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**Exploring Investment Dynamics in Renewable Energy for Low-Carbon Economies through a Global Comparative Analysis**

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**Abstract**
The objective of this research is to meticulously examine the factors influencing investment patterns in renewable energy sources within both low-carbon and high-carbon economies. In order to confront these challenges, we proposed a dynamic panel analysis focusing on renewable investment across a representative sample of 29 countries. The findings reveal a comparable dynamic in renewable energy investments across both panels, with dependencies on factors such as nuclear power generation, GDP, and technological efficiency. The empirical results underscore a collective commitment among nations to diminish their environmental footprint, as evidenced by a discernible reduction in CO2 intensity. This strategic shift aligns with the global imperative to foster sustainable practices and underscores a conscientious endeavor to transition towards cleaner, renewable energy sources. This trend not only reflects a growing environmental consciousness but also signifies a proactive response to the imperative of fostering a low-carbon future. Derived from the estimation results, our analysis suggests that achieving energy sustainability hinges on the strategic utilization of renewable resources. This strategic integration can effectively complement existing nuclear technology, provided that both sources transcend their respective limits. This nuanced approach advocates for a balanced and diversified energy portfolio, emphasizing the synergistic potential of renewables and nuclear technology in exceeding their individual capacities.
**Keywords**: renewable energy, low-carbon economies, investment dynamics
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## 1. INTRODUCTION

There is a global consensus that anthropogenic greenhouse gas (GHG) emissions are a pivotal factor contributing to the persistent global warming trend. The overarching reliance on traditional fossil fuels, notably a resurgence in the extensive use of coal, within the framework of overall economic growth has been identified as a primary source of heightened CO2 emissions originating from the energy sector (Jaccard et al., 2003). This increased carbon dioxide output from the energy sector is acknowledged as a significant contributor to climate change on a substantial scale. The Kyoto Protocol, recognized by some as an initial step in the global commitment to combat climate change, sought to curtail the aggregate emission of carbon dioxide and other greenhouse gases. Primarily directed at industrialized nations, the agreement acknowledged the historical contributions of these nations to emissions while recognizing the imperative for more substantial efforts in mitigating climate change. Nevertheless, criticisms arose, asserting that the prescribed measures were insufficient to address the magnitude of the environmental challenge. Notably, industrialized countries, some of which were in the process of overcoming prior conditions of underdevelopment, grappled with the dual challenge of economic growth and emissions reduction, contributing to ongoing debates about equity and responsibility in the context of climate action. In more recent times, international agreements have underscored the imperative of technology transfer to developing countries, emphasizing the urgency of constraining CO2 emissions to cap the global temperature rise within the confines of a 2°C limit. These accords have also delineated specific measures aimed at the preservation and sustainable management of forests, recognizing their pivotal role in climate change mitigation.

With regard to electricity production, it is noteworthy that all employed technologies exert some degree of impact on the environment. Consequently, beyond the conventional economic considerations of reliability and safety, there exists a distinctive ethical responsibility towards future generations. This ethical imperative underscore the importance of conducting comprehensive "footprint" analyses of the plant environment, ensuring a conscientious evaluation of the long-term environmental consequences associated with various electricity generation technologies.

Hence, a substantial reduction in the adverse environmental effects of the energy sector can be achieved through a greater proportion of renewable energy sources in the overall electricity generation. However, it is crucial to acknowledge that the implementation of renewable energy strategies generally entails three significant technological shifts: foremost, energy conservation measures on the demand side (Blok, 2005; Lund, 1999); secondly, enhancements in the efficiency of energy production (Lior, 1997; 2002); and thirdly, the substitution of fossil fuels

