Application of the rating method in energy security assessments at the regional level

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Abstract. The article presents a method for generating standardized values of energy security indicators and standardized qualitative assessments of the state of energy security, based on the use of a convolution apparatus for qualitative assessments of the state of the most important indicators of energy security. An analysis of the dynamics, main trends and scale of changes in the state of energy supply when using this method is presented using the example of an assessment of the constituent entities of the Russian Federation located on the territory of the Volga Federal District.

Introduction

The concept of energy security (ES) is interpreted as "the state of protection of citizens, society, the state, and the economy from threats of shortages in meeting their energy needs with economically available energy resources of acceptable quality, and from threats of disruption of the uninterrupted power supply" [1,2, etc.]. An indicative assessment of the level of energy security of a particular region of the country is carried out according to three, largely interconnected, blocks of indicators: production and resource availability of the fuel and energy supply system of the region; reliability of the fuel and energy supply system of the region; state of fixed production assets (BPA) of energy systems in the region (Table 1). Taking into account the characteristics of the energy supply of individual regions, previously [1,3,4, etc.], the threshold values of indicative indicators for different groups of constituent entities of the Russian Federation, as well as the relative shares of indicators in the overall system of their value, were expertly determined. Using the method of convolution of the obtained values of the analyzed indicators, integral assessments of the state of the economic security of the constituent entities of the Russian Federation were formed.

Research shows that individual indicators are measured in different units, and in order to obtain an integral assessment of a region's economic security, the principle of normalizing indicator values depending on the ratio of their values to threshold values can be applied. To do this, it is proposed to use a special normalization apparatus that allows you to work with both increasing and decreasing values of indicators, that is, with those indicators whose state improves as the value increases and with those whose state improves as their values decrease.

Table 1. The composition of the most important indicators of regional energy security.

1. The block of industrial and resource security of the fuel- and energy supply of the region
1.1. The ratio of the total available capacity of the region's power plants to the maximum electric load of consumers on its territory. 1.2. The ratio of the amount of available capacity of power plants and the capacity of inter-system connections of the region with neighboring consumers to the maximum electric load on its territory. 1.3. Opportunities to meet the needs of boiler heating oil (BHO) from the region's own sources.
2. The block of reliability of fuel and energy supply of the region
2.1. The share of the dominant resource in total consumption of BHO in the region. 2.2. Share of the largest power plant in the installed electric capacity of the region. 2.3. The level of potential supply of demand for fuel in the conditions of a sharp cooling (10% consumption of consumption) in the region.
3. Block of the state of the BPA of energy systems in the territory of the region
3.1. Degree of depreciation of the BPA in the energy sector of the region. 3.2. The ratio of the average annual input of installed capacity and reconstruction of power plants in the region over the previous 5-year period to the established capacity of the region.

The conversion of indicator values expressed in various units of measurement into normalized ones is carried out according to the following expression:

$$X_i^N = \frac{x_{PCi} - X_i^t}{x_{C,i} - x_{PC,i}}, \quad (1)$$

where X_i^N – is the normalized value of indicator i in the analyzed period, rel. units; X_i^t – is the actual value of the indicator in the system of initial units; $X_{PC,i}$, $X_{C,i}$ - respectively, the threshold values of the pre-

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crisis and crisis states of the indicator i in the system of initial units.

In accordance with the calculation algorithm, the normalized threshold value $X^N_{PC,i}$ - is always equal to zero and is the starting point of the pre-crisis states of the indicator, and the normalized value $X^N_{C,i}$ - is equal to -1 and represents the boundary of transition to crisis status of indicators.

In [5], the method of normalizing indicative indicators was used using the example of the Central and Southern Federal Districts. Based on the results of the analysis of the obtained normalized indicators and their graphical display, it became necessary to further adjust the overlap of threshold values. And correlate the specific weights of each i-th normalized indicator to unity. The fact is that if the acceptable threshold value for some indicator, for example, overlaps by 100 percent or more, then the state of the indicator still remains acceptable, but this indicator pulls up the entire integral assessment and crisis and pre-crisis assessments may be lost other indicators. The same with crisis values. You should not take into account too great a depth of the crisis; it is enough to focus on crisis values that do not distort the overall integral assessment too much. In this regard, it was decided that any significant overlap of the threshold value of the indicator should be reduced to a sufficient margin: 25% for acceptable conditions and 50% for crisis ones.

