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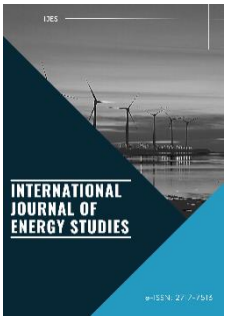

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The impact of transition from fossil fuels to renewable energy on carbon emissions: The case of the European Union

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Highlights

- The study examined the effects of the EU's transition from fossil fuels to renewable energy sources on carbon emissions in detail.
- The aim of this research is to scientifically demonstrate the effectiveness of the policies implemented in this process by analysing the impact of the transition from fossil fuel use to renewable energy sources on carbon emissions in the period between 1990-2015 in the EU.
- The findings of this study will provide policymakers with valuable guidance on shaping the EU's energy policies.
- The results of the analysis can be used to verify the effectiveness of renewable energy policies, improve existing ones, and identify strategies for future energy transitions.

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ABSTRACT

The aim of the study is to examine the effects of fossil fuel consumption and renewable energy consumption on carbon emissions (CO_2). In this context; energy consumption and carbon emission data of European Union countries for the period 1990-2015 are analysed using Descriptive Statistics, Time Series Regression Analysis (Least Squares - OLS) and Heteroskedasticity Control (Huber-White HC1 Correction) methods. According to the results of the regression analysis evaluating the impact of fossil fuel consumption on carbon emissions, an increase in fossil fuel consumption increases carbon emissions at a statistically significant level ($p = 0.0000$). It was determined that a 1% increase in fossil fuel consumption rate increases carbon emissions by approximately 0.167 metric tonnes. This result clearly demonstrates the role of fossil fuel use in carbon emissions and its environmental damage. This finding is consistent with the direct effect of fossil fuel use on greenhouse gas emissions, which is frequently emphasised in the literature. According to the results of the analysis examining the effect of renewable energy consumption on carbon emissions, the increase in renewable energy use significantly reduces carbon emissions ($p = 0.0000$). A 1% increase in renewable energy consumption rate leads to a decrease of 0.155 metric tonnes in carbon emissions. This finding proves the undeniable importance of renewable energy sources in combating climate change. The results reveal that renewable energy investments are important not only for energy supply security but also for environmental sustainability. It provides strong evidence that the European Union's renewable energy targets should be raised and policy support mechanisms should be maintained.

Keywords: Fossil fuel consumption, Renewable energy consumption, Carbon emissions, Descriptive statistics, Time series regression analysis, Huber-white hc1 correction.

1. INTRODUCTION

The acceleration of industrialisation has led to a significant increase in global energy demand. This demand is largely met by fossil fuels. The intensive use of fossil fuels results in carbon emissions that cause serious environmental problems, such as global warming and climate change. Consequently, policies aimed at reducing carbon emissions are gaining prominence worldwide, and the importance of renewable energy resources is increasing (IEA, 2022). Broadly speaking, renewable energy sources are systems that constantly renew themselves and pollute less. Unlike fossil resources, these do not contain CO_2. The main advantage of renewable energy sources is that they can be found anywhere in the world depending on geographical and geopolitical circumstances. Countries do not need to import them and they alleviate the problem of energy dependence (Kralova and Sjöblom, 2010).

Burning fossil fuels causes CO_2 emissions, leading to climate change and other environmental issues. The extraction, transport and consumption of fossil fuels therefore create numerous environmental and health problems. Consuming fossil fuels such as coal, oil and natural gas releases large amounts of CO_2 into the atmosphere, causing global warming and climate change. The extraction and transport of fossil fuels cause devastating ecological damage, including habitat destruction and water pollution. These environmental impacts emphasise the need to transition to renewable energy sources that are more sustainable and less harmful to the environment. As awareness of the environmental damage caused by fossil fuels has grown, the world has started to turn to alternative energy sources (Haggar, 2011; Geller, 2002).

Renewable energy sources are considered the main element of the energy transition and have the potential to reduce greenhouse gas emissions by limiting the use of fossil fuels. In this context, the relationship between the transition to renewable energy and fossil fuel consumption and carbon emissions is an important area of research. The European Union (EU) is a leading region in the adoption of environmentally sensitive energy policies and is at the forefront of the fight against global climate change. As a signatory to international agreements such as the Kyoto Protocol (1997) and the Paris Climate Agreement (2015), the EU has committed to increasing the use of renewable energy and reducing carbon emissions. It is therefore extremely important to measure the impact of EU member states' efforts to implement renewable energy policies and reduce fossil fuel use on carbon emissions (World Bank, 2023).

