

# Issues of an integral assessment of the state of Russia's energy security at the federal level

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**Abstract.** The paper is devoted to the issue of an integral assessment of the state of Russia's energy security at the federal level. A methodology for the formation of such an assessment is proposed. Qualitative assessments of the state of energy security of the main objects of indicative analysis were formed on the basis of assessments of the qualitative state of the most important indicators of energy security. The paper presents a method of convolution of qualitative assessments of energy security for all objects of indicative analysis. As an example, integral qualitative assessments of Russia's energy security for 2015 and 2016 are formulated. The analysis of formulated qualitative assessments makes it possible to understand the main problems of ensuring Russia's energy security in the modern period.

## 1 Introduction

The main provisions of the Doctrine of Energy Security of the Russian Federation [1] contain various aspects of energy security (ES). These aspects should be assessed annually at the federal level. In [2, 3], approaches to the estimation of threshold and current values of the most important indicators of ES characterizing these aspects were described.

The problem of an integral assessment of the energy security of the country as a whole remains open to this day. What is this assessment and what are the directions and dynamics of this change from year to year?

Based on earlier studies [2, 3] and statements [1], 14 objects of indicative analysis (OIA) were identified. These objects include 47 indicators. How can we assess the ES of the country as a whole? The values of some indicators deteriorate over time in terms of ES, the values of others improve. How does the situation with the country's ES change in this case? To answer these questions, it is necessary to develop a methodical approach to the formation of an integrated assessment of the country's ES with any number of analysed indicators.

Current literature includes some works on energy security research. The most suitable ones are listed below. In Russia, this issue is most fully covered in [1-5]. Some researchers in the world have dealt with the identification of the most significant indicators. For example, this issue is covered in [6-9]. In [6], on the example of India, the authors describe the relationship of energy security with business, social processes and with the management of society. In [7] a look at the main problems of ensuring China's energy security based on the use of some major indicators. First of all, in this work, there are problems of importing energy resources to China. In [8] questions are raised about the problems

of ensuring the energy security of Europe from the standpoint of the use of renewable energy resources. The paper analyzes the degree of participation in this process of the Desertec project (construction of the big solar power system in the Sahara). In [9] a general structure for the description and analysis of the energy security in an energy system is presented. The paper is devoted to the methodology of energy security research in the context of one system. Unlike energy independent Russia, it is important for most countries to monitor not only the structure of their energy balance. Particularly important is the share of the largest energy supplier in their total volume of energy resources import.

## 2 Methodological approach for the qualitative assessment of the OIA state from the standpoint of energy security

### 2.1 Qualitative assessment of the state of energy security indicators

The current values of the indicators are compared with their thresholds, justified in advance. For indicators of the federal level, this was done in [2].

The process of assigning the value of an indicator to a certain state can be represented as follows:

$$A_{ij} = f_{ij}(S_{ij}) = \begin{cases} N, S_{ij} < S_{ij}^{PC} \\ PC, S_{ij}^{PC} \leq S_{ij} < S_{ij}^C \\ C, S_{ij} \geq S_{ij}^C \end{cases} \quad i = 1, n; j = 1, k \quad (1)$$

where  $A_{ij}$  - qualitative assessment of the state of the  $j$ -th indicator of the  $i$ -th OIA;  $n$  - number of OIA;  $k$  - number of indicators in each OIA;  $S_{ij}$  - the actual value of the  $j$ -th

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indicator of the  $i$ -th OIA;  $S_{ij}^{PC}, S_{ij}^C$  - threshold values of the  $j$ -th indicator of the  $i$ -th OIA (pre-crisis and crisis, respectively);  $N, PC, C$  - possible state of energy in the aspect displayed by the  $j$ -th indicator of the  $i$ -th OIA (normal, pre-crisis and crisis, respectively).

