Economic Modeling of Energy Security: Simulation of Economic Processes (Case of Ukraine Gas System)

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Abstract. The paper considers issues of ensuring energy security in Ukraine. The first part of the paper is devoted to the analyses of the existing threats to energy security and the possibilities of guaranteeing this security. It was shown that the current level of energy security is unsatisfactory. It poses a real threat to the economic and national security of Ukraine. One of the most important elements of ensuring energy security in Ukraine is the production, import, and distribution of natural gas. The second part of the paper provides a detailed statistical analysis of the natural gas supply in Ukraine. Based on economic-mathematical approaches, forecasts for state production, import and transit of gas for 2018-2020 are calculated. With the help of cluster analysis, the clusterization of regions of Ukraine by the energy security level was made in the third section. We received five clusters according to the levels of gas supply. It was concluded that the government should carefully and transparently approach the negotiation processes with other states interested in joint projects for the extraction and supply of oil and gas to Ukraine.

1 Introduction

Energy is the basis of the Ukrainian industrial economy, which ensures the functioning of all branches, the formation of a significant share of the revenue part of the budget and the receipt of foreign exchange funds. Therefore, the effective use of energy potential serves as the basis for the further economic development of the country, which has a direct impact on the welfare of the citizens. It is the key to its independence, social and political stability, can help to integrate Ukraine into the European and world community, and serve the defence of its national interests [1-2]. The struggle for energy resources in world markets is becoming acuter, prices of giant mining companies are dumping. The international conflicts, the risks of stability of energy supply and critical pollution of the environment in the extraction and use of energy resources are increasing. Therefore, energy security has recently become the subject of increased attention of the international community, individual countries and their associations, in particular, the European Union. This subject is within the scope of scientific research.

The need for assessing the level of energy security in Ukraine is at the urgent necessity. The factor of energy security should be taken into account by any state authorities when preparing and making decisions regarding the directions of the country's social and economic development, the development of the energy sector, in particular, and in developing measures to break the critical state in energy supply and environmental protection of Ukraine. However, general assumptions and policy talks are nothing, without sound and exact calculations. Thus, the purpose of the paper is to assess the energy security in Ukraine with the help of economic modeling approach. Taking in account the deepness of the topic, we decided to concentrate our attention at the analyzing particularly the consumption, extraction, and transportation of natural gas, as the most politically discussed topic at the agenda with Russia. Therefore, the following objectives are addressed according to the logic of the research:

1. To consider energy security and its criteria in the range of the main threats (section 2).
2. To conduct statistical assessment and forecasting of volumes of consumption, extraction, transportation of natural gas to Ukraine (section 3).
3. To carry out the clusterization of the regions of Ukraine under the level of energy security (particularly, the current state of Ukraine's gas system) (section 4).

Once the answers to the above questions have been found, a cafeteria of policy recommendations based on insights may be represented to apply in the section “Conclusions and Discussion”.

2 The concept of energy security

The concept of "energy security" has become widely used and is closely related to the security of the country. Ukraine belongs to countries that are not sufficiently provided with energy resources. Energy security is one of the most important components of the economic security of any country and affects the phenomena and processes not only of the energy system but also of the economy and society as a whole [3-5].
The term "energy security" is used almost everywhere in economic and political discussions that are related to energy supply. But different authors put different meaning in the concept of energy security. Attempts to determine the essence of the concept of "energy security" were not systematic and are marked by a variety of approaches, and some with insufficient justification [2]. Existing definitions are based on several basic approaches in which energy security is considered as [2-9]:

- the state of protection of citizens, society, and economy from the threats of unsatisfactory energy supply;
- the state of protection of interests (national, state, public) in the energy sector;
- the state of power supply systems (in particular fuel and energy) under different conditions.

In order to clarify this issue, first of all, it is necessary to define the object of energy security. If we consider the energy security of the country, on a national scale, then two approaches can be distinguished:
1) the fuel and energy complex (FEC), or the energy supply system of the country, including the fuel and energy complex and its management as an energy security fa-

cility [10]. This approach examines the security of the fuel and energy complex in unfavourable political and economic conditions (internal and external), in case of unsuccessful actions of the country's authorities and unfavourable actions of other countries, as well as natural and man-made disasters.
2) the economy, society, country [1, 11]. In this case, the security of the facility from the impact of destabilizing energy factors is considered, and threats to energy security come, first of all, from the unfavourable development of the fuel and energy complex (or energy supply system in general).

Other approaches are a variation of the above. In our opinion, the second approach is more successful. It allows to take into account the full range of destabilizing energy effects in the country, in particular: loss of access to energy resources, inefficient energy consumption, damage to the environment from the functioning of the fuel and energy sector, social conflicts (due to high rates of energy prices growth, degradation or alienation of mining regions, etc). This requires both an understanding of the concept of energy security, and the definition of an energy security facility, the development of methodological bases for assessing the level of energy security, criteria, and indicators of energy security and the organization of appropriate information support for such assessments.

