ЕКОНОМІКА ТА УПРАВЛІННЯ НАЦІОНАЛЬНИМ ГОСПОДАРСТВОМ

UDC 330.341.1

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ENERGY SECURITY OF THE NATIONAL ECONOMY BASED ON A SYSTEMS APPROACH

Urgency of the research. *Forming the energy policy of the national economy on the basis of the energy security concept will ensure making balanced management decisions concerning the future energy development of the country.*

Target setting. *Both in the world and Ukrainian practices, the most common approach to forming a model of energy security is based mainly on sources of energy supply. However, such approach does not reflect the aggregation of the complexity of the relationship in energy systems.*

Actual scientific researches and issues analysis. *Problems of studying national energy security are highlighted in works of such scientists as J. Jewell and A. Cherp, A. Kachynskyi, B. Kruyt, A. Mikhalevych, B. Sovakul, A. Shevtsov, A. Smenkovskyi, as well as of different international organizations.*

Uninvestigated parts of general matters defining. *The concept of energy security requires further consideration in the context of a systems approach and its operationalization at the methodological level.*

The research objective *is the conceptualization of energy security on the basis of a systems approach and its operationalization using the 4E model.*

The statement of basic materials. *The article studies the features of functioning of energy systems and proposes a system concept of energy security. The authors suggest considering the subsystems of energy supply, energy conversion and energy consumption as its components, the assessment of energy security of which at the methodological level is performed using the corresponding system indicators: energy dependency, energy efficiency and energy conservation. The stable existence of an energy system is ensured by such a component of energy security as energy self-sufficiency. In the work, the approbation of the proposed methodological approach to the assessment of energy security in Ukraine has been carried out.*

Conclusions. *Energy security should be considered as a system category, and its concept based on a systems approach. The operationalization of energy security is based on its assessment by means of the methodological approach using the 4E model: energy conservation, energy efficiency, and energy dependency, as well as energy self-sufficiency.*

Keywords: *energy security; energy system; energy dependency; energy efficiency; energy conservation.*

DOI: *10.25140/2410-9576-2018-1-2(14)-79-92*

УДК 330.341.1

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ЕНЕРГЕТИЧНА БЕЗПЕКА НАЦІОНАЛЬНОГО ГОСПОДАРСТВА НА ОСНОВІ СИСТЕМНОГО ПІДХОДУ

Актуальність теми дослідження. *Формування національної енергетичної політики на основі концепції енергетичної безпеки забезпечить прийняття зважених управлінських рішень щодо майбутнього енергетичного розвитку країни.*

Постановка проблеми. *У світовій та українській практиках поширеним є підхід до формування моделі енергетичної безпеки переважно за джерелами енергозабезпечення. Однак, такий підхід не віддзеркалює агрегування усієї складності відносин в енергосистемах.*

Аналіз останніх досліджень і публікацій. *Проблемам дослідження національної енергетичної безпеки присвячені роботи таких науковців як Дж. Джуел та А. Черп, А. Качинського, Б. Круйт, А. Міхалевича, Б. Совакул, А. Шевцова, А. Сменьковського, а також різних міжнародних організацій.*

Виділення недосліджених частин загальної проблеми. *Потребує подальшого осмислення концепція енергетичної безпеки з позиції системного підходу та її операціоналізація на методичному рівні.*

Постановка завдання. *Метою цієї статті є концептуалізація енергетичної безпеки на основі системного підходу та її операціоналізація на основі моделі «4Е».*

Виклад основного матеріалу. *Досліджено особливості функціонування енергосистем та запропоновано системну концепцію енергетичної безпеки. В якості складових авторами пропонується розглядати підсистеми енергозабезпечення, енергоперетворення та енергоспоживання, оцінка якості функціонування яких на методичному рівні проводиться за системними індикаторами енергозалежності, енергоефективності та енергозбереження. Стале існування енергосистеми забезпечує така складова енергетичної безпеки як енергодостатність. В роботі проведено апробацію запропонованого методичного підходу до оцінки енергетичної безпеки в Україні.*

Висновки. *Енергетична безпека повинна розглядатися як системна категорія, а її концепція базуватися на системному підході. Операціоналізація енергетичної безпеки спирається на методичний підхід до її оцінки на основі моделі «4Е»: енергозбереження, енергоефективність та енергозалежність, а також енергодостатність.*

Ключові слова: *енергетична безпека; енергетична система; енергозалежність; енергоефективність; енергозбереження.*

Urgency of the research. The energy component plays an extremely important role in ensuring national security and sustainable development of a national economy. The uneven distribution of primary fuel and energy resources (PFERs), the difference in their economic value and technological imperfection of equipment determine using various approaches to the formation of national energy policies. An approach to shaping the energy policy based on modeling energy security is generally accepted. However, the latter is considered a complex economic category, which reflects various aspects of the use of PFERs in a national economy.

