The analysis of changes in the distribution of renewable energy consumption in the EU countries

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Abstract

The main research objective of the paper is to evaluate the changes in the distribution of renewable energy sources (RES) in the period between 1995 and 2014. The share of RES in total primary energy supply in the analysed period increase twofold (from 8% in 1995 to 16% in 2014). Thus, it might be interesting to check which types of RES develop more than others. Principal component analysis (PCA) is used to describe the share of different RES in overall renewable energy (RE) in EU member countries in the period between 1995 and 2014. The results of analysis for the year 1995 are compared with the results obtained for the year 2014, and the comparison indicates which RES gain in importance during the last 20 years. PCA also allows for describing RE development and identifying the direction of progress in this area, including progress resulting from technological advances. The main types of RES include: hydropower, wind energy, solar energy, tide, wave and ocean, biomass and renewable wastes and geothermal sources. The analysis demonstrates that three types of RES - hydropower, bioenergy and geothermal energy - predominate in analysed European countries in 1995. During the next years the share of RE in the energy mix increases, and the distribution of RES changes, with a notable increase of the share of wind and solar energy in the overall share of RES.

Keywords: *Renewable energy, European Union, PCA*

JEL Classification: C38, N740, Q2

1 Introduction

The EU dependence on import of energy sources contributes to the growing interest in renewable energy sources (hereafter RES), which is reflected in the introduction of relevant directives in the area of energy policy. The first one, issued in 2001, Directive 2001/77/EC[2], aimed at obtaining 7.5% share of energy from RES in the total gross electricity consumption in 2010 and 5.75% share of biofuels in the consumption of transport fuels. Another, Directive 2003/30/EC[3], aimed at the promotion of the use of biofuels and other renewable fuels for transport. In accordance with Directive 2009/28/EC[4], the EU member countries should

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[2] Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from RES in the internal electricity market.

[3] 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.

[4] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources.

increase their share of energy from renewable sources in the overall energy consumption. The European climate and energy package includes targets for 2020: a 20% reduction in the EU greenhouse gas emissions below the 1990 levels, raising the share of the EU energy consumption produced from RES to 20%, and a 20% improvement in the EU's energy efficiency. Additionally, at least 10% of the final consumption of energy in transport should come from RES. Although over the last 20 years the share of RES in the energy mix increases on average from 8% to almost 16%, it should be noted that the speed of development of RES is not the same in all EU countries.

Literature reports numerous studies on the development of renewable energy (for example, Sen nad Ganguly, 2017), but they often focus on individual countries (Dunjić et al., 2016, Câmpeanu and Pencea, 2014, Zakery et al., 2015) or only on electricity (Paska and Surma, 2014). Moreover, these papers do not review current changes in the structure of energy generated from renewable sources, especially with the use of methods capturing the most important factors of these changes. The study described in the paper is based on principal component analysis (PCA hereafter), which is used to describe different shares of RES in overall RE. The results of the analysis for the year 1995 are compared with the results obtained for the year 2014, which reveals which RES gain in importance during the last 20 years. PCA also allows for describing RE development and identifying the direction of progress in this area, including progress resulting from technological advances.

The aim of the paper is to evaluate the changes in the distribution of RES in the period between 1995 and 2014.

The study is conducted for 26 EU countries, excluding Malta and Cyprus, due to their almost non-existent share of RE in TPES, and the fact that they are totally dependent on import of energy sources.

Choosing the year 1995 as a reference point is dictated by the fact that it was the year in which the EU initiated legal procedures aimed at promoting RE development. That year the European Commission published *Green Paper*[5], which delineates the European Union energy policy and lists three basis targets connected with gas and electricity monopolies. It was also the year in which another official document, *White Paper. An Energy Policy for the European Union*[6], was issued by the Commission of the European communities. It contains a detailed

[5] Green Paper: For a European Union Energy Policy. European Commission, COM(94) 659, Brussels 1995.
[6] White Paper: An Energy Policy for the European Union. COM (95) 682 final, 13 December 1995.

set of regulations within the area of energy policy and states general frameworks of this policy in the EU countries (i.e. globalisation of energy markets, ecological problems, technology, institutional responsibility of the community, etc.).

The remainder of the paper is organized as follows. Section 2 briefly presents the empirical methodology used in the study, the description of the data can be found in Section 3, Section 4 reports and comments on the empirical results, and the last section contains final conclusions.

2 Methodology and data

The study compares the distribution of RES in the EU countries in the year 1995 and the year 2014. In order to capture correlations between different sources of RE, the distribution is obtained via classical principal component analysis (PCA).

