

# Renewable energy in European countries, retrospective analysis

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**Abstract.** This study performs an exploratory analysis of the evolution of primary production of RES for EU28 countries over the ten years studied. Through the analysis, the document presents: the structure of production by sectors of production and by renewable energy sources, analyses the evolution of the mentioned indicators both in total and in detail on each renewable energy source and allows the identification of differences in the level of production from RES: between countries and regions. The analysis shows that these countries have implemented EU strategies in the field and exceeded the proposed target for 2020 starting from 2017. Among the most important RESs in primary energy production were the sources: Hydro, Wind and Solar, in the countries from the EU28 due to the existence of a natural potential that has been exploited and encouraged by the country-specific internal policies, but also due to the development of technologies and lower costs for these renewable energy sources.

## 1. Introduction

Insufficiency or depletion of resources has led to the search for solutions in most countries to replace the old traditional energy sources with renewable energy sources (RES). The causes of increased energy consumption worldwide are either due to the development of the society or as a result of the electrification of new areas and for a sustainable development the provision of adequate and reliable energy services at affordable costs, from safe and ecological resources in accordance with current needs, is a continuous challenge [1, 2].

Although the technology of resource exploitation and energy consumption has evolved, we are facing consequences of the degradation of natural resources that cannot be stopped but only improved [3, 4]. The effects of these degradations are manifested as a global catastrophe, both through climate change [5] and by the emission of greenhouse gases [6, 7]. The approach for the countries to increase energy from RES is a necessity of strategic importance that allows both sustainable development and energy security [8-10].

According to studies by [11], the sustainable growth of an economy depends on the development of the renewable energy sectors, and the development of the financial market makes it possible to access the financing of investments in the field of renewable energy. The link between the variables: financial structure, corporate finance and economic growth is also emphasized by [12] and [13], explaining why there are economic differences between countries and why in some countries investments in technologies are more accessible than in other countries. From other studies [14] show us how increasing



investments in technologies for the exploitation of renewable energy is faster in developed countries than in other countries less developed.

At the EU level, topics such as: resource efficiency, environmental care and climate action appear more and more frequently, thus debates, in which directives are updated or revised (to contribute to sustainable development), and then projects or procedures are initiated to support the implementation of the Europe 2020 strategy (for smart, sustainable and uniform growth) [15-16].

Thus, the Council of the European Union [17] has shown that in order to reach the target of reducing greenhouse gas emissions by 40%, an energy saving of about 25% must be obtained by 2030, and the annual report from 2017 [9] underlines that the decarbonization of the transport sector is the biggest challenge given the high energy consumption, which is a necessity to fulfil the Paris Agreement.

The objectives of the article are: (1) to outline the energy structure by sources; (2) to present the evolution of total production and detailed the production by sources of renewable energy in the EU28 countries; (3) to indicate the differences between regions of Europe regarding the production of RES; (4) to compare the development of production from renewable energy from 2017 year with to 2020 target and to discuss the causes which was contribute of the results obtained. The paper aims to present an overall analysis of the different types of renewable energy sources, in terms of production, 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

The analysis included the existing data for the 28 EU member countries, and subsequently the data were processed and analysed both individually in the country and in comparison, with the 28 EU average, making a comparative analysis of the production according to the renewable energy sources. The Eurostat database was used to collect the following data starting with 2008: Primary production, Energy productivity, Share of renewables in electricity production. Data collection was done August 20, 2019 and all data available till that date were included in the analysis. The European country with data available for all years of interest (2008-2017) was included in the analysis. The countries included in the analysis along with abbreviation and region in Europe are: Northern region (EE, LT, LV, IR, DK, FI, SE, UK), Western region (LU, BE, NL, AT, FR, DE), Southern region (MT, CY, SI, HR, GR, PT, ES, IT), Eastern region (HU, SK, BG, CZ, PL, and RO).

Primary production is the production from renewable energy from Hydro, Wind, Solar, Solid biofuels and All other renewables.