## 2.2 Qualitative assessment of the OIA state from the standpoint of energy security

The next step should be to assess the qualitative state of each of the 14 OIA specified in the Energy Security Doctrine, [1]. All objects are characterized by corresponding indicators of the federal level in the number from 1 to 7. The process of forming such a qualitative assessment is presented below:

$$Q_i = F_i(A_{i1}, \dots, A_{ik}), i = 1, n \quad (2)$$

where  $Q_i$  - qualitative assessment of the state of the  $i$ -th OIA;  $n$  - the number of OIA;  $A_{i1}, \dots, A_{ik}$  - qualitative assessments of the status of  $k$  indicators in the  $i$ -th OIA.

The rules  $F_i$  on which  $Q_i$  is determined can be different for each  $i$ -th OIA. The simplest way is to analyze the significance of each particular indicator in the summary significance of all indicators for the analyzed object. In other words, it is possible to determine the "specific weight" of a particular indicator in the sum of the weights of all indicators of the analyzed object. Further, we summarize all the specific weights of indicators whose values are in the same qualitative state. The sums of specific weights, grouped by qualitative conditions, will allow to form a qualitative assessment of the state of the whole object of analysis. At the first stage, considering the approximate equivalence of indicators within a single object, it can be assumed that they all have the same specific weight in the total sum of the weights. This assumption follows from the consideration of specific indicators for the relevant objects of analysis [2, 3].

After determining the specific weights of all indicators in the overall system of their significance (while we agreed that within the framework of one OIA they all have the same weight), it is possible to form a qualitative assessment of the state of each analysis object from the standpoint of energy security. This can be done as follows:

$$Q_i = \begin{cases} N, \sum_{j=1}^k V_{ij}^N \geq \delta_N \\ PC, \sum_{j=1}^k V_{ij}^C < \delta_C \text{ and } \sum_{j=1}^k V_{ij}^N < \delta_N \\ C, \sum_{j=1}^k V_{ij}^C \geq \delta_C \end{cases} \quad (3)$$

where  $Q_i$  - qualitative assessment of the state of the  $i$ -th OIA;  $k$  - number of traced indicators in the  $i$ -th OIA;  $V_{ij}^N, V_{ij}^C$  - the specific weight of the  $j$ -th indicator in the

$i$ -th OIA, located in the area of normal and crisis values, respectively;  $\delta_N, \delta_C$  - values that characterize the level of achievement of a normal or crisis state, respectively.

Since we are talking about specific weights, it is clear that the sum of all the specific weights of indicators for one object is equal to one. In studies of the regional level of indicative analysis [4], the value of reaching the normal state  $\delta_N$  was determined to be 0.7. A smaller value may mean that more than 30% of the sum of the specific weights of the indicators is in the zone of crisis values. The value  $\delta_C$  was taken equal to 0.4 and means that the state of energy security can be characterized as a crisis if 40% or more of the sum of the specific weights of the indicators is in a state of crisis. All other cases characterized the pre-crisis state. When analyzing the federal level of ES it is proposed to use the same rules.

## 3 Formation of an integral qualitative assessment of the state of energy security for the country as a whole

### 3.1 Convolution of qualitative assessments of the state of energy security across all analysis objects

Carrying out the above procedures will allow to determine the qualitative assessment of the state of each OIA from the ES positions. Next, we will carry out the procedure for convolution of the qualitative states of ES of all OIA in order to obtain an integral qualitative assessment of the state of the country's ES. In this case, we are dealing with different objects of analysis (Table 1) in terms of the significance of the impact on the country's ES. To compare the significance of these objects with each other, we can use, as in [4], a method of pairwise comparison of their significance relative to each other. This can be done expertly using the method of interpolating the opinions of a group of experts in the field of ES. As a result of this comparison, it is possible to obtain a certain specific gravity of a specific analysis object in the total sum of "weights" of all the objects under study. This specific weight will show the significance of this object for ensuring the country's EE in the overall system of significance of the analyzed objects. We can determine this specific weight as follows:

$$V_i = \sum_{j=1}^n v_{ij} / \sum_{i=1}^n \sum_{j=1}^n v_{ij}, \quad (4)$$

where  $V_i$  - specific weight of the  $i$ -th object of analysis in the system of evaluated objects;  $n$  - number of OIA;  $v_{ij}$  - the conditional significance of the  $i$ -th object of analysis in comparison with the  $j$ -th object.

