"Floating" threshold values for energy security indicators describing the tariffs of energy resources

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***Abstract* — The paper briefly presents the methodological approaches to analyzing the energy security and the system of indicators used in Moldova. One of the tasks is to determine the threshold values of indicators, which, when exceeded, indicate a state of crisis.**

The threshold values are determined for the entire time series of values and for each indicator individually. Different approaches can be used. However, for the indicators describing energy tariffs, the attempts to use fixed thresholds for the entire time series were unsuccessful.

Tariffs for energy resources and GDP are interrelated. Tariffs are involved in the calculations of Intermediate Consumption - one of the GDP components. The growth of tariffs is one of the reasons for the decline in GDP.

In this regard, there was a need for a special new approach to the development of threshold values of tariff indicators that would be related to annual changes in GDP.

The idea that the growth of tariffs should not exceed the GDP growth was used to determine the threshold values.

The annual values of the maximum possible growth of tariffs are obtained based on the dynamics of the GDP growth. They gave the ("floating") thresholds for tariff indicators for each year of the time series.

***Index Terms* — indicator, tariff, GDP, energy security, threshold values**

I. Introduction

Energy security is considered comprehensively, given the diversity of aspects of the power system and energy sector operation (a multidisciplinary approach) [1-2].

The authors of [3] place an emphasis on the need for an analysis of energy supply in terms of 4 aspects: the availability, accessibility, economic feasibility and environmental compatibility. The study of energy security is necessary for the development of energy policy and and reduction in energy dependence [4-5].

Modeling of energy security taking into account the economic, technical and environmental aspects is carried out in [6].

Modeling can include an analysis of various scenarios of balancing energy flows and take into account the involvement of renewable energy sources in order to reduce emissions, analysis of economic advantages [7-8].

The indicative analysis is a method of research on the energy security of the power system and energy sector [9]. The methodology makes it possible to form a system of indicators, determine the crisis threshold values of indicators, compare current and thresholds values, determine the degree of criticality of each indicator, define a general final index of energy security, and form a list of measures to ensure and improve the level of energy security [10-15].

The system of indicators reflects the state of the energy in Moldova and includes more than 50 indicators [11]. They are structured in 10 blocks:

Block № 1 - provision of fuel;

Block № 2- production of electricity and heat;

Block № 3 - transport and distribution of electricity;

Block № 4 - import of electricity;

Block № 5 - the ecological block (CO2 emissions);

Block № 6 - consumption of electricity and heat;

Block № 7 - the economic block (tariffs for electricity and heat, debts in the energy sector, energy and electricity intensity);

Block № 8 - investments;

Block № 9- own fuel and energy resources;

Block № 10 - social and personnel aspects of the energy sector;

An analysis of time series and a comparison of current and crisis values on the scales of crisis are performed for each indicator. The scales of crisis have normal, pre-crisis and crisis intervals, which are further divided into ranges in the ratio of 1,2; 1.4; 1.6; 1.8 and >1.8 from the normal state [10].

Threshold values can be provided by the expert or

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http://dx.doi.org/10.25729/esr.2018.02.0009
Received: July 23, 2018. Revised: September 6, 2018. Accepted: September 14, 2018. Available online: October 15, 2018.

obtained analytically. The expert method is simple and convenient but its downside is subjectivity. Attempts were made to obtain analytic expressions for threshold values (by the method of principal components, discriminant analysis, and some others). The resulting crisis and pre-crisis values were close to each other, [10].

A method of functional interrelations is proposed in [11]. The essence of the method is that the threshold values of indicators are calculated analytically and only one indicator - GDP growth - is provided by expert. The method shows more stringent thresholds compared to expert ones, on average, by 10%.

For each indicator, the threshold values are determined individually, depending on the nature of the indicator. For some indicators, the threshold value is calculated with respect to the base level, for some – based on a range of values, and for some – based on an average multi-year value.

For some indicators, the determination of threshold values is a complex task. In particular, the threshold values have not been established for most of the environmental indicators. For some economic indicators, it is also difficult to determine the threshold values by calculation or to justify expert values.

There are threshold values for all indicators of energy security. They are the same for the entire time series.

There are several indicators, however, for which this approach is unsatisfactory. These are the indicators of tariffs for electricity, heat, and gas. The attempts to determine a fixed boundary for the crisis state were unsuccessful. It is difficult to substantiate a value that can be considered as critical for the tariffs. Tariffs constantly vary. They are linked with the overall economic situation. Moreover, tariffs affect GDP, as they are involved in the formation of "Intermediate Consumption", i.e. one of the GDP components. The higher the tariffs, the greater the value of "Intermediate Consumption" and, correspondingly, the lower the GDP.

