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## **Biomass as the Most Popular Renewable Energy Source in EU**

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**Abstract:**

**Purpose:** The aim of this research is to assess and discuss the diversity of European Union countries due to renewable energy production from biomass and changes over time.

**Design/Methodology/Approach:** The diversity of EU countries was examined using the cluster analysis. Analysis was conducted based on data from Eurostat. The time scope covers the years 2007 and 2016. The analysis includes four diagnostic features; the share of solid biofuels in total biomass and renewable waste production, the share of biogas in total biomass and renewable waste production, the share of renewable municipal waste in total biomass and renewable waste production and the share of liquid biofuels in total biomass and renewable waste production.

**Findings:** The analysis shows that the European Union countries are characterized by diversity in the use of individual biomass sources as an energy source. The countries of the central part of Europe mainly use biomass from municipal waste. A fairly large share was also recorded in the use of biogas and liquid biofuels. The countries of northern and partly eastern Europe mainly use solid biomass. In contrast, countries in partly Eastern and Western Europe mainly use solid and liquid biomass.

**Practical Implications:** The results refer to the assumptions of energy policy.

**Originality/Value:** The study is related to the EU current issues energy policy and circular economy. The results can be a contribution to the analysis of the circular economy implementation.

**Keywords:** European Union, renewable energy, solid biomass, biogas, municipal waste, liquid biomass.

**JEL classification:** O13, P18, Q42.

**Paper Type:** Research study.

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## **1. Introduction**

Energy is an integral part of society and plays a pivotal role in its socio-economic development by raising the standard of living and the quality of life (Mirza *et al.*, 2008). Post oil crises shifted the focus of energy planners towards renewable resources and energy conservation (Ramachandra *et al.*, 2004). Although rising concerns about climate change and sustainability have accelerated research efforts to seek alternative sources of energy (Tapia *et al.*, 2019). In recent decades, an increasingly important component of national policy agendas for many countries had been invested in renewable energy sources. In more recent years the European Union has been the leader in these initiatives. The effect of the activities was a significant increase in the consumption of energy from renewable sources (Marinescu, 2019).

Therefore, the European Commission has set a long-term goal to develop a competitive, resource efficient and low carbon economy by 2050 (EC, 2011). Considering the above, biomass is one of the renewable resources that could play a substantial role in a more diverse and sustainable energy mix (Bridgwater *et al.*, 2002). Biomass is associated with the concept of bioeconomy, which covers the production and consumption of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy (EC, 2012). The importance of the issue is indicated by the inclusion of biomass and bioproducts as a priority area in the new EU concept which is the circular economy (EC, 2015), operationalization for business practice to implement the idea of sustainable development (Ghisellini *et al.*, 2016).

Biomass is one of the most popular and universal resources on earth (Țenchea *et al.*, 2019). Hence the dominance of biomass in the structure of energy consumption from renewable sources in the EU is important. Biomass and waste have the highest share in total renewable energy production, exceeding 60%. Biomass and renewable waste production increases year by year (Eurostat, 2009; 2018). Of course, not every country has equal access to this source. In order to answer the question about the role and structure of biomass as an energy source in the European Union, the aim of the article is to assess the diversity of renewable energy production from biomass and changes over time.

## **2. Literature Review**

Biomass as energy resource is a significant part of energy consumption and is as old as humanity (Bildircia and Özaksoy, 2018). It has been used as an energy source for thousands of years, ever since humans started burning wood to cook food or to keep warm (Chang *et al.*, 2003; Janiszewska *et al.*, 2018; Timmons *et al.*, 2014). Biomass is a term for all organic material that stems from plants (including algae, trees and crops). Biomass is produced by green plants converting sunlight into plant material through photosynthesis and includes all land- and water-based vegetation, as well as

all organic wastes (McKendry, 2002). Biomass can be examined in three categories: woody (forests and agro-industrial plantations, bush trees, urban trees, and farm trees), non-woody (crop residues – straw, leaves, plant stems, processing residues – saw dust, bagasse, nutshell, husks, domestic wastes) and animal wastes (animal husbandry) (Mirza *et al.*, 2008; Rosillo-Calle *et al.*, 2008; Bekele *et al.*, 2013). Therefore biomass can come either directly from a primary source (for example plants) or indirectly (from urban, industrial or rural waste) (Papoutsidakis *et al.*, 2018).

