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# Investigation the Biomass in OECD Countries and Turkey: Comparative Analysis with Classification Algorithms

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**Abstract:** In this study, energy and renewable energy issues were investigated. The goal of the study; Investigation of energy production in OECD countries is the identification of the factors affecting it. As per the cluster analysis conclusions; OECD countries are separated into three groups. Also; Classifying models were used to analyze the relationship between biomass and waste generation; energy use, carbon dioxide emissions, and primary energy consumption obtained in OECD countries. Regression analysis, correlation analysis, and decision tree analysis were applied. Carbon dioxide emissions have been the most influential variable on energy production from biomass and waste. The findings of the study propose to design energy policies towards sustainable goals. The study confirms the hypothesis that the economic cycle will help reduce inefficiencies in the energy sector, resulting in higher yields based on key factors identified from biomass. According to the literature, an investigation on various factors related to the field of biomass has been made. Also, this study examined and compared three important variables, which were determined differently from the literature, with classification analyzes that were not performed before. For this reason, it is a support for the literature and an original study.

**Keywords:** Renewable energy; biomass; clustering method; multiple linear regression analysis; decision tree analysis.

# OECD Ülkeleri ve Türkiye'de Biyokütlenin Araştırılması: Sınıflandırma Algoritmaları ile Karşılaştırmalı Analizi

**Öz:** Bu çalışmada enerji ve yenilenebilir enerji konuları incelenmiştir. Çalışmanın hedefi; OECD ülkelerinde biyokütle enerji üretiminin araştırılması, onu etkileyen faktörlerin tanımlanmasıdır. Kümeleme analizi sonuçlarına göre; OECD ülkeleri üç gruba ayrılmaktadır. Ayrıca; OECD ülkelerinde elde edilen biyokütle ve atık üretimi ile enerji kullanımı, karbondioksit emisyonları ve birincil enerji tüketimi arasındaki ilişkiyi analiz etmek için sınıflandırıcı modellerden faydalanılmıştır. Regresyon analizi, korelasyon analizi ve karar ağacı analizi uygulanmıştır. Karbondioksit salınımı, biyokütle ve atıktan enerji üretimi üzerinde en etkili değişken olmuştur. Çalışmadaki bulgular, sürdürülebilir amaçlara yönelik enerji politikaları tasarlamayı önermektedir. Çalışma, ekonomik döngünün enerji sektöründeki verimsizlikleri azaltmaya yardımcı olacağı ve biyokütleden belirlenen temel faktörlere dayalı olarak daha yüksek verimle sonuçlanacağı hipotezini doğrulamaktadır. Literatürdeki çalışmalar incelendiğinde biyokütle alanı ile ilgili çeşitli faktörlerle çalışmalar yapılmıştır. Ayrıca çalışma, literatürden farklı olarak belirlenen üç önemli değişkeni daha önce yapılmamış sınıflama analizleri ile incelemiş ve karşılaştırmıştır. Bu sebeple literatüre destek ve özgün bir çalışma niteliğindedir.

**Anahtar Kelimeler:** Yenilenebilir enerji; biyokütle; kümeleme yöntemi; çoklu doğrusal regresyon analizi; karar ağacı analizi.

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## 1. Introduction

With economic growth, the need for energy increases day by day. At this point, it is thought that renewable energy sources provide solutions to these problems will provide an economic and social contribution to countries in many areas. Consumption of renewable energy harms short-term and long-term economic development [1]. This study includes an analysis of electricity generation from biomass and waste from annual renewable energy sources of OECD countries. The study is important today to help the strategies planned for the economic development of the countries, to draw attention to the issue of renewable energy and biomass, to share the current data, and to investigate the potential productions of the countries.

All economic actions take a conversion, and it takes place with energy. Energy does not need to have a certain level of relationship with other production agents and is very important for all countries [2]. According to the IEA, 82% of the world's energy requisition is met from fossil energy sources such as oil, coal, and natural gas. Therefore, it can be said that economies are subject to fossil energy resources [3]. In the last century, the increase in global energy requisition more than the population rise and the effects of economies on fossil energy sources created some economic and environmental concerns [4]. Approximately 50% of the energy will be provided through renewable resources in 2040 [5].