Let us present the application of this approach using the example of constituent entities of the Russian Federation located on the territory of the Volga Federal District.

Let us first present the results obtained using conventional indicative analysis. Then, in order to more conveniently compare the results and compare the dynamics of the state of energy supply in different regions, we will apply the approach of normalizing the obtained quantitative estimates.

Results of indicative ES analysis by regions of the Volga Federal District

This section provides information on the qualitative state of energy security indicators for the constituent entities of the Russian Federation on the territory of the Volga Federal District, as well as a qualitative description of the state of energy security of these constituent entities for 5 years: from 2017 to 2021, Table. 2-5. The initial information for the study was taken in accordance with statistical information for 2017-2021. [6-8], as well as with the necessary information on specific regions. As a result of the analysis of relevant data for the subjects of the Volga Federal District, it is possible to judge the trends inherent in the energy sector of the studied territories in ensuring energy security. In table Table 2 presents information on assessing the status of indicators for the block of production and resource security of the fuel and energy supply system for 2017 and 2021. in the subjects of the Volga Federal District.

Table 2. The status of indicators on the territory of the subjects of the Volga Federal District of the district for the block of production and resource provision of the fuel and energy supply system for 2017, 2021.

Region, area	Indicator	Dimen-sion	The threshold values of the indicator		The meaning and status of the indicator, year			
			N	C	2017		2021	
Republic Bashkortostan	1.1	un.	0,5	0,3	1,2	N	1,3	N
	1.2	un.	1,5	1,2	2,4	N	2,5	N
	1.3	%	40	20	24,5	PC	21,6	PC
Republic Mari El	1.1	un.	0,5	0,3	0,5	PC	0,5	N
	1.2	un.	1,5	1,2	5,2	N	5,3	N
	1.3	%	40	20	57,7	N	63,7	N
Republic Mordovia	1.1	un.	0,5	0,3	0,7	N	0,7	N
	1.2	un.	1,5	1,2	2,7	N	2,7	N
	1.3	%	40	20	0	C	0	C
Republic Tatarstan	1.1	un.	0,5	0,3	1,6	N	1,7	N
	1.2	un.	1,5	1,2	3,5	N	3,4	N
	1.3	%	40	20	24,7	PC	22,8	PC
Republic Udmurtia	1.1	un.	0,5	0,3	0,4	PC	0,4	PC
	1.2	un.	1,5	1,2	2,9	N	3,1	N
	1.3	%	40	20	2,7	C	3,6	C
Chuvash Republic	1.1	un.	0,7	0,5	1,78	N	2,4	N
	1.2	un.	1,5	1,2	5,5	N	5,9	N
	1.3	%	40	20	0,4	C	0,1	C
Kirov region	1.1	un.	0,5	0,3	0,8	N	0,8	N
	1.2	un.	1,5	1,2	2,5	N	2,6	N
	1.3	%	40	20	3,1	C	3,3	C

Nizhny Novgorod region	1.1	un.	0,7	0,5	0,8	N	0,8	N
	1.2	un.	1,5	1,2	1,9	N	1,9	N
	1.3	%	40	20	59,8	N	71,8	N
Orenburgskaya region	1.1	un.	0,5	0,3	1,1	N	1,7	N
	1.2	un.	1,5	1,2	1,4	PC	2,1	N
	1.3	%	40	20	123,3	N	76,8	N
Penza region	1.1	un.	0,5	0,3	0,5	N	0,4	PC
	1.2	un.	1,5	1,2	2,6	N	2,5	N
	1.3	%	40	20	1,2	C	1	C
Permian edge	1.1	un.	0,5	0,3	2,1	N	2,3	N
	1.2	un.	1,5	1,2	2,8	N	3,2	N
	1.3	%	40	20	21,2	PC	22,1	PC
Samara region	1.1	un.	1,2	1,1	1,5	N	1,6	N
	1.2	un.	1,5	1,2	3,8	N	4,1	N
	1.3	%	40	20	48,1	N	44,1	N
Saratovskaya region	1.1	un.	0,5	0,3	3,2	N	3,2	N
	1.2	un.	1,5	1,2	7,1	N	7,1	N
	1.3	%	40	20	46,2	N	54,3	N
Ulyanovskaya region	1.1	un.	0,5	0,3	0,9	N	1,1	N
	1.2	un.	1,5	1,2	14,2	N	12,5	N
	1.3	%	40	20	1,3	C	1,8	C