Target setting. The boundaries of energy security are rather blurred, which leads to difficulties in measuring and shaping the main objectives of the state energy policy, as well as finding ways to ensure it. Traditionally, when discussing issues of energy security, attention is focused rather on sources of energy supply than on the needs, interests that it is called upon to meet and the valuable effects it should provide. The priority of goals of energy supply over those of efficient energy consumption determines the current nature of national energy solutions in the policies of most countries: the search for new importing suppliers, diversification of supply routes, getting discounts from the market price for energy resources, etc. However, this approach does not bring down the urgency of the problem of energy security but only substitutes it with issues of ensuring reliable energy supply. The conceptualization and operationalization of energy security should be aimed at defining the boundaries of this concept in order to eliminate "overlaps" between the goals of the energy security policy, sustainable development, and economic efficiency as well as at the development of an effective methodological approach to its assessment.

Actual scientific researches and issues analysis. Presently, the research of problems of energy security are highlighted in works of leading foreign and Ukrainian scientists, namely, J. Jewell and A. Cherp [1], A. Kachyns'kyy [2], B. Kruyt [3], A. Mikhalevych [4], B. Sovacool [5], A. Smenkovskyi [6], and others. At the same time the problem is of concern to different international organizations: the International Energy Agency, the World Energy Council, the World Bank, the United Nations, European Commission, and others [7-18]. However, it can be objectively stated that there are no effective models of energy security that are capable of ensuring counteraction to negative factors.

In the scientific literature there are two theoretical and content approaches to the definition of the concept "energy security", namely its interpretation as the uninterrupted supply of energy and energy carriers [1]; uninterrupted satisfaction of energy demand in the context of sustainable development [12].

Central place among the presented theoretical approaches is occupied by the concept of uninterrupted energy supply, which has contributed to the development of all other theoretical directions, with the focus remaining on sources of energy supply and uninterrupted energy supply. The initial definition, which gave impetus to the development of the whole spectrum of scientific research on this subject, is its interpretation by the International Energy Agency (IEA) as "the uninterrupted availability of energy sources at an affordable price". However, today the IEA's main focus in studying the issue of energy security is on risks related to "energy sources and infrastructure for their provision", which emanate from various natural, economic and political factors [7]. The most complete in this group is the definition proposed by the World Energy Council (WEC) which, by energy security, means "effective management of primary energy supplies from internal and external sources, the reliability of the energy infrastructure and the ability of energy suppliers to meet current and future demand" [14]. A common characteristic of the first group of definitions is the understanding that an increase in the relative level of energy deficit is the main problem of (threat to) energy security, and for the implementation of energy security policies a balance between the interrupted supply of certain types of energy and the level of prices for them is necessary.

The second approach defines energy security in the context of the dominant scientific paradigm of sustainable development. In a number of definitions, references to economic, social or environmental constraints can be found. Most completely the concept of energy security in the context of sustainable development is disclosed in documents of the European Commission (Green Paper of Commission of the European Communities 2000 [18]), in which the concept acquires the following meaning: "ensuring the well-being of its citizens and the proper functioning of the economy, the uninterrupted physical availability of energy products on the market, at a price which is affordable for all consumers (private and industrial), while respecting environmental concerns and looking towards sustainable development".

In the official documents of Ukraine there reflected a transition from the first to the second approach, and from 2013 the concept of energy security already implies ensuring sustainable development: "the economic situation that contributes to the efficient use of the country's energy resources, availability of a sufficient number of energy producers and suppliers in the energy market, as well as accessibility, differentiation, and environmental compatibility of energy resources" [19; 20]. Although the new understanding of this term points to the importance of the environmental component of energy security, it still focuses on energy sources (suppliers and energy producers), placing energy consumption beyond the scope of energy security: energy security only facilitates the efficient use of PERs.

Summarizing the carried out analysis, it can be noted that all the interpretations of this concept explicitly or implicitly include the idea of counteracting dangers that affect the uninterrupted energy supply. The variety of the available interpretations is determined by a number of limitations, filters of complexity, which are proposed to measure the security or risk of changes exclusively in the field of energy supply.

Uninvestigated parts of general matters defining. The problems of studying energy security become even more complicated at the methodological level. Thus, in the process of operationalization of energy security most scientists and scientific institutes do not consider the interrelation between the conceptual scheme and its methodological tools, offering an intuitive list of indicators presented by the local criteria for measuring energy security [1-6]. This work proposes to develop a systems approach to studying energy security at the conceptual level and provide its operationalization at the level of methodological support.

The research objective is the conceptualization of energy security on the basis of a systems approach and its operationalization using the 4E model: energy conservation – energy efficiency – energy dependency – energy self-sufficiency.

The statement of basic materials. Studying the problems of energy security should be built on understanding the philosophical aspects of the phenomenon "security", which can be defined by the following:

– there are several empirical approaches to understanding security: as a state of protection from threats, as a specific activity, as certain states [21], but they cannot be considered as theoretical (general and universal) ones;

– not all needs are an object of security, but only those that are an attribute of the existence of subjects of the system and security itself, and are realized through their activities, i.e., interests;

– security is represented as a set of interrelations between subjects that are in a certain hierarchical (vertical) structure of the system (individual → society → nature), and at the same time these relations are horizontally ordered (agreed);

– security of the system is determined by the actions of its individual elements but is undivided between them ("security for oneself through security for all"): "security of the system is equivalent to the safety of its weakest element" [23; 24];

– the concept of security is built on the laws of dialectics.

