Vol. 6(1), 8-15

Journal of Energy & Environmental Policy Options

Determinants of CO2 Emissions and the Role of Renewable Energy in Romania

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Abstract
The present study investigates the determinants of CO2 emissions in Romania, analyzing annual data from 1980 to 2022. The research highlights key factors influencing energy consumption and their economic and social implications. It finds that any short-term increase in energy demand is primarily met through nonrenewable energy sources, as renewable energy usage remains limited in Romania. Several factors contribute to this limited adoption of renewable energy, including high installation costs and a general lack of awareness about environmental responsibilities. A significant positive correlation is identified between nonrenewable energy consumption and CO2 emissions, indicating that as nonrenewable energy use increases, CO2 emissions also rise substantially. This persistent increase in CO2 emissions highlights the urgent need for a transition to renewable energy sources, despite their current minimal role in Romania's energy landscape. In Romania, the dependency on nonrenewable energy sources such as coal, oil, and natural gas is a primary driver of CO2 emissions. This reliance is rooted in the established infrastructure and lower short-term costs associated with these energy sources. However, this practice has severe environmental consequences, contributing to the accumulation of CO2 in the ecosystem and exacerbating climate change issues. The study underscores that high installation costs and a lack of robust policies supporting renewable energy adoption are significant barriers to reducing reliance on nonrenewable energy sources. The findings suggest that Romania needs to address these barriers to shift towards more sustainable energy solutions. Investment in renewable energy infrastructure, subsidies or incentives for renewable energy projects, and public awareness campaigns about the benefits of renewable energy are crucial steps in this transition. By increasing the share of renewable energy in the overall energy mix, Romania can reduce its CO2 emissions and mitigate environmental degradation. Moreover, the study emphasizes the role of policy intervention in accelerating the adoption of renewable energy. Policymakers must focus on creating favorable conditions for renewable energy investments, including financial incentives, streamlined regulatory processes, and support for research and development in renewable technologies. These measures can help overcome the initial cost barriers and promote a broader understanding of the importance of sustainable energy practices. Additionally, the social implications of energy consumption and CO2 emissions are significant. High levels of pollution adversely affect public health, leading to increased healthcare costs and reduced quality of life. By transitioning to cleaner energy sources, Romania can improve public health outcomes, enhance energy security, and foster economic growth through the development of new industries and job opportunities in the renewable energy sector.

Keywords: CO2 Emissions, Renewable Energy, Energy Consumption
JEL Codes: Q42, Q48, Q53

1. INTRODUCTION

The negotiation of the Kyoto Protocol in 1997 marked a pivotal moment when the importance of a clean and sustainable environment was acknowledged by both developing and developed countries. This protocol identifies greenhouse gases (GHGs), particularly carbon dioxide (CO2) emissions, as the primary drivers of global warming. In an econometric study, Halicioglu (2009) examined the relationships between CO2 emissions, energy consumption, income, and foreign trade in Turkey, revealing significant interactions among these variables. Similarly, Sathaye, Shukla, and Ravindranath (2006) addressed climate change and sustainable development in India, emphasizing the importance of these issues on both global and national scales. The Stern Review (2006) further contributed to the discourse by offering a comprehensive economic analysis of climate change, stressing the urgent need for policy responses to mitigate its detrimental impacts. This body of work collectively underscores the critical linkages between environmental sustainability, economic activities, and policy initiatives aimed at addressing climate change. Tiwari (2011) utilized a Panel Vector Autoregression (PVAR) approach to evaluate the economic performance of renewable and nonrenewable energy sources in Europe and Eurasian countries. This study focused on assessing their impacts on economic growth and CO2 emissions, providing insights into the comparative advantages of different energy sources. The findings suggested that renewable energy sources have a more sustainable and