The most often biomass is classified by direction of origin – agricultural biomass, forestry biomass and biomass from wastes (Janiszewska and Ossowska, 2018; Kołodziej and Matyka, 2012; Godlewska-Majkowska and Zarębski, 2012). Eurostat (2009 and 2018) uses the biomass classification according to the final product solid biofuels, biogas, renewable municipal waste and liquid biofuels.

An important property of biomass is the ability to change into heat, liquid, solid or gaseous fuels, and other chemical products (Khan *et al.*, 2015). Biomass energy can reduce the consumption of non-renewable energy sources due to its advantages. It is available locally and abundantly, technically flexible in energy conversion (Cao and Pawłowski, 2013). It is a clean, renewable energy source that can have a positive impact on the environment, the economy and energy security (Janiszewska and Ossowska, 2016). The environmental, economic and social benefits reward the technological and other limits caused by the less favorable chemical properties of biomass (Vassilev *et al.*, 2015).

Among the renewable energy sources, especially biomass can be used to meet a variety of energy needs, including generating electricity, heating homes, fueling vehicles, and providing process heat for industrial facilities. Biomass energy generates also less air emissions, reduces the amount of waste sent to landfills, and decreases our reliance on foreign oil. Moreover, energy from biomass can create new jobs and help revitalize rural communities (Cihan *et al.*, 2009). Europe has a number of well-established traditional bio-based industries; agriculture, food, feed, fiber, forest-based industries (Scarlat *et al.*, 2015). Therefore, it has favorable conditions for the development of energy production from biomass. Biomass is subject of interest not only to practitioners, but also to scientists. This is evidenced by numerous scientific studies in this field (Perea-Moreno *et al.*, 2019).

### 3. Research Methods

The analysis was based on Eurostat data (Eurostat 2009, 2018). The time range covers the years 2007 and 2016. The European Union countries were divided into 4 clusters based on cluster analysis. The Euclidean metric was applied as a function of similarity. The following formula was used (Parysek and Wojtasiewicz, 1979):

$$d_{ik} = \sqrt{\sum_{j=1}^m (x_{ij} - x_{kj})^2}, \quad (1)$$

where:  $d_{ik}$  – distance between  $i$ -th and  $k$ -th object (for  $i = k = 1, 2, \dots, n$ ),  $x_{ij}$  – value  $j$ -th variable for  $i$ -th object (for  $j = 1, 2, \dots, m$ ),  $x_{kj}$  – value  $j$ -th variable for  $k$ -th object. Calculations were based on standardized variables. Moreover, Ward method was applied in estimating the distance between clusters (Parysek and Wojtasiewicz, 1979; Murtagh and Legendre, 2014).

The analysis includes four diagnostic features; the share of solid biofuels production (excluding charcoal) in total biomass and renewable waste production (%), the share of biogas production in total biomass and renewable waste production (%), the share of renewable municipal waste production in total biomass and renewable waste production (%) and the share of liquid biofuels production in total biomass and renewable waste production (%). The choice of indicators was based on the substantive and statistical criteria, as well as the availability of complete data.

