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Poland's Energy Security in Light of a Statistical Analysis

Abstract

Energy security is a multi-faceted notion, being subject to evolution due to its changing character as an entity, a state, a process and a phenomenon. Discussion of the topic involves not only the question of energy security (treated both objectively and subjectively), but also the issue of its measurement, its main factors and determinants.

The aim of this article is to attempt to formulate an answer to the following research questions:

- *what is the energy security of a state and what is its nature?*
- *which indices can be used to define the energy security of a state?*
- *what is Poland's energy security status in comparison with other European Union states in the light of statistical analysis?*

In the research on Poland's energy security compared to the European Union, data clustering was carried out according to the following methods: the Ward method, the full bond (furthest neighbourhood) method, analysis using the k-means method, and multidimensional scaling. In order to define the shifts in the direction of Poland's energy security, synthetic indices for 2000 and 2008 have been calculated. Obtaining the answers to the above questions allowed for defining the main trends in Poland's activities aimed at increasing its energy security.

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1. Introduction

Energy security is a multi-faceted notion, being subject to evolution due to its changing character as an entity, a state, a process and a phenomenon. Discussion of the topic involves not only the question of energy security (treated both objectively and subjectively), but also the issue of its measurement, its main factors and determinants.

As Poland's energy security is conditioned by its membership in the EU, it is important to characterise it in comparison with other EU member states, and show similarities and differences in this respect. The process of creation of the single market of electric energy and the implementation of its principles are important determinants in the energy security of European Union member states, including Poland.

In our research on Poland's energy security compared to the European Union, data clustering was carried out according to the following methods: the Ward method, the full bond (furthest neighbourhood) method, analysis using the k-means method, and multidimensional scaling. The following indices were applied: Stirling index, energy dependence index, grid losses index, using renewable sources of energy index, and energy intensity index. As energy security is a dynamic process, changing over time, synthetic indices for 2000 and 2008 have been calculated to define the directions of these changes.

The statistical data used in the analyses come from the website and research of Eurostat, as well as from the materials of the European Commission concerning the European market of electric energy and from the reports of international corporations and institutions involved in the energy sector in the years 2000 and 2008. These comprise the latest, accessible, and complete statistical data.

2. The notion and essence of energy security

For many years the issue of energy security has been treated as a problem belonging to the sphere of politics, and as such was not regarded as really vital for the functioning of the economy. It belonged to the sphere of *low politics*, i.e. to the group of issues defined as technical and attention-absorbing for officials, yet remaining out of the domain of state strategic planning (Kaczmarski 2010, p. 11).

Since the beginning of World War II, coal and oil have been the basis of the European power industry, and the wide availability of these resources explains why the issue of supplying the economy with energy was not treated as a strategic category.

Events such as the oil crisis of 1973, the end of the cold war, and sudden increases in fuel prices have led to a change of approach to energy security and sparked animated discussions surrounding it.

However, it was the successive Russian-Ukrainian gas crises, record oil prices in the summer of 2008, the second war in Iraq, the Russian Federation's invasion of territory within Georgia (not without an actual context of energy), the issue of global warming, and the global economic crisis and its consequences for the prices of raw materials and investments in the energy industry which elevated the issue of energy security to a priority level and gave it strategic significance in the functioning of the economies of particular countries.

These events also had a considerable impact in emphasising the issue of energy security in Polish economic policy. Polish-Ukrainian conflicts highlighted the great dependence on Russian gas, which in 2008 amounted to almost 70% of total energy usage (*Energy-Yearly Statistics 2008*). On the other hand, the issue of climate change and the EU climate and energy package accentuated the future uncertainty of using high-emission coal in Poland.

Thus, energy security is more than just an objective element of the generally understood term *security,* defined as the national security of a state. In fact, it has also become a part of the economic security of the state. Uninterrupted access to raw materials and energy at a reasonable price has become extremely important for every country. This in turn affects production and consumption, as well as the functioning of the economy as a whole.

Energy security has varied definitions in the specialist literature, The number and shape of definitions is constantly evolving due to the changing character of energy security as an entity, a state, a process and a phenomenon. The discussion concerning it is more than just a discussion on national energy security (Riedel 2010, p. 13). Security can be defined with reference to an individual, a local and regional community. or the international community. It is closely related to the policy of constant development, prevailing economic factors, the development of energy markets, and socio-economic changes in information technologies (Cziomer et al., 2008, p. 18). Thus, energy security is an ambiguous, multidimensional, and dynamic notion.

According to its simplest definition, energy security is "the availability of sufficient resources at a reasonable price" (Yergin 2006, pp. 70-71). It comprises such elements as: integration of the market (of oil, gas, electrical energy), diversification of resources, and margin of security (e.g. in the form of reserves). A more detailed definition of energy security emphasises "the availability of energy which is adequate, at a reasonable price, reliable, indispensable both from the point of view of technological development and from the perspective of human security" (Umbach 2008, pp. 1-23).

One of the more frequently quoted definitions is the one formulated by the American economic analyst D. Yergin, according to whom, “the aim of energy security is to guarantee an appropriate and reliable level of energy supplies at reasonable prices, in a way which is not a threat to the basic values and aims of the state” (Yergin 1988, p. 10).