PCA is normally applied as a method of variable reduction or for the detection of the structure of the relationship among variables. The information available in a group of variables is summarized by a number of mutually independent principal components. Each principal is basically the weighted average of the underlying variables. The first principal component always has the maximum variance for any of the combinations. If more than one principal component is generated, they are uncorrelated. For each principal component the eigenvalue (variance) indicates the percentage of variation in the total data explained.

The empirical analysis is conducted using the data which describe the share of RES in TPES in a sample of 26 European Union member states: Austria, Belgium, Bulgaria, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, Hungary, Greece, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. The analysis covers the period between 1995 and 2014, and the data are obtained from the European Commission websites[7]. The study does not include Cyprus and Malta due to the fact that, in the analysed period, the share of RES in TPES in these countries is almost zero.

The dataset demonstrates the share of RES in overall RE. The main types of RES include: hydropower (HYDRO), wind energy (WIND), solar energy (SOLAR), tide, wave and ocean (TIDE), biomass and renewable wastes (BIOMASS), and geothermal sources (GEOTHERMAL).

[7] Energy datasheets: EU-28 countries (https://ec.europa.eu/energy/en/data-analysis/country, accessed on 30.10.2016 r.

3 Results

A detailed description of variables is provided in Table 1. As the table demonstrates, the share of RES in the period between 1995 and 2014 is not stable. Biomass constitutes the greatest share in overall RE: both in 1995 and in 2014 its share in the EU is on average 69%. The second most common RES is hydropower, whose share in overall RE decreases from 28% in 1995 to almost 15% in 2014. A substantial increase can be noticed in the share of wind energy, whose average share in overall RE for the EU countries increases from 0,6% in 1995 to almost 10% in 2014. The greatest, over a tenfold, growth can be noticed in the average use of solar energy: in 1995 solar energy in the EU constitutes only 0.4% of overall RE, while 20 years later - over 4%.

	Mean		**Min**		**Max**		**SD**	
Variable/year	**1995**	**2014**	**1995**	**2014**	**1995**	**2014**	**1995**	**2014**
HYDRO	0.2750	0.1463	0.0000	0.0002	0.8434	0.4278	0.2072	0.1311
WIND	0.0064	0.0993	0.0000	0.0000	0.0778	0.4599	0.0163	0.1038
SOLAR	0.0040	0.0428	0.0000	0.0000	0.0636	0.2118	0.0121	0.0520
TIDE	0.0001	0.0001	0.0000	0.0000	0.0026	0.0019	0.0005	0.0004
BIOMASS	0.6937	0.6962	0.1566	0.3828	1.0000	0.9371	0.2226	0.1623
GEOTHERMAL	0.0207	0.0154	0.0000	0.0000	0.4103	0.1975	0.0802	0.0392

Table 1. Summary statistics – the share of renewable energy sources in the renewable energy mix.

As mentioned above, the share of RES in TPES in the analysed period increases twofold (from 8% in 1995 to 16% in 2014). Thus, it might be interesting to check which types of RES develop more than others. To do so, we use PCA to describe and compare the distribution of RES. Table 4 presents the results of PCA for RES in 1995 and 2014.

In 1995 only two first principal components are sufficient to explain about 92% of variance in the original variables. The results also demonstrate that in 1995 these two principal components depend on the combinations of only three types of RES: hydropower, biomass and geothermal. In 2014, however, it is necessary to use three first principal components to explain 90% of total variance in the original variables. These principal components depend on the combinations of all types of RES, excluding tide. These results indicate that the distribution of RES in the EU countries changed dramatically over the last 20 years.

The results obtained for 1995, (Table 2) reveal that the first principal component ($PC_{95}1$) is related to two types of RES: biomass and hydropower. Hydropower is positively correlated with the first principal component ($PC_{95}1$), while biomass is negatively correlated with this component ($PC_{95}1$). It means that in 1995 the first principal component ($PC_{95}1$) divides the European countries into the ones which use hydropower but not biomass and the ones which use biomass but not hydropower as their main type of RES.

	$PC_{95}1$	**$PC_{95}2$**	**$PC_{95}3$**	**$PC_{95}4$**	**$PC_{95}5$**	**$PC_{95}6$**
HYDRO	0.675	0.471	-0.326	0.128	0.183	0.408
WIND			0.755	0.48	0.182	0.408
SOLAR			0.277	-0.851	0.182	0.408
TIDE					-0.913	0.408
BIOMASS	-0.734	0.349	-0.353	0.121	0.183	0.408
GEOTHERMAL		-0.810	-0.350	0.121	0.183	0.408
Cumulative variance	0.703	0.924	0.969	0.999	1.000	1.000

Table 2. Principal component analysis for renewable energy sources in 1995.