The main source of the emission of various greenhouse gases, particularly carbon dioxide (CO_2), is fossil fuel consumption. These gases are released into the atmosphere when energy resources such as oil, coal and natural gas are burned, and they trigger global warming by strengthening the greenhouse effect. The environmental sustainability of energy systems based on fossil fuels is low (Climate Watch, 2023). In contrast, renewable energy sources (such as wind, solar, hydroelectric, geothermal and biomass) offer significant advantages over fossil fuels in terms of carbon emissions. Increasing the use of renewable energy sources reduces the carbon intensity of energy production, thereby limiting greenhouse gas emissions and contributing significantly to the goal of preventing climate change (IEA, 2022). However, the transition from fossil fuels to renewable energy involves more than just increasing the use of renewable resources; it also requires reducing the use of fossil resources. Therefore, the decrease in fossil fuel consumption rates, the increase in renewable energy rates, and the combined effect of these two factors on carbon emissions must be considered in tandem. The main objectives of EU energy policies are to ensure energy supply security, increase energy market competitiveness and establish environmental sustainability. Since the 1990s, the EU has shaped its energy policies around strategies supporting the transition to a carbon-neutral economy. In this context, the process initiated by the Kyoto Protocol has been reinforced by the Paris Climate Agreement, with ambitious targets set for the period between 2030 and 2050. These include increasing the share of renewable energy, improving energy efficiency, and significantly reducing carbon emissions. The Paris Climate Agreement aims to reduce global warming by achieving zero emissions by 2050. In line with this goal, signatory countries are expected to develop plans to reduce greenhouse gas emissions. A significant portion of greenhouse gas emissions comes from logistics activities. The selection of logistics village locations, along with reducing traffic congestion and developing multimodal transportation, is important in terms of reducing greenhouse gas emissions. The selection of logistics village locations to be established using public resources has the potential to contribute to the emission reduction and sustainable development goals required by the Paris Climate Agreement (European Commission, 2022). As a result of EU policies, the proportion of renewable energy in total energy consumption has steadily increased, while fossil fuel consumption has decreased. These trends are expected to have positive environmental consequences. In this context, demonstrating the impact of the transition to renewable energy on carbon emissions is crucial for shaping future policies.

Today, the environmental damage caused by carbon emissions has reached significant levels. Research and development (R&D) activities that aim to reduce environmental damage, such as

carbon capture and storage and clean coal technologies, are intended to reduce gas emissions. A large proportion of carbon emissions are caused by the use of fossil fuels in the energy sector, and as energy consumption increases, so do carbon emissions. Fossil fuels leave solid and gaseous residues after combustion. These residues cannot be utilised and cause environmental pollution (DEKTMK, 2010).

The study aimed to determine the impact of the EU's transition from fossil fuels to renewable energy sources on carbon emissions. To this end, relevant data from EU countries between 1990 and 2015 was used. The energy crisis in Europe resulting from the Russia-Ukraine war and the selection of EU countries in this context highlight the importance of this study. The study will analyse the effects of changes in EU energy policies and evaluate the effectiveness of energy transition policies in achieving environmental goals. This study aims to demonstrate the effectiveness of the policies implemented in this process by analysing the impact of the transition from fossil fuel use to renewable energy sources on carbon emissions in the EU between 1990 and 2015. It is therefore crucial to determine the impact of fossil fuel consumption rates on carbon emissions, measure and evaluate the effect of renewable energy consumption on carbon emissions, and reveal the effect of the ratio of fossil fuel to renewable energy consumption on carbon emissions. The findings of this study will provide policymakers with valuable guidance on shaping EU energy policies. The results of the analysis can be used to verify the effectiveness of renewable energy policies, improve existing policies, and identify strategies for future energy transitions.

2. LITERATURE

Carbon dioxide emissions, which cause the greenhouse effect, are primarily caused by the use of fossil fuels in energy production and consumption. Many studies have recently been carried out to reduce these emissions.

In their study on the importance of energy, Sato et al. (1998) analysed Japan's future energy options. They used MARKAL, an optimal allocation model for the energy market, to analyse the period from 1990 to 2050. The results of the study showed that it would not be possible to reduce carbon emissions to levels lower than those in 1990 without utilising nuclear energy. Therefore, increasing nuclear energy expenditure could significantly reduce carbon emissions. Liaskas et al. (2000) aimed to determine the factors causing changes in industrial carbon emissions levels in their study. They analysed changes in output level, energy intensity, fuel mix and structural change

