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Evolution and Impact of the European Union's Energy Policy: From Fossil Fuels to Renewable Energy and Greenhouse Gas Emissions Reduction

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Abstract:

Purpose: *This scientific work focuses on analyzing the energy transformation in the European Union (EU) from 2000 to 2021, considering the shift from fossil fuels to renewable energy sources and strategies for reducing greenhouse gas emissions. The research aims to understand how the EU's energy policy has influenced the structure of energy production and consumption, as well as the emission of greenhouse gases in its member states, with particular emphasis on key initiatives such as the Kyoto Protocol, the 2020 climate and energy package, and the European Green Deal.*
Design/methodology/approach: *Utilizing a comprehensive dataset and a variety of research methods, this work provides empirical insights into the effects of the EU's energy policy. The analysis examines the impact of implemented initiatives and regulations on the energy mix, noting an increase in the share of renewable energy and a decrease in GHG emissions.*
Findings: *The study revealed that these initiatives and regulations have contributed to a significant change in the energy mix, marking an increase in renewable energy's share and a decline in GHG emissions. However, the research also uncovers challenges and disparities in achieving these goals among different member states.*
Practical implications: *This work makes a significant contribution to the discussion on the efficiency and future directions of the EU's energy policy. It highlights the importance of a holistic approach to energy transformation, which considers both environmental and economic needs and points to the necessity of further research and investment in technological innovation.*
Originality/value: *These findings are crucial for understanding the process of energy transformation in the EU and can serve as a valuable source of information for policymakers, researchers, and stakeholders interested in sustainable development and energy policy.*

Keywords: *Energy Transformation, EU Energy Policy, Renewable Energy Sources, Greenhouse Gas Emissions, European Green Deal, CO2 Emissions Reduction.*

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Research funding: *The project is financed within the framework of the program "Green technologies as a pathway to the competitiveness of Intercompact Sp. z o. o." has received funding under the Financial Mechanism of the European Economic Area (EEA), in line with priority axis 19 of the Norwegian Financial Mechanism 2014-2021, action 19.1 New Products and Investments, and sub-action 19.1.1 Environmentally Friendly Technologies - Green growth. The aim of the project is to increase the competitiveness of Intercompact Sp. z o. o. by introducing innovative and energy-efficient technological solutions, as well as by intensifying the use of renewable energy sources in the enterprise. The project includes the implementation of an advanced process for cutting sheets up to 10 mm thick using a state-of-the-art 6 kW fiber laser cutter and the construction of a 192 kW photovoltaic installation that will power the company's plant in Łebcz. These initiatives are expected to lead to the development of Intercompact, an increase in revenue, job creation, and a reduction in electricity consumption, which will contribute to its competitive edge in the market. The total value of eligible expenditures amounts to 3,085,500.00 PLN, of which the funding from the EEA Financial Mechanism constitutes 1,672,025.00 PLN.*

1. Introduction

The energy transformation of the European Union (EU) from fossil fuels to renewable energy sources and the reduction of greenhouse gas emissions represents one of the most significant and current challenges of our times (Gielen *et al.*, 2019; Rodriguez *et al.*, 2017; Dogan *et al.*, 2016; Zou *et al.*, 2021).

This scientific work focuses on analyzing both the historical and current energy policies of the EU, examining their impact on the structure of energy production and consumption, as well as greenhouse gas emissions in the member states (Pociovalisteanu *et al.*, 2010). This topic gains importance in the context of the global need to respond to climate change and international commitments, such as the Paris Agreement and the European Green Deal (Ślosarski, 2022).

The implementation of this energy transformation is crucial not only from an environmental protection standpoint but also for the future economic and political landscape of the Union (Antimiani *et al.*, 2023; Thalassinos *et al.*, 2022).

The study conducted in this work aims to answer how EU policies and initiatives have influenced changes in the energy sector and what are the visible trends in terms of reducing dependency on fossil fuels and increasing the share of renewable energy. Furthermore, this work investigates how these changes contribute to global goals for the reduction of GHG emissions.