On the other hand, according to the International Energy Agency (IEA), energy security should be perceived in practice as a problem of risk management, i.e. “the reduction of risk and consequences of disruptions to an acceptable level” (IEA 2007, p. 161). The state of energy security can be described as continuous access to energy at a reasonable price, while at the same time taking into consideration the issues related to protection of the natural environment. The IEA distinguishes between long-term and short-term energy security. Long-term energy security is closely linked with planned or completed investments (especially infrastructural ones) which facilitate energy supply, and, at the same time, closely correlated with the economic development of a given country and the needs of the natural environment. Short-term energy security is defined by the IEA as the ability of the energy system to quickly react to sudden changes in demand for energy and its supply. This organisation also recommends an analysis of energy security within the context of particular fuels (their supply, richness and consumption), as well as an analysis of infrastructure (distribution and industrial networks, pipelines, etc).

In this context, A. Monaghan is right to underline the fact that energy security is conditioned by strategic planning, aimed at diversification of fuels and resources, and also effectiveness and flexibility in the energy sector (Monaghan 2005, p. 2). The complexity of the problem of energy security is also pointed out by G. Luft and A. Korin, for whom a starting point of the analysis is the fact that specific countries will perceive energy security in different ways, so it will always be difficult to formulate one definition of this phenomenon. Thus, energy security is a different issue in India, where approximately half of the population does not have access to electricity, or in Africa and Southern Asia, where millions of people suffer from power outages because of an unstable energy system, than in the developed countries with their growing energy consumption. Thus energy security means a different set of conditions for each country, depending on its geographic location, geologic resources, international policies and relationships with other countries, and its political and economic system (Luft, Korin 2009, pp. 5-6).

In Poland, Art. 3 point 16 of the Act on Energy law defines energy security “as the condition of an economy to meet the prospective demands of recipients for fuels and energy in a way which is technically and economically justified, while, at the same time, meeting the requirements of environmental protection" (The Act of 10 April 1997, Energy law). On the other hand, in *Energy Policy till 2030,* energy security is understood as "a guarantee of stable supplies of fuel and energy on a level which allows for fulfilling the needs of the country, at prices which are acceptable to the economy and society, with the assumption of optimal usage of the state fuel resources and through diversification of the sources and directions of supplies of oil and liquid and gas fuels" (*Energy Policy till 2030, p.7).*

The above-quoted definitions contain a common element – certainty of supplies and acceptability and affordability of energy prices. The remaining elements, such as respect for the environment, sustainable development in an economically justified way, or independence of the state, result mainly from the individual hierarchy of values adopted by the author of a given definition.

Creating an ideal definition of energy security is a difficult task and frequently the definitions referred to are subject to criticism. S. Müller-Kraenner, in his analysis of energy security, poses the following questions: What does physical availability of energy products mean, which price is affordable, and can we be certain that not only environmental protection but also human rights and democracy are respected when specific raw materials are extracted? (Müller-Kraenner 2007, p. 130).

On the other hand, W. Bojarski, in his analysis of the definitions of energy security in Polish law, criticises two formulations for their lack of clarity in defining the notion (Bojarski 2004, p. 48):

- *"in an economically justified way"* – is a formulation one-sidedly interpreted as *a way profitable for the supplier,* or even as *ensuring economically justified prices for the supplier* (avoiding risk), contradicting the rules of the competitive market in this way;
- *"meeting the requirements of environmental protection"* – this is the right principle in normal conditions of supply, however, it is not the most important one in various emergency, critical or unusual situations, in which meeting energy demand is especially important. Giving an absolute priority to environmental protection and placing it above the protection of recipients in such conditions seems to be debatable.

Typologies of energy security take into account different criteria, some of which are subjective and some of which are objective. In terms of subjective criteria one can distinguish between the energy security of producer countries and that of consumer countries. For exporters (producers), energy security concerns the security of demand which will guarantee the sale of raw materials (this is the case for gas in Russia, or oil in Saudi Arabia). Exporters of fuels perceive energy security as ensuring a market for their raw materials at reasonable (for them) prices. For consumers who do not have their own resources and are forced to import raw materials, energy security will be perceived, first of all, as certainty of supplies of raw materials and stability of the prices of these raw materials and the conditions of their transit.

In terms of objective criteria, the following aspects of energy security can be distinguished:

- strategic-geopolitical – referring mainly to the results of dependence on the import of raw materials or the use of exports for carrying out foreign policy;
- economic – for the consumer this means the possibility of acquiring the required amount of energy at an affordable price, and for the producer, a market for raw materials at a profitable price;
- ecological – an ever more important aspect in concepts of energy security, involving respect for the natural environment through, e.g. curbing fossil fuels, aiming to decrease CO_2 emissions, using sustainable technologies e.g. sequestration;
- infrastructural – the state of the infrastructure and investments in its development directly affects the energy security of a given country, region, etc.

3. Methods of assessment of energy security

A range of institutions try to make assessments of energy security of given countries on the basis of various indices and methods. For example, the European Commission bases its assessment on the Energy System Model – PRIMES (*The PRIMES Energy System Model Summary Description*, p. 4). The construction of PRIMES began in 1993, and since its inception the model has been concentrating on the market mechanisms affecting changes in the demand and supply of energy as aspects of energy security, also within the context of development and absorption of new technologies. The PRIMES model was also supposed to be a tool for studying connections between energy policy and the development of technology. The present version of this model (version PRIMES 2) has replaced the original version.

PRIMES 2 is a system of modelling which simulates the market solution of balance between demand and supply of energy in the European Union member states. The model defines balance by finding a price level, for each form of energy, at which producers will produce exactly as much energy as consumers will need and receive.