factors using the algebraic decomposition method. They concluded that it is possible to reduce carbon emissions without adversely affecting economic growth. Apergis et al. (2010) investigated the causal relationship between carbon emissions, nuclear energy consumption, renewable energy consumption, and economic growth in 19 developed and developing countries between 1984 and 2007, employing a panel error correction model. According to the long-run estimates, nuclear energy consumption is negatively correlated with emissions, while renewable energy consumption is positively correlated with emissions. In the short term, the study concluded that nuclear energy consumption plays an important role in reducing carbon emissions, whereas renewable energy consumption does not contribute to emission reductions. Pao and Tsai (2011) examined the dynamic relationship between pollutant emissions, energy consumption, and output in Brazil between 1980 and 2007. According to the results of their causality analysis, a strong bidirectional causal link was found between income, energy consumption and emissions. As a result of the study, Brazil adopted a dual strategy: increasing energy infrastructure investment to reduce CO_2 emissions and prevent their negative impact on economic growth, while accelerating energy conservation policies to reduce energy waste and increase efficiency. Taking into account data from 15 EU countries between 1995 and 2010, Abolhosseini et al. (2014) investigated the impact of renewable energy developments, energy technology innovations and environmental taxes on CO_2 emissions. They concluded that increases in environmental taxes and innovations in energy technologies reduce CO_2 emissions. In their study, Zaidi et al. (2018) analysed the impact of different types of energy on CO_2 emissions by examining data from Pakistan between 1970 and 2016. They concluded that renewable energy reduces CO_2 emissions. Additionally, it was found that natural gas and coal, both non-renewable energies, increase carbon emissions the most. In their study on selected countries that consume the most renewable energy, Ansari et al. (2020) analysed data from 1991 to 2016 using the Pooled Mean Group Estimator (PMGE), FMOLS and DOLS methods. The study found that economic growth and non-renewable energy consumption have a positive effect on CO_2 emissions, while renewable energy consumption, globalisation and urbanisation have a negative effect. Hadj (2021) examined the impact of biofuel consumption on CO_2 emissions in Saudi Arabia using the NARDL method for the period 1984–2017. His study found that an increase in biofuel consumption and urbanisation levels reduces CO_2 emissions in both the short and long term. In the short term, financing green energy projects reduces CO_2 emissions by decreasing the use of fossil fuels and natural resources. However, in the long term, increased utilisation of fossil fuels and natural resources increases CO_2 emissions. Shahzad et al. (2021) investigated the relationship between economic complexity, fossil fuel consumption, and

CO_2 emissions in the USA between 1965 and 2017, using the quantile ARDL method. Their study revealed that economic complexity and fossil fuel consumption increase CO_2 emissions. In his study, Zhang (2022) examined the impact of renewable energy sources and R&D expenditure on CO_2 emissions, using the E5 countries as a sample. The results, obtained using dynamic GMM and FMOLS methods, showed that an increase in geothermal and hydro energy production leads to environmental degradation, whereas nuclear and wind power sources, as well as R&D expenditure, reduce it. Arnaut and Dada (2023) analysed the impact of economic complexity and the use of renewable and non-renewable energy sources on CO_2 emissions, using data from the United Arab Emirates from 1995 to 2017. Using the ARDL method, they concluded that non-renewable energy, income level, financial development and globalisation variables positively affect CO_2 emissions.

In this study, a single region (the European Union) and a specific time period (1990-2015) were used in terms of data and methodology. The dataset used in the research consists of energy consumption and carbon emission data for European Union countries covering the years 1990-2015. The beginning of this period, 1990, coincides with the period before the Kyoto Protocol, when global awareness of climate change increased. The final year of the analysis, 2015, covers the year in which the Paris Climate Agreement, the focal point of global energy transition policies, was signed. The analysis of the derived variable "ratio of fossil fuels to renewable energy in energy consumption," which constitutes the originality of the study, was conducted to assess the direct impact of the transformation in energy composition on carbon emissions.

3. APPLICATION

The research analyses the impact of the transition from fossil fuel use to renewable energy on carbon emissions in EU countries. In the analysis, answers to the questions such as 'Does fossil fuel consumption significantly increase carbon emissions?', 'Does renewable energy consumption significantly decrease carbon emissions?' and 'Does the ratio of fossil fuel consumption to renewable energy have a significant effect on carbon emissions?' are sought.

3.1. Definition of Data Set and Variables

This study has some data and methodological limitations. The analysis is limited to a single region (European Union) and a specific time period (1990-2015). Only basic energy consumption rates are considered in the analysis and variables such as economic growth and population growth are

not included in the analysis. The data set used in the study consists of energy consumption and carbon emission data of the European Union countries covering the years 1990-2015. The beginning of this period, 1990, coincides with the period before the Kyoto Protocol, when global awareness increased in the fight against climate change. The last year of the analysis, 2015, covers the year in which the Paris Climate Agreement, which is the focal point of global energy transition policies, was signed. The data set consists of 26 years of continuous time series data, which is a suitable period for consistent and meaningful analyses.