#### 4. Results

In EU countries, solid biofuels are the dominant source of energy in total biomass and waste production (Table 1). In 2007 the share of total solid biofuels production in total biomass and waste production was 78%, while in 2016 there was 70%. However, total production of solid biofuels in EU countries increased from 93.3 Mtoe in 2007 to 134.5 Mtoe in 2016. The share of solid biofuels production (excluding charcoal) in total biomass and waste production in EU countries oscillated between zero and 99%. The lowest share of solid biofuels production in total biomass and waste production occurred in Malta, Netherlands, Cyprus, Germany and United Kingdom. The highest share of solid biofuels production in total biomass and waste production occurred in Estonia, Croatia, Slovenia, Romania and Latvia. Comparing the share of solid biofuels production in total biomass and waste production of the EU countries in 2016 and 2007, changes were noted. In 26 countries of the EU there was a decrease in value of this indicator. The largest decrease occurred in Cyprus, Belgium and Italy. Only in two countries an increase in share of solid biofuels production occurred, Denmark and United Kingdom.

Comparing 2007 to 2016, in terms of the share of biogas production in total biomass and waste production, there was a high increase from 6% to 12%. In 2007 total biogas production was 5.8 Mtoe, while in 2016 it amounted to 16.6 Mtoe. This was the largest increase among all analyzed biomass sources. The share of biogas production in total biomass and waste production in EU countries oscillated between 0.5% and 73%. The lowest share of biogas production in total biomass and waste production occurred in Romania, Estonia, Finland, Sweden and Lithuania. The highest share of biogas production in total biomass and waste production occurred in Malta, Cyprus, United Kingdom, Germany and Luxembourg. Comparing the share

of biogas production in total biomass and waste production in 2016 and 2007, an increase was noted in 24 EU countries. The largest increase occurred in Malta, Cyprus and Germany. Only in four countries a decrease of share of biogas production in total biomass and waste production occurred in United Kingdom, Ireland, Spain and The Netherlands.

**Table 1.** Biomass final products share in total biomass and waste production in EU member states in 2007 and 2016

Specification	Solid biofuels (excluding charcoal)		Biogas		Renewable municipal waste		Liquid biofuels	
	Share in total biomass and waste production (%)							
	2007	2016	2007	2016	2007	2016	2007	2016
EU-28	78.1	70.0	6.3	12.3	8.0	7.4	7.6	10.2
Belgium	76.4	56.8	7.7	10.0	12.8	16.8	3.2	16.5
Bulgaria	99.7	87.3	0.0	4.7	0.0	2.3	0.3	5.7
Czechia	90.5	76.9	3.2	15.6	2.5	2.2	3.8	5.3
Denmark	67.8	69.9	4.3	9.6	23.8	20.2	4.2	0.3
Germany	50.4	45.5	14.2	30.3	14.3	11.6	21.1	12.6
Estonia	99.4	99.2	0.6	0.8	0.0	0.0	0.0	0.0
Ireland	71.3	60.9	19.6	15.2	0.0	17.3	9.1	6.6
Greece	89.5	76.8	3.1	9.8	0.0	0.0	7.4	13.4
Spain	82.4	74.1	4.2	3.4	6.0	3.3	7.4	19.1
France	75.8	70.2	2.6	4.8	11.3	9.8	10.3	15.2
Croatia	99.6	97.0	0.1	3.0	0.0	0.0	0.3	0.1
Italy	83.6	65.9	5.0	17.1	9.1	7.9	2.3	9.1
Cyprus	96.1	42.6	3.1	54.6	0.0	0.9	0.8	1.9
Latvia	98.5	94.0	0.5	4.1	0.0	0.0	1.0	2.0
Lithuania	96.3	88.6	0.3	2.4	0.0	1.6	3.4	7.4
Luxembourg	69.9	66.0	11.3	20.8	18.8	13.2	0.0	0.0
Hungary	95.7	80.9	1.0	3.0	2.3	2.2	1.0	13.8
Malta	0.0	0.0	0.0	73.1	0.0	0.0	0.0	26.9
The Netherlands	50.7	36.2	8.8	8.5	34.3	21.1	6.2	34.3
Austria	86.9	84.2	3.7	5.6	2.4	3.1	6.9	7.1
Poland	96.2	83.6	1.4	3.4	0.0	1.0	2.4	12.0
Portugal	91.2	84.4	0.5	2.6	3.1	3.4	5.3	9.6
Romania	99.4	94.5	0.0	0.5	0.0	0.0	0.6	4.9
Slovenia	96.3	95.3	2.7	4.7	0.0	0.0	1.0	0.0
Slovakia	85.3	71.4	1.3	13.0	3.4	1.7	10.0	13.9
Finland	97.3	93.5	0.6	1.3	1.6	3.5	0.6	1.8
Sweden	91.4	88.0	0.5	1.6	6.0	7.8	2.1	2.6
United Kingdom	29.2	49.2	48.0	33.3	11.1	10.5	11.7	7.0

