# A COMPARATIVE ANALYSIS OF THE DEVELOPMENT OF SUSTAINABLE ENERGETIC RESOURCES IN POLAND WITH RELATION TO OTHER EU COUNTRIES

**Agata Mesjasz-Lech**

*Czestochowa University of Technology*

**Abstract:** Power engineering belongs with those industry branches which put the heaviest burden on the environment. Producing electrical power involves the emission of dust and carbon and sulphur dioxide which count as major air pollutants. That is why one of the Polish and EU energy policy goals is the environmental protection against the negative effects of energetical activity connected with electrical power production through the use of renewable energy resources. Ecoogistics provides technical and organizational decisions direction to reduce the negative effects of economic activity on the environment. In this context, the production of electricity from renewable sources will be an area of interest of eco-logistics. The present work has characterized crucial documents such as The White Book – Energy for the Future: Renewable Energy Resources, and The Green Books which determine the directions of the long-term policy and specify the quantitative goals with respect to the use of renewable energy resources. Moreover, current legal documents regulating the turnover of the energy produced from unconventional and renewable resources in Poland have been presented. Especially the law from 10 April 1997 – Energy Law (Journal of Laws, 2006, issue 89, item 625) and the Law from 2 April 2004 on the change of the laws: Energy Law and The Environmental Protection Law (Journal of Laws, issue 91, item 875). Individual European countries' energy markets differ according to the economic development specificities of those countries, their climate, numbers of citizens and diverse strategies for investments in energy resources. The work attempts also at determining the rate of development of Polish market of renewable energy resources with comparison to the EU countries. With this objective in view, following methods have been used: multidimensional comparative analysis with particular focus on the cluster analysis, building of taxonomic measure of development and determining the time delay which characterizes Polish market of renewable resources when compared to its counterparts in the analyzed countries. The database covers the 1997-2006 period and deals with such aspects as: renewable energy production with the division according to the resource it is produced from: sun, wind, water, the emission of carbon dioxide, percentage of renewable resources energy in the total use of energy, use of renewable resources of energy in different sectors (industry, services, agriculture, households, electrical power consumption). Information gathered thanks to the research can constitute the base for designing appropriate energy policy concerning the use of renewable energy resources in production of electrical power and lead to the improvement of existing sources and looking for new solutions.

**Keywords:** ecologistics, renewable energy resources, The White Book, multivariate comparative analysis, cluster analysis.

## 1. Introduction

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 [1.].
Present global energy system is predominantly based on utilization of fossil fuels, coal, oil, and natural gas and its exploitation of creates pollution on local, regional, and global scales [2.]. But there are a lot of benefits of renewable energy policies [3., 5.].
Process of electric energy production cases the big pollution of the environment. The carbon dioxide, the sulphur dioxide and dust are basic air pollution emitted as a result of electric energy production. The environmental protection against negative results of activities connected with energy production is one of purposes of the Polish energy policy, realized by power stations [6.].
Ecologistics provides technical and organizational decisions direction to reduce the negative impact of manufacturing processes on the environment. In this context, the production of electricity from renewable sources will be an area of interest of ecologistics.

## 2. The Polish power market – basic activities

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.
Guidelines with respect to the use of renewable energy sources are provided in many EU documents. Polish regulations have to be compliant with the European standards. The principles of energy policies with respect to renewable energy sources are specified in Green Books.

- Energy for the future: renewable energy resources
- Towards the European strategy for safe energy supplies,
- Energy efficiency or how to get more using less,
- European strategy for sustainable, competitive and safe energy

The White Book – Energy for the future: renewable energy sources is a key document outlining the directions of long-term policies and identifying the quantitative goal of use of renewable energy.
In order to ensure the implementation of the provisions concerning the use of renewable energy sources and specified in the white and Green Books, the following directives were approved [7.]:

- Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market (OJ EC L 283 of 27 October 2001),
- Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings (OJ EC L 1/65 of 4 January 2003),
- Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport (OJ EC L 123 of 17 May 2003),
- Council Directive 2003/54/EC of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC (OJ EC L 176/37 of 15 July 2003),
- Council Directive 2003/96/EC of 27 October 2003 on restructuring the Community framework for the taxation of energy products and electricity (OJ EC L 283/51 of 31 October 2003),

- Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EC (OJ EC L 52 of 21 February 2004),
- Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 on establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council (OJ EC L 191 of 6 July 2005),
- Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC (OJ EC L 114 of 27 April 2006).