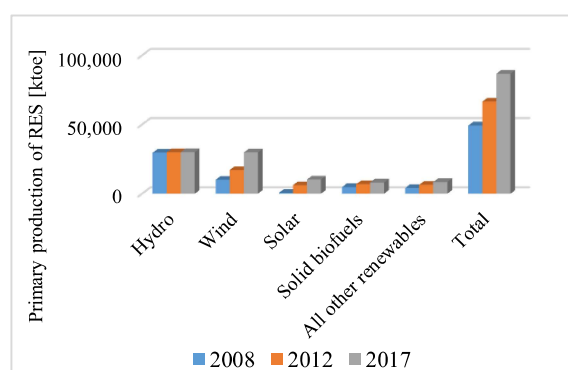
The energy productivity indicator allows the measurement of the gross domestic product by the raw energy available according to the analysed calendar year. This indicator gives an image of the increase of the energy consumption in relation to the increase of the GDP. The gross available energy is calculated as: Primary production + Recovered & recycled products + Imports - Exports + Stock changes.

Share of renewables in electricity production is the amount of energy generated in total renewable energy, including all sources: wind, solar, hydro, solid biofuels and all other "renewable" (marine, geothermal, municipal renewable waste, liquid biofuels and biogas).

### 3. Energy Structure

The production of electricity from conventional sources together with the production from renewable sources allows the provision of energy and the gradual increase of the latter as a result of the benefits related to low carbon emissions, reduction of own technological consumption, diversification electricity supply sources, promoting the circular economy (recycling). Thus, the need to analyse the evolution of energy production in RES starts from the development possibilities as a result of the production of electricity storage capacities that will contribute to the integration of RES in SEN, given their intermittent / variable nature.

Figure 1 shows the primary production of renewable energy on the 4 categories of sources: Hydro, Wind, Solar, Solid biofuels and All other renewables, according to the Eurostat database.



**Figure 1.** Primary renewable energy production on RES  
Source: Processed by authors based on data from Eurostat

Analysing Figure 1 we can see that in the three years presented the following changes occurred: the production of renewable energy from the Hydro source decreased by 25.53% (from 60.14% in 2008 to 34.61% in 2017), the Wind source increased by 13.93% (from 20.47% in 2008 to 34.40% in 2017), Solar increased by 10.54% (from 1.3% to 11.84%), Solid biofuels and All other renewables remained relatively constant at EU 28 (Solid biofuels: from 9.77% to 9.39%, and All other renewables: from 8.30% to 9.76%). Although, as a value of the production source, Hydro recorded an increase (in 2008 being 29,640.63 : 49,284.07 ktoe as compared to 2017 being 30,001.70 : 86,681.66 ktoe) as a share in total this decreased by 25.53% as a result of faster changes of the other sources: Wind increased by 13.93% (in 2008 it was 10,092.83 : 49,284.07 ktoe and in 2017 it was 29,814.46 : 86,681.66 ktoe), Solar increased by 10.54% (640.96 : 49,284.07 ktoe in 2008 and 10,265.91 : 86,681.66 ktoe in 2017), Solid biofuels decreased by 0.38% (4,816.85 : 49,284.07 ktoe in 2008 and 8,140.62 : 86,681.66 ktoe in 2017) and All other renewables increased by 1.45% (4,092.81 : 49,284.07 ktoe in 2008 and 8,458.97 : 86,681.66 ktoe in 2017).

#### 3.1. Main Renewable Energy Indicators Evolution

In 2016, the World Energy Council states that by 2050 the emerging economies will be the ones that will double the energy production from RES [19].