However, in 2014 (Table 3) the first principal component ($PC_{14}1$) differentiates the countries which either use a lot of hydropower and wind energy as their main types of RES but little biomass or the ones which use little hydropower and wind energy and a lot of bioenergy. In 1995 three types of RES - hydropower, biomass and geothermal energy - are correlated with the second principal component ($PC_{95}2$). However, hydropower and biomass are positively and geothermal energy is negatively correlated with the second principal component ($PC_{95}2$). It means that the European countries which use hydropower and bioenergy as their main type of RES and do not use geothermal energy (or vice versa) are described by the second principal component ($PC_{95}2$). However, in 2014 the highest value of the factor loadings for the second principal component ($PC_{14}2$) is obtained for hydropower and wind energy. The component also depends on the combination of solar, biomass and geothermal energy. Thus, the second principal component ($PC_{14}2$) characterizes the countries which use hydropower as their main type of RES and do not use wind energy (or vice versa). The third principal component ($PC_{14}3$) indicates these European countries which use solar as well as geothermal energy as their main types of RES and use small shares (less than average) of other RES.

	PC$_{14}$1	PC$_{14}$2	PC$_{14}$3	PC$_{14}$4	PC$_{14}$5	PC$_{14}$6
HYDRO	0.533	0.608	-0.355	-0.143	0.183	0.408
WIND	0.150	-0.745	-0.470		0.182	0.408
SOLAR		-0.127	0.706	-0.525	0.182	0.408
TIDE					-0.913	0.408
BIOMASS	-0.826	-0.212	-0.212	-0.120	0.183	0.408
GEOTHERMAL		0.331	0.331	0.830	0.183	0.408
Cumulative variance	0.461	0.768	0.904	0.999	1.000	1.000

Table 3. Principal component analysis for renewable energy sources in 2014.

Fig. 1 presents the results of PCA for RES in 1995 and Fig. 2 presents the results in 2014.

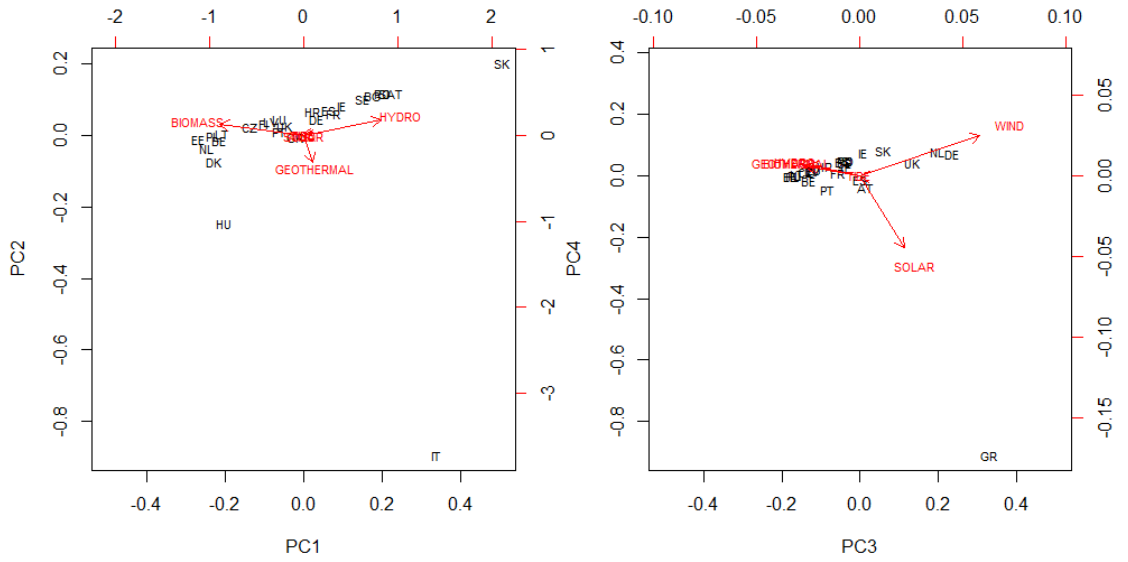

Fig. 1. The results of PCA for renewable energy sources in 1995.

The results demonstrated in Fig. 1 reveal a large concentration of most countries close to the average values of all variables. There are, however, some exceptions: Italy, Greece, and Slovakia are the countries which drive large values of the second, first and fourth principal component, respectively. In 1995 in most EU countries biomass and hydropower are the main types of RES. Slovakia and Italy has the highest share of hydropower in RES and, at the same time, a low share of biomass. Estonia, Netherlands, Poland, Denmark, Belgium, and Lithuania

display a high share of biomass and a low share of hydropower. Variance of the second principal component results from a high share of geothermal energy in total RES in Italy (about 40%) and in Hungary (10%). Greece stands out from other countries due to its relatively high share of renewable energy obtained from solar energy (6% share of solar energy in RES in Greece, which is 10 times more that in Germany, the forerunner). On the other hand, Denmark is characterised by a relatively high share of wind energy (2%) in its RE mix.