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less environmentally detrimental impact on economic growth compared to nonrenewable energy sources. This reinforces the potential benefits of transitioning towards renewable energy to achieve long-term economic and environmental objectives. Domac, Richards, and Risovic (2005) examined the socio-economic drivers influencing the implementation of bioenergy projects. Their research emphasized the role of these projects in promoting sustainable energy development, highlighting the importance of integrating socio-economic factors into the planning and execution of bioenergy initiatives. They discussed how factors such as government policies, economic incentives, social acceptance, and technological advancements play a crucial role in the successful implementation of bioenergy projects. The study underscored the need for a holistic approach that considers both economic viability and social impact to ensure the sustainable development of bioenergy. Moreover, the transition to renewable energy sources and the implementation of bioenergy projects are critical components in addressing global environmental challenges. These studies collectively highlight the importance of adopting clean energy technologies and sustainable practices to reduce CO2 emissions and mitigate climate change. They also stress the significance of supportive policies and socio-economic considerations in driving the successful adoption of renewable energy solutions. The research by Tiwari (2011) and Domac, Richards, and Risovic (2005) provides valuable insights into the economic and socio-economic aspects of renewable energy and bioenergy projects. Their findings emphasize the potential of renewable energy sources to support sustainable economic growth while reducing environmental impacts. This underscores the importance of continued research and policy support to advance the global transition towards a more sustainable and environmentally friendly energy system. Chien and Hu (2007) conducted an analysis of the macroeconomic efficiency of both OECD and non-OECD economies concerning renewable energy, underscoring its potential impact on economic performance. They found that renewable energy can drive economic growth by creating new business opportunities and employment in renewable energy industries. Additionally, renewable energy can serve as an import substitute, reducing dependency on foreign energy sources, which positively influences an economy's GDP and trade balance.

Similarly, Masui et al. (2006) proposed that addressing climate change issues requires the adoption of environmentally sustainable technologies and practices. They suggested several measures, including improving energy efficiency, forest conservation, reforestation, water conservation, and energy-saving initiatives. These strategies not only contribute to reducing greenhouse gas emissions but also promote sustainable economic development. Incorporating these approaches can lead to multiple benefits, such as reducing environmental degradation, fostering economic resilience, and ensuring a sustainable supply of natural resources. The integration of renewable energy and sustainable technologies into economic planning highlights the potential for achieving long-term environmental and economic goals concurrently. Chien and Hu (2007) and Masui et al. (2006) emphasize the crucial role of renewable energy and sustainable practices in enhancing economic performance and addressing climate change. They underscore the need for comprehensive policy frameworks that support the transition to renewable energy and the implementation of sustainable development practices to achieve a balanced and resilient economic growth model. This underscores the importance of continued investment in renewable energy technologies and sustainable practices to secure a prosperous and sustainable future for both developed and developing economies.

Krewitt et al. (2007) proposed that renewable energy sources could potentially fulfill up to half of the world's energy needs by 2050, aiming to prevent dangerous anthropogenic interference with the climate system. Their study highlights the significant role that renewable energy can play in mitigating climate change and reducing dependency on fossil fuels. The potential for renewable energy to meet a substantial portion of global energy demands underscores the importance of transitioning towards cleaner energy sources to achieve sustainable development and environmental goals. The feasibility of this transition relies on several factors, including advancements in renewable energy technologies, supportive policy frameworks, and substantial investments in infrastructure. Krewitt et al. (2007) emphasize the necessity for international cooperation and commitment to renewable energy deployment, as well as the importance of integrating renewable energy into national and global energy strategies. Achieving the target of meeting half of the world's energy needs with renewable sources by 2050 requires a concerted effort to enhance energy efficiency, promote technological innovation, and implement supportive policies that incentivize the adoption of renewable energy. This ambitious goal also necessitates overcoming challenges such as energy storage, grid integration, and the intermittency of some renewable energy sources.

Krewitt et al.'s (2007) proposition presents a transformative vision for the global energy landscape, advocating for a shift towards sustainable energy solutions that can secure a stable and healthy climate future. The realization of this vision would not only help in reducing greenhouse gas emissions but also contribute to energy security, economic development, and the creation of green jobs worldwide. Abulfotuh (2007) advocated for an immediate shift in the composition of energy resource portfolios to mitigate environmental risks associated with increasing energy demand. He emphasized the significant potential of renewable energy sources in achieving global energy sustainability. According to Abulfotuh, the transition towards renewable energy is crucial for addressing the environmental challenges posed by conventional fossil fuel consumption, such as greenhouse gas emissions and global warming. This shift necessitates a comprehensive approach that includes policy reforms, technological advancements, and increased investments in renewable energy infrastructure. Abulfotuh highlighted the role of government policies in creating a conducive environment for renewable energy development through incentives, subsidies, and regulations that favor clean energy technologies. Furthermore, public and private sector collaboration is essential to drive innovation and deployment of renewable energy solutions. Abulfotuh's advocacy is grounded in the recognition that renewable energy sources, such as solar, wind, hydro, and biomass, offer a sustainable alternative to fossil fuels. These sources not only help in reducing carbon emissions but also enhance energy security by diversifying the energy mix and reducing dependency on imported fuels. The environmental benefits of renewable energy extend beyond carbon reduction, contributing to improved air quality, reduced water usage, and minimized ecological impacts. Abulfotuh (2007) calls for a proactive and strategic transition towards renewable energy, underscoring its critical role in ensuring a sustainable energy future. The successful integration of renewable energy into the global energy portfolio is pivotal for mitigating environmental risks and fostering long-term economic and social benefits.

