ACTA UNIVERSITATIS LODZIENSIS
FOLIA OECONOMICA 224, 2008

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ASSESSMENT OF THE LEVEL OF DEVELOPMENT OF THE POWER MARKET OF THE EUROPEAN UNION COUNTRIES

Abstract: This study aims at determining the level of development of the Polish power industry sector in comparison with the sectors of other European Union countries with the use of the multidimensional comparative analysis method, paying special attention to cluster analysis, the structure of the taxonomic development measure and time-lag determination, which characterises the Polish power industry sector compared to its equivalents in the countries analysed.

Key words: The power market of the European Union, renewable sources of energy, multidimensional comparative analysis, synthetic measures of development, cluster analysis

1. INTRODUCTION

The power industry sector is one of the most important branches of industry, without which the economy could not function efficiently, and the more so to develop. It is a very difficult task to create a clear power policy that would include current and long-term challenges and take into account the importance of individual issues. It involves the need to constantly analyse the development of the market and to select tools to implement power policy, taking into consideration their effects, advantages, limitations as well as opportunities and risk related to them.

The creation of a uniform power market in Europe is currently in a transitional phase – there are no longer separate national markets, but it still is not a homogenous European Union market. Regional markets play a more and more important role, which is often perceived as a transitory step towards the creation of a uniform European market. On the one hand, they extend the scope of national markets and increase the number of participants, but on the other hand, there is a fear that the present situation will inhibit the process of creation of a common, uniform market (Hajdrowski 2006).

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The situation on the power market of individual European countries is diversified, which results from the nature of economic development, the number of inhabitants, the climate, as well as different strategies of investing in energy sources.

This study aims at determining the level of development of the Polish power industry sector in comparison with the sectors of other European Union countries with the use of the multidimensional comparative analysis method, paying special attention to cluster analysis, the structure of the taxonomic development measure and time-lag determination, which characterises the Polish power industry sector compared to its equivalents in the countries analysed.

2. THE POWER INDUSTRY SECTOR FROM A GLOBAL PERSPECTIVE

The current status and the most probable scenario for the power industry sector from a global perspective are presented in the report of the Directorate General for Research of the European Commission entitled "WETO 2030" of 2003. This scenario is based on a few premises: it is assumed that the global demand for power will increase between 2000 and 2030 at a rate of 1.8% per year; the dynamics of this process, resulting from the economic development and the increase of world population (annual increase of 3.1% and 1% respectively), is hindered by the increase of efficiency of the use of power (1.2% per year) which results from the influence of structural changes in economy, technological development as well as the rise in power prices. Industrialised countries will display a slow drop in the increase in demand for power (for example, to the level of 0.4% per year in the EU countries), with a simultaneous rapid increase in the developing countries. It is expected that in 2030 over a half of the global demand for power will belong to the developing countries (today this share amounts to about 40%) (Malko 2007).

The structure of overall demand for energy will be still dominated by mineral fuels. Petroleum will remain the basic source of energy (34%), outstripping carbon fuels (28%).

Global petroleum resources are sufficient to satisfy the needs for at least the next three decades. Petroleum output between 2000 and 2030 will increase by about 65%, reaching the level of 120 millions of barrels a day. Petroleum will still remain the dominant fuel, with a diversified regional share – from 40 to 50% in 2030.

The demand for natural gas will be slightly lower in comparison to coal (25%), and the main form of its usage will be to generate electric energy. In the EU countries natural gas will play the role of the second most important primary energy carrier (after petroleum). Natural gas resources are rich and it is anticipated that its new deposits will increase the global reserves by 10%. Natural gas output will double in the period discussed in this study, but significant changes will appear in the regional output structure: about 33% of output will be generated by the former USSR countries (CIS), and the remaining output will be relatively evenly shared by other regions.

There are no predictions concerning limitations of coal resources until 2030. Coal output should double between 2000 and 2030, with geographical dominance of Asia and Africa (about 50% of global output).

Generation of electric energy will be on a constant increase at an annual average rate of 3%. Over a half of output in 2030 will come from technologies that appeared in the 1990s and later, such as the gas-steam cycle, advanced coal technologies and renewable sources of energy – RSE. The share of natural gas in the generation of electric energy will be on a constant increase in three main regions that produce gas (CIS, the Middle East and Latin America), and the share of coal will decrease in all other regions, except North America (where stability is expected) and Asia (a rapid increase in this share). Faster development of electric energy generation technologies will bring about significant changes in the generation structure, which will particularly affect the costs of reduction of carbon dioxide emission. However, it should be remembered that the electrical power engineering sector is only responsible for 1/3 of global emission of this greenhouse gas.

The pace of the development of nuclear power engineering will be slower than the pace of the increase in electric energy generation, and the market share in the structure will decrease in 2030 to 10%.

Renewable sources of energy will double their share (from 2% in 2000 to 4% in 2030) due to a significant growth in the importance of wind power engineering. Nuclear power engineering and renewable sources of energy in the EU will participate in the structure of demand for energy at the level of about 20%.

As it is anticipated that all sectors will develop at a similar pace, the demand structure will not be subject to significant changes: 35% industry, 25% transport, 40% the housing and services sector. However, taking into account geopolitical regions, the models of power consumption will be diversified: in the developed countries the fastest development (and increase in demand for energy) will characterise the social housing and services sector, whereas in the developing countries all sectors will develop at a similar pace of 2–3% per year.

Prices of coal fuels will rise considerably, however, they will be subject to certain fluctuations caused by political reasons and natural disasters. Regional differences in gas prices will gradually vanish as a result of standardisation of the regional import structure. Prices of coal will remain relatively stable.