In the past, people used biomass resources such as leaves and wood as the main energy source in their daily lives. Although fossil fuel has changed biomass and has been chosen for use in urban areas, biomass has become an increasingly important selection in the energy industry today [6]. Biomass can be stored and used on-demand [7]. It can also increase the safety of biomass fuels and reduce carbon dioxide emissions [8]. Biomass energy resources, which is regarded as one the notable renewable resources, is made up of vegetable and animal-based, and urban-industrial wastes. Vegetable-based renewable energy resources comprise forest products, some tree species that are capable of rapidly growing, seaweed and algae. Biomass utilized as animal waste is used to generate energy from obtained animal manure [9]. Urban and industrial-based wastes involve municipal and industrial wastes, also called municipal waste [10]. The vast majority of the biomass used in the urban area can be transformed into everyday life [6].

Energy production from biomass or organic solid waste takes a biochemical flow [11]. While applying biochemical processes such as fermentation, biomass is turned into biofuels with the nutritive effect of living organisms [12]. The remaining energy needs of the world are met by nuclear 4.9%, hydroelectric 2.5%, and the rest from other sources, respectively [13].

Biogas meets the substantial amount of heat generation across Asia. There are about one hundred thousand large-scale biogas plants in China in 2014 and they produce 43 million residential-scale gas [6]. The biogas plant was established in India for more than 82.730 families in 2014 and the total profit is 4.75 million. Approximately 24% of biogas production in South Korea is used for heat generation throughout the year [14]. In 2016, it is envisaged that gases will be cleaned and $H_2$ gas is obtained and in 2018, hydrogen generated from biomass will be integrated into vehicles. The first biogas sector in Turkey as Bursa, Istanbul, Ankara, Gaziantep, Samsun, biogas production from waste, industrial plants, and biogas from municipal waste and biogas consist of a qualified project [15].

## 2. Literature Review

Renewable energy and biomass have been the subject of many types of research in recent years and different interpretations have been introduced. This article provides comprehensive research on advances and challenges in biomass gasification technology. It provides suggestions for stakeholders and policymakers to popularize this technology while working for a society in the dissemination of technology for the daily needs of society [16]. Simanjuntak and Zainal studied sawdust gasification in a cylindrical fluidized bed gasifier comprised of two zones. It was observed that the equivalence ratio varied from 0.148 to 0.203 on System stabilization temperature, composition, the heating value of the producer gas, and gasifier performance [17]. Akyürek et al. conducted a modeling study to examine the hydrogen production potential of pepper wastes with air-stream gasification technology. Due to the high $O_2$ content in the pepper residue, the air/fuel and steam/fuel ratios were taken as 0.05. The gasification temperature for the developed model is 877 °C. According to the modeling result, the hydrogen content in the gas produced by the gasification of pepper wastes was 49.08% [18]. Banerjee et al. developed a kinetic model for different raw materials. Model; Includes pine, maple-oak maize, seed maize, corn stone, and watery grass and steam conditions under oxygen-enriched air ranging from 21% to 45% [19]. Memari et al. examined carbon tax and trade policies to provide biomass. They observed that there was a linear increase as a result of the study. Also, The carbon price can lead to nonlinear reductions in total emissions. The impact of different policies on biomass has been investigated. The purpose is different to investigate carbon regulation policies [20]. Olufemi et al. focused on optimum production and characterization of biodiesel from Spirogyra. Parametric optimization with Minitab software was used to design the experiment using Central Composite Design (CCD). Fourier Transform Infrared Spectroscopy (FTIR) analysis of biodiesel showed the intensity of the strong -C=O ester bond. The characterizations performed confirmed good conformity with conventional diesel specifications and standards [21]. This review article provides an insight into the data on different biomasses and their contribution to the economy of both countries. Turkey and in the future energy scenarios, Malaysia was aimed to compare the potential of renewable energy and biomass [22]. Görgülü, using 2018 Turkish Statistical Institute (TUIK) data, was carried out in two stages. In the first stage of the study, the amount of animal waste and biogas potential that can be obtained according to the number of animals was calculated and the energy potential was calculated. In the second stage, the energy potential was calculated by finding the theoretical biomass potential that can be obtained from agricultural wastes according to the production amount of some agricultural products and the acceptances made. According to the calculations, the energy potential that can be obtained from animal wastes in Burdur province, where the highest potential is in the central district, was determined as 447733.2 GJ (10,693.92 TEP) [23]. This article explores the properties of raw materials, gasification methods, pretreatments, and future values. Due to the heterogeneous nature of the non-woody biomass, it is important to apply the specified pre-treatments before gasification. Non-woody biomass has the potential to improve fuel quality by combining a small percentage of high-quality carbon with fuel pellets for gasification [24]. This study analyzed the relationship and interaction between biomass energy use rate and the environment. The development and use of biomass energy are of great importance to come up with recommendations and strategies [25]. Akyürek, determined the effect of biogas production from agricultural residues and municipal solid waste (MSW) on greenhouse gas emission reduction for the Mediterranean Region. The results reveal that the region has a biogas production potential of 1942.6 million $m^3$/year, corresponding to 11.11 TWh of energy generation capacity [26]. This study also defines the communities based on the keywords of the publications obtained. Six communities or clusters have been found. The focus is on obtaining liquid fuel from biomass. Finally, eight clusters were observed, depending on the cooperation between countries. All this focused on the three countries to which it belongs. to different clusters: India, USA, and UK [27].

