

Evolution of renewable energy consumption in the European countries

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Abstract. This study performs an exploratory analysis of the evolution of consumption of RES for EU28 countries over the ten years studied. Through the analysis, the document presents: the consumption by sectors of production and by renewable energy sources, analyses the evolution of consumption from RES: between countries and regions. Regarding the consumption of RES, it is increasing, reaching in 2017 compared to 2008 to increase by 147.8%.

1. Introduction

Renewable energy sources have become increasingly important in recent years due to the negative consequences of energy consumption using fossil fuels (climate change, price increases in energy consumption, greenhouse effect, etc.) but also government policies favourable to renewable energy consumption. The Special Report on Renewable Energy Sources and Climate Change Mitigation [1] shows that the increase in greenhouse gases has resulted from the provision of energy services and the effects of renewable energy consumption lead to lower greenhouse gas emissions. greenhouse gases [2-3], sustainable development, energy security and reducing the impact on the environment and health [4].

Thus, it is found that most states are trying to develop policies that support the consumption of energy from renewable sources, both at the level of the household consumer and at the level of the industrial consumer. The economic development of the countries and the increase of the living standard show us more and more the energy dependence and the increased need to find substitutes that will allow the access to the consumption and the assurance that it will be able to be realized in the long term [5-6]. For this, scientists have faced various challenges to support the consumption of renewable energy and technological progress has made it possible to obtain solutions to ensure storage, eliminate frequency fluctuations, connection to the network, technical solutions that are constantly improving [7-8].

The objectives of the article are: (1) to discuss the perspectives of consumption from renewables energies in EU28 countries; (2) to indicate the differences between regions of Europe regarding the consumption of RES. The paper aims to present an overall analysis of the different types of renewable energy sources, in terms of consumption, using data existing in the Eurostat database, obtaining a comparison with the results recorded in 2008-2012-2017, for EU countries 28.



2. Material and method

A comparative analysis of the countries of the EU was carried out using the following indicators: energy consumption by activity sectors, electricity obtained according to the renewable energy source (hydro, wind, solar, solid biofuels, all others renewables), energy consumption by total energy and from renewable energy, consumption by consumption categories (electricity, heating and cooling and transport), real GDP per capita and Turnover per capita.

Real GDP per capita was calculated as the ratio of real GDP to the average one-year population. GDP measures the value of the total final output of goods and services produced by an economy over a given period. It includes all goods and services that have a market and all products or services of general government and non-profit institutions. This indicator allows the measurement of the economic activity in a country and shows us the level of development, respectively the standard of living (material) that exists in that country.

The indicator Turnover per capita includes the total income from sales (excluding VAT) of goods and services made by enterprises during a calendar year which were calculated by reference to the average number of inhabitants in that country. The evolution of this indicator may be upward due to the increase in revenues, respectively production, which could justify the increase in energy consumption in some countries.

3. Energy consumption

According to the International Energy Agency [9], global energy demand increased in 2017 compared to 2016 by 2.1%, compared to the average increase of 0.9% recorded in the last 5 years, which is due to 40% of China and India. At the level of fossil fuels the increase was found in oil (1.6% barrels / day, in 2017 compared to the rate of 1% in the last decade), in natural gas (3%, of which 30% for China) and in coal (increase of 1%, reversing the downward trend of the last two years, being determined by the demand in Asia).

In order to observe the effects of the steps initiated by the countries of the EU 28, vis-à-vis the energy consumption was realized Figure 1, where the final demand for energy by consumption sectors is presented.

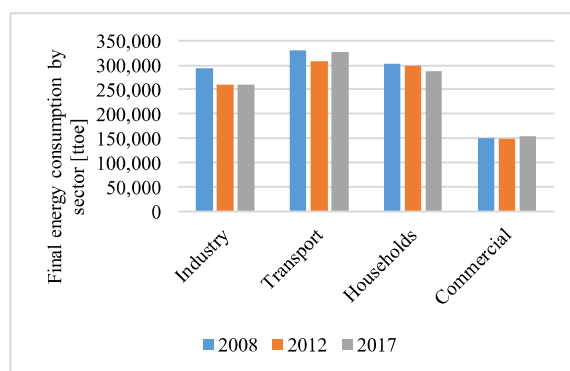


Figure 1. Final demand for energy by consumption sectors

Source: Processed by authors based on data from Eurostat

From the analysis of Figure 1 it can be observed that in 2017 compared to the year 2008 the total energy demand for consumption by sectors, measured in thousand tons of oil equivalent (ttoe), decreased in EU

28 countries by 4.4% (from 1,077,346.68 ttoe in 2008 to 1,029,924.44 ttoe in 2017). The largest decrease was recorded in the industry of 11.07% (32,486.5 ttoe), in households of 5.05% (15,327.7 ttoe), in transport of 1.07% (3,536.68 ttoe). An increase was registered only in the commercial sector of 2.62% (3,928.64 ttoe).