According to indicator 1.1, the situation is acceptable in the Republic of Mari El, Nizhny Novgorod, Orenburg and Saratov regions. The maximum electrical load here is provided with a reserve of its own power generating capacities. As for electrical connections with neighboring regions (indicator 1.2), their capacity, in the event of large-scale emergency situations with energy supply, can be assessed as acceptable. Also, thanks to a sufficient amount of production of own BHO in certain regions (fuel oil in Nizhny Novgorod, Samara, Mari El, coal and gas in the Orenburg region, fuel oil and natural gas in the Saratov region), acceptable values of indicator 1.3 are provided. A crisis situation according to indicator 1.3 can be noted in Mordovia, Kirov, Chuvash and Ulyanovsk regions due to insufficient volumes of BHO production or its complete absence. The situation with respect to the block of indicators "Reliability of fuel and energy supply to the region" is presented in Table. 2.

Table 3. Characteristics of the state of indicators on the territory of the subjects of the Volga Federal District for the fuel and energy supply reliability block for 2017, 2021.

Region, area	**Indica-tor**	**The threshold values of the indicator, %**		**The meaning and status of the indicator, year**			
		N	**C**	**2017**		**2021**	
Republic Bashkortostan	2.1	40	70	94,1	C	95,3	C
	2.2	50	70	35,0	N	32,7	N
	2.3	100	<100	91	C	91	C
Republic Mari El	2.1	40	70	97,5	C	91,7	C
	2.2	50	70	31,4	N	31,7	N
	2.3	100	<100	91	C	91	C
Republic Mordovia	2.1	40	70	99,9	C	99,8	C
	2.2	50	70	89	C	87,6	C
	2.3	100	<100	94	C	94	C
Republic Tatarstan	2.1	40	70	99,5	C	99,4	C
	2.2	50	70	27,9	N	27,1	N
	2.3	100	<100	93	C	93	C
Republic Udmurtia	2.1	40	70	95,8	C	97,6	C
	2.2	50	70	52,5	PC	56,8	PC
	2.3	100	<100	91	C	91	C
Chuvash Republic	2.1	40	70	98,8	C	99,7	C
	2.2	50	70	62,8	PC	62,8	PC
	2.3	100	<100	91	C	91	C

Kirov region	2.1	40	70	90,7	C	93,6	C
	2.2	50	70	45,9	N	46,8	N
	2.3	100	<100	>100	N	>100	N
Nizhny Novgorod region	2.1	40	70	95,5	C	90,0	C
	2.2	50	70	45,9	N	46,8	N
	2.3	100	<100	>100	N	>100	N
Orenburgskaya region	2.1	90		87,3	N	91,7	PC
	2.2	50	70	63,2	PC	61,4	PC
	2.3	100	<100	>100	N	>100	N
Penza region	2.1	40	70	98,4	C	97,8	C
	2.2	50	70	77,8	C	82,8	C
	2.3	100	<100	>100	N	>100	N
Permian edge	2.1	40	70	97,0	C	95,0	C
	2.2	50	70	42,5	N	43,1	N
	2.3	100	<100	>100	N	>100	N
Samara region	2.1	40	70	97,7	C	97,5	C
	2.2	50	70	41,9	N	42,6	N
	2.3	100	<100	>100	N	>100	N
Saratovskaya region	2.1	40	70	98,2	C	97,3	C
	2.2	50	70	60,3	PC	60,8	PC
	2.3	100	<100	>100	N	>100	N
Ulyanovskaya region	2.1	40	70	98,3	C	99,2	C
	2.2	50	70	49,8	N	42,2	N
	2.3	100	<100	>100	N	>100	N