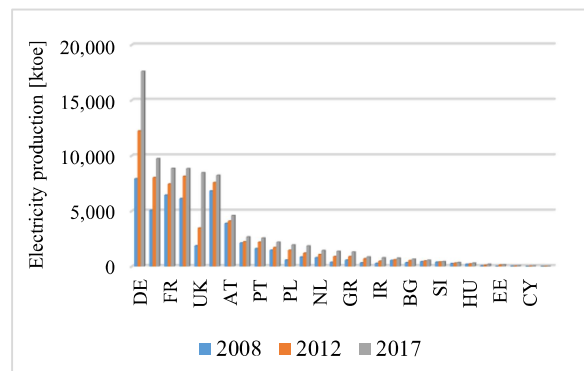
##### 3.1.1. Renewable Energies—Primary Production

Global growth or growth in RES, China and the US produced half of the growth of renewable energy production (EU 8%, and Japan and India 6% growth each) [19]. Thus, this increase played a positive role

in the growth of energy with low carbon emissions, the electricity produced worldwide increasing by 6.3% (380 TWh).

Although worldwide the specialized institutions report an increase in the production of RES (according to the data presented above), the study carried out allows obtaining additional information for each country within Europe (EU28), which has been analysed for a period of 10 years, which allow one to conclude that growth is not only achieved as a result of technology [14] but there are other causes as well.

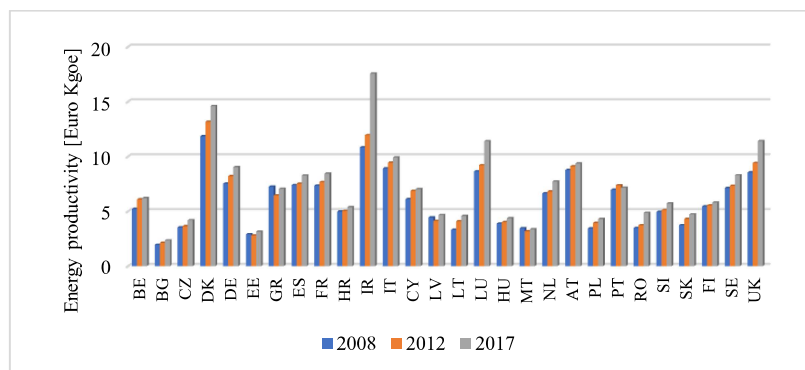
The total electricity production from renewable energy sources in the 28 EU countries taken into consideration was 86,681.66 ktoe in 2017 and in 2008 it was 48,284.07 ktoe (an increase of about 1.80 times is observed). This increase can be observed separately in each country, according to Figure 2, where electricity production is expressed in ktoe (thousand tons of oil equivalent).



**Figure 2.** Distribution of the primary electricity production of REN  
Source: Processed by authors based on data from Eurostat

Comparing the year 2008 with the year 2017, we can see in Figure 2, that there is a tendency to increase the production of electricity, from renewable energy sources, in most countries. Countries whose electricity production from RES is above the EU28 average, in 2017 compared to 2008, are: Germany (17,609.98 ktoe ÷ 7,915.99 ktoe), Italy (9,728.58 ktoe ÷ 5,060.31 ktoe), France (8,847.72 ktoe ÷ 6,433.37 ktoe), Spain (8,830.72 ktoe ÷ 6,124.45 ktoe), United Kingdom (8,464.66 ktoe ÷ 1,861.74 ktoe), Sweden (8,223.25 ktoe ÷ 6,813.76 ktoe) and Austria (4,591.53 ktoe ÷ 3,879.55 ktoe). If we look at the share of the electricity production of each country in the total electricity production of the EU28 and compare the year 2017 with the year 2008 we see that in the first four places we find countries where the biggest increases have taken place: the United Kingdom (from 3.78% to 9.77%), Germany (from 16.06% to 20.32%), Poland (from 1.18% to 2.24%) and Italy (from 10.27% to 11.22%), while in other countries we have the largest decreases: Sweden (from 13.83 % to 9.49%), France (from 13.05% to 10.21%), Austria (from 7.87% to 5.3%) and Spain (from 12.43% to 10.19%).

In order to see if the increase of the electricity production is given by a corresponding increase of the energy productivity was realized Figure 3. The energy productivity indicator measures the amount of economic output obtained per unit of gross energy.



