The Role of Renewable Energy in the Efforts to Combat Climate Change in the CEE-4 Countries

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Abstract: The European Union's strategic objective is to augment the proportion of renewable energy sources within its energy mix. This initiative is primarily driven by the need to address the pressing issue of climate change, with a secondary objective of maintaining its position as a global leader in high-performance technologies. As members of the European Union, the CEE-4 countries (Czech Republic, Hungary, Poland, Romania) attach considerable importance to the development of this type of energy, setting ambitious targets and allocating substantial investment to this sector. The present article aims to analyse the latest trends in the renewable energy sector in the CEE-4 countries. In the initial section of the article, an extensive review of the pertinent literature was conducted. This entailed the examination of significant articles and studies within the field, with the objective of identifying existing gap in the available research. In the second part of the paper, a quantitative analysis was conducted that included four indicators related to renewable energy. The primary findings indicate that the CEE-4 countries demonstrate a commendable performance in terms of the proportion of renewable energy sources utilised, in comparison to the European Union average. This is particularly noteworthy when considering these countries' communist past and their relatively recent accession to the European Union. Furthermore, Romania is the CEE-4 country that ranks highest on three of the four indicators. Nevertheless, the full potential of renewable energy sources has yet to be realised. To address this issue, several measures must be taken. These include the improvement of support schemes for renewable energy sources, the construction of new facilities, particularly those dedicated to solar and wind power, and the modernisation of existing cogeneration plants.

Key words: renewable energy, climate change, CEE-4 countries, policies
JEL Classification: Q42, Q48, Q49, Q54

1. Introduction

The transition to renewable energy signifies a considerable structural shift in energy supply and consumption within an energy system. The transition to sustainable energy represents a contemporary phenomenon that is being implemented with the aim of mitigating the effects of climate change. Most of the sustainable energy is of a renewable nature. The current transition aims to reduce greenhouse gas emissions rapidly and sustainably from the energy sector, primarily by phasing out fossil fuels and shifting as many processes as possible to low-carbon electricity (Saleh et al., 2024).

The European Union's most significant challenge is to become the first climate-neutral continent by 2050. In pursuit of this objective, the European Commission unveiled the European Green Deal on 11 December 2019.

This initiative constitutes the most ambitious plan to date to assist European citizens and businesses in benefitting from the sustainable green transition (Sustelo et al, 2023). The measures that have been implemented include an initial roadmap for key policies. The measures adopted include actions such as reducing emissions, investing in research and innovation, and protecting the environment in the EU (Rayner et al., 2023). Of particular significance is the fact that the European Green Deal establishes a equitable trajectory for the transition. The objective of the programme is to ensure that no person or region is left behind as future changes take effect (Ottomano et al., 2025).

The European Green Deal will contribute to the Clean Industrial Deal. It is part of the Commission's strategy to implement the United Nations 2030 Agenda and its sustainable development goals. It will also boost competitiveness and innovation in the EU. These are just some of the priorities announced in the current Commission's political guidelines. It has developed several plans to make the economy safer, more sustainable, with lower emissions (Costadone et al., 2023). In addition to efforts to combat climate change by reducing greenhouse gas emissions, the use of renewable energy sources is likely to create a more secure and diversified energy supply, reduce air pollution, and create jobs in the environmental and renewable energy sectors (Batra, 2023).

Considering the European Union's target of achieving a 20% share of renewable energy by the year 2020, the Union adopted Directive 2018/2001/EU on the 11th of December 2018, with the aim of promoting the utilisation of energy from renewable sources. The most recent amendment to this directive (Directive (EU) 2023/2413) incorporates a binding renewable energy target for the EU of 42.5% for 2030, with the objective of achieving 45%.

On 18 May 2022, the Commission published the REPowerEU plan. The strategy outlined in this plan involves the implementation of a series of measures designed to swiftly reduce reliance on fossil fuels from the Russian Federation. The objective is to accomplish this objective prior to 2030 by expediting the transition to clean energy. The REPowerEU plan is comprised of three distinct components. The first section of the report focuses on energy savings, the second section focuses on clean energy production, and the third section focuses on the diversification of energy sources within the European Union.