Carbon dioxide emissions refer to the total amount of CO_2 from industrial activities such as the combustion of fossil fuels (coal, oil, natural gas, etc.) and cement production. The CO_2 emissions data used in the analysis are in metric tonnes per capita (metric tons per capita). The data source is open data provided by Climate Watch and published by the World Resources Institute (WRI). These data are licensed under Creative Commons BY-NC 4.0 (Climate Watch Data, 2023).
Fossil fuel energy consumption refers to the percentage (%) share of fossil resources such as coal, oil and natural gas in total energy consumption. A high share indicates that the country or region has a high dependence on fossil energy resources. Data are taken from the database of the International Energy Agency (IEA) and are subject to the licence and conditions of use determined by the IEA (IEA, 2023).

Renewable energy consumption refers to the percentage (%) of energy obtained from renewable sources such as hydroelectric, solar, wind, biomass and geothermal energy in total final energy consumption. High renewable energy consumption indicates low dependence on fossil fuels and has the potential to reduce carbon emissions. The data used in the analysis were obtained through the World Bank Open Data Catalogue and are shared under the Creative Commons Attribution (CC BY) license (World Bank Data Catalog, 2023).

The ratio of fossil fuels to renewable energy in energy consumption is derived by the researcher by dividing the ratio of fossil fuel use in energy consumption by the ratio of renewable energy use and represents the transition process from fossil energy to renewable energy. As this ratio increases, it is understood that the use of fossil fuels is more dominant than renewable energy in the country or region, thus energy transition remains limited. A decrease in the ratio indicates that the use of renewable energy is increasing compared to fossil fuels and energy transition is taking

place effectively. This ratio was developed in order to analyse one of the main hypotheses of the study, "The Effect of Transition from Fossil Fuels to Renewable Energy on Carbon Emissions".

3.2. Method and Analysis

All analyses used in the study were conducted with EViews 12 statistical software, which is widely preferred in academic and applied economics research. EViews 12 was chosen because it offers a powerful and user-friendly interface especially in time series and regression analyses. In the analysis process, firstly descriptive statistics were used to understand the general structure of the data, and then regression analyses were performed to test the direction and significance of the relationships.

Three basic pre-test were used in accordance with the purpose of the study: Descriptive statistics consist of mean, median, maximum and minimum values, standard deviation, skewness, kurtosis and Jarque-Bera normality test. Thanks to these statistics, the basic characteristics of the data distribution were determined and the general behaviour of the variables to be used in the analysis was understood. In the study, Time Series Regression Analysis (Least Squares - OLS) method was used to determine the relationships between dependent and independent variables. The reason for choosing this method is that it is a reliable and common tool for modelling changes over time and measuring the explainability of changes in the dependent variable by independent variables. Huber-White (HC1) heteroskedasticity consistent standard error correction was used to check whether the homoskedasticity assumption, one of the assumptions of regression analysis, was met. With this method, the problem of possible variability in variances was controlled and the consistency of standard errors and statistical inferences was ensured.

Within the scope of the research, three different regression models that take carbon emissions (CO_2 emissions - metric tonnes per capita) as the dependent variable were created. Each model is designed to test the hypotheses of the research and to assess the impact of the transition from fossil fuel use to renewable energy on carbon emissions in multiple ways.

Model 1 was created to analyse the impact of fossil fuel energy consumption on carbon emissions. The basic assumption of the model is that an increase in the rate of fossil fuel energy consumption increases carbon emissions. The model form is given below:

$$CO_{2t} = \beta_0 + \beta_1 (FossilFuelConsumption_t) + \epsilon_t \quad (1)$$

CO_{2t}, carbon emissions per capita (metric tons per capita); FossilFuelConsumptiont, fossil fuel energy consumption in total energy consumption (%); ϵt is the error term.

Model 2 was established to test the effect of renewable energy consumption on carbon emissions. The assumption of this model is that renewable energy consumption will reduce carbon emissions. The model form is given below:

$$CO_{2t} = \beta_0 + \beta_1 (RenewableEnergyConsumption_t) + \epsilon_t \quad (2)$$

Renewable Energy Consumption is expressed as the share (%) of renewable energy consumption in total final energy consumption.

Model 3 is constructed to test the effect of the variable derived by the researcher representing the transition from fossil fuels to renewable energy on carbon emissions. It is assumed that as this ratio increases, the share of fossil fuels in energy consumption increases compared to renewable energy, thus carbon emissions will also increase. The model form is given below:

$$CO_{2t} = \beta_0 + \beta_1 (Fossil / RenewableOrigin_t) + \epsilon_t \quad (3)$$

Fossil / RenewableOrigint is the ratio of fossil fuel use in energy consumption divided by the ratio of renewable energy use.

In all three models, carbon emissions have been selected as the dependent variable and it is aimed to evaluate the effects of independent variables separately and to present the results comparatively. This method provides a detailed and comprehensible framework for policy makers to evaluate the effectiveness of energy transition policies.

