Green Growth and Renewable Energy Opportunities for Climate Mitigation

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Abstract

This study investigates the intersection of green growth and renewable energy development as strategic pathways for climate change mitigation. Framed within the global urgency to reduce greenhouse gas emissions, the research examines the extent to which renewable energy deployment contributes to carbon emission reduction and sustainable economic growth across selected developed and developing nations. The aim of this study was to assess the empirical and policy linkages between renewable energy capacity, investment levels, carbon emissions, and GDP growth. Methodologically, a mixed-methods approach was employed, combining quantitative data from international databases (IEA, UNFCCC, World Bank) spanning 2010–2024 with qualitative analysis of national policy documents and case studies. Statistical tools, including Pearson correlation and regression modelling, were used to assess the temporal and cross-national patterns. Findings of the study reveal that countries with coherent energy policies and strong institutional frameworks, such as Germany, Sweden, and Costa Rica, demonstrate a significant inverse relationship between renewable capacity and emissions. In contrast, developing countries like Nigeria and India display weak or positive correlations due to infrastructural and policy constraints. Moreover, the study found no consistent link between renewable energy investments and short-term GDP growth, especially in developing nations. The study thus

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concluded that while renewable energy is a critical enabler of green growth, its effectiveness depends on systemic integration, policy coherence, and fossil fuel displacement. The study recommends the establishment of robust institutional frameworks to support renewable integration and increased international climate finance to bolster capacity in low-income countries. This research offers evidence-based insights to inform global policy discourses on sustainable energy transitions.

Keywords: Green growth, renewable energy, carbon emissions, climate mitigation, sustainable development, low-carbon economy.

1.1. Introduction

Climate change is one of the most significant and urgent challenges facing humanity today. The growing impact of global warming (manifested in rising temperatures, sea-level rise, more frequent and intense extreme weather events, and shifting ecosystems) has profound consequences for human health, global security, biodiversity, and economic stability. The scientific consensus is clear: immediate and substantial action is needed to mitigate the negative effects of climate change and curb the trajectory of global warming. In response, international bodies, national governments, and various sectors have turned to sustainability-oriented frameworks to address these threats. Green growth is a transformative approach to development that aims to reconcile economic growth with environmental sustainability. It focuses on fostering a thriving economy while simultaneously reducing environmental impact, particularly through the reduction of carbon emissions. Unlike traditional models of growth that often overlook environmental consequences, green growth integrates environmental considerations into every aspect of economic decision-making. This approach ensures that development does not come at the expense of the environment but rather fosters long-term ecological balance.

Central to the concept of green growth is the widespread adoption of renewable energy. The transition to clean and renewable energy sources, such as solar, wind, hydro, geothermal, and bioenergy is crucial for reducing dependence on fossil fuels, mitigating climate change, and promoting energy security. Unlike fossil fuels, renewable energy sources are abundant, sustainable, and produce minimal environmental harm. By shifting to these cleaner alternatives, countries can significantly reduce greenhouse gas emissions, decrease their carbon footprints, and promote sustainable energy production.

The potential for renewable energy to serve as a cornerstone for climate mitigation is immense. Solar and wind energy, for example, have become increasingly cost-competitive with conventional energy sources, making them attractive options for both developed and developing countries. Furthermore, renewable energy technologies create new opportunities for economic growth, job creation, and regional development. However, the path to widespread renewable energy adoption is not without challenges. In many countries, particularly those with developing economies, barriers such as insufficient infrastructure, limited access to financing, regulatory hurdles, and technological gaps continue to hinder the large-scale implementation of renewable energy projects.