The article investigated different pyrolysis products, their yields, and the factors. Also, that the properties of pyrolysis products depend on the biomass used and Pyrolysis products such as bio-oil have been shown to contribute to the local economy [28]. Sajdak et al. by performing chemical analyzes in their studies and determining the relationships with various regression analysis methods; developed models for calculating the contents of the elements and the combustion temperature. For analysis, coal, biomass, and biochar were selected. Biochar was produced from various types of biomass by various processes. It was revealed that the results obtained from the study were confirmed by the estimated models [29]. Cheng et.al stated that areas have microorganisms that can convert biomass to biomass energy [30]. Xu et al. studied five biomass-based electricity generation plans in China and their environmental impact with statistical data. It is stated that coal-based electricity generation technology is used in the current system. It is stated that uncertainty analysis is applied to give reliability and accuracy to the study [31]. Soliño et al. examined the policy of transition from conventional electricity production to forest biomass through electricity selection through consumer preference selection experiment analysis. It was stated that the consistency of responses using preference experiments and the effect of payment time interval on payment and margin requirements were examined by methodological test [32].

## 3. Material and Method

### 3.1. Material

In the study, to evaluate the primary energy consumption of OECD countries in 2012 with the production of electricity from biomass; clustering and classification algorithms are used. IBM SPSS Modeler 11.0 and IBM SPSS Statistics 20.0 package program are used in data analysis.

### 3.2. Method

Cluster analysis and classification models were used in the study. The model performance obtained afterward has been measured.

#### 3.2.1. Cluster Analysis

Cluster analysis; units are used to decompose homogeneous clusters and describe specific examples based on differences or similarities between specified variables [33]. In this study, dendrograms were used. In addition, clustering has been created with the K-Means algorithm. K-Means Clustering; The K-Average algorithm aims to find the most appropriate fragmentation in the data based on the minimum error function [34].

#### 3.2.2. Linear Regression Analysis

In the regression analysis, the extent to which one or more variables affect one or more other variables is examined. Multiple linear regression analysis was used in this study. It is used to examine the effect of one or more variables on the dependent variable [35]. The effect levels of three determined variables were seen.

#### 3.2.3. Decision Tree Classification Algorithms

C&R decision tree algorithm was used in this study. The CRT algorithm presents the factors that have an effect on the predicted variable as a tree structure according to their significance level [36].

#### 3.2.4. Performance Criterion: MAPE

Model performances are measured according to the difference between the output produced by the actual system for a given input and the output obtained by applying the same input to the model. Mean absolute percentage error (MAPE) was used to measure the performance of the model in eq.1 [37].

MAPE:

$$\frac{1}{T}\sum\left|\frac{y_i-\widehat{y_i}}{y_i}\right| x100 \quad (1)$$

$y_i$ : Real observation values
$\widehat{y_i}$ : Estimated values

## 4. Experimental Results and Discussion

Descriptive statistics of selected indicators of OECD countries for 2012 are given in Table 1.