**Figure 3.** Distribution of energy productivity

Source: Processed by authors based on data from Eurostat

From Figure 3 energy productivity increased in 2017 compared to 2008 in most countries. The most spectacular growth, measured in Euro per kilogram of oil equivalent (kgoe), as the difference between 2017 and 2008, was recorded in: Ireland (17.6 kgoe), Denmark (14.5 kgoe) followed by Luxembourg (11.4 kgoe) and United Kingdom (11.3 kgoe).

From the comparison of Figure 2 with Figure 3 at the level of 2017, it can be observed that the electricity production from renewable sources increases compared to the previous years as well as the energy productivity. The growth of the two indicators is not the same in each country, the countries registering different growths, this on the one hand because the energy productivity indicator cumulates all the energy sources (not only the renewable ones) and on the other because the production of renewable energy, are affected by climate factors not only by technology.

Table 1 presents the production of electricity from renewable energy, from 2017, the countries grouping themselves by the region of which they belong: Northern Europe (NE), Western Europe (WE), Southern Europe (SE) and Eastern Europe (EE).

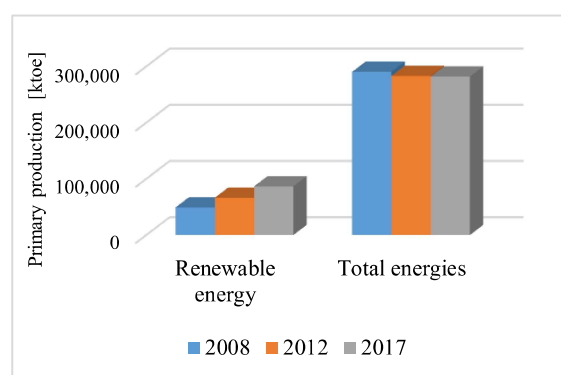
Table 1. Electricity production from RES by regions

Region	Country	Production	Region	Country	Production
NE	EE	148.88	SE	MT	14.19
	LT	192.83		CY	38.32
	LV	349.00		SI	433.24
	IR	775.88		HR	747.79
	DK	1,847.62		GR	1,294.32
	FI	2,663.41		PT	2,562.30
	SE	8,223.25		ES	8,830.33
	UK	8,464.66		IT	9,728.58
WE	LU	49.01	EE	HU	294.45
	BE	1,353.73		SK	559.11
	NL	1,433.43		BG	648.76
	AT	4,591.53		CZ	855.20
	FR	8,847.72		PL	1,938.85
	DE	17,609.98		RO	2,185.29

From the analysis of Table 1 it is found that in the Northern region, the countries: United Kingdom and Sweden recorded values above the region average (2,833.19 ktoe), in the Western region the countries: Germany and France recorded values above the region average (5,647.57 ktoe), in the Southern region the countries: Italy and Spain recorded values above the region average (2,956.13 ktoe) and in the Eastern region the countries: Romania and Poland recorded values above the region average (1,080.28 ktoe). It can also be noted that the countries in the North, West and South of Europe regions (presented above) have record EU28 average values (3,095.77 ktoe).

### 3.1.2. Share of renewables in electricity production

Figure 4 shows the primary production of electricity from renewable sources and the primary production of total energy which was obtained by summing the production from all the countries included in the EU 28.



**Figure 4.** Distribution of primary electricity production  
Source: Processed by authors based on data from Eurostat

From the analysis of Figure 4 we can see that compared to 2008 (49,284.1 ktoe) in 2017 (86,681.7 ktoe) the primary renewable energy production increased by 175.88%. At the level of total energy obtained from all sources (traditional and conventional) it is found that the production of electricity decreased by 0.98%, although the production of electricity from renewable sources increased significantly.

### 3.1.3. Renewable electricity output

In order to know the share of the electricity production from RES by categories of renewable sources and by country, we identified the countries that in 2017 registered values above the EU28 average and which was in the first four places at each renewable energy source, according to Table 2.