2. Literature Review

The European Union's energy policy has undergone significant transformation over the past few decades, reflecting global trends and a growing awareness of the need for environmental protection and combating climate change (Hainsch *et al.,* 2022; Ahmad *et al.,* 2020). A defining moment that set the direction of these changes was the adoption of the Kyoto Protocol in 1997 (UN, 1998), the first international agreement aimed at reducing greenhouse gas (GHG) emissions. As a signatory, the EU committed to reducing its GHG emissions by 8% in the period 2008-2012 compared to 1990 levels (Ojaghlou *et al.,* 2023).

In response to these commitments, the EU adopted a series of directives and regulations that shaped its energy policy. In 2001, Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market was adopted, marking a milestone in promoting renewable energy sources (RES) in member states (European Parliament, 2001).

Subsequently, in 2009, the EU adopted the climate and energy package, which included the "20-20-20" targets for 2020: 20% reduction in GHG emissions compared to 1990 levels, 20% share of energy from renewable sources in overall energy consumption, and 20% improvement in energy efficiency. These ambitious targets obliged member states to transform their national energy sectors, increase the share of RES and improve energy efficiency (European Parliament, 2009).

Further progress in this area came with the adoption of the European Green Deal in 2019, which was the EU's response to the growing climate challenges. The European Green Deal envisions transforming the EU into a climate-neutral economy by 2050, requiring a further shift away from fossil fuels towards sustainable energy sources (Taylor, 2020; Anika *et al.,* 2022). As part of this strategy, the EU aims to increase the share of RES in its energy mix and further limit GHG emissions, in line with the 2015 Paris Agreement (European Commission, 2021; UNFCCC, 2016).

The analyzed actions of the EU in the area of energy policy show how the organization adapts its strategy to global environmental challenges (Proedrou, 2023; Inês *et al.,* 2020; Fraune *et al.,* 2018). Transitioning from fossil fuels to renewable energy and reducing GHG emissions have become key objectives that the EU is pursuing through a comprehensive approach that includes regulations, investments in innovation and technology, support for the green transformation in member states, and international cooperation.

This evolution of EU energy policy, although still ongoing, is testament to its commitment to building a sustainable and more resilient energy future (Domorenok *et al.,* 2023; Vieira *et al.,* 2021). Nevertheless, there is a justified need to conduct research analysis to determine the extent and degree to which the assumptions adopted by member states are being realized over the years.

3. Methodology

In the course of conducting this scientific research, an analysis of data on the production and consumption of fossil fuels, the level of electricity production from both fossil fuels and renewable energy sources, and the emission of greenhouse gases in 27 European Union countries was carried out. The time frame of the analysis covers the years 2000-2021, with the distinction that data on greenhouse gas emissions are available up to the year 2020. This limitation arises from the lack of availability of more recent data for the group of countries being analyzed.

It should be emphasized that the study focuses on the economies of the 27 EU member countries, without distinguishing the changing composition of Union membership over time. This methodological choice stems from the need to ensure consistency and comparability of data over a long period. The analysis was conducted from the perspective of the current composition of the European Union, allowing for a fuller understanding and interpretation of the results in the context of the current economic and political situation in the EU.

In terms of analyzing fossil fuel production, a data aggregation method was used, covering resources such as coal, oil, and natural gas. Similarly, for alternative energy sources, values for various sources present in individual countries during the analyzed period were summed.

This method of data aggregation is essential for conducting a coherent and reliable long-term analysis of the economies of the 27 EU member states. It enables a comprehensive picture of changes occurring in the energy sector over the study period, as well as allowing for international comparisons and inferences about trends and energy policies at the EU level.