**Source:** Own study based on Eurostat 2009 and 2018.

In 2007 the production of municipal waste amounted to 7.4 Mtoe, while in 2016 it amounted to 10.0 Mtoe. However, the share of municipal waste in total biomass and waste production decreased from 8% in 2007 to 7.4% in 2016. The share of renewable municipal waste production in total biomass and waste production in EU countries fluctuated between zero to 21%. In seven EU countries (Estonia, Greece, Croatia, Latvia, Malta, Slovenia and Romania) the production of municipal waste

did not occur. While the highest share of renewable municipal waste production in total biomass and waste production occurred in Netherlands, Denmark, Ireland, Belgium and Luxembourg. Comparing the share of renewable municipal waste production in total biomass and waste production in 2016 and 2007 an increase was noted in 9 EU countries. The largest increase occurred in Ireland, Belgium and Bulgaria. While a decrease was noted in 11 EU countries. The largest decrease occurred in The Netherlands, Luxembourg and Denmark. In the remaining 8 countries the value of this indicator was on the same level.

Total production of liquid biofuels in EU in 2007 was 7.1 Mtoe, while in 2016 it amounted to 13.8 Mtoe. While the total share of liquid biofuels production in total biomass and waste production in the EU increased from 8% in 2007 to 10% in 2016. The share of liquid biofuels production in total biomass and waste production in the EU countries ranged from zero to 34%. The lowest share of liquid biofuels production in total biomass and waste production occurred on Estonia, Luxembourg, Slovenia and Croatia. While the highest share of liquid biofuels production in total biomass and waste production occurred in The Netherlands, Malta, Spain, Belgium and France. Comparing the share of liquid biofuels production in total biomass and waste production of the EU countries in 2016 and 2007, favorable changes were noted. In 21 countries an increase occurred, the largest in The Netherlands, Malta and Belgium.

On the basis of selected indicators, using the cluster analysis method, the EU countries were divided into groups. In both 2007 and 2016 the following groups of countries were distinguished by diversified groups with the high use of municipal waste, biogas and liquid biofuels group, solid biofuels group, biofuels group (Table 2, Figure 1).

The first group is diversified with the high use of municipal waste. Overall, the biomass mix of these countries is quite diverse. As in the other groups, solid biofuels predominate, but the share is much lower than average (less than 60% in 2007 and 2016). The countries of this group are characterized by the highest share of renewable municipal waste production in total biomass and waste production, the values of the indicator exceeded 16% in 2007 and 14% in 2016. In 2007 the first group included 6 countries (Belgium, Denmark, Italy, Luxembourg, Malta, The Netherlands) this number increased to 9 in 2016 (Belgium, Denmark, Germany, Ireland, France, Italy, Luxembourg, The Netherlands and United Kingdom). It is worth adding that the first group covers the most populated and urbanized areas, hence the significant consumption of municipal waste.

The second group has changed the most spatially. In 2007 this group covered Germany and United Kingdom but in 2016 also Malta and Cyprus. In both analyzed the countries of this group have the highest share of biogas production in total biomass and waste production (over 30% in 2007 and over 60% in 2016). In addition, the characteristic feature of this group is the smallest share of solid biofuels

(about 40% in 2007 and 21% in 2016) and high share of liquid biofuels in total and waste production (over 16% in 2007 and over 14% in 2016) according to the other groups. Due to the specifics, Malta and Cyprus have limited possibilities of biomass production. They are island, small countries, that are slowly introducing other renewable sources into the energy mix (mainly solar energy).