PRIMES is a model which serves a general purpose – it is used for forecasting, constructing scenarios, and analyses of the effects of administrative decisions. It is applied in both medium- and long-term analyses of energy security.

In Poland, no complex study of energy security comprising all sub-sectors of the power industry has been carried out for a long time. Such an attempt was made in the report, *Energy Security of Poland 2010,* prepared by the Kościuszko Institute (Energy security of Poland 2010. Inception report). It presented the proposal of an assessment model which consists of a set of macro and micro criteria referring to the infrastructural conditions of two energy sectors: liquid fuels and oil and also natural gas. An analysis of these two sectors of the Polish power industry was based on aggregate indices, which are constructed as a part of the multidimensional comparative analysis within a multidimensional analysis of data. The criteria proposed in this report were described and quantified according to the assumed "weights".

The authors of the report point out that the received aggregate indices do not present an assessment of the reliability of the energy system, but a certain global assessment of the state energy security of Poland. Only the observation of its changes over time can have great informative significance. This allows for comparing the security index concerning oil and liquid fuels with the index for natural gas. Such a comparison shows that the state of security regarding natural gas in Poland is much worse than energy security concerning oil and liquid fuels. The model applied in the report of the Kościuszko Institute is not final, and has many drawbacks. Firstly, it does not contain an analysis of the electricity sector, which is much more difficult to assess than other sectors, as it requires the availability of very current data which only the energy enterprises possess. Secondly, it lacks an analysis of the renewable sources of energy sector, which, to a large degree, determines the energy security of a state.

Referring to the main trend of the discussion on the essence and scope of the notion of energy security, one should point out that due to its multidimensional character there are many and various indices of energy security. They include the following aspects (Kaliski, Staśko 2006, pp. 24-26):

- the share of imported energy fuels within the energy balance,
- the degree of fuels diversification,
- the energy intensity index of the economy,
- the share of renewable energy in gross final energy production,
- the durability index of fuel resources,
- the size and sufficiency of reserves of energy fuels which are at the state's disposal,
- the index of import and export dependence,
- the reliability of energy networks (electro-energy, transport, etc),
- the concentration of energy intensive industries,

- the index of capital expenditures, including future internal demand for energy,
- index of emissivity of the economy.

None of the above indices, applied separately reflects the state of energy security; it only shows a particular aspect of energy security. These indices have to be selected and analysed in certain groups to ensure their complementarity (Riedel 2010, pp. 24-26).

4. A statistical analysis of energy security of Poland – static and dynamic approaches

Energy security is a complex category, which is why it remains difficult to measure and assess. Its measurement requires the selection of many different indices referring to its various aspects i.e.: economic, technical and those concerning the natural environment. It should be underlined that in the specialist literature there is no single index that fully characterises energy security or single formula for determining the energy security of the country.

The author has made an assessment of the energy security of Poland on the basis of the indices calculated, leading to an analysis of the energy security of Poland using the following methods of a multidimensional statistical analysis: data clustering carried out with the Ward method, the k-means method, and also multidimensional scaling. These studies contain indices comprising the objective scope of energy security, such as: grid losses index, the share of the power coming from renewable energy sources within the total power usage, energy dependence index, index of energy intensity of the economy, and the Stirling index (Pach-Gurgul 2012, pp. 177-186).

a) Grid losses index

This is an index belonging to technical indices – illustrating the condition of the electro-energy infrastructure which, when in a good condition, increases the energy security of the state[1].

$$W_t = \frac{S_s}{Pe} \tag{1}$$

where:

S_s – grid losses of electrical energy,

Pe – production of electrical energy.

[1] The author's study, according to the instructions concerning technical indices included in: M. Kaliski, D. Staśko, *Energy security in the economy….*, op. cit., p. 114-115.

b) Index of utilisation of renewable energy

This index is necessary for an analysis of the energy security of a state. It is calculated as a share of renewable energy in the total power available.

$$Wz = \frac{M_{od}}{M} \tag{2}$$

where:

M_{od} – share of the power coming from renewable energy resources,
M – total installed power.

Development of renewable energy sources is a priority in ensuring energy security and gaining independence from fuel imports (Müller-Kraenner 2007, p. 130).

c) Energy dependence index[2]

This index is calculated as a ratio of the net value of energy imports and the consumption of primary energy.

$$W_{ze} = \frac{\mathrm{Im}_e}{Ke} \tag{3}$$

where:

Im_e – net value of energy imports,
Ke – consumption of primary energy.

The higher the index is, the greater is the energy dependence of a given state. There are also countries in the EU, such as Denmark, where this index has negative values, showing that Denmark is energy independent.

d) Energy intensity index

The energy intensity of production may be defined as the energy consumed in the production process, in a production company, in an industry, or in the national economy, or meaning a specific production quantity in the production with which this energy is involved.

The differences in the level of energy intensity between the economies of specific countries are determined by numerous factors, such as the level of socio-economic development, the structure of the economy, the advancement of the technologies used in the economy, domestic resources base, climate, the structure of production, and the consumption of primary energy carriers. (Kuciński 2006, p. 120).

[2] Eurostat's ratio.