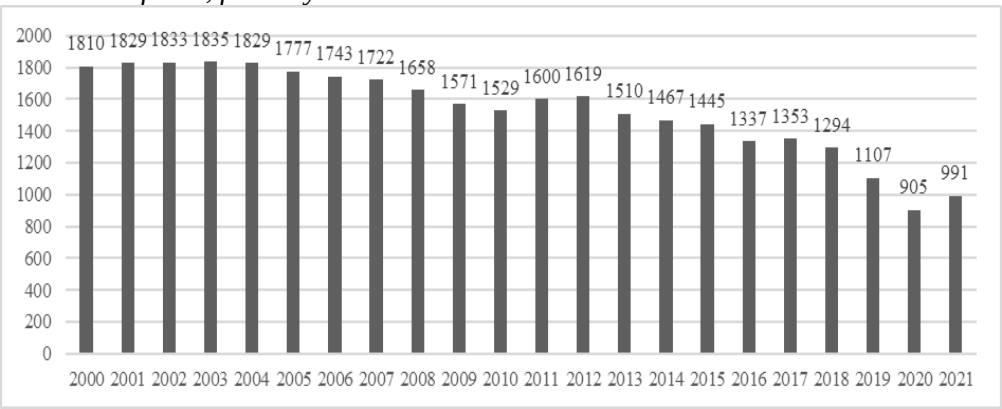
4. Research Results and Discussion

The analysis began with data on the total daily production of fossil fuels in the 27 EU countries, expressed in thousands of tons, for the years 2000-2021.

From the analysis of the chart presented in Figure 1, it is evident that a downward trend is observed during the examined period. The total daily production of fossil fuels in the 27 European Union countries in 2021 was 45.25 percentage points lower than in the year 2000.

However, it is worth noting that there were also periods of increase during the analyzed period, specifically in the years 2000-2003, 2011-2012, 2017, and 2021. The largest annual decrease in total daily production of fossil fuels was recorded in 2020, where it fell by 18.24 percentage points. Conversely, the highest annual increase was noted in 2021, with an increase of 9.51 percentage points.

Figure 1. *Total daily production of fossil fuels in the 27 EU countries, expressed in thousands of tons, for the years 2000-2021.*



Source: *Own elaboration based on statistical data from the World Bank.*

Considering the level of data aggregation, it should be emphasized that the production level in individual countries of the analyzed group is diverse. Based on statistical data obtained from individual countries, Table 1 presents a classification of economies in terms of the level of daily production of fossil fuels.

Table 1. *Daily production level of fossil fuels in the 27 EU countries in the years 2000 and 2021.*

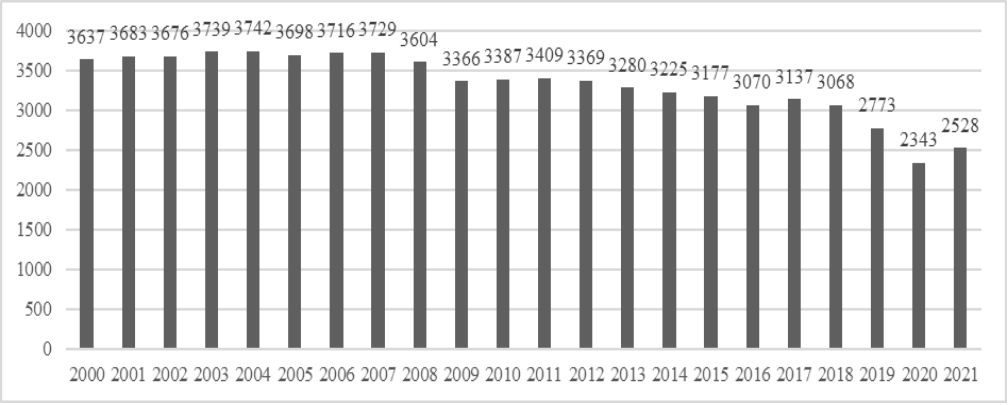
Level of daily fossil fuel production	2000	2021
Up to 10,000 tons per day	Austria, Belgium, Croatia, Cyprus, Estonia, Finland, Ireland, Lithuania, Latvia, Luxembourg, Malta, Portugal, Slovakia, Sweden	Austria, Belgium, Croatia, Cyprus, Denmark, Estonia, Finland, France, Ireland, Lithuania, Latvia, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia, Spain, Sweden
11-50 thousand tons per day	Denmark, France, Hungary, Italy, the Netherlands, Slovenia	Greece, Hungary, Italy
51-100 thousand tons per day	Bulgaria, Romania, Spain	Bulgaria, Czech Republic, Romania
Over 100 thousand tons per day	Czech Republic, Germany, Greece, Poland	Germany, Poland

Source: *Own elaboration based on statistical data from the World Bank.*

The conclusions drawn from the analysis of Figure 1 and the data presented in Table 1 indicate that alongside the reduction in the nominal amount of fossil fuel production, there has also been a significant change in the structure of country distribution across different production groups. An increase was observed in the

number of countries classified into the group with marginal and low daily production of fossil fuels compared to the group of countries with moderate and high production. Additionally, a change was noted in the proportion of countries with high daily production of fossil fuels in the total number of analyzed economies - a decrease from 76.50% in 2000 to 66.26%. Subsequently, data regarding the daily consumption of fossil fuels were analyzed, which is presented in Figure 2.