If we analyse the changes from 2017 compared to 2008, they notice that the weights regarding the distribution within the year by sectors have changed as well, so we have a decrease of the weight in the industry sectors of 1.90%, followed by households of 0.19% and an increase in the sectors: transport of 1.07% and commercial of 1.02%.

3.1. Renewable electricity share of total electricity output

Energy generation has increased worldwide by 3.1%, i.e. 780 TWh in 2017, as electricity demand has grown faster than global demand for other energies [9]. This increase is explained both as a result of increased demand for electricity in emerging economies and as a result of the electrification of new areas (China 6% as a result of global warming, India 12%, as a result of electrification and a 10% increase registered in other emerging economies in Asia).

3.1.1. Hydro

This is considered a clean energy resource, which does not produce residual products that cause acid rain or greenhouse gases. The development of hydropower is considered important because it helps to mitigate the energy crisis and largely removes the effects of environmental pollution. Hydropower plants have several advantages over other energy sources, among which we mention: high level of reliability, high efficiency, low operating and maintenance costs, adaptability to load changes. Among the disadvantages we mention: the high initial costs of the installations, the dependence on rainfall, the change of the flow level that affects the flora and fauna of the area, sometimes leading to the flooding of the land and the habitat [10]. The energy obtained from the Hydro source is the oldest renewable energy (used since ancient times), which has relatively low costs, but also the largest use worldwide [10]. This energy is considered to have less harmful effects on the environment, because it does not generate pollution and does not require water consumption for cooling [11-14].

In 2017, worldwide hydroelectric power production increased by 22%, with 40% of the increase being registered by the US while in the EU it decreased [13].

The study shows that in the EU countries 28 the situation remains constant at this type of energy source, for electricity, during the 10 years analysed, comparing the year 2008 (29,640.63 ktoe), 2012 (29,946.87 ktoe) and 2017 (30,001.7 ktoe).

Figure 2 shows the distribution of the electricity production generated by the Hydro source, for each country expressed as a share in the total renewable energy production from the Hydro source, from the 28 countries studied.

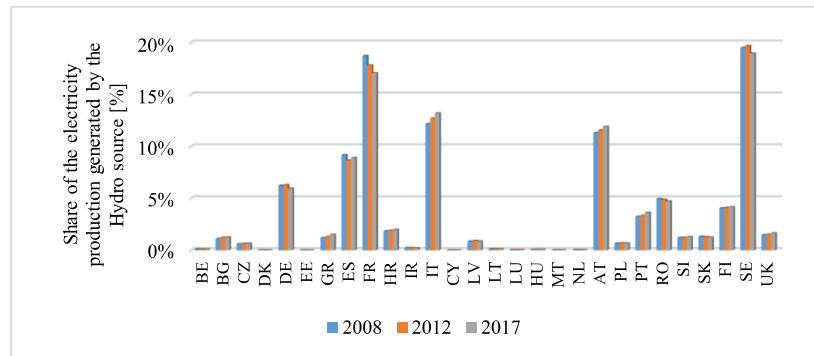


Figure 2. Distribution of electricity from the Hydro source
Source: Processed by authors based on data from Eurostat

From the analysis of Figure 2 it is found that the countries that generate the most energy for electricity from the Hydro source are: Sweden (2008: 19.49%; 2012: 19.67%; 2017: 18.96%), France (2008: 18.71%; 2012: 17.80%; 2017: 17.06%), Italy (2008: 12.17%; 2012: 12.67%; 2017: 13.20%), Austria (2008: 11.3%; 2012: 11.55%; 2017: 11.90%). In some countries the total share decreased which is correlated with the decrease in production: Sweden (98.43%) and France (92.29%), and in other countries the production increased: Italy (109.78%) and Austria (106.61%), which means that the decrease in the total share is due to the increase in production in other countries.

However, the decrease in energy from the Hydro source into nine country could be explained and by the climate changes recorded in recent years, as a result of global warming that led to lower rainfall and higher temperatures. The negative impact of climate change on hydropower in regions dominated by climate oscillations is supported and demonstrated by various studies [15-18]. On the other hand, due to the high dependence of the Hydro source on water resources, the large investments required for the creation of new reservoirs are difficult to support for the countries with emerging economies (Eastern Europe), these countries managing to limit themselves only to the management of the old and that is why in these countries a cause of production decline could be this too.

3.1.2. Wind

If at first wind energy was used as mechanical energy, then it could be transformed through modern wind turbines into electricity [14-16]. Thus, today's modern wind turbines can produce electricity from 50-60 KW up to 500-1500 KW. Worldwide, according to IEA, the electricity produced from the renewable source: Wind registered the highest increase of 36%, China contributing with a combined increase of solar and wind energy of 40% [1]. This increase is due to the location of new record capacities to produce this type of energy and as a result of reducing some losses. In the EU there was 15.6 GW (of which 3.1 GW was offshore), with the world capacity reaching 510 GW [9].