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with diverse forms of renewable energy (Afgan and Carvalho, 2002; 2004). These interrelated changes collectively contribute to a more sustainable and environmentally responsible energy paradigm. When contemplating large-scale renewable energy implementation plans, a country must integrate renewable sources into a new energy system guided by energy savings and efficiency measures (refer to, for instance, Li, 2005; Ghanadan and Koomey, 2005). However, it is important to note that these measures, while essential in the current state of the art, are not independently adequate to achieve sustainability goals and maintain manageability of climate change. Additional, comprehensive strategies and multi-faceted approaches are imperative to address the complexity of transitioning to a sustainable and climate-resilient energy landscape. In a recent development, the International Energy Agency (IEA) has identified a potential solution to enhance energy efficiency and diminish CO2 emissions. Acknowledging the protracted timelines associated with the development of new technologies and considering the distinctive attributes of renewable sources, the IEA advocates for the adoption of extensive nuclear facilities and technologies for carbon capture and storage as a pragmatic approach. This recommendation underscores a strategic and multifaceted perspective that seeks to leverage existing technologies while concurrently exploring advancements to address the pressing challenges of energy efficiency and carbon emission reduction. A crucial concern pertains to the CO2 emissions per GDP, commonly referred to as the CO2 intensity of GDP, arising from fossil fuel combustion. This metric is notably sensitive to meteorological conditions and the overarching demand for power, reflecting the intricate interplay of various factors influencing the carbon footprint associated with economic activities. While energy efficiency undoubtedly contributes to the carbon intensity equation, it is essential to emphasize that the predominant factor influencing carbon intensity is the composition of the energy structure. In essence, carbon intensity poses a central challenge related to energy quality, specifically concerning the ratio of clean energy sources within the broader energy framework. The intricate relationship between energy structure and carbon emissions per unit of economic output underscores the importance of transitioning towards cleaner energy alternatives to effectively mitigate environmental impact and foster sustainable economic development.

Certain developed nations have successfully curtailed their CO2 footprint through the strategic deployment of nuclear power plants. In contrast, other countries are focusing on alternative approaches to diminish their environmental impact. This includes initiatives aimed at enhancing energy efficiency or adopting a paradigm shift in their energy structure, marked by substantial investments in renewable energy sources. These diverse strategies underscore the global commitment to address climate change by exploring a spectrum of solutions tailored to each nation's unique circumstances and priorities. Both nuclear and renewable energy technologies stand out for their environmentally friendly characteristics, as they do not produce polluting gases. A burgeoning body of scientific literature is dedicated to renewable energy sources and their intersection with the sustainability of economic growth over the medium to long term. Numerous authors, including Sary and Soytas (2004) and Bradley et al. (2007), have delved into the causal relationship between renewable energy consumption and economic growth, particularly in countries with diverse characteristics, yielding inconclusive results. This underscores the complexity of the interplay between renewable energy dynamics and economic development, necessitating further research and nuanced analyses for a comprehensive understanding. Several studies have explored the normative perspective and factors influencing the adoption of energy from renewable sources. Works by Bird et al. (2005) and Menz and Vachon (2006) have delved into these aspects. Additionally, Matsui et al. (2008) have specifically examined the role and potentials of nuclear energy systems within the context of a sustainable development framework. These studies contribute to a broader understanding of the normative considerations and determinants that shape the trajectory of renewable and nuclear energy pathways in the pursuit of sustainability.

Their argument underscores a commitment to sustainable development through a policy emphasizing energy conservation, while concurrently emphasizing the pivotal role that nuclear power plants play in safeguarding the environment. The contention highlights the intricate relationship between strategic energy policies, conservation efforts, and the unique contribution of nuclear energy in achieving broader environmental sustainability objectives.

The objective of this study is to examine the determinants influencing investments in renewable energy sources within two distinct panels of countries: one characterized by low CO2 intensity and another comprising nations with high CO2 per GDP. This dual-panel approach enables a comprehensive analysis of the driving forces behind investments in renewable energy, taking into account the contrasting environmental contexts of these country sets.

The countries constituting the former panel are distinguished by their remarkable efficiency in production processes, manifesting as a low carbon dioxide emission per unit of GDP. These nations, recognized as "low carbon economies," stand out for their commitment to integrating a substantial share of CO2-free technologies into their electricity production portfolios. Notably, this includes a robust utilization of nuclear and renewable energy sources, reflecting a strategic emphasis on environmentally sustainable practices in their energy sector.