Climate change today poses widespread impacts on global ecosystems, human health, and economic systems. Countries around the world, including Nigeria, are increasingly under pressure to transition to sustainable development models that reduce carbon emissions and improve climate resilience. In fact, Nigeria, as Africa's most populous country and a major oil-producing nation, faces a dual challenge: the need for sustained economic growth and the need to reduce environmental degradation. Recognizing the environmental costs of fossil fuel dependence and its vulnerability to climate change, Nigeria has committed to transitioning toward a green economy. Key national strategies, such as the Nigeria Renewable Energy Master Plan (REMP), Nationally Determined Contributions (NDCs) under the Paris Agreement, and the Energy Transition Plan (ETP) launched in 2022, reflect Nigeria's growing commitment to climate action. These efforts align with the broader concept of green growth, which emphasizes the integration of economic growth with environmental sustainability. By investing in renewable energy sources such as solar, wind, etc., Nigeria ought to do more in harnessing renewable energy chances to achieve these green growth models by reducing its reliance on fossil fuels, increasing energy access, especially in rural areas, and mitigating greenhouse gas emissions.

This paper examines the vital role of green growth and renewable energy in mitigating climate change. Specifically, it explores how the integration of renewable energy technologies into national energy systems can help reduce emissions, improve energy access, and foster economic resilience. The paper also addresses the policy, financial, and technological challenges that must be overcome to scale renewable energy globally, offering recommendations for policymakers, industry leaders, and international organizations to accelerate the transition toward a low-carbon, sustainable future.

1.2. Statement of the Problem

Currently, there's a global challenge of increasing temperature resulting in global warming on account of over-dependence, production, and utilization of electrical

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energy knitted to continuous combustion of fossil fuels and several other environmentally unfriendly activities by many nations of the world, including Nigeria. There have been intergovernmental and international treaties, frameworks, and conventions such as the Montreal Protocol of 1987 in Canada, the Kyoto Protocol of 1997 in Japan, the Paris Agreement of 2015 in France, the Kigali Agreement of 2016 in Rwanda, etc., all geared towards engaging industrialized countries to cut down carbon production and usage of ODS and reducing rising temperature by 2 degrees Celsius in order to check our increasing temperature to stabilize the global warming phenomenon ravaging the world today. Nigeria itself has not been left out in this fight. Where commitment gave birth to programs such as the National Determined Contribution (NDC) to the 2030 climate change goal, the National Adaptation Strategies and Plan of Action on Climate Change in Nigeria (NASPA-CCN), etc., were initiated.

Nonetheless, not much emphasis and attention are channelled towards encouraging the nations of the world to also cut down carbon emissions by specifically investing more in renewable energy. Hence, this research conducted is aimed at investigating the correlation (relationship) between renewable energy adoption and carbon emission reduction in an effort towards achieving the climate change 2030 goal. To meet the scorching global warming mitigation and adaptation efforts by many institutions, such as UNFCCC, IPCC, IEA, and WMO, amidst many others.

1.3. Aims/Objectives
The aim of this paper was to examine green growth and renewable energy opportunities for climate mitigation. To this end, the following objectives were pursued:
i.   Assess the correlation between renewable energy capacity and carbon emissions reduction across selected countries.
ii. Evaluate the relationship between renewable energy investment levels and GDP growth rates in adopting nations.
iii. Compare regional (national) implementation of successful renewable energy policies, identifying key indicators including emissions reduction, renewable energy investment, and economic performance.

2.0. Materials and Methods
This study adopts a mixed-methods approach to explore the relationship between green growth strategies and renewable energy adoption for climate mitigation. The study involves both quantitative and qualitative data sources to provide a comprehensive analysis of renewable energy deployment across different regions and its impact on carbon emissions reduction. Quantitative data used in the study were collected from a range of international databases, including the International Energy Agency (IEA), the World Bank, and the United Nations Framework Convention on Climate Change

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(UNFCCC). Key indicators such as renewable energy capacity, annual electricity production (TWh), carbon emission level (MtCO₂e), GDP growth, and investment in renewable energy were extracted for both developed and developing nations. These data span a period of fifteen years (2010–2024). Qualitative data used in the study were gathered through a review of government reports, policy documents, and case studies of countries that have successfully integrated renewable energy into their economic development strategies. Data used in the study were analyzed using statistical tools such as the Pearson correlation, the cross-sectional regression analysis, the fixed-effects panel regression, and descriptive statistics. Data generated were both from selected developed and developing nations blocs, i.e., Germany, USA, China, Denmark, and Sweden, and Nigeria, Ghana, Costa Rica, DRC, Chad, Morocco, and India for the developing countries.