Figure 2. *Total daily consumption of fossil fuels in the 27 EU countries, expressed in thousands of tons, for the years 2000-2021.*



Source: *Own elaboration based on statistical data from the World Bank.*

The analysis of the chart presented in Figure 2 reveals a progressive decline in the total consumption of fossil fuels during the examined period, with episodic periods of increase. The total daily consumption of fossil fuels in the 27 European Union countries in 2021 was lower by 30.49 percentage points compared to the year 2000.

However, it is important to note that there were also periods of increase during the analyzed period, such as in the years 2000-2001, 2003-2004, 2006-2007, 2010-2011, 2017, and 2021. The largest annual decrease in total daily fossil fuel consumption was recorded in 2020, where it fell by 15.49 percentage points. Conversely, the highest increase was observed in 2021, reaching 7.89 percentage points.

Considering the degree of data aggregation, it should be emphasized that the level of consumption in individual countries is varied. Based on statistical data collected from individual countries, Table 2 presents a classification of economies according to the level of daily consumption of fossil fuels.

Table 2. *Daily consumption level of fossil fuels in the 27 EU countries in the years 2000 and 2021.*

Level of daily fossil fuel consumption	2000	2021
Up to 10,000 tons	Cyprus, Estonia, Lithuania, Latvia,	Croatia, Cyprus, Estonia,

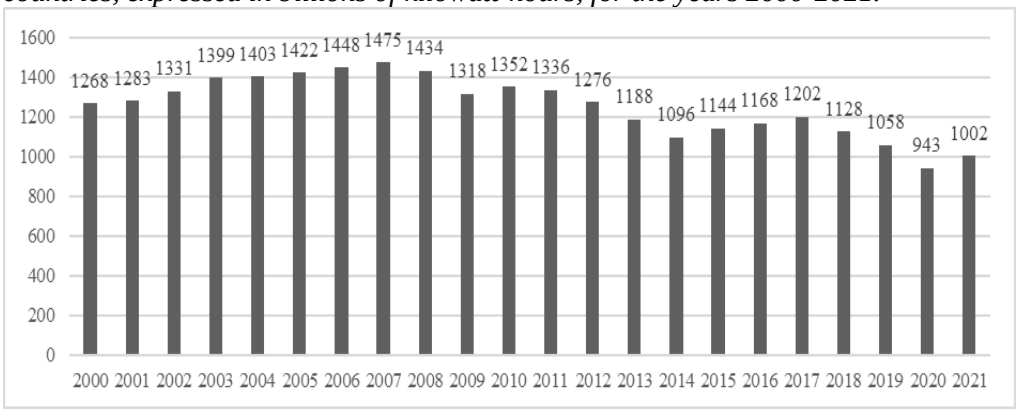
per day	Luxembourg, Malta	Lithuania, Latvia, Luxembourg, Malta
11-50 thousand tons per day	Austria, Croatia, Denmark, Finland, Ireland, Slovakia, Slovenia	Austria, Denmark, Finland, Hungary, Ireland, Portugal, Slovakia, Slovenia, Sweden
51-100 thousand tons per day	Bulgaria, Hungary, Portugal, Sweden	Belgium, Bulgaria, Greece, Romania
Over 100 thousand tons per day	Belgium, Czech Republic, France, Germany, Greece, Italy, the Netherlands, Poland, Romania, Spain	Czech Republic, France, Germany, Italy, the Netherlands, Poland, Spain

Source: *Own elaboration based on statistical data from the World Bank.*

Based on the data presented in Table 2, it can be observed that alongside the reduction in the nominal amount of fossil fuel consumption, there has also been a significant change in the structure of country distribution among different consumption groups. An increase was observed in the number of countries with relatively marginal and low daily consumption of fossil fuels compared to countries with moderate and high daily consumption levels.