In stark contrast, the countries constituting the latter panel exhibit a discernibly high environmental footprint, characterized by an elevated production of CO2 per unit of GDP. Within this group, our investigation centers on discerning the divergences among these nations by honing in on two key metrics: energy efficiency and the magnitude of nuclear electricity consumption within their production portfolios. This analytical approach provides a comprehensive understanding of the distinct energy dynamics at play, shedding light on the factors contributing to the heightened environmental impact observed in countries with a substantial CO2 output relative to their GDP. The obtained results provide valuable insights for strategic planning in the establishment of new power plants. Moreover, they contribute to a comprehensive understanding of the evolving energy policies adopted by countries, particularly in these dynamic years marked by a shifting environmental sensibility. This knowledge is instrumental in shaping informed decisions for future energy infrastructure development, aligning with the global imperative of fostering sustainable and environmentally conscious practices in the evolving landscape of energy production. This paper tackles these complex issues through the application of a dynamic panel analysis, focusing on investments in renewable sources across a diverse sample of 29 countries. These nations exhibit distinct economic and social structures, coupled with varying levels of economic development. The dynamic panel analysis serves as a robust methodological approach to unravel the nuanced dynamics influencing investment patterns in renewable energy within this heterogeneous group of countries.

## 2. VARIABLES SELECTION AND DATA SOURCES

The dataset employed in this study spans an annual time series encompassing the years 1980 to 2008. The data sources are derived from the U.S. Energy Information Administration (EIA) and cover key variables, including Total Renewable Electricity Net Generation (REN), Gross Domestic Product adjusted for $2000 constant prices (GDP), Energy Intensity (EI), CO2 emissions, and Nuclear Electricity Net Consumption (Nuc). This comprehensive dataset allows for a detailed exploration of the interrelationships among renewable energy investments, economic indicators, energy intensity, carbon emissions, and nuclear electricity consumption over the specified period. The literature offers various approaches for assessing the progress of renewable energy sources. One method involves measuring the displacement of traditional energy sources within the overall energy supply. Alternatively, another approach entails quantifying the total volume of renewable energy produced, as outlined by Bird et al. (2005). These distinct methodologies provide complementary perspectives, allowing for a comprehensive evaluation of the advancements in the utilization and production of renewable energy. In our paper, the investment in renewable energy sources (ShREN) is elucidated as the ratio between renewable generation and the variance between Total Net Electricity Generation and Net Electricity Imports. This formulation provides a specific metric to quantify the proportion of renewable energy investment in the overall electricity generation landscape, taking into account both domestically generated electricity and net imports.

In the context of nuclear energy, our approach involves the utilization of the ratio of Nuclear Electricity Net Consumption (ShNUC) to the variance between Total Net Electricity Generation and Net Electricity Imports. This methodology ensures a comprehensive consideration of the entire electricity generation portfolio. The unaccounted portion, not explicitly incorporated into the model, is attributed to fossil fuel sources. This method allows for a nuanced assessment of nuclear energy's contribution in relation to the overall electricity generation mix. The proportion of Renewable Electricity Net Generation serves as a viable proxy for assessing investments in renewable energy sources. Simultaneously, Energy Intensity, defined as the total primary energy consumption per unit of GDP (expressed in Btu per Year 2005 U.S. $), functions as a proxy for technological efficiency. These chosen proxies provide meaningful indicators to evaluate the extent of reliance on renewable energy and the efficiency of technology deployment within the energy sector. To mitigate variability, the variables Gross Domestic Product (GDP), Energy Intensity (EI), and CO2 emissions have been logarithmically transformed. This transformation helps stabilize the distribution of these variables, making the statistical analyses more robust and facilitating a more reliable exploration of the relationships within the model. Panel dataset of OECD countries and developing countries (Brazil, China and India) is used in order to limit the effect of the small time span of the aggregated data. There are three main issues that can be solved using a panel dataset.