3.3. Analysis Results

3.3.1. Descriptive statistics

Table 1. Descriptive statistics of variables (1990-2015)

Variables	Average	Median	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis	Jarque-Bera (Probability)
CO_2 Emissions (metric tonnes per capita)	7,698	7,908	8,489	6,402	0,56	-1,008	2,910	4,414 (0,110)
Fossil Fuel Consumption (%)	76,211	77,076	80,881	69,675	3,171	-0,066	2,435	2,257 (0,323)
Renewable Energy Consumption (%)	10,795	9,729	17,601	6,908	3,433	0,830	2,252	3,584 (0,166)
Fossil/Renewable Energy Consumption Ratio	7,759	8,463	11,708	3,970	2,358	-0,240	1,850	1,688 (0,429)

Table 1 summarises the basic statistics on energy consumption and carbon emissions of the European Union countries. The average per capita carbon emission is about 7.7 metric tonnes, while the average fossil fuel use is 76.21% and the average renewable energy use is 10.79%. The ratio of fossil fuels to renewable energy is 7.76 on average. The Jarque-Bera test results of all variables reveal that the data are close to a normal distribution ($p > 0.05$).

3.3.2. Trends of variables over the years

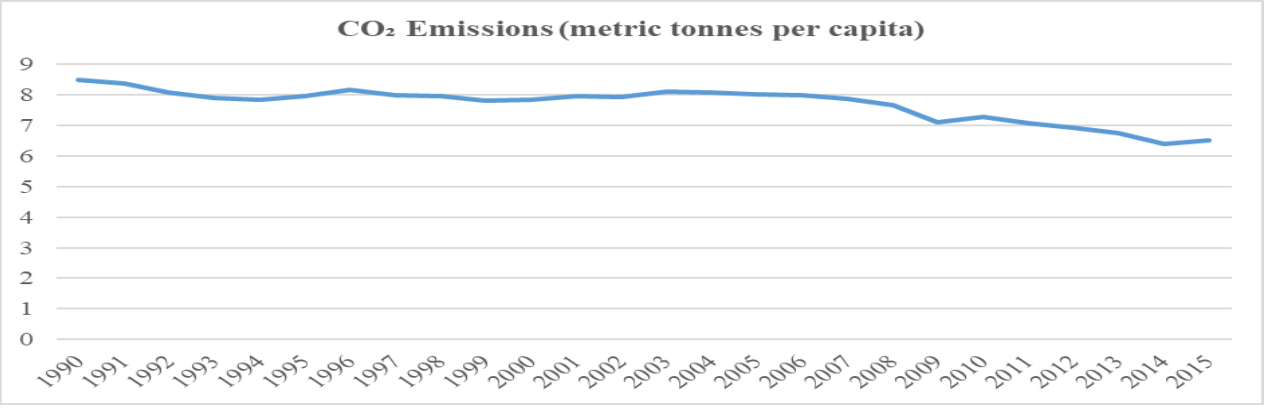

Figure 1. Change in CO_2 emissions over the years (1990-2015) (World Bank Data Catalog, 2023)

In general, a steady downward trend is observed in carbon emissions. Especially in the post-2008 period, the decline has become more pronounced.

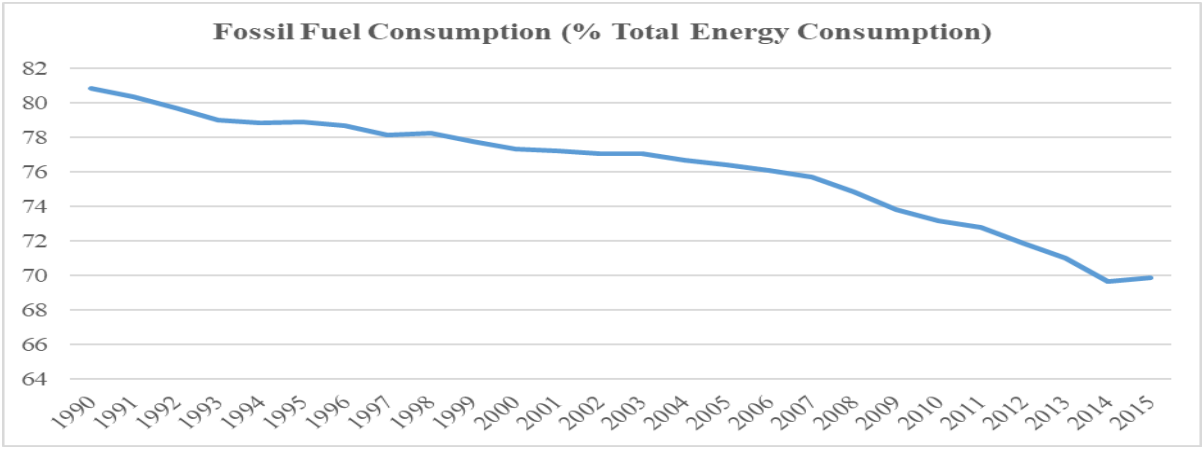

Figure 2. Change in fossil fuel consumption rate over the years (1990-2015) (World Bank Data Catalog, 2023)

There has been a steady and significant decrease in fossil fuel consumption, with the share in total energy declining from 80.88 per cent to 69.89 per cent.

