Ensuring Russia's Energy Security at the Regional Level: Methodology of Evaluation, Results and Main Trends

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***Abstract* – The paper is devoted to an assessment of the state of regional energy security, and an analysis of the main trends and scale of changes in the state of energy security in the regions of Russia. The approaches to obtaining an integrated assessment of energy security at the regional level are presented. The expert opinions on the relative importance of key indicators are given. Specific regions of Russia are examined on the example of the Siberian Federal District. Regions of Russia with an unsatisfactory state of energy security are identified, and the dynamics of changes in the state of energy security in all of Russia's regions during the period from 2012 to 2016 are shown. Factors and reasons for the formation of negative and positive energy security trends are analyzed. The main directions of activities to improve the level of energy security in most regions of Russia are presented.**

***Index Terms*—Energy security, Integral assessment, Indicators, Regional level.**

I. Introduction

One of the most important activities to achieve and maintain the required level of energy security in Russia is monitoring and indicative analysis of the energy security status. This is an essential component for the formation of control, analytical and coordination functions of the State regulation in the field of energy security. The aims of monitoring the energy security of the Russian Federation and its regions are to identify the observed and expected processes, phenomena and parameters that determine the level and threats to energy security. At the same time, the identification process is based on a system of indicators that adequately describe the situation in this or that aspect of energy security. Thus, the meaning and essence of monitoring and indicative analysis lie in displaying information on the degree of implementation of energy security threats, using an indicator system, when comparing the numerical values of these indicators with their threshold values. In accordance with this, Melentiev Energy Systems Institute of Siberian Branch of the Russian Academy of Sciences (ESI SB RAS) has developed a database for the justification and decision-making on ensuring the energy security of the Russian Federation and its regions. It is also important to analyze the dynamic range of indicators values and their qualitative assessments in order to understand the direction of emerging energy security trends.

The angles of considering the issue of energy security in Russia and other countries slightly differ. For many countries, this is, first of all, the independence from external energy supplies and diversification of energy supply sources. This understanding of energy security is found in the materials of the International Energy Agency [1], European Parliament [2] and others. In Russia, energy security is understood as a state of protection of citizens, society, the State and the economy from the threat of a failure to meet their energy needs with economically accessible energy resources of acceptable quality, and from threats of energy supply interruption [3, 4]. In fact, we are talking about balancing the supply and demand of energy or eliminating energy shortage in different conditions.

There are different approaches to monitoring energy security. They are implemented at the country level and affect primarily the issues of fuel supply, economy, and environment. In [5], the authors pay special attention to the following indicators: resource estimates, reserves to production ratios, diversity indices, import dependence, political stability, energy price, a share of zero-carbon fuels, market liquidity. The authors of [6] focus on problems of fuel and energy supply of consumers in dependence on primary energy production, external primary energy supplies, and functioning of external

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primary energy suppliers.

Many researchers pay much attention to the issues of sustainable development of the national economy [7].

The authors of [8] present various opinions about the nature and methods of research into energy security issues. All methods described in this paper reveal comprehensively the features of the energy security study in terms of a country or a region of the world. These methods take into account the political and economic nature of the relationships between players in the energy market and can be undoubtedly applied to the research at the country level. Considerable attention is paid to the diversification of energy suppliers. At the same time, at the level of countries and regions of the world, technical issues of energy supply sustainability of a territory within countries are usually not considered. Research [9] is also devoted to the geopolitical problems of ensuring the energy security of individual countries. It shows that the opportunities to ensure demand for energy are the main driving force for economic growth and social welfare improvement of any country. The issues of energy security at the level of countries and regions of the world are described in [10]. The study presented in [11] deals with energy security indicators also at the country level. The study presented in [12] conceptualizes energy security as consisting of the interrelated factors of availability, affordability, efficiency, sustainability, and governance. It then matches these factors with 20 metrics constituting an energy security index measuring international energy security performance across 18 countries. Comprehensive studies have been carried out but again they focus on the level of countries and regions of the world. Almost the same questions and at the same level are presented in [13, 14].

The authors of [15] analyze the trends in energy security across the three Baltic countries. The aggregate measures of energy security are devised by means of multi-criteria decision-making techniques. The choice of energy security indicators was based on the priorities set out in the European Union energy policy.

In general, the investigation into the energy security problems of individual territories within a particular country should address other issues. First of all, these are the issues of technical availability of final types of energy for consumers under different operation conditions of energy systems, and only after the technical availability is achieved, all the other components of regional energy security can be discussed.

In other sources, for example, in [16], the authors pay more attention to the issues of meeting the environmental requirements. Speaking about the national level, some researchers, for example [17], focus on the role of renewable energy resources in ensuring energy security. This can certainly help but largely depends on the climatic and geographic features of the country or region.

There are virtually no studies on the assessment of the energy security of individual regions. Apparently, this is due to the fact that in some countries some regions have a much smaller area of the territory than in Russia. At the same time, they are connected with each other by energy relations much more closely and intensively.

To assess the state of energy security in Russia's regions and, to identify emerging trends in this regard, appropriate monitoring and analysis of the state of domestic energy are needed. Such an assessment can be performed in accordance with the methodology for monitoring the state of Russia's energy security at the regional level, i.e. based on the monitoring of the most important indicators of the energy sector operation at a given point in time.