In addition to the concept of an energy security facility, the concept of a threat to energy security is important for determining its essence. Based on the general concept, a threat is a phenomenon with predictable but uncontrolled events that can lead to undesirable consequences. Threats may occur as a result of someone's actions (evil intentions), spontaneously formed when the system functions or can be the cause of factors not subject to man (natural disasters, etc.).Threats to energy security are short-term or long-term events that may destabilize the energy mix, limit or disrupt energy supply, lead to accidents and other negative consequences for energy, economy, and society [1, 10, 12-14].

Table 1. Threats to Ukraine's energy security

Economic	Economics with a high energy dependence
Socio-political	The annexation of the Crimea, the aggravation of the conflict in the East of the country, Russian policy
Natural	Lack of fuel supplies - energy resources
Technogenic	Accident on the NPP in Chernobyl, the consequences of which despite the 30-year-old antiquity are still relevant
Foreign policy	Monopolization of energy markets
Foreign economy	Organization of energy import
Imperfection of management	Despite a number of issued laws and decisions, the management of the energy security is not perfect

From the whole spectrum of threats, main energy threats are related to:

- the energy supply system,
- the policy of domestic energy supply and energy consumption,
- the organization of energy imports,

- the financing of energy needs,
- the ensuring the state's energy independence,
- the monopolization of the energy market,
- the social consequences of energy policy,
- the negative impact of energy on the environment, etc.

Thus, we can determine the energy security of the country as the condition of the security against energy threats, when:

- justified enough, reliable and technically safe supply of the economy and the population with energy resources, (unfortunately, the economy of Ukraine and its population are permanently under pain of not providing energy resources);
- ensuring the impossibility of significant internal and external pressure on the state management related to the energy sphere (external pressure is Russian Gazprom, the internal pressure is Naftogaz);
- warranting an acceptable level of harmful environmental impact from the production and use of energy;
- there is an absence of social tension in society (significant conflicts, strikes, and other social problems) related to the energy sector (subsidies at the moment somewhat stabilized social tension).

Therefore, based on the above, we give the following definition of Ukraine's energy security – *the ability of the state to ensure the efficient use of its own fuel and energy resources, to optimize the diversification of sources and ways of supplying of energy resources to Ukraine to ensure the vital activity of the population and the functioning of the national economy in the normal, emergency and martial way, to prevent sharp price fluctuations on fuel and energy resources or to create conditions for painless adaptation of the national economy to new prices for these resources.*

Proceeding from this definition, energy security is an integral part of maintaining a self-sufficient level of economic and national security of Ukraine based on the effective use of its fuel and energy potential with minimal negative consequences for the environment.

Failure to respond adequately to precautionary measures and to delay the deployment of large-scale promising projects will threaten the formation and implementation of state policy in the fuel and energy complex and ensure the strategic interests of Ukraine in the Eurasian economic space.

3 Statistical assessment of the current gas situation in Ukraine

Ukraine is one of the world's countries with stocks of all kinds of fuel and energy raw materials (oil, natural gas, coal, peat, uranium, etc.), but the degree of supply and production of reserves does not create the necessary level of energy independence. Natural gas accounts for the largest share of sources of primary energy supply in Ukraine - about 40%, but its own production is only one-third of consumption. That is why we decided to concentrate our attention on its analyses as the prior. This actuality is supported by last events with Russian supply of gas to Ukraine agenda. As the inadequacy of own gas production is compensated by the import of Russian natural gas.

In general, gas consumption in Ukraine can be described as excessive and inefficient. First of all, it concerns the population and objects of municipal heat energy, since gas prices and tariffs for heat are substantially underestimated. As a result, final consumers are not interested in reducing consumption and implementing energy efficiency measures. In addition, the current situation creates an opportunity for arbitration operations (speculation on the difference in price) due to the inappropriate use of gas, which is transited to the needs of the population. There are significant technological losses in the distribution of heat and gas, with significant potential to decrease.

Analyzing official statistics [16] one can conclude that the change in the volume of natural gas consumption in Ukraine for all years is characterized by a first rapid decline, then a sharp increase. However, from 2011-2014 there is a significant decline. The most significant reduction in gas consumption occurred in 2009, compared to 2008, it amounted to -14.4 billion cubic meters of used gas, and the most significant increase was in 2003, compared with 2002 +6.5 billion cubic meter. After the Revolution of Dignity and the annexation of Crimea, the occupation of Donbas, where a huge number of enterprising consumers were located, and the whole gas consumption dropped till 32 billion cubic meters. This amount is just a little above than 2/5 of the consumption level in 1998.