According to indicator 2.1, in all subjects of the Volga Federal District, the share of gas, as the dominant resource, in the total consumption of BHO is extremely high and amounts to 90-95%, which cannot be acceptable from an energy supply standpoint. As for the share of the largest power plant in the installed electrical capacity of the regions, in general the situation is acceptable. Exceptions are the Republic of Udmurtia (Izhevsk CHP-2), the Chuvash Republic (Cheboksary HPP), the Orenburg region (Iriklinskaya SDPP) and the Saratov region (Balakovo NPP). Here the share of the largest source is more than 60%, and the situation from an energy security point of view is assessed as pre-crisis. The crisis situation according to this indicator is in the Republic of Mordovia (the largest power plant Saranskaya CHP-2, which accounts for more than 70% of installed capacity and more than 60% of electricity generation), as well as in the Penza region (more than 80% is the share of Penza CHP-1, in addition, The Penza region is an energy-deficient region both in terms of electricity and power, and the deficiency is compensated by the flow of electricity from neighboring regions). The most important indicative indicators include indicator 2.3 (Table 3), reflecting the level of potential supply of demand for fuel and energy resources in conditions of a sharp cold snap (10% surge in consumption) in the territories of the region. It is estimated based on the results of model studies described in [2,3,9] as the amount of supply of boiler and furnace fuel to consumers during a possible peak cold snap, with an increase in CHP consumption by 10%. The subjects of the Volga Federal District belong to regions with a particularly cold climate with the average temperature of the coldest five days below minus 30°C [10]. The very high share of natural gas in certain regions, noted as a crisis from an energy supply point of view, determines a crisis situation with the possibility of providing consumers with fuel in conditions of increasing demand during sudden cold snaps in the Volga Federal District. Research shows that in such a situation the supply of the required amount of gas cannot always be ensured. At the same time, in the Kirov region, despite the fact that there is no own production of BHO, and the share of natural gas in the balance of BHO is 93%, the presence of powerful gas pipeline corridors in the region makes it possible to meet the peak increase in demand for fuel in the event of a sharp cold snap. The same can be said in the Perm region, Penza and Nizhny Novgorod regions. According to the indicators of the block "State of BPA of energy systems in the region", averaged data on wear and tear of BPA of energy industries were taken into account, Table. 4.

Table 4. Characteristics of the state of indicators on the territory of the subjects of the Volga Federal District in the block of the state of the BPA of energy systems for 2017, 2021.

Region, area	Indica-tor	Dimen-sion	The threshold values of the indicator		The meaning and status of the indicator, year			
			N	C	2017		2021	
Republic Bashkortostan	3.1	%	40	60	54,7	PC	51,9	PC
	3.2	%	2	1	1,9	PC	2,2	N
Republic Mari El	3.1	%	40	60	42,4	PC	47,5	PC
	3.2	%	2	1	0,9	C	0,9	C
Republic Mordovia	3.1	%	40	60	55,7	PC	58,6	PC
	3.2	%	2	1	0	C	1,3	PC
Republic Tatarstan	3.1	%	40	60	40,3	PC	41,8	PC
	3.2	%	2	1	2,6	N	1,7	PC
Republic Udmurtia	3.1	%	40	60	54,1	PC	58,5	PC
	3.2	%	2	1	5,9	N	1,0	C
Chuvash Republic	3.1	%	40	60	57,1	PC	60,9	C
	3.2	%	2	1	0,7	C	0,7	C
Kirov region	3.1	%	40	60	57,5	PC	61,7	C
	3.2	%	2	1	6,7	N	0,5	C
Nizhny Novgorod region	3.1	%	40	60	44,3	PC	49,6	PC
	3.2	%	2	1	2,4	N	0,2	C
Orenburgskaya region	3.1	%	40	60	61,6	C	63,9	C
	3.2	%	2	1	0,6	C	1,7	PC
Penza region	3.1	%	40	60	68	C	73,9	C
	3.2	%	2	1	0	C	0	C
Permian edge	3.1	%	40	60	47,3	PC	51,5	PC
	3.2	%	2	1	3,4	N	2,3	N
Samara region	3.1	%	40	60	50,4	PC	53,7	PC
	3.2	%	2	1	0,1	C	0,1	C
Saratovskaya region	3.1	%	40	60	63,6	C	0,1	C
	3.2	%	2	1	0,1	C	0,2	C
Ulyanovskaya region	3.1	%	40	60	55,7	PC	60,7	C
	3.2	%	2	1	0,8	C	1,9	PC

According to the third block of indicators, the condition in none of the subjects cannot be called completely acceptable. In terms of the degree of depreciation of the main production assets of the energy sector, as well as in terms of the average annual commissioning of installed capacity, the Chuvash Republic, Kirov, Penza and Saratov regions are in a state of crisis. In the Republic of Bashkortostan, according to indicator 3.2, the state moved from pre-crisis to acceptable due to the commissioning of a number of solar power plants with a total capacity of 50 MW in 2020-2021, as well as units at the Novo-Salavatskaya CHP and Ufa CHP-1. In the Orenburg region, the situation changed from crisis to pre-crisis due to the commissioning of solar power plants with a total capacity of 327 MW over a 5-year period.