Additionally, there was a shift in the proportion of countries with relatively high daily fossil fuel consumption in the overall compilation of analyzed economies, decreasing from 85.78% in 2000 to 75.40% in the analyzed period. Figure 3 presents the distribution of electricity production derived from fossil fuels in the years 2000-2021.

Figure 3. *Total amount of electricity generated from fossil fuels in the 27 EU countries, expressed in billions of kilowatt-hours, for the years 2000-2021.*



Source: *Own elaboration based on statistical data from the World Bank.*

The analysis of the chart presented in Figure 3 shows a progressive decline in the level of electricity generated from fossil fuels during the examined period, with characteristic downward waves. The total amount of electricity generated from fossil fuels in the 27 European Union countries in 2021 was 20.99 percentage points lower

compared to the year 2000. However, it is important to note that there were also periods of increase during the analyzed period, such as in the years 2000-2007, 2010, 2015-2017, and 2021.

The largest annual decrease in the total amount of electricity generated from fossil fuels was recorded in 2020, reaching 10.92 percentage points. Conversely, the highest increase was noted in 2021, where it amounted to 6.29 percentage points.

Considering the level of data aggregation, it should be emphasized that the total amount of electricity generated from fossil fuels in the analyzed countries is varied. Based on statistical data collected from individual countries, Table 3 presents a classification of economies according to the amount of electricity generated from fossil fuels.

Table 3. *Size of electricity production from fossil fuels in the 27 EU countries in the years 2000-2021.*

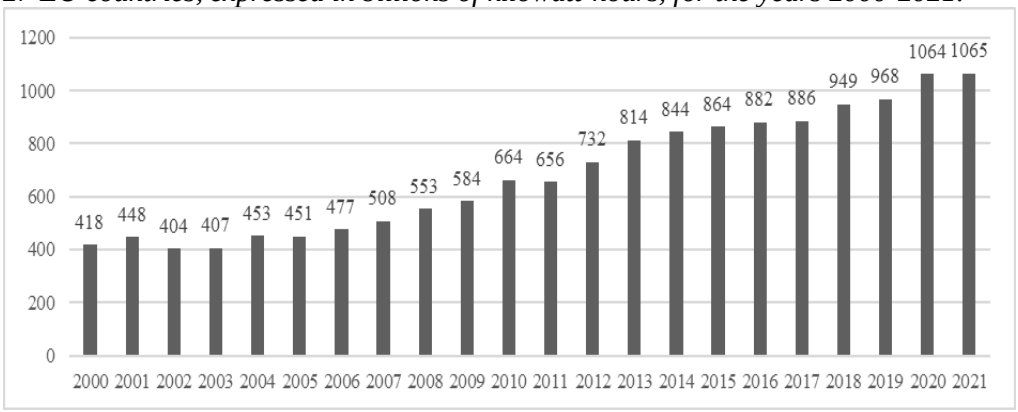
Amount of electricity generated from fossil fuels	2000	2021
Up to 10 billion kilowatt-hours	Croatia, Cyprus, Estonia, Lithuania, Latvia, Luxembourg, Malta, Slovakia, Slovenia, Sweden	Croatia, Cyprus, Denmark, Finland, Estonia, Lithuania, Latvia, Luxembourg, Malta, Slovakia, Slovenia, Sweden
11-50 billion kilowatt-hours	Austria, Belgium, Bulgaria, Denmark, Finland, France, Greece, Hungary, Ireland, Portugal, Romania	Austria, Belgium, Bulgaria, Czech Republic, France, Greece, Hungary, Ireland, Portugal, Romania
51-100 billion kilowatt-hours	Czech Republic, the Netherlands	The Netherlands, Spain
Over 100 billion kilowatt-hours	Germany, Italy, Poland, Spain	Germany, Italy, Poland

Source: *Own elaboration based on statistical data from the World Bank.*

The analysis of the data from Table 3 indicates that, along with the reduction in the amount of electricity generated from fossil fuels, there was also a significant change in the structure of country distribution among different groups. An increase was observed in the number of countries with relatively marginal and low levels of electricity production from fossil fuels compared to countries with moderate and high levels of production.