It is anticipated that global carbon dioxide emission will increase faster than demand for energy (average annual increase of 2.1%), which in 2030 will be twice as high as the level of 1990. This increase is supposed to come to 18% in the EU, and in the USA – to about 50%. The share of carbon dioxide emission in the developing countries will increase and between 1990 and 2030 and will exceed 50% at the global scale (Malko 2007).

As of today, these forecasts should be corrected in relation to a few aspects. It is worth paying special attention, among others, to faster than expected rate of rise in petroleum prices and natural gas prices indexed by petroleum prices, a series of serious failures of electrical power engineering systems, indicating the insufficiency of generated power and transmission of power, and a change of attitude (especially typical of the European Union) to coal as the fuel. It will cease to be an undesirable fuel and will become the strategic reserve of Europe and an important factor in increasing energy safety. The idea of nuclear power engineering is also being reintroduced as a realistic fuel option in large power engineering facilities.

3. THE EUROPEAN POWER MARKET – BASIC EUROPEAN COMMUNITY DOCUMENTS

The restructuring of the energy industry sector in Europe has been carried out for at least twenty years. In the fist years of liberalisation scientific and regulatory circles were mainly interested in short-term effectiveness and competitiveness of companies from this sector. The need to determine long-term effectiveness was first noticed in countries that were the first to liberalise the power market and to complete the first investment cycle in new circumstances, i.e. in England and Wales. Other power markets are just getting closer to the stage of complete liberation of the power market and an increase in investment risk related to it. Such a situation is currently observable on the most liberalised markets, e.g. in Spain, Germany and the Scandinavian countries.

Numerous documents of the European Commission, which are secondary sources of legislation, provide for possibilities to achieve EU strategic goals by way of achieving partial goals. Directives form the core of regulation, in particular with respect to the power generation sector. The relevant major directives are as follows (Malko 2006):

– Directive on uniform rules of an internal electric energy market (2003/54/EC),

– Directive on uniform rules of an internal natural gas market (2003/55/EC),

– Directive on integrated prevention to pollution and control thereof (96/91/EC),

– Directive on reduction of emissions from large incineration objects (2001/80/EC),

– Directive on national limits of pollution emissions (2001/87/EC),

– Directive on promotion of renewable sources of energy (2001/77/EC),

– Directive on energy parameters of buildings (2002/91/EC),

– Directive on promotion of electric energy generated in combination with heat generation (2004/8/EC),

– Directive on actions to secure supplies of electric energy (2005/89/EC),

– Directive on efficiency of ultimate use of energy (2006/32/EC).

Other relevant EU documents should also be mentioned:

– regulation on conditions applicable to access to cross-border exchange of electric energy (1228/2003/EC),

– regulation establishing general rules of providing support to trans-European power grids (807/2004/EC),

– decision on a set of guidelines for trans-European grids (1229/2003/EC),

– decision approving a long-term program of actions in the energy field Intelligent energy – Europe 2003–2006, (1230/2003/EC).

However, it is the so-called *white books* that are documents formulating strategic goals of the Community and individual Member States. White books are prepared on the basis of sectoral documents – green books, covering specialist fragments of integration within the EU and prepared General Directorates of the Commission or initiated by a commissioner.

With an energy white book in the offing, mention should be made of two green books, published by the General Directorate of Energy and Transportation. The first of them (of 2000) has a characteristic sub-heading: Towards a European security strategy of energy supplies. The most recent document of that rank – the green book of 2006 – expands the scope of discussion, signalling as the area of interest a strategy promoting balanced, competitive and secure energy.

Basing on the book, the current situation in the sector of energy may be characterised as follows:

• Investments are needed urgently. In Europe alone satisfaction of demand for energy and replacement of ageing infrastructure will require investments of one trillion euro over the next 20 years.

• Our dependence on imports has been growing. Unless we make energy from internal sources more competitive, then over the next 20 or 30 years about 70% of EU demand for energy will be covered with imports as opposed to 50% nowadays.

• Reserves are concentrated in few countries. Now about one half of EU gas consumption is covered with supplies from three countries (Russian, Norway and Algeria). If the existing trends continue, gas imports will grow by 80% over the next 25 years.

• Global demand for energy has been growing. World demand for energy – and CO2 emissions – are expected to grow by 2030 by about 60%. Global oil consumption is to grow by 20% at an expected annual rate of 1.6% annually.

• The crude oil and gas prices have been growing. Over the last two years, the prices have almost doubled in the EU, similarly to electric energy prices. That may result in larger savings in energy consumption and more innovation.

• Europe has not yet developed fully competitive internal energy markets. Only when such markets exist, EU citizens can enjoy the benefits from secure energy supplies and lower prices. To achieve that, it is necessary develop cross-border connections, to develop and apply an effective legal framework as well as strict observance of EU rules of competition.

4. RENEWABLE ENERGY SOURCES IN THE EUROPEAN UNION STRATEGY

The first step towards specifying strategic goals of renewable power industry came with *the green book* approved by the European Commission in November 1996. The strategy had one basic goal – achieving a 12% share of renewable energy sources (RES) in the energy consumption structure in the EU by 2010.

Entry into the UE of new member states (with unknown RES share in their energy balances) made implementation of this task much more difficult. Wide usage of the RES potential should be an important tool in reducing the dependency on external energy sources and in achieving reduction in the CO2 emission.

Basic information on the production and consumption of energy from renewable sources in the European Union countries in the years 1999–2004 are included in Table 1.