The energy intensity of an economy is strongly related to its level of socio-economic development, however, this relation is not linear, thus requiring further interpretation. A low level of energy intensity of an economy may concern both countries with a very high and countries with a very low level of socio-economic development, in spite of the existing differences in the size and structure of consumption of primary energy carriers and generated GDP. In countries with a high level of development, consumption of energy resources per one inhabitant is usually high, yet their low energy intensity may result from a high efficiency of management of specific energy carriers and technological progress. In the case of countries with a low level of socio-economic development, low energy intensity is the result of low GDP and, at the same time, of a relatively low consumption of energy resources. Usually, the studies of energy intensity apply to the index of gross national income:

- **Energy intensity index for gross national income**

$$e = \frac{E}{D} \tag{4}$$

where:
E – the quantity of the energy consumed,
D – the value of the gross national income.

e) Stirling's index

The diversification of supplies is regarded as one of the basic aspects of energy security. The most frequently applied measure of this diversification is Stirling's index, defined as follows:

Stirling's index:

$$W_{ST} = -\sum_{j=1}^{m} u_j \ln u_j \tag{5}$$

where:
u_j – the participation of *j*-th carrier,
m – the number of primary energy carriers.

Its value increases together with the increase of the carriers within the energy balance, and reaches the maximum value for equal shares of these carriers within the balance. The analysis of energy security in light of Stirling's index suggests that the most beneficial is an even structure of the energy supplied to the domestic market.

The above indices are presented in Table 1 for 2000, and Table 2 for 2008. The normalisation of these indices was made by means of their unification. Destimulants were transformed into stimulants. In order to examine energy security, objects were grouped which allowed for the determination of a group of countries that can be characterised with similar parameters of energy security.

Table 1. Energy security indices for 2000

Country	2000				
	Grid losses index (%)	Use of renewable energy index	Energy dependence	Energy intensity index (kgoe/1000 Eur)	Stirling's index
Austria	5.68	0.66	0.66	140.67	1.30
Belgium	4.39	0.09	0.78	234.77	1.37
Bulgaria	15.37	0.24	0.47	1332.85	1.47
Cyprus	5.58	0.00	0.99	237.44	0.17
The Czech Republic	6.75	0.14	0.23	671.06	1.24
Denmark	5.84	0.19	-0.35	114.03	1.26
Estonia	14.57	0.00	0.32	805.99	1.04
Finland	3.93	0.18	0.56	248.49	1.53
France	5.62	0.22	0.52	178.88	1.36
Greece	7.94	0.30	0.70	204.92	1.01
Spain	8.90	0.37	0.77	196.69	1.33
The Netherlands	4.56	0.02	0.39	183.20	1.10
Ireland	8.42	0.14	0.85	135.41	1.06
Lithuania	11.21	0.15	0.60	576.34	1.37
Luxemburg	12.00	0.94	1.00	162.99	0.78
Latvia	23.98	0.72	0.60	440.46	1.23
Malta	12.26	0.00	1.00	189.24	0.00
Germany	5.74	0.13	0.60	166.60	1.41
Poland	9.80	0.07	0.11	483.64	1.01
Portugal	8.34	0.42	0.85	197.68	1.06
Romania	12.76	0.28	0.22	906.05	1.42
Slovakia	5.95	0.32	0.65	815.40	1.11
Slovenia	5.95	0.32	0.53	299.77	1.53
Sweden	7.62	0.50	0.39	177.67	1.31
Hungary	13.75	0.01	0.55	492.21	1.38
Great Britain	8.26	0.04	-0.17	144.63	1.30
Italy	6.94	0.28	0.87	147.60	1.05

Source**:** the author's own research on the basis of the following data: *BP Statistical Review of World Energy June 2010*, *Energy-yearly statistics 2008*, Luxembourg: Publications Office of the European Union, 2010.

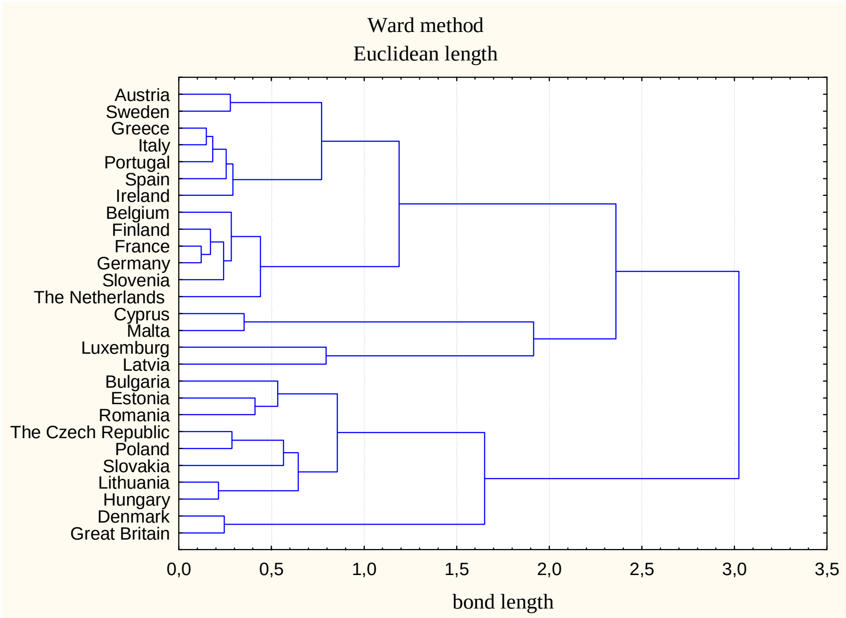
Table 2. Energy security indices for 2008