**Table 1.** Descriptive statistics.

| | Mean | Standard Deviation |
|---|---|---|
| Per_Capita_Energy_Use (kWh) | 4364.9 | 2962.1 |
| Carbon_dioxide_emission (million ton) | 210 | 270 |
| Production_of_energy_from_biomass (kWh) | 8.31 | 14.74 |
| Primary_energy_consumption (Mtep) | 173.12 | 399.32 |

According to Table 1, Per capita energy use is 4364.9 ± 2962.1 kWh; Carbon dioxide emission is 210 ± 270 million tons; Production of energy from biomass is 8.31 ± 14.74 kWh and Primary energy consumption is 173.12 ± 399.32 Mtep.

**Table 2.** K-Mean analysis.

| Country number | Countries | Cluster | Distance | Country number | Countries | Cluster | Distance |
|---|---|---|---|---|---|---|---|
| 1 | Germany | 1 | 0.000 | 17 | Iceland | 2 | 2.763 |
| 2 | Australia | 2 | 0.907 | 18 | Japan | 3 | 10.473 |
| 3 | Austria | 2 | 2.378 | 19 | Canada | 2 | 5.023 |
| 4 | Belgium | 2 | 2.531 | 20 | Korea | 2 | 1.789 |
| 5 | USA | 3 | 1.086 | 21 | Luxembourg | 2 | 2.637 |
| 6 | Czech Republic | 2 | 0.455 | 22 | Hungary | 2 | 0.657 |
| 7 | Denmark | 2 | 1.746 | 23 | Mexican | 2 | 0.127 |
| 8 | Estonia | 2 | 2.188 | 24 | Norway | 2 | 2.347 |
| 9 | Finland | 3 | 3.808 | 25 | Poland | 2 | 4.006 |
| 10 | France | 2 | 3.427 | 26 | Portugal | 2 | 0.032 |
| 11 | Netherlands | 2 | 4.901 | 27 | Chile | 2 | 0.810 |
| 12 | Ireland | 2 | 2.454 | 28 | Slovakia | 2 | 2.086 |
| 13 | Spain | 2 | 1.868 | 29 | Slovenia | 2 | 2.517 |
| 14 | Sweden | 3 | 2.197 | 30 | Turkey | 2 | 2.351 |
| 15 | Switzerland | 2 | 0.529 | 31 | New Zealand | 2 | 2.160 |
| 16 | Italy | 3 | 3.381 | 32 | Greece | 2 | 2.505 |

### 4.1. Cluster Analysis Findings

*Hierarchical Clustering Method Findings*: Hierarchical clustering analysis is used to interpret the analysis correctly and to obtain efficient results. The dendrogram of the groups belonging to the countries according to the number of clusters using this method obtained. The distance between countries other than Germany and Japan is a unit. The merger of countries at one unit distance means that the production progress and production amounts are similar to each other over the years. These countries are combined with Germany and Japan in approximately six units. This cluster is characterized by the fact that these countries are close to the production of electricity from biomass and waste, and the percentage of the increase in production between years is similar.

In the K-Mean analysis, the clustering membership was taken in three and the quantitative significance is shown in Table 2.

In the K-Means clustering analysis, when the number of clusters for the last six years data is taken as three; while Germany is in the 1st cluster, the USA, Sweden, Japan, Finland, and Italy are among the third countries and attract attention among other countries. In Table 1, Turkey is located in the 2nd set with 2.351 units of distance. Germany alone formed the cluster. Considering the 2019 development levels of the countries that stand out in this table, Germany is among the highly developed countries with 0.916 high, USA 0.915, Finland 0.883, Sweden 0.907, 0.873, and Japan 0.891 development indexes. Accordingly, it can be said that the result of the analysis is related to the high level of development.

### 4.2. Classifier Model Findings

In this study, it is aimed to determine how the criteria determined by the help of classification models affect the output variable.

#### 4.2.1. Multiple Linear Regression Analysis Findings

Analysis; Correlation analysis was used to see the mathematical model among them in terms of energy use, carbon dioxide emission, and primary energy consumption variables with electrical energy generation from biomass as dependent variable. Table 3 shows the summary of the model.

