Does the Increase in Renewable Energy Influence GDP Growth? An EU-28 Analysis

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Abstract: The aim of our study was to analyze whether the increase in the use of renewable energy can help GDP growth. The research carried out shows that renewable energy has the ability to decrease or neutralize the negative impact of greenhouse gases (GHG), but also to maintain economic growth. We focused our analysis on the EU-28 as we know that the EU Commission’s aim, in the near future, is to join forces to reduce the GHG used and move to renewable sources. We used a panel analysis with data between 2000 and 2019 from all Member States, and our results showed that their economic growth is influenced positively by the production of renewable energy, the GHG per capita, and the GHG intensity per GDP.

Keywords: renewable energy sources; economic growth; greenhouse gases; EU-28

1. Introduction

The current climate and global energy context have led to unprecedented actions taken by the responsible factors in the field of energy and environment. Coal, oil, gas, and other fossil fuels are natural resources used over time as energy sources both for the population and industrial consumption. The intensive use of these sources and their burning to generate energy has led to the creation of greenhouse gases (GHG). Greenhouse gases are those that produce and absorb infrared radiation in the range of wavelengths emitted by Earth [1], representing, in the opinion of some authors, a group of gases with a significant contribution to global warming and climate change [2,3].

According to the Kyoto Protocol [4], there are seven gases—nonfluorinated (carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O)) and fluorinated ones (hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF₆), and nitrogen trifluoride (NF₃))—which had to be reduced by 8% between 2008–2012 compared to 1990.

Today’s climate change is influenced by human actions, which are quite large and with visible effects [5]. Modern society has induced changes in the atmospheric composition through its actions in all areas of activity, becoming the main source of global climate change at present, with major effects in the future. The atmospheric concentrations are determined by the balance between sources (gas emissions from human activities and natural systems) and dissipation (removal of gas from the atmosphere by conversion to a different chemical compound) [6]. In order to correct the ecological imbalance produced, policies in the field of environment and energy have been promoted, aiming at measures to reduce the emissions of greenhouse gases. There are two distinct ways to achieve these goals: reducing consumption and promoting renewable energy sources. However, reducing energy consumption due to rapid population growth is very difficult to achieve [7]. The exponential growth of the population has attracted a high consumption of resources.

The traditional resources are generally considered nonrenewable and are limited to the existent deposits [8]. The tension between needs and resources increases from one year...
to another [9]. An estimation of the depletion horizon of classical resources was made in order to make forecasts, based on different consumption and development scenarios. By using a scenario of increasing consumption in the next 100 years [10], with a percentage of only 2% [11], predicted on a scientific basis, the estimation of global fossil fuel reserves identified and evaluated so far has led to worrying results: they could be exhausted in about 100 years. The forecast on the types of fossil resources available is even more worrying, in the sense that the somewhat clean fossil reserves have an even closer depletion horizon [12]. In this situation, the effective solution remains as the large-scale recovery of renewable and recoverable energy, also known as green energy.

Energy plays a very important role in economic growth and poverty reduction. However, in 2015, there were about 1.3 billion people, representing 15% of the world’s population, who did not yet have access to electricity [13]. Studies have shown that an energy system based on renewable energy could provide electricity in a more economical, sustainable, long-term, nonpolluting way to a larger number of people. The development and promotion of renewable energy sources can stimulate employment by creating jobs in the new “green” technology sector.

The European Commission has recently adopted the European Union Action Plan on “zero air, water and soil pollution,” a key result of the European Green Pact [14] and also the main theme of the European Union’s Green Week in 2021. The plan establishes an integrated program with a long-term vision, until 2050: a planet where environmental pollution is reduced to zero and the health of humans and natural ecosystems are no longer threatened by it.

All relevant EU policies must be interconnected to combat and prevent pollution, and a particular focus is placed on how to use digital solutions for this purpose. It envisages reviewing current EU legislation to identify remaining gaps in the European law and situations where a better and more effective implementation of actions is needed to meet these legal obligations. The European Union’s objectives in relation to climate change [15], health, biodiversity, and natural resource efficiency are based on a number of initiatives in the sectors of agriculture, food, energy, industry, the circular economy, and mobility [16].

As a result of EU pressure, in the future, EU countries will have to gradually give up coal and further develop green energy production.

As we can see, the focus has been placed on renewable energies, known in the literature as green energies [17]. They are considered in practice to be the ones that come from sources that regenerate themselves in a short time or are virtually inexhaustible sources. Thus, the energy of sunlight, wind, running water, biological processes, and geothermal heat can be captured by humans using various processes.