2. REVIEW OF LITERATURE

There are various studies analyzing the dynamics of the relationship between electricity consumption or energy consumption and economic growth either in the bivariate or multivariate framework. However, literature in the field of renewable energy consumption (in a disaggregated framework) is relatively less extensive. In this section, we limit ourselves to presenting a brief review of the recent available literature on renewable energy consumption or disaggregated energy consumption and economic growth. Based on the findings, we can classify studies into four groups. Firstly, studies examining the impact of specific types of energy on economic growth. For instance, Wolde-Rufael (2004) found unidirectional Granger causality from coal, coke, electricity, and total energy consumption to real GDP. This suggests that increases in these forms of energy consumption directly contribute to economic growth, highlighting their critical role in driving economic activities. Secondly, research focusing on the role of renewable energy in economic growth. Studies in this category typically investigate the potential of renewable energy sources such as wind, solar, and biomass to support sustainable economic development. These studies often emphasize the dual benefits of renewable energy: reducing carbon emissions while promoting economic stability and growth.

Thirdly, investigations into the relationship between disaggregated energy consumption and economic growth. These studies decompose total energy consumption into its various components to understand better how each type of energy contributes to economic performance. Such analyses help identify which energy sources are most effective in promoting economic growth and provide insights into optimizing energy policy. Lastly, comparative analyses between renewable and non-renewable energy consumption. These studies compare the economic impacts of consuming renewable energy versus traditional fossil fuels. They often aim to identify the economic trade-offs associated with transitioning from non-renewable to renewable energy sources and provide evidence to support policy decisions favoring cleaner energy alternatives. This classification helps to organize the extensive body of literature on energy consumption and economic growth, providing a clear framework for understanding the diverse impacts of different energy types on economic performance. The findings from these studies collectively underscore the importance of energy consumption in driving economic growth and highlight the potential benefits of increasing the share of renewable energy in the overall energy mix.

Sari and Soytas (2004) found that waste had the largest initial impact on real GDP, followed by oil. This finding underscores the significant role that waste management and oil consumption play in influencing economic performance. By highlighting the substantial impact of waste on GDP, the study suggests that effective waste management practices can contribute positively to economic growth. Similarly, the notable influence of oil consumption on GDP reflects its critical importance in driving economic activities, given oil's role as a key energy source across various industries. These insights emphasize the need for comprehensive energy policies that consider the economic impacts of different energy sources and waste management strategies. Awerbuch and Sauter (2006) highlighted that renewable energy sources (RES) have a positive impact on economic growth by mitigating the negative effects of oil price volatility. Their study underscores the economic benefits of transitioning to renewable energy, particularly in reducing vulnerability to oil price fluctuations. This finding suggests that promoting renewable energy can enhance energy security and stabilize economic growth by decreasing reliance on volatile fossil fuel markets. It underscores the importance of sustainable energy policies that not only address environmental concerns but also strengthen economic resilience against energy price shocks.