**Table 3.** Summary of model.

| Model | R | $R^2$ | Adjusted $R^2$ | Std. error of estimation |
|---|---|---|---|---|
| 1 | 0.861 | 0.741 | 0.714 | 7.880 |

According to Table 3, it can be seen that the adjusted $R^2$ values were 0.714 %. The ratio of the dependent variable of the independent variables used in the analysis is above the average. It shows that $R^2$ value is sufficient for the descriptiveness of the model. Relationships between variables are analyzed in Table 4.

**Table 4.** Multiple linear regression model/Independent variables and their coefficients.

| Model 1 | Coefficients | | Std. Coefficients | t | Significance Level |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | | |
| Constant | 2.862 | 2.603 | | 1.100 | 0.280 |
| Carbon Dioxide E. | 5.11E-003 | 0.005 | 0.094 | 0.940 | 0.355 |
| Primary Energy C. | 3.07E-002 | 0.004 | 0.832 | 8.368 | 0.000 |
| Energy use | -2.16E-004 | 0.000 | -0.043 | -0.454 | 0.653 |

To indicate the contributions of the variants of the model, the table of coefficients obtained from the regression analysis, shown in Table 4 were examined. When the significance values in the coefficients table according to Table 4 are examined, it was found that the most important variable affecting the production of electricity from biomass and wastes was Carbon Dioxide emission. After that, the second variable is primary energy consumption with B values. Energy use affects biomass production in a negative and inverse ratio.

The histogram and scatter diagram of electrical energy generation from biomass and wastes are shown in Figure 1. If the residual values are zero or close to zero, this means that the study is successful.

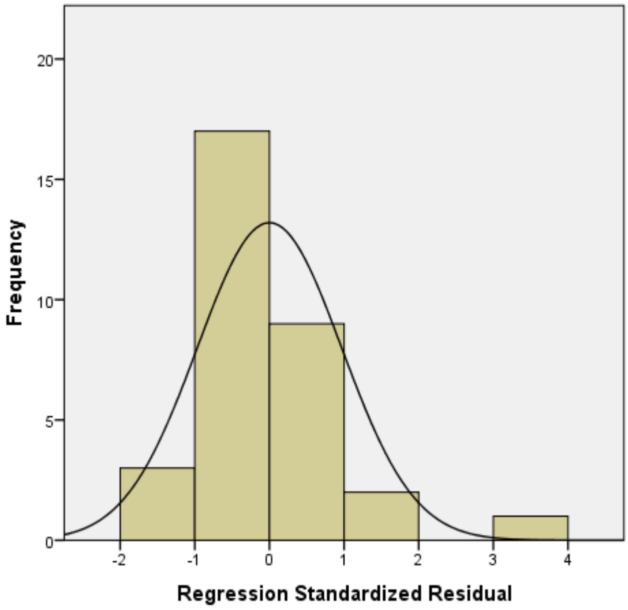


**Figure 1.** Biomass and waste electrical energy production histogram

Multiple linear regression equation in the model:

Production Capacity of Biomass and Waste: 2.862 + [(3.07E-002) x Primary Energy Consumption)] + [(5.11E-003) x Carbon Dioxide Emission] + [(-2.16E-004) x Energy Use].

As a result of multiple linear regression analysis, it was first checked whether the results provide assumptions. Three variables that have the greatest effect on the production of electricity from biomass and wastes were examined. It was seen that the $CO_2$ emission of these variables affected the production of electrical energy from biomass and wastes more than the primary energy consumption and energy use variables.

Estimated biomass values for each country were calculated by considering the equations in the model. According to this calculation, the current biomass values and estimated values were compared and the MAPE ratio was calculated. The MAPE ratio was found to be 41.7%. Extreme values in evaluation are not included in the analysis. The value found proves that the model is valid according to the validity evaluation in the literature [34]. Frechtling says “very good” for models with mean absolute percent error values below 10%, “good” for models between 10% and 20%, and “acceptable” for models between 20% and 50%. More than 50 models are classified as "wrong and faulty" [38]. When the results were evaluated, it was seen that regression analysis, according to the estimations made, could be an economical and correct choice to estimate the production of electricity from biomass and waste.

### 4.2.2. Decision Tree Analysis Findings

Decision tree analysis was conducted for the reason of the effects of the factors in this study on estimated production. The factors are determined as primary energy consumption, energy use, and $CO_2$ emission. While the C&R Tree algorithm decision tree model is being examined, the decision tree findings of countries' energy production from biomass are shown in Figure 2.

