Multidimensional comparative analysis as a tool for assessing the level of development of energy markets in selected European countries

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Abstract. The most important factor affecting the economic development of societies is access to electricity at an acceptable price. The constantly developing economy generates an increasing demand for electricity. The energy resources used for energy production are diverse in the European Union countries, hence the assessment of the level of development of energy markets is a multidimensional problem. This article undertakes comparative studies on determining the level of sustainable development of energy markets in selected Member States. Sustainable development of energy markets is a phenomenon characterized by many variables that simultaneously concern various aspects including environmental, economic, technical and technological and social problems, which means that sustainable development can be described by many different variables, the number of which can reach up to several dozen. In this case, comparative analysis using traditional methods becomes impossible. The multidimensional analysis method was used to classify countries into homogeneous clusters in terms of the level of development of energy markets. Multidimensional comparative analysis, or MCA for short, deals with methods and techniques for comparing multi-feature objects. MCA is a formally coherent set of statistical methods for purposeful selection of information about elements of a certain community and detection of regularities in the mutual relations of these elements. MCA is an interdisciplinary method that uses achievements and methods used in other fields. Multivariate comparative analysis is a method in which the analysis is performed in many stages and in many directions. Research results indicate the position of the energy market development in Poland in comparison to selected Member States.

1. Introduction
The objectives of the energy policy of the European Union countries have changed over time. New goals appeared in response to the oil crises of the 1970s, which affected many countries and led to new directions in Europe's energy policy focused primarily on reducing dependence on oil. The search for new energy sources causes a dynamic development of renewable sources in the European Union and an increase in energy efficiency.
The main goal of energy policy is energy security and affordability, as well as reducing carbon dioxide emissions [1,2]. Many European energy and gas markets have been liberalized and open to competition in order to increase cost-effectiveness and lower prices for consumers.

A reasonable industrial and energy policy as well as environmental protection policy may lead to the emergence of new national industries including the development of new technologies in the energy sector [3,4]. All these circumstances make the creation of energy policy (figure 1) an increasingly complex problem in the European Union. The aim of the article is to indicate the diversity of member countries in terms of the structure of energy balances, including the energy resources used. As a result of comparative analysis, it is possible to identify similar countries in terms of energy resources used, which is an innovative contribution to the diagnosis of the current situation.

![Figure 1. The objectives of energy policy](image)

2. Methodology and Data
The characteristics of energy markets are a classic multidimensional issue, as each country can be described by a set of many variables.

The energy sector affects every area of society's life, i.e. has an impact on the economic, environmental and social sector of human activity. The IAEA initiated this indicator project in 1999 in cooperation with various international organizations, including the IEA and UNDESA, and some Member States of the IAEA. The original name was Indicators for Sustainable Energy Development (ISED). This name was later modified to Energy Indicators for Sustainable Development (EISD) to reflect the view held by some users that ‘sustainable energy development’ refers only to renewable energy and not to the broader spectrum of energy choices. International Atomic Energy Agency United Nations Organizations present an original set of 41 indicators for sustainable energy development. Sustainable energy development indicators can be included, among others, into the following groups: indicators on energy resources, efficiency of their use, environmental pollution during the exploitation of raw materials and energy production technologies, economic indicators, accessibility to energy for society, energy dependence [5].
Based on forty-one indicators, the availability of data for testing was analysed. Based on the available data in the Eurostat database, nine key diagnostic variables characterizing the energy sector of the member states were collected for the purpose of the study. The diagnostic variables are: Consumption of electric energy generated from renewables per capita (TWH/person), Hard coal consumption (million tons/person), Greenhouse gas emissions per capita, Available for final consumption Gigawatt-hour per person, Final energy consumption thousand tons of oil equivalent (TOE) per person, Petroleum available for final consumption (Gigawatt-hour), Natural gas (Terajoule gross calorific value - GCV) per person, Energy intensity of GDP (Kilograms of oil equivalent (KGOE) per thousand euro, Import dependency %. Based on these variables, a relative assessment of the level of development of the energy market was made for selected countries such as: Germany, France, Great Britain, Italy, Spain, Poland and Sweden, which are the biggest producers of energy in EU (table 1).

**Table 1. Energy production in 1990 and 2013 [tGWh]**

|       | 1 990 | 2 013 | 2013/1990 |
|-------|-------|-------|-----------|
| Germany | 508.6 | 596.7 | 17%       |
| France | 401.2 | 548.7 | 37%       |
| Great Britain | 300.1 | 341.3 | 14%       |
| Italy  | 205.1 | 278.8 | 36%       |
| Spain  | 144.6 | 274.5 | 90%       |
| Poland | 123.4 | 150.0 | 22%       |
| Sweden | 142.5 | 149.5 | 5%        |

Source: own elaboration based on: Eurostat [6]

The comparative analysis process began with a comparison of countries in terms of nine diagnostic variables that were divided into stimulants and destimulants (table 2). Data classified as stimulants should be interpreted positively if their values increase, whereas destimulants should be interpreted positively if their values decrease. To introduce the comparability of data with different dimensions and units, the data were subjected to a standardization process that allows the data to be interpreted as dimensionless. The closer the value 1 is interpreted positively, the closer the value 0 is interpreted as the value interpreted negatively. Diagnostic variables that have been subjected to the normalization process according to formulas 1 and 2 [7].