The aim of our study was to analyze whether the increase in the use of renewable energy over the GHG can help GDP growth based on the correlations between green energy consumption, greenhouse gases, and economic growth in EU-28 countries from 2000 to 2019. In this sense, we state that the main objectives and the novelty of our study consist of:

- An analysis of how the recent developments have impacted the relation between renewable energy and economic growth in the EU-28 countries;
- A confirmation of the fact that green energy sources have a good impact on the economy regardless of their type;
- Validation of the role of the increase in the production of renewable energy on the economic growth and on the GHG emissions.

The paper is organized into five sections: introduction, literature review, database and methodology, results, and conclusions and final remarks.

As mentioned above, renewable energy is an essential part of efforts to reduce the degradation of the environment. It is of general interest all over the world. The importance of this topic is also proved by the fact that, in the recent years, renewable energy, sustainable development, and environmental protection have continued to be main topics not only for governments and international bodies, but also for many conferences and research articles.
2. Literature Review

Today, climate change is causing the greatest concern among the world’s population. Particularly aggressive meteorological phenomena in some regions of the globe are the main reason for applying a set of measures in the medium and long term.

Global warming and energy security are worldwide concerns [18]. Nations and organizations are continuously looking to identify all generating factors and ways of neutralizing them, by developing, adopting, implementing, and evaluating environmental policies. According to the European Environment Agency, in order to mitigate climate change, there is a need to reduce or prevent the emissions linked to human activities. The growing concern about global warming and energy security has activated the idea of renewable energy as the most appropriate option to support future energy needs for consumption.

A major challenge facing the population in the 21st century is how to find a balance between the accelerated process of environmental degradation and the achievement of sustainable economic growth that does not affect future generations [19]. A study conducted in the period 1995–2015 on EU-28 confirms the existence of positive and significant long-term links between renewable energy consumption, environmental sustainability, and economic growth. Research results indicate that carbon emissions, real gross fixed capital formation, and environmental factors are the main elements of long-term growth in the European Union. Thus, by exploiting renewable energy sources in the EU countries, the pollution of the environment is mitigated by reducing the number of noxious substances. Consequently, achieving the Sustainable Development Goals (SDGs) by 2030 through renewable energy consumption and reducing carbon emissions is an achievable target in the EU-28 countries. These objectives must be adopted as soon as possible by all European countries as a necessary and effective global policy.

In another study, researchers [20] developed a model of renewable energy consumption that used annual data over a period of 20 years (1996–2016) in the most populous countries in Africa (Ethiopia, South Africa, Nigeria, DR Congo, and Egypt). Socio-economic, macroeconomic, and institutional factors generated 34 predictive variables that were modeled with Bayesian Model Averaging (BMA). The research results showed that an increase in electricity consumption, urban population, and human capital are the main determinants of renewable energy consumption in some countries. An increase in any of these determinants primarily causes an increase in renewable energy consumption.

The new European model offers sustainable, inclusive, and smart growth. Increasing the share of renewable energy consumption in total energy is one of the factors that improve the quality of economic growth, similar to development, research, and investment in human capital [21]. The authors of the research tested the correlation between renewable energy consumption for ten Member States of the European Union in Central and Eastern Europe and economic growth over a period of 25 years (1990–2014), using the autoregressive and distributed modeling procedure. This technique captures causal relationships in the short and long term.

The short-term results show that the dynamics of renewable energy consumption and gross domestic product are independent in Romania and Bulgaria, while in countries such as Hungary, Lithuania, and Slovenia, increased renewable energy consumption improves economic growth. The two-way causality hypothesis between economic growth and renewable energy consumption is validated in the long run both for the analyzed group of countries and seven states in Central and Eastern Europe that were studied individually. The results validate the feasibility of the Europe 2030 targets for increasing energy efficiency. Public policy proposals are made to achieve these objectives.

In line with these recent studies, our first hypothesis looks into the relation between renewable energy and economic growth in the EU-28 countries to analyze how recent developments are explaining it:

Hypothesis 1 (H1). The level of renewable energy influences positively the economic growth on a long term, as also explained by [19–21].
It can be seen, according to the research on a sample of EU-28 during 2003–2014 [22], that the average share of renewable energy in transport fuel consumption is 3%, while the average share of renewable energy in gross final consumption energy is 15%. According to the EU Directive 2009/28/EC, these values are below the thresholds of 10% and 20%, respectively. The research results indicate a positive influence of renewable energy in general (geothermal energy, biomass, wind energy, hydropower, and solar energy) on the gross domestic product per capita. Biomass energy has the greatest influence on economic growth, according to studies by researchers. In addition, it confirms the positive influence of primary renewable energy production on economic and sustainable growth. In addition, this study found a long-term relationship between the primary renewable energy production, energy dependence, and gross domestic product per capita, an idea also analyzed in our article. The research results indicate that, both in the short and long term, a one-way causal relationship from sustainable economic growth to primary renewable energy production supports the hypothesis of energy conservation.