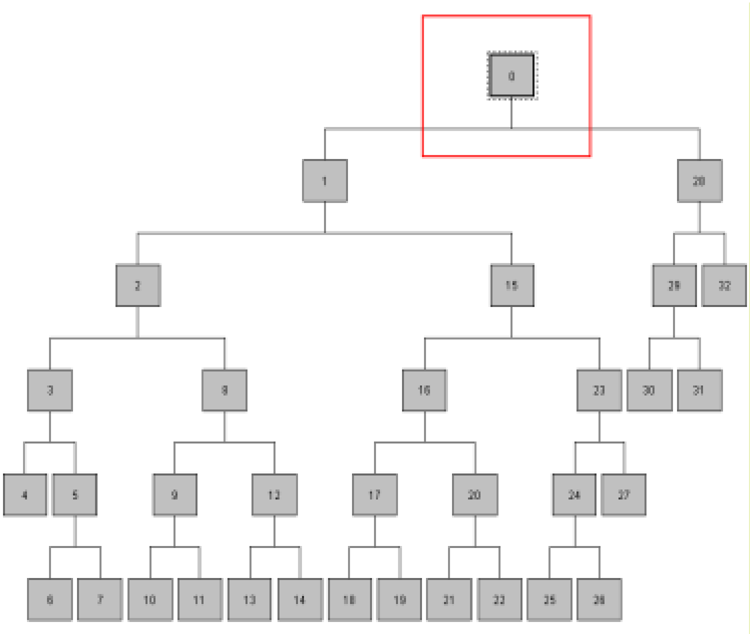

**Figure 2.** Decision tree for production quantity estimation

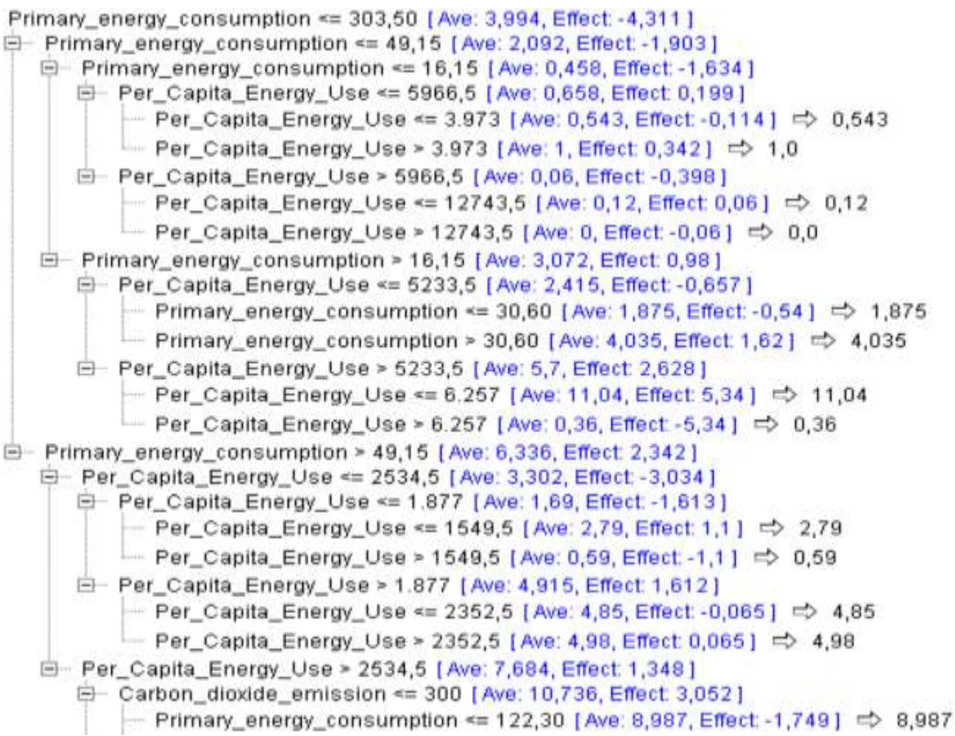


**Figure 3.** Rules for CR&T analysis

According to Figure 2, primary energy consumption was seen as the most important independent variable affecting the amount of electricity production from biomass and wastes. After primary energy consumption, energy use had the first branch. The result of the algorithm for this analysis is shown in Figure 3.