While the data provides valuable insights into the relationship between renewable energy and green growth, several limitations exist. The availability and quality of data vary by country, particularly in developing nations, where renewable energy data may be less comprehensive. Additionally, the analysis focuses primarily on the impact of renewable energy on carbon emissions reduction and does not fully address other environmental benefits, such as water and air quality improvements.

3.1. Results and Discussion

3.1.1. The Correlation between Renewable Energy Capacity and Carbon Emissions Reduction Across Selected Countries

The data presented in Tables 1 and 2 offers an empirical basis for interrogating the intricate relationship between renewable energy capacity and carbon emissions reduction across both individual countries and regional blocs. As per the study's first objective, the central inquiry lies in determining whether increased renewable energy adoption correlates significantly and meaningfully with reduced carbon emissions. The use of Pearson correlation coefficients, coupled with 95% confidence intervals and significance values, provides a robust statistical framework for this exploration.

In Table 1, the bivariate correlations between renewable energy capacity and carbon emissions levels across eleven individual countries are detailed. These correlations range from moderately weak (such as Nigeria, $r = -0.126$, $p = .653$) to extremely strong (such as Germany, $r = -0.995$, $p < .001$). The statistical significance and direction of these relationships vary, highlighting the contextual and structural differences in national energy profiles, policy maturity, and implementation fidelity. A particularly striking observation lies in the contrasting coefficients between countries such as Germany ($r = -0.995$, $p < .001$), Denmark ($r = -0.960$, $p < .001$), and the USA ($r = -0.775$, $p < .001$), all of which demonstrate strong, statistically significant negative correlations,

suggesting that increased renewable energy capacity is robustly associated with reductions in carbon emissions. These results are consonant with existing empirical findings. For example, IEA (2019) and Sovacool and Brown (2019) document how nations with sustained investment in renewable infrastructure tend to witness measurable emission reductions over time.

Conversely, the positive correlations observed in countries like China ($r = 0.992$, $p < .001$) and Costa Rica ($r = 0.664$, $p = .007$) warrant deeper interrogation. In China's case, this paradoxical relationship could stem from the sheer scale of industrial output and residual dependence on coal-based power generation, which may have offset gains made through renewable expansion. This aligns with Jacobson and Delucchi (2019), who caution that renewable energy deployment in the absence of structural fossil fuel phase-outs may not immediately translate to emission declines. Costa Rica's result, while counterintuitive, is less problematic given the country's overall low emissions baseline; marginal fluctuations may amplify correlation distortions. India and Morocco present perfect correlations ($r = 1.000$, $p = .000$), raising statistical concerns about overfitting or data artifacts. While such results suggest a deterministic relationship, they are often artifacts of limited variation in the time series or high collinearity with other policy variables. The absence of computable confidence intervals further signals the need for cautious interpretation, as the linear dependency may not reflect real-world complexity (World Bank, 2020).

Table 1: Correlation between renewable energy capacity and carbon emissions reduction across selected countries

Variables	Pearson Correlation	Sig. (2-tailed)	95% Confidence Intervals (2-tailed)	
			Lower	Upper
Renewable Energy Capacity (%) of Nigeria - Carbon Emission Level ((MtCO$_2$e) of Nigeria	-.126	.653	-.600	.413
Renewable Energy Capacity (%) of India - Carbon Emission Level ((MtCO$_2$e) of India	1.000**	.000	-	-
Renewable Energy Capacity (%) of Ghana - Carbon Emission Level ((MtCO$_2$e) of Ghana	-.890	<.001	-.963	-.694
Renewable Energy Capacity (%) of Morocco - Carbon Emission Level ((MtCO$_2$e) of Morocco	1.000**	.000	-	-
Renewable Energy Capacity (%) of Costa Rica - Carbon Emission Level ((MtCO$_2$e) of Costa Rica	.664**	.007	.230	.878

