Energy in the Context of Sustainable Development

Tatsiana G. Zoryna[1,*], Alexander A. Mikhalevich[1]

[1] Institute of Power Engineering of the Academy of Sciences of Belarus, Minsk, Belarus.

***Abstract* — The paper is concerned with the theoretical and methodological framework of the sustainable energy development and presents a notion of the sustainable energy development for a region. The methodology for a comprehensive assessment of the sustainable energy development is considered, and criteria for the sustainable energy development evaluation are identified. These criteria include the availability of resources, directions of social and economic development, demand for energy resources, and energy security. Based on this methodology a complex index is developed for estimation of the sustainable energy development, and for energy monitoring of the objects by an additive aggregation method. Based on the proposed index, the level of sustainable energy development of the Eurasian Economic Union (EEU) countries for 2016 was analyzed.**

***Index Terms* — energy, sustainable development concept, index of sustainable energy development**

I. Introduction

In September 2015, the UN members adopted the 2030 Agenda for Sustainable Development [2]. It contains a number of goals to eradicate poverty, preserve the resources of the planet and ensure prosperity for everybody. One of the goals is to provide general access to affordable, reliable, sustainable and modern energy sources for all. Each of the 17 goals contains a number of indicators to be reached within 15 years.

In the context of energy development until 2030, in particular, this entails:

- ensuring universal access to affordable, reliable and modern energy services;
- substantially increasing the share of renewable energy in the global energy mix;
- doubling the global rate of improvement in energy efficiency;
- enhancing international cooperation to facilitate the access to clean energy research and technology including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology;
- expanding infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries

II. The notion and the methodology to assess the sustainable energy development

There are a number of interpretations of this notion. We believe that the simplest and most accurate is the following: the sustainable energy development is the development of a self-regulating system of energy supply and energy consumption providing energy security, equally accessible satisfaction of energy needs and aspirations of all social strata at conservation of the environment.

This definition shows that sustainable energy development is a wider concept than energy security, since in addition to economic, technological and political factors it also includes ecological and social ones. Besides, energy supply and energy consumption are considered as interdependent parts of one system capable of self-regulation.

Moreover, sustainable development is subject to significant influence of a number of global energy risks, including:

- expansion of the energy system scale;
- threat of an imbalance between energy demand and supply, first of all, in terms of oil fuel;
- high level and instability of the world oil prices, the end of the cheap oil and gas era;
- disproportions in the world energy infrastructure because of hydrocarbon resources concentration in the areas remote from the main centers of consumption.

* Corresponding author.
E-mail: tanyazorina@tut.by

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90% of the world GDP is produced in the countries importing energy resources;

- risks of natural and technogenic catastrophes and system accidents, in part because of terrorist and subversive actions;
- negative environmental impact of energy;
- wide scale of energy poverty which means 2 billion people lacking the opportunity to use energy services in acceptable commercial and technological conditions.

The theory and practice of using the concept of sustainable development in energy have various approaches to understanding and methods to assess the condition of the given sector from the point of view of sustainable development. The issues of sustainable energy development were considered in the studies conducted by such experts as D. L. Green [2], I. Dincer [3], S. Connors [4], M.V. Myasnikovich [5], K. Prandecki [6], H. Rogall [7], G.W. Frey [8], etc. The methodologies for assessment of sustainable energy development were worked out by the World Energy Council [9] and Georgia Institute of Technology, USA [10].

At the same time, the existing approaches are focused on the determination of separate elements and factors characterizing sustainable energy development rather than on comprehensive consideration of this phenomenon.

Based on an analysis of the studies carried out by national and foreign scientists, we have identified the indicators of sustainable energy development.

All these factors can be divided into the following categories:

1) by the direction of influence – into external and internal ones;

2) by the sphere they relate to – into economic, technological, social, and ecological ones;

3) by the assessment principles of the sustainable energy development – into availability of resources, the directions of social and economic development, demand for energy resources, energy security.

A method to calculate the indicators of sustainable energy development is presented in Table 1.

The weight of the indicators is determined by the method of group expert assessment at direct estimation. At the same time, each expert establishes preferences of indicators when comparing all possible pairs, i.e. considering all possible pairs of indicators the expert establishes in each of them the reason, which, according to their opinion, exerts a greater influence on the result [12].

According to the Concept of sustainable development [1] and taking into account the specific features of energy distinguishing it from other industries (involvement in provision of the national security, mandatory generating capacity reserve, etc.), the economic, technological, social and ecological aspects are equivalent. In this regard, the identical weight equal to 0.25 is assigned to each of the factors.