This allows to give our own empirical understanding of the concept "security" at the philosophical level as a state of an open system that ensures its existence and guarantees satisfaction of interests of its elements, as well as actions aimed at its (state) achievements. The presented definition proves the idea of the authors that security should be considered as a system concept. The methodology of its investigation can and should be built on the general system theory (L. von Bertalanffy [25]), the viable system theory (S. Beer [26]).

Traditionally, when investigating energy security problems, its certain components (blocks) are singled out: energy dependency, energy efficiency, price volatility, energy availability, environmental sustainability, energy equality, etc. [1-6]. However, this approach seems to be not well grounded and thus ineffective and does not lead to weighty results and conclusions. Therefore, in this paper, it is proposed to replace the block approach with the systems one based on the structure of the energy system itself, whose elements serve a basis for further assessment of the energy security indicators.

The basis of the system concept of energy security is energy systems and the relationship between their individual elements concerning the satisfaction of energy interests. This brings us to understanding by objects of energy security the attributes of the energy system and energy interests of its elements (Fig. 1).

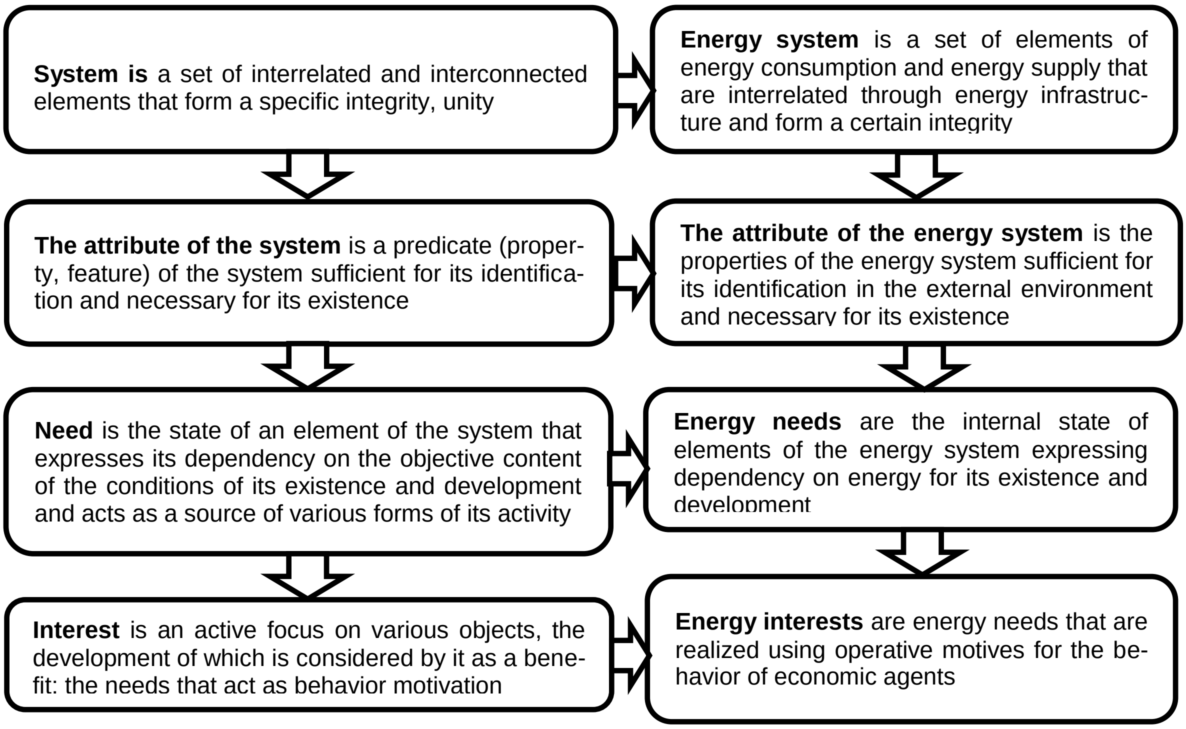

Fig. 1. Problem field of objects of energy security (developed by the authors based on [21; 22; 24])

The problem field shown in Fig. 1 allows to put forward the author's empirical definition of the concept "energy security", which refers to the state of the energy system that ensures its existence and development, which guarantee satisfaction of energy interests of its elements as well as actions aimed at achieving it.

A simple open system model, proposed by L. von Bertalanffy [25] is considered acceptable for studying problems of energy security systems. The energy system represents an open system that is part of, first, a higher-order energy system (external energy system); second, a more complex socio-economic system, and, third, an ecosystem (nature). The resources applied in the energy system are components of the socio-economic system (technology and human resources, information, etc.), PFERs, which the energy system itself removes from the ecosystem. PFERs, which give components of a higher complexity that represent the result of vital activity and are estimated as economic benefits introduced into the socio-economic system, are subject to conversion. At the same time, waste and emissions are dumped to the ecosystem from the energy system.