Country	2008				
	Grid losses index (%)	**Use of renewable energy index**	**Energy dependence**	**Energy intensity index (kgoe/1000 Eur)**	**Stirling's index**
Austria	5.14	0.65	0.70	138.06	1.29
Belgium	5.01	0.10	0.80	199.82	1.35
Bulgaria	10.36	0.32	0.52	944.16	1.46
Cyprus	3.01	0.00	0.98	213.39	0.19
The Czech Republic	5.58	0.13	0.28	525.30	1.42
Denmark	6.47	0.25	-0.22	103.13	1.32
Estonia	10.67	0.03	0.24	570.51	1.13
Finland	4.3	0.19	0.55	217.79	1.52
France	5.71	0.24	0.51	166.74	1.35
Greece	7.12	0.29	0.73	169.95	1.07
Spain	4.78	0.39	0.81	176.44	1.36
The Netherlands	4.32	0.09	0.35	171.58	1.14
Ireland	7.57	0.22	0.90	106.52	1.09
Lithuania	7.25	0.20	0.60	417.54	0.71
Luxemburg	3.82	0.72	0.99	154.61	0.79
Latvia	15.13	0.73	0.58	308.74	1.17
Malta	14.71	0.00	1.00	194.88	0.00
Germany	4.72	0.25	0.61	151.12	1.49
Poland	8.12	0.09	0.30	383.54	1.10
Portugal	9.1	0.51	0.83	181.53	1.17
Romania	11.06	0.32	0.28	614.57	1.51
Slovakia	3.46	0.35	0.65	519.68	1.51
Slovenia	4.93	0.34	0.55	257.54	1.50
Sweden	7.32	0.51	0.38	152.08	1.19
Hungary	9.71	0.02	0.64	401.35	1.42
Great Britain	7.24	0.09	0.26	113.66	1.22
Italy	6.4	0.26	0.85	142.59	1.14

Source**:** the author's own research on the basis of the following data: BP Statistical Review of World Energy June 2010, *Energy-Yearly Statistics 2008*, Luxembourg: Publications Office of the European Union, 2010 edition.

During the first stage of the research, the security analysis was performed according to Ward's method (cf. Fig. 1 below).

Figure 1. The dendritic structure of energy security obtained using the Ward method, for 2008



Source: the author's own research.

Table 3. The elements of security groups obtained using the Ward method

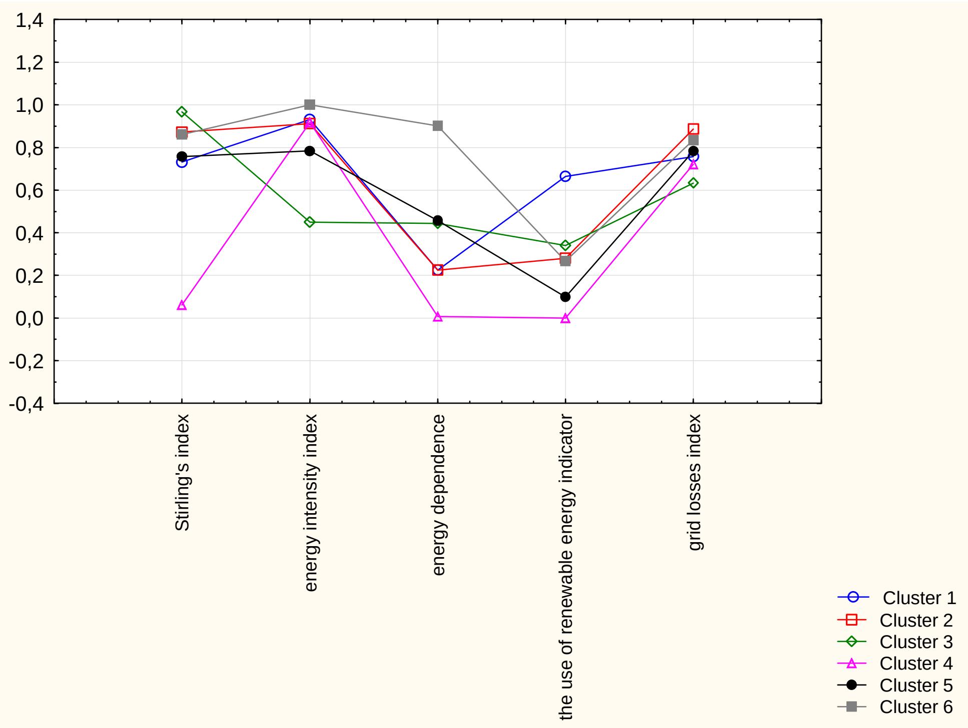
Cluster 1	Austria, Sweden, Greece, Italy, Portugal, Spain, Ireland
Cluster 2	Belgium, Finland, France, Germany, Slovenia, the Netherlands
Cluster 3	Cyprus, Malta
Cluster 4	Luxemburg, Latvia
Cluster 5	Bulgaria, Estonia, Romania, the Czech Republic, **Poland**, Slovakia, Lithuania, Hungary
Cluster 6	Denmark, Great Britain

Source: the author's own research.

This method allows one to see the similarity between Poland and such countries as the Czech Republic, Estonia, Lithuania, Hungary, Romania, Slovakia and Bulgaria as far as energy security in 2008 is concerned.

In order to determine the sources of the similarities between the obtained data clustering, the k-means analysis was performed (cf. Fig. 2 below).

Figure 2. A diagram of energy security analysis for 2008 obtained using the k-means method



Source: the author's own research.