The quantity of electric energy consumption from renewable energy sources has grown since 2001 (Figure 1.).

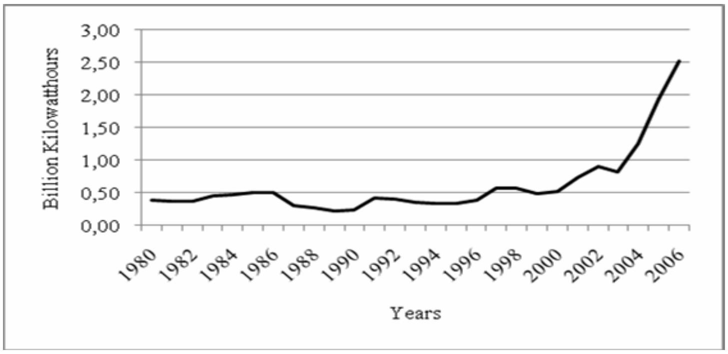


Figure 1. Net geothermal, solar, wind, and wood and
waste electric power consumption in Poland (in billion kilowatthours)
*Source: own calculation*

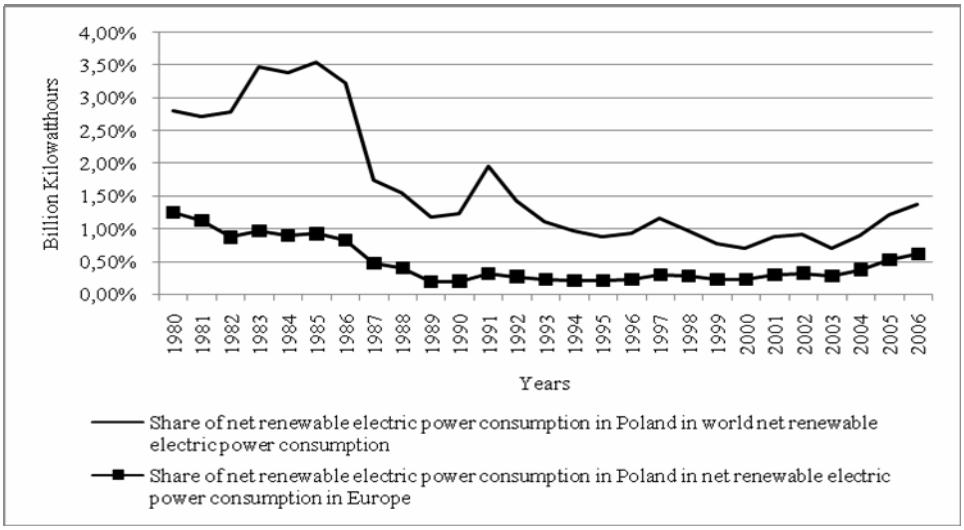


Figure 2. Share of net renewable electric power consumption in Poland
in world and European net renewable electric power consumption
*Source: own calculation*

Share of net renewable electric power consumption in Poland in world and European net renewable electric power consumption is low (it adds from 0.7% to 3.55% beside world and from 0.19% to 1.25% beside Europe) and has decreased from 1980.

## 3. Taxonomic analysis

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.
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 [8.].

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. 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:

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

where

$x_{jt}$ stands for the value of the $j$ diagnostic variable ($j = 1,\dots, m$) in the $i$ object ($i = 1,\dots, n$). An object may be a business entity, a geographical location, a period or a point in time, etc. [9.]

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 [1.].

## 4. Empirical results

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 [8.]:

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

where:

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

- the maximum value of this variable

$$\|Q\| = \max_i \{q_i\} \quad (i = 1, \ldots, n), \tag{2}$$

- the maximum statistical value of this variable

$$\|Q\| = \overline{q} + 2s_q \tag{3}$$

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

- the sum of values of the variable

$$\|Q\| = \sum_{i=1}^{n} q_i \ , \tag{4}$$

- the range of the variable

$$\|Q\| = \max_i \{q_i\} - \min_i \{q_i\} \tag{5}$$

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 (1) were determined with the assumption that the synthetic variable rate is given in formula (3), whereas realisations of the $q_i$ synthetic variable are determined using unit weights, normalisation according to formula

$$x^{'}_j = \frac{x_j - \overline{x}}{s} \tag{6}$$

where:

$x_i$ – the value of the j variable, $\overline{x}, s$ - the average and standard deviation for the j variable,

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:

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

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:

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

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

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

$X_1$ – Total National Emissions Carbon Dioxide (Thousands of tons),

$X_2$ – Share of Renewable Energy - Contribution of electricity from renewables to total electricity consumption (%),

$X_3$ – Renewable Energies Primary Production (Thousands tons of oil equivalent (TOE)),

$X_4$ – Renewable Energies Final Energy Consumption (Thousands tons of oil equivalent (TOE)),

$X_5$ – Energy Intensity of the Economy - Gross inland consumption of energy divided by GDP (at constant prices, 1995=100) - kgoe (kilogram of oil equivalent) per 1000 euro,

$X_6$ – Gross Domestic Product (Millions of euro), chain-linked volumes, reference year 2000 (at 2000 exchange rates)

$X_7$ – Primary Production Hydro Power (Thousands tons of oil equivalent (TOE)),

$X_8$ – Primary Production Wood & Wood Waste (Thousands tons of oil equivalent (TOE)),

$X_9$ – Primary production Biomass & Wastes (Thousands tons of oil equivalent (TOE)),

$X_{10}$ – Renewable Energies Final Energy Consumption - Industry (Thousands tons of oil equivalent (TOE))

$X_{11}$ – Renewable Energies Final Energy Consumption - Households (Thousands tons of oil equivalent (TOE))

$X_{12}$ – Biogas Primary Production (Thousands tons of oil equivalent (TOE)),

$X_{13}$ – Net Installed Capacity – Wind Turbines (MW).

Variables $X_1$ and $X_5$ are destimulants while the other ones are stimulants. The analysis did not cover Malta as much data is unavailable. The values of each variable were converted per capita to receive intensity ratios.

As a next step, the variables were standardised and values of a synthetic development measure were estimated for each EU country in each year of the period of 1997-2006. With such values, a ranking of EU countries was made by the extent of use of renewable energy sources. The results are presented in Tables 1. and 2.

Table 1. Results of linear classification – synthetic measure of development of the renewable energy sources in the countries of the European Union between 1997 and 2001

| 1997 | development measure | 1998 | development measure | 1999 | development measure | 2000 | development measure | 2001 | development measure |
|---|---|---|---|---|---|---|---|---|---|
| se | 0,5878 | se | 0,5734 | se | 0,5826 | se | 0,5900 | se | 0,5774 |
| fi | 0,5004 | fi | 0,5030 | fi | 0,5093 | fi | 0,5193 | fi | 0,5154 |
| at | 0,3601 | at | 0,3405 | at | 0,3567 | at | 0,3569 | at | 0,3676 |
| dk | 0,3155 | dk | 0,3142 | dk | 0,3178 | dk | 0,3227 | dk | 0,3232 |
| lv | 0,3017 | lv | 0,3097 | lv | 0,2973 | lv | 0,2819 | lv | 0,2930 |
| pt | 0,2953 | pt | 0,2815 | pt | 0,2670 | pt | 0,2741 | pt | 0,2809 |
| fr | 0,2399 | fr | 0,2326 | fr | 0,2357 | si | 0,2575 | si | 0,2537 |
| si | 0,2234 | si | 0,2101 | si | 0,2251 | fr | 0,2304 | fr | 0,2292 |
| es | 0,2138 | es | 0,2100 | es | 0,2127 | es | 0,2191 | es | 0,2280 |
| ee | 0,2068 | de | 0,2036 | de | 0,2056 | de | 0,2109 | de | 0,2181 |
| de | 0,2042 | it | 0,1975 | ee | 0,2005 | ee | 0,2038 | ee | 0,2119 |
| it | 0,1995 | ee | 0,1962 | it | 0,1974 | it | 0,1978 | it | 0,1952 |
| ie | 0,1947 | ie | 0,1959 | ie | 0,1911 | ie | 0,1915 | ie | 0,1858 |
| ro | 0,1874 | uk | 0,1891 | uk | 0,1864 | uk | 0,1857 | gr | 0,1836 |
| uk | 0,1872 | ro | 0,1777 | ro | 0,1843 | gr | 0,1803 | uk | 0,1787 |
| gr | 0,1810 | gr | 0,1737 | gr | 0,1799 | ro | 0,1747 | sk | 0,1680 |
| nl | 0,1743 | nl | 0,1679 | nl | 0,1693 | be | 0,1742 | lt | 0,1670 |
| lt | 0,1609 | lt | 0,1603 | lt | 0,1667 | nl | 0,1709 | nl | 0,1669 |
| be | 0,1540 | pl | 0,1535 | be | 0,1601 | lt | 0,1705 | be | 0,1667 |
| pl | 0,1532 | be | 0,1490 | pl | 0,1537 | pl | 0,1559 | ro | 0,1652 |
| sk | 0,1491 | sk | 0,1441 | sk | 0,1469 | sk | 0,1487 | pl | 0,1552 |
| cy | 0,1474 | cy | 0,1433 | cy | 0,1440 | cy | 0,1455 | cy | 0,1425 |
| hu | 0,1399 | lu | 0,1385 | hu | 0,1378 | hu | 0,1411 | hu | 0,1356 |
| cz | 0,1384 | hu | 0,1372 | cz | 0,1365 | lu | 0,1383 | lu | 0,1300 |
| lu | 0,1301 | cz | 0,1340 | lu | 0,1327 | cz | 0,1295 | cz | 0,1291 |
| bg | 0,1123 | bg | 0,1175 | bg | 0,1218 | bg | 0,1240 | bg | 0,1166 |