The analysis of the absolute change in velocity for all years under consideration is characterized by a change in the sign of absolute velocity, that is, the alternation between acceleration and deceleration of absolute velocity change, indicating unevenness in the change of the volume of natural gas consumption in Ukraine during the period under research. The dynamics of changes in the volume of gas consumption demonstrates a downward trend. Therefore, it can be expected in subsequent years to reduce the consumption of natural gas to 16.2 billion cubic meters in 2021.

In order to obtain a better picture of the current energy situation in Ukraine, it is also necessary to consider the volume of natural gas consumption by the population and industries, separately. In recent years there has been a decline in gas consumption by the Ukrainian population over the past 16 years. Currently, more than 1,000 cities and towns are gasified in Ukraine, and over 25,000 villages. Gas is delivered to almost 150 thousand enterprises and communal consumers.

Several factors contribute to the reduction of natural gas consumption among the population. First of all, a large-scale introduction of gas meters has played a positive role. In early 2008, they were installed in more than 55% of household gas consumers, while in apartments where the gas was used for heating, this share exceeded 85%. Until recently, the gas heating had a lion's share of rising gas consumption by households. However, the rise in gas prices and the expected increase in tariffs, which should hit the most the categories of consumers, significantly slowed down the process of installing new gas boilers. In private homes, electric heaters became more often used for heating. In addition, in recent years, gas is slightly less used for cooking due to the widespread use of such kitchen appliances as electric kettles, microwave ovens, etc.

Experts suggest several ways to further gas savings in the residential sector. The simplest of them is to equip all gasified apartments and private houses with meters along with a significant increase in gas prices for the population (which in Ukraine now are 4-8 times lower than in Europe). It is assumed that then consumers will themselves care about saving and not wasting gas. According to some estimates, due to this, the use of gas by households can be reduced by 30% that is to about 12 billion cubic meters [16]. Taking into account the downward trend, we can assume that in the next three years the situation will not change.

We used Holt-Winters method and polynomial regression to forecast natural gas consumption by the population of Ukraine for the next three years (table 2). For the Holt-Winters forecast model, the optimal $\alpha = 0.8$ and $\beta = 0.4$ were taken. Selection of parameters carried out with the help of "reasonable" override and minimization of mistakes of known data-models. Here, we have admit that just most successful results of trend modelling is presented in the subsequent figures. Taking in account normality and stationarity of data, as well as available period of observations we reveal the most significant results of forecasting.

Table 2. Forecast of gas consumption by the population of Ukraine, 2018-2020, billion cubic meters.

Year	By the Holt-Winters method	By polynomial trend
2018	16.11	17.30
2019	14.62	14.93
2020	13.12	12.37

Similarly to the situation with consumption of gas by the population of Ukraine, volumes of gas consumption by the industrial sector of the economy in the last 16 years have decreased almost twice, as can be seen from the official statistics [16]. Initially, the fall in gas prices in the Ukrainian economy was already due to the crisis in 2009. Then, the volume of production of the largest industrial consumers of gas - producers of fertilizers and metallurgists - dropped sharply. The fall in turnover in the construction complex has reduced the demand for materials such as bricks and cement, the production of which also uses natural gas. In the deep crisis, the sugar industry, mechanical engineering, and metalworking, which are also large gas consumers, turned out to be. Lastly, the decrease in electricity production due to the decrease in its consumption allowed practically to abandon the use of gas in this area as well. Although there has been a slight upturn in 2010-2011, the political situation in the country and relations with its neighbours, the main exporters of gas to Ukraine, have strongly influenced the further transportation and use of gas.

For the next three years, taking into account the significant error of the predicted values for the polynomial function, the forecast for 2018-2020 was made by Holt-Winters model, with the values of the smoothing coefficients $\alpha = 0.8$ and $\beta = 0.1$ (table 3).

Table 3. Forecast of gas consumption by the industrial sector of Ukraine by Holt-Winters method, billion cubic meters

Year	Volume, billion cubic meters

2018	7.67
2019	6.47
2020	5.28

The production of natural gas in Ukraine began in 1912. A new stage in the development of the gas industry began with the commissioning of the largest Shebel in a gas field in Ukraine (the volume of reserves - 650 billion cubic meters) and the discovery of a number of large deposits in the late 50's and 60's. In 1975, the volume of gas extraction in Ukraine reached the historical maximum and since then has been gradually declining, stabilizing in 1998. In the last 15 years, the annual volume of gas production is in the range of 18 to 21 billion cubic meters. In the meantime, Ukraine ranks fifth in Europe in terms of gas production [17].