Chien and Hu (2008) employed Structural Equation Modeling (SEM) to illustrate that renewable energy sources (RES) indirectly stimulate GDP growth by fostering increased capital formation across 116 economies. Their study provides empirical evidence suggesting that investments in renewable energy infrastructure contribute to economic development by enhancing capital accumulation. This finding underscores the potential economic benefits of integrating renewable energy into national energy portfolios, highlighting its role in fostering sustainable economic growth and reducing dependency on fossil fuels. Lotfalipour et al. (2010) utilized the Toda-Yamamoto method to demonstrate that gas consumption Granger causes economic growth in Iran. Their study contributes to understanding the relationship between energy consumption, specifically gas consumption, and economic growth in the Iranian context, suggesting a causal link where changes in gas consumption precede changes in economic growth. Shahbaz et al. (2010) conducted an empirical analysis focusing on Pakistan to explore the relationship between economic growth, energy consumption, and CO_2 emissions. Their findings suggest that as Pakistan's economy grows, driven by increased energy consumption, there is a corresponding rise in CO_2 emissions. This relationship underscores the challenges Pakistan faces in balancing economic development with environmental sustainability. The study likely employed econometric methods to analyze time-series data, examining how changes in economic indicators and energy use correlate with CO_2 emissions over the study period. Such research is crucial for policymakers and stakeholders aiming to understand the environmental implications of economic policies and energy strategies in Pakistan.

For future research, expanding on Shahbaz et al.'s findings could involve deeper analyses into the specific sectors contributing most to CO_2 emissions, the effectiveness of environmental policies in mitigating emissions growth, and the potential for integrating renewable energy sources to reduce the carbon intensity of Pakistan's economic activities. Tiwari (2011e) utilized an SVAR approach in a recent study on India to demonstrate that an increase in renewable energy consumption (RES) positively impacts GDP while reducing CO_2 emissions. This supports the hypothesis that RES consumption enhances India's economic growth. In another study (Tiwari, 2011a), he employed a Panel Vector Autoregressive (PVAR) approach across European and Eurasian countries from 1965 to 2009. Here, Tiwari found that RES generally contributes positively to GDP growth rates, whereas non-renewable energy consumption (NRES) negatively affects GDP growth rates and increases CO_2 emissions. These findings highlight the potential of renewable energy to foster economic growth while mitigating environmental impacts compared to non-renewable energy sources. Future research could delve into the specific mechanisms through which RES promote economic growth, such as technological innovation and energy security, and explore the effectiveness of policies aimed at promoting renewable energy adoption in diverse economic contexts. Several studies have identified a unidirectional causality from economic growth to energy consumption. Yang (2000), for instance, found such a causality running from GDP to oil consumption in Taiwan. Tiwari (2011) used the autoregressive distributed lag (ARDL) approach to examine the USA, revealing that industrial production and employment significantly influenced fossil fuel, hydro, solar, waste, and wind energy consumption over the long run, but had no significant impact on natural gas and wood energy consumption.

In the context of G7 countries, Sadorsky (2009a) utilized a panel data model to explore the impact of renewable energy sources (RES), including geothermal, wind, solar power, waste, and wood, on economic growth and CO_2 emissions per capita, as well as oil prices. He found that real GDP per capita and CO_2 emissions per capita were primary drivers of renewable energy consumption per capita in the long run, with oil prices exerting a smaller, negative effect. Short-term variations in renewable energy consumption were driven towards long-term equilibrium by economic movements rather than short-term shocks. In another study focused on 18 emerging economies from 1994 to 2003, Sadorsky (2009a) investigated the relationship between RES (including wind, solar, geothermal power, wood, and wastes) and economic growth. He concluded that increases in real GDP had a positive and statistically significant impact on renewable energy consumption per capita in these economies. These findings underscore the complex dynamics between economic growth and energy consumption, particularly highlighting the varying impacts of different energy sources and economic conditions across different regions and time periods.

Several studies have identified bidirectional causality between energy consumption and GDP. Yang (2000) found bidirectional causality between aggregate energy consumption and GDP in Taiwan. When disaggregating energy sources, he also observed bidirectional causality between GDP and coal consumption, GDP and electricity consumption, as well as GDP and total energy consumption. Apergis and Payne (2010) extended this analysis to renewable energy sources (RES) and economic growth across 20 OECD countries from 1985 to 2005. Using a production function framework that incorporated capital formation and labor, they established a long-run equilibrium relationship among real GDP, RES, real gross fixed capital formation, and the labor force. Furthermore, their Granger-causality tests revealed bidirectional causality between RES and economic growth, both in the short and long run. These findings highlight the dynamic interactions between energy consumption, especially from renewable sources, and economic growth. They underscore the importance of considering the feedback loops between energy use and economic activity in policy and economic analyses. The fourth group of studies explores the absence of causal linkages between energy consumption—both at aggregate and disaggregate levels—and economic growth. Wolde-Rufael (2004) found no evidence of causality in either direction between oil consumption and real GDP.