Table 4 The composition of the groups determined with the *k*-means method for energy security

Cluster 1	Austria, Luxemburg, Latvia, Portugal, Sweden
Cluster 2	Belgium, Finland, France, Greece, Spain, Ireland, Germany, Slovakia, Slovenia, Italy
Cluster 3	Bulgaria, Romania
Cluster 4	Cyprus, Malta
Cluster 5	The Czech Republic, Estonia, The Netherlands, Lithuania, **Poland,** Hungary, Great Britain
Cluster 6	Denmark

Source: the author's own research.

According to the above analysis, Poland is located in cluster 5, with such countries as the Czech Republic, Estonia, Lithuania and Hungary. This cluster also comprises Great Britain and the Netherlands. The countries within this group are characterised by a quite high mean value of Stirling's index, yet lower than in the countries belonging to clusters 2, 3 or 6. This may result from the fact that these countries have a diversified energy mix, yet there are some resources which play a key role in their energy system. In the case of Poland, coal is the dominating fuel in the energy mix, with gas and oil to a lesser extent, while renewable energy resources are present to a very low degree and there is no nuclear energy. The remaining countries of cluster 5 have a similar situation – in their energy balances the key role is played either by coal (Estonia, the Czech Republic), or gas and oil (the Netherlands, Great Britain, Lithuania, Hungary).

The countries belonging to cluster 5, including Poland, are quite energy intensive economies. Their energy dependence index in turn is at an average level, which results from the fact that these countries have their own energy resources – in Poland’s case these are mainly hard coal and lignite deposits. These countries’ average value of the index of renewable energy use is at a low level, posing a large challenge for them in the context of strengthening their energy security. The existing grid losses are relatively low and this resembles the average values of this index in clusters 1 and 4.

Austria, Luxemburg, Latvia, Portugal and Sweden comprise the countries belonging to cluster 1. They are characterised by an average value of Stirling’s index, similar to its level in cluster 5. In these countries oil plays a dominating role in their energy mixes, with Sweden also having a significant share of nuclear energy. The average value of energy intensity in these countries is low. The energy dependence of these countries is high and the entire cluster can be characterised by a high average value of the index of renewable energy use.

Cluster 2, obtained by the *k*-means analysis, is composed of Belgium, Finland, France, Greece, Spain, Ireland, Germany, Slovakia, Slovenia and Italy. In these countries, the average value of Stirling’s index is quite high, which can be explained by a diversified energy mix and equal shares of particular fuels in the balance of energy carriers for these countries. These countries resemble those in cluster 1 with regards to low energy intensity and high energy dependence. The renewable energy use index is moderate in comparison with other clusters, whereas the grid losses index is the lowest of all clusters.

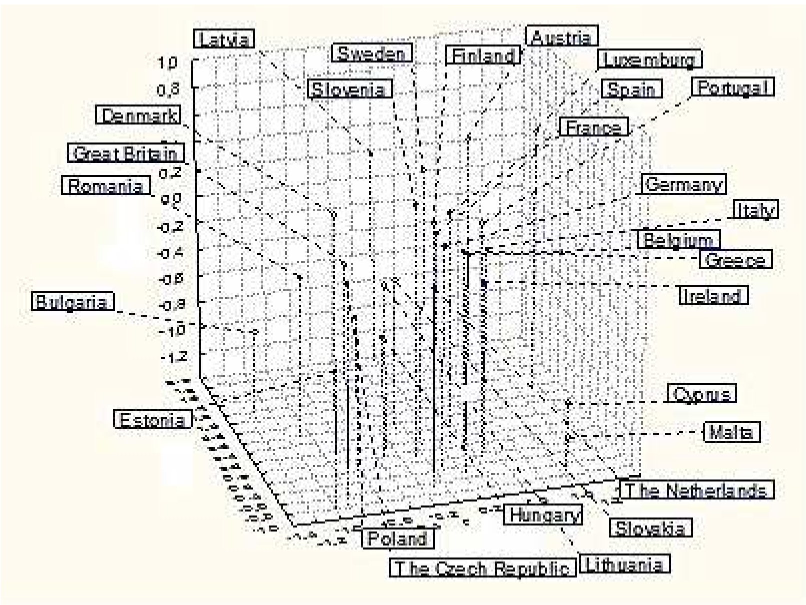
In the case of the countries belonging to cluster 3, i.e. Bulgaria and Romania, average values of these differ significantly from those in countries from clusters 1 and 2. These countries are characterised by a medium value of Stirling’s index, which proves that they have a good diversification in energy fuels and an effective and balanced structure of energy carriers. The economies of these countries are highly energy intensive, with medium energy dependence. In Romania and Bulgaria hydropower and biomass combustion are developing fast, leading to a medium value of the index of renewable energy use. The medium value of the grid losses index is the highest of all clusters, which might be the result of outdated energy infrastructure.

Malta and Cyprus are the two counties making up cluster 4. The economies of these countries are characterised by low energy intensity and the lowest degree of development of renewable energy sources as compared with all other clusters. As a consequence, these countries are highly energy dependent, as practically all their energy fuels are imported. Stirling's index is very low in these countries, which reflects a low diversification of energy carriers.

Denmark alone makes up cluster 6 – standing out among all other EU member states with regards to the energy security indicators analysed here. This is a country with a high value of Stirling's index. At the same time, it is characterised by a very low energy intensity of economy and the lowest energy dependence in the entire EU. The index of renewable energy use is relatively high and the grid losses index, as a result of the high technological level of its infrastructure, is low.