Economic growth and energy demand in emerging economies create an opportunity for these countries to increase their renewable energy consumption. By 2030, renewable wind, solar, geothermal, wave, and tidal energy are expected to be the fastest growing segments of the energy industry [23]. This type of consumption is seen as a means of reducing carbon dioxide emissions, with an average annual growth rate of 6.7%. The interest in the renewable energy sources has other reasons as well, including the volatility of oil prices and the concerns of environmental decay.

The referred-to studies explain that all types of renewable energies can positively affect the economic growth.

Contrary to previous studies, there are authors [24] who do not examine the link between the renewable energy sources (RES) and the economic growth, but rather focus on the real gross domestic product (GDP), an idea developed in our study during 2000–2019. Panel data models of the EU-28 countries covering the period 2007–2017 were used, which offers a low and positive level of the relationship between the impact of GDP per capita and the share of RES in final consumption.

Basically, it is not important how you produce the energy, because, if it is green energy, this can have a good impact on the economy. Therefore, our second hypothesis is presented below:

**Hypothesis 2 (H2). Each type of renewable energy can have a positive effect over GDP growth, according to recent studies [22–24].**

The strong relationship between renewable energy source and economic growth is discussed in the literature. Sardowsky [25] noted the positive and statistically significant impact of increasing real income (per capita) on renewable energy consumption (per capita) on 18 emerging economies. Apergis and Payne [26] examined this relationship using a group of twenty OECD (The Organization for Economic Co-operation and Development) countries over a 20 years period (1985–2005), which revealed a long-term equilibrium between renewable energy consumption, real GDP, real gross fixed capital formation, and labor force. A two-way hypothesis between renewable energy consumption and economic growth was observed in the short and long term.

Ntanos et al. [27] analyzed the link between renewable energy consumption and economic growth in 25 European countries, expressed as GDP per capita for a period of 10 years (2007–2016). Statistical analysis showed that all variables are strongly correlated. The correlation between the dependent variable of GDP and independent renewable energy sources (RES) and non-RES, gross fixed capital formation, energy consumption, and labor is strong in the long run. The research results show that there is a close correlation between economic growth and RES consumption for countries with a higher GDP than other countries with a lower GDP.

A recent study [28] looked into the effect of growth and energy consumption on CO₂ emissions. The relationship between energy consumption, growth, and CO₂ emissions
was assessed using various statistical procedures. Seventy countries were analyzed over a period of 20 years (1994–2013). The test results showed that the study variables (population, capital stock, and growth) have a bidirectional causal relationship with CO\textsubscript{2} emissions, while energy consumption has a one-way relationship and that there is a long-term relationship between the variables studied (consumption energy and growth) and CO\textsubscript{2} emissions. There is a direct link between energy consumption, economic growth, and a significant positive impact on CO\textsubscript{2} emissions. The study supports the need for a global transition to a zero-carbon or near-zero economy.

Manta et al. [29] estimated the link between renewable energy use, CO\textsubscript{2} emissions, economic growth, and financial development for ten Central and Eastern European countries over a period of 17 years (2000–2017). The results of the research indicate that in the long run, financial development can help reduce CO\textsubscript{2} emissions.

Another study by Sterpu et al. [30] examined the relationship between gross domestic product, per capita greenhouse gas (GHG) emissions, gross domestic energy consumption, and renewable energy consumption for 28 countries in the European Union, for a period of 26 years (1990–2016). The conclusion of this study is that an increase in gross energy consumption leads to an increase in GHGs in the long run, while an increase in renewable energy consumption leads to a reduction in GHG emissions.

The long-term relationship between renewable energy consumption and economic growth within the framework of the traditional production function in European countries over a period of 20 years (1995–2016) was analyzed by Kasperowicz [31], the results suggesting that there is a long-term equilibrium relationship between the two of them and that renewable energy consumption has a positive impact on economic growth. Another study [32] focused on the same relationship with a specific emphasis on the role of fossil energy prices in determining renewable energy consumption in seven OECD Europe countries, where no Granger causality was found between renewable energy consumption and the crude oil price.

All these studies explain that the increase in the production of renewable energy will have both a positive effect on the economic growth and will also decrease the GHG emissions. These lead to our third hypothesis:

**Hypothesis 3 (H3).** *The impact of the GHG on the economic growth has decreased in recent years as the level of significance is not so high, according to studies [28–31].*

Renewable energy sources (RE) have an important role to play in meeting the objectives of the 2030 Agenda for Sustainable Development. The patterns and trends of EU energy policy describe, by identifying leaders in this area, an opportunity to analyze their actions and the possible implementation of the solutions at the regional and national levels in each Member State [33]. The main purpose of energy policy in the field of renewable energy sources (RES) is to increase production from environmentally friendly sources; therefore, trends were determined to assess the rate of achievement of the national target for changing the share of energy from renewable sources in the total gross energy consumption, an approach found in our work as well. Fourteen EU member states reached the 2020 targets and four have exceeded the 2030 targets. The main renewable energy sources (RES) were biofuels and hydropower. The best situation was observed in the case of Denmark, Ireland, and the United Kingdom. These countries significantly increased the share of renewable energy in total energy consumption and, compared to other EU countries, they reduced energy consumption and greenhouse gases.