The conditional significance  $v_{ij}$  is the average value of the opinions of the experts on the relative importance of the  $i$ -th object of analysis before the  $j$ -th. The matrix

of conditional comparative significance of objects of the analysis of ES is presented in Fig. 1.

To fill this matrix, the knowledge of experts in the field of ES is used. In determining the optimal number of experts, one can use the classical theory of tests, which shows the dependence of the increase in the reliability of the aggregate judgments of the subjects on the number of subjects [5-7].

	1	2	3	...	n
1	1	$U_{12}$	$U_{13}$	...	$U_{1n}$
2	$U_{21}$	1	$U_{23}$	...	$U_{2n}$
3	$U_{31}$	$U_{32}$	1	...	$U_{3n}$
...	...	...	...	1	...
n	$U_{n1}$	$U_{n2}$	$U_{n3}$	...	1

Fig. 1. The matrix of conditional comparative significance of OIA of ES

These studies show that the median value of the accuracy of the estimates obtained by the three experts is an order of magnitude and twice that of those obtained by one or two experts, then increases insignificantly, reaching a maximum in the range of five to nine experts. If the "importance weights" of experts are equal, then their optimal number can be within 3-5 people.

### 3.2 Integral qualitative assessment of the ES state at the country level

The steps above allow us to make a qualitative assessment of the state of the EE at the country level. The process of obtaining such an assessment is presented below:

$$G = \begin{cases} N, \sum_{i=1}^n V_i^N \geq \gamma_N \\ PC, \sum_{i=1}^n V_i^C < \gamma_C \text{ and } \sum_{i=1}^n V_i^N < \gamma_N \\ C, \sum_{i=1}^n V_i^C \geq \gamma_C \end{cases} \quad (5)$$

where  $G$  - a qualitative assessment of the state of the country's ES;  $N$  - number of analyzed analysis objects;  $V_i^H, V_i^K$  - the specific weight of the  $i$ -th object of analysis, located in the area of normal and crisis values, respectively;  $\gamma_N, \gamma_C$  - coefficients that characterize the level of achievement of a normal or a crisis state, respectively

Values  $\gamma_H$  and  $\gamma_K$  can be adopted according to the same logic as for the values  $\delta_H, \delta_K$  in the description of (3).

Further, it is possible to form a qualitative assessment of the state of energy security of the country as a whole. At the same time, it is important to understand that this qualitative assessment is formed on the basis of the

numerical values of the most important indicators of the federal level.

Any qualitative assessment must necessarily be accompanied by supporting materials containing information on the state of individual objects of analysis. This information allows us to understand which aspects of the provision of EB should first of all be paid attention. At the same time, each OIA is characterized by specific indicators of EB. An analysis of the current values of these indicators allows us to determine the directions in which it is necessary to initiate activities to improve the situation with the provision of ES.

## 4 An example of practical research

### 4.1 Assessment of the qualitative state of energy security for the objects of indicative analysis

We will apply the above methodological approach to assess the real situation with the provision of Russia's ES at the federal level. Information on the OIAs and specific indicators that characterize these objects is presented in the list below:

Object 1. The ratio of the annual increase in the balance reserves of primary fuel-energy resources (FER) to the volumes of their extraction.

Indicators 1.1-1.4 "Ratio of the increase in recoverable balance reserves of the type of primary FER for the accounting year to the total volume of production of this type of FER in the country for the same year" for oil, gas, coal and uranium, respectively (for uranium for 5 years).

Object 2. The share of natural gas in the structure of the balance of primary FER.