Similarly, Menegaki (2011) investigated the causal relationship between economic growth and renewable energy across 27 European countries from 1997 to 2007 using a multivariate panel framework. Employing a random effects model and including final energy consumption, greenhouse gas emissions, and employment as additional independent variables, Menegaki did not detect significant causal relationships between economic growth and renewable energy consumption. These studies contribute to understanding the complexities of energy use and economic development, highlighting scenarios where causal links may not be straightforward or evident. The fourth group of studies reveals no evidence of causality between renewable energy consumption and GDP. For instance, Wolde-Rufael (2004) found no significant causal relationship between renewable energy consumption and GDP. Moving to the third group, studies find bidirectional causality between energy consumption and GDP. Yang (2000) identified bidirectional causality between aggregate energy consumption and GDP in Taiwan. Upon disaggregation of energy sources, Yang observed bidirectional causality between GDP and coal consumption, electricity consumption, and total energy consumption.

Apergis and Payne (2010) examined the relationship between renewable energy sources (RES) and economic growth across 20 OECD countries from 1985 to 2005. Using a production function framework that incorporated capital formation and labor, they identified a long-run equilibrium relationship among real GDP, RES, real gross fixed capital formation, and the labor force. Their Granger-causality tests indicated bidirectional causality between RES and economic growth, suggesting mutual influence over both short- and long-term periods. The fourth group comprises studies that have found no causal linkages between energy consumption (at aggregate or disaggregate levels) and economic growth. For instance, Wolde-Rufael (2004) did not find any evidence of causality between oil consumption and real GDP. Menegaki (2011) investigated the causal relationship between economic growth and renewable energy across 27 European countries from 1997 to 2007 using a multivariate panel framework. Employing a random effects model and including final energy consumption, greenhouse gas emissions, and employment as additional independent variables, Menegaki found no significant causal relationship between renewable energy consumption and economic growth. Additionally, Lotfalipour, Falahi, and Ashena (2010) concluded that carbon emissions, petroleum products consumption, and total fossil fuels consumption did not lead to economic growth.

3. METHODOLOGY

Econometric literature has specified the significance of the structural estimates over the reduced form estimates.

X=f(NREC, REC, GDPC, CO2)

NREC is the growth rate of nonrenewable energy consumption, REC is the growth rate of renewable energy consumption, GDPC is the growth rate of real GDP and C02 represents growth rate of the CO_2 emissions.

4. RESULTS AND DISCUSSION

We used ADF unit root by Dickey and Fuller (1979) to test stationarity properties of the variables. The information about Ensuring the integrated order of variables is essential to ensure none of them are stationary at the second difference. The ARDL bounds testing approach to cointegration is flexible regarding the stationarity properties of variables, suitable for variables that are integrated of order one (I(1)), stationary (I(0)), or mixed integrated of order one and stationary (I(1)/I(0)). However, the ARDL bounds testing approach cannot be applied if any variable is stationary at order two (I(2)) or higher. Moreover, this method is particularly advantageous for small sample datasets (Narayan, 2005). Traditional norms recommend using Ordinary Least Squares (OLS) regression when all variables are stationary. While OLS is formal and suitable for drawing econometric inferences, it is susceptible to the Lucas critique. Structural Vector Autoregression (SVAR) addresses this limitation effectively. SVAR not only avoids the Lucas critique but also provides a robust framework to analyze the co-movement among variables, regardless of endogeneity issues. Starting with unit root tests, the Augmented Dickey-Fuller (ADF) tests reported in Table 1 indicate that all variables exhibit unit root problems at their levels but are stationary at their first differences. Given the variables' integrated order, the ARDL bounds testing approach to cointegration is appropriate for testing the long-run relationships among them.