This is analyzed in detail in [16-18], where the authors derive a formula that relates tariffs to GDP:

$$\Delta T\ (\%) = \alpha\ \Delta GDP\ (\%) \tag{1}$$

This formula can be expressed in words as follows: if the GDP increases by Δ% in comparison with the previous year, the tariffs can be increased by no more than Δ%. The α is a binding coefficient. In order for the economy to develop, the tariff growth should be less than the GDP growth, i.e. $\alpha < 1$.

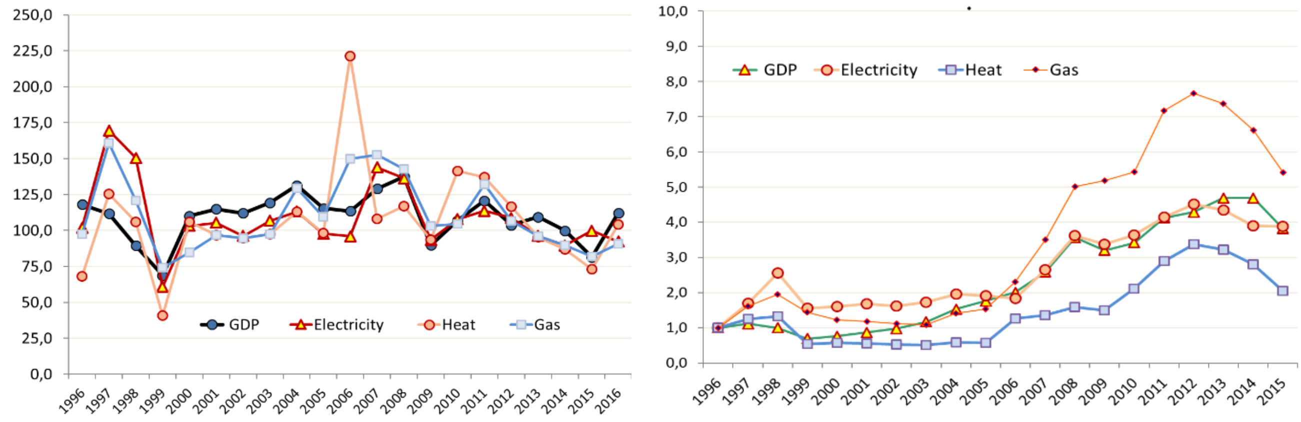
This formula shows the dynamic relationship between tariff growth and GDP growth. The fact of their influence, however, remains unobtrusive.

Energy security, by definition [9], is aimed at providing the necessary fuel and energy resources not only to the country, territory, region but also to a specific person. Tariff values have a direct impact on the standard of living of the population and on their incomes, which remain after deducting the costs paid for energy from the average per capita income.

In this regard, the attempts to introduce the boundary tariff values in the form of a percentage of the base level, a percentage of the average multi-year level, and other approaches proved unsuccessful.

Table 1. GDP growth and Tariffs changes for Previous and Base Year.

Year	Exchange rate, Lei/$	GDP		Tariffs			Tariffs, Previous year = 100			Tariffs, Base year=100 (1997)		
		Billions USD	Ratio to previous year	Electricity, $/MWh	Heat, $/Gcal	Gas, $/1000 m^3	Electricity, %	Heat, %	Gas, %	Electricity, per unit	Heat, per unit	Gas, per unit
1996	4,6	1,7	1,18	0,03	32,6	61,1	102	68	98	1	1	1
1997	4,62	1,9	1,12	0,05	40,9	98,3	170	125	161	1,70	1,25	1,61
1998	5,37	1,7	0,89	0,08	43,4	118,8	151	106	121	2,55	1,33	1,94
1999	10,52	1,17	0,69	0,05	17,7	88,0	61	41	74	1,55	0,54	1,44
2000	12,43	1,29	1,10	0,05	18,7	74,5	103	106	85	1,60	0,57	1,22
2001	12,87	1,48	1,15	0,05	18,1	72,0	105	97	97	1,69	0,56	1,18
2002	13,57	1,66	1,12	0,05	17,2	68,2	96	95	95	1,62	0,53	1,12
2003	13,94	1,98	1,19	0,05	16,7	66,4	107	97	97	1,73	0,51	1,09
2004	12,33	2,6	1,31	0,06	18,9	85,8	113	113	129	1,96	0,58	1,40
2005	12,60	3	1,15	0,06	18,6	93,9	98	98	109	1,92	0,57	1,54
2006	13,13	3,41	1,14	0,06	41,1	140,6	96	221	150	1,84	1,26	2,30
2007	12,14	4,4	1,29	0,08	44,5	214,6	144	108	153	2,65	1,36	3,51
2008	10,39	6,06	1,38	0,11	52,0	306,8	136	117	143	3,61	1,59	5,02
2009	11,11	5,44	0,90	0,10	48,6	316,5	93	93	103	3,38	1,49	5,18
2010	12,37	5,81	1,07	0,11	68,7	331,4	108	141	105	3,64	2,11	5,42
2011	11,74	7,02	1,21	0,13	94,3	437,9	114	137	132	4,14	2,89	7,17
2012	12,11	7,28	1,04	0,14	110,1	467,8	109	117	107	4,51	3,38	7,66
2013	12,59	7,97	1,09	0,13	105,1	450,0	96	96	96	4,34	3,22	7,37
2014	14,04	7,96	1,00	0,12	91,3	403,7	90	87	90	3,89	2,80	6,61
2015	18,82	6,49	0,82	0,12	66,7	330,6	100	73	82	3,89	2,04	5,41