The primary objective of our paper endeavour is to undertake a comprehensive analysis of the renewable energy sector within the CEE-4 countries (Czech Republic, Hungary, Poland, Romania). Consequently, a quantitative analysis of the primary indicators associated with renewable energy will be conducted, with the objective of evaluating and comparing the levels of development of the CEE-4 countries in this regard, considering their communist past and their relatively late accession to the European Union.

2. Literature review

The European Union has identified the promotion of renewable energy as a key priority for the 21st century. The public has become increasingly concerned about climate change, greenhouse gas emissions, environmental damage, and energy security (Ruiz et al., 2023; Gajdzik et al., 2024). This has prompted European institutions to advocate for the transition from fossil fuels to cleaner and more sustainable energy systems. Renewable energy sources, including solar, wind, hydroelectric, geothermal, and biomass, are currently regarded as pivotal in achieving climate neutrality and long-term economic sustainability (Saeed et al., 2024; Gayen et al., 2024).

As demonstrated in the relevant literature (Escribano et al. 2023; Algarni et al., 2023; Xiao et al., 2025), the development of renewable energy sources has been shown to be advantageous in terms of environmental impact, in addition to generating economic, technological, and geopolitical benefits. Researchers (Hanna et al., 2024; Tamasiga et al., 2026) believe that the transition towards a low-carbon economy is significant for industrial development, the labour market, innovation, and the way different regions of Europe collaborate.

A significant aspect within the existing literature pertains to the evolution of the European Union's renewable energy policy over time. The Renewable Energy Directive establishes common objectives for Member States and establishes a uniform framework for the promotion of renewable energy sources. Previous EU policies sought to achieve the "20-20-20" targets. These objectives aimed to reduce greenhouse gas emissions by 20%, enhance energy efficiency by 20%, and augment the share of renewable energy consumption by 20%, all by the year 2020. Recent initiatives, including the European Green Deal and the "Fit for 55" package, have set forth more ambitious objectives, such as achieving climate neutrality in the European Union by 2050.

Experts (Raikar et al., 2024; Arzo et al., 2024; Sun et al., 2025) theorise that if governments maintain consistent policies and do not frequently amend legislation, investments in renewable energy projects will be

significantly more straightforward. This phenomenon can be attributed to the divergent operational practices of institutions, the varying levels of economic development, and the distinct political priorities of each region. Consequently, there are discrepancies in the utilisation of renewable energy across various regions of the European Union (Dogan et al., 2023).

Another salient topic that has been the subject of discussion in the academic literature pertains to the integration of renewable energy sources into the EU's energy systems. Renewable energy sources, such as wind and solar power, are contingent on meteorological conditions. Researchers (Sahoo et al., 2023; Obakhume et al, 2025) have expressed the view that there is a necessity to modernise power grids, to build interconnections between countries, and to develop energy storage technologies. In the realm of energy systems, there is an increasing emphasis on the significance of smart grids and battery systems, particularly in scenarios where a substantial share of energy is derived from renewable sources (Al-Shetwi et al., 2025).

Several studies (Wang et al., 2023; Thellufsen et al., 2023; Pastore et al., 2025) have been conducted about sector coupling, a concept defined as the integration of electricity generation with the transportation, heating, and industrial sectors. It is the opinion of experts in the field (Prina et al., 2023; Son et al., 2023) that sector coupling has the potential to enhance the system's flexibility and contribute to a reduction in the overall costs associated with carbon emission reduction. Researchers (Amini et al., 2024) also highlight the growing significance of digital technologies, artificial intelligence, and data-driven energy management systems in optimising the distribution and consumption of renewable energy.