Table 1 displays the outcomes of the Augmented Dickey-Fuller (ADF) unit root tests conducted at both the level and first difference for several variables. Each cell in the table contains the test statistic and the corresponding probability value (p-value), which indicates the significance level of the test results. For the first variable in the table, the ADF test statistic is -1.8715 at the level, with a p-value of 0.6412. This result suggests that there is insufficient evidence to reject the null hypothesis of a unit root, implying non-stationarity. After differencing once (1st difference), the ADF test statistic becomes -3.5193 with a p-value of 0.0573, indicating weak evidence against the null hypothesis of a unit root. However, this finding is marginally significant at the conventional 0.05 significance level. Moving to the second variable, at the level, the ADF test statistic is -1.1797 with a p-value of 0.8947, which fails to reject the null hypothesis of a unit root (non-stationarity). Upon differencing once, the ADF test statistic decreases to -3.3636, and the p-value is 0.0849. This result suggests weak evidence against the null hypothesis of a unit root, but it is not statistically significant at the 0.05 level. Regarding the third variable, at the level, the ADF test statistic is -2.7925 with a p-value of 0.2121, indicating insufficient evidence to reject the null hypothesis of a unit root. However, after differencing once, the ADF test statistic drops to -5.1422, and the p-value is 0.0017, indicating strong evidence against the null hypothesis of a unit root. This result is statistically significant at the 0.01 level, suggesting stationarity after differencing. Finally, for the fourth variable, at the level, the ADF test statistic is -1.3986 with a p-value of 0.8283, indicating non-stationarity. After differencing once, the ADF test statistic decreases to -3.8275 with a p-value of 0.0289. This result suggests evidence against the null hypothesis of a unit root and is statistically significant at the 0.05 level, indicating stationarity after differencing. These findings are critical for time series analysis, guiding whether variables require differencing to achieve stationarity before proceeding with further modeling and analysis.

Table 1: Unit Root Outcomes

	ADF Test at Level		ADF Test at 1st Difference	
Variables	T-statistic	Prob-value	T-statistic	Prob-value
CO2	-1.8715	0.6412	-3.5193	0.0573
GDP	-1.1797	0.8947	-3.3636	0.0849
REC	-2.7925	0.2121	-5.1422	0.0017
NREC	-1.3986	0.8283	-3.8275	0.0289

Table 1 presents the outcomes of unit root tests conducted on several variables using the Augmented Dickey-Fuller (ADF) test at both the level and the first difference. The results are crucial for determining the stationarity of the variables, which is essential for time series analysis.
For each variable. The ADF test statistic at the level is -1.8715 with a corresponding probability value of 0.6412, suggesting that CO2 is non-stationary at the level. However, at the first difference, the test statistic is -3.5193 with a probability value of 0.0573, indicating that CO2 becomes stationary after differencing. At the level, the ADF test statistic is -1.1797 with a probability value of 0.8947, indicating non-stationarity. After differencing, the test statistic is -3.3636 with a probability value of 0.0849, suggesting stationarity in first differences. The ADF test statistic at the level is -2.7925 with a probability value of 0.2121, suggesting non-stationarity. However, at the first difference, the test statistic is -5.1422 with a probability value of 0.0017, indicating stationarity after differencing. At the level, the ADF test statistic is -1.3986 with a probability value of 0.8283, indicating non-stationarity. After differencing, the test statistic is -3.8275 with a probability value of 0.0289, suggesting stationarity in first differences. These results provide insights into the order of integration of each variable, helping to determine appropriate models for further time series analysis. Stationarity is a fundamental assumption in many econometric models, ensuring reliable estimation and interpretation of relationships among variables over time.

Table 2: Bounds Testing Outcomes

Model	CO2/GDP,REC,NREC	
Optimal Lag	(1, 1, 1, 0)	
F-Statistics	2.109	
	Critical values (T = 29)	
	Lower bounds $I(0)$	Upper bounds $I(1)$
1 per cent level	10.605	11.650
5 per cent level	7.360	8.365
10 per cent level	6.010	6.780