Indicator 2.1 "Share of natural gas in the structure of the balance of primary FER"

Object 3. Dynamics of the level of prices inside the country for the main types of FER.

Indicators 3.1-3.6 "The annual index of changes in prices (tariffs) in the country's average for the type of FER for the accounting year in relation to the previous year" for gas, coal, fuel oil, light oil products (in general), electricity, heat, respectively.

Object 4. The amount of non-payments in the retail and wholesale electricity markets.

Indicator 4.1 "Relation of the amount of non-payments to sales organizations in the country as a whole from retail electricity consumers for electricity supplied to them (consumers) in the accounting year to the total selling price of all electricity supplied to retail customers in the same year, attributed to the same indicator for previous year".

Indicator 4.2. The same for electricity generating companies from grid companies.

Indicator 4.3. The same for network companies from sales organizations.

Object 5. Implementation of investment programs by the fuel and energy complex (FEC).

Indicators 5.1-5.5 "The ratio of the actual annual volumes of investments in the FEC for the forthcoming

analysis of the three-year period to the volume of investments planned by the investment programs of this sector over the same period" for production and transport of oil and gas condensate; Oil refining; Gas industry; Coal industry; Electric power industry, respectively.

Object 6. The relative change in the specific energy intensity of GDP.

Indicator 6.1 "Relative change in the specific energy intensity of Russia's GDP in the calculated year as compared to the previous year."

Object 7. The share of fossil primary FER used in the domestic market in the total volume of their extraction.

Indicators 7.1-7.3 "Ratio of the share of the fossil primary FER type used in the domestic market in the accounting year in the total volume of its production in the country in the same year to the same indicator in the previous year" by types of FER: oil (oil refining); gas; coal respectively.

Object 8. Terrorist acts on fuel and energy complex objects, main factors, measures taken.

Indicator 8.1. "The ratio of the number of officially recorded acts of terrorism at the FEC facilities in the calculated year to the number of such acts in the previous year".

Indicator 8.2 "The ratio of the total amount of economic damage from terrorist acts at FEC facilities in the calculated year to the same value in the previous year"

Object 9. Stability of providing consumers with various types of FER (including in the regional context).

Indicators 9.1-9.5 "Relative total shortage of FER type for the country as a whole in the calculated year" for gas, coal, fuel oil, light oil products in general, electricity, respectively.

Indicators 9.6-9.8 "The level of potential supply of demand for the type of FER in the territory of the federal district in the conditions of sharp cooling" for boiler-furnace fuel in general; Electricity; Thermal energy, respectively

Object 10. Strikes at FEC facilities, main factors.

Indicator 10.1 "The ratio of the number of strikes at FEC facilities in the whole country in the calculated year to the same indicator in the previous year".

Indicator 10.2 "The ratio of total damage across the country from strikes at FEC facilities in the calculated year to the same indicator in the previous year".

Object 11. Physical depreciation of fixed production assets by branches of the FEC and related industries.

Indicators 11.1-11.7 "Ratio of physical depreciation of fixed production assets in the FEC in the accounting year to the same indicator 5 years ago" for the FEC as a whole; Gas industry; Extraction and transport of oil; Oil refining; Coal industry; Electric power industry; Power machine building, respectively.

Object 12. Emergency situations at the FEC facilities.

Indicator 12.1 "Relation of the total number of emergencies in the FEC in the calculated year to the same value in the previous year".

Indicator 12.2 "The ratio of total economic damage from emergencies to the FEC as a whole in the calculated year to the same value in the previous year".

Object 13. The share of exports of Russian FER in total exports, including the share of the Asia-Pacific region, in total exports.

Indicator 13.1 "Ratio of the share of Russian export of FER in the calculated year in the total volume of the country's exports to the same amount in the previous year".

Indicator 13.2 "Share of the Asia-Pacific region in total exports of Russian FER in the calculated year".

Object 14. Share of oil refining and petrochemical products in total exports of Russian FER.