To distinguish investment decisions in countries with varying CO2 per GDP ratios, we employ the median of the distribution of each country's mean CO2 intensity. Countries with mean CO2 intensity below the median are categorized as low carbon economies, while those exceeding the median are deemed high carbon economies. Subsequently, the sample is bifurcated into two distinct subsamples: one comprising low carbon countries and the other encompassing the remaining nations characterized by higher carbon intensity. This segmentation allows for a targeted analysis of investment dynamics within each subset, providing insights into the nuanced considerations associated with renewable energy investments in different environmental contexts. Certainly, the categorization of low carbon economies is inherently intricate, as it encompasses a multifaceted concept that involves the implementation of comprehensive, long-term policy plans. These plans span various critical domains, including but not limited to transport, energy, and climate change. The classification of economies as low carbon reflects a commitment to a holistic approach, indicating concerted efforts to address and mitigate environmental impact across diverse sectors with a focus on sustainability and reduced carbon emissions. Recently, the European Commission has been actively exploring cost-efficient strategies to enhance the climate-friendliness and energy efficiency of the European economy. In pursuit of these goals, the Commission has proposed a comprehensive roadmap, outlining a strategic path forward to address environmental concerns while promoting sustainable and resource-efficient practices across various sectors of the economy. This initiative aligns with the broader global imperative to transition towards a more environmentally conscious and resilient economic framework.

In our paper, our analysis extends to the production of goods and services, employing a criterion where countries categorized as low carbon economies are those that demonstrate a higher level of output while concurrently minimizing their environmental impact. This approach aligns with the notion that efficiency in production processes, coupled with a reduced environmental footprint, characterizes economies making substantial progress toward achieving sustainability goals. The consideration of production efficiency and environmental impact provides a nuanced perspective on the complex interplay between economic activities and ecological responsibility. The decision to split the sample using the median, rather than quartiles, is driven by the imperative to maintain a relevant sample dimension while still adhering to the principle of granularity in our analysis. While using quartiles might provide additional granularity, it could potentially lead to smaller sample sizes in each subgroup, which may compromise the statistical robustness of the analysis. Therefore, opting for the median ensures a balance between granularity and sample size, allowing for meaningful insights into the investment decisions of low and high carbon economies while maintaining statistical reliability. The first subsample, including Austria, Brazil, Denmark, Finland, France, Ireland, Israel, Italy, Japan, Norway, Portugal, Sweden, Switzerland and United Kingdom is made up of the low carbon economies. The second subsample comprising the countries with high $CO_2$ per GDP: Australia, Belgium, Canada, Chile, China, Greece, India, South Korea, Luxemburg, Mexico, Netherlands, New Zealand, Spain, Turkey and USA. Given the lack of data, countries excluded by the OECD panel are: Czech Republic, Poland, Slovak Republic, Slovenia and Germany (which is not included because of difficulty in time series reconstruction until 1989). Accession candidate countries and enhanced engagement ones are also not considered. All the countries included in dataset are categorized as high income by World Bank. Only Brazil, Mexico, Chile and Turkey are categorized as upper middle income while China and India are in the lower middle-income group.

Prior to delving into the dynamics of the country panel, we initiate our analysis with an exploratory examination. This preliminary analysis aims to elucidate the evolving trends in the energy policy choices of these countries. By conducting this exploratory phase, we seek to uncover patterns, trends, and shifts in the energy policy landscape, providing valuable context for the subsequent in-depth investigation into the panel dynamics. To achieve this objective, factor analysis is employed, utilizing the identical variables identified for the general model of the moments proposed by Arellano and Bond (1991), which will be utilized in subsequent analyses. This method is chosen with the primary motivation of establishing a comprehensive framework to assess the performance of countries over the 29-year period from 1980 to 2008. The application of factor analysis provides a structured approach to distill essential patterns and underlying factors that contribute to the evolution of energy policy choices during this timeframe. The stability of factor loadings over time is notable, contributing to a consistent distribution of variables on the primary axes. This distribution enables the identification of a meaningful physical interpretation for the two principal axes, which collectively explain approximately 70% of the total variability. This level of explanatory power proves adequate for discerning key features in the evolution of energy choices made by various countries. The robustness of the factor loadings allows for reliable insights into the overarching patterns and trends characterizing the energy policy landscape across the considered nations.