*Source: own calculations based on data from [10.]*

where:

at - Austria, be – Belgium, bg – Bulgaria, cy - Cyprus, cz - Czech Republic, dk – Denmark, ee – Estonia, fi – Finland, fr- France, de – Germany, gr – Greece, hu- Hungary, ie- Ireland, it – Italy, lv – Latvia, lt – Lithuania, lu- Luxembourg, nl – Netherlands, pl – Poland, pt- Portugal, ro – Romania, sk – Slovakia, si – Slovenia, es – Spain, se – Sweden, uk– United Kingdom.

Table 2. Results of linear classification – synthetic measure of development of the renewable energy sources in the countries of the European Union between 2002 and 2006 cont.

| 2002 | development measure | 2003 | development measure | 2004 | development measure | 2005 | development measure | 2006 | development measure |
|---|---|---|---|---|---|---|---|---|---|
| se | 0,5589 | se | 0,5878 | se | 0,5504 | se | 0,6042 | se | 0,6032 |
| fi | 0,5102 | fi | 0,5004 | fi | 0,5486 | fi | 0,5404 | fi | 0,5265 |
| at | 0,3587 | at | 0,3601 | at | 0,3596 | at | 0,3704 | at | 0,3815 |
| dk | 0,3200 | dk | 0,3155 | dk | 0,3296 | dk | 0,3404 | dk | 0,3316 |
| lv | 0,3033 | lv | 0,3017 | lv | 0,3191 | lv | 0,3306 | lv | 0,3309 |
| pt | 0,2623 | pt | 0,2953 | pt | 0,2694 | pt | 0,2718 | pt | 0,3006 |
| si | 0,2457 | fr | 0,2399 | si | 0,2544 | si | 0,2538 | de | 0,2541 |
| de | 0,2206 | si | 0,2234 | es | 0,2323 | de | 0,2438 | si | 0,2512 |
| es | 0,2176 | es | 0,2138 | de | 0,2277 | ee | 0,2335 | es | 0,2363 |
| fr | 0,2157 | ee | 0,2068 | ee | 0,2204 | es | 0,2319 | fr | 0,2208 |
| ee | 0,2124 | de | 0,2042 | fr | 0,2122 | fr | 0,2154 | ee | 0,2120 |
| ie | 0,1884 | it | 0,1995 | it | 0,1872 | ie | 0,2026 | ie | 0,2113 |
| it | 0,1876 | ie | 0,1947 | ie | 0,1872 | it | 0,1879 | it | 0,1885 |
| gr | 0,1786 | ro | 0,1874 | gr | 0,1792 | gr | 0,1851 | gr | 0,1879 |
| uk | 0,1754 | uk | 0,1872 | uk | 0,1740 | be | 0,1838 | be | 0,1829 |
| ro | 0,1672 | gr | 0,1810 | be | 0,1684 | uk | 0,1802 | uk | 0,1793 |
| lt | 0,1657 | nl | 0,1743 | ro | 0,1668 | ro | 0,1752 | nl | 0,1715 |
| sk | 0,1629 | lt | 0,1609 | lt | 0,1646 | lt | 0,1730 | cz | 0,1707 |
| nl | 0,1613 | be | 0,1540 | nl | 0,1635 | nl | 0,1715 | ro | 0,1705 |
| be | 0,1601 | pl | 0,1532 | sk | 0,1583 | cz | 0,1706 | lt | 0,1701 |
| pl | 0,1487 | sk | 0,1491 | cz | 0,1578 | sk | 0,1685 | sk | 0,1648 |
| hu | 0,1390 | cy | 0,1474 | lu | 0,1462 | pl | 0,1508 | pl | 0,1492 |
| cy | 0,1340 | hu | 0,1399 | pl | 0,1451 | hu | 0,1459 | lu | 0,1455 |
| cz | 0,1310 | cz | 0,1384 | hu | 0,1370 | lu | 0,1454 | hu | 0,1454 |
| lu | 0,1210 | lu | 0,1301 | cy | 0,1302 | cy | 0,1316 | cy | 0,1252 |
| bg | 0,1165 | bg | 0,1123 | bg | 0,1186 | bg | 0,1243 | bg | 0,1184 |