In this stage, the index is calculated according to the following formula:

Table 1. A method to calculate the indicators characterizing sustainable energy development and their classificationt.

Factor	Indicator	Explanations concerning calculation
Economic	Availability of credit resources	Difference of 1 and the average interest rate for the credits and deposits of banks in national currency
	Share of energy in GDP	Ratio of the sum of the energy industries output to the total output
	Return on energy sales	Ratio of the sum of the energy industries gross profit to the total energy industries gross revenue
	Share of non-dominant energy resources in the total energy resources import	Difference of 1 and the share of the dominant energy resource in the total energy resources import
Technological	Share of own energy resources in the total energy consumption	Difference of 1 and the share of the imported energy resources in the total energy consumption
	Share of investment in energy	Ratio of investment into the energy industries to the total investment
	Energy-GDP ratio	Ratio of energy consumption to GDP
	Share of capacities not involved in the energy industry	Difference of 1 and the ratio of the sum of primary oil refining volume, electricity production, gas through gas pipelines transportation volume and oil through oil pipelines transportation volume converted to uniform measurement units, to the total capacities for primary oil refining, electricity generating capacities, gas pipelines capacity and oil pipelines capacity converted to uniform measurement units
Social	Employment rate	Difference of 1 and the share of the unemployed in the total labor force
	Education	The indicator of the same name from HDI is used [11]
	Availability of fuel and energy for population	Difference of 1 and the relation of fuel and energy expenses to the total expenses of households
	Population electrification rate	Share of the population having access to electricity
Ecological	Forest area level	Share of the forest area in the total land area of the country
	Life expectancy	The indicator of the same name from HDI is used [11]
	Coefficient of reducing energy resources consumption	Difference of 1 and the ratio of energy resources consumption for the reporting period to that in the previous year
	CO2 emissions caused by energy consumption per capita	Difference of 1 and volume of CO2 emissions from energy consumption divided by the population number

Table 2. Initial data and calculation results of the index of sustainable energy development for the EEU in 2016

Indicator	Weight	Belarus	Russia	Kazakhstan	Kyrgyzstan	Armenia
Group indicators characterizing economic factors	0,250	0,379	0,442	0,414	0,321	0,316
Availability of credit resources	0,285	0,739	0,866	0,834	0,778	0,840
Share of energy in GDP	0,194	0,115	0,226	0,134	0,048	0,046
Return on sales in energy	0,306	0,131	0,120	0,281	0,000	0,098
Share of non-dominant energy resources in the total energy resources import	0,215	0,492	0,535	0,298	0,419	0,174
Group indicators characterizing technological factors	0,250	0,418	0,616	0,642	0,651	0,509
Share of own energy resources in the total energy consumption	0,267	0,146	1,000	0,917	0,759	0,304
Share of investment in energy	0,276	0,174	0,281	0,343	0,191	0,076
Energy-GDP ratio	0,285	0,929	0,918	0,924	0,914	0,946
Share of capacities not involved in the energy industry	0,172	0,383	0,055	0,229	0,784	0,796
Group indicators characterizing social factors	0,250	0,923	0,908	0,925	0,900	0,826
Employment rate	0,210	0,950	0,945	0,950	0,923	0,824
Education	0,198	0,796	0,804	0,794	0,664	0,743
Availability of fuel and energy for population	0,372	0,929	0,887	0,935	0,956	0,769
Population electrification rate	0,220	1,000	1,000	1,000	0,998	1,000
Group indicators characterizing ecological factors	0,250	0,566	0,577	0,378	0,418	0,461
Forest area level	0,404	0,425	0,498	0,012	0,033	0,117
Life expectancy	0,138	0,792	0,773	0,763	0,781	0,844
Coefficient of reducing energy resources consumption	0,156	0,010	0,015	0,000	0,000	0,000
CO2 emissions from energy consumption per capita	0,302	0,939	0,883	0,887	0,983	0,982
Index of sustainable energy development	1,000	0,571	0,636	0,590	0,573	0,528

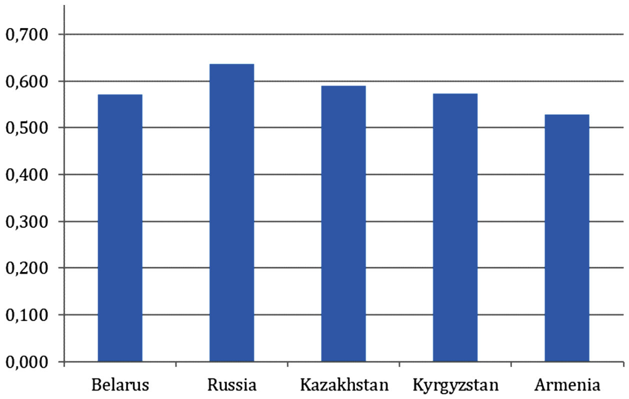

Fig. 1. Index of sustainable energy development for the EEU countries in 2016.