Today, the following features are typical for gas production in Ukraine:

- high degree of depletion of initial reserves of large deposits;
- low rates of exploration of new stocks;
- low quality of new stocks [17-18].

Therefore, every year the state oil and gas companies in Ukraine reduce gas production. There is sucking out of these deposits of recent stocks. At the same time, investment in exploration of new deposits is falling dramatically, which in the future 10-20 years means a reduction of gas production from the current 20 billion to 14-15 billion cubic meters per year [16].

After analyzing the chain indicators for 1990-2016, we can conclude that the change in the volume of gas production in recent years is characterized by a dynamic decline. After the Revolution of Dignity in 2014, the volume of production decreased by 1500 million cubic meters compared to 2013. In fact, 2014 has become a real test for the Ukrainian oil and gas industry. Several significant events have taken place that has fundamentally changed the market, first of all, gas. Through the occupation of Crimea, Ukraine lost control of the state-owned company "Chornomornaftogaz" and over the Black Sea shelf, where two new floating installations were operating. Ukraine lost almost 2 billion cubic meters of gas annually or 10% of its production. Another part of the extractive capacity is located in the occupied territory of the Donbas, and here the losses were less - 50 million cubic meters [16, 19]

By the Holt-Winters method (alpha=0.8, beta=0.1), forecasts were made for the expected output of gas in Ukraine for the next three years (table 4).

Table 4. Forecast of gas production in Ukraine from 2014 to 2017 by Holt-Winters method, billion cubic meters

Year	**Volume, billion cubic meters**
2018	14.91
2018	14.43
2020	13.96

The dynamics of changes in the volume of the transit of natural gas through the territory of Ukraine to European countries over the past 16 years shows that there is a general tendency towards a recession. If 1998 is the base for comparison, then in the following years the volume of transit is steadily decreasing. After the sharp change from 2008 to 2009, the volume of gas transit decreased from 119.6 to 95.8 billion cubic meters. This may be due to the fact that it was at that time when the country was undergoing a significant economic downturn. Although in the next two years, the volume of transit increased, the level at least of the 2000 year was not achieved. In general, it can be concluded that for the past 16 years, the volume of gas transported by Ukraine has been reduced (Ukraine has stopped importing Russian gas since November 2015). Table 5 shows the forecasts of natural gas transit through the territory of Ukraine in the next 3 years. In this case, the Holt-Winters method (alpha=0.4, beta=0.1) and linear regression were used to predict. We can definitely say that in the future, Ukraine will be expected to reduce gas transit volumes to European countries.

Table 5. Forecast of the transit of natural gas through Ukraine on 2014-2017, billion cubic meters

Year	By Holt-Winters	By linear regression
2018	74.89	72.01
2019	72.82	68.48
2020	70.76	64.95

The high degree of wear and tear of fixed assets of Gas Transportation System (GTS) determines the need for their modernization in the next decade. At the same time, the scale of works depends directly on the load on the GTS, which is determined by the volume of gas being transported. The main priority of the further operation of the GTS is to ensure reliable gas supplies to the domestic market with a minimum level of investment and expenditure; thus, it is necessary to conserve or decommission the unloaded segments of the GTS.

4 Clusterization of the regions of Ukraine according to the level of energy security (gas supply).

The main hypothesis we put for this stage: Ukraine has a homogenous situation as to gas supply at the regional level. If the hypothesis will be tested and not proved, we would suggest the development of decentralized regional energy strategies under the umbrella of the state Energy Strategy.

Thus, it is necessary to conduct the clustering of regions according to the data on natural gas consumption in 2014-2015 [21]. We need to use these data, as no recent years information is available. One can argue that the clustering could be currently not so meaningful, as only the variable "natural gas consumption" is used. Of course, the procedure could be enhanced with the addition of further variables: for example, volatility in demand, service levels, gas pressure fluctuations, etc. But preliminary correlation and factor analyses insured us in the significant explanation power of the used characteristic. As the analyses on redundant/omitted variables indicates that we can continue with one most correlated and representative one - the data on natural gas consumption.

We use cluster analysis to identify homogenous groups of countries on the base of the descriptive factor(s). K-means clustering is a method to quickly cluster large data sets. We define the number of clusters in advance. This is useful to test different models with a different assumed number of clusters. In general, the k-means method will produce exactly k different clusters of the greatest possible distinction. It should be mentioned that the best number of clusters k leading to the greatest separation (distance) is not known as a prior and must be computed from the data. By means of clustering with the K-mean method [19-20], we define separate groups (clusters) of the regions according to their level of gas supply (the factor that we had chosen as descriptive on the base of preliminary factor analyses). Subsequently, we suppose to divide the regions into 2, 3 and 5 clusters.