Energy production from RES in the analyzed period increased by 21%. Biomass and water energy could boast the highest share in its structure while solar energy had the lowest share. The highest increase was recorded in the wind energy production (+312%) while water energy recorded a decrease of 5.1%.

A considerable increase of the final energy consumption from the RES in transport is also worth mentioning. It is connected in the first place with an increase in the demand for ethanol and biodiesel.

Energy coming from renewable sources is most frequently used for the production of electric energy (Table 1 and 2). A key role is played by water power plants whose installed power exceeds 10MW. A considerable increase of production can also be observed in the usage of solar and wind energy coming from wind power plants. In countries like Australia, Latvia or Sweden the share (%) of electric energy from renewable sources in the electric energy consumption is considerable.

Table 1

Production and consumption of energy from renewable sources in the European Union countries in the years 1999–2004

Specification	1999	2000	2001	2002	2003	2004	04/99
Total production (w 1000 toe)	89 643	92 979	97 520	95 797	10 2698	108 811	+ 21.4%
water energy	27 525	29 000	30 609	25 559	24 932	26 128	-5.1%
wind energy	1 221	1 913	2 320	3 070	3 815	5 033	+312.2%
solar energy	372	417	474	537	617	743	+99.7%
geothermal energy	4 299	3 403	3 614	3 906	5 275	5 360	+24.7%
biomass energy	56 226	58 246	60 503	62 725	68 059	71 547	+27.3%
Final consumption (in 1000 toe)	42 309	43 995	45 295	45 903	47 236	48 657	+15.0%
including:							
industry	14 589	15 462	15 394	15 954	15 406	15 940	+9.3%
services, households, etc.	27 328	27 928	29 184	28 975	30 535	30 867	+12.9%
transport	391	604	718	974	1 295	1850	+373.2%
Production of electric energy from RES (in GWh)	328 123	346 378	395 927	341 021	340 127	372 756	+13.6%
from solar energy	75	111	171	258	438	736	+881.3%
from wind energy	14 204	22 250	26 976	35 708	44 364	58 539	+312.1%
in water power plants wit the installed power of up to 1MW	8 770	8 688	8 833	9 009	9 142	9 509	+8.4%
in water power plants with the installed power of up to10 MW	29 845	32 157	31 738	30 033	26 814	32 350	+8.4%
in water power plants with the installed power of over 10 MW	277 510	292 039	313 832	252 197	245 973	262 404	-5.4%
from wood and its waste	-	-	20 208	24 070	29 199	36 554	+80.9%*
from communal waste	11 923	13 383	13 754	16 240	18 580	19 661	+64.9%
from biogas	-	-	7 391	9 214	9 981	11 542	+56.2%*

* comparison 04/01

Source: own calculations on the basis of Eurostat.

The European Commission approved in April 2006 preliminary assumptions of a new 7th European Union Framework Program for Research, Technological Development and Demonstration for the years 2007–2013. The subprogram "energy" includes eight fields – thematic priorities (Wiśniewski 2005):

– hydrogen and fuel cells (stationary, portable and transport applications),

– production of fuels from renewable energy sources (liquid biofuels with biogas and hydrogen in transport),

– renewable energy sources for warmth and cold production,

– sequestration of CO2 in non-emission power plants,

– clean coal technologies,

– intelligent power grids,

– power efficiency,

– socioeconomic research and activities supporting the energy policy management.

All these actions confirm a huge interest in renewable sources of electric energy and predict their even faster development in the nearest future.

Table 2

Share (%) of electric energy from renewable sources in the gross electric energy consumption in 1997 and its estimated share in 2010 in European Union countries

Country	1997	2010	Country	1997	2010
Austria	70.0	78.1	Latvia	42.2	49.3
Belgium	1.1	6.0	Lithuania	3.3	7.0
Cyprus	0.05	6.0	Luxembourg	2.1	5.7
Czech Republic	3.8	8.0	Malta	0	0.5
Denmark	8.7	29.0	Netherlands	3.5	9.0
Estonia	0.2	5.1	Poland	1.6	7.5
Finland	24.7	31.5	Portugal	38.5	39.0
France	15.0	21.0	Slovakia	17.9	31
Germany	4.5	12.5	Slovenia	29.9	33.6
Greece	8.6	20.1	Spain	19.9	29.4
Hungary	0.7	3.6	Sweden	49.1	60.0
Ireland	3.6	13.2	United Kingdom	1.7	10.0
Italy	16.0	25.0			

Source: Krawczyński 2006.

5. COMPARISON OF GENERAL-PURPOSE OBJECTS

The accession of Poland to the European Union requires an intensified implementation of procedures to adjust various fields of social and economic life to European standards. These activities are aimed at achieving a balanced development of the countries and regions of unified Europe. However, it is necessary to determine the degree of spatial diversification of individual areas and to specify possible developmental similarities in the field examined (Młodak 2006, p. 7).

The basic objective of the taxonomic analysis is to assess the degree of diversity of objects described with the use of a set of characteristic features and to determine clusters of these objects with regard to developmental similarities, as well as to obtain homogeneous object classes with respect to their characteristic properties. These procedures make it possible to determine the so-called development measure. This measure is a synthetic quantity that is the resultant of all variables describing units in the population examined. Therefore it may be used for linear ordering of elements of a given population.

There are numerous methods to create synthetic variables. They make use of suitably selected diagnostic variables (features). The selection of diagnostic variables is a particularly important task, as final results of research are to a large extent conditional upon it. In most cases there are many features that may be used to describe a given complex phenomenon examined. Usually, individual features convey different information, some of them are more important than the others, each feature is characterised by different variability and a different unit. It is suggested to use indicative variables in comparative analyses, i.e. per capita, per surface unit. Sticking to absolute values may lead to distortion of results.