Integral assessment of ES by regions of the Southern Federal District

Taking into account the previously presented and analyzed values of the main indicators, integral assessments of the level of energy security in the territories of the constituent entities of the Volga Federal District were obtained. To form these estimates, an approach was used based on convolution of indicator values, taking into account their specific weights. Qualitative characteristics of the state of all discussed indicators from table. 2-4, were collected from the corresponding territories and processed according to a specially developed methodology [3,4,9]. As a result, a qualitative integral assessment of the state of energy security in the regions of the Volga Federal District was obtained, presented in Table. 5.

Table 5. Integrated qualitative assessment of the state of energy security in the territory of the subjects of the Volga Federal District for 2016, 2020.

Years	The order numbers of the estimated ES indicators								The sum of the specific weights by state			Quality condition ES
	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
Republic Bashkortostan												
2017	N	N	PC	C	N	C	PC	PC	0,29	0,38	0,32	PC
2021	N	N	PC	C	N	C	PC	N	0,29	0,26	0,45	PC
Republic Mari El												
2017	PC	N	N	C	N	C	PC	C	0,41	0,23	0,35	C
2021	N	N	N	C	N	C	PC	C	0,41	0,12	0,45	C
Republic Mordovia												
2017	N	N	C	C	C	C	PC	C	0,63	0,12	0,24	C
2021	N	N	C	C	C	C	PC	PC	0,50	0,25	0,24	C
Republic Tatarstan												
2017	N	N	PC	C	N	C	PC	N	0,29	0,26	0,45	PC
2021	N	N	PC	C	N	C	PC	PC	0,29	0,38	0,32	PC
Republic Udmurtia												
2017	PC	N	C	C	PC	C	PC	N	0,42	0,31	0,26	C
2021	PC	N	C	C	PC	C	PC	C	0,55	0,31	0,13	C
Chuvash Republic												
2017	N	N	C	C	PC	PC	PC	C	0,55	0,20	0,24	C
2021	N	N	C	C	PC	PC	C	C	0,67	0,07	0,24	C
Kirov region												
2017	N	N	C	C	N	N	PC	N	0,25	0,12	0,62	N
2021	N	N	C	C	N	N	C	C	0,50	0	0,49	PC
Nizhny Novgorod region												
2017	N	N	N	C	N	N	PC	N	0,12	0,12	0,75	N
2021	N	N	N	C	N	N	PC	C	0,24	0,12	0,62	PC
Orenburgskaya region												
2017	N	PC	N	N	PC	N	C	C	0,25	0,21	0,52	PC
2021	N	N	N	PC	PC	N	C	PC	0,12	0,32	0,54	PC
Penza region												
2017	N	N	C	C	C	N	C	C	0,58	0	0,41	C
2021	PC	N	C	C	C	N	C	C	0,58	0,10	0,30	C
Permian edge												
2017	N	N	PC	C	N	N	PC	N	0,12	0,26	0,62	PC
2021	N	N	PC	C	N	N	PC	N	0,12	0,26	0,62	PC
Samara region												
2017	N	N	N	C	N	N	PC	C	0,24	0,12	0,62	PC
2021	N	N	N	C	N	N	PC	C	0,24	0,12	0,62	PC
Saratovskaya region												
2017	N	N	N	C	PC	N	C	C	0,37	0,07	0,54	PC
2021	N	N	N	C	PC	N	C	C	0,37	0,07	0,54	PC
Ulyanovskaya region												
2017	N	N	C	C	N	N	PC	C	0,38	0,12	0,49	PC
2021	N	N	C	C	N	N	C	PC	0,38	0,12	0,49	PC