2 clusters. The cluster initial centres on factor basis were as follows: 3,073 for the first cluster and -0,980 for the second. After 4 iterations cluster centres changed. The new final centres for each of the clusters were defined: 1,46405 and -0,462. It is precisely how far or close to the centre of each of the clusters was the factorial sign of each of the elements, and, accordingly, the distribution was split into clusters. The first cluster included industrial areas with the highest population and population density. This is precisely the reason why the use of natural gas in these areas is the most. The second cluster included both industrial and agro-industrial areas.

3 clusters. To understand whether there is such a pattern that the most densely populated areas with an industrial slope use more gas than others, we will make a new breakdown - in 3 clusters. After two iterations, new cluster centres were calculated (Table 6), and, according to that, the regions of Ukraine were divided into clusters.

Table 6. The initial and final cluster centres

Variable	The initial cluster		
	1	2	3
Feature of factor	3,073	1,225	-0,980
Variable	Final cluster		
	1	2	3
Feature of factor	3,073	0,841	-0,613

Now, we received that the third cluster contains the largest number of elements (16), 1^{st} – 1, 2^{d} – 8. We can conclude that it will be logical further break the regions into clusters in order to reduce the number of elements in the third cluster and to distribute them more or less uniformly by qualitative characteristics.

In this case, with the division of regions into three clusters, only one region (Dnipropetrovsk Oblast) entered the first cluster. The entire other regions that were included in the first cluster of the previous clusterization, adding Poltava, Cherkasy, and Lviv regions were added to second cluster. Dnipropetrovsk Oblast, which is the only one in the first cluster, is one of the first places in Ukraine in terms of economic development, especially in such fields as mining and food industry, metallurgy, energy, plant growing, besides being the first in the country by population and the second largest by area (after Odessa region).Taking into account all of the above facts, it becomes clear why the supply of natural gas in this area is the greatest.

Let's consider in more detail the second cluster, which includes: Kharkiv, Odessa, Donetsk, Kiev, Poltava, Cherkasy and Lviv regions and the city of Kyiv. All regions of this cluster have a high level of economic development and a sufficiently rich set of own raw materials. In general, the common figures in these regions are that they are well developed in such industries as mechanical engineering, fuel and energy, chemicals, and light industry.

As for the third cluster, it consists of different economic potential areas:

- industrial: Zaporizhia Oblast, Mykolaiv Oblast, Luhansk Oblast, Sumy Oblast;
- industrial and agrarian: Vinnytsia Oblast, Khmelnytsky Oblast, Zhytomyr Oblast, Chernihiv Oblast, Ivano-Frankivsk Oblast, Ternopil Oblast;
- agrarian-industrial: Volyn Oblast, Chernivtsi Oblast, Kherson Oblast, Zakarpattia Oblast, Kirovohrad Oblast and Rivne Oblast.

5 clusters. Therefore, it makes sense to continue separating into clusters. When splitting into 4 clusters, no more useful results were obtained, since the regions that were in the third cluster with the previous division were left in it, but the second cluster was divided into two new ones. Therefore, the following division was made on 5 clusters. After three iterations (Table 7), the following final cluster centres were obtained for each of the new five clusters:

Table 7. The initial cluster centres

Variable	The initial cluster				
	1	2	3	4	5
Feature of factor	3,073	1,186	-0,980	1,704	0,658
Variable	Final cluster				
	1	2	3	4	5
Feature of factor	3,07363	1,11576	-0,65254	1,70492	0,33245

As can be seen in Table 8, the third cluster contains the largest number of elements. The fourth and first cluster generally consist of only one element, but it was verified that the further division into six clusters was not appropriate, since the third cluster does not change its dimension equally. Therefore, we will continue to consider the division of regions of Ukraine into five clusters (Tables 8).

Table 8. Clusterization of the regions of Ukraine by the level of gas supply to 5 clusters (1-3)

First cluster		Second cluster		Third cluster	
Oblast	Distance to the centre	Oblast	Distance to the centre	Oblast	Distance to the centre

Dniprope-trovsk	0,000	Kharkiv	0,071	Mykolaiv	0,315
-	-	Odessa	0,180	Rivne	0,199
-	-	Kyiv city	0,109	Vinnytsia	0,199
-	-	-	-	Sumy	0,133
-	-	-	-	Khmelny-tskyi	0,066
-	-	-	-	Zhytomyr	0,008
-	-	-	-	Ivano-Frankivsk	0,003
-	-	-	-	Chernihiv	0,030
-	-	-	-	Ternopil	0,033
-	-	-	-	Luhansk	0,394
-	-	-	-	Zakarpattia	0,211
-	-	-	-	Volyn	0,229
-	-	-	-	Kirovohrad	0,238
-	-	-	-	Kherson	0,248
-	-	-	-	Chernivtsi	0,328