Based on S. Beer's Viable System Mode (VSM), all energy systems are considered recursive [26]: i.e., each energy system is part of itself and at the same time contains other viable / recursive systems (subsystems for energy supply, energy conversion and energy consumption), and it is part of a viable high-level system (socio-economic one, which is itself part of the ecosystem).

System decomposition implies the determination of subsystems and individual elements. The model of the structure of the energy system depends on the level at which the breaking down is stopped. As a result of the decomposition of the energy system considered in this work, there singled out subsystems of energy supply, energy conversion and energy consumption (Fig. 2).

It is the combination of the systems of energy supply, energy conversion and energy consumption that allows to consider the uninterrupted energy cycle that includes such stages of conversion of PFERs: extraction of PFERs → conversion of PFERs to energy and energy carriers → consumption of energy and energy carriers. Application of this approach within the framework of the system concept of energy security allows achieving significant results in reducing consumption volumes. Thus, the conservation of energy and energy carriers in the subsystem of energy consumption provides additional savings for the entire energy system: expenses of the energy conversion subsystem and costs of extracting PFERs in the energy supply subsystem decrease.

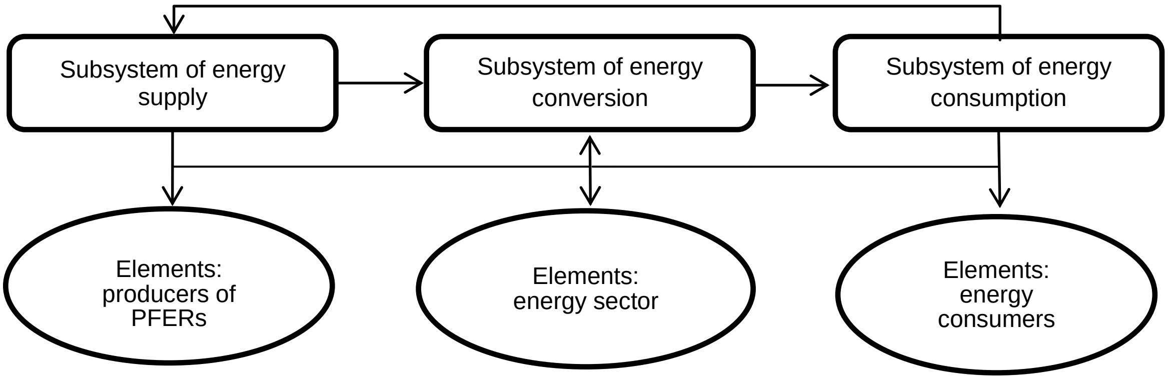

Fig. 2. Simplified model of the energy system structure

It can be noted that a specific feature of the energy system is that each element of the energy supply subsystem can potentially be transformed in the energy conversion subsystem to any type of energy and energy carriers, and at the same time used as raw materials and materials in the non-energy sphere of the energy consumption subsystem. For example, coal can be transformed into electricity, used to generate heat energy, consumed as boiler-stove fuel from which synthetic motor fuels can be obtained, or used as raw materials for non-energy consumption in the chemical industry. The direction of energy flows in a particular energy system is determined by its existing production and technological base, and, therefore, the strengthening of energy security is associated with its development.

Measurement of energy security should be carried out in the order reverse to the movement of energy flows in the energy system: from the subsystem of energy consumption to the subsystem of energy conversion, and then to the subsystem of energy supply. Thus, changing the block approach to the systems one leads to a new understanding of components of energy security, which should be presented by energy subsystems (Fig. 3). Thus, the presented systems approach to studying energy security problems gives rise to a new methodological approach to its assessment, based on analysis of indicators of subsystems of an integral energy system.

The problem of energy security is considered in the context of market relations in open energy systems, although issues of energy security are not limited to the market issue. The central place in energy security is occupied by the issue of ensuring satisfaction of energy interests, since all dangers have a negative impact on satisfaction of interests of its elements and their existence (Fig. 4).

In this case, satisfaction of energy interests is possible through balancing energy supply and demand. This paper emphasizes the fundamental importance of harmonization of the subsystems of energy supply, energy conversion and energy consumption in contrast to traditional approaches based on consideration of sources for satisfying energy demand in the required quantity and at affordable prices. Ensuring energy security means achieving such a state of the energy system when its subjects are aware of the effective level of their own energy consumption, which ensures their functioning in the chosen mode of operation and promotes their development, while energy producers are able to satisfy energy interests in the required quantity and of a proper quality.