The extant literature further underscores the economic and social dimensions of the transition to renewable energy sources within the European Union. Investment in the field of renewable energy has been demonstrated to have a positive correlation with employment opportunities, particularly within sectors such as manufacturing, construction, maintenance, and the development of new technologies. The extant research in this field indicates that the renewable energy industry has a beneficial effect on regional economies, enhancing their growth and increasing business competitiveness (Vîrjan et al., 2023). However, researchers (Georgescu et al., 2025) also identify challenges related to unequal economic capacities among Member States.

Developed countries have greater financial resources with which to invest in renewable energy projects, while less developed countries encounter difficulties in identifying funding sources. Another significant issue that has been highlighted by researchers (Esiri et al., 2023) is that of public acceptance. Residents have been known to attempt to impede the development of renewable energy projects, including wind farms, power lines, and solar farms. Consequently, experts (Ryder et al., 2023) advocate for public involvement to ensure transparent decision-making processes and to empower communities to play an active role.

The existing literature has addressed issues related to energy communities and citizens involved in renewable energy systems. Energy communities are defined as groups of individuals, local authorities, and businesses that collaborate to produce, utilise, and oversee renewable electricity (Ahmed et al., 2024). Researchers (Abdulkareem et al., 2024) hypothesise that projects involving the local community can facilitate citizen participation in decision-making processes and promote familiarity with renewable energy technologies. These initiatives have the potential to reduce household energy costs and address the issue of energy access for vulnerable populations.

Research in this field demonstrates that solar photovoltaic systems are frequently utilised in energy communities due to their relative cost-effectiveness and the ability to be deployed expeditiously. Nevertheless, several challenges have the potential to impede the development of community projects. The challenges experienced by these entrepreneurs include the bureaucratic processes involved in setting up a business and the difficulty in securing funding. Research in this area suggests that simpler legal frameworks and greater financial support for citizen-led renewable energy initiatives are recommended (Schwanitz et al., 2024).

Even though renewable energy is intended to be environmentally sustainable, researchers have also focused on how it can have a negative impact on the environment. Large-scale renewable energy infrastructure, including wind turbines and solar farms, has the potential to exert a detrimental effect on biodiversity, ecosystems, and land use if not meticulously designed (Apoorva et al., 2025). The construction of wind farms has been demonstrated to exert an effect on bird populations, whilst hydropower projects have been shown to exert a detrimental effect on aquatic ecosystems. Solar farms require substantial land areas, in some cases.

Renewable energy technologies are dependent on critical minerals and rare earth elements that are utilised in the manufacture of batteries, solar panels, and wind turbines. Researchers (Antony Jose et al., 2024) have posited that it is imperative to employ mining practices that do not compromise environmental integrity, to establish recycling systems, and to cultivate a circular economy.

A comprehensive review of extant literature indicates that the European Union has made significant progress in the use of renewable energy over the past two decades. At present, wind and solar power account for a significant share of the electricity produced in Europe, and many countries continue to expand their use of renewable energy (Dolge et al., 2023). However, researchers (Singh et al., 2024) concur that there are still significant challenges to address, including the integration of the technology into the power grid, the amount of electricity it can store, policy coordination, funding inequalities, and how to gain public acceptance.

Future research will address these issues, with a particular focus on ways to do so, the use of computers and technology, hydrogen-based technologies, and ensuring access to energy for all. Most experts concur that achieving climate neutrality by 2050 will necessitate enhanced cooperation between regions, the implementation of long-term investment plans, and governance approaches that integrate the environment, technology, the economy, and society.

The research gap identified in the relevant literature pertains to the lack of studies examining the status of renewable energy in the CEE-4 countries. In consideration of the distinctive historical trajectory of these countries – encompassing their transition from communism to accession and integration into the European Union – and within the framework of the region's geopolitical environment, renewable energy, an indispensable component of the energy sector, necessitates more focused analytical scrutiny.

3. Methodology

The methodological design of this paper is mixed, based on an analysis of the key indicators reflecting the state of renewable energy in the CEE-4 countries (Romania, the Czech Republic, Hungary, and Poland), using the latest Eurostat data, and on a qualitative review of the relevant literature in the field.