Fourth cluster		Fifth cluster	
Oblast	Distance to the centre	Oblast	Distance to the centre
Donetsk	0,000	Kyiv	0,326
-	-	Poltava	0,027
-	-	Cherkasy	0,067
-	-	Lviv	0,067
-	-	Za-porizhzhia	0,353

Only Dnipropetrovsk region enters to the first cluster. Nevertheless, in the second cluster, there are just three regions: the Kharkiv and Odessa regions and the city of Kyiv. These are the regions with the highest population density in Ukraine, while Kharkiv and Odessa regions are among the largest in Ukraine by area, in particular, the Odessa region is the largest region in Ukraine. They are also the largest industrial centres of the country, which means that there are many factories, such as:

- the Cement Slate Plant in Balakleya (Kharkiv region) (the one of the largest in Europe);
- the OJSC "Odessa Plant of Radial Drilling Machines" (the only company in the country producing diamond-boring, coordinate-boring, radial-drilling and honing

machines and the only one in the south of Ukraine company producing castings of ferrous and non-ferrous metals for machine-building);

- the Darnytsky railway car repair factory (Kyiv) (the only potential user of gas in these areas).

So, after considering the first two clusters, we can conclude that:

- Dnipropetrovsk region has the highest level of gas supply, and uses the largest amount of natural gas for the needs of industry and population;
- Kharkiv and Odessa regions and the city of Kyiv, which are part of the second cluster, rank second in volume of natural gas use.

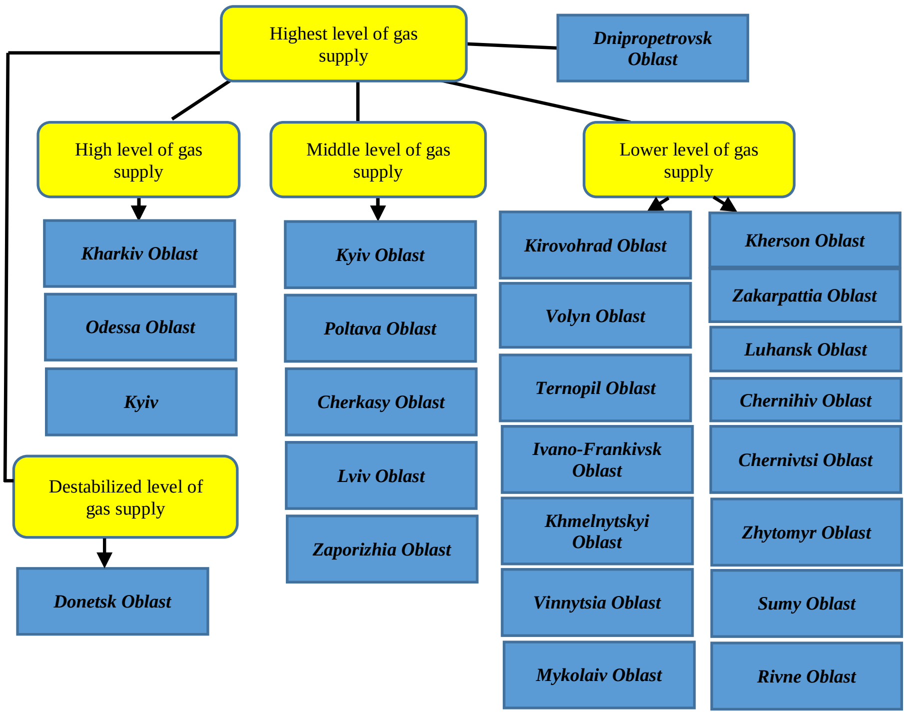

Fig. 4. The regions of Ukraine clusterized by the level of gas supply [21]

The third cluster is now compounded of more agro-industrial regions, and Luhansk oblast, which over the past year reduced the use of natural gas by 67% compared to 2014. That is those regions that use a small volume of natural gas.

Only the Donetsk oblast entered the fourth cluster. This can be explained by the fact that earlier this region has used almost the same volumes of natural gas as the Dnipropetrovsk region. However, due to the current situation in the East, gas usage has decreased sharply (as in the Luhansk region, but more prominent from the economic point of view there is a reduction in the industrial capacity of the Donetsk region).

The fifth cluster included Kyiv, Cherkassy, Poltava, Lviv and Zaporizhzhia regions. These areas have not only a powerful industrial complex, but also make a significant contribution to the country's agricultural complex. Therefore, we can say that the fifth cluster included those areas that use the average amount of natural gas to meet the needs of the region.

So, in summary, the most optimal was the division into five clusters, since this division most accurately characterizes the regions of Ukraine by the level of gas supply. Figure 5 shows the results of the breakdown of regions of Ukraine into clusters according to the level of natural gas usage:

- the highest level;
- high level;
- average level;
- low level;
- the destabilized level (the level of sharp decline in natural gas consumption, due to the influence of political and economic factors).

