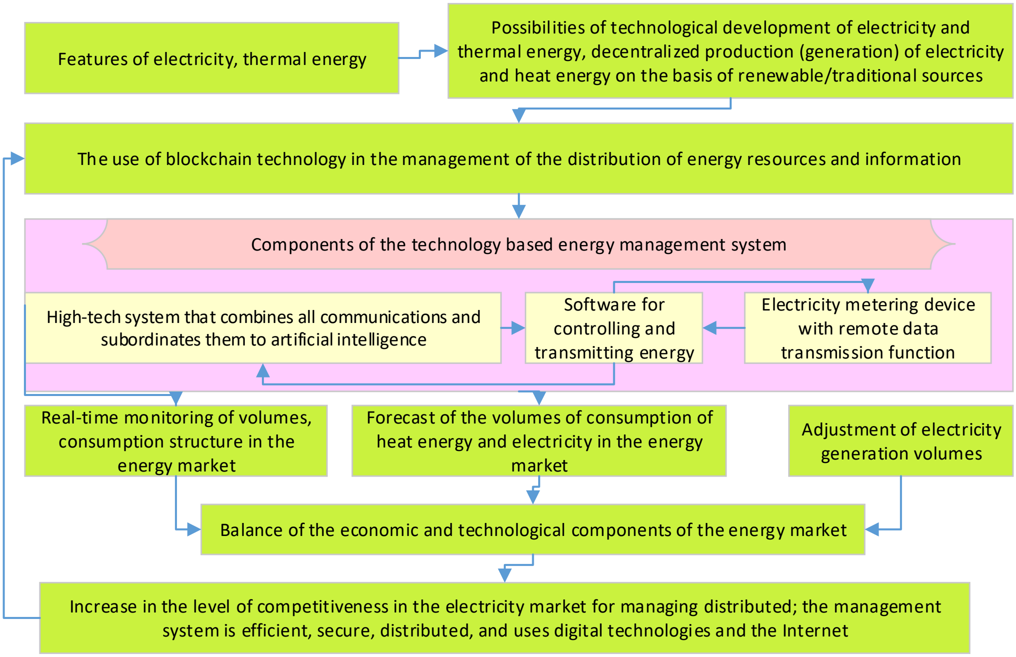

Fig. 5: Blockchain technology management system

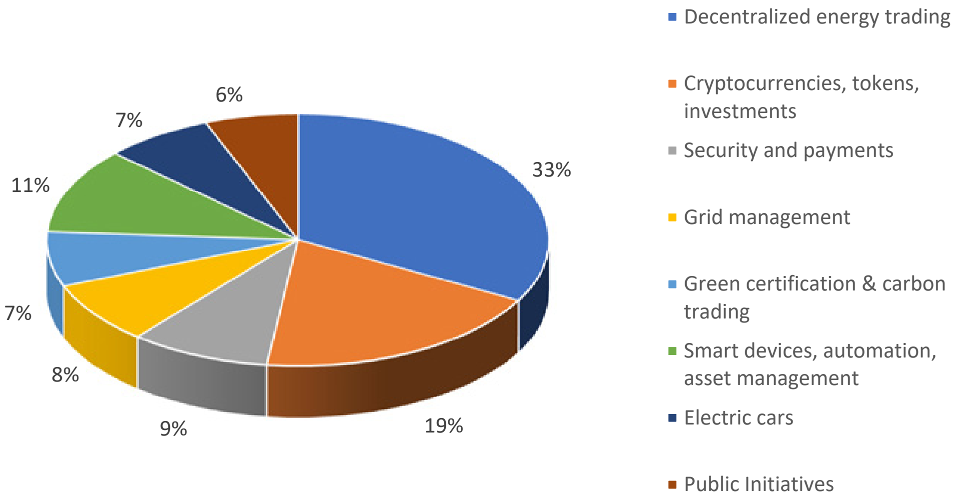

Fig. 6: Scenarios of blockchain use in energy sector projects

Table 6: Indicators of the level of energy efficiency of the energy system of Ukraine until 2035 based on the use of blockchain technology

Indicators	Values of indicators by years					Deviation of 2035 until 2015	
	2015	2020	2025	2030	2035	Absolute	Relative
Energy intensity of GDP, total primary energy supply calculated as the sum of production (extraction), import, export, international bunkering of vessels and changes in energy reserves of the country, toe/thousand dollars GDP	0.28	0.20	0.18	0.15	0.13	– 0.15	–53.57
Fuel costs for the amount of electricity sent to the energy market, generated at TPS, kg oe/kWh	396	384	367	353	334	–62	–15.66
Specific costs in the production of heat by boiler stations, kg oe/Gcal	165	160	155	150	145	–20	–12.12
Share of losses in electrical grids, %	> 12	10	9	8	< 7.5	-	-
Share of losses in heat networks, %	> 20	< 17	< 13	< 11	< 10	-	-

a digital replica of all information recorded within the framework of accessing it. Storage of all transactions taking into account their chronological order is a distinctive feature of this structure. Figure 6 shows the ratio of different uses of blockchain in the energy sector (Fig. 6).