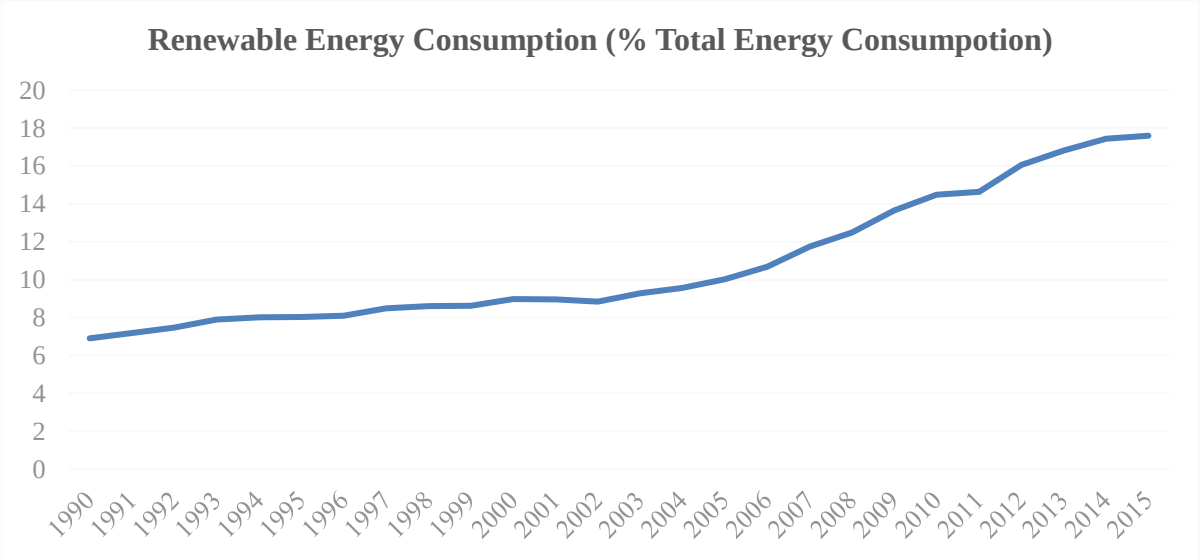

Figure 3. Change in renewable energy consumption rate over the years (1990-2015) (World Bank Data Catalog, 2023)

There is a clear upward trend in renewable energy utilisation, which rose from 6.9% at the beginning of the period to 17.6% at the end of the period.

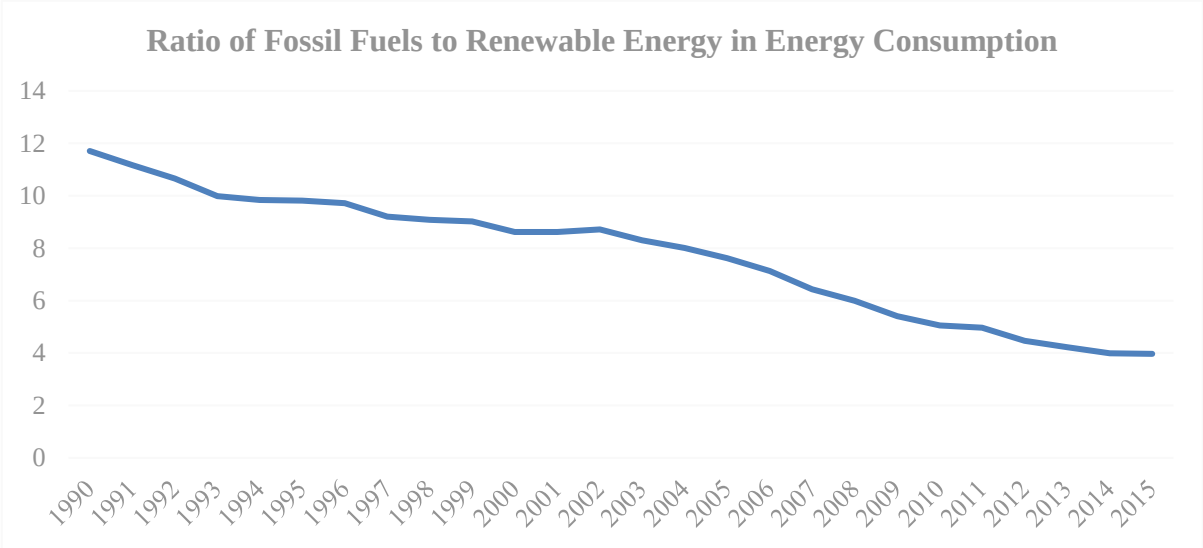

Figure 4. Change in the ratio of fossil fuels to renewable energy in energy consumption over the years (1990-2015) (World Bank Data Catalog, 2023)

There is a sharp downward trend in the ratio of fossil fuels to renewable energy, from approximately 11.71 to 3.97.