6. DIAGNOSTIC VARIABLES

Diagnostic features may be selected in two ways:

- diagnostic features included in a collection are such quantities which – in the light of the factual knowledge possessed about the phenomenon examined – constitute the most important characteristics of objects compared,
- the selection of features takes place by means of processing and analysing statistical information using formal procedures.

However, it seems most appropriate to combine both of the above procedures. Then, based on factual knowledge, a list of the so-called potential diagnostic variables is compiled, which is later reduced using formal methods with respect to statistical properties of initially examined features.

Diagnostic variables, according to the direction of impact on the phenomenon examined, include stimulants, destimulants and nominants (Zawada 2006, p. 329).

Stimulants are variables whose rise in quantity indicates desirable development of the complex phenomenon examined.

Destimulants are variables whose fall in quantity indicates desirable development of the complex phenomenon examined.

Nominants are variables that are characterised by a specific degree of saturation (i.e. the nominal value), and any deviations from it indicate improper development of the phenomenon examined.

The point of departure of the construction of synthetic variables is the observation matrix

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots\cdots & x_{1n} \\ x_{21} & x_{22} & \cdots\cdots & x_{2n} \\ \vdots & \vdots & \cdots\cdots & \vdots \\ \vdots & \vdots & \cdots\cdots & \vdots \\ x_{n1} & x_{n2} & \cdots\cdots & x_{mn} \end{bmatrix}$$

where x_{it} stands for the value of the i diagnostic variable (i = 1,…, m) in the t object (t = 1,…, n). An object may be a business entity, a geographical location, a period or a point in time, etc.

Diagnostic variables may have different names, a different range of variability, which makes it impossible to compare them directly. So they should be made comparable by means of standardisation (normalisation). There are three basic groups of normalising transformations: standardisation, unitarisation and quotient transformation.

For the sake of this study all variables were normalised by means of quotient transformation with regard to a point of reference using the formula below:

$$x'_{ij} = \frac{x_{ij}}{\overline{x}_{oj}}, \tag{1}$$

where:

x_{ij} – the value of the j variable for the i unit (i = 1, …, n; j = 1,…, k);

$\overline{x}_{oj}$ – the average value for the j variable (point of reference);

n – the number of objects;

k – the number of variables.

It is proposed in this study to classify power markets of the countries analysed using the following diagnostic features:

X_1 – consumption of electric energy generated by renewable sources of energy (Geothermal, Solar, Wind, and Wood and Waste) per inhabitant (TWh/person);

X_2 – hard coal consumption (million tons/person);

X_3 – carbon dioxide emission (Million Metric Tons of Carbon Dioxide/person);

X_4 – Primary Energy Consumption (Quadrillion Btu/person);

X_5 – electric energy consumption (TWh/person);

X_6 – petroleum consumption (Thousand Barrels per Day /person);

X_7 – natural gas consumption (Billion Cubic Feet/person);

X_8 – energy intensity of the economy - gross inland consumption of energy divided by GDP (kilogram of oil equivalent per 1000 euro);

X_9 – Total Electricity Installed Capacity (MW/person).

These data concern the period from 1995 to 2004 and come from www.eia.doe.gov.

The following features were included in the group of stimulant variables:

X_1 – this variable – from the point of view of the power policies of the European Union – is more preferred in the energy balance of the EU countries due to the strategy of the EU to promote energy generated by renewable sources.

X_4 – primary energy is understood as the sum of energy contained in primary energy carriers, such as: hard coal, brown coal, petroleum, natural gas, peat coal, fuel wood, animal and plant solid waste fuel, solid and liquid industrial waste, municipal waste, other raw materials used to generate energy (e.g. methanol, ethanol), water energy used to produce electric energy, water energy used to produce electric energy, solar energy used to produce electric energy or heat, geothermal energy used to produce electric energy or heat. Its higher consumption indicates higher use of renewable sources of energy and is at the same time related to the level of economic development of a given country.

X_5 – used due to the relationship between electric energy consumption and the level of social and economic development of a given country. To put it simply, one could say that the higher the development level of a given country is, the higher electric energy consumption. The level of consumption of electric energy has a significant influence on the operation of this energy sector (e.g. it influences the volume of energy purchased from neighbouring countries, the level of investment outlays for the electrical power engineering sector, power intensity in power plants, etc.).

X_7 – due to the preference to use this source of energy as the substitute of hard coal for heating, generating electric energy, preparing meals.

X_9 – this feature was classified as a stimulant due to issues related to energy safety of a given country.

The following features were included in the group of destimulant variables:

X_2, X_6 – as high values of these variables indicate a significant use of natural resources and pollution by carbon dioxide, dust and similar substances that are discharged in the process of combustion.

X_3 – as emission of greenhouse gases has a significant impact on the process of climate warming and the European Community promised a significant reduction of these gases.

X_8 – as a low value of this variable indicates a lower use (consumption) of energy to achieve an increase in the GDP level.