Another study [34] determined and compared the level, trends, and variation in the energy consumption in different economic sectors in the EU countries during 2010–2019. An analysis of the share of renewable energy consumption of the economy was performed, as well as an assessment of the relationship of these indicators with the economic level of development of countries and the impact on the environment in the form of greenhouse gas emissions from energy consumption. The authors of the article considered changes in
the values of the studied indicators, the differentiation between countries, and the results of correlation and regression analysis.

3. Database and Methodology

This section provides a concise and accurate description of the experimental results, their interpretation, and the conclusions that can be drawn from this study. Our research starts with the analysis of the production of renewable energy ability to maintain economic growth considering that the most developed countries are focusing on these types of environmentally friendly sources of energy.

From the data provided by Eurostat in 2019, they show that the country with the highest production of renewable energy is Germany, followed by France, Italy, Sweden, and Spain. At the opposite pole are Malta, Luxembourg, Cyprus, Slovenia, and Ireland.

As can be seen from Figure 1, the EU average for renewable energy production is 8899.3 toe. Of the EU countries, only 9 (Poland, Austria, Finland, UK, Spain, Sweden, Italy, France, and Germany) have products above the European average, while the rest are below the European average, some of them with a very low production (Malta, Luxembourg, and Cyprus).

![Figure 1. Production of renewable energy in EU-28 in 2019 (toe).](image-url)

Furthermore, we conducted an analysis of the share of renewable energy in the EU Member States in correlation with the economic development and GHG CO\textsubscript{2} for 2019 emissions to investigate whether there is a connection at present. In Figure 2, we present the level of GDP per capita in comparison with the share of green energy from total energy consumption, and we can conclude that, for the moment, not all the performant economies made the transition to renewable energy.
Furthermore, we conducted an analysis of the share of renewable energy in the EU Member States in correlation with the economic development and GHG CO\textsubscript{2} emissions for 2019 to investigate whether there is a connection at present. In Figure 2, we present the level of GDP per capita in comparison with the share of green energy from total energy consumption, and we can conclude that, for the moment, not all the performant economies made the transition to renewable energy.

In Figure 3, we analyzed the correlation between renewable energy and GHG CO\textsubscript{2} emissions. Usually, the Member States that have a high share of green energy in the total energy consumption do not produce a high amount of CO\textsubscript{2} emissions, but many of them are economic powers such as DE, UK, FR, IT, or ES, which are still CO\textsubscript{2} production-based economies.

An Environmental Kuznets Curve is presented in our study in order to see the correlations between GDP growth and GHG consumption in EU-28 in 2019 as shown in Figure 4.

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![Figure 3. Share of renewable energy and GHG CO\textsubscript{2} emissions (Mt CO\textsubscript{2} per year).](image)

An Environmental Kuznets Curve is presented in our study in order to see the correlations between GDP growth and GHG consumption in EU-28 in 2019 as shown in Figure 4.

![Figure 4. Environmental Kuznets curve between the GDP per capita and the total GHG consumption per capita in 2019.](image)

The aim of our study was to analyze whether the increase in the use of renewable energy in recent years can lead to GDP growth. In order to do this, we used panel data of EU-28 countries for the 2000–2019 period, data provided by Eurostat—European Commission and World Development Indicators (WDI)—World Bank. The dependent and independent variables are presented in Table 1.

**Table 1.** Dependent and independent variables.

| Symbol       | Variable                                      | Explanation                                                                                                                                                                                                 | Relevant Studies in the Literature |
|--------------|-----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| GDP/capita   | GDP/capita                                    | Per capita gross domestic product (GDP) is calculated by dividing a country’s GDP by its population. It is a value that distributes the economic output of a country to the number of people. | [19–21]                           |
| GDP Growth   | GDP growth (annual %)                         | The real economic growth rate is the annual growth of a nation’s gross domestic product (GDP). GDP is the market value of goods and services produced in a country over a period of time. | [19–21]                           |
| Total Renew  | Total production renewables and biofuels toe (ton of oil equivalent) | Renewable energy (green energy) includes solar energy (thermal, photovoltaic, and concentrated), wind energy, hydropower, tidal energy, geothermal energy, ambient heat captured by heat pumps, biofuels, and the renewable part of waste. | [19–21]                           |
| Prod Biomass | Total production biomass toe (ton of oil equivalent) | Biomass consists of plant material and metabolic residues of animal origin (garbage) used as fuel to produce electricity or heat (examples: wood, straw, stalks of certain crops (sunflower), energy crops, and waste from forests, yards, or farms). | [22,23]                           |
Table 1. Cont.