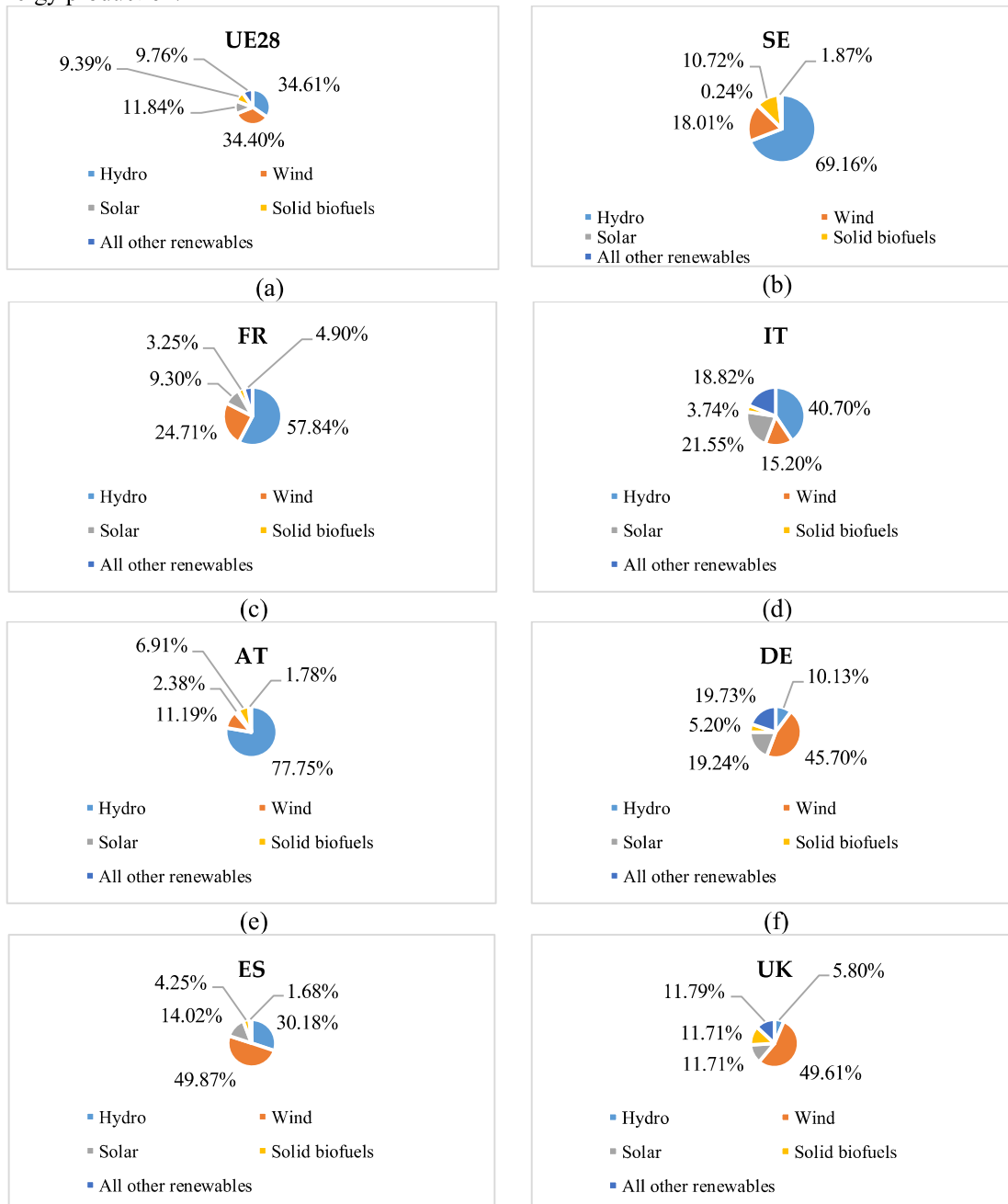
Table 2. Ranking of countries by primary production