a) b)

Figure 1. GDP growth and tariffs changes for the previous year (a) and base year (b) in current prices.

The formulas linking GDP growth and tariff growth, in fact, determine the allowable critical limits for tariffs for each year, i.e. "floating" for the time series. They determine the threshold values for tariffs. This approach allows us to solve the problem of threshold values for indicators of tariffs for fuel and energy resources.

The values of GDP growth (current prices) are shown in Table 1 and Figure 1. Table 1 includes the data on an increase in the tariffs for natural gas (for the population), electricity and heat. The data of Tables 1-2 are given for 1997-2015, which enables an analysis for a long period.

According to formula (1), the tariff growth should not exceed the GDP growth. We accept this thesis as a general rule to determine thresholds for each year. If the percentage of GDP growth in the previous year, for example, for 1997/1996, is 112%, then 12% is the limiting value for the tariff increase in 1997. In reality, they were raised:

- by 70% - for electricity;
- by 25% - for heat;
- by 61% - for gas.

Thus, the increase in tariffs in 1997 for all three types of energy resources was excessively high. This caused a decline in GDP from 1.9 to 1.7 billion dollars or up to 89% of GDP in 1998 (1998/1997). Thus, the decline in GDP was 11% (current prices).

Despite this fact, in 1998, the tariffs were raised again:

- by 51% - for electricity;
- by 6% - for heat;
- by 21% - for gas.

Later, in 1999, GDP declined, even more, amounting to 1.17 billion dollars or 69% (1999/1998). In 1998, the tariffs did not increase.

Next year, in 2000, GDP could grow a little and reach $ 1.29 billion or 10% (1999/1998). The tariffs were increased:

- by 3% - for electricity;
- by 6% - for heat.

There was no increase in the tariffs for gas.

Continuing this analysis, one can see similar trends for other years.

The percentage of the GDP growth is not positive for all years. There are years when there was a decline in GDP and the percentage of growth was negative. For such cases, the crisis threshold value can be left at the level of the last GDP growth. In general, in such years, the tariffs should not be raised but should be reduced by an amount equal to the percentage of GDP decline.

Table 2 demonstrates the GDP growth for the previous year and crisis and pre-crisis threshold values for the above data.

Table 2. Crisis and Pre-Crisis Threshold Values.

Year	GDP growth by the previous year, %	Crisis threshold values, %	Pre-crisis threshold values (half of the crisis), %
1997	12	12	6
1998	-11	0	0
1999	-31	0	0
2000	10	10	5
2001	15	15	7,5
2002	12	12	6
2003	19	19	9,5
2004	31	31	155
2005	15	15	75
2006	14	14	7
2007	29	29	14,5
2008	38	38	19
2009	-10	0	0
2010	7	7	3,5
2011	21	21	10,5
2012	4	4	2
2013	9	9	4,5
2014	0	0	0
2015	-18	0	0

A. Principles of determining the crisis threshold values

1) For the years when GDP increases by Δ (%), the tariffs can be raised by no more than Δ (%). The crisis

threshold for the tariff indicators is equal to Δ, the pre-crisis threshold is equal to ½ Δ;

2) For the years when the GDP growth is 0%, there should be no tariff growth at all. The crisis threshold for tariff indicators is 0 (%);

2) For the years when there is a decline in GDP, the tariffs should be reduced by a similar amount. In extreme cases, the tariffs should be kept at the previous level, so that GDP could have a positive increase, but there should not be any rise in the tariffs. The crisis threshold will also be 0%. Accordingly, the pre-crisis threshold is also 0%.