In order to visualise Poland's energy security in comparison with other EU member states multidimensional scaling was performed. The obtained results suggest that Poland's situation is similar to that of the Czech Republic, Hungary, Lithuania, Slovakia and the Netherlands (cf. Fig. 3 below).

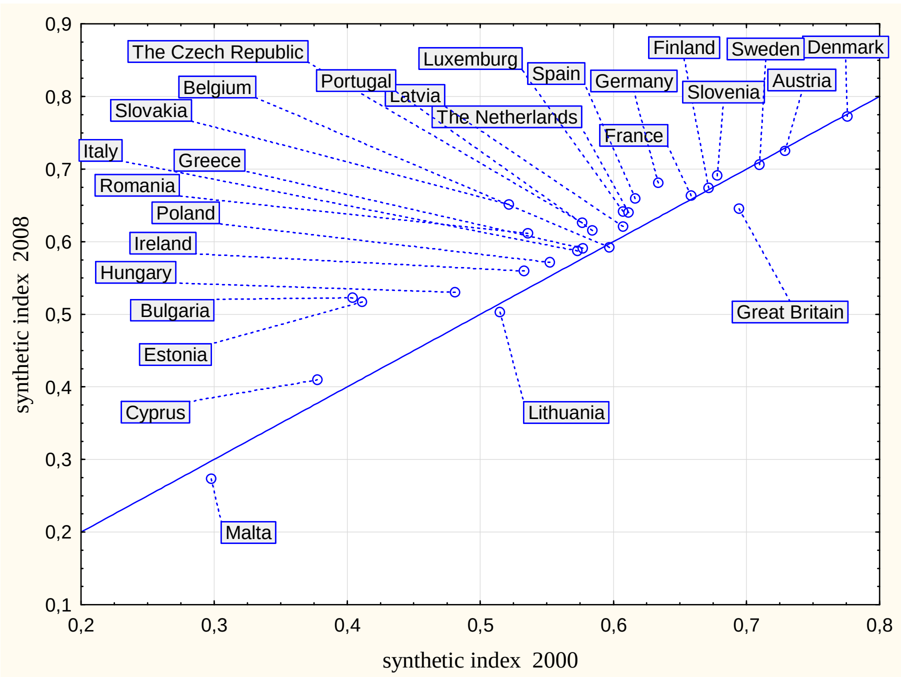
Figure 3. The results of multidimensional scaling for energy security in the EU members states in 2008



Source: the author's own research.

Given the fact that energy security is a process that changes over time, in order to characterise this process synthetic indices have been calculated for 2000 and 2008 (taking into consideration earlier indices of energy security). On the basis of the results, the EU states have been ranked from "the least safe to the safest" (cf. Fig. 4. below)[3]. The horizontal axis represents the value of the synthetic index for 2000. The better situation of a given country in terms of energy security, the larger the index value and the further to the right a point representing this country is placed. The results of the synthetic index for 2008 are interpreted accordingly. Additionally, on the graph there is a line between points $y = x$. The points which are below this line reflect countries whose situation in 2000 in terms of energy security was better than in 2008. The points above this line show the countries which made some progress in terms of energy security during this interval.

Figure 4. Comparison of the synthetic index for energy security in 2008 and the synthetic index in 2000



Source: the author's own research.

[3] The variables characterising energy security may be interpreted as stimulants and de-stimulants. This makes it possible to present the issue in a synthetic way and to carry out linear ordering of the objects with regards to all variables.

The above presentation of synthetic indices calculated for 2000 and 2008 suggests that Poland, with regards to energy security, ranks 20th among other EU states, which demonstrates that Poland's level of energy security is below average. It must be stressed, however, that Poland's position in 2008 improved in comparison with that of 2000. Malta, in turn, has the worst situation among EU countries as far as energy is concerned, as its security deteriorated in the above period. Denmark has the best position with regards to the indices analysed, and Denmark is generally regarded as a country which is energy independent and energy secure.

5. Actions for Poland's energy security

Poland, as compared with other EU countries, has a specific structure of electricity production, based on more than 90% usage of domestic coal, which has a positive influence on the level of energy security as far as raw materials are concerned. However, with regards to its significant emission of CO_2 gasses, such a wide use of coal in energy production decreases Poland's energy security in its environmental dimension.

Therefore, some further use of coal in Poland, in accordance with the principles of energy policy within the EU, and first of all, with the EU climate and energy package, must encompass the implementation of high-performance and sometimes costly technologies using emission-free coal combustion processes connected with CO_2 removal from flue gases and its geological storage. Moreover, taking into account Poland's existing dependence on oil and gas imports, it is necessary to diversify the supply directions. In order to meet its demands, Poland has to import approximately ⅔ of its natural gas and 95% of oil, out of which 94% of oil and 80% of gas imports come from Russia. The following projects are intended to minimise this dependence:

- in the field of oil: the development of oil-pipeline Odessa-Brody, from Ukraine to Polish refineries in Płock and Gdańsk (still under discussion),
- in the field of gas: the construction of LNG terminal in Świnoujście, an increase of the volume of underground gas storage containers.

A significant improvement of energy security will result from the development, modernisation of, and investments into transmission and distribution systems. The existing conditions of domestic transmission and distribution lines do not meet the requirements of sound energy security, which is evidenced by the occurrence of serious breakdowns in the networks servicing Poland in recent years (e.g. a breakdown in Szczecin in 2008, and in Małopolska in 2010).