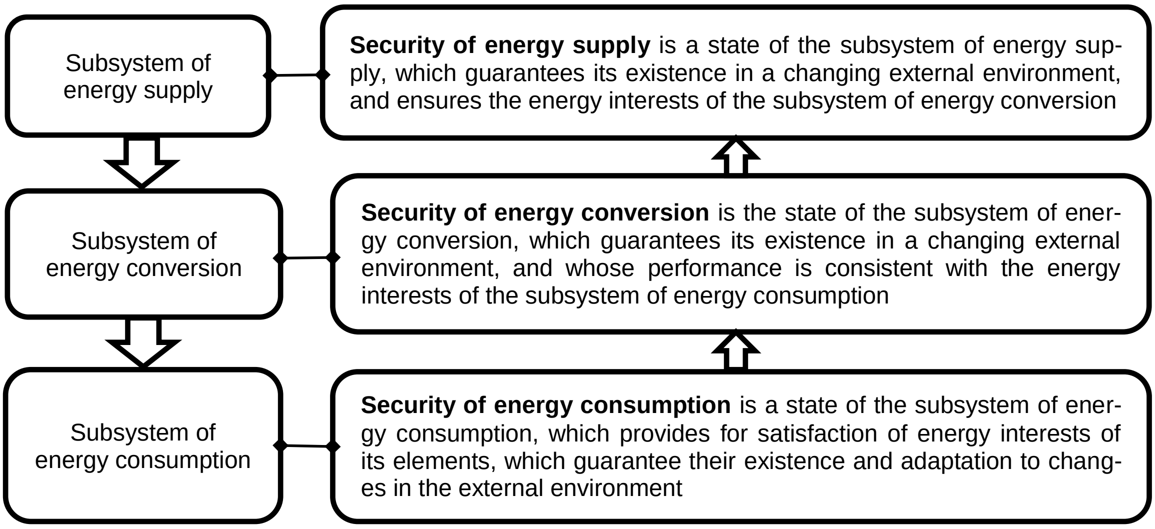

Fig. 3. System components of energy security

At the same time, prices act as regulatory links that determine the behavior of entities: limit their unreasonable needs, and transform the reasonable needs into energy interests.

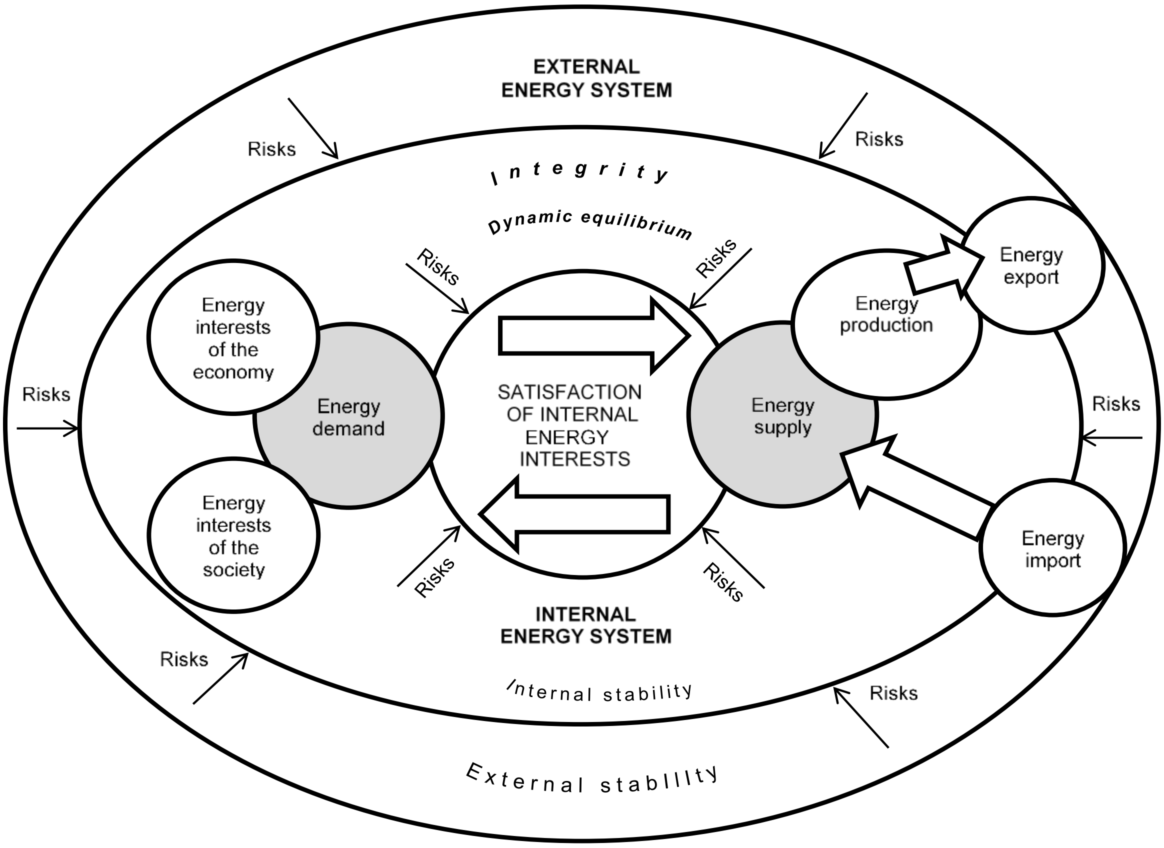

Fig. 4. Economic model of the energy system functioning

The operationalization of the systems approach to the study of energy security issues involves the development of a methodological approach to its assessment at the national level. The identified subsystems of energy security make it possible to propose three system indicators that will reflect the state of their functioning and development:

– for the subsystem of energy consumption, it is expedient to use the integral index of energy conservation, which determines the technological progressiveness of the final energy consumption;

– for the energy conversion subsystem, there used the integral index of energy efficiency, which reflects the property of an economic system for efficient conversion of PFERs (both domestic and imported ones) to other types of final energy;

– for the subsystem of energy supply, the integral index of energy dependency is used, which is measured as the level of dependency from the monopoly import of PFERs and their derivatives in the total amount of their primary supply of the country.