Intermediate intervals of the crisis scale are calculated using the general principle:

For the crisis interval (C):

C (cth) = C • 1.2 (**C**risis **TH**reat);

C (cc) = C • 1.4 (**C**risis **C**ritical);

C (ce) = C • 1.6 (**C**risis **E**mergency).

For the pre-crisis (PC) interval, the values are divided into 3 equal groups:

PC (i) = PC (Pre-Crisis **I**nitial);

PC (d) = PC + (K-PC) • 1/3 (Pre-Crisis **D**eveloping);

PC (c) = PC + (K-PC) • 2/3 (Pre-Crisis **C**ritical);

B. *Example*

For example, in 1997, the GDP growth rate is 12%. Consequently, the crisis threshold is also 12%. The scale ranges are calculated using the above formulas:

C = 12%; PC = 6%; C (cth) = 14.4%; C (cc) = 16.8%; C (ce) = 19.2%.

PC (i) = 6%; PC (d) = 8%; PC (c) = 10%.

The scale of crisis is constructed based on the calculated values. The 1997 tariffs were marked on it. In 1997, the gas tariff increased by 62%, the electricity tariff by 79%, and the heat tariff - by 26%. These values immediately fall within the interval of a crisis emergency state.

Similar calculations were performed for other years. The results obtained using a qualitative analysis of the tariff growth values are as follows:

- 1997 The GDP (1997/1996) increased by 11.76%, therefore, the tariffs could not be increased. In actuality, however, the tariffs were increased by 70.33% - for electricity, by 26% - for heat and by 61.57% - for gas. Therefore, this situation is a crisis for all tariffs. Electricity - "C", Heat - "C", and Gas -"C";
- 1998 There was no increase in GDP (1998/ 1997), hence, the tariffs should not have been raised at all. The increase in tariffs had to be equal to 0. In fact, all three types of the tariffs grew. Therefore, this situation is a crisis with respect to tariffs. Electricity - "C", Heat - "C", and Gas-"C";
- 1999 There was no increase in GDP (1999 /1998), therefore, the tariffs should not have been raised at all. In actuality, however, the tariffs for electricity and gas increased. Therefore, this situation is a crisis for these two tariffs. Electricity - "C", and Gas-"C";
- 2000 There was an increase in the value of GDP (2000/1999), hence, the tariffs could be raised by the value of the GDP growth (10.09%). In fact, the tariffs for electricity and heat grew by 22% and 25%, respectively. Thus, this situation is a crisis for these two tariffs. Electricity - "C", and Heat - "C";
- 2001 There was an increase in the value of GDP (2001/ 2000), consequently, the tariffs could be raised by the value of the GDP growth (by 14.91%). In fact, the tariffs grew only by 9.02% for electricity, and did not change for heat and gas. Therefore, the situation for all tariffs is normal;
- 2002 There was an increase in GDP (2002/ 2001), hence, the tariffs could be raised by the value of the GDP growth (by 12.161%). In fact, the tariffs grew only by 1.5% for electricity, and did not change for heat and gas. Therefore, the situation for all tariffs is normal;
- 2003 There was an increase in GDP (2003/2002), consequently, the tariffs could be raised by the value of the GDP growth (by 19.28%). In fact, the tariffs rose only for electricity - by 9.63%, and did not change for heat and gas. Therefore, the situation for all tariffs is normal;
- 2004 There was an increase in GDP (2004/ 2003), hence, the tariffs could be raised by the value of the GDP growth (by 31.31%). In fact, the tariffs rose only for gas - by 14.25%, and did not change for heat and electricity. Therefore, the situation for all tariffs is normal;
- 2005 There was an increase in GDP (2005/2004), therefore, the tariffs could be raised by the value of the GDP growth (by 15.38%). In fact, the tariffs rose only for