This paper presents materials characterizing the state of energy security in the regions of Russia for all Federal Districts. Such estimates were obtained using the methodology for energy security monitoring [18]. All regions are ranked according to the state of their energy security. The studies conducted in different time frames (2012, 2016) allowed assessing the direction of changes in the energy security situation in the regions of Russia and the dynamics of these changes over the past five years.

A detailed analysis of how the energy security requirements are met for each indicator is examined in this paper on the example of the Siberian Federal District.

II. A METHOD OF ENERGY SECURITY MONITORING AT THE REGIONAL LEVEL IN RUSSIA

At present, the assessment of the state of regional energy security in the country [18, 19] is based on the use of a system of indicators conventionally distributed across three interrelated blocks, Table. 1.

The values of the indicators characterize the energy security situation in the region in terms of an analyzed aspect. Separation of individual blocks is necessary to obtain an idea of the most important aspects of regional energy security. Each of the indicators presented in Table 1 has its own, previously expertly generated and justified, threshold value. It is the threshold values that determine the boundary of the assignment of the actual value of the indicator to a particular area of qualitative states.

In most cases, these indicators can be taken from official statistics, some of them are calculated specifically. Indicator 2.3 “The ability to meet fuel demand in the conditions of a sharp cooling (10% increase in consumption) in the region” is calculated using a set of mathematical models specially developed by the Melentiev Energy Systems Institute SB RAS [20]. These models allow determining the possibilities of supplying the necessary volumes of all energy types to end consumers under different conditions, including peak demand for energy resources in case of a sharp cooling.

The method in [18] uses two threshold values for each indicator. The pre-crisis threshold value of the indicator means a boundary value between the normal and pre-crisis state of the energy sector in the aspect described by this indicator. The crisis threshold means the boundary between the pre-crisis and crisis states. These threshold values are determined in [18] expertly and indicate the boundaries of the transition of a particular indicator from one qualitative state to another. If the indicator is in a negative state, it is necessary to apply the measures that will help improve the energy security situation in terms of an analyzed aspect.

Table 1. The Most Important indicators of regional energy security

1. Block of energy resource production and availability for the fuel and energy supply system of a region
1.1. The ratio of the total available capacity of the region’s power plants to the maximum electric load of consumers in the region. 1.2. The ratio of the available capacity of power plants and the capacity of inter-system ties between regions to the maximum electric load in the region. 1.3. Possibilities of meeting the demand for primary energy from the region’s sources.
2. The block of fuel and energy supply reliability in the region
2.1. The share of the dominant resource in the total primary energy consumption in the region. 2.2. The share of the largest power plant in the installed electric capacity in the region. 2.3. The ability to meet fuel demand in the conditions of a sharp cooling (10% increase in consumption) in the region.
3. Block of the state of the basic production assets of energy systems in the region
3.1. The degree of depreciation of the basic production assets of the energy sector in the region. 3.2. The ratio of the average installed capacity commissioned annually and the power plant capacities reconstructed over the last 5-year period to the installed capacity in the region.

Based on the comparison of actual values of specific indicators with their thresholds, the level of crisis indicators is estimated. In this case, however, it is impossible to assess the state of the energy security as a crisis one in the entire region. Some indicators may have the values acceptable from the energy security standpoint, the values of others may be in a crisis or pre-crisis state. The picture can vary from region to region and from year to year. Accordingly, in order to form a final qualitative assessment of the energy security state in the region, it is necessary to convolve the qualitative assessments of the status of individual indicators in a single integrated assessment of energy security of the analyzed territory.

The state of an indicator, depending on the location of its values on the state scale, is estimated as follows:

$$f(S_i)=\begin{cases} N,\ S_i < S_i^{PC} \\ PC,\ S_i^{PC} \le S_i < S_i^{C} \quad i=1,n \\ C,\ S_i \ge S_i^{C} \end{cases} \tag{1}$$

where n –the number of indicators being evaluated; S_i – actual (expected) value of the i-th indicator; S_i^{PC}, S_i^{C} - pre-crisis and crisis threshold values of the i-th indicator; N,PC,C - a qualitative assessment of the state of the energy sector in terms of the aspect indicated by the i-th indicator: normal, pre-crisis and crisis, respectively.

Due to the fact that the indicators chosen for the assessment are not equally important, an integral assessment takes into account the significance of each specific indicator in their common set or “specific weights” of all indicators in the overall system of their value. Each indicator is compared in pairs with other indicators within 1. The expert group determines the weighted average expert value of conventional significance of the i-th indicator in comparison with the j-th indicator. The specific weight of the indicator in the total sum of weights is determined by the equation:

$$V_i = \sum_{j=1}^{n} \upsilon_{ij} \Big/ \sum_{i=1}^{n}\sum_{j=1}^{n} \upsilon_{ij} \tag{2}$$

where V_i - is the specific weight of the i-th indicator in the system of indicators being evaluated; υ_{ij} - conventional significance of the i-th indicator in comparison with the j-th indicator.

Based on the above-described comparison, we qualitatively assess the energy security status of specific regions of Russia:

$$Q = \begin{cases} N,\ \sum_{i=1}^{n} V_i^N \ge \delta_N \\ PC,\ \sum_{i=1}^{n} V_i^C \prec \delta_C \ \text{è}\ \sum_{i=1}^{n} V_i^N \prec \delta_N \ , \quad i=1,n \\ C,\ \sum_{i=1}^{n} V_i^C \ge \delta_C \end{cases} \tag{3}$$

where Q – an integral assessment of the qualitative state of the region's energy security; V_i^N, V_i^C - a specific weight of the i-th indicator, which is in the range of normal and crisis values, respectively; δ_N, δ_C - coefficients that characterize a normal or a crisis state, respectively.