3.3.3. Regression models and results

Within the scope of the analysis, three different regression models were created and the effects of independent variables on carbon emissions were evaluated separately. EViews 12 software was used in the analyses. Due to the heteroskedasticity problem, standard errors were corrected by Huber-White (HC1) method. Table 2 shows fossil fuel consumption model results.

Model 1: The Effect of Fossil Fuel Consumption on Carbon Emissions

Table 2. Fossil fuel consumption model results

Variables	Coefficient	Standard Error	t-Statistic	p-Value
Constant Term (C)	-5,0632	0,7154	-7,0777	0,0000*
Fossil Fuel Consumption (%)	0,1674	0,0094	17,7561	0,0000*
R^2 = 0,8915, Adjusted R^2 = 0.8870, F-Statistic = 197.2558 (p=0.0000)				

According to this model, a 1% increase in fossil fuel consumption increases carbon emissions by 0.167 metric tonnes. The results reveal a strong relationship at 1% significance level. Table 3 shows renewable energy consumption model results.

Model 2: Impact of renewable energy consumption on carbon emissions

Table 3: Renewable Energy Consumption Model Results

Variables	Coefficient	Standart Error	t-Statistic	p-Değeri
Constant Term (C)	9,3730	0,1112	84,2550	0,0000
Renewable Energy Consumption (%)	-0,1551	0,0097	-16,0691	0,0000
R^2 = 0,8969, Adjusted R^2 = 0,8926, F-Statistic = 258,2177 (p=0,0000)				

This result clearly shows that renewable energy consumption reduces carbon emissions. A 1% increase in renewable energy consumption reduces carbon emissions by 0.155 metric tonnes. Table 4 shows fossil/renewable energy consumption ratio model results.

Model 3: The Effect of the Ratio of Fossil Fuels to Renewable Energy in Energy Consumption on Carbon Emissions

Table 4. Fossil/renewable energy consumption ratio model results

Variables	Coefficient	Standart Error	t-İstatistiği	p-Değeri
Constant Term (C)	6,0457	0,1987	30,4332	0,0000
Fossil/Renewable Energy Consumption Ratio	0,2129	0,0220	9,6508	0,0000
R^2 = 0,7971, Adjusted R^2 = 0,7886, F- Statistic = 93,2708 (p=0,0000)				

This model reveals that the ratio of fossil fuel use to renewable energy use has a strong positive effect on carbon emissions. As this ratio increases, carbon emissions increase significantly.

In conclusion, all three models are in line with theoretical expectations and emphasise the importance of the European Union's energy transition policy in reducing carbon emissions.

3.4. Evaluation of Analysis Results

According to the regression analysis results evaluating the effect of fossil fuel consumption on carbon emissions, an increase in fossil fuel consumption increases carbon emissions at a statistically significant level ($p = 0.0000$). It was determined that a 1% increase in fossil fuel consumption rate increases carbon emissions by approximately 0.167 metric tonnes. This result clearly demonstrates the role of fossil fuel use in carbon emissions and its environmental damage. This finding is consistent with the direct impact of fossil fuel use on greenhouse gas emissions, which is frequently emphasised in the literature (IPCC, 2018; WRI, 2023). The findings also show the importance of the European Union's policies to reduce fossil fuel use. The policies adopted by the EU to reduce fossil fuels are of primary importance for achieving global climate targets. According to the results of the analysis examining the effect of renewable energy consumption on carbon emissions, an increase in renewable energy use significantly reduces carbon emissions ($p = 0.0000$). A 1% increase in renewable energy consumption rate leads to a decrease of 0.155 metric tonnes in carbon emissions. This finding proves the undeniable importance of renewable energy sources in combating climate change. The results reveal that renewable energy investments are important not only for energy supply security but also for environmental sustainability. It provides strong evidence that the European Union's renewable energy targets should be raised and policy support mechanisms should be maintained.

The analysis of the derived variable, ‘The ratio of fossil fuels to renewable energy in energy consumption’, which provides the originality of the study, was carried out to assess the direct impact of the transformation in energy composition on carbon emissions. As a result of this analysis, it was found that an increase in the ratio of fossil fuels to renewable energy increases carbon emissions strongly and statistically significantly ($p = 0.0000$). A 1 unit increase in the ratio leads to an increase in carbon emissions of about 0.213 metric tonnes. This result emphasises the importance of reducing the weight of fossil fuels in the energy mix and increasing the share of renewable energy. In particular, reducing the ratio of fossil fuels to renewable energy should be one of the priority targets of energy policies. Thus, it will be possible to ensure environmental sustainability.