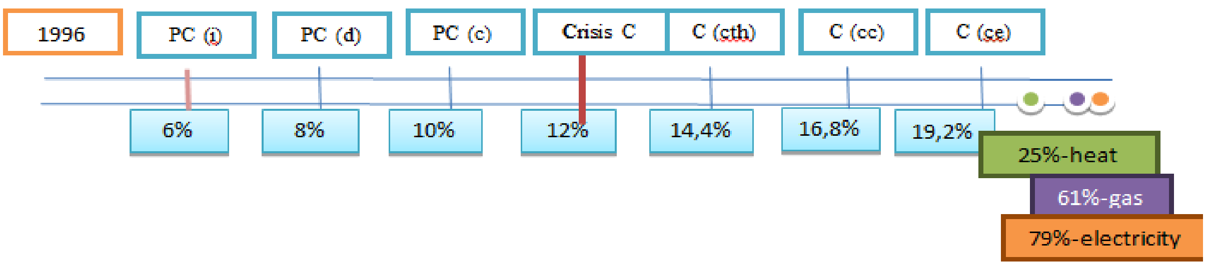


Figure 2. The scale of the crisis for the indicators of 3 tariffs: for electricity, heat and natural gas. The scale depicts the actual values for 1997 in the form of 3 color points.

gas - by 11.81%, and did not change for heat and electricity. Thus, the situation for all tariffs is normal;

- 2006 There was an increase in GDP (2006/2005), consequently, the tariffs could be raised by the value of the GDP growth (by 13.60%). In fact, the tariffs rose only for heat - by 130.77% and for gas - by 56.04%, and did not change for electricity. Therefore, this situation is a crisis for these two tariffs (heat and gas) Heat - "C", and Gas-"C";

- 2007 There was an increase in GDP (2007/2006), therefore, the tariffs could be raised by the value of the GDP growth (by 29.11%). In fact, the tariffs for electricity grew by 33.11%, for gas - by 41.06%, and did not change for heat. Thus, this situation is a crisis for these two tariffs. Heat - "C", and Gas-"C";

- 2008 There was an increase in GDP (2008/ 2007), thus, the tariffs could be raised by the value of the GDP growth (by 37.64%). In fact, the tariffs increased by 16.75% - for electricity, by 22.39% - for gas, and did not change for heat. Therefore, this situation is a crisis for electricity tariff. Electricity - "C";

- 2009 There was no growth of GDP (2009/2008), consequently, the tariffs should not have been raised at all. In fact, the tariff for gas increased by 11.81%, and the tariffs for electricity and heat did not change. Therefore, this situation is a crisis only for the gas tariff. Gas-"C";

- 2010 In 2010, GDP increased to the 2009 level, i.e. by 6.9%, consequently, the tariffs could be increased by no more than 6.9%. In actuality, however, the tariff for electricity increased by 20%, for heat - by 57.37%, and for gas - by 16.52%. Therefore, this situation is a crisis for all tariffs. Electricity - "C", Heat - "C", and Gas-"C";

- 2011 In 2010, the increase in GDP compared to 2009 was 20.7%, hence, the tariffs could be raised by no more than this amount. In reality, the tariff for electricity increased by 7.97%, for heat – by 30.23%, and for gas – by 25.43%. Therefore, this situation is a crisis for two tariffs (heat and gas). Heat - "C", and Gas-"C"

- 2012 In 2012, GDP increased to the level of 2011, i.e. by 3.32%, thus, the tariffs could be increased by no more than this amount. In fact, the tariff for electricity was increased by 12.3%, for heat - by 20.43%, and for gas - by 10.23%. Therefore, this situation is a crisis for all tariffs. Electricity - "C", Heat - "C", and Gas-"C";

- 2013 In 2013, the increase in GDP compared to the 2012 level was 9.38%, therefore, the tariffs could be raised by no more than this amount. In actuality, they changed a little: the electricity tariff remained the same, the heat tariff decreased by 0.71%, and gas tariff did not change. Therefore, the situation is normal for all tariffs;

- 2014 In 2014, there was no increase in GDP compared to 2013. The tariffs should not have been raised. They did not rise. The situation is normal.

- 2015 There was no GDP growth in 2015/2014, but there was a decline (-18.47%). The actual increase in electricity tariff was 33.86%, the tariff for heat decreased, and the tariff for natural gas grew by 9.81%. The tariffs had to be lowered instead of the increase or at least they had to be maintained at the level of the previous year. Electricity - "C", and Gas-"C".

The further study is aimed at including new threshold values for these indicators (tariffs of natural gas, electricity, and heat) in the software for the analysis and monitoring of energy security and for calculations during annual monitoring.

II. Conclusion

A new methodological approach is proposed to determine the threshold values for three indicators of energy security, reflecting tariffs for natural gas, electricity, and heat.

The new methodological approach implements the idea that the tariff growth should not exceed the GDP growth.

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