From the analysis of renewable energy produced with the help of the wind in the countries of the EU28 this has tripled in the 10 years studied (2008: 10,092.83 ktoe; 2012: 17,134.57 ktoe; 2017: 29,814.49 ktoe). Figure 3 shows the distribution of the share of the electricity production from the Wind source for each country expressed as a share in the total renewable energy production from the Wind source, from the 28 countries studied.

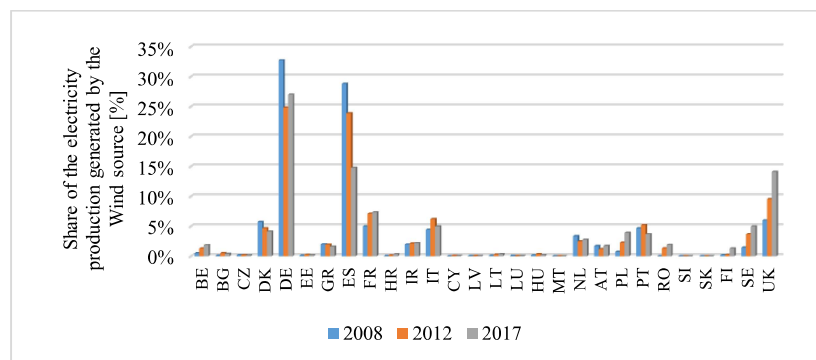


Figure 3. Distribution of the electricity production from Wind sources
Source: Processed by authors based on data from Eurostat

From the analysis of Figure 3 it is found that the countries that generate the most electricity production from the Wind source are: Germany (2008: 32.7%; 2012: 24.8%; 2017: 27%), Spain (2008: 28.8%; 2012: 23.90%; 2017: 14.8%), United Kingdom (2008: 6%; 2012: 9.6%; 2017: 14.1%), France (2008: 5%; 2012: 7.1%; 2017: 7.3%). Although in some countries the share of total decreased, the production registered a significant increase in 2017 compared to 2008: Germany (243.97%), Spain (151.54%), United Kingdom (693.45%) and France (434.65%).

The fluctuations in energy production from the Wind source can be explained as a result of the climate changes that led to the change of the wind speed in certain geographical areas, a fact also explained by some studies [21-22].

3.1.3. Solar

The solar energy source was one of the most promising energies that was considered to have the greatest contribution in reducing the energy crisis [23-25]. With the development of photovoltaic technology, the exploitation of this energy source has increased continuously [26-28].

The electricity produced from the solar renewable source is obtained with the help of photovoltaic installations. The solar source is considered an environmentally friendly renewable resource that allows to obtain the energy needed for heating or cooling a home as well as to produce electricity [29-32].

Worldwide, the electricity produced from the photovoltaic source registered an increase of 27%, and a large part of this increase is attributed to China [9].

Analysing electricity, from renewable solar source, at the level of the countries of the EU28 it has increased about 16 times in the 10 years studied (from 640.96 ktoe in 2008 to 10,265.91 ktoe in 2017).

Figure 4 shows the distribution of the electricity generated by the Solar source for each country expressed as a share in the total renewable energy production from the Solar source, from the 28 countries studied.

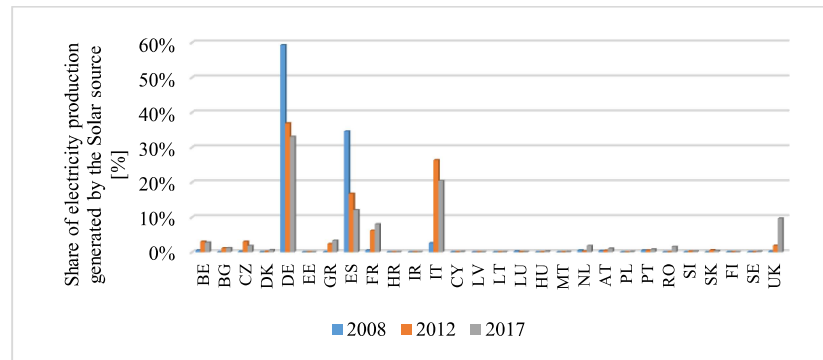


Figure 4. Distribution of the electricity production from the Solar source
Source: Processed by authors based on data from Eurostat