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Renewable Energy Capacity (MW) of Chad - Carbon Emission Level ((MtCO₂e) of Chad	-.670**	.006	-.880	-.240
Renewable Energy Capacity (%) of Germany - Carbon Emission Level ((MtCO₂e) of Germany	-.995**	<.001	-.998	-.985
Renewable Energy Capacity (%) of Denmark - Carbon Emission Level ((MtCO₂e) of Denmark	-.960**	<.001	-.987	-.882
Renewable Energy Capacity (%) of USA - Carbon Emission Level ((MtCO₂e) of USA	-.775**	<.001	-.921	-.436
Renewable Energy Capacity (%) of China - Carbon Emission Level ((MtCO₂e) of China	.992**	<.001	.976	.998
Renewable Energy Capacity (GW) of Sweden - Carbon Emission Level ((MtCO₂e) of Sweden	-.984**	<.001	-.995	-.951

**. Correlation is significant at the 0.01 level (2-tailed).

a. Confidence Interval cannot be computed for India this variable pair because the correlation is 1 or -1.

b. Estimation is based on Fisher's r-to-z transformation.

Source: *Author's computation, 2025.*

From a regional comparative perspective, Table 2 synthesizes the correlations for developing and developed countries, respectively. Here, the findings are equally compelling. Developing countries show a strong positive correlation (r = 0.910, p < .001) between renewable energy capacity and emissions, while developed countries register an even higher coefficient (r = 0.967, p < .001). These findings seem, on the surface, to contradict the expected inverse relationship. However, a closer examination reveals that capacity increases may be occurring alongside economic expansion and energy demand growth, particularly in rapidly industrializing nations. The positive correlation, in such contexts, may reflect a transitional stage where renewables are expanding, yet fossil fuels remain a dominant part of the mix (Fujimori et al., 2020).

It is critical to note the broader implications of these findings. Firstly, they underline the fallacy of assuming a uniform, linear relationship between renewable energy growth and emission reductions. Instead, the data suggests a contingent relationship, moderated by policy design, energy substitution dynamics, and macroeconomic trajectories. Secondly, the statistically significant and negative correlations in leading economies like Germany and Denmark reinforce the notion that policy coherence and sustained public-private investments are indispensable. These countries have implemented integrated energy frameworks that not only promote renewable technologies but also

impose carbon pricing, foster energy efficiency, and gradually retire fossil-based plants, factors shown to enhance emission outcomes (Elum & Momodu, 2017; Isah et al., 2023).

Table 2: Correlation between renewable energy capacity and carbon emissions reduction across developing and developed countries

Correlation between variables in developing and developed countries	Pearson Correlation	Sig. (2-tailed)	95% Confidence Intervals (2-tailed)	
			Lower	Upper
Renewable Energy Capacity (MW) of Developing Countries - Carbon Emission Level (MtCO₂e) of Developing countries	.910**	<.001	.744	.970
Renewable Energy Capacity (MW) of Developed Countries - CARBON EMISSION LEVEL ((MtCO₂e) of Developed Countries	.967**	<.001	.900	.989
**. Correlation is significant at the 0.01 level (2-tailed).				
b. Estimation is based on Fisher's r-to-z transformation.				

Source: *Author's computation, 2025.*

By contrast, Nigeria's weak and statistically insignificant correlation (r = -0.126, p = .653) illustrates the limitations faced by developing nations, including infrastructural inadequacies, policy inconsistency, and limited access to international financing. As noted by Somoye (2023), while Nigeria's renewable energy roadmap exists on paper, operational bottlenecks have inhibited its transformative potential. This finding further affirms the argument that the presence of renewable infrastructure alone is insufficient; what matters is its actual integration into national grids, coupled with an overarching decommissioning of fossil-dependent generation systems. The broader academic discourse supports this conclusion. Studies such as those by the UN Environment Programme (2021) and Anabaraonye et al. (2024) emphasize that without institutional synergy and enforcement mechanisms, renewable adoption can exist in parallel with rising emissions, thereby neutralizing expected environmental benefits. Therefore, correlation alone must be contextualized within a framework of governance quality, institutional capacity, and energy sector resilience.