Based on the monitoring of the dynamic range of the integral indicator values, such an assessment indicates in which direction the energy security level of a particular region is changing and which region the Federal District or the country should pay attention to, first of all.

III. An Analysis of the Energy Security State in the Regions of Russia

In order to demonstrate the efficiency of the methodological approach, to identify and assess the trends in changes in the most important energy security factors of the subjects of Russia, the following steps were taken:

– based on statistical information, a database was created for all regions of Russia [21-23];

– the values of all the indicators indicated in Table 1 are estimated over a time span from 2012 to 2016;
– the values of energy security indicators were quantitatively correlated with their threshold values corresponding to specially designated groups of territories;
- using the expression (3) we obtained integral assessments of the energy security state in each of the analyzed regions.

The analysis of the obtained data on all subjects of Russia demonstrates the trends in the energy security situation.

Based on the analysis conducted for the time span of 2012-2016, the energy security situation has not changed radically in 80% of the regions. In general, information on the attribution of these regions to the areas of crisis, normal or pre-crisis state is presented in Figure 1. As evidenced by an analysis of Figure 1, most of the regions of the Russian Federation are located in the area of the crisis and pre-crisis state of energy security.

Let us consider the regions where the energy security situation has changed qualitatively for the analyzed period.

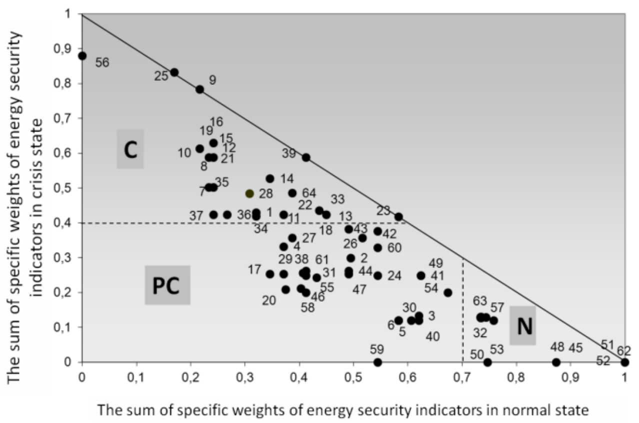

Figure1. The final state of energy security of the subjects of Russia, 2016.

1 - The Republic of Karelia; 2 - the Republic of Komi; 3 - Vologda Region; 4 - Kaliningrad Region; 5 - Leningrad Region; 6 - Murmansk Region; 7 - Novgorod Region; 8 - Pskov Region; 9 - Belgorod Region; 10 - Bryansk Region; 11 - Vladimir Region; 12 - Voronezh Region; 13 - Ivanovo Region; 14 - Kaluga Region; 15 - Kostroma Region; 16 - Kursk Region; 17 - Lipetsk Region; 18 - Moscow Region; 19 - Orel Region; 20 - Ryazan Region; 21 - Smolensk Region; 22 - Tver Region; 23 - Yaroslavl Region; 24 - The Republic of Dagestan; 25 - Kabardino-Balkaria Republic; 26 - Republic of North Ossetia-Alania; 28 - the Chechen Republic; 29 - Stavropol Territory; 30 - Krasnodar Territory; 31 - Volgograd Region; 32 - Rostov Region; 33 - Republic of Kalmykia; 34 - Republic of Bashkortostan; 35 - Republic of Mordovia; 36 - Republic of Udmurtia; 37 - Chuvash Republic; 38 - Orenburg Region; 39 - Penza Region; 40 - Perm Territory; 41 - Samara Region; 42 - Saratov Region; 43 - Ulyanovsk Region; 44 - Sverdlovsk Region; 45 - Tyumen Region; 46 - Chelyabinsk Region; 47 - Altai Territory; 48 - Kemerovo Region; 49 - Novosibirsk Region; 50 - Omsk Region; 51 - Tomsk Region; 52 - Krasnoyarsk Territory; 53-Irkutsk Region; 54 - Republic of Buryatia; 55 - Republic of Tyva; 56 - The Altai Republic; 57 - the Republic of Sakha (Yakutia); 58 - Primorsky Territory; 59 - Khabarovsk Territory; 60 - Amur Region; 61 - Kamchatka Territory; 62 - Sakhalin Region; 63 - Chukotka Autonomous District; 64 - Jewish Autonomous Region.

These regions are presented in Table 2. In this Table *N*, *PC* and *C* mean qualitative assessment of the state of the energy sector in the aspect indicated by the i-th indicator: normal, pre-crisis and crisis, respectively.

In 2016, the crisis situation was noted in all the regions of the Central District, with the exception of the Lipetsk, Ryazan and Tula regions. In the Tula region (Table 2), the crisis situation shifted to the pre-crisis one due to the commissioning of capacities in 2013-2015 (at the 190 MW Novomoskovskaya thermal power plant and the start-up of two 225 MW hydroelectric generators at Cherepetskaya thermal power plant).