From the analysis of Figure 4 it is found that the countries that generate the most electricity from the Solar source for electricity are: Germany (2008: 59.29%; 2012: 36.88%; 2017: 33%), Spain (2008: 34.58%; 2012: 16.73%; 2017: 12.06%), Italy (2008: 2.59%; 2012: 26.37%; 2017: 20.42%), United Kingdom (2008: 0.23%; 2012: 1.89%; 2017: 9.65%). Thus, it is found that in some countries it is decreasing while in others it is increasing. And at this source it is found that the decrease in the total share in 2017 compared to 2008 shows the appearance or increase of production in other countries. Thus, in the countries mentioned above, it is found that production registered a significant increase from one year to another: Germany (891.43%), Spain (558.49%), Italy (12,633.33%), United Kingdom (67,793.35%)

In the studies [31,8], it is emphasized that the production of energy from the solar source has become competitive in the regions with favourable geological conditions. However, the results obtained in Table 9 show us that the production of solar energy in large quantities is found only in 3 countries in Europe, which shows us that the high prices of the technology and the low efficiency, as well as the deficiencies from the infrastructure are factors that are still an impediment for the exploitation of this renewable energy source.

3.1.4. Solid biofuels

Electric energy obtained from solid biofuels is an energy obtained from renewable sources, which has grown in recent years. Worldwide energy production from biofuels increased by 2% [9]. The energy obtained with the help of biofuels also registered an increase especially in the field of transport but also of electricity [30-32].

In the countries of the EU28 there is a doubling of the electricity production from solid biofuels, during the 10 years studied (2008: 4,816.85 ktoe; 2012: 6,866.33 ktoe; 2017: 8,140.62 ktoe).

Figure 5 shows the distribution of electricity production generated by the Solid biofuels source for each country expressed as a share in the total renewable energy production from “Solid biofuels” source, from the 28 countries studied.

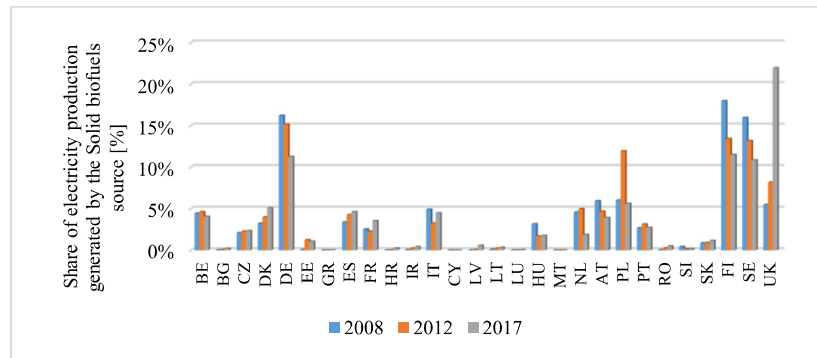


Figure 5. Distribution of the electricity production from the Solid biofuels source
Source: Processed by authors based on data from Eurostat

From the analysis of Figure 5 it is found that the countries that generate the most electricity from the Solid biofuels source are: United Kingdom (2008: 5.47%; 2012: 8.16%; 2017: 21.93%), Finland (2008: 17.96%; 2012: 13.41 %; 2017: 11.50%), Germany (2008: 16.2%; 2012: 15.14%; 2017: 11.26%), and Sweden (2008: 15.94%; 2012: 13.16%; 2017: 10.83%). In all these countries there is an increase in production in 2017 compared to 2008 even if the total share decreased as follows: United Kingdom (677.96%), Finland (108.21%), Germany (117.43%), and Sweden (114.76 %). According to the results of Figure 5, only 4 countries register values of more than 10% as a share of energy from solid fuels, and of these in 3 countries there is a decrease of share of production from country in total production from UE in 2017.

In order to use energy production on a larger scale from the source Solid fuels a decisive role will have to have the technical innovation that will allow in the future the solid biofuel densification and the creation of biofuels that will offer higher temperatures and with lower acquisition costs [33-34].

3.1.5. All other renewables

By the electricity produced from other renewable sources we mean the electricity produced by: Gaseous and liquid biofuels, renewable municipal waste, geothermal, and tide, wave & ocean. According to IEA: European Union, China and India contributed with the 82% to the global growth of energy from the bio source [9].

As a result of the increase of population density in the big cities but also as a result of the increase of the standard of living, an increase of the waste is observed, and their management has become a necessity of the modern society [35-37]. Solid waste is an important source of energy in large cities and urban governance and public-private partnership play a decisive role in their management [38-40].

In the countries of the EU28 it is found that the electricity produced from other renewable energy sources doubled during the ten years studied (2008: 4,092.80 ktoe and 2017: 8,458.97 ktoe).

Figure 6 shows the distribution of the electricity production obtained from the "All other renewable" source for each country expressed as a share in the total renewable energy production from the All other renewable source, from the 28 countries studied.