The grid will be able to monitor its condition online (collect, process information regarding both the production process and electricity consumption). This will facilitate the transition from the use of traditional sources to generate electricity to renewable (non-traditional) ones, that is, take into account the differences that exist in the process of generating electricity from renewable sources, provide on-line monitoring of volumes, the structure of consumption in the market. The system will automate the processes of production/consumption, purchase/sale of generated energy. Also, the introduction of blockchain technology in the energy sector will solve the problem of a significant distance between places of energy generation from renewable sources and industrial centers. Moreover, the use of blockchain technology is not limited only to the energy and financial sectors of the economy but is gradually expanding due to related industries. Here is an example of possible use of blockchain technology in the energy system of one of the countries of Eastern Europe (Ukraine) and possible increase in the efficiency of the energy sector (Table 6).

In the crisis conditions that the economy of Ukraine is characteristic of, the problems of accounting for energy costs, energy saving are relevant. The economy of Ukraine is one of the most energy-intensive in Europe and in the world as a whole. The long period of inactivity in finding ways to save energy resources is one of the main reasons for this situation. According to the energy strategy of Ukraine for the period up to 2035, the level of energy intensity of GDP of Ukraine (Table 6) should be decreased by more than half (53.57 %), and other energy efficiency indicators are also projected to be decreased.

CONCLUSION

Today, the concept of critical infrastructure protection is implemented both in European legislation and in the national legislation of EU member states (pan-European critical infrastructure is considered to be of cross-border (within the EU) significance. Only two sectors (energy, transport) are identified as priorities at the European level. The model of energy management system of Eastern Europe countries based on blockchain technology was developed, which will contribute to the decentralization of energy transactions, generation and supply of energy based on renewable and traditional sources, will solve the problem of significant distance between renewable energy sources and industrial centers (their main consumers). The suggested model will facilitate the adoption of balanced, innovation decisions by civil servants of national executive bodies on the harmonious development and decentralization of the energy sector of the economy. The method of intellectualization of energy systems was further developed, which is based on the distribution of networks, departure from intermediaries and the transition to direct interaction with counterparties, processing, analysis of the array of non-financial information contained in agreements, has a unified form required for energy market participants, representatives of the financial sector, and application of “Smart Grid” (electrical grid including operational, energy saving measures, renewable energy sources, energy efficiency resources, etc.).

The introduction of electronic management of electricity parameters, production/distribution will contribute to reforming and further harmonious development of the energy sector of the economy, in accordance with European regulations and requirements.

AUTHOR CONTRIBUTIONS

S. Bogachov performed an experimental design and analyzed the data. A. Kirizleyeva defined the concept and methodology of the research. O. Mandroshchenko ranked the data into tables and figures. S. Shahoian performed the literature survey. Y. Vlasenko customized the manuscript to meet the requirements of the GJESM Journal.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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ABBREVIATIONS

A_1, A_2, A_3	Volumes of electric, thermal energy, thermal energy of hot water supply, respectively
A_r	Other types of energy
c_1, c_2, c_3	Coefficients that include constants characteristic of the corresponding type of energy
et al.	Others
etc	And so on
EU	European Union
Fig.	Figure
$F_1, F_2, F_3,$ F_4, F_5, F_6	Factors influencing the energy sector of the critical infrastructure of the country
F_l	Factors influencing the corresponding sector of the critical infrastructure of the country
g	Specific heat capacity
Gcal	gigacalories
GDP	Gross domestic product
GNP	Gross natinal product
HPS	Hydroelectric power station
I	Load current
I_k	Critical infrastructure of the country
k	Load factor, which characterizes the ratio of active energy to total energy
kg	Kilograms
l	Number of factors influencing the critical infrastructure sectors of the country
m	Heating mass
№	Sequence number
n	Number of critical infrastructure sectors of the country
NPS	Nuclear power station
oe	Oil equivalent
P2P	Peer-to-peer
$S_{I_k}^{E}$	Energy sector of the critical infrastructure of the country
t_1, t_2, t_3	Time of production, use of the corresponding type of energy
toe	Tonne of oil equivalent
TPS	Thermal power station
U	Voltage (phase or line) in the power supply system
USA	United States of America
W	Total volumes of electricity
ΔQ	Difference between the final (maximum permissible) and initial temperature of the substance

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