The first principal axis exhibits a contrast between variables related to production scale (LnGDP), pollution levels (LnCO2), and high energy intensity (LnEI) against the share of renewable sources (ShREN) relative to total energy production. On the other hand, the second principal axis contrasts variables associated with CO2 emissions and energy intensity against the shares of renewable and nuclear energy production (ShNUC), emphasizing low-pollution alternatives. Consequently, countries characterized by high production achieved through conventional pollutants and exhibiting energy inefficiency would be positioned in the first quadrant of this analysis. This quadrant serves as an indicative space where nations with certain undesirable energy characteristics are identified based on the interplay of these principal axes. In the analysis, countries falling into the second quadrant are those with a less substantial production, primarily realized through conventional production processes. On the other hand, the third quadrant accommodates countries where a significant level of production is not attained, despite a notable application of renewable energy sources. These distinctions in the quadrants provide a nuanced understanding of countries' energy dynamics, considering both the scale of production and the nature of the energy sources utilized. The fourth quadrant is designated for countries characterized by a high production level achieved with a substantial proportion of nuclear energy, resulting in a correspondingly low level of CO2 emissions. This quadrant identifies nations that have strategically integrated nuclear energy into their energy portfolios, demonstrating a commitment to reducing carbon emissions while maintaining a robust production output. The distinct placement of countries within each quadrant serves as a visual representation of their unique energy profiles, considering both production scale and the environmental impact of their energy choices. The distribution of the countries considered in the analysis demonstrates a considerable stability over time, with a few noteworthy exceptions that will be discussed shortly. This overall stability underscores the persistence of certain patterns and trends in the energy choices made by these countries, providing a foundation for understanding the evolution of their energy policies throughout the analyzed period.

## 3. RESULTS AND DISCUSSION

Low carbon Countries show the estimated autoregressive component significant at lag 1. We point out that the 1% increase in the level of renewable energy at time *t-1* increases the same investment at time *t* of 0.37%, while GDP growth equates to an increase in the level of 0.59%. Also the energy intensity shows a direct relationship with investment in renewable energy sources. Emissions of carbon dioxide and nuclear consumption have an inverse relationship with the outcome variable, as expected. Countries invest in renewable energy sources on the basis of past investments and GDP. Also the technological efficiency affects the investment in renewable energy sources. The investments in renewable sources are decreased by the presence of the nuclear power plants.

**Table 1: Regression Results**

| Low Carbon Countries | | High Carbon Countries | | Full Sample | |
|---|---|---|---|---|---|
| Variables | Estimates | Variables | Estimates | Variables | Estimates |
| $REN_{-1}$ | 0.37*** | $REN_{-1}$ | 0.59*** | $REN_{-1}$ | 0.42*** |
| EI | 0.48*** | EI | 0.31*** | EI | 0.44*** |
| $CO_2$ | -0.52*** | $CO_2$ | -0.38*** | $CO_2$ | -0,53*** |
| GDP | 0.59*** | GDP | 0.31*** | GDP | 0.52*** |
| NUC | -0.35*** | NUC | -0.12*** | NUC | -0.12*** |
| Constant | -16.94*** | C | -8.78*** | C | -14.77*** |

The second section of Table 1 presents estimates for countries characterized by a high CO2/GDP ratio. These nations base their investment decisions in new renewable power plants on historical trends, akin to the aforementioned countries. Similar to their counterparts, these countries' decisions are influenced by factors such as the level of production and technological efficiency. The underlying objective of these investments is to contribute to the reduction of CO2 emissions, aligning with broader sustainability and environmental goals. As anticipated, there is an inverse relationship observed in CO2 emissions, signifying that the share of nuclear energy generation is inversely related as well. This relationship aligns with expectations, as increased utilization of nuclear energy tends to be associated with lower CO2 emissions, contributing to the overall objective of reducing the carbon footprint in the energy sector. The inverse correlation emphasizes the role of nuclear energy in countries with high CO2/GDP ratios as a strategic choice for mitigating environmental impact. Additionally, the estimates obtained from the full sample corroborate the earlier findings. All variables, except carbon dioxide emissions and the share of nuclear consumption, exhibit a direct relationship with the outcome variable. In both samples, the Sargan test for overidentification rejects the null hypothesis, indicating that the model instruments are correctly identified. This robustness in results across the full sample further reinforces the validity of the identified relationships between the considered variables and the investment decisions in renewable energy sources.