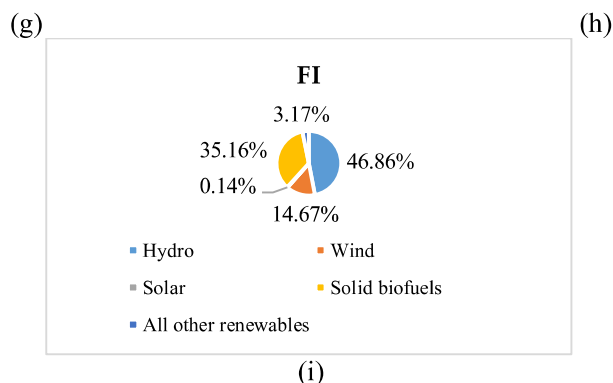
Types of RES	2008				2017			
	I	II	III	IV	I	II	III	IV
Hydro	SE	FR	IT	AT	SE	FR	IT	AT
Wind	DE	ES	UK	DK	DE	ES	UK	FR
Solar	DE	ES	IT	BE, FR	DE	ES	IT	UK
Solid biofuels	FI	DE	SE	PL	UK	FI	DE	SE

All other renewables	DE	IT	UK	FR	DE	IT	UK	FR
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From the analysis of Table 2 we can see that in the renewable energy sources: Hydro and All other renewables we have on all 4 places the same countries, both in 2008 and 2017. At the energy sources: Wind, Solar and Solid biofuels on the first three places remain the same countries both in 2008 and in 2017, while on the 4th place we have other countries.

Figure 5 shows the countries that registered in 2017 the best results for primary renewable energy production.





(i)  
Figure 5. Distribution of RES by countries  
Source: Processed by authors based on data from Eurostat

From the analysis of Figure 5 it is observed that in 2017, the largest share in most countries is given by the Hydro sources: Austria (e), Sweden (b), France (c), Wind: Spain (g), United Kingdom (h), Germany (f) and Solid biofuels: Finland (i), United Kingdom (h), Sweden (b). In Figure 6 (a) the total values registered in the countries of the EU 28 show us that RES presents the following classification: Hydro, Wind, Solar, All other renewables, and Solid biofuels.

If we analyse the performance of these countries in comparison with the other countries, in all energy sources, in 2017, we observe that the most performing country in terms of renewable energy production is: Germany which produces electricity from all 4 energy sources, this ranking first in three of them (I - Wind; I - Solar; I - All other renewables; III - Solid biofuels), followed by United Kingdom (I - Solid biofuels; III - Wind; III - All other renewables, IV Solar), France (II - Hydro; IV - Wind; IV - All other renewables), Italy (II - All other renewables, III - Hydro, III - Solar), Sweden (I - Hydro, IV - Solid biofuels), Spain (II - Wind, II - Solar), Finland (II - Solid biofuels), Austria (IV - Hydro). We note that we have the first places: three countries in the western region of Europe (Germany, France, and Austria), three countries in the northern region of Europe (Sweden, United Kingdom, and Finland) and two countries in the southern region of Europe (Spain, Italy). These recorded performances can be explained, both because of the size of these countries, of the level of evolution, but also as a result of the possibilities of easier access to the financial structures and new technologies, a fact also supported in the studies of [12, 14].

According to Figure 1, the largest RES production for electricity is obtained from renewable sources Hydro and Wind. This shows us also the results obtained in Figure 5, where for the countries presented, the highest weights recorded are obtained from the sources Hydro (5.80% ÷ 77.75%) and Wind (11.19% ÷ 49.87%), followed by the sources: Solar (0.14 % ÷ 19.24%), Solid biofuels (3.74% ÷ 35.16%) and All other renewables (1.68 ÷ 18.82%).

#### 4. Conclusions

From the study we can see that there is a concern at EU28 level for energy production from RES, which are increasing in 2017 compared to 2008. Due to the economic growth but also to the development of technologies in the RES field, in the last years, in the countries of the EU28, it can be observed that there is a decrease of the energy produced from the Hydro source (due to the climatic changes and the elimination of some non-performing hydroelectric plants) and an increase for the Wind and Solar source. From the analysis we can see that at least 13 countries have exceeded their target for 2020 (Table 1),