The quantitative analysis is based on Eurostat data to illustrate the level of development of the CEE-4 countries in terms of renewable energy use. The present analysis was conducted utilising four pertinent indicators, namely: the share of renewable energy sources in final energy consumption, the share of renewable energy sources in electricity consumption, renewable energy in the heating and cooling sector, and renewable energy used in the transport sector.

The present article provides an analysis of the challenges and opportunities inherent in the development of renewable energy. In addition, it offers a comparative analysis of the CEE-4 countries.

The primary limitation of this study is the absence of European Union statistics for the year 2025; consequently, it is imperative to extend the research in subsequent studies once these data are available.

4. The development of the renewable energy sector in the CEE-4 countries

The implementation of renewable energy sources can offer numerous advantages, including the mitigation of greenhouse gas emissions, the diversification of energy supplies, and the reduction of reliance on fossil fuels. The European Union is set to generate a significant number of employment opportunities in the domain of novel "green" technologies, as it endeavours to enhance the share of renewable energy. This constitutes a fundamental component of the Energy Union and the Clean Industrial Deal.

This section of the article presents statistical data on the proportion of energy from renewable sources in the total energy consumption of the CEE-4 countries, broken down by the three main consumption sectors (electricity, heating and cooling, and transport). The data is based on the latest figures from Eurostat. These renewable energy sources include wind, solar (thermal and photovoltaic), hydropower, wave energy, geothermal energy, heat extracted by heat pumps, biofuels, and the renewable fraction of waste.

4.1. Energy from renewable sources in gross final energy consumption

The Renewable Energy Directive 2009/28/EC (RED I) stipulates that final energy consumption pertains to the energy supplied to industry, transport, households, services (including public services), agriculture, forestry, and fisheries for energy purposes. This encompasses the consumption of electricity and heat by the energy sector for the purpose of electricity and heat generation, in addition to losses of electricity and heat that occur during distribution and transmission.

In 2024, the EU accounted for 25.2% of the global energy consumption from renewable sources. This indicates an increase of 0.7 percentage points compared to the 2023 figures, and a figure that is more than three times the 2004 percentage (9.6%). A recent EU directive (2023/2413) has led to an increase in the EU's target for

the utilisation of energy from renewable sources. The target has been increased from 32% to 42.5%, with a goal of reaching 45%. Consequently, it is incumbent upon EU countries to collaborate in order to achieve the 2030 target. The objective is to increase the market share by more than 17% over the next six years.

Figure 1: Share of energy from renewable sources in final energy consumption in 2024 (CEE-4, %)

Source: Authors based on Eurostat data, 2025

As demonstrated in Figure 1, the most recent data available concerning the proportion of renewable energy in final energy consumption within the CEE-4 countries is illustrated. Romania had the highest share, at 25.4%, followed by the Czech Republic at 19.2%, Hungary at 18.3%, and Poland at 17.8%.

4.2. Renewable energy in the electricity sector

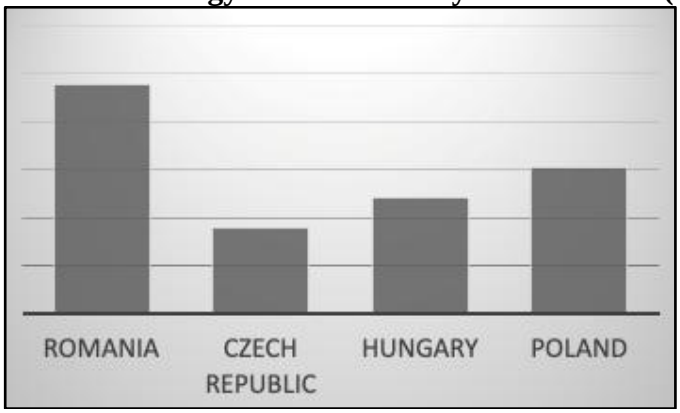
The share of electricity produced from renewable sources is defined as the ratio of electricity produced from such sources to the total electricity consumed within a given country. According to the Renewable Energy Directive, the term 'final consumption of electricity from renewable sources' refers to electricity produced from renewable energy sources. This encompasses hydroelectric power plants (excluding electricity derived from pumped-storage plants that utilise water already pumped upstream), as well as electricity generated from solid biofuels/waste, wind, solar, or geothermal installations. The Directive also stipulates that electricity produced using water and wind should be treated in the same way.