During the analyzed period, the situation improved in such regions as the Republic of Mari El, the Republic of Tatarstan, the Kirov region, Kurgan region, Magadan region and the Republic of Crimea. The improvement in the situation was due to the active policy of renewal of fixed production assets, and the implementation of planned capital repairs in electric and heat power industries, which made it possible for the regions to reach the pre-crisis values, thus moving from the range of the crisis values. For example, the Republic of Tatarstan has commissioned 590 MW of new generating capacities in the last three years of the analyzed period (2014-2016). Gas production in the Republic increased almost threefold, which enhanced the capability to meet the needs for primary energy from the region's sources and allowed the Republic to shift to the range of normal values of the corresponding indicator (1.3) (Table 2).

In the Republic of Crimea, the situation improves every year, due to the implementation of projects for the construction of generation facilities in the Republic and the provision of a reliable and uninterrupted power supply. The region has significant potential for the development of alternative energy sources, such as solar and wind. In 2014, the Republic of Crimea put into operation a 25 MW wind farm, and in 2015-2016, it commissioned four lines of Energy Bridge to connect the power system of Crimea to the UES of Russia (UES South), with a total capacity of 800 MW. However, at the same time, deterioration of power equipment on the peninsula is about 70%, which requires appropriate attention and measures to reduce it.

It is worth paying attention to the regions where the energy security situation stabilized in six years, and by 2016 had moved to the region of acceptable values. There are only four such subjects (5% of the total number of those analyzed): the Astrakhan Region, the Nizhny Novgorod Region, the Republic of Khakassia and the Transbaikal Territory. The conditions for improving the situation were: modernization of electric power equipment, annual commissioning of new generating capacities and, as a consequence, a decrease in the share of the largest source in the installed electric capacity in the region (indicator 2.2), and an increase in the ability to meet the demand for primary energy from the region's own sources.

Table 2. Assessment of the qualitative state of energy security in selected regions of Russia.

Year	The order numbers of the energy security indicators								The sum of the specific weights by state			The qualitative state of energy security
	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	Boundaries of states			
	Specific weights of indicators								C[1]	PC	N[2]	
	0,104	0,138	0,133	0,120	0,079	0,170	0,127	0,129				
1	2	3	4	5	6	7	8	9	10	11	12	13
Arkhangelsk Region												
2012	N	N	C	PC	N	C	PC	N	0,303	0,247	0,450	**PC**
2016	N	N	C	PC	N	C	H	K	0,432	0,120	0,448	**C**
Tambov Region												
2012	N	N	C	C	PC	PC	C	PC	0,380	0,378	0,242	**PC**
2016	N	N	C	C	PC	PC	C	C	0,509	0,249	0,242	**C**
Tula Region												
2012	N	N	C	C	PC	PC	C	C	0,509	0,249	0,242	**C**
2016	N	N	C	C	N	PC	PC	N	0,253	0,297	0,450	**PC**
Karachay-Cherkess Republic												
2012	N	N	C	C	N	N	N	N	0,253	0	0,747	**N**
2016	N	N	C	C	N	N	N	PC	0,253	0,129	0,618	**PC**
Astrakhan Region												
2012	N	N	N	N	PC	N	PC	C	0,129	0,206	0,665	**PC**
2016	N	N	N	N	PC	N	PC	N	0	0,206	0,794	**N**
Mari El Republic												
2012	N	N	PC	C	N	C	PC	C	0,419	0,26	0,321	**C**
2016	N	N	N	C	N	C	PC	N	0,29	0,127	0,583	**PC**
Republic of Tatarstan												
2012	N	N	PC	C	N	C	PC	C	0,419	0,26	0,321	**C**
2016	N	N	N	C	N	C	PC	PC	0,29	0,256	0,454	**PC**
Kirov Region												
2012	N	N	C	C	N	N	C	C	0,509	0	0,491	**C**
2016	N	N	C	C	N	N	C	N	0,38	0	0,62	**PC**
Nizhny Novgorod Region												
2012	N	N	N	C	N	N	PC	C	0,249	0,127	0,624	**PC**
2016	N	N	N	C	N	N	PC	N	0,12	0	0,88	**N**
Kurgan Region												
2012	N	N	C	C	C	N	C	C	0,588	0	0,412	**C**
2016	N	N	C	C	PC	N	PC	N	0,253	0,206	0,541	**PC**
The Republic of Khakassia												
2012	N	N	N	PC	C	N	PC	N	0,079	0,247	0,674	**PC**
2016	N	N	N	PC	C	N	N	N	0,079	0,12	0,801	**N**
Transbaikal Territory												
2012	PC	PC	N	PC	PC	N	PC	C	0,129	0,568	0,303	**PC**
2016	N	N	N	PC	N	N	PC	N	0	0,247	0,753	**N**
Magadan Region												
2012	N	N	C	C	C	N	PC	C	0,461	0,127	0,412	**C**
2016	N	N	PC	C	C	N	PC	C	0,328	0,26	0,412	**PC**
Republic of Crimea												
2012	C	N	C	C	N	N	PC	C	0,486	0,127	0,387	**C**
2016	C	N	C	C	N	N	PC	N	0,357	0,127	0,516	**PC**

[1] The state of energy security in the region is considered as a crisis if the sum of the specific weights of indicators in state "C" exceeds 0.4.

[2] The state of energy security in the region is considered as normal if the sum of the specific weights of indicators in the state "N" exceeds 0.7.

IV. An analysis of energy security situation in the selected federal district

The results of the energy security analysis for the years 2012 and 2016 are presented below for illustration.