| Symbol       | Variable                                      | Explanation                                                                                                                                                                                                 | Relevant Studies in the Literature |
|--------------|-----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| Prod Hydro   | Total production hydro toe (ton of oil equivalent) | Hydropower is based on the force of water falling. In special installations and constructions, water that falls or flows quickly is used to produce electricity. This is done by converting the kinetic energy of water into electrical or mechanical energy in special constructions called larger or smaller hydropower plants. | [22,23]                          |
| Prod GEO     | Total production geothermal toe (ton of oil equivalent) | Geothermal power is the power generated by the hot water in the earth, called geothermal energy (volcanoes, hot water, or geysers). The technologies used include special dry steam filling stations, binary cycle power plants, and fast steam power plants. | [22,23]                          |
| Prod Wind    | Total production wind toe (ton of oil equivalent) | Wind energy uses wind energy to supply mechanical energy through wind turbines installed in special, tall buildings located in certain areas. Mechanical energy is transformed by electric generators into electrical energy. Wind energy is the most popular source of green, renewable energy, with a minor impact on the environment compared to burning fossil fuels (coal, oil, crude oil, etc.). | [22,23]                          |
| Prod Solar   | Total production solar toe (ton of oil equivalent) | Solar energy (green, renewable energy) is the conversion of energy from sunlight into electricity, either directly using photovoltaic panels (PV) or solar cells or indirectly using concentrated solar energy or a combination of it. This type of energy is used both to heat buildings and to produce hot water. | [22,23]                          |
| Renew Share  | Share of renewable energy in gross final energy consumption (percentage) | Gross final consumption of renewable energy is the amount of renewable energy consumed for electricity, heating or cooling, and transport in the Member States of the European Union that use various types of renewable energy (wind, geothermal, solar, etc.) and expressed as a share of gross energy consumption. | [19–21]                          |
| GHG Intens Energy | GHG intensity of energy [kg CO₂ eq./toe] | Greenhouse gas emissions intensity of energy consumption. The indicator is calculated as the ratio between energy-related GHG emissions and gross inland consumption of energy. It expresses how many tons of CO₂ equivalents of energy-related GHGs are being emitted in a certain economy per unit of energy that is being consumed. | [29]                             |
| GHG Intens GDP | Total GHG-GDP intensity [ton CO₂ eq./M€15] | Greenhouse gases are divided by GDP (expressed in constant prices) between 1990 and 2019. It is expressed as an index in which the 1990 intensity for the EU15 is equal to 100. The intensity of the EU28 is relative to the EU15. A trend line below 100 indicates economic growth simultaneously with a relative decoupling of greenhouse gases. Currency conversion rates are used for a common currency, or different currencies. They eliminate differences in price levels between countries and allow for significant comparisons based on GDP. This is the appropriate unit for comparing a country’s performance over a period of time. | [29]                             |
Table 1. Cont.

| Symbol | Variable | Explanation | Relevant Studies in the Literature |
|--------|----------|-------------|-----------------------------------|
| CO₂    | Greenhouse gas emissions- CO₂ emissions-national total [Mt CO₂] | Carbon dioxide (CO₂) emissions are emissions from the burning of fossil fuels (coal, oil, and natural gas) and the manufacture of cement. These emissions include carbon dioxide produced during the consumption of solid, liquid, and gaseous fuels, as well as the combustion of gases. | [27–30] |
| GHG    | Greenhouse gas emissions-GHG emissions-national total [Mt CO₂] | Greenhouse gas (carbon dioxide, water vapor, and methane) is any gas that has the property of absorbing infrared radiation (net thermal energy) emitted from the Earth’s surface and reflecting it back to the Earth’s surface, thus contributing to the greenhouse effect. | [27,29,30] |
| GHG Capita | Total GHG per capita [t CO₂ eq./capita] | Total greenhouse gas (GHG) emissions per capita are calculated as the ratio between the amount of greenhouse gas emissions in a state and the population of that country. This indicator provides data provided by the accounting based on the production of emissions of carbon dioxide, hydrofluorocarbon, nitrogen oxide, methane, perfluorocarbon, and sulfur hexafluoride in the country. | [29] |
| EDU    | Education expenditure to GDP (percentage) | Total level of education expenditure to GDP | [22] |
| HDI    | Human development index | The level of human development index | [23] |

Source: Eurostat 2019.