Additionally, there was a shift in the share of countries with relatively high levels of electricity production from fossil fuels in the overall composition of the analyzed economies, decreasing from 62.50% in 2000 to 55.54%. Figure 4 presents the distribution of electricity produced from alternative energy sources in the years 2000-2021.

Figure 4. *Total amount of electricity generated from renewable energy sources in the 27 EU countries, expressed in billions of kilowatt-hours, for the years 2000-2021.*



Source: *Own elaboration based on statistical data from the World Bank.*

The analysis of the chart presented in Figure 4 shows a significant increase in the level of electricity generated from renewable energy sources during the examined period. It is noteworthy that there were only three one-year periods of production decline compared to the previous year, specifically in 2002, 2005, and 2010. The total amount of electricity generated from renewable energy sources in the 27 European Union countries in 2021 was higher by 154.56 percentage points compared to the year 2000.

The largest annual decrease in the total amount of electricity generated from renewable energy sources was recorded in 2002, amounting to 9.98 percentage points. Conversely, the highest increase was observed in 2010, reaching 13.64 percentage points. Considering the degree of data aggregation, it should be noted that the total amount of electricity generated from renewable sources in the analyzed countries is varied. Based on statistical data obtained from individual countries, Table 4 presents a classification of economies according to the amount of electricity generated from renewable energy sources.

Table 4. *Size of electricity production from renewable energy sources in the 27 EU countries in the years 2000-2021.*

Amount of electricity generated from renewable energy sources	2000	2021
Up to 10 billion kilowatt-hours	Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Greece, Hungary, Ireland, Lithuania, Latvia, Luxembourg, Malta, the Netherlands, Poland, Slovakia, Slovenia	Bulgaria, Cyprus, Estonia, Hungary, Lithuania, Latvia, Luxembourg, Malta, Slovakia, Slovenia

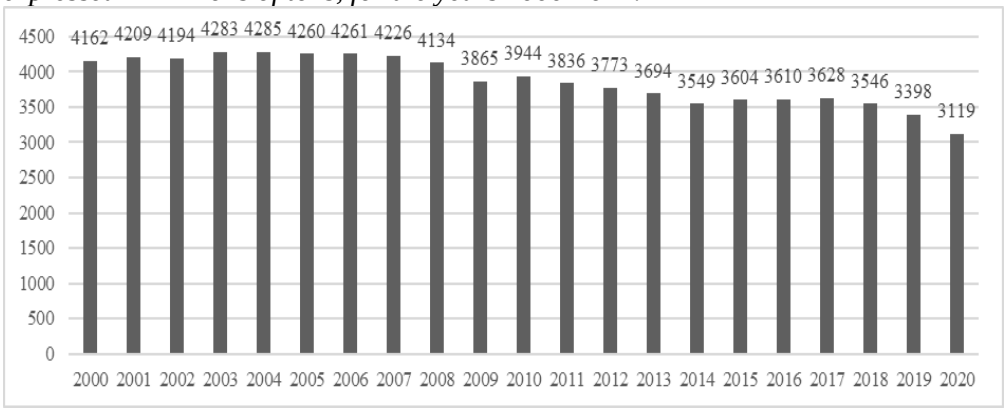
11-50 billion kilowatt-hours	Austria, Finland, Germany, Portugal, Romania, Spain	Belgium, Croatia, Czech Republic, Denmark, Finland, Greece, Ireland, the Netherlands, Poland, Portugal, Romania
51-100 billion kilowatt-hours	France, Italy, Sweden	Austria
Over 100 billion kilowatt-hours	-	France, Germany, Italy, Spain, Sweden

Source: *Own elaboration based on statistical data from the World Bank.*

Using the information contained in Table 4, it can be observed that the increase in the amount of electricity generated from renewable energy sources was also associated with a significant change in the structure of country distribution according to their assigned groups. A decrease was noted in the number of countries with a relatively marginal level of electricity production from renewable sources in favor of countries with low, moderate, and high levels of production.