An important project increasing the energy security of Poland and other EU member states will consist in the creation and operation of a uniform electrical energy market. The assumption is that this market will create an area in which there will be no obstacles to energy transmission between EU member states. Once Poland is encompassed within the Trans-European network, contributing to the development of cross-border connections, Polish energy security will improve. Given this context, it is extremely important to built the energy connection between Germany, Poland and Lithuania, in particular the Alytus-Ełk connection.

It must be emphasised that EU regulations, especially in the field of ecology, are quite difficult to comply with, as they do not always take into consideration the cumulative effects of the premature disconnection of many efficient coal blocks for failure to meet the EU emission criteria. Therefore, the promotion and development of renewable sources of energy is extremely important in Poland, as then the share of these energy sources in the overall energy balance will be increased. It was emphasized in the *Poland's energy policy till 2030* as well as in the report prepared for the Ministry of Economy: *Energy Mix 2050. The Analysis of Scenarios for Poland.*

Also some other actions are important to increase Poland's energy security, and these comprise:

- the increase of efficient energy use – resulting in a decrease in the use of energy while maintaining a not-worsened consumer effect;
- development of strategic reserves of raw materials – domestic emergency reserves to be used in emergency situations and guaranteeing a continual energy supply;
- creation of efficient conditions for competition in the energy market, which is beneficial for consumers and has a positive influence on prices;
- investments into safe and modern energy supply infrastructure;
- contracts with raw materials suppliers – enhancing the guarantee of supplies and predictable prices.

These activities also reflect EU strategy on energy security indicated in the most recent EU documents[4].

[4] Compare with: *Making the internal energy market work* (http://ec.europa.eu/energy/gas_electricity/internal_market_en.htm, date of access: 29.06.2013), *Energy Roadmap 2050* (*http*://ec.europa.eu/energy/energy2020/roadmap/index_en.htm, access date: 29.06.2013*);Renewable Energy: a major player in the European energy market* (http://ec.europa.eu/energy/renewables/communication_2012_en.htm, date of access: 29.06.2013).

6. Conclusions

In the light of the analysis carried out, it must be stated that energy security, understood as "the condition of an economy to meet the prospective demands of recipients for fuels and energy in a way which is technically and economically justified, while, at the same time, meeting the requirements of environmental protection" is a significant challenge for both Poland and the other EU member states.

This is confirmed by the results of both static and dynamic analyses. The statistical analysis carried out shows a similarity, with regards to energy security, between Poland and, first of all, the countries of Central and Eastern Europe, such as Bulgaria, Estonia, Romania, the Czech Republic, Slovakia, Lithuania and Hungary. The synthetic indicators obtained through calculation, forming the basis for a dynamic presentation of the energy security of EU member states for 2000 and 2008, show that Poland is ranked in one of the lowest positions among EU members states (ranked 20th), with only a slight improvement in this ranking position in 2008 compared with 2000.

However, Poland has a very specific structure of energy production in comparison with other countries within the EU. Its energy structure is more than 90% based on coal, and only to a slight degree on gas and renewable sources of energy. It also must be pointed out that coal is a natural source of energy for Polish electrical power engineering, having a positive impact on energy security as far as resources are concerned. With regards to its high CO_2 gas emissions as a result of burning coal, Poland's energy security in its environmental dimension is relatively low. This is the main reason that it is especially significant to acquire and implement modern technologies – so called "clean coal technologies" – to enhance Poland's energy security.

Moreover, in order to increase energy security Poland should implement several of the above-mentioned steps concerning increased diversification of energy carriers, increasing the share of power generated by renewable sources of energy, decreasing energy intensity and energy dependence, and increasing of electrical energy saving through efficient use.

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Streszczenie

BEZPIECZEŃSTWO ENERGETYCZNE POLSKI W ŚWIETLE ANALIZY STATYSTYCZNEJ

Bezpieczeństwo energetyczne jest pojęciem wieloaspektowym, podlegającym ewolucji ze względu na zmieniający się jego charakter, jako bytu, stanu, procesu i zjawiska. W sferze dyskusji znajduje się nie tylko przedmiot i podmiot bezpieczeństwa energetycznego, ale również problem jego pomiaru oraz jego głównych uwarunkowań i determinant.

Celem artykułu jest próba znalezienia odpowiedzi na następujące pytania badawcze:

- *co to jest bezpieczeństwo energetyczne kraju oraz jaka jest jego istota?*
- *przy pomocy jakich wskaźników można określić bezpieczeństwo energetyczne kraju?*
- *jak wygląda bezpieczeństwo energetyczne Polski na tle innych krajów Unii Europejskiej w świetle przeprowadzonej analizy statystycznej?*

W badaniach nad bezpieczeństwem energetycznym Polski na tle Unii Europejskiej została zastosowana analiza skupień przeprowadzona metodą Warda i metodą pełnego wiązania (najdalszego sąsiedztwa) oraz analiza metodą k-średnich i skalowanie wielowymiarowe. W celu uchwycenia kierunków zmian bezpieczeństwa energetycznego Polski zostały obliczone wskaźniki syntetyczne dla 2000 r. i 2008 r. Uzyskanie odpowiedzi na powyższe pytania pozwoliło określić główne kierunki działania Polski na rzecz zwiększenia bezpieczeństwa energetycznego kraju.