Our purpose was to estimate the effect of the increase in the production of renewable energy in total and for different sources on the GDP growth by using a panel data fixed-effects regression model, having the general specification further presented. The model is based on the premises of the study [22]:

\[ Y_{it} = \alpha_0 + \beta_1 X_{it} + \beta_2 C_{it} + \epsilon_{it} \]

where \( i = 1, 2, \ldots, 28 \) represent the EU-28 countries, and \( t = 2000, 2001, \ldots, 2019 \) represent the analyzed years. \( Y \) is the dependent variable used to express the economic growth. \( X \) are the independent variables used to express the renewables energy measures. \( C \) are the control variables. \( \beta_1 \) and \( \beta_2 \) are parameters and \( \epsilon \) is the error term.

The descriptive statistics for the variables used in the models is presented in Table 2. It shows trends in the consumption and production of renewable energy in the EU countries. The total production of renewable energy has an average value of 5891 with an upper value of 45,839 recorded in Germany and a low level of 38.0 in Malta. At the European level, biomass has the largest production, followed by hydro-energy, wind energy, solar energy, and geothermal energy. Our results are consistent with other analyzed studies. Even if the share of renewable energy consumption in the total energy consumption in EU-28 still has a low level, in recent years, there have been some improvements. The cases of Sweden and Finland succeeded in passing the 50% target in 2019. In terms of greenhouse gases, there are large differences between countries, with values ranging from 2.32 to 1077.75.
We have also tested for identifying multi-collinearity. The correlation matrix resulted in this sense is presented in Table 3. We did not consider the variables correlated at a higher level than 0.4 in the same regression. This approach is based on the fact that, otherwise, bias coefficients of the independent variables can be obtained in the regression models upon which the research was conducted.

### Table 3. The correlation matrix.

| Variable         | Total Renew | Prod Biomass | Prod Hydro | Prod Geo | Prod Wind | Prod Solar | Renew Share | GHG Intens Energy | GHG Intens GDP | CO₂ | GHG | GHG Capita | EDU | HDI |
|------------------|-------------|--------------|------------|----------|-----------|------------|--------------|-------------------|----------------|-----|-----|-----------|-----|-----|
| Total Renew      | 1.00        |              |            |          |           |            |              |                   |                |     |     |           |     |     |
| Prod Biomass     | 0.97        | 1.00         |            |          |           |            |              |                   |                |     |     |           |     |     |
| Prod Hydro       | 0.71        | 0.60         | 1.00       |          |           |            |              |                   |                |     |     |           |     |     |
| Prod Geo         | 0.36        | 0.21         | 0.35       | 1.00     |           |            |              |                   |                |     |     |           |     |     |
| Prod Wind        | 0.77        | 0.73         | 0.25       | 0.07     | 1.00      |            |              |                   |                |     |     |           |     |     |
| Prod Solar       | 0.73        | 0.66         | 0.25       | 0.25     | 0.87      | 1.00       |              |                   |                |     |     |           |     |     |
| Renew Share      | 0.20        | 0.20         | 0.37       | −0.07    | 0.00      | −0.02      | 1.00         |                   |                |     |     |           |     |     |
| GHG Intens Energy| −0.28       | −0.26        | −0.38      | 0.05     | −0.06     | −0.01      | −0.51        | 1.00              |                |     |     |           |     |     |
| GHG Intens GDP   | −0.35       | −0.30        | −0.36      | −0.14    | −0.28     | −0.21      | −0.14        | 0.39              | −0.18          | 1.00|     |           |     |     |
| CO₂              | 0.70        | 0.72         | 0.33       | 0.30     | 0.62      | 0.51       | −0.30        | 0.11              | −0.18          | 1.00|     |           |     |     |
| GHG              | 0.70        | 0.72         | 0.35       | 0.30     | 0.61      | 0.50       | −0.31        | 0.10              | −0.18          | 1.00| 1.00|           |     |     |
| GHG Capita       | −0.19       | −0.14        | −0.27      | −0.09    | −0.09     | −0.39      | 0.32         | −0.09             | 0.01           | 0.00| 1.00|           |     |     |
| EDU              | −0.10       | −0.05        | 0.01       | −0.19    | −0.19     | −0.26      | 0.32         | −0.27             | −0.24          | −0.23| −0.02| 1.00      |     |     |
| HDI              | 0.39        | 0.40         | 0.21       | 0.04     | 0.38      | 0.29       | 0.10         | −0.27             | −0.13          | 0.27| 0.26| 0.28      | 0.19| 1.00|

### 4. Results and Conclusions

In this section, we tested the renewable energy factors that can influence GDP growth. The results are presented in Table 4. We used a panel regression model with cross-section fixed effects (according to Hausmann test) to highlight whether the production of renewable energy of an EU state can influence economic growth.
### Table 4. The model estimated results.