[1] The state of ES in the region is recognized as a crisis if the sum of the shares of indicators in the state "C" exceeds 0,4

[2] The state of ES in the region is recognized as normal if the sum of the specific weights of the indicators in the "N" state exceeds 0,7

As shown by the analysis of data on the qualitative state of the most important indicators of energy security in the constituent entities of the Russian Federation on the territory of the Volga Federal District (Table 5), of the 14 subjects examined, an acceptable situation with the provision of energy security in the analyzed period was observed only in the Nizhny Novgorod region, and then only in 2017 ., and by 2021 it has moved to a pre-crisis state due to the deterioration of the situation with the renewal of the electric power industry's general fund. In seven regions of the district, the situation is also assessed as pre-crisis: the Republic of Bashkortostan, Tatarstan, Orenburg region, Perm region, Samara, Saratov and Ulyanovsk regions. In the remaining six regions, the situation is assessed as a crisis, including according to the indicators of the state of the BPA of the energy sector, due to the high share of gas in the balance of consumption of BHO and, accordingly, the insufficient ability to meet the needs for BHO in conditions of peak-increasing winter demand: Mari El, Mordovia, Udmurtia, Chuvash Republic, Penza and Kirov regions.

Normalization of ES indicator values

The next stage in the work was the normalization of the obtained indicator values for all subjects of the Volga Federal District, in accordance with expression (1). Based on the obtained values for a 5-year period, graphs of the state of normalized indicator values for the corresponding blocks were constructed, Fig. 1-3. The threshold values of the indicators were also taken into account here as normalized; where according to expression (1) "crisis" = - 1, "pre-crisis" = 0. Thus, all states located in the range of values below "-1" can be considered crisis, in the range from "-1" to "0" - pre-crisis and in the area above "0" - acceptable. The obtained results of normalized values for each indicator for the regions of the Volga Federal District are presented in graphs (Fig. 1-3). Comparing the results obtained in the graphs with those previously presented in the tables (Tables 2-4), one can note the clearly expressed dynamics of changes in the level of energy security in the regions, which allows us to examine the situation in more detail and take measures to improve it. For example, according to indicator 1.1 (Fig. 1), almost all subjects, except the Republic of Udmurtia, have a sufficient supply of available power. As for ind. 1.2, then, due to fairly high indicators, significantly exceeding the threshold values of the indicators (more than 100%), a restriction was applied to a sufficient margin of 25%. Therefore, on the graph, all these subjects of analysis "coincided" at around 1.25, with the exception of the Orenburg region, where there was a transition from the pre-crisis to an acceptable state according to this indicator, due to a slight increase in generating capacity by 2021. According to indicator 1.3 (Fig. 1), the analysis showed a positive trend in meeting the needs for BHO from own sources in the Nizhny Novgorod and Saratov regions. There is some deterioration in the situation, but still within the range of pre-crisis values for this indicator, in the Republics of Bashkortostan and Tatarstan. According to indicator 2.1 (Fig. 2) - "Share of the dominant resource in the total consumption of BHO", one can immediately note the absence of regions in the zone of an acceptable state from the point of view of energy security. According to indicator 2.2 (the share of the largest power plant in the installed capacity of the region), one can note the division of regions according to all three states of the indicative analysis - crisis, pre-crisis and acceptable.