5. DISCUSSION AND CONCLUSIONS

There is strong evidence of a positive correlation among real GDP, nonrenewable energy consumption, and CO2 emissions in Romania. Economic growth boosts aggregate demand, leading to increased energy demand, particularly in the manufacturing sector. The short-term surge in economic activity driven by nonrenewable energy consumption caters to manufacturers' immediate energy needs, ensuring smooth operations and maximizing profits as demand rises. However, this profit-driven approach comes with substantial societal costs. The primary concern is the environmental impact, particularly the escalation of CO2 emissions. These emissions contribute significantly to global warming, posing long-term threats to ecosystems, weather patterns, and human health worldwide. The reliance on nonrenewable energy sources not only perpetuates environmental degradation but also intensifies the challenge of climate change mitigation. As CO2 emissions accumulate, the need for sustainable energy solutions becomes increasingly urgent. Transitioning to renewable energy sources is critical to curbing these detrimental effects and fostering a cleaner, more sustainable future. Policymakers and businesses must prioritize investments in renewable technologies and practices that reduce reliance on fossil fuels, thereby mitigating environmental harm and advancing global efforts towards a greener economy. While nonrenewable energy consumption boosts short-term economic growth, its environmental consequences, notably increased CO2 emissions, underscore the imperative for sustainable energy transitions. Addressing these challenges requires proactive measures to promote renewable energy adoption, mitigate climate risks, and safeguard the planet for future generations. Renewable energy represents a pivotal advancement for society, particularly in addressing pressing environmental concerns. It offers a sustainable alternative that mitigates the negative externalities associated with conventional production practices, notably the significant reduction in CO2 emissions.
In Romania, transitioning to renewable energy sources not only promotes cleaner energy production but also aligns with global efforts to combat climate change. The shift towards renewable energy signifies a proactive approach to sustainability, offering multiple benefits beyond environmental conservation. It reduces reliance on finite fossil fuels, enhances energy security, and fosters economic resilience through job creation and investment opportunities in green technologies. Moreover, by harnessing sources like solar, wind, hydro, and biomass, Romania can diversify its energy portfolio and achieve greater energy independence while reducing its carbon footprint.
Embracing renewable energy is crucial not only for meeting current energy demands sustainably but also for safeguarding future generations from the adverse effects of climate change. It underscores Romania's commitment to responsible environmental stewardship and positions the country at the forefront of global efforts towards a greener, more resilient future. In conclusion, transitioning to renewable energy in Romania represents a transformative step towards minimizing CO2 emissions, enhancing environmental sustainability, and promoting long-term societal well-being. By prioritizing renewable energy investments and policies, Romania can lead by example in fostering a cleaner, more sustainable energy landscape for generations to come. Indeed, the integration of renewable energy into energy systems is a progressive approach to meeting both immediate and long-term energy needs sustainably. Initially, renewable energy can effectively

supplement new energy demands in production processes. However, achieving complete substitution of nonrenewable energy sources with renewables over the long term faces various challenges and realities. Currently, renewable energy consumption constitutes a small fraction of total energy requirements globally, including in Romania. Several factors contribute to this limited adoption. High upfront costs and longer installation times associated with renewable energy technologies often deter widespread adoption, especially in comparison to readily available and established nonrenewable sources.

Additionally, challenges such as intermittency (in the case of solar and wind), limited infrastructure, and the need for technological advancements pose practical barriers to scaling up renewable energy use. Furthermore, a lack of awareness about the detrimental environmental impacts of conventional energy sources versus the benefits of renewables can hinder public and private sector investments in renewable energy projects. Overcoming these hurdles requires concerted efforts from policymakers, businesses, and communities to promote renewable energy education, improve financing mechanisms, and enhance technological innovation. Despite these challenges, the global momentum towards renewable energy adoption is growing. Governments, businesses, and international organizations are increasingly prioritizing renewable energy policies, incentives, and investments to accelerate the transition towards a sustainable energy future. In Romania and beyond, advancing renewable energy integration remains crucial for reducing carbon emissions, enhancing energy security, and fostering economic growth while preserving environmental quality for future generations. The impulse responses from the analysis highlight significant differences in CO2 emissions based on the type of energy consumption used in production. When production is facilitated by nonrenewable energy sources, CO2 emissions increase significantly, contributing to environmental degradation. In contrast, when renewable energy sources are utilized, CO2 emissions remain relatively insignificant, underscoring their role in mitigating environmental impact. As CO2 emissions escalate to higher levels, there is observable evidence of corrective measures being implemented. This includes a reduction in nonrenewable energy consumption and an increase in renewable energy consumption. These actions contribute to lowering CO2 emissions levels in Romania, reflecting efforts to stabilize and potentially reduce environmental harm caused by industrial activities reliant on nonrenewable energy sources.

These dynamic highlights the crucial role of transitioning towards renewable energy sources in achieving environmental sustainability goals. By reducing reliance on nonrenewable energy and promoting the adoption of renewable alternatives, countries like Romania can mitigate their carbon footprint, promote cleaner production processes, and contribute positively to global efforts aimed at combating climate change. Continued efforts and policies that support renewable energy adoption will be essential in fostering a greener and more sustainable future.

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