*Source: own calculations based on data from [10.]*

where:

at - Austria, be – Belgium, bg – Bulgaria, cy - Cyprus, cz - Czech Republic, dk – Denmark, ee – Estonia, fi – Finland, fr- France, de – Germany, gr – Greece, hu- Hungary, ie- Ireland, it – Italy, lv – Latvia, lt – Lithuania, lu- Luxembourg, nl – Netherlands, pl – Poland, pt- Portugal, ro – Romania, sk – Slovakia, si – Slovenia, es – Spain, se – Sweden, uk– United Kingdom.

The highest values of development measures are noted for the Scandinavian countries and for Austria while the lowest values – for Central and Eastern European countries and for Luxembourg. In the studied period, Poland was in a group of countries with the lowest level of use of renewable energy sources.
Attention should be paid to the Czech Republic and Germany which is subsequent years were progressing in the ranking and Romania which in the analysed period was clearly losing in relation to the other EU countries.
A complement of the assessment of the level of development of power sectors of the European Union countries in respect of renewable energy sources 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 dendrogram – of similarities and differences among the countries analysed from the point of view of the features analysed (see Figures 3. and 4.).

In 1997 the following groups of countries could be identified:
- Cyprus, Greece, Italy;
- the Netherlands, Belgium;
- Poland, Hungary, Slovakia, the Czech Republic,
- Slovenia, Spain, France, Portugal;
- Austria, Latvia;
- Finland, Sweden;
- Ireland, United Kingdom, Denmark.

In 2006 the groups were made up of the following countries:
- Poland, Hungary, Slovakia, Lithuania,
- Romania, Bulgaria
- Estonia, Czech Republic,
- Portugal, Slovenia,
- Latvia, Austria;
- Finland, Sweden;
- Italy, Greece, France;
- Spain, Ireland.

Both in 1997 and in 2006 the following countries were classified in one group:
- Finland and Sweden,
- Poland, Hungary and Slovakia,
- Belgium and the Netherlands,
- Austria and Latvia.

The other countries differ in terms of membership in groups of countries with a view to the development of the renewable energy market in the studied years.
In 1997 the most similar countries were Germany with Ireland, Belgium with the Netherlands and Cyprus with Greece. In 2006 – Poland with Hungary, Belgium with the Netherlands and Greece with Italy.
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.