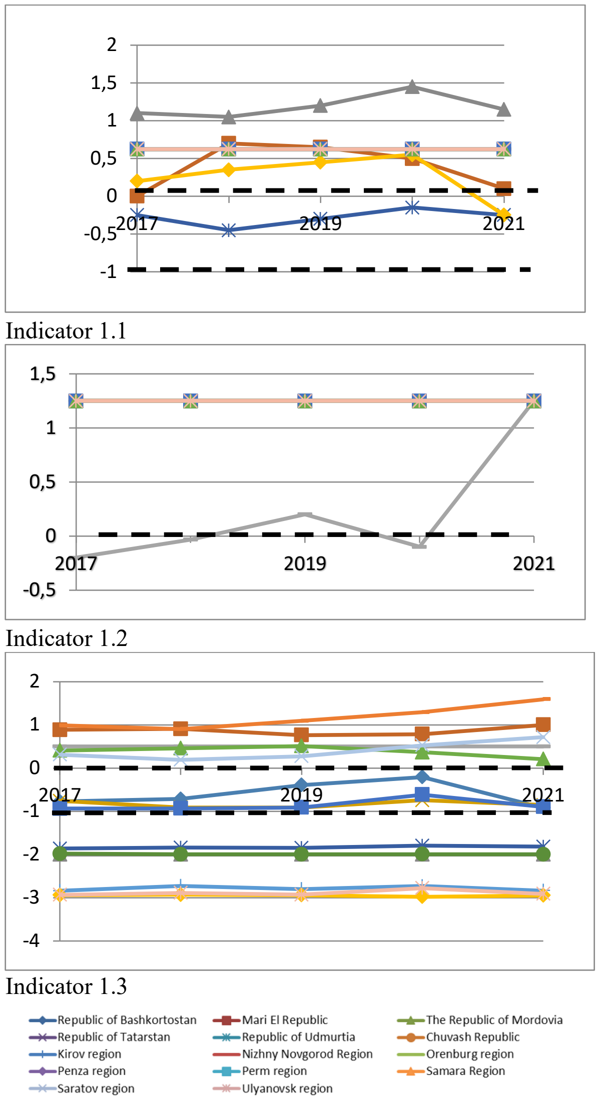
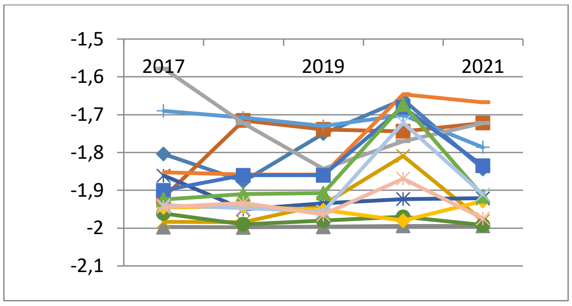
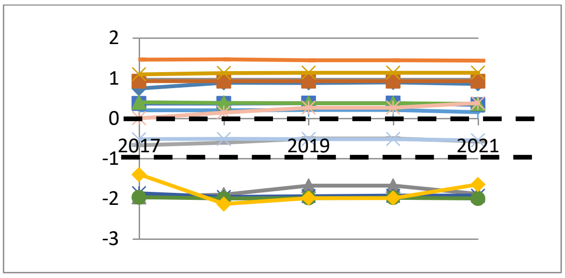


Fig. 1. Analysis of the situation with the provision of ES requirements for the first block of indicators in the regions of the Volga Federal District.

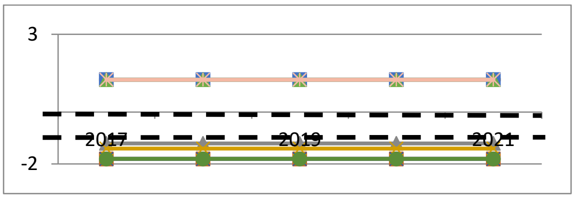
A fairly high reserve of values for the index. 2.3 on the graph (Fig. 2) determines their reduction in this case and the accepted sufficient margin of 25% above the threshold value for regions in conditions of sudden cooling.



Indicator 2.1



Indicator 2.2



Indicator 2.3

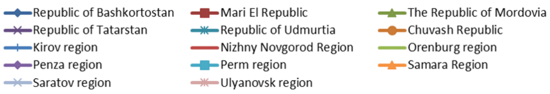
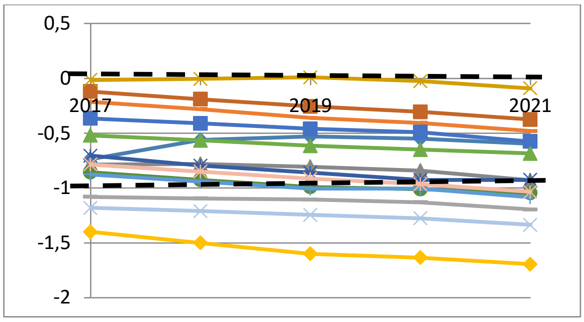
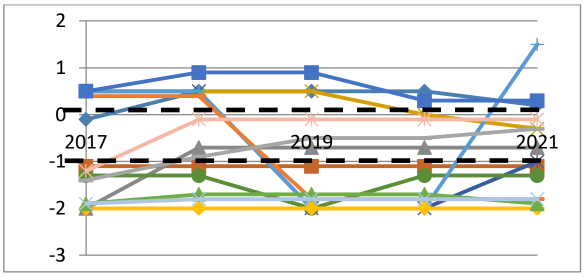


Fig. 2. Analysis of the situation with the provision of ES requirements for the second block of indicators in the regions of the Volga Federal District.