Along with the qualitative assessment of the energy security level in the regions in 2016, in order to show some trends, we provide the information on the qualitative assessment of the relevant indicators in 2012. An analysis of the data from the corresponding Tables for the subjects of the Siberian Federal District makes it possible to briefly characterize the trends inherent in the energy sector in the light of energy security requirements.

The information on the first block of indicators is shown in Table 3.

Table 3. Characteristics of the status of indicators in the subjects of the Siberian Federal District for the block of energy resource production and availability for the fuel and energy supply system for 2012, 2016.

Region	Indicator	Unit of measurement	The threshold values of the indicator[3]		Value and status of indicator			
			N	C	2012		2016	
1	2	3	4	5	6	7	8	9
Altai Territory	1.1	unit	0,5	0,3	0,74	N	0,72	N
	1.2	unit	1,5	1,2	3,03	N	3,1	N
	1.3	%	60	40	1,55	C	1,75	C
Kemerovo Region	1.1	unit	0,5	0,3	0,85	N	1,01	N
	1.2	unit	1,5	1,2	2,27	N	2,55	N
	1.3	%	40	20	5,88	N	1052	N
Novosibirsk Region	1.1	unit	0,5	0,3	1,03	N	1,03	N
	1.2	unit	1,5	1,2	2,18	N	2,18	N
	1.3	%	40	20	33,7	N	40,4	N
Omsk Region	1.1	unit	0,5	0,3	0,84	N	0,86	N
	1.2	unit	1,5	1,2	2,44	N	2,46	N
	1.3	%	40	20	48,3	N	36,9	PC
Tomsk Region	1.1	unit	0,5	0,3	0,81	N	0,77	N
	1.2	unit	1,5	1,2	2,76	N	2,77	N
	1.3	%	60	40	121	N	294	N
Krasnoyarsk Region	1.1	unit	0,7	0,5	1,65	N	2	N
	1.2	unit	1,5	1,2	2,39	N	2,74	N
	1.3	%	60	40	140	N	142	N
Irkutsk Region	1.1	unit	0,7	0,5	1,58	N	1,6	N
	1.2	unit	1,5	1,2	2,11	N	2,13	N
	1.3	%	60	40	122	N	122	N
The Republic of Khakassia	1.1	unit	0,7	0,5	2,85	N	2,42	N
	1.2	unit	1,5	1,2	4,67	N	4,28	N
	1.3	%	60	40	557	N	740	N
Transbaikal Territory	1.1	unit	1,0	0,8	1,22	N	1,19	N
	1.2	unit	1,5	1,2	1,6	N	1,57	N
	1.3	%	60	40	266	N	233	N
The Republic of Buryatia	1.1	unit	0,5	0,3	1,31	N	1,28	N
	1.2	unit	1,5	1,2	3,35	N	3,19	N
	1.3	%	60	40	49,6	PC	76,1	N
Tyva Republic	*1.1*	*unit*	*0,5*	*0,3*	*0,38*	*PC*	*0,22*	*C*
	1.2	unit	1,5	1,2	1,18	C	1,78	N
	1.3	%	60	40	199	N	240	N
Altai Republic	1.1	unit	0,5	0,3	0	C	0,13	C
	1.2	unit	1,5	1,2	0	C	0,13	C
	1.3	%	60	40	7,69	C	12,2	C

[3]The boundaries of the state areas ("N" - acceptable (normal) state of energy security for this indicator, "C" - a crisis state).

According to the first set of indicators, most subjects of the Siberian Federal District have an acceptable situation from the energy security standpoint. The exception is the Republic of Altai, where the values of the indicators are in a crisis state (Table 3). Here we can note a low level of the maximum electrical load of consumers. The situation, however, started slowly to improve in 2014-2016. Three solar power plants with a total capacity of 15 MW were commissioned (Kosh-Agach solar power plants -1, 2, and Ust-Kansk solar power plant), and new capacities are planned to be put in operation in the future.

Compared to 2012, in 2016, the values of indicator 1.2 for the Republic of Tyva lie in the range of acceptable values. In 2014, owing to the modernization of the Kyzylskaya and Chadan substations the transfer capability of the intersystem ties was increased to 280 MW of which up to 100 MW can be transferred to Western Mongolia. However, in general, the problem of energy shortage in the Republic is not solved.

As for the first block of indicators, in particular, indicator 1.3 ("Possibilities of meeting the demand for primary energy from the region's own sources"), as we can see, the

Altai Territory and the Republic of Altai have crisis values. In the Omsk Region by 2016 the situation worsened due to a 20% decrease in the fuel oil production over the past five years. In the Republic of Buryatia, the values of the indicators have moved into the region of acceptable ones, as a result of the development of a number of small coal deposits for local needs and an increase in the level of coal production by 30% over the past five years.

The satisfactory situation in terms of the first block of indicators is in the Republic of Khakassia. The maximum electrical load is ensured by a sufficient margin. Extraction of significant volumes of coal provides positive values of the indicator of supply with its own primary energy.