The provisions of EU Directive 2018/2001 stipulate that electricity generated from hydro and wind sources must be standardized to account for year-to-year variations in weather conditions. The present section is concerned with the presentation of results that have been obtained with these provisions in mind.

The increase in renewable energy in electricity consumption between 2014 and 2024 is indicative of the growth of solar and wind energy in the EU. In 2024, the share of electricity in the EU derived from renewable sources accounted for more than 50% of the total consumption (47.5%), marking an increase of approximately 2 percentage points compared to the preceding year (45.4% in 2023).

At the EU level, wind and hydro power together accounted for nearly two-thirds of the electricity generated from renewable sources (38% and 26.4%, respectively). The residual electricity was derived from solar sources (23.4%), solid biofuels (5.8%), and alternative renewable sources (6.1%). Solar energy is expanding at an accelerated rate. In 2008, the share of the market was 1%. This indicates that electricity from solar sources has increased significantly, from 7.4 TWh in 2008 to 304 TWh in 2024.

Figure 2: Renewable energy in the electricity sector in 2024 (CEE-4, %)



Authors based on Eurostat data, 2025

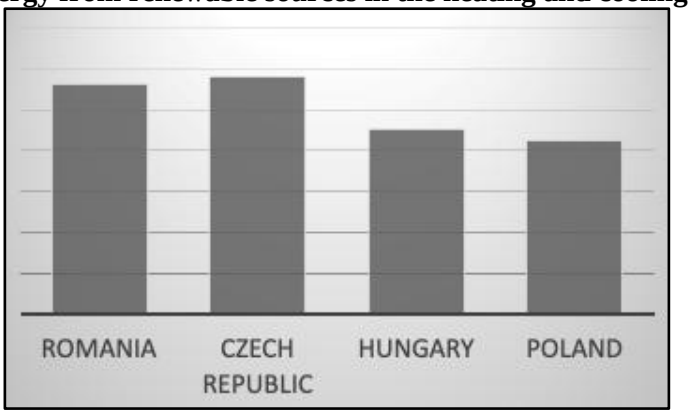
Figure 2 illustrates the proportion of renewable energy in electricity consumption within the CEE-4. As is evident, Romania is leading the field with 47.6% of its electricity being produced from renewable sources, followed at a considerable distance by Poland (30.4%), Hungary (24.1%), and the Czech Republic (17.9%).

4.3. Renewable energy in heating and cooling

To calculate the amount of energy from renewable sources utilised for heating and cooling purposes, the analysis encompasses the evaluation of energy consumption in industry, households, services, agriculture, forestry, and fisheries for heating and cooling, in addition to district heating produced from renewable sources. The term 'final consumption for heating and cooling' is used to denote the final consumption of all energy products, except for electricity, for purposes other than transportation. It also incorporates heat consumption for own use at power and heating plants, as well as heat losses from networks.

In 2024, the share of energy from renewable sources in the total energy used for heating and cooling across the EU was 26.7%. This represents a substantial increase of 11.7% since 2004. The observed rise can be attributed to advancements in industry, services, and households. Additionally, heat pumps have the capacity to capture energy from the ambient air, thereby enabling the provision of heating and cooling for buildings.