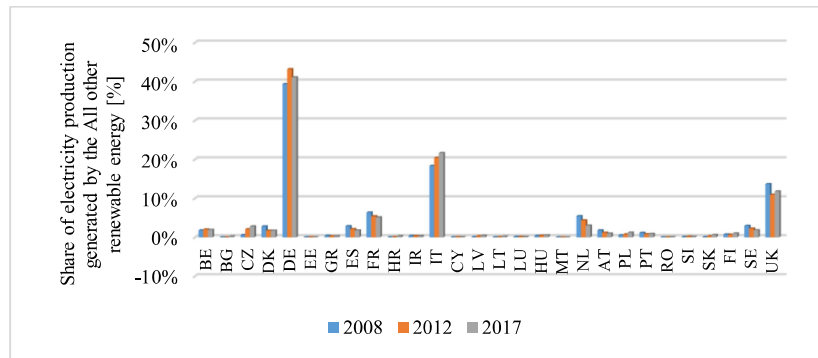


Figure 6. Distribution of the electricity production from the source All other renewable energy
Source: Processed by authors based on data from Eurostat

From the analysis of Figure 6, it is found that the countries that generate the most electricity from solid fuels are: Germany (2008: 39.4%; 2012: 43.2%; 2017: 41.1%), Italy (2008: 18.4%; 2012: 20.4%; 2017: 21.60%), United Kingdom (2008: 13.7%; 2012: 10.9%; 2017: 11.8%), and France (2008: 6.4%; 2012: 5.4%; 2017: 5.1%). Although in some countries there is a decrease in the share of production in total production from one year to another, this does not show a decrease in production in these countries because the gross data shows a doubling in almost all countries mentioned, as follows: Germany (215.63%), Italy (243.57%), United Kingdom (178.43%), and France (166.75%). The energy production from the All other renewable energy source has higher values in only 3 countries, which tells us that the price-performance ratio, attributed to the technology, does not offer enough advantages to be attractive and exploited by several countries.

3.2. Renewable Energy Consumption

Figure 7 shows the consumption of renewable energy and from all sources, at EU28 level. If in 2008 the renewable energy consumption was 11.38% (138,102.6 ktoe ÷ 1,219,755.7 ktoe), then in 2012 it was 14.68% (169,377.1 ktoe ÷ 1,151,156.0 ktoe), and in 2017 of 17.53% (203,671.6 ktoe ÷ 1,169.60).

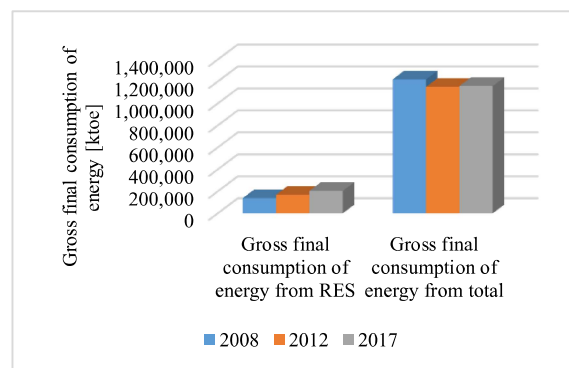


Figure 7. The distribution of energy consumption
Source: Processed by authors based on data from Eurostat

From the analysis of Figure 7 it is observed that the energy consumption from RES increased from one year to another by 47.8% if we compare the year 2017 with the year 2008 (2012/2008 with 22.7% and 2017/2012 with 20.5%), while the consumption by total energy decreased by 5% (2012/2008 decreases by 5.6% and 2017/2012 increases by 0.7%).

Figure 8 shows the evolution of renewable energy consumption by types of consumption: electricity, heating and cooling and transport, for EU 28 countries.

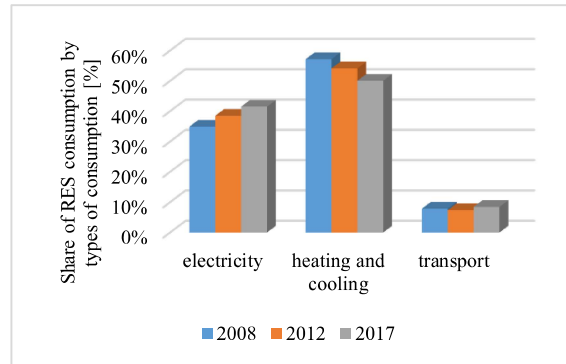


Figure 8. RES consumption by categories of consumption
Source: Processed by authors based on data from Eurostat

From the analysis of Figure 8 it is observed that the highest consumption at the level of the 3 years represented is given by the consumption for heating and cooling which is decreasing from year to year (2008: 57.2%; 2012: 54.1%; 2017: 50.1%), followed by consumption for electricity that is growing (2008: 34.9%; 2012: 38.5%; 2017: 41.5%) and consumption for transport, which is relatively constant (2008: 7.9%; 2012: 7.4%; 2017: 8.4%).

Figure 9 shows the distribution of renewable energy consumption for all the countries studied expressed as a share in the total renewable energy consumption.