The presence of abrupt externalities, inherent in the current stage of development of ecological and socio-economic systems, necessitates the artificial introduction of a separate integral index of energy self-sufficiency, which characterizes the minimum attributes of the energy system necessary for its existence.

Thus, the 4E model, which consists of such components as energy conservation (EC), energy efficiency (EE), energy dependency (ED) and energy self-sufficiency (ES), is based on the author's methodological approach to the assessment of energy security of a national economy. All components of energy security are equivalent, i.e., they have the same importance for security of an energy system.

Further we present the main results of studying the assessment of these four system indicators.

The integral index of energy conservation is intended to characterize the gap in the trends in the volumes of economic activity and energy consumption. While for the dynamics of economic activity a growing trend is desirable, the dynamics of energy consumption should reflect a decline or a stable trend. The comparison of these two trends (the gap between the two indicators) allows to determine the progressiveness of the final energy consumption.

Thus, the energy conservation index for a particular type of economic activity is calculated as the difference between the volume index of production and the energy consumption index. Negative values of this indicator and its regressive dynamics are considered a positive characteristic, i.e., the increase in the volumes of economic activity should outstrip the dynamics of energy consumption. The integral index of energy conservation (EC) is proposed to be calculated by the formula (1):

$$EC = \sum_{i=1}^{N} \gamma_{\mathrm{i}} \times (IFEC_i - VIP_i), \quad (1)$$

where γ_i – specific weight of the i[th] sector of the economy in the inter-sectoral balance;

$IFEC_i$ – index of final energy consumption of energy resources by the relevant sector of the economy;

VIP_i – volume index of production the relevant sector of the national economy.

The calculation of the integral index of energy conservation (reference value is equal to 1) implies the standardization of local contributions to the achievement of the national target and is presented in Tab. 1.

Table 1

Estimation of energy conservation indices in the national economy of Ukraine

Indicator	2010	2011	2012	2013	2014	2015
Volume index of production	105.2	111.8	112.4	111.6	103.8	93.9
Index of final energy consumption	109.5	102.5	96.4	95.1	92.7	78.9
Weighted index of energy conservation	-0.1	-3.7	-3.7	1.2	-4.3	-5.9
Standardized index of energy conservation	0.003	0.186	0.184	0.000	0.216	0.295
Integral index of energy conservation	0.295					

The traditional way of the assessment of energy efficiency is calculating the energy conversion efficiency (*ECE*), which is the ratio of amount of final energy produced to amount of PFERs in energy terms. In this research, energy efficiency is understood as the economic energy conversion efficiency (*EECE*), which takes into account not only the amount of energy consumed and produced but also the cost of final energy and PFERs used for its production, and can be calculated by the formula (2):

$$\mathrm{EE} = EECE_{ij} = \frac{Output_{ij}}{Input_{ij}} \times \frac{Price_j}{Price_i} \quad , \tag{2}$$

where $Output_{ij}$ – output of the jth type of final energy of the ith type of PFERs;

$Input_{ij}$ – consumption of the ith type of PFERs for producing the jth type of final energy;

$Price_j$ – market price for the jth type of final energy;

$Price_i$ – market price for the ith type of PFERs.

The expediency of applying this index is justified by the different economic value of both PFERs and final energy in energy terms.

The calculation of the integral energy efficiency index requires consideration of the structure of consumption of PFERs for their conversion into final types of energy and standardization of the values of economic energy conversion efficiency (*EECE*) in terms of priority of their use for the production of certain types of final energy (Tab. 2).

Table 2

Economic energy conversion efficiency of PFERs in 2015

Indicator		Economic energy conversion efficiency (EECE)				Structure of PFERs for conversion				Standardized values of EECE			
		CrO	NG	C	Bio	CrO	NG	C	Bio	CrO	NG	C	Bio
Types of energy and energy carriers	EE	0.37	0.64	1.16	0.77	0.08	0.42	0.96	0.94	0.13	0.22	0.40	0.26
	TE	0.63	1.16	1.74	1.40	0.04	0.58	0.04	0.06	0.13	0.24	0.35	0.28
	MF	1.03	0.58	0.57	0.14	0.88	–	–	–	0.45	0.25	0.25	0.06
EE of the ith type of PFERs											0.41	0.23	0.39
Structure of PFERs											0.12	0.29	0.57
Integral index of EE										0.34			

CrO – crude oil; NG – natural gas; C – coal; Bio – biofuel; EE – electrical energy; TE – thermal energy; MF –motor fuel

The economic interpretation of local values is as follows:

1) if its value is greater than 1, then the technology is considered efficient, and it is expedient to use the ith type of PFERs and produce the jth type of final energy;

2) if the value of this index is less than 1, this corresponds to the situation when less than 1 monetary unit of final energy is produced per monetary unit spent on consumption of PFERs and such use of PFERs is considered inefficient;

3) among the several technologies for production of the jth type of final energy, the most efficient is the one for which the value of the economic energy conversion efficiency (*EECE*) is higher.