**Table 2.** Diversification of biomass production in EU member states – researched groups and features in 2007 and 2016

Specification	Solid biofuels (excluding charcoal)	Biogas	Renewable municipal waste	Liquid biofuels	Number of countries
	Share in total biomass and waste production (%)				
2007					
1 – diversified group with the high use of municipal waste	58,1	6,2	16,4	2,6	6,0
2 – biogas and liquid biofuels group	39,8	31,1	12,7	16,4	2,0
3 – solid biofuels group	96,2	1,0	1,1	1,6	14,0
4 – biofuels group	81,9	5,8	3,9	8,5	6,0
Average for all countries	81,0	5,3	5,8	4,4	28,0
2016					
1 – diversified group with the high use of municipal waste	57,9	16,6	14,3	11,3	9,0
2 – biogas and liquid biofuels group	21,3	63,9	0,5	14,4	2,0
3 – solid biofuels group	90,2	3,9	2,0	3,9	12,0
4 – biofuels group	77,4	6,5	1,6	14,5	5,0
Average for all countries	72,6	12,7	5,8	8,9	28,0

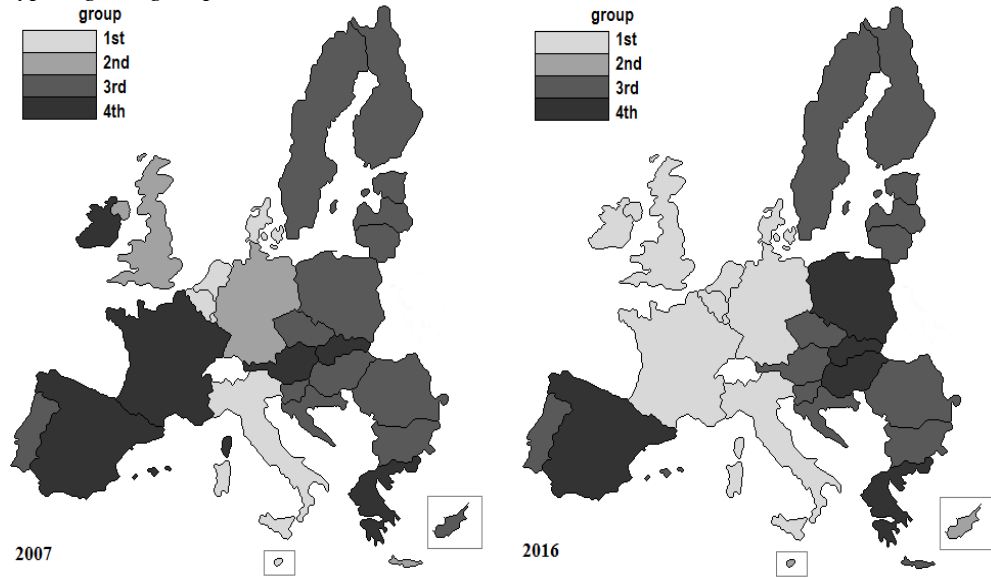
*Source:* Own study.

The third is the solid biofuels group. A characteristic feature of this group is the highest share of solid biofuels in total biomass and waste production, the value of this indicator exceeded 90% in both analyzed years. Other biomass products are of minor importance in this group. In both analyzed years the third group is the biggest group – consisting of fourteen countries in 2007 and twelve in 2016. In 2007 third group covered Bulgaria, Czechia, Estonia, Croatia, Latvia, Lithuania, Poland, Portugal, Romania, Slovenia, Finland, Sweden, Cyprus, Hungary. In 2016 Poland, Cyprus, Hungary are included in other groups and Austria is classified in the third group. Generally the third group countries with the high forest cover, hence the predominance of solid biomass in total biomass and waste production.