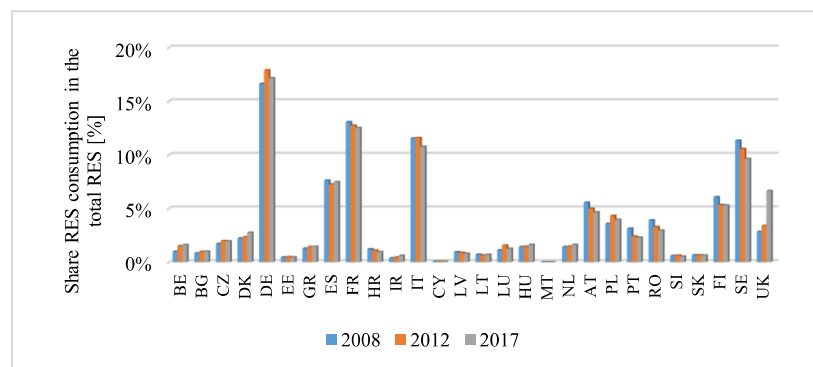


Figure 9. Distribution of consumption from RES
Source: Processed by authors based on data from Eurostat

Analysing Figure 9 we find that the share of renewable energy consumption is increasing in some countries (UK, Germany, Spain, Poland, Czech Republic, Denmark) while in other countries it is declining (France, Italy, Sweden, Spain, Finland, Austria). Although the share of consumption of methionine countries is decreasing in some countries from the analysis of production volume it is found that it increased in all countries mentioned (United Kingdom (346.53%), Germany (152.39%), Poland (162.73%), Czech Republic (168.71%), Denmark (182.44%), France (141.77%), Italy (137.95%), Sweden (125.74%), Spain (145%), Finland (128.96%), Austria (124.29%).

Figures 10 and 11 shows the economic indicators: Real GDP per capita and Turnover per capita, in order to observe the differences between the countries and to be able to perform comparative analysis of available data.

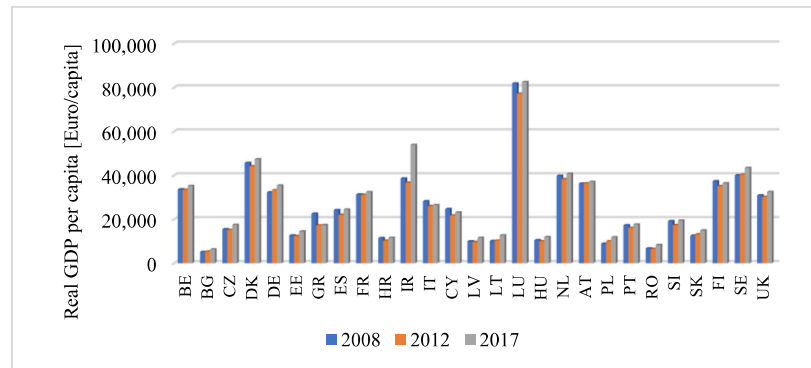


Figure 10. Distribution of Real GDP per capita

Source: Processed by authors based on data from Eurostat

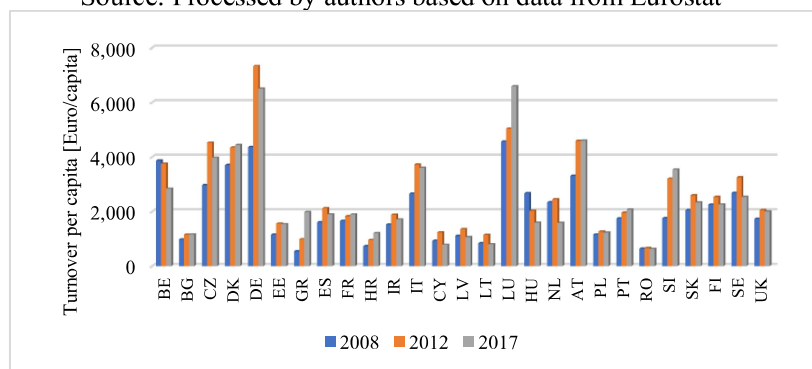


Figure 11. Distribution of Turnover per capita

Source: Processed by authors based on data from Eurostat

From the analysis in Figure 10 it can be seen that the Real GDP per capita indicator shows an upward trend in year 2017 compared to 2008, which shows that the economic activity recorded by each country increased due to the increase in the value of final production of goods and services produced by the economy. The highest increase of the Real GDP per capita indicator, in 2017 compared to 2008, is registered in the following countries: Ireland (139.61%), Poland (132.66%) and Romania (123.63%) which shows an improvement in the level the final production of goods and services generated by the economy of that country. Values of the Real GDP per capita indicator lower in 2017 compared to 2008 are found in the following countries: Greece (77.17%), Cyprus (93.68%), Italy (93.84%) and Finland (97.51%) where there is a deterioration of economic activity.