| Variable       | (1)          | (2)          | (3)          | (4)          | (5)          | (6)          | (7)          | (8)          |
|----------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Total Renew    | 0.00003538 * |              |              |              |              |              |              |              |
|                | (2.05)       |              |              |              |              |              |              |              |
| Prod Biomass   |              | 0.000089 *   |              |              |              |              |              |              |
|                |              | (1.81)       |              |              |              |              |              |              |
| Prod Hydro     |              |              | 0.002 *      |              |              |              |              |              |
|                |              |              | (1.75)       |              |              |              |              |              |
| Prod GEO       |              |              |              | 0.0008       |              |              |              |              |
|                |              |              |              | (0.84)       |              |              |              |              |
| Prod Wind      |              |              |              |              | 0.0002 **    |              |              |              |
|                |              |              |              |              | (1.74)       |              |              |              |
| Prod Solar     |              |              |              |              |              | 0.003 **     |              |              |
|                |              |              |              |              |              | (2.17)       |              |              |
| Renew Share    | −0.13 **     | −0.10 *      | −0.08        | −0.12 *      | −0.13 **     | −0.09 *      | −0.09 *      | −0.12 **     |
|                | (−2.05)      | (−1.71)      | (−1.43)      | (−1.94)      | (−1.96)      | (−1.67)      | (−1.68)      | (−2.02)      |
| GHG Intens Energy | −0.005 ***   | −0.004 ***   | −0.004 ***   | −0.004 ***   | −0.004 ***   | −0.004 ***   | −0.004 ***   | −0.004 ***   |
|                | (−4.22)      | (−4.08)      | (−4.09)      | (−4.23)      | (−4.24)      | (−4.21)      | (−4.15)      | (−4.23)      |
| GHG Intens GDP | 0.002 *      | 0.002 *      | 0.002 *      | 0.002 *      | 0.002 *      | 0.002 *      | 0.002 *      | 0.002 *      |
|                | (1.68)       | (1.74)       | (1.68)       | (1.70)       | (1.44)       | (1.68)       | (1.68)       | (1.54)       |
| CO₂            |              |              |              | 0.006 *      |              |              |              |              |
|                |              |              |              | (1.71)       |              |              |              |              |
| GHG Capita     | 0.19         | 0.16         | 0.15         | 0.25 *       | 0.20         | 0.18 **      | 0.19         | 0.24 *       |
|                | (1.39)       | (1.12)       | (1.06)       | (1.69)       | (1.44)       | (1.35)       | (1.32)       | (1.67)       |
| EDU            | −3.10 ***    | −3.11 ***    | −3.12 ***    | −3.12 ***    | −3.09 ***    | −3.11 ***    | −3.10 ***    | −3.11 ***    |
|                | (−5.29)      | (−5.30)      | (−5.31)      | (−5.34)      | (−5.26)      | (−5.30)      | (−5.29)      | (−5.30)      |
| HDI            | −20.02 *     | −19.55 *     | −19.73 *     | −20.02 *     | −19.70 *     | −19.55 *     | −20.02 *     | −20.02 *     |
|                | (−1.91)      | (−1.93)      | (−1.94)      | (−1.93)      | (−1.90)      | (−1.93)      | (−1.91)      | (−1.93)      |
| R-Squared      | 28.63%       | 28.50%       | 28.57%       | 28.60%       | 28.59%       | 28.45%       | 28.52%       | 28.69%       |
| Number of Observations | 560          | 560          | 560          | 560          | 560          | 560          | 560          | 560          |

Where: *, **, and *** represent significance levels of 10%, 5%, and 1%.

A panel regression model was used. We did not consider in the same regression the variables correlated at a higher level than 0.4. The T-statistics are in parentheses. The symbols *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

According to the results above, the economic growth in EU-28 states is influenced positively by the production of renewable energy, the GHG per capita, and the GHG intensity per GDP. In addition, the economic growth is influenced negatively by the consumption of renewable energy from total energy consumption and the GHG intensity energy. The control variables confirm our model as the GDP growth is positively influenced by the CO₂ and GHG level, as stated by the literature referred to in Section 2, at the same time being negatively influenced by the education expenses in GDP and the HDI index. The negative influence is explained by the fact that in the EU-28 countries, the highest GDP growth is recorded in Central and Eastern European (CEE) countries where the education expenses and the HDI level are not so high in comparison with the developed western economies from Europe.

Our results are according to those from the literature review as the renewable energy production can be considered a determinant of the economic growth. As a consequence, an increased production of renewable energy is seen as a potential growth engine for the economy, similar to research, development, and investment in human capital. Many studies have concluded that an increased production and consumption of renewable energy can increase the quality-of-life together with economic growth, leading to a more sustainable economic environment. From our point of view, a better environmental protection is a fundamental condition of social welfare and making a change to sustainable energy production can cave this result.
We performed a sensitivity analysis to see whether the economic growth in terms of renewable energy can be determined by a specific source of production of energy. The results show that hydro energy, wind energy, and solar energy production are often higher in the EU states where there is a higher economic growth, while biomass and geothermal power do not seem to influence the increase in economy. As we mentioned above, GHG consumption per capita is positively correlated to the economic growth, which is an expected result, both according to the literature review and also to our expectations as developed EU states have a higher need for consuming products and services that implies GHG.