According to the second set of indicators, the situation in a large part of the regions is aggravated by an excessively high share of the dominance of one of the imported resources (indicator 2.1, Table 4)

Table 4. Characteristic of the status of indicators in the subjects of the Siberian Federal District for the fuel and energy supply reliability block

Region	Indicator	Unit of measurement	Threshold values of the indicator			Value and status of indicator			
			N	PC	C	2012		2016	
1	2	3	4	5	6	7	8	9	10
Altai Territory	2.1	%	40		70	92,4	C	88,5	C
	2.2	%	50		70	22,8	N	24,2	N
Kemerovo Region	2.1	%	90	>90		83,5	N	96,0	N
	2.2	%	50		70	25,8	N	23,7	N
Novosibirsk Region	2.1	%	40		70	72,6	C	68,9	PC
	2.2	%	50		70	39,4	N	39,4	N
Omsk Region	2.1	%	40		70	50,6	PC	54,3	PC
	2.2	%	50		70	43,4	N	42,8	N
Tomsk Region	2.1	%	90	>90		68,7	N	62,9	N
	2.2	%	50		70	24,3	N	27,7	N
Krasnoyarsk Region	2.1	%	90	>90		73,5	N	75,4	N
	2.2	%	40		50	39,2	N	32,8	N
Irkutsk Region	2.1	%	90	>90		76,5	N	70,6	N
	2.2	%	40		50	34,12	N	33,9	N
The Republic of Khakassia	2.1	%	90	>90		96,5	PC	96,5	PC
	2.2	%	40		50	90,9	C	89,5	C
Transbaikal Territory	2.1	%	90	>90		96,4	PC	98,1	PC
	2.2	%	30		40	29,3	N	28,3	N
The Republic of Buryatia	2.1	%	40		70	95,1	C	94,2	C
	2.2	%	50		70	83,3	C	79,1	C
Tyva Republic	2.1	%	90	>90		97,2	PC	100	PC
	2.2	%	50		70	36,3	N	59,5	PC
Altai Republic	2.1	%	40		70	53,8	PC	43,8	PC
	2.2	%	50		70	100	C	64,1	PC

[4] Indicator 2.3 is estimated based on the results of studies on the model of the energy sector as the extent to which the consumer is provided with primary energy in case of possible cooling, increasing consumption by 10%. For all subjects of the Siberian Federal District, increased consumption is fully met, which corresponds to the zone of acceptable (normal) states.

In 2012-2016, the coal share in the Republic of Buryatia and the Altai Territory exceeded 90%. The pre-crisis situation, with a share of the dominant resource, is observed in the Novosibirsk, Omsk regions, the Republic of Khakassia, Tyva, as well as in the Transbaikal Territory and the Altai Republic.

In the Irkutsk region, Kemerovo region and the Krasnoyarsk Territory, the situation for this indicator can be considered acceptable, due to the dominance of their own energy resources in these regions. At the same time, the qualitative assessment of the "pre-crisis" state in the self-reliant regions (belonging to group 1) indicates the advisability of greater diversification of the fuel and energy supply in order to increase the systems readiness for potential changes in the structure of the fuel and energy balance in the country and its regions for various reasons, including the prices for primary energy resources.

According to indicator 2.2 (the share of the largest power plant in the installed electric capacity of the territory), the most acute situation is observed in the Republic of Buryatia (Gusinoozerskaya thermal power plant - 79% of the total installed capacity) and Khakassia (Sayano-Shushenskaya hydropower plant - 89% of the total installed capacity). Since in the event of an accident, such a high share of a single source is very dangerous due to possible problems in the electricity supply to consumers.

According to this indicator, the situation in the Altai Republic has improved in recent years, moving from crisis to pre-crisis state by commissioning new capacities and redistributing the load.

The Republic of Tyva is in the pre-crisis state where, from the energy security standpoint, it is desirable to develop the trend of generating capacity growth to cover the increasing demand for electricity (mobile gas turbinepower plant - 59% of the installed capacity in the region).

Another important aspect affecting the energy security in the regions is the state of the main production assets of the energy sector. The averaged data on the wear and tear of the main production assets in the energy industries in the regions, correlated with the book value of these industries in these regions, allow us to approximately estimate the average wear and tear in the energy sector of the regions.

As is evidenced by Table 5, the energy equipment in the Novosibirsk Region, Altai Republic, and the Altai Territory has deteriorated in recent years (and, most importantly, continues to deteriorate at a fairly rapid pace).

Table 5. Characteristics of the status of indicators in the subjects of the Siberian Federal District for the block of state of the main production assets of energy systems

Region	Indicator	Unit of measurement	The threshold values of the indicator		Value and status of indicator			
			N	C	2012		2016	
1	2	3	4	5	6	7	8	9
Altai Territory	3.1	%	40	60	58,5	PC	60	C
	3.2	%	2	1	1,6	PC	1,7	PC
Kemerovo Region	3.1	%	40	60	47,5	PC	43,7	PC
	3.2	%	2	1	3,7	N	1,9	N
Novosibirsk Region	3.1	%	40	60	55	PC	61	C
	3.2	%	2	1	1	C	0,7	C
Omsk Region	3.1	%	40	60	38,3	N	36,7	N
	3.2	%	2	1	9	N	7,3	N
Tomsk Region	3.1	%	40	60	33,6	N	39,7	N
	3.2	%	2	1	12,2	N	0,9	C
Krasnoyarsk Region	3.1	%	40	60	44	PC	38	N
	3.2	%	2	1	2,9	N	4,9	N
Irkutsk Region	3.1	%	40	60	54,2	PC	53,7	PC
	3.2	%	2	1	1,8	PC	0,6	C
The Republic of Khakassia	3.1	%	40	60	39,5	N	38,7	N
	3.2	%	2	1	7,7	N	4,4	N
Transbaikal Territory	3.1	%	40	60	48,3	PC	47,7	PC
	3.2	%	2	1	2,9	N	3,9	N
The Republic of Buryatia	3.1	%	40	60	45,9	PC	43,4	PC
	3.2	%	2	1	2	PC	5	N
Tyva Republic	3.1	%	40	60	50,1	PC	58,4	PC
	3.2	%	2	1	29,2	N	7,3	N
Altai Republic	3.1	%	40	60	62	C	70	C
	3.2	%	2	1	0	C	33,7	N