Additionally, the share of countries with relatively high production of electricity from renewable sources changed. In 2000, none of the analyzed countries achieved a production level of electricity above 100 billion kilowatt-hours from renewable sources. In 2021, this level was reached by 5 countries, which together accounted for 66.41% of the total electricity production from renewable sources in the analyzed group of countries. Subsequently, an analysis of data regarding greenhouse gas emissions was conducted, which is presented in Figure 5.

Figure 5. *Total amount of greenhouse gases emitted in the 27 EU countries, expressed in millions of tons, for the years 2000-2021.*



Source: *Own elaboration based on statistical data from the World Bank.*

The chart presented in Figure 5 shows an overall decrease in the level of greenhouse gas emissions during the examined period, with short periods of increase. The total greenhouse gas emissions in the 27 European Union countries in 2020 were lower by 25.08 percentage points compared to the year 2000.

However, it is important to note that there were also periods of emission increases during this time, for example, in the years 2000-2001, 2003-2004, 2006, 2010, and 2015-2017. The largest annual decrease in greenhouse gas emissions was recorded in 2020, amounting to 8.21 percentage points. The largest increase in emissions compared to the previous year occurred in 2003 and amounted to 2.12 percentage points.

Considering the degree of data aggregation, it should be emphasized that the emission of greenhouse gases in the individual analyzed countries is diverse. Based on statistical data from individual countries, Table 5 classifies economies according to the level of greenhouse gas emissions.

Table 5. *Level of greenhouse gas emissions in the 27 EU countries in the years 2000-2020.*

Amount of greenhouse gases emitted	2000	2020
Up to 10 million tons	Cyprus, Luxembourg, Malta	Cyprus, Estonia, Luxembourg, Malta
11-50 million tons	Croatia, Estonia, Lithuania, Latvia, Slovakia, Slovenia	Bulgaria, Croatia, Denmark, Finland, Lithuania, Latvia, Slovakia, Slovenia, Sweden
51-100 million tons	Austria, Bulgaria, Denmark, Finland, Hungary, Ireland, Portugal, Sweden	Austria, Belgium, Greece, Hungary, Ireland, Portugal, Romania
Over 100 million tons	Belgium, Czech Republic, France, Germany, Greece, Italy, the Netherlands, Poland, Romania, Spain	Czech Republic, France, Germany, Italy, the Netherlands, Poland, Spain

Source: *Own elaboration based on statistical data from the World Bank.*

In connection with the observed reduction in greenhouse gas emissions, the structure of country distribution among different emission groups also underwent significant changes. An increase in the number of countries with lower greenhouse gas emissions was observed. Additionally, there was a change in the share of countries with relatively high greenhouse gas emissions in the context of the overall analyzed economies – it decreased from 82.59% in 2000 to 73.55% in 2020.

5. Conclusions, Proposals, Recommendations

This scientific work, focusing on assessing the efficiency of the energy transformation in the European Union countries, brings significant conclusions regarding changes in the production and consumption of fossil fuels, the increase in energy production from renewable sources, and the decrease in greenhouse gas emissions. These results indicate the overall success of EU policies aimed at

sustainable energy development. However, in the context of these findings, further research and development in several key areas appear to be important.

The first area is a detailed analysis of the impact of the European Union's energy policy on the efficiency of national economies, considering how diverse strategies of individual countries influence the dynamics and efficiency of the energy transformation process. Understanding this aspect is crucial for evaluating the effectiveness and future directions of actions within the EU.

Another important area of research is technological development in the renewable energy sector. Studying how innovations and investments in new technologies contribute to changes in production, distribution, and energy consumption can provide valuable insights for future directions of the energy sector's development.

It is also worth conducting a comparative analysis with other world regions to understand global trends, challenges, and best practices in energy transformation. Such an international perspective will allow for a better understanding of the EU's position against other global players.

Additionally, it is essential to examine how the energy transformation affects societies, including the labor market, industry structure, and local communities. This is important to understand the social consequences of these changes and to develop strategies that will support a fair energy transition.

Thus, this article can serve as a reference point for further research work in this field.

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