When Figure 3 is examined, while the primary energy consumption is ≤ 303.500 Mtep, the estimated production amount is 3.994 billion kWh; While the primary energy consumption is ≤ 49.150 Mtep, the estimated production amount is 2.092 billion kWh; While the primary energy consumption is ≤ 16.150 Mtep, the estimated production amount is 0.458 billion kWh, Carbon dioxide emission is ≤ 300 million tons, estimated production amount is 10.736. While the carbon dioxide emission is > 300 million tons, the estimated production amount is 3.87 billion kWh. Energy use is ≤ 5966 kWh, the estimated production amount is 0.658 kWh; it is > 3.973, the estimated production amount is 1; it is > 5966 kWh, the estimated production amount is 0.06. While energy use is ≤ 5233 per kWh, the estimated production amount is 2.415 kWh; it is > 5233per capita, the estimated production amount is 5.7 kWh.

When the results are examined; while primary energy consumption is increasing, it is seen that the production of electric energy from biomass and wastes also increased. It is seen that there is a direct correlation between this variable and the variable. Also, when the carbon dioxide emission increases, it is seen that the production of electric energy from biomass and wastes is reduced. The energy use affects the production after primary energy consumption. When it decreases, the production increases and there is an inverse relationship between the variable and the dependent variable. The decision tree analysis also identified countries that did not affect the average. In these countries; primary energy consumption is ≤ 16.150 and carbon dioxide emission is ≤ 10.500 million tons. Only one country has been identified and this country is Iceland with a development level of 0.899. 2 million tons of carbon dioxide emission did not affect the production. High primary energy consumption values were developed countries such as the USA, Japan, Germany, Canada, and Korea, respectively. It is seen that these countries (the USA are excluded from the analysis because they have extreme values) are the most affected countries by the total production value and the estimated production value in the analysis. Turkey, meanwhile, despite having a medium level of development with 125.3 million tons, consumption was found to have values close to other developed countries. The estimation data found is compared with the actual data. Error results were calculated as Average Absolute Percentile Error (MAPE). The MAPE ratio was found to be 41.7%. Extreme values in evaluation are not included in the analysis. The value found proves that the model is valid according to the validity evaluation in the literature [34]. When the results were evaluated, it was seen that regression analysis, according to the estimations made, could be an economical and correct choice to estimate the production of electricity from biomass and waste. Comparison of classification algorithms in Figure 4.

Results for output field Production_of_energy_from_biomass

Individual Models

Comparing $E-Production_of_energy_from_biomass with Production_of_energy_from_biomass

| | |
|---|---|
| Minimum Error | -15,259 |
| Maximum Error | 29,171 |
| Mean Error | 0,0 |
| Mean Absolute Error | 4,843 |
| Standard Deviation | 7,502 |
| Linear Correlation | 0,861 |
| Occurrences | 33 |

Comparing $R-Production_of_energy_from_biomass with Production_of_energy_from_biomass

| | |
|---|---|
| Minimum Error | -3,767 |
| Maximum Error | 2,653 |
| Mean Error | -0,0 |
| Mean Absolute Error | 0,637 |
| Standard Deviation | 1,096 |
| Linear Correlation | 0,997 |
| Occurrences | 33 |

**Figure 4.** Comparison of classification algorithms

In the research, multiple linear regression analysis and CRT algorithm, which is one of the decision trees, were used as the classification model. In the model performance comparison, the MAE value was examined. When the MAE value was examined, it was determined that the CRT decision tree had a lower error value compared to the regression analysis.

## 5. Conclusion

The share of biomass waste from renewable sources is higher compared to previous years. Although there is not as much production as the USA, Japan and Germany, electricity production from biomass energy; especially Istanbul, Ankara, Adana, Çanakkale, Konya, Balıkesir, Mersin, İzmir, Samsun, Tekirdağ, Kocaeli, Afyon, Elazığ, Hatay, Bursa and Eskişehir, and many cities continue with a steady increase in Turkey. Inter-country multiple comparisons were made with the analysis. The USA, Japan, and Germany are in the top 3. Turkey is located in the lower level is that despite the existing potential. Therefore potential resources that use renewable energy resources should be investigated. Also, more effort should be devoted to renewable energy to reduce Turkey's energy imports in economic development and industrialization results.