5 Conclusions and discussion

The paper had demonstrated the good application of Computational Economics and Economic Modelling in the sense of simulation of economic processes with further restrained and grounded development of economic strategies and conclusions. Only mathematical methods and results of its application can provide the deprived of subjectivity ground for the economic theories and its principles.

One of the main goals of the state energy policy, in particular, its embodiment in the Energy Strategy till 2030, is the satisfaction of Ukraine in fuel and energy resources by increasing the share of their own production and easing external energy dependence by reducing the volume of their imports. However, accordance with it, Ukraine only in 2030 should reach the energy intensity that Poland has achieved last year. It turns out that the strategy throws Ukraine away for almost 20 years compared with the EU countries. So, there is the urgent necessity to talk about the optimality of this Energy Strategy.

The provided research revealed that the current level of energy security is unsatisfactory, which poses a real threat to the economic and national security of Ukraine. The capacity of the energy objects to withstand the influence of potentially dangerous factors is constantly decreasing.

From the mathematical modelling point of view, the narrow places and lacks of modelling are quite obvious: the reaction to price changes (price-volume elasticity) and per capita consumption as well as the consumption of industrial customers, preferably, could be included in the regression, since a simple trend extrapolation is very naïve, since it is based on data that has massive structural breaks. However, our task was not to reveal the variation of the time series of current natural gas consumption, production, and transmission in the factors impact, but, to consider these indicators as litmus of energy security. In particular, in this paper we attempted to see the gas situation in its trend if nothing changes and the tendencies are sustainable. Therefore, just dependence on time is taking in consideration.

Considering the situation with the gas production in Ukraine, we have to state that during the years of Ukraine's independence in the field of gas supply there has been no improvement in quality indicators, and quantitative gas supply has deteriorated largely. Given that this industry provides Ukraine with about 30-40% of the needs of Ukraine. There are no investments for development of new deposits, then it is inappropriate to rely on full energy independence. Therefore, the government should carefully, transparently approach the negotiation processes with other states interested in joint projects for the extraction and supply of oil and gas to Ukraine.

Despite the fact that production conditions are constantly complicated, Ukraine managed to maintain relatively stable volumes of gas production over the past 15 years. Only during the last 3 years owing to the occupation of the part of the territory, Ukraine decreased production. There is a reason to assume that in subsequent years annual production volumes will be able to remain at the level of 16-18 billion cubic meters. The consumption of gas declined substantially for the last years as well. Especially, due to the occupation of territory in the East of the country, where about one-fifth of industrial potential was located. The industry consumption of gas declined to 30% of the level at the start of the century. Household consumption dropped almost twice for the last 16 years. Gas transmission is also decreased, but not so dramatically. Even in 2017, the level of transmission increased by 14% compared to 2016. At the same time, new threats arose when Russian Gazprom broke contracts for further gas transmission.

The cluster analysis that was conducted revealed the most optimal division of the regions of Ukraine into five clusters, according to the levels of gas supply: the highest, high, average, low and destabilized (the level of sharp decline in natural gas consumption, due to the influence of political and economic factors). From this distribution, it can be concluded that most regions have a low level of energy security, which means that the further development of energy industries in Ukraine, in particular, oil and gas, should become one of the main points of the future state policy. In industries such as, for example, metallurgy, the state should promote technological innovation in production to enhance energy efficiency and competitiveness. Mining, heat and power, automobile production, as well as light industry, form a «problem areas» group. That is those industries that do not generate high added value but at the same time have a significant potential for domestic demand. Therefore, these industries should be strengthened using innovation to develop the internal market. In mining, the following are inherent: the low added value of production; significant amounts of subsidization and unfair profits due to the redistribution of natural rent; low growth rates and critical indicators of fixed assets depreciation. This, potentially, has a threat of high accident rates and even man-made disasters. The share of these economic activities is decreasing over time. Therefore, the state should just provide «social investments». This way, the state ensures the painless closure of enterprises and retraining of workers for employment in more profitable economic activities. This actions will contribute to the energy security of the state.