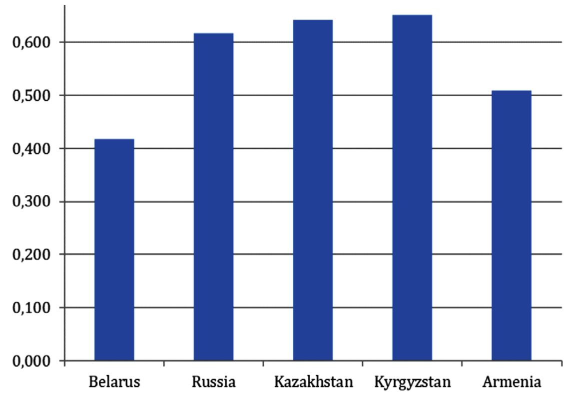

Fig 3. Group indicators characterizing technological factors of the EEU countries sustainable energy development in 2016.

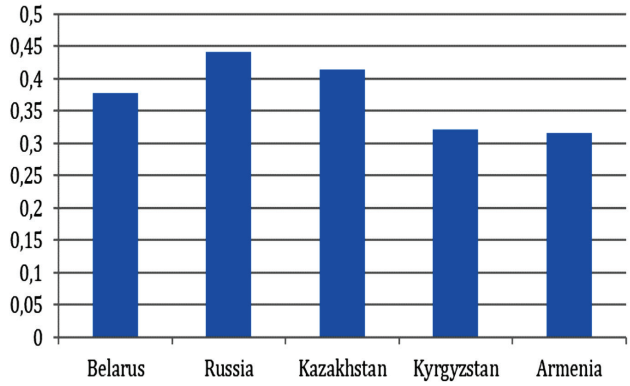

Fig 2. Group indicators characterizing economic factors of the EEU countries sustainable energy development in 2016.

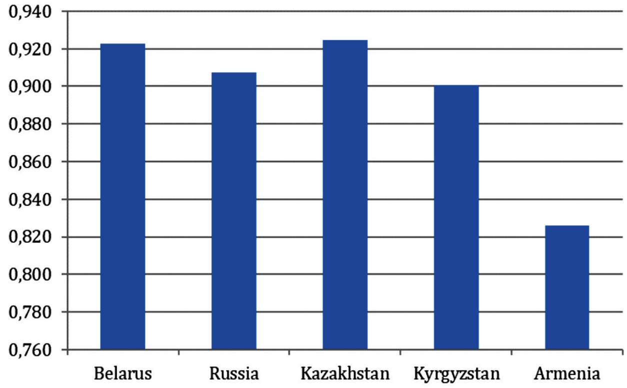

Fig. 4. Group indicators characterizing social factors of the EEU countries sustainable energy development in 2016.

$$I = \sum_{j=1}^{k} z_j \sum_{i=1}^{m} x_{ij} f_{ij},$$

where I – index of sustainable energy development; z_j – weight of j factor ; x_{ij}- weight of i indicator for j factor; f_{ij}- value of i indicator for j factor; k – number of factors; m–number of indicators.

III. Ranking of countries on the level of sustainable energy development

After calculation of the indices of sustainable energy development for different countries, they were ranked. The country with the highest value of the index is assigned 1.

On the basis of the given methodology, the index of sustainable energy development for the EEU (the Eurasian Economic Union) countries in 2016 was calculated (Table 2). Sources of information for calculating the index were the data of national statistics, the database of the International Energy Agency and the World Bank.

As evidenced by Figure 1, Russia is ranked first in the level of sustainable energy development in 2016, Kazakhstan is the second. Belarus and Kyrgyzstan are at a close level; Armenia is the last among the EEU countries. In general, for the EEU countries, except for Russia, the value of the index characterizing the level of sustainable energy development varies from 0.500 to 0.600, for Russia it exceeds 0.600.