In the study, after the research was conducted with cluster analysis, variables were examined with classifier models and the electrical energy consumption from biomass. Correlations and degrees of influence between these variables were investigated. Thus, Turkey and the world with biomass regression and decision tree analysis after looking at the overall situation has designated these sources most affecting the relationship between three variables. As a result of these analyzes, the reliability level was measured by making comparisons between methods. In addition, a logical model was proposed with the resulting values.

When recent studies have examined the literature of the OECD countries and Turkey-based on comparison is an important source of renewable energy such as biomass and there is no analysis of the situation in different ways. The study awaits an answer to the question that will read in this missing section in the literature. The current state of biomass energy resources in Turkey and OECD countries has been investigated in this study.

In the rapidly globalizing world, the importance of renewable energy sources is increasing. It's thought that biomass energy resources, which have an important share among these resources, will contribute greatly to energy production in the world if necessary studies are carried out. In addition, when the domestic and world studies are examined, it is recommended to carry out more comprehensive studies on biomass energy resources. For this reason, it is aimed that the study will provide encouragement and a different guiding perspective to the studies planned to be carried out in this field in the future.

Paper explained that The article found that the use of biomass energy reduces carbon emissions, and $CO_2$ emissions were examined with causality analysis. In the study, the effect of carbon emissions has been revealed by examining the energy production of $CO_2$ emissions. It has been discovered that biomass energy is a natural energy source that helps decarbonization [39]. In this study, data for the period 1980-2015 were obtained in 26 OECD countries. The relationship between renewable and non-renewable electricity consumption and economic growth has been investigated [40].

The study examined the effect of biomass energy consumption on economic growth in 26 OECD countries for the years 1980-2013. OECD countries should improve their biomass energy infrastructure as an important renewable energy source to support economic growth [41]. This aim is to examine the impact of energy consumption and non-renewable energy consumption on development in OECD countries. According to estimates, the impact of biomass energy consumption on per capita sustainable development is positive. Although statistically significant, the effect of non-renewable energy on sustainable development is negative [42]. This article discusses energy efficiency by examining an integrated model associated with technology and urbanization in energy-related fields. The results show that paying attention to the environment does not affect productivity in general, while utilizing renewable resources reduces it [43]. The main countries studying biomass production are the United States, followed by China, India, Germany, and Italy. Six clusters were found as a result of the study. The most important are the countries that obtain liquid fuel from biomass. Based on cooperation between countries and biomass research, eight clusters have been observed. Three countries stood out: the USA, India, and the UK [23]. According to the findings, the real gross domestic product increased per capita positively affected the per capita energy use growth rate. Major countries are Germany, Australia, Austria, Belgium, Canada, Denmark, Spain, USA, Finland, France, Greece, Netherlands, Italy, Luxembourg, Norway, Portugal, Sweden, and New Zealand [44].

In the literature, energy is compared. The need for these energies has been explored. The extent to which some of the determined indicators affect energy-based economic growth has been investigated. The biomass energies of countries such as OECD were investigated with some analysis methods. Our study shows that the need for renewable energy and biomass energy is gradually increasing as a result of the analysis. It emphasizes that the current biomass energy of OECD countries and Turkey is not sufficiently evaluated and countries should be more researchers on this issue. With these aspects, the study supports the current studies in the literature. In addition, the important indicators affecting biomass energy were examined by classification methods and regression analysis. As a result of these analyzes, the effect of indicators on biomass energy was calculated numerically. When the literature was examined, the indicators were evaluated with different analyzes in the studies. The effects of the three indicators determined in our study were not analyzed numerically by comparative analysis previously performed together in the literature. With these aspects, this study supports the literature and is an original study.

The study can be considered to be the source of other researches in this direction. If the current resource and data shortages are eliminated, it is considered that the studies that will contribute to the literature can be increased and will provide energy saving, high income-employment level, economic growth, and high agricultural opportunities to our country.

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**Author(s) Contributions**

MNTE and FE wrote up the article. The authors read and approved the final manuscript.

**Conflicts of Interest**

The author declares no conflict of interest.

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