The performances of the models were compared with R^2 (coefficient of determination) and adjusted R^2 values. The R^2 value for the fossil fuel consumption model (Model 1) is 0.8915, the R^2 value for the renewable energy consumption model (Model 2) is 0.8969 and the R^2 value for the fossil-renewable energy ratio model (Model 3) is 0.7971. These results show that all three models have high explanatory power.

The model with the highest explanatory power is the renewable energy consumption model, which supports the idea that renewable energy use should be encouraged in terms of energy policies. On the other hand, although the fossil-renewable energy ratio model has a relatively lower explanatory power, it is a valuable model that clearly demonstrates the impact of energy transition on carbon emissions.

4. CONCLUSION AND RECOMMENDATIONS

The findings of the study show that renewable energy is effective in reducing carbon emissions in the EU, while fossil fuel consumption increases the pressure on the environment. Therefore, it is essential to develop and implement strategies to reduce the share of fossil fuel consumption in total energy consumption. Moreover, the ratio of fossil fuels to renewable energy in energy consumption has a strong increasing effect on carbon emissions. The findings support that the energy transition policies of the European Union countries are effective and that this transformation plays a crucial role in reducing carbon emissions. Thanks to renewable energy, it is possible to use clean (environmentally friendly) technologies that reduce carbon emissions; energy efficiency is ensured; the use of non-renewable resources such as wood, coal and oil is proportionally reduced; as a result of these, the demand pressure of humanity on the world (carbon emissions) is reduced.

In order to reduce the ecological footprint in the EU, it can be suggested to diversify the energy mix by including more renewable energy sources in the energy consumption basket, to encourage private sector participation in the development of the renewable energy sector through appropriate unbundling of energy generation, transmission and distribution processes, and to increase the share of renewable energy sources in electricity generation by giving more weight to renewable energy R&D expenditures. In addition, sector-specific ecological footprint research could be conducted to provide policy makers with better perspectives to prioritise specific areas where dependence on fossil fuels can be reduced. In this context, policies to reduce fossil fuel consumption (carbon tax,

removal of fossil fuel subsidies, etc.) should be maintained and improved. In addition, renewable energy sources should be popularised and financial incentives should be increased. In particular, it is important to make renewable energy investments attractive and to encourage technological innovation. Finally, a holistic energy policy should be adopted to reduce the fossil-renewable ratio and the energy transition should be accelerated.

DECLARATION OF ETHICAL STANDARDS

The author/The authors of the paper submitted declare/declares that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

CONTRIBUTION OF THE AUTHORS

Mehmet Ali Polat: Analysed the case, wrote the manuscript.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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APPENDICES

Eviews Outputs

Dependent Variable: CO2 EMISSIONS
Method: Least Squares
Date: 03/18/25 Time: 20:35
Sample: 1 26
Included observations: 26
Huber-White-Hinkley (HC1) heteroskedasticity consistent standard errors and covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-5.063233	0.715377	-7.077709	0.0000
FOSSIL FUEL CONSUMPTION	0.167448	0.009430	17.75619	0.0000

R-squared	0.891528	Mean dependent var	7.698179
Adjusted R-squared	0.887009	S.D. dependent var	0.562425
S.E. of regression	0.189055	Akaike info criterion	-0.419758
Sum squared resid	0.857800	Schwarz criterion	-0.322981
Log likelihood	7.456854	Hannan-Quinn criter.	-0.391890
F-statistic	197.2556	Durbin-Watson stat	0.570425
Prob(F-statistic)	0.000000	Wald F-statistic	315.2824
Prob(Wald F-statistic)	0.000000		

Dependent Variable: CO2 EMISSIONS
Method: Least Squares
Date: 03/18/25 Time: 20:36
Sample: 1 26
Included observations: 26
Huber-White-Hinkley (HC1) heteroskedasticity consistent standard errors and covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.373047	0.111246	84.25500	0.0000
RENEWABLE ENERGY CONSUMPTION	-0.155149	0.009655	-16.06915	0.0000

R-squared	0.896877	Mean dependent var	7.698179
Adjusted R-squared	0.892580	S.D. dependent var	0.562425
S.E. of regression	0.184335	Akaike info criterion	-0.470321
Sum squared resid	0.815505	Schwarz criterion	-0.373545
Log likelihood	8.114179	Hannan-Quinn criter.	-0.442453
F-statistic	208.7308	Durbin-Watson stat	0.808841
Prob(F-statistic)	0.000000	Wald F-statistic	258.2177
Prob(Wald F-statistic)	0.000000		