Transformation formula for stimulants:

$$ z_x = \frac{x_y - \min_x}{\max_x - \min_x} $$(1)

Transformation formula for destimulants:

$$ z_x = \frac{\max_x - x_y}{\max_x - \min_x} $$ (2)

where:

- $x_y$ - the value of the diagnostic variable
- $z_x$ - the normalized value of $x_y$
Table 2. Classification of variables into stimulants and destimulants

| Variables                                                                 | Stimulants/destimulants |
|---------------------------------------------------------------------------|-------------------------|
| 1  Consumption of electric Energy generated from renewables per capita (TWH/person), | stimulant               |
| 2  Hard coal consumption (million tons/person),                           | destimulant             |
| 3  Greenhouse gas emissions per capita,                                   | destimulant             |
| 4  Available for final consumption Gigawatt-hour per person,              | stimulant               |
| 5  Final energy consumption thousand tons of oil equivalent (TOE) per person,| stimulant               |
| 6  Petroleum available for final consumption (Gigawatt-hour),             | destimulant             |
| 7  Natural gas (Terajoule gross calorific value - GCV) per person,        | stimulant               |
| 8  Energy intensity of GDP (Kilograms of oil equivalent (KGOE) per thousand euro, | destimulant             |
| 9  Import dependency %.                                                   | destimulant             |

Source: own elaboration based on: Eurostat

3. Results and discussion

The analysis of the largest seven electricity producers among member countries is presented on radar charts, which present standardized values calculated for all member countries. Due to the transparency and readability of the data, only selected countries, i.e. countries with the largest amount of electricity production, are presented in the charts. A comparative analysis was presented for the data available on the Eurostat website for 2018.
Figure 3. Analysis of the development level of France energy market
Source: own elaboration based on data from Eurostat

Figure 4. Analysis of the development level of the UK energy market
Source: own elaboration based on data from Eurostat
Figure 5. Analysis of the development level of Italy energy market
Source: own elaboration based on data from Eurostat

Figure 6. Analysis of the development level of Spain energy market
Source: own elaboration based on data from Eurostat
As shown in the graphs, five countries in the studied group have got significant similarity in terms of nine diagnostic variables, i.e. Germany, France, UK, Italy and Spain (figure 2-8). In terms of energy market development, Poland and Sweden differ significantly from these countries.

The structure of energy sources used in Europe differs slightly from the world structure. In recent years, renewable energy sources (RES) have increased their share in the European energy balance, competing with coal, oil, gas and nuclear energy [8, 9]. Currently, new directives related to the integration of energy markets and environmental protection are implemented in the European Union, which have a significant impact on the shape of energy policy in the member countries. The most important of them are: Directive on uniform rules for the internal market in electricity (2003/54/EC),
Directive on uniform rules for the internal market in natural gas (2003/55/EC), Directive on integrated pollution prevention and control (96/91/EC), Directive on the reduction of emissions from large combustion plants (2001/80/EC), Directive on the promotion of renewable energy sources (2001/77/EC), Directive on the promotion of electricity generation in combination with heat generation (2004/8/EC) and many others.

The impact of these regulations on functioning energy and fuel sectors is a challenge for both mining and energy companies in Poland [10-12].

The most unique situation concerns the energy market in Poland in relation to other European Union countries studied, consisting in the highest level of coal use in the energy structure (about 80%). The energy structure of Poland requires a transformation in order to increase the share of renewable sources in the structure in accordance with adopted directives by 2030 [13-16].

4. Conclusions
As shown in presented research, multivariate analysis tools play an important role in describing the phenomena characterized by many diagnostic variables that can be clearly displayed in graphical form. The presented multidimensional analysis of selected European Union countries shows a significant similarity in terms of the level of development of energy markets for highly developed countries such as: Germany, France, UK, Italy, Spain and Sweden. The situation of Poland against the background of selected countries is significantly different from them.

A more detailed analysis was presented in the Ziolo et.al research, which showed significant differences between the Member States in terms of the impact of financial aspects on the environmental dimension, distinguishing between developed countries and converging economies.

The results of the analyses carried out show the significant diversity of Member States in terms of energy markets, the energy transformation process is, therefore, complex and the pace of change should be varied, what is more so as energy markets have a strong impact on the economic situation in the countries. This paper shows that all member countries are significantly diversified in terms of energy, i.e. they use different energy resources in their energy mix structure and energy generation technologies available in the country, therefore, a direct comparative analysis of the progress of countries in the pursuit of the energy transformation is a complex problem.

The demonstrated diversity in terms of the level of development of energy markets should contribute to demonstrating diverse recommendations for meeting the 2030 environmental goals tailored for individual groups of the Member States similar in terms of selected criteria.

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