A negative influence in the share of the amount of renewable energy consumed for electricity, heating and cooling, and transport from the total energy consumption was recorded, which actually presents the reality behind the results above that the states that are producing and consuming high amounts of renewable energy are also producing high amounts of GHG.

Energy is crucial for economic progress, but the growth of the world’s contemporary population, which requires more energy from conventional depletable resources, rising energy prices, and environmental concerns, threatens the sustainable economic growth. Energy cannot be created or destroyed; it can only be transformed from one source to another. However, the shift to renewable energy from naturally occurring resources promotes energy security, while also addressing issues such as global warming and climate change.

The research results confirm the initial hypothesis, namely, the economic benefits of using renewable energy led to improved living standards [35,36]. The analysis shows that the European leaders in the field of renewable energy are the Nordic countries: Sweden, Finland, and Denmark. For Sweden, this is mainly due to hydroelectric power, which provides more than 40% of national electricity production. In addition, the Swedes mainly use biofuels to heat their homes. In addition, Denmark, a country that has long been dependent on energy imports, now receives 43% of its electricity from wind farms, after investments in the late 1970s led to the gradual closure of thermal power plants. On the other hand, the Netherlands and Luxembourg are the EU Member States with the lowest renewable energy consumption, 6.6% and 6.4% of gross final energy consumption, respectively. Despite investments in offshore wind farms, the Netherlands is far from meeting its 2020 Green Pact targets. France has preferred to invest in nuclear energy, which currently supplies more than 70% of its electricity production. Coal remains the cornerstone of Germany’s energy policy, in part as a result of the Berlin Government’s 2011 decision to shut down all nuclear power plants by 2022. Coal is responsible for 37% of Germany’s electricity production and over 30% of thermal energy. As a result, Europe’s largest economy intends to phase out coal in order to meet its commitments to reduce pollutant emissions.

Our results support other opinions [34], as found in the research conducted that all EU Member States need to be aware of their energy consumption and their contribution to environmental pollution and take effective and sustainable corrective action as soon as and as much as possible. We agree that attention should be paid to policy proposals and funding opportunities for achieving national goals in obtaining high shares of renewable energy in their final energy consumption, as some authors emphasize [24].

5. Final Remarks

EU countries are very diverse. Differences in economic growth, energy, and environmental policies can differ substantially. The interpretation of the drivers to rely more on renewable energies can also be very different. Some of these drivers might be related to the availability of funds and the support provided by the respective governments to stimulate the shift toward renewable energies independently from cost considerations. In this general context, our study also aimed to answer the following question: Does the increase in renewable energy influence GDP growth? The results obtained in this paper can justify the recent political decisions in the EU regarding the change to renewable energy
and the decision to reduce GHG production across the EU Member States. According to our conclusion above, GDP growth can be maintained by renewable energy, and this has actually happened in recent years, so the change can be performed without affecting the economic positions of the countries. Of course, in this period, GHG were also produced to increase the economy, but in recent years, many Member States have successfully performed part of this transition. We point out that all types of renewable energy can have a positive impact on the economic growth, so we can state that everyone, regardless of their geographical characteristics, can have sustainable growth if they want to go green.

Our study also shows that overall energy consumption has a positive impact on economic growth, especially as green energy can have multiple benefits. The inclusion of such policies in future EU and national strategies is justified. It is known that EU Directive 2009/28/EC provided that “the share of renewable energy consumption in final energy consumption should reach 20% by 2020”, even though many countries are far from achieving this goal.

Renewable energy sources accounted for 13.2% of the EU-28’s gross domestic energy consumption in 2016, according to data provided by Eurostat. “Wood and other solid biomasses continue to make the largest contribution to the range of renewable energy sources. Hydropower and wood accounted for 91.5% in 1990. However, the growth rate since then has been much slower than for other sources. As a result, their combined share fell to 59.3% in 2016.”

For the future, economic growth can be maintained through higher green energy consumption. The main findings of this research are those mentioned below:

Considering the recent developments on the relation between the economic growth and the level of renewable energy sources, positive influence has been shown.

The assumption that all types of renewable energies can positively affect the economic growth was validated.

The analysis of the effect of the increase in the production of renewable energy both on the economic growth and the GHG emissions has been performed.

This study is limited to the fact that the population of the EU-28 states is numerically different with implications on GDP per capita. Another limitation of the research is generated by the fact that some EU countries have started investing in green energy in time, out of conviction or necessity, and others are only now developing green energy capacities being obliged by European regulations in the field.

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