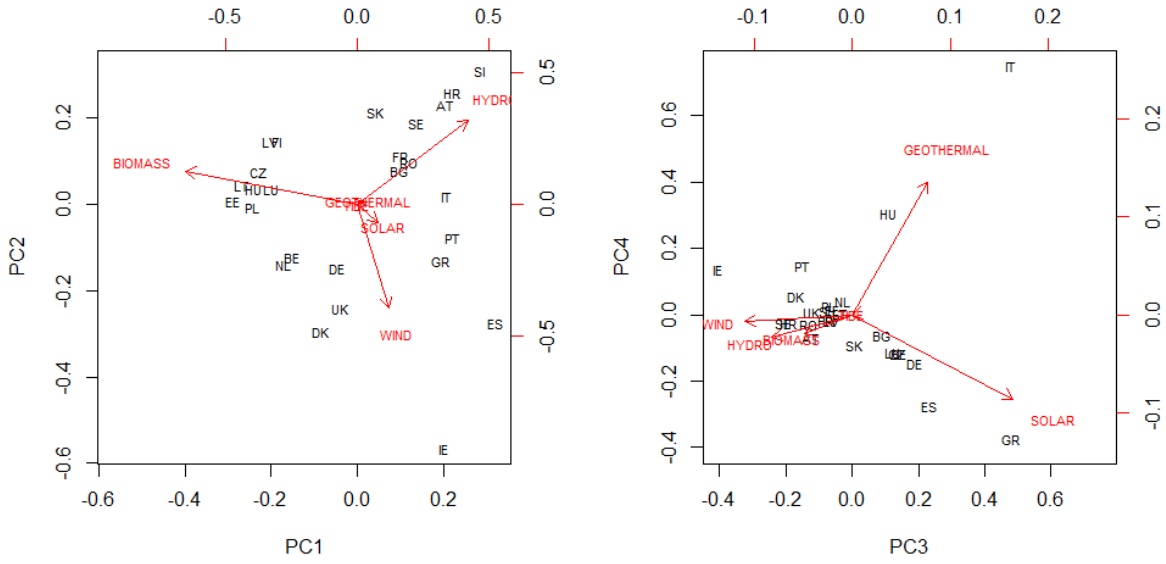

Fig. 2. The results of PCA for renewable energy sources in 2014.

Fig. 2 reveals a significantly greater diversity in the shares of different types of RES in the EU countries in 2014 than in 1995. There is a group of countries with high shares of biomass as their RES but small shares of hydropower (Estonia, Lithuania, Poland, Hungary, Czech Republic). Another group is characterised by an opposite distribution of RES, i.e. a low share of biomass and a large share of hydropower (Spain, Slovenia, Croatia, Portugal). In many European countries (Ireland, Denmark, Spain, United Kingdom) in the analysed period the share of wind energy as a renewable energy source increases. As far as solar energy is concerned, Greece maintains its leading position, while geothermal energy again is the most important energy source in Italy (in comparison to other countries).

Conclusion

The analysis reveals that RE development in the EU member countries is relatively diverse. In the analysed period all EU countries increase their shares of RES in the energy mix, however, this increase is uneven, and the shares of particular RES in particular countries are not the same.

Three types of RES - hydropower, bioenergy and geothermal energy - predominate in analysed European countries in 1995, which can be divided into the ones which use hydropower but not biomass and the ones which use biomass but not hydropower as their main type of RES. During the next years the share of RE in the energy mix increases and the distribution of RES changes, with a notable increase of the share of wind and solar energy in the overall share of RES.

The results from 1995 reveal a large concentration of most countries close to average values of all variables, while the results from 2014 reveal a significantly greater diversity in the shares of different types of RES in the EU countries than in 1995. It is possible to single out individual countries which use only one specific source of renewable energy, e.g. Italy uses geothermal energy, and Greece uses solar energy.

The changes in the distribution of renewable energy include not only the increase in the share of RE in the energy mix in the EU member states but also the kinds of RE used by them. During the last 20 years technological progress has allowed for using such renewable energy sources as wind or the sun, which, together with decreasing costs of investment in new sources is conductive to the stability of economy.

It should be mentioned that the project of the new directive regarding renewable energy sources (Renewable Energy Directive – RED II) for the period 2020 – 2030 advocates withdrawal from promoting the first generation biofuels as a renewable energy source (unless it is used in high-efficiency cogeneration), which means that biomass is treated differently than other RES.

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