Energy dependency is measured as the level of dependency from the monopoly import of PFERs and their derivatives in the total volume of their primary supply of the country and can be calculated by the formula (3):

$$ED = 100 - \sum_{i=1}^{N} \gamma_i \times \frac{Import_i}{TPES_i} \times \beta i \times 100\%, \tag{3}$$

where γ_i – specific weight of the ith type of PFERs in the energy balance;

$Import_i$ – total import of the ith PFERs;

$TPES_i$ – total primary energy supply by the ith type of PFERs;
βi – share of the monopoly importer in the total volume of imports of the ith type of PFERs.

The standardization of this index implies its comparison with the national boundary values, on the basis of which a monopoly position in the market is determined. The calculation of the level of Ukraine's energy dependency is presented in Tab. 3.

Table 3

Energy dependency of the national economy in 2015

Indicators	C	CrO	OP	NG	Bio
Production, ths toe.	17423	2618	-	14814	2606
Import, ths toe.	9940	238	7887	13288	30
Export, ths toe.	-487	-22	-90	0	-539
Net import, ths toe.	9453	216	7797	13288	-509
Total supply of primary energy, ths toe.	27344	2851	7700	26055	2102
Energy dependency by types of fuel and energy resources, %	0.36	7.58	101.26	51.00	-24.22
Specific weight of the ith type of PFERs in the total energy balance, %	30.4	3.2	8.5	28.9	2.3
Share of the dominant import, %	54.3	99.9	46	37.3	81.9
The country of origin of the imported FER by the dominant importer	Russia	Kazakhstan	Belarus	Russia	Turkey
Energy dependency on monopoly imports, %	19.74	8.34	47.12	19.02	1.17
Energy independency on monopoly imports, %	80.26	91.66	52.88	80.98	98.83
Standardized values of energy independency from monopoly imports, %	0.436	0.762	0.000	0.457	0.967
Integral index of energy dependency	0.3111				

C – coal; CrO –crude oil; OP – oil products; NG – natural gas; Bio – biofuel

Assessment of the energy self-sufficiency of the national economy involves calculating the country's minimum energy demand (MED) for corresponding types of PFERs in the event of an emergency, that is, necessary to maintain the existence of the energy system. The MED is calculated on the basis of the necessity to cover 100 % of the vital needs (food, agriculture, living conditions of the population, public services) and 25 % of the needs of other types of economic activity (mining, processing industry and construction) in the final types of energy (electricity, heat energy, motor fuels, as well as final consumption of natural gas and solid fuels).

The assessment of the MED level is based on a retrospective analysis of the annual energy balance in the corresponding areas of final energy consumption (Tab. 4):

$$ES = \sum_{i=1}^{N} \gamma_i \times \frac{Output_i + Stocks_i}{MED_i} \times 100\% \quad (4)$$

where γ_i – specific weight of the ith supply of PFERs in the energy balance of the country;
$Output_i$ – total output of the ith type of PFERs;
$Stocks_i$ – available stocks by the ith type of PFERs at the beginning of the year;
$MEDi$ – minimum energy demand by the ith type of PFERs.

The recalculation of the level of final energy consumption to the level of the demand for primary fuel and energy resources is carried out taking into account the highest level of the actual ECE by the spheres of energy conversion: crude oil→ motor fuel (0.54), coal → electrical energy (0.32); natural gas → a) natural gas (is not converted); b) thermal energy (0.75); others → others (are not converted).

Table 4

Estimation of the minimum energy demand (MED) in 2015

Indicator	Sphere of use	Type of final energy					
		EE	TE	NG	MF	Others [1]	Total
Annual energy demand, ths toe.	Food industry	350	740	165	114	28	1397
	Agriculture	287	212	129	1300	28	1956
	Household sector	2874	3184	9083	14	1400	16555
	Transport	585	0	1572	6554	38	8749
	Public services	1878	1560	195	92	113	3838
	Extractive industry	844	75	293	276	2	1490
	Process industries	3039	2049	2279	269	5622	13258
	Construction	64	16	25	155	3	263
	Total	6961	6231	11793	8249	3014	36248
ECE	CrO				0.54		
	NG		0.75	1			
	C	0.32				1	
	Bio					1	
Minimum demand for PFERs, ths toe.	CrO				15276		15276
	NG		8308	11793			20101
	C	21753				1392	23145
	Bio					1622	1622

EE – electrical energy; TE – thermal energy; NG – natural gas; MF –motor fuel
[1] - biofuel, wastes and coal

The level of energy self-sufficiency of the country is calculated as the ratio of the minimum demand for PFERs to annual production level and stocks available at the beginning of the year using formula (4) and is presented in Tab. 5.