7. SYNTHETIC MEASURES OF DEVELOPMENT

The point of departure for a multidimensional comparative analysis is to determine the above-mentioned synthetic measures of development. These measures are determined according to the formula (T. Grabiański, S. Wydymus, A. Zeliaś 1989, p. 91) :

$$q_i^{'} = \frac{q_i}{\|Q\|} \; (i = 1, \ldots, n), \tag{2}$$

where: "n" is the number of objects, $\|Q\|$ is the synthetic variable rate, that could be:

- the maximum value of this variable

$$\|Q\| = \max_i \{q_i\} \; (i = 1, \ldots, n), \tag{3}$$

- the maximum statistical value of this variable

$$\|Q\| = \overline{q} + 2s_q \tag{4}$$

whereas $\overline{q}$ and s_q are the arithmetic average and standard deviation of the synthetic variable,

- the sum of values of the variable

$$\|Q\| = \sum_{i=1}^{n} q_i \, , \tag{5}$$

- the range of the variable

$$\|Q\| = \max_i \{q_i\} - \min_i \{q_i\} \tag{6}$$

In the research concerning the assessment of the level of development of power markets of the European Union countries measures of development given in formula (2) were determined with the assumption that the synthetic variable rate is given in formula (4), whereas realisations of the q_i synthetic variable are determined using unit weights, normalisation according to formula (1) and as the formula of aggregation of normalised variables – the Euclides distance in relation to the top pole of the set. This consequently leads to the following expression:

$$q_i = \left[\frac{\sum_{j=1}^{m} (x'_{ij} - x'_{0j})^2}{m} \right]^{1/2} \quad (i = 1, \ldots, n), \tag{7}$$

where x'_{ij} are standardised values of the j diagnostic variable for the i object, whereas x'_{0j} are coordinates of the top pole of the set (the development model) determined based on the following relationship:

$$x'_{0j} = \begin{cases} \max\limits_{i} \left\{ x'_{ij} \right\} & \text{for stimulants} \\ \min\limits_{i} \left\{ x'_{ij} \right\} & \text{for destimulants} \end{cases} \tag{8}$$

The n and m symbols appearing in the above formulas stand for the number of objects and the number of diagnostic variables.

Values of measures obtained are presented in Table 3 and are organised starting from countries with the highest level of development of the power sector.

The country characterised by the least disparity from the development model during the decade analysed is Finland. Finland achieved this result thanks to a strong increase in consumption of energy coming from renewable sources and little consumption of hard coal that occurred during the period analysed.

The remaining positions were taken by: Denmark, Sweden, Holland, Germany and Italy. Estonia was the most distant country in relation to the model in all periods analysed. Austria, which in 1995 was on the fourth place, gradually, year by year increased the gap between the leading countries and finally took the 13th place in 2004. Spain, which was on the 13th place in 1995, took the fourth place in 2004. So huge changes in the level of development of the power market in these countries result, above all, from the influence of such factors as the size of gas consumption, the size of power installed and the share of energy coming from renewable sources.

Greece, Bulgaria, Cyprus and Romania are countries that take the last four positions in the Table (before Estonia). They come out slightly worse than Poland, which used to take the 23rd place in 1995, and in 2004 it went up to the 21st position. During the period analysed Poland was characterised by the lowest electric energy consumption per one inhabitant, little usage of energy generated by renewable sources and high consumption of hard coal, which certainly influenced the increase of disparity in relation to the model in all periods analysed.

Table 3

Results of linear classification – synthetic measure of development of the power sector in the countries of the European Union between 1995 and 2004