Indicator 14.1 "Ratio of the share of oil refining and petrochemical products in the total export of FER in the calculated year to the same indicator five years ago".

As mentioned above, we assume that the weights of all indicators in each OIA are equal. According to this, the specific weights of the indicators were calculated in Table 1. Also in Table 1, Qualitative assessments of the state of specific indicators are presented. They were formulated in accordance with (1). The process of forming these estimates was presented in [3]. In this paper, due to save space, this process is not given, but Table 1 shows the results for 2015-2016. [2, 3].

All indicators of the federal level in Table 1 are distributed according to the corresponding analysis objects. A qualitative assessment of the ES state for each object is formed according to (3). The data in Table 1 allow one to view the criticality of the state of an object of analysis from the ES positions. The evaluation of this state is performed according to (2) and (3). It can be seen from the table 2 that in 2015-2016 four OIAs (Nos. 5, 6, 11, 13 (list of OIAs)) were in the crisis zone from the ES positions, and two objects (Nos. 2 and 4) were in the pre-crisis zone. At the same time, the situation at OIA no. 2 "The share of natural gas in the structure of the balance of primary FER" improved in 2016 from crisis to pre-crisis, thanks to the reduction of this share below the threshold of 55%. Eight objects (No. 1, 3, 7, 8, 9, 10, 12 and 14) were in an acceptable state from the ES standpoint. At the same time, the situation at OIA no. 7 "The share of fossil primary FER used in the domestic market in the total volume of their extraction" has radically changed to normal by 2016. This was due to a relative decrease in gas use and increased use of coal. This led to an increase in the balance of the species structure of domestic consumption of boiler-furnace fuel.

#### **4.2 Integral qualitative assessment of the state of Russia's energy security at the federal level**

The next step is the formation of an integral qualitative assessment of the state of Russia's energy security at the federal level. It is possible to implement it after the formation of the specific weights of each OIA in the common system of weights of all objects. This is done according to (4) and as shown in Fig. 1 using the principles of pairwise comparison of the conditional significance of specific OIA. This process takes into account the independent opinions of four experts in the field of energy security research. The objects of analysis in pairs were correlated, so that the sum of their relative

**Table 1.** The results of the qualitative assessment of the ES state for OIA.

OIA, year of analysis		The qualitative state of the ES indicators								ES state			Assessment
										C	PC	N	
		The indicator number in OIA								Transition boundary			
		1	2	3	4	5	6	7	8	0,4	0,7	Sum of specific weights	
1	Specific weight	0,25	0,25	0,25	0,25								
	2015	N	N	N	N					0	0	1	N
	2016	N	N	N	N					0	0	1	N
2	Specific weight	1											
	2015	C								1	0	0	C
	2016	PC								0	1	0	PC
3	Specific weight	0,17	0,17	0,17	0,17	0,17	0,17						
	2015	N	N	N	N	N	N			0	0	1	N
	2016	N	N	N	N	N	N			0	0	1	N
4	Specific weight	0,33	0,33	0,33									
	2015	PC	C	PC						0,33	0,67	0	PC
	2016	PC	C	PC						0,33	0,67	0	PC
5	Specific weight	0,2	0,2	0,2	0,2	0,2							
	2015	PC	N	C	C	C				0,6	0,2	0,2	C
	2016	C	N	C	C	C				0,8	0	0,2	C
6	Specific weight	1											
	2015	C								1			C
	2016	C								1			C
7	Specific weight	0,33	0,33	0,33									
	2015	PC	C	C						0,67	0,33	0	C
	2016	PC	N	N						0	0,33	0,67	N
8	Specific weight	0,5	0,5										
	2015	N	N							0	0	1	N
	2016	N	N							0	0	1	N
9	Specific weight	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13				
	2015	N	N	N	N	N	N	PC	N	0	0,13	0,87	N
	2016	N	N	N	N	N	N	PC	N	0	0,13	0,87	N
10	Specific weight	0,5	0,5										
	2015	N	N							0	0	1	N
	2016	N	N							0	0	1	N
11	Specific weight	0,14	0,14	0,14	0,14	0,14	0,14	0,14					
	2015	C	C	C	PC	PC	PC	PC		0,43	0,57	0	C
	2016	C	C	C	PC	PC	PC	PC		0,43	0,57	0	C
12	Specific weight	0,5	0,5										
	2015	N	N							0	0	1	N
	2016	N	N							0	0	1	N
13	Specific weight	0,5	0,5										
	2015	C	PC							0,5	0,5	0	C
	2016	C	N							0,5		0,5	C
14	Specific weight	1											
	2015	N								0	0	1	N
	2016	N								0	0	1	N