The Turnover per capita indicator, presented in Figure 11, is an indicator that expresses the total of all sales (excluding VAT) of goods and services made by enterprises and recorded higher values in 2017 compared to 2008 in countries such as: Greece (367.53%), Slovenia (200.74%), Germany (148.97%), Luxembourg (144.41%). In 2017, lower values were registered, compared to 2008, in 8 countries out of the 28 included in the study: Hungary (59.51%), Netherlands (67.62%), Belgium (73.36%), Cyprus (84.50%), Lithuania (94.75%), Sweden (94.61%), Latvia (96.06%) and Romania (98.10%), which shows a decrease in turnover, respectively a worsening of the economy for this

countries. Although the turnover decreased in these countries, we can still see that the GDP increased in 2017 compared to 2008, only excepted Greece and Cyprus where is registered a decrease.

According to the evolution of the 2 indicators presented in Figures 10 and 11, we can conclude that in most of the analysed countries there was an increase in the value of total final production of goods and services that would justify the increase in energy consumption in RES.

3.3. Type of consumption

Table 1 presents the energy consumption for electricity, heating and cooling and transport, from renewable energy, in 2017, the countries grouping according to the region of which they belong: Northern Europe (NE), Western Europe (WE), Europe of South (SE) and Eastern Europe (EE).

Table 1. The consumption of renewable energy for electricity, heating and cooling and transport, in the regions of Europe [ktoe]

Region	Country	Consumption	Region	Country	Consumption
NE	EE	943.94	SE	MT	38.28
	IR	1,246.76		CY	161.84
	LT	1,439.39		SI	1,084.90
	LV	1,644.69		HR	1,960.13
	DK	5,628.81		GR	2,950.42
	FI	10,810.17		PT	4,700.74
	UK	13,572.09		ES	15,264.57
	SE	19,674.79		IT	21,999.86
WE	LU	249.71	EE	SK	1,308.02
	BE	3,311.00		BG	2,041.02
	NL	3,337.74		HU	2,559.32
	AT	9,527.98		CZ	3,997.62
	FR	25,577.24		RO	6,039.92
	DE	35,027.09		PL	8,073.48

From the analysis of Table 1 it is observed that the highest energy consumption above the region average is recorded as follows: in the North region (average region: 6,870.08 ktoe) in the countries: Sweden, United Kingdom and Finland, in the West region (average region: 12,838.46 ktoe) in the countries: France and Germany, in the Southern region (average of the region: 6,020.09 ktoe) in the countries: Italy and Spain, and in the Eastern region (average of the region: 4,003.23 ktoe) in the countries: Poland and Romania. If we compare the average of the region with the average of EU28 countries (7,291.84 ktoe) we find that only the North region has the average over that of Europe. These values can be explained both as a result of the different size of the countries studied and as a result of the economic power, respectively of the purchasing power of both the population and the economic agents, being known that the technology required to obtain and consume from the RES implies at the moment incurring high costs.

3.3.1. Electricity

Figure 12 shows the distribution of electricity consumption from RES expressed as a share in the total RES from EU28.

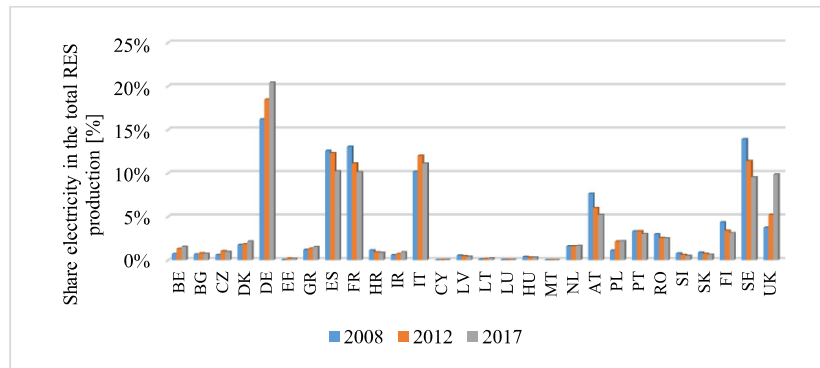


Figure 12. Distribution of consumption for electricity from RES
Source: Processed by authors based on data from Eurostat

The analysis in Figure 12 shows that only in the countries: Germany, Italy, United Kingdom, the share of renewable energy consumption for electricity increases, while in the countries: Spain, France, Sweden, Finland, it is decreasing, this due to increasing the share in other countries and not decreasing consumption. From the analysis of raw data, we have that consumption in 2017 is higher than in 2008 in all countries studied. Various studies show us that the consumption of electricity from renewable energy has increased in some countries as a result of the development of exploitation technology but also of energy storage, the emergence of electric vehicles, of various incentives or subsidies granted by some governments to stimulate buyers, who acquires products that do not produce greenhouse gases [19, 40-41]. The results of these studies are also supported by the results obtained in Figure 12, where it is observed that in the more economically developed countries more substantial increases of electricity consumption have taken place from renewable sources.