Table 5

Energy self-sufficiency of the national economy in terms of PFERs

PFERs	MED, ths toe.	Annual output, ths toe.	Energy self-sufficiency in terms of output, %	Stocks, ths toe.	General energy self-sufficiency, %	Specific weight of the i^{th} energy resource, %	Standardized values of energy self-sufficiency
CrO	15276	2037	13.3	821	18.7	0.16	0.1306
NG	20101	14814	73.7	10755	127.2	0.394	0.8882
C	23145	11688	50.5	2050	59.4	0.414	0.4144
Bio	1622	2323	143.2	–	143.2	0.032	1.0000
Total	60144	30862	280.7	13626	82.28	1	0.574

The general level of energy security of the country is calculated as the average of its four components, since all the components are equivalent, and is equal to 0.381 (Fig. 5).

Thus, the integral index of energy security is boundary with its value being between the crisis and the pre-crisis state (on the Harrington's desirability scale). The subsystem of energy consumption is characterized by the lowest value (the energy conservation index is 0.295), which indicates the fuel and raw materials orientation and technological backwardness of the national industry. The energy component has reached its highest level (energy self-sufficiency index is 0.574) due to the surplus production of solid PFERs and the presence of significant stocks of natural gas in storage facilities.

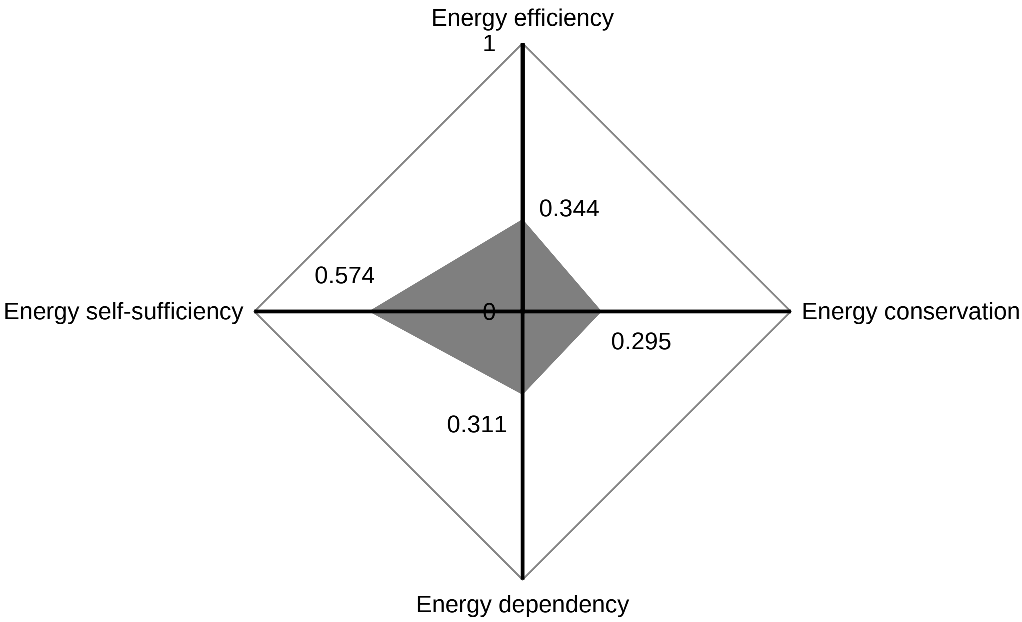

Fig. 5. Profile of energy security of Ukraine in 2015

Conclusions. The conceptualization of energy security shows that it should be considered on the basis of a systems approach. The principal assertions justifying its system concept are as follows:

1) objects of energy security are the attributes of an energy system and energy interests of its elements;

2) energy security is considered as the internal state of the energy system;

3) import and export are a priori regarded as entropy processes presenting dangers for its integrity and existence;

4) assessment of energy security should be based on qualitative and quantitative characteristics of its subsystems: energy supply, energy conversion and energy consumption;

5) measurement of energy security is carrying out in a reverse order in relation to the direction of movement of energy flows in the energy system: security of energy consumption → security of energy conversion → security of energy supply.

The operationalization of energy security is based on the development of a methodological approach to its assessment by subsystems of energy consumption, energy conversion and energy supply, for evaluation of which three system indicators have been proposed: indicator of energy conservation, energy efficiency and energy dependency. To determine the attributes of the energy system that support its existence, energy self-sufficiency is additionally introduced to the composition of these indicators.

The approbation of the proposed methodological approach to the Ukrainian energy system has allowed to conclude that its current level is low.

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Received for publication 01.03.2018

Бібліографічний опис для цитування :

Khaustova, V. Ye. Energy security of the national economy based on a systems approach / V. Ye. Khaustova, T. I. Salashenko, O. V. Lelyuk // Науковий вісник Полісся. 2018. – № 2 (14). Ч. 1. – С. 79-92.

ЕКОНОМІКА ТА УПРАВЛІННЯ НАЦІОНАЛЬНИМ ГОСПОДАРСТВОМ

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