The situation in the energy industries in most of the other regions of the District continues to deteriorate, remaining in the middle of the pre-crisis range in such regions as Irkutsk Region, Republic of Tyva, Republic of Buryatia, and Kemerovo Region. With the renewal and modernization of the basic production assets of the energy sector, in 2016 positive trends were observed in Khakassia, due to the active restoration and modernization of the Sayano-Shushenskaya hydropower plant, modernization at the Abakanskaya thermal power plant and the commissioning of two power units with a total capacity of 256 MW. In the Kemerovo Region, Kuzbassenergo carried out a major overhaul of 11 turbine units, and power units were put into operation at Novokuznetskaya gas turbine power plant. In the Omsk Region and the Republic of Buryatia, acceptable values of the indicator are also associated with an active policy for capital repairs and reconstruction of power generating capacities. To a large extent, the value of this indicator is due to the commissioning of new capacities, major repairs and technical re-equipment of existing power generating sources.

The crisis situation in the aspect reflected by indicator 3.2 is observed in Novosibirsk region, Tomsk region, Irkutsk region and the Republic of Altai, where the commissioning of new capacities during the analyzed 5-year period was insufficient, and practically no serious work was done to modernize the installed equipment, which in turn led to a decrease in the level of energy security in the regions. Smaller capacities were put into operation and some equipment upgrades were carried out in the Altai Republic and the Altai Territory (130 MW was commissioned at Barnaulskaya thermal power plant -2 in 2016), but in insufficient (in terms of energy security) volumes to reverse the negative trends towards the aging of the basic production assets. According to the indicator of the renewal of power generating equipment in the Irkutsk Region and the Transbaikal Territory, the number of new capacities put in operation was insufficient. In the Irkutsk Region in 2012, a turbine unit with a capacity of 50 MW was launched at the Novo-Irkutsk thermal power plant. In the Transbaikal Territory, a hydroelectric unit with a capacity of 225 MW was commissioned at Kharanorskaya hydropower plant in the same year. In addition, major repairs of equipment and reconstruction were carried out. These actions brought the situation in terms of this indicator into an acceptable state from the energy security standpoint in the Transbaikal Territory but they were insufficient for the Irkutsk Region to cope with the crisis.

Table 6. Qualitative assessment of the energy security state in the subjects of the Siberian Federal District

Year	Numbers of energy security indicator								The sum of the specific weights by state			The qualitative state of energy security
	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	Boundaries of states			
	Specific weights of indicators								C[5]	PC	N[6]	
	0,104	0,138	0,133	0,120	0,079	0,170	0,127	0,129				
1	2	3	4	5	6	7	8	9	10	11	12	13
Altai Territory												
2012	N	N	C	C	N	N	PC	PC	0,253	0,256	0,491	PC
2016	N	N	C	C	N	N	PC	PC	0,253	0,256	0,491	PC
Kemerovo Region												
2012	N	N	N	N	N	N	PC	N	0	0,127	0,873	N
2016	N	N	N	N	N	N	PC	N	0	0,127	0,873	N
Novosibirsk Region												
2012	N	N	PC	C	N	N	PC	C	0,249	0,260	0,491	PC
2016	N	N	N	C	N	N	К	C	0,376	0	0,624	PC
Omsk Region												
2012	N	N	N	PC	N	N	N	N	0	0,120	0,880	N
2016	N	N	PC	PC	N	N	N	N	0	0,253	0,747	N
Tomsk Region												
2012	N	N	N	N	N	N	N	N	0	0	1	N
2016	N	N	N	N	N	N	N	C	0,129	0	0,871	N
Krasnoyarsk Region												
2012	N	N	N	N	N	N	PC	N	0	0,127	0,873	N
2016	N	N	N	N	N	N	N	N	0	0	1	N
Irkutsk Region												
2012	N	N	N	N	N	N	PC	PC	0	0,256	0,744	N
2016	N	N	N	N	N	N	PC	C	0,129	0,127	0,744	N
The Republic of Khakassia												
2012	N	N	N	PC	C	N	N	N	0,079	0,120	0,801	N
2016	N	N	N	PC	C	N	N	N	0,079	0,120	0,801	N
Transbaikal Territory												
2012	N	N	N	PC	N	N	PC	N	0	0,247	0,753	N
2016	N	N	N	PC	N	N	PC	N	0	0,247	0,753	N
The Republic of Buryatia												
2012	N	N	PC	C	C	N	PC	PC	0,199	0,389	0,412	PC
2016	N	N	N	C	C	N	PC	N	0,199	0,129	0,674	PC
Tyva Republic												
2012	PC	C	N	PC	N	N	PC	N	0,138	0,351	0,511	PC
2016	N	C	N	PC	PC	N	PC	N	0,242	0,326	0,432	PC
Altai Republic												
2012	C	C	C	PC	C	C	C	C	0,880	0,120	0	C
2016	C	C	C	PC	PC	C	C	N	0,672	0,199	0,129	C

[5] The state of energy security in the region is considered as a crisis if the sum of the specific weights of indicators in state "C" exceeds 0.4

[6] The state of energy security in the region is considered as normal if the sum of the specific weights of indicators in the state "N" exceeds 0.7

The above-presented and analyzed values of the main indicators form the basis for an integrated assessment of the energy security level in the subjects of the Siberian Federal District. To obtain such an assessment, an approach based on the convolution of indicator values was used, taking into account their specific weights. Qualitative characteristics of the state of all the indicators discussed in Table 3-5, were collected according to the respective territories and processed according to a special method. As a result, a qualitative final assessment of the energy security status of the territories of the subjects of the Siberian Federal District was presented in Table 6.