Thus, it can be noted that Ukraine is facing complex challenges at the present stage of its development. Increasing global energy efficiency, reducing its own production, occupying territories with industrial potential, and restricting Russia's gas transit have created a number of problems to ensure Ukraine's gas and energy security. As a result, extremely rapid and painful reforms must take place in the country. First of all, it is a question of a significant increase in the efficiency of the use of all resources. In particular, today Ukraine loses 3-4 times more energy transmission than the European countries lose on average. The second way is to modernize enterprises, especially the steelmaking industry, which can reduce energy consumption by at least 15%. The third way is to increase the efficiency of heat preservation in buildings and district heating. The depreciation of the corresponding communications is about 85%, which requires a cardinal replacement. This will reduce household energy consumption by about 15-20%. Finally, the third way is to transfer production to more technologically but less energy-intensive goods. Unfortunately, today Ukraine specializes in the production of goods with low value-added, and therefore it requires significant investments in new technological areas. The fourth way is still expensive enough, but the experience of the EU shows that without it, it will not work. Today in EU countries, on average, 20% of all energy is produced by renewable sources, whereas in Ukraine this share does not exceed 4%. At the same time, the potential for the development of such sources in Ukraine is simply unbelievable: garbage is almost not processed, which means that only at the expense of institutional changes it is possible to achieve an increase in energy security by at least 20%.

However, it should be noted that all the steps considered require significant political support, which is very difficult to implement in the country preparing for the presidential and parliamentary elections in 2019. Unfortunately, this political component is still a significant threat to Ukraine's energy security.

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References

1. Bobrov, Y.: Conceptual approaches to the definition of “energy security”. Strategic Priorities 2, 70-75 (2012)
2. Yergin, D.: Ensuring energy security. Foreign affairs 2(85), 69-82 (2006) doi:10.2307/20031912
3. Korchun, V.: Energy Security of Ukraine as a Component of the Foreign Economic Policy of the State. Scientific Bulletin of the Lesya Ukrainka Volyn National University 3, 58-63 (2010)
4. International Energy Agency, http://www.iea.org/subjectetcqueries/keyresult.asp/, last accessed 20/3/2018
5. Resolution of the Cabinet of Ministers of Ukraine "On Approval of the Energy Strategy of Ukraine for the Period until 2030" No. 145 of March 15, 2006, http://zakon1.rada.gov.ua/laws/show/145-2006-%D1%80, last accessed 10/3/2018
6. Energy Strategy of Ukraine, Journal "League of Law", http://ligazakon.ua/l_doc2.nsf/link1/FIN38530.html, last accessed 13/3/2018
7. Energy 2020 – A strategy for competitive and secure energy. Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions/ COM (2010) 639 final/ 10 November 2010, European Commission’s Directors -General for Energy and Transport homepage, http://ec.europa.eu/energy/strategies/2010/2020_en/html, last accessed 10/3/2018

8. Kharlamova, G.: Ecological and Economic Convergence: Moving to Sustainable Energy, Bulletin of the Taras Shevchenko National University of Kyiv. Economics 150, 44-49 (2013)
9. Chernyak, O., Kharlamova, G., Stavytskyy, A.: Energy Perspective 2030 for Ukraine in the Context of the EU Integration. Emerging Issues in the Global Economy, In: Proceedings in Business and Economics, p. 113-129. Springer, Cham. (2017) doi.org/10.1007/978-3-319-71876-7_10
10. Bobrov, Y.: Energy security of the state: the emergence of the phenomenon, the current state, prospects of development. Scientific works of NDFI, 8, 134-144 (2011)
11. Kharlamova, G., Nate, S., Chernyak, O.: Renewable Energy and Security for Ukraine: Challenge or Smart Way? Journal of International Studies 9(1), 88-115 (2016) DOI: 10.14254/2071-8330.2016/9-1/7
12. Winzer, C.: Conceptualizing energy security, Energy policy 46, 36-48 (2012)
13. Nyman, J.: Rethinking energy, climate, and security: a critical analysis of energy security in the US, Journal of International Relations and Development 21(1), 118-145 (2018)
14. Dannreuther, R.: Energy security. John Wiley & Sons. (2017)
15. The Energy Strategy of Ukraine for 2015-2030, http://mpe.kmu.gov.ua/minugol/doccatalog/document?id=50366, last accessed 13/3/2018
16. Naftogaz of Ukraine homepage, http://naftogaz-europe.com, last accessed 13/4/2018
17. Energo.resurs homepage, http://energetyka.com.ua, last accessed 15/3/2018
18. Van de Graaf, T., Colgan, J.: Russian gas games or well-oiled conflict? Energy security and the 2014 Ukraine crisis, Energy Research & Social Science 24, 59-64 (2017)
19. Hartigan, J., Wong, M.: Algorithm AS 136: A K-Means Clustering Algorithm. Journal of the Royal Statistical Society. Series C (Applied Statistics), 28(1), 100–108 (1979) doi:10.2307/2346830
20. Kaufman, L., Rousseeuw, P.: Finding groups in data: an introduction to cluster analysis. John Wiley & Sons. (2009)
21. Ukrgaz web-page, http://ukrgaz.biz/vikoristannya-gazu-za-minulij-rik-skorotilosya-na-21/, last accessed 15/2/2018