For the third block of indicators (Fig. 3), due to the insufficiently active policy in updating the BPA of the energy sector of the Volga Federal District, the values are located mainly in the zone of pre-crisis and crisis values. Sharp changes in index values. 3.2 (Fig. 3) are observed due to long breaks between the commissioning of new capacities and significant renewal of fixed production assets in the regions.



Indicator 3.1



Indicator 3.2

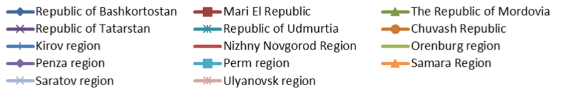


Fig. 3. Analysis of the situation with the provision of ES requirements for the third block of indicators in the regions of the Volga Federal District.

To obtain the final integral assessment of the level of ES, the normalized values of the indicators were convoluted taking into account their specific weights. The resulting complex integral assessment of the state of the energy supply of the subjects of the Volga Federal District is presented in Fig. 4. From the assessment presented in Fig. 4, as well as in Table 5, it is clear how the situation with the integral assessment of regional energy security has changed, but the use of normalized indicators allows us to visualize not only the main trends and dynamics in providing energy security, but also show proximity to acceptable or crisis state from the point of view of electronic security. Thus, as a result of the study, a slightly different picture was obtained on the integral assessment graph in comparison with the final table of indicators.

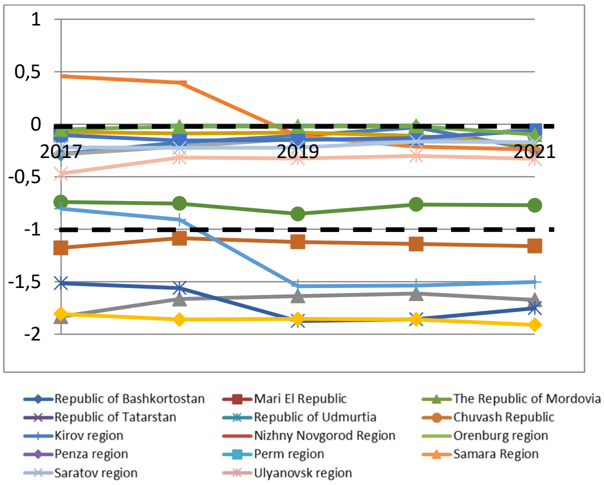


Fig. 4. Integrated qualitative assessment of the state of energy security in the regions of the Volga Federal District.

All subjects (Fig. 4) are located in the zone of pre-crisis values, and the Perm Territory and Nizhny Novgorod Region are in the acceptable zone, while according to the results of a qualitative assessment (Table 5), all subjects in 2021 were in crisis and pre-crisis states. The clarification occurred as a result of the application of the standardization method, which made it possible to more accurately determine the state of the regions on the scale of the crisis state from the point of view of economic security.

Conclusion

The approach discussed in the article differs from those used previously in that the integral assessment takes into account not only qualitative, but also quantitative assessments of the situation with ensuring energy security according to individual indicators. The use of this approach makes it possible to obtain normalized values of indicators, which in turn correctly reflect the obtained results of assessing the state of the regional energy security, and also more clearly and in detail show the dynamics of changes in the situation with the provision of energy security, both for each individual indicator and comprehensively for the subjects. The analysis showed that in the regions of the Volga Federal District, which largely do not have their own sources of fuel and energy resources, there is a crisis situation with the share of gas in the total consumption of BPA and with the share of the largest generating source. In general, it should be noted that in almost all regions the situation with the aging of the energy sector is rapidly deteriorating, and, consequently, with the danger of an increase in the number of emergencies with fuel and energy supply to consumers due to the failure of one or another equipment.

The study was carried out within the framework of the state assignment project FWEU-2021-0003 (registration number. AAAA-A21-121012090014-5) for fundamental research of the SB RAS.

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