Country	'95	Country	'96	Country	'97	Country	'98	Country	'99	Country	'00	Country	'01	Country	'02	Country	'03	Country	'04
FI	0.7567	FI	0.7576	FI	0.7589	FI	0.7717	FI	0.7549	FI	0.7908	FI	0.7344	FI	0.7362	FI	0.7164	FI	0.7007
DA	0.4217	DA	0.4701	DA	0.4859	DA	0.5140	DA	0.5736	DA	0.5231	DA	0.6472	DA	0.6479	DA	0.6730	DA	0.6822
SW	0.3517	SW	0.3547	SW	0.3533	SW	0.3486	SW	0.3582	SW	0.3549	SW	0.4091	SW	0.4103	SW	0.4547	SW	0.4746
AU	0.3025	NL	0.3287	NL	0.3128	NL	0.3124	NL	0.3313	NL	0.3115	NL	0.3475	NL	0.3478	GM	0.3572	SP	0.3929
NL	0.2892	AU	0.2988	AU	0.2686	GM	0.2745	GM	0.2805	GM	0.2775	GM	0.3344	GM	0.3355	NL	0.3544	GM	0.3831
BE	0.2597	GM	0.2745	GM	0.2662	AU	0.2639	IT	0.2741	AU	0.2723	SP	0.3129	SP	0.3140	SP	0.3458	NL	0.3767
GM	0.2596	BE	0.2698	IT	0.2518	IT	0.2566	BE	0.2695	IT	0.2630	IT	0.2947	IT	0.2956	IT	0.3153	IT	0.3272
LU	0.2442	IT	0.2562	BE	0.2489	BE	0.2514	AU	0.2693	BE	0.2553	BE	0.2853	BE	0.2861	UK	0.2968	UK	0.3061
IT	0.2408	UK	0.2431	UK	0.2422	UK	0.2479	UK	0.2635	UK	0.2519	UK	0.2818	UK	0.2824	BE	0.2917	BE	0.3021
UK	0.2321	PO	0.2390	FR	0.2348	EI	0.2360	SP	0.2539	PO	0.2413	PO	0.2738	PO	0.2747	PO	0.2836	EI	0.2999
PO	0.2302	FR	0.2384	PO	0.2313	FR	0.2354	PO	0.2501	EI	0.2411	EI	0.2675	EI	0.2678	EI	0.2813	PO	0.2897
FR	0.2286	LU	0.2366	SP	0.2245	PO	0.2326	FR	0.2471	FR	0.2396	FR	0.2643	FR	0.2651	FR	0.2763	FR	0.2855
SP	0.2070	SP	0.2178	LU	0.2245	SP	0.2314	LU	0.2464	SP	0.2388	AU	0.2560	AU	0.2529	AU	0.2656	AU	0.2814
EI	0.2038	EI	0.2111	EI	0.2228	LU	0.2306	EI	0.2452	LU	0.2326	SL	0.2328	SL	0.2334	HU	0.2429	HU	0.2675
HU	0.2025	HU	0.2072	SL	0.2112	HU	0.2130	SL	0.2191	HU	0.2163	LU	0.2300	LU	0.2321	SI	0.2403	SI	0.2462
SL	0.1974	SL	0.2042	HU	0.2090	SL	0.2124	HU	0.2181	SL	0.2149	HU	0.2274	HU	0.2285	SL	0.2363	SL	0.2429
SI	0.1886	SI	0.1939	EZ	0.1968	EZ	0.2008	EZ	0.2126	SI	0.2058	SI	0.2253	SI	0.2264	LG	0.2243	LG	0.2378
EZ	0.1865	EZ	0.1904	SI	0.1952	SI	0.2003	SI	0.2089	LG	0.2030	LG	0.2099	LG	0.2101	LU	0.2209	LU	0.2178
LH	0.1844	LG	0.1872	LG	0.1924	LH	0.1972	LG	0.1999	EZ	0.2006	MT	0.2012	MT	0.2022	MT	0.2092	MT	0.2127
LG	0.1815	LH	0.1868	LH	0.1893	LG	0.1968	MT	0.1896	LH	0.1979	LH	0.1985	LH	0.2021	LH	0.2057	LH	0.2109
RO	0.1799	MT	0.1790	RO	0.1867	MT	0.1905	LH	0.1888	MT	0.1958	EZ	0.1961	EZ	0.1978	EZ	0.1958	PL	0.1973
MT	0.1753	RO	0.1773	MT	0.1820	RO	0.1863	RO	0.1843	PL	0.1915	PL	0.1900	PL	0.1911	PL	0.1946	CY	0.1951
PL	0.1708	PL	0.1750	PL	0.1809	PL	0.1854	PL	0.1817	RO	0.1899	RO	0.1872	RO	0.1879	CY	0.1938	EZ	0.1935
CY	0.1691	CY	0.1734	CY	0.1788	CY	0.1834	CY	0.1812	CY	0.1892	CY	0.1842	CY	0.1853	RO	0.1892	RO	0.1904
GR	0.1627	GR	0.1678	GR	0.1684	GR	0.1722	GR	0.1686	GR	0.1757	GR	0.1687	GR	0.1702	GR	0.1825	GR	0.1683
BU	0.1627	BU	0.1548	BU	0.1554	BU	0.1550	BU	0.1506	BU	0.1708	BU	0.1528	BU	0.1499	BU	0.1496	BU	0.1514
EN	0.1306	EN	0.1222	EN	0.1200	EN	0.1316	EN	0.1138	EN	0.1295	EN	0.0986	EN	0.0957	EN	0.0549	EN	0.0258

where: A-Austria, BE – Belgium, BU – Bulgaria, CY - Cyprus, EZ - Czech Republic, DA – Denmark, EN – Estonia, FI – Finland, FR- France, GM – Germany, GR – Greece, HU- Hungary, EI- Ireland, IT – Italy, LG – Latvia, LH – Lithuania, LU- Luxembourg, MT – Malta, NL – Netherlands, PL – Poland, PO – Portugal, RO – Romania, SL – Slovakia, SI – Slovenia, SP – Spain, SW – Sweden, UK– United Kingdom. Source: own calculations.

8. ASSESSMENT OF LAGS IN THE LEVEL OF DEVELOPMENT OF POWER MARKETS

Synthetic measures of development make it possible to reduce the **X** initial observation matrix of the following dimensions n x m x k (n – number of objects, m – number of diagnostic variables, k – number of moments or periods) to a two-dimensional matrix n x k that contains a realisation of synthetic variables for each object in the form of the k-dimensional time series.

Table 4

Assessments of parameters of linear trend function for synthetic measures of development

Country	Linear trend function			Country	Linear trend function		
	α p–value	β p–value	R^2		α p-value	β p-value	R^2
1	2	3	4	5	6	7	8
AU	0.02905	–0.00316	**0.249**	**LG**	0.17430	0.00544	**0.924**
	0.0000	0.08074			0.0000	0.0000	
BE	0.24503	0.00489	**0.601**	**LH**	0.18122	0.00272	**0.879**
	0.0000	0.00489			0.0000	0.0000	
BU	0.16030	–0.00092	**0.071**	**LU**	0.24243	–0.00197	**0.348**
	0.0000	0.2304			0.0000	0.0427	
CY	0.16940	0.00254	**0.853**	**MT**	0.17085	0.00416	**0.984**
	0.0000	0.0000			0.0000	0.0000	
EZ	0.19444	0.00048	**0.043**	**NL**	0.29032	0.00744	**0.731**
	0.0000	0.56246			0.0000	0.0009	
DA	0.39972	0.02985	**0.918**	**PL**	0.17083	0.00273	**0.907**
	0.0000	0.0000			0.0000	0.0000	
EN	0.1562	–0.0098	**0.659**	**PO**	0.21532	0.00714	**0.841**
	0.0000	0.0027			0.0000	0.0001	
FI	0.78056	–0.00595	**0.398**	**RO**	0.17954	0.00115	**0.631**
	0.0000	0.0298			0.0000	0.0037	
FR	0.21794	0.00610	**0.860**	**SL**	0.19370	0.00486	**0.944**
	0.0000	0.0000			0.0000	0.0000	
GM	0.23052	0.01341	**0.835**	**SI**	0.17737	0.00649	**0.936**
	0.0000	0.0001			0.0000	0.0000	
GR	0.16525	0.00095	**0.204**	**SP**	0.16567	0.01967	**0.874**
	0.0000	0.1067			0.0000	0.0000	
HU	0.19083	0.00589	**0.809**	**SW**	0.31137	0.01376	**0.750**
	0.0000	0.0002			0.0000	0.0007	
EI	0.19190	0.01012	**0.967**	**UK**	0.22036	0.00808	**0.914**
	0.0000	0.0000					
IT	0.22704	0.00918	**0.897**		0.0000	0.0000	
	0.0000	0.0000					