As is evidenced by the data in Table 6, the best condition for energy security is observed in the Tomsk Region and the Krasnoyarsk Territory. The level of energy security in the Kemerovo region, Omsk region, Irkutsk region, and the Transbaikal Territory can be considered close to acceptable. It is necessary to pay serious attention to indicators, whose values in these territories lie in the zones of "crisis" and "pre-crisis" values. This signals serious fuel and energy supply problems in the territories in the part described by the values of the respective indicators. In addition, the negative state of the indicators characterizing the state of the basic production assets and the renewal of the energy sector in these regions hinders the improvement in energy security.

The most acute energy security situation is in the Republic of Altai. Here, the crisis situation of most of the monitored indicators is evident. This concerns both the degree of the maximum electrical load and the share of the largest power generating source in the installed capacity in the Republic and the wear and tear of the main production assets of the energy sector.

An analysis of the dynamics of qualitative assessments of energy security in the regions and quantitative values of the weights of indicators in different states from 2012 to 2016 allows drawing a conclusion that the energy security situation during this period on average had positive trends: for all subjects of the Siberian Federal District, with the exception of the Republic of Altai.

V. The main energy security trends in the regions of Russia

In order to identify the trends in the changes in the regional energy security in terms of individual indicators, we will analyze the change in their state from 2012 to 2016. In Table 7 as a percentage, the qualitative conditions of various indicators are presented for the years 2012 and 2016.

Based on the comparative analysis and data presented in Table 7, the following results were obtained. The situation in the regions has changed slightly over the six-year period in terms of the indicators: 1.1 (The ratio of the total available capacity of the region's power plants to the maximum electric load of consumers in the region), 1.2 (The ratio of the amount of available capacity of power plants and the intersystem ties between regions to the maximum electric load in the region), 1.3 (Possibilities of meeting the demand for primary energy from the region's sources) and 2.3 (the ability to meet fuel demand under in case of a sharp cooling (10% increase in consumption) in the region).

Table 7. The indicators of energy security in the regions and the assessment of the energy security state in the Russian regions (2012, 2016), %

Indicator	Status of the indicator by region			
	Year	N	PC	C
1.1	2012	79	5	16
	2016	79	4	17
1.2	2012	90	5	5
	2016	92	4	4
1.3	2012	34	9	57
	2016	36	9	55
2.1	2012	18	17	65
	2016	13	18	69
2.2	2012	49	25	26
	2016	53	20	27
2.3	2012	57	16	27
	2016	56	17	27
3.1	2012	6	72	22
	2016	10	70	20
3.2	2012	35	17	48
	2016	46	13	41

The situation with the share of the dominant resource in the total consumption of primary energy in the region worsened by 5% (indicator 2.1). This situation is observed in all the regions of the Central, North Caucasian, Volga Federal Districts, as well as the Kaliningrad, Leningrad, Murmansk, Novgorod and Pskov regions of the North-West Federal Districts that do not have sufficient sources of their own for primary energy production, and where gas is the dominant type of fuel.

According to indicator 2.2 (The share of the largest power plant in the installed electric capacity of the region), the situation as a whole, across the country, has improved by 5% due to the commissioning of new capacities. The commissioning of new capacities along with repairs led to a certain improvement in the situation in terms of indicator 3.1 (Degree of depreciation of the basic production assets of the regional energy sector) - by 4% and indicator 3.2 (The ratio of the average annual commissioning of installed capacity and reconstruction of power plants in the region over the last 5-year period to the installed capacity in the region) - by 11%. Although at the same time, in all the regions of Russia the current values of the degree of equipment wear and tear are 50-60% and the situation requires close attention.

VI. Conclusion

In general, the energy security situation in the subjects of Russia is unsatisfactory. Most of the regions are characterized by crisis and pre-crisis values of the indicator weights.

It is worth noting that a relatively high percentage of regions have an acceptable energy security situation in terms of indicator 1.2 (The ratio of the available capacity of power plants and the transfer capability of intersystem ties between regions to the maximum electric load of consumers in the region) - 92% and indicator 1.1 (The ratio of the total available capacity of the region's power plants to the maximum electric load of consumers in the region) - 79% of the regions.

As evidenced by Table 7, the pre-crisis situation in 70% of the regions is affected by the unsatisfactory state of indicator 3.1, i.e. the degree of depreciation of the basic production assets in the energy sector in the region. As in the majority of the subjects of the Russian Federation, the current values of the equipment wear are 50-60%.

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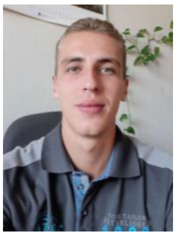

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