Figure 2 shows the group indicator characterizing economic factors of the EEU countries sustainable energy development in 2016.

As seen from Figure 2, Russia is ranked first in the group indicator characterizing economic factors of sustainable energy development. This is caused, first of all, by the absence of imported energy resources in its energy consumption and the highest share of energy in GDP among the countries under analysis. Kazakhstan is the second. This country had the highest profitability of energy among

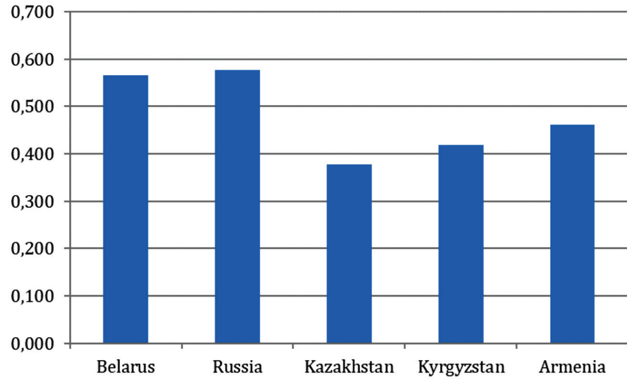

Fig. 5. Group indicators characterizing ecological factors of the EEU countries sustainable energy development in 2016.

the EEU countries and insignificant need to import energy resources. Armenia is ranked last owing to a low share of energy in GDP, low profitability and an insignificant share of non-dominant energy resources.

Figure 3 shows the group indicator characterizing technological factors of the EEU countries sustainable energy development in 2016.

As seen from Figure 3, Kyrgyzstan and Kazakhstan hold the leading positions in the group indicator characterizing technological factors of sustainable energy development, firstly - at the expense of a considerable amount of capacities that are not involved in the energy industry, secondly - at the expense of the share of own energy resources in the total energy consumption. Belarus is ranked last due to the lowest share of own energy resources in the total energy consumption.

Figure 4 shows the group indicator characterizing social factors of the EEU countries sustainable energy development in 2016.

As is demonstrated by Figure 4, Belarus and Kazakhstan are ranked first in the group indicator characterizing social factors of sustainable energy development in 2016, thanks to high employment rate and high availability of fuel and energy for the population. Armenia is the last due to a more considerable, than in the other examined countries, share of fuel and energy expenses in the total expenses of households.

Figure 5 shows the group indicator characterizing ecological factors of the EEU countries sustainable energy development in 2016.

It is obvious from Figure 5, that Belarus and Russia hold the leading position in the group indicator characterizing ecological factors of sustainable energy development in 2016 because of the high level of forest area in comparison with the other EEU countries and a positive coefficient of reducing energy resources consumption. Kazakhstan is ranked last in this group indicator due to the lowest level of forest area and life expectancy among the countries in question.

IV. Conclusion

Thus, Russia is ranked first in the level of sustainable energy development due to the high group indicators characterizing economic and ecological factors. Kazakhstan is the second because of high economic and social factors. Kyrgyzstan is the third owing to the high group indicator of technological factors and the average level of the other group indicators. Belarus is ranked fourth because of low group indicators characterizing economic and technological factors. Armenia is the last, although it has a high technological potential. Despite the differences in group indicators, all the countries have almost the same level of sustainable energy development, consequently, we can draw a conclusion that the coordinated economic policy and operation of the common energy market will allow the EEU countries to enrich each other with their experience in the improvement of various aspects of sustainable development.

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Tatsiana G. Zoryna was born in 1973. She graduated from Belarusian State Economic University (BSEU) in 1996, received the PhD degree in Economics and National Economy Management from BSEU in 2007 and the degree of Doctor Habilitatus in 2017. Now she works as a leading researcher in the Institute of Power Engineering of the Academy of Sciences of Belarus and holds a Chair of Business Economics and Law in BSEU. Her current interests are energy economics, sustainable development, logistics and marketing.

Alexander A. Mikhalevich was born in 1938. He graduated from Belarusian Polytechnic Institute in 1961, received the degree of PhD in Engineering in 1975. He has been professor since 1978 and Academician of the National Academy of Sciences of Belarus since 2000. Now he works as a Chief Researcher in the Institute of Power Engineering of the Academy of Sciences of Belarus. His current interests are nuclear power engineering, energy planning, heat- and mass transfer at physical and chemical transformations, optimization of heat processes and equipment, renewable energy sources.