Source: own calculations.

When assessing these time series of synthetic measures of development for individual countries, one may notice that in many cases they do not indicate clear developmental tendencies. Therefore trend models, whose analytical form was expressed by linear, logarithmic, inverse and square transformations of measures of development and (or) the t time variable, were calculated for each country using the smallest squares method. The best results – from the perspective of the degree of adjustment of empirical data and significance of parameter assessments – were obtained using the linear trend function form

$$q_{it} = \alpha_0 + \beta_0 t, \tag{9}$$

The results of assessments are presented in Table 4.

When analysing the results of assessments of trend function parameters, one may draw a conclusion that a significant influence of the time variable on the shaping of measures of development is exerted by linear functions of the following countries: Belgium Denmark, Hungary, Germany, Spain, France, Ireland, Italy, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Sweden, Great Britain, Estonia, Latvia, Lithuania and Cyprus.

Structural parameters of linear forms of a development trend were used to determine the developmental lag of the Polish power sector between 1995 and 2004 in comparison to sectors of countries mentioned below.

The size of lag between the two A and B objects in the t period is equal to the number of time units, which have to elapse for the A object to obtain the level of development of the B object in the same period (Zeliaś 1991, p. 92). Assuming that the shaping of measures of development of both objects may be well described using linear trend functions with the following parameters:

$$\text{for the A object:} \quad m^A = \alpha_0 + \beta_0 t, \tag{10}$$

$$\text{for the B object:} \quad m^B = \alpha_i + \beta_i t, \tag{11}$$

the lag between the objects is expressed by the following formula:

$$\Delta_i t = \frac{\alpha_0 - \alpha_i}{\beta_i} + \left(\frac{\beta_0}{\beta_i} - 1 \right) \cdot t \tag{12}$$

where:

$\Delta_i(t)$ –stands for time lag expressed in years,

α_0, β_0 –are structural parameters of the linear developmental tendency of the country analysed,

α_i, β_i –are structural parameters of the linear developmental tendency of the model country.

Table 5 contains assessments of lags in the operation of the Polish power sector in relation to other countries.

The lag of Poland in relation to such countries as Lithuania, Latvia, Slovenia and Malta is relatively small and ranges from 3 to 7 years. A definitely larger developmental gap that ranges from 12 to 16 years appears between Poland and Denmark, France, Germany, Italy, Portugal and Great Britain. It is worth paying attention to the degree of the lag of the Polish power sector in relation to Belgium, Sweden and the Netherlands. Only Cyprus and Romania are outdistanced by Poland.

Table 5

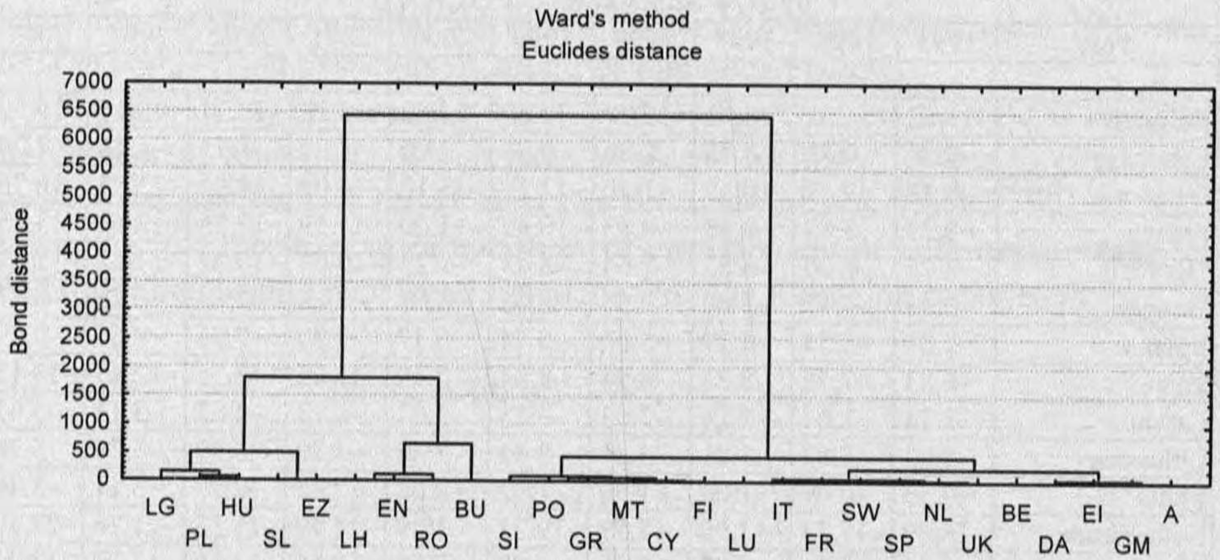
Lags in the development of the Polish power sector in relation to other selected European Union countries between 1995 and 2004