3.3.2. Heating and cooling

Figure 13 shows the distribution of consumption of renewable energy for heating and cooling expressed as a share in the total RES from EU28.

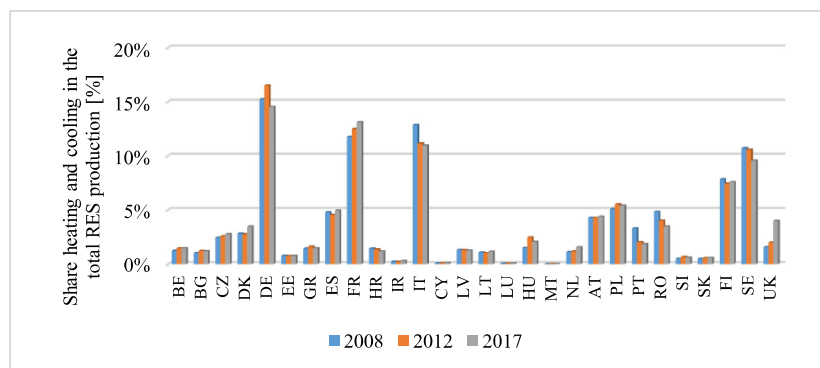


Figure 13. Distribution of RES consumption for heating and cooling
Source: Processed by authors based on data from Eurostat

From the analysis of Figure 13 it is found that the share of renewable energy consumption for heating and cooling has increased in countries such as: France, Spain, Poland, United Kingdom and has decreased in countries such as: Germany, Italy, Sweden, Finland, Romania. From the analysis of the

actual quantity consumed in 2017 compared to 2008, it is found that it decreased only in Portugal (72.96%) and Romania (93.11%), in the rest of the countries registering an increase.

The use of energy for heating and cooling from renewable sources is a fact most often reported in the literature by many specialists [42, 43, 26, 27] as a result of the development of the society, the increase of the standard of living but also as a result of the development of technologies capable of meeting these modern demands. The use of renewable energy for heating and cooling is also signalled by the results in Figure 13, where it is observed that, together with the larger countries and smaller countries in the south-east of Europe, they register consumption.

3.3.3. Transport

Figure 14 shows the distribution of consumption of RES for transport, at EU 28 level, expressed as a share in the total.

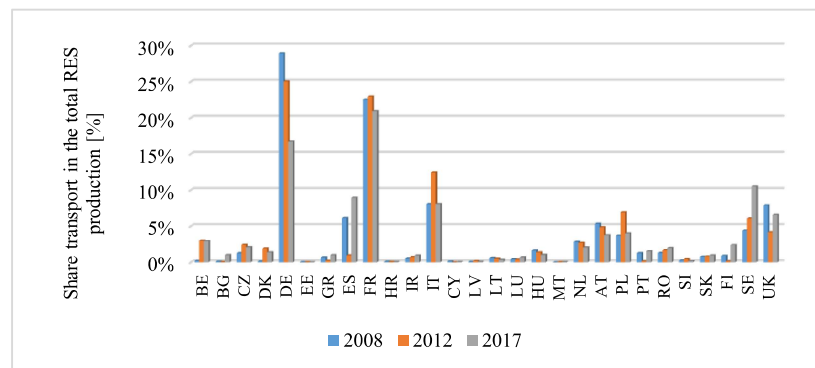


Figure 14. Distribution of consumption for transport from RES
Source: Processed by authors based on data from Eurostat

The analysis in Figure 14 shows that the share of renewable energy consumption for transport in total increased in countries such as Sweden, Spain and Romania and decreased in countries such as Germany, France, United Kingdom, Italy and Austria. Analysing the quantity consumed in 2017 compared to 2008, it is found that it increased in all countries, except for a few countries where there was a decrease: Cyprus (60.61%), Germany (91.34%) and Hungary (99.14%).

The use of renewable energy for transport is found in a larger proportion in the more developed countries, as a result of the stronger development of transport, which is linked to the more developed infrastructure and faster access to technology.

4. Conclusions

From the study we can see that there is a concern at EU28 level for energy consumption from RES, in the total energy consumption has registered a increase.

In terms of energy consumption, both from fossil fuels and RES, there is a decrease in the demand for energy for industry and an increase in the demand for transport and household in EU28 countries. The decrease in energy consumption in the industry can be attributed to the modernization of technologies and the disintegration of some non-performing consumers, and the increase of the energy demand for transport and household is due to the economic growth registered in several countries which implicitly led to the economic well-being found in the population by increasing the level to live.

The highest energy demand, from renewable energy sources in 2017 is for heating and cooling (50.1%) followed by electricity (41.5%) and transport (8.4%).

References

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