The estimates underscore a noteworthy finding: past investments in renewable energy sources exert a significant influence on current investment decisions across all three samples. This suggests a continuity of behavior among countries that have previously demonstrated a proclivity for and sensitivity towards renewable energy sources. The persistence of such behavior indicates a sustained commitment to renewable energy initiatives and reflects the enduring impact of prior investment decisions on the current renewable energy landscape in these countries.

If statistical significance is considered, the estimates in the low carbon economies generally exhibit higher magnitudes, in absolute value, than those in the high carbon sample, with the exception of the autoregressive parameters. Specifically, the influence of investments in renewable energy sources appears to be more pronounced in high carbon countries compared to their low carbon counterparts. This finding suggests that in countries characterized by higher carbon intensity, the impact of past investments in renewable energy is more substantial, emphasizing the potential for stronger and more immediate effects on current investment decisions in the renewable energy sector. Countries characterized as low carbon economies exhibit a pronounced inclination toward investing predominantly in renewable sources. This strategic emphasis aligns with their commitment to minimizing environmental impact, reducing their carbon footprint, and adhering to international agreements that they have ratified. The concerted effort to prioritize renewable energy investments underscores a proactive approach toward sustainability and environmental stewardship in these nations. The observed inverse relationship between investments in renewable sources and the share of nuclear consumption is noteworthy. This inverse correlation suggests that countries with a substantial share of nuclear consumption tend to complement their energy mix by investing more in renewable sources. The consistent base load electricity provided by nuclear power plants, coupled with their lack of greenhouse gas emissions, likely creates a conducive environment for these countries to pursue additional investments in renewable energy. This strategic combination aims to achieve an optimal energy mix, balancing the benefits of nuclear power with the added sustainability and diversification offered by renewable sources, and possibly facilitating subsidies for renewable energy investments. In the realm of industrial production technologies, factor analysis has revealed that fast-growing countries exhibit a tendency to prioritize rapid growth without placing particular emphasis on the environmental impact of their production processes. This observation suggests that, in the pursuit of economic expansion, certain countries may prioritize efficiency and scale without giving due consideration to the environmental consequences of their industrial activities. This finding underscores the potential tension between economic growth objectives and environmental sustainability, signaling the need for strategic policies that reconcile both priorities. Conversely, other countries that have traditionally maintained stability within the high-income cluster demonstrate a greater propensity to prioritize technologies characterized by lower environmental impact and enhanced energy efficiency. This indicates a nuanced approach where certain economically stable nations place a heightened emphasis on adopting technologies that align with sustainability goals and prioritize energy efficiency. The contrast in technological preferences underscores diverse strategies employed by countries with distinct economic trajectories, reflecting varying degrees of commitment to environmental responsibility within the realm of industrial production technologies.

Indeed, the estimates from Table 1 reveal a discernible inverse relationship between CO2 emissions and investments in renewable energy, coupled with a direct relationship with energy intensity. Furthermore, the positive relationship observed with the level of national income suggests that the resources required for investments in renewable energy become more readily available after attaining a sufficiently high gross domestic product. This underscores the economic prerequisites for substantial investment in renewable energy, highlighting the role of national income as a facilitating factor in advancing sustainable and environmentally conscious energy practices. The disparities in investment choices and the imperative for sustainable energy development offer a rich avenue for analysis. Electricity generation stations reliant on renewable and nuclear sources can be viewed as complementary in terms of their environmental impact. Moreover, investments in renewable energy sources may be conditioned by the existence of nuclear power plants. This interplay underscores the intricate relationships within the energy sector, where the presence of nuclear energy infrastructure can influence the trajectory of investments in renewable sources, forming a synergistic approach that aims to address environmental concerns and achieve sustainable energy development.