Country analysed – POLAND										
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Model countries										
Belgium	–15.62	–16.02	–16.50	–16.94	–17.39	–17.80	–18.28	–18.71	–19.16	–19.59
Cyprus	0.64	0.71	0.78	0.86	0.93	1.00	1.08	1.15	1.22	1.29
Denmark	–8.58	–9.49	–10.39	–11.30	–12.21	–13.10	–14.03	–14.94	–15.85	–16.76
France	–8.27	–8.83	–9.38	–9.93	–10.49	–11.00	–11.59	–12.15	–12.69	–13.25
Germany	–5.25	–6.04	–6.83	–7.64	–8.43	–9.23	–10.03	–10.82	–11.62	–12.42
Hungary	–3.93	–4.47	–5.00	–5.54	–6.08	–6.62	–7.16	–7.69	–8.23	–8.77
Ireland	–2.81	–3.54	–4.27	–5.00	–5.74	–6.47	–7.20	–7.93	–8.66	–9.39
Italy	–6.83	–7.54	–8.23	–8.94	–9.64	–10.30	–11.05	–11.75	–12.45	–13.15
Latvia	–1.14	–1.64	–2.14	–2.63	–3.13	–3.63	–4.13	–4.63	–5.13	–5.63
Lithuania	–3.82	–3.82	–3.81	–3.81	–3.81	–3.80	–3.80	–3.79	–3.79	–3.78
Malta	–0.35	–0.69	–1.04	–1.39	–1.73	–2.08	–2.42	–2.77	–3.11	–3.46
Netherlands	–16.69	–17.33	–17.96	–18.59	–19.23	–19.9	–20.49	–21.13	–21.76	–22.39
Portugal	–6.85	–7.46	–8.08	–8.70	–9.32	–9.94	–10.56	–11.18	–11.79	–12.41
Romania	–6.17	–4.81	–3.45	–2.11	–0.75	0.60	1.96	3.31	4.66	6.02
Slovakia	–5.14	–5.58	–6.02	–6.46	–6.90	–7.34	–7.79	–8.22	–8.66	–9.09
Slovenia	–1.59	–2.17	–2.74	–3.33	–3.91	–4.49	–5.07	–5.65	–6.23	–6.81
Spain	–0.59	–1.46	–2.32	–3.18	–4.04	–4.91	–5.77	–6.63	–7.49	–8.35
Sweden	–11.02	–11.82	–12.62	–13.42	–14.22	–15.00	–15.83	–16.63	–17.43	–18.24
United Kingdom	–6.79	–7.45	–8.12	–8.78	–9.45	–10.10	–10.77	–11.43	–12.06	–12.76

Source: own calculations.

9. CLUSTER ANALYSIS

A complement of the assessment of the level of development of power sectors of the European Union countries is the cluster analysis carried out by means of the agglomeration method of the closest contiguity to 2004. This enabled a graphical presentation – in the form of dendogram – of similarities and differences among the countries analysed from the point of view of the features analysed (see Graph 1). It is possible to clearly distinguish three groups of countries characterised by a similar level of development of the power market. The first group consists of Central and East European countries: Latvia, Poland, Hungary, Slovakia, the Czech Republic, Lithuania, Estonia, Romania and Bulgaria. The second group are the Mediterranean basin countries: Slovenia, Portugal, Greece, Malta and Cyprus. The third group comprises of: Luxembourg, Italy, France, Sweden, Spain, the Netherlands, Great Britain, Belgium, Denmark, Ireland, Germany and Austria. So geographical location as well as the climate, regional cooperation, linked electrical power systems and similar structure of the use of renewable sources of energy turned out to be important factors.



Graph 1. Dendogram of similarities and differences among the countries analysed from the point of view of development of the power market

S o u r c e: own calculations.

10. CONCLUSION

The calculations and analyses performed make it possible to formulate the following conclusions:

- Power sectors of individual countries of the European Union, despite implementation of the principles of the community power policy adopted by them, differ in organisational structure and the ways of operating and the level of development achieved.
- Finland and Denmark are considerably different from other EU countries as far as the level of development of the power market is concerned.
- This diversity results from the nature of economic development, the number of inhabitants, the climate, as well as different strategies of investing in energy sources.
- The influence of geographical location of a country on the similarity of the development of its power market in relation to neighbouring countries is also very visible.
- Estonia, Bulgaria and Greece are countries characterised by the lowest level of development of the power market in relation to other European Union member states.
- In the periods analysed the estimated values of measures of development ranked Poland twentieth (twenty third) among twenty seven countries analysed.
- Further directions of research in this sphere should take into account: expanding the time trial, supplementing the set of diagnostic variables with more features, ordering objects in the development scale using the statistical as well as the dynamic approach.

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OCENA POZIOMU ROZWOJU RYNKU ENERGII KRAJÓW UNII EUROPEJSKIEJ

W pracy podjęto próbę określenia poziomu rozwoju polskiego sektora energetycznego na tle sektorów krajów Unii Europejskiej wykorzystując do tego metody wielowymiarowej analizy porównawczej ze szczególnym uwzględnieniem analizy skupień, budowy taksonomicznego miernika rozwoju oraz określenia opóźnienia czasowego, jakim charakteryzuje się polski sektor energetyczny na tle jego odpowiedników w analizowanych krajach.

Słowa kluczowe: rynek energii Unii Europejskiej, odnawialne źródła energii, wielowymiarowa analiza porównawcza, syntetyczne mierniki rozwoju, analiza skupień.