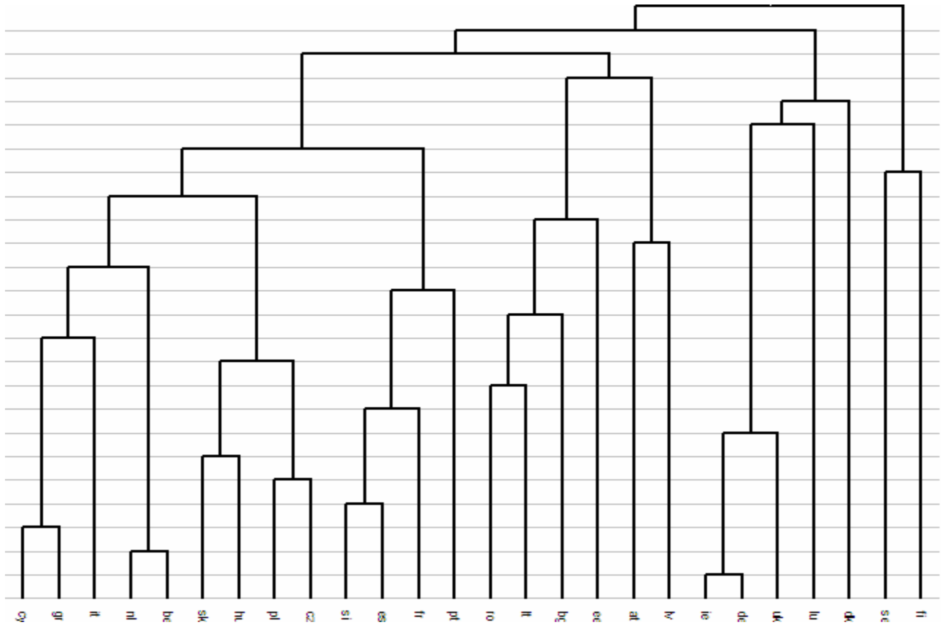

Figure 3. Dendrogram of similarities and differences among the countries analysed from the point of view of development of the power market in respect of renewable energy sources in 1997

*Source: own calculation*

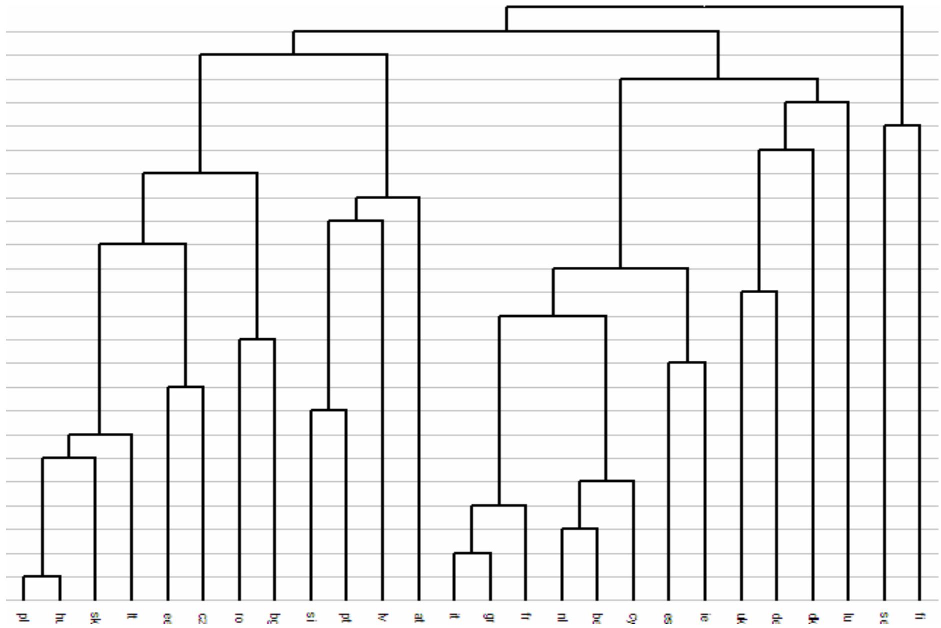

Figure 4. Dendrogram of similarities and differences among the countries analysed from the point of view of development of the power market in respect of renewable energy sources in 2006

*Source: own calculation*

## 5. Conclusions

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 in respect of renewable energy sources achieved.
- Finland and Sweden are considerably different from other EU countries as far as the level of development of the power market in respect of renewable energy sources 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.
- Czech Republic, Cyprus, Luxemburg and Bulgaria are countries characterised by the lowest level of development of the power market in respect of renewable energy sources in relation to other European Union member states.
- In the periods analysed the estimated values of measures of development ranked Poland twentieth (twenty second) among twenty six 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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