Figure 3: Share of energy from renewable sources in the heating and cooling in 2024 (CEE-4, %)



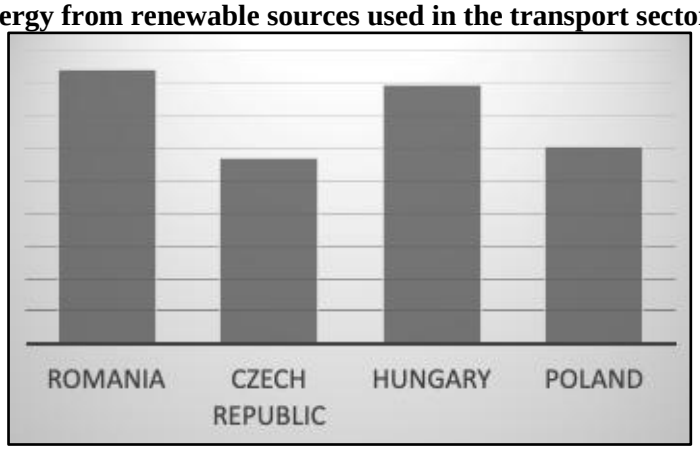
Source: Authors based on Eurostat data, 2025

Figure 3 illustrates the share of renewable energy utilised for heating and cooling purposes in the CEE-4 countries. As is evident, the Czech Republic occupies the first position with 29.1%, closely followed by Romania with 28.1%. Hungary (22.8%) and Poland (21.3%) demonstrate a significant disparity in their performance.

4.4. Renewable energy in the transport sector

The EU has formally adopted a mandate to establish a unified target of 29% for the incorporation of renewable energy sources (including liquid biofuels, hydrogen, biomethane, "green" electricity, and analogous fuels) in the domain of transportation by the year 2030. In contrast to the initial target of a 29% reduction, countries may opt for a more ambitious approach, aiming to reduce the greenhouse gas intensity of transport fuels by a minimum of 14.5% by the year 2030. The share of energy from renewable sources such as wind and solar power in transportation has increased from 1.4% in 2004 to 11.2% in 2024.

Figure 4: Share of energy from renewable sources used in the transport sector in 2024 (CEE-4, %)



Source: Authors based on Eurostat data, 2025

Figure 4 illustrates the share of energy from renewable sources in the transport sector in the CEE-4. As is apparent from the data, Romania occupies the first position with 8.4%, closely followed by Hungary with 7.9%. The findings of this study indicate that Poland and the Czech Republic demonstrated substandard outcomes in relation to the specified indicator, with figures standing at 6% and 5.7%, respectively, in the case of Poland and the Czech Republic.

6. Conclusion

Renewable energy is a pivotal component in the ongoing efforts to combat climate change, and the European Union accords significant importance to the objective of achieving carbon neutrality. Considering this, the EU has established ambitious targets for renewable energy.

The first conclusion of our research is that, despite these countries' communist past and the specific challenges stemming from it – namely, their late accession to the European Union, economic transition, and heavy bureaucracy – all four CEE-4 countries are performing well in terms of renewable energy use.

The second conclusion relates to the fact that progress in renewable energy in the CEE-4 countries has been steady since these countries joined the European Union. This is evidenced by the figures reported by these countries regarding the four indicators analysed (the share of renewable energy sources in final energy consumption, the share of renewable energy sources in electricity consumption, renewable energy in the heating and cooling sector, and renewable energy used in the transport sector) relative to the EU average, according to the latest Eurostat data.

The third conclusion of this article concerns Romania, which ranks first among the CEE-4 countries on three of the four indicators analysed. Despite being the most recent of these countries to accede to the European Union, Romania has achieved considerable progress in terms of increasing the share of renewable energy sources. This rapid progress can be attributed to two key factors: firstly, the implementation of generous support schemes from 2016 onwards, and secondly, a collective understanding of the long-term objectives among all stakeholders. In terms of the subsequent measures to be implemented by Romania in this domain, it is imperative to augment the renewable energy generation capacity (predominantly wind and solar), expand the clean energy capacity derived from nuclear sources, modernise existing cogeneration facilities, and construct new ones.

The primary limitation of this study is the absence of European Union statistics for the year 2025; consequently, it is imperative to extend the scope of the research in subsequent studies once these data are available.

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