## 4. CONCLUSION

In this paper, we undertake an analysis of the determinants driving investments in renewable energy sources, examining three distinct samples. The first sample encompasses low carbon countries, characterized by a low $CO_2$ per GDP ratio. These nations utilize a diverse portfolio for electricity generation, incorporating fossil fuel, renewable, and nuclear sources. The second sample consists of countries that emit a higher amount of carbon dioxide per unit of GDP during electricity production. Third sample analyzes all countries considered in this paper. The coexistence of nuclear power plants seems to exert a suppressing influence on the inclination to invest in renewable energy. This suggests a dynamic where the availability of nuclear energy may mitigate the emphasis on, or urgency for, expanding investments in renewable sources. The relationship between these energy sources, characterized by a certain interdependence, prompts a nuanced examination of how the presence of nuclear power infrastructure can shape the trajectory of renewable energy investments in the broader context of sustainable energy development. This phenomenon is accentuated in our analysis, where a significant factor contributing to this dynamic is the presence of economically advanced countries that bolster their electricity generation share from nuclear power. The advanced economic status of these nations appears to correlate with a greater reliance on nuclear energy, potentially influencing the investment landscape for renewable sources. This intricate interplay between economic development, energy mix, and investment decisions underscores the multifaceted nature of energy policies in the context of advanced economies. Moreover, the imperative to diminish environmental impact incentivizes high carbon economies to augment their investments in renewable sources. This reflects a recognition of the pressing need to transition toward cleaner and more sustainable energy alternatives in order to mitigate the adverse environmental effects associated with higher carbon intensity. The observed increase in renewable investments among high carbon economies underscores a crucial shift towards more environmentally conscious energy practices in response to global sustainability imperatives. Certainly, the endeavor to diminish carbon intensity is inherently tied to a two-fold strategy: amplifying the utilization of clean energy sources and curtailing coal consumption per unit of GDP. This dual approach aligns with global efforts to transition towards a low-carbon future, emphasizing the pivotal role of clean energy adoption and the gradual phasing out of coal-dependent practices in achieving a more sustainable and environmentally responsible energy landscape. Indeed, when a country aspires to attain a specific carbon intensity goal, it faces the strategic choice between enhancing energy efficiency and reshaping its energy structure. This involves considering options like investing in wind power, solar power, or other renewable sources. The decision-making process hinges on finding a balanced and effective approach that aligns with the nation's unique circumstances, resources, and environmental objectives. Whether through optimizing efficiency or transitioning to cleaner energy sources, these decisions play a crucial role in shaping the trajectory of carbon intensity reduction initiatives. Optimizing returns in the pursuit of clean energy goals necessitates a delicate balance, achieved when the marginal gains from improving energy efficiency align with the benefits derived from investing in clean energy sources. This equilibrium provides the central government with a spectrum of alternatives for formulating an effective clean energy strategic plan. By implementing robust policies and concerted efforts, substantial improvements in energy efficiency can be realized, with the potential to capture and utilize various forms of "energy wastage," such as heat. This approach offers a promising avenue to significantly enhance useful energy outputs without resorting to increased reliance on fossil fuels. The strategic significance of the energy sector demands concerted attention from countries, especially considering the escalating demand for electrical power, which is only partially met by renewable energy sources. Presently, renewable energy sources fall short in ensuring continuous power supply during peak hours. As alternatives, countries often resort to fossil fuel-based power plants, which, as anticipated, have a considerable environmental impact and contribute to increased $CO_2$ emissions. Another option is the establishment of new nuclear power plants, which can curtail environmental footprint but necessitate meticulous planning and substantial investments. The challenge lies in finding a balanced and sustainable approach that meets energy demands while minimizing adverse environmental effects. Achieving energy sustainability necessitates a path that involves the utilization of renewable resources, which can act in tandem with nuclear technology under the condition that both surpass their inherent limitations. Future research endeavors may focus on incorporating additional socioeconomic variables and investigating the impact of subsidies on investments in renewable sources. This expanded scope of inquiry aims to provide a more comprehensive understanding of the interplay between various factors influencing energy sustainability and the efficacy of policies aimed at fostering renewable energy development.

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