weights in the pair was 1 (for example: 0.7 and 0.3 or 0.2 and 0.8, etc.). From the sum of the experts' opinions on the conditional significance of one OIA to another, we obtained averaged arithmetic values of comparative estimates in all possible pairs of objects [3]. This was done by interpolation. On this basis, the specific weights of each OIA in the system of evaluated objects were calculated. The result of this work is presented in the corresponding column of Table 2. Comparative analysis of OIA specific weights showed that objects nos. 11, 10, 5 that ranked 1, 2, and 3 places, respectively, can be recognized as the most significant for evaluating of energy security. Knowing the specific weights and

qualitative assessments of the ES state for each OIA (Table 1), according to (5), we can to form an integral qualitative assessment of Russia's ES at the federal level. The process of obtaining this assessment is also presented in the Table 2.

The data in Table 2 show that the state of Russia's EB at the federal level improved qualitatively, moving from the crisis situation in 2015 to the pre-crisis in 2016.

This was facilitated by the following processes that were mentioned above in the comments to Table 1:

**Table 2.** Formation of an integral assessment of the Russia's ES in 2015, 2016.

OIA	Specific weight	Qualitative assessment					
		2015	2016				
1	0,073	N	N				
2	0,078	C	PC				
3	0,066	N	N				
4	0,070	PC	PC				
5	0,085	C	C				
6	0,078	C	C				
7	0,065	C	N				
8	0,064	N	N				
9	0,047	N	N				
10	0,088	N	N				
11	0,091	C	C				
12	0,079	N	N				
13	0,058	C	C				
14	0,059	N	N				
Integral assessment							
ES state		C	PC	N	C	PC	N
Transition boundary		0,4	-	0,7	0,4	-	0,7
Sum of specific weights		0,455	0,070	0,475	0,312	0,148	0,540
<b>Integral assessment of Russia's ES</b>		<b>C</b>			<b>PC</b>		

- transition from a crisis to a pre-crisis state of the OIA "The share of natural gas in the structure of the balance of primary FER" due to a decrease in this share below the crisis level of 55%;
- transition from the crisis to the pre-crisis state of the OIA "The share of fossil primary FER used in the domestic market in the total volume of their extraction". This was due to the relative reduction in the use of gas and increased use of coal, which contributed to a better structure of the domestic consumption of energy fuel.

## 5 Conclusion

The paper shows the principles of conducting a comprehensive indicative analysis of the state of Russia's energy security at the federal level. A methodical approach to the formation of such an integral qualitative assessment is presented. An example of the formation of this estimate is based on information on the current status of the indicators of energy security at the federal level. It is shown that there are positive tendencies forming a qualitative improvement in the state of ES from 2015 to 2016. Periodical carrying out of such an assessment is necessary. The analysis of the dynamic range of qualitative assessments of the state of OIAs will allow us to comprehensively assess the directions and scale of the implementation and development of trends in the state of the country's ES in general.

Obtaining such an assessment is not an end in itself, it must necessarily be accompanied by assessments of the situation for OIAs with access to the current values of the most important indicators of the federal level.

The application of such an integrated approach will make it possible to more reasonably formulate the necessary areas of activity and specific measures to increase the level of ES in the conditions of realization of threats to Russia's ES.

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