The fourth is the biofuels group. A characteristic feature of this group is the high share of liquid and solid in total biomass and waste production – a total of over 90% in both analyzed years. In addition, countries in this group are characterized by a quite low share of biogas production and share of renewable municipal waste production in total biomass and waste production. The fourth group includes six countries in 2007 (Ireland, Greece, Spain, France, Austria and Slovakia) and five in

2016 (Greece, Spain, Hungary, Poland, and Slovakia). A large part of the biomass in these countries comes from agriculture and forestry.

**Figure 1.** Diversification of EU member states due to the biomass production–typological groups in 2007 and 2016



Source: Own study.

## 5. Discussion

The European Union, has launched ambitious goals to incentivize the use of renewable energies. The EU Renewable Energy Directive sets targets to achieve at least 32% of its total energy use with renewables by 2030 (EU, 2018). Greater use of renewable energy sources in the European Union can ensure a more sustainable energy sector and reduce the dependence on energy imports (Mengova, 2019). Biomass at EU level is expected to remain a major contributor to renewable energy (Scarlat *et al.*, 2015).

However, the key condition for bioenergy development is the availability of reliable, affordable and sustainable biomass (EU, 2018). The core challenge of a sustainable bioeconomy in the EU seems to be finding a balance between the demands of the economy for food, energy and materials on the one hand and the sustainable supply capacities of natural systems (nationally and globally) on the other hand (O'Brien *et al.*, 2017). An imbalance between these elements can lead to competition between food supply and biomass production, reindustrialization and centralization of the agri-food production, over-exploitation of natural resources and loss of biodiversity as well as a loss in consumer trust (Imbert *et al.*, 2017).



Bioenergy contributes to the EU energy security. Most of the demand is covered from local produced biomass (Scarlat *et al.*, 2019). Biomass for energy has a key role within the EU policy support for renewable energy sources, but a method for implementing support for biomass energy sector differs in the EU countries. The EU and national support is an important factor in the use of biomass (Banja *et al.*, 2019). For EU biomass sources agriculture and forestry residues should not increase significantly in the future. Therefore energy crops on arable land or marginal land will be able to provide the greater part of the growing demand for biomass (Bentsen and Felby, 2012).

Cascading the use of biomass could improve resource efficiency and limit the pressure on natural resources. If well managed, bioenergy pathways can deliver significant greenhouse gas savings, whilst ensuring food security and protecting ecosystems and the services they provide from deforestation, degradation of habitats and loss of biodiversity. Bioenergy production can also bring significant opportunities to deliver social, environmental and economic benefits and contribute to rural development (Scarlat *et al.*, 2019). Actions taken in the field of bioenergy use have positive effects, but there are still challenges in the field of sustainable renewable energy sources. These challenges are market failures, lack of information, access to raw materials for future renewable resource deployment, and most importantly our (human) way of utilizing energy in an inefficient way (Owusu and Asumadu-Sarkodie, 2016).

## 6. Conclusion

According to the aim of the article the diversity of renewable energy production from biomass of the EU was assessed. The analysis indicates the important role of biomass as an energy source. Biomass has the largest share in total renewable energy production in the European Union. Solid biomass has dominated the structure of energy production from biomass over the past decade. Nevertheless, in the analyzed period its share dropped by almost 10%. However, the share of energy production from biogas and liquid biofuels increased.

The European Union countries are characterized by diversity in the use of biomass as an energy source. The countries of the central part of Europe mainly use biomass from municipal waste. A fairly large share was also recorded in use of biogas and liquid biofuels. The countries of northern and partly eastern Europe mainly use solid biomass. This is the result of high afforestation in most of these countries. In contrast, countries in Western and partly Eastern Europe mainly use solid and liquid biomass.

The use of biomass as an energy source depends on natural conditions, energy policy and the situation in individual countries. However, observing the energy policy pursued by the European Union and global trends, one should expect a further increase in the use of biomass for energy purposes.

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