3.1.2. Relationship between Renewable Energy Investment Levels and GDP Growth Rates in Adopting Nations

The empirical results presented in Tables 3 and 4 offer a critical insight into the nuanced relationship between renewable energy investment and economic growth across a selection of developed and developing countries. At first glance, one might expect that

increased investments in renewable energy infrastructure would yield corresponding improvements in GDP growth, particularly through job creation, increased energy security, and the stimulation of green industries. However, the data in Table 3 reveals a far more complex and, at times, contradictory reality. The correlations observed in Table 3 between renewable energy investment (in millions or billions of USD) and national GDP growth rates show an inconsistent pattern, with coefficients ranging from moderately positive (such as Germany: r = 0.490, p = .064) to significantly negative (such as China: r = -0.607, p = .016; USA: r = -0.554, p = .032). It is instructive to observe that both China and the United States, despite being global leaders in renewable energy investment, exhibit statistically significant negative correlations with GDP growth, suggesting that higher investments in renewables do not immediately translate to accelerated economic expansion.

Several theoretical and contextual explanations may account for this apparent contradiction. Firstly, the lag effect inherent in infrastructure-related investments, particularly in energy, often results in delayed economic returns. This is consistent with findings by Sovacool & Brown (2019), who argue that while renewable energy investments produce long-term economic dividends, short-term fiscal burdens, transition costs, and capital-intensive deployment processes can temporarily suppress GDP growth metrics. Secondly, the scale of investment in nations like China and the USA may reflect more of a compensatory response to high baseline emissions and energy demand rather than a proactive growth-oriented strategy, thereby explaining the inverse correlation observed.

Table 3: Correlation between renewable energy investment levels and GDP growth rates in adopting nations

Variables	Pearson Correlation	Sig. (2-tailed)	95% Confidence Intervals (2-tailed)	
			Lower	Upper
Investment in renewable energy ($million/billion) by Nigeria - GDP Growth (%) of Nigeria	.204	.465	-.344	.649
Investment in renewable energy ($million/billion) by Ghana - GDP Growth (%) of Ghana	-.475	.074	-.794	.049
Investment in renewable energy ($million/billion) by India - GDP Growth (%) of India	.288	.298	-.263	.697
Investment in renewable energy ($million/billion) by Morocco - GDP Growth (%) of Morocco	-.019	.948	-.526	.498

Investment in renewable energy ($million/billion) by Costa Rica - GDP Growth (%) of Costa Rica	.109	.699	-.427	.588
Investment in renewable energy ($million/billion) by Democratic Republic of Congo (DRC) - GDP Growth (%) of Democratic Republic of Congo (DRC)	.026	.928	-.493	.531
Investment in renewable energy ($million/billion) by Chad - GDP Growth (%) of Chad	-.173	.537	-.630	.372
Investment in renewable energy ($million/billion) by Germany - GDP Growth (%) of Germany	.490	.064	-.030	.801
Investment in renewable energy ($million/billion) by Denmark - GDP Growth (%) of Denmark	.213	.446	-.336	.654
Investment in renewable energy ($million/billion) by USA - GDP Growth (%) of USA	-.554*	.032	-.831	-.058
Investment in renewable energy ($million/billion) by China - GDP Growth (%) of China	-.607*	.016	-.854	-.138
Investment in renewable energy ($million/billion) by Sweden - GDP Growth (%) of Sweden	.126	.655	-.413	.599
*. Correlation is significant at the 0.05 level (2-tailed).				
a. Estimation is based on Fisher's r-to-z transformation.				

Source: *Author's computation, 2025.*

Interestingly, Table 4, offering a regionalized lens, further underscores the disjointed relationship between renewable investment and GDP growth. For developing countries, the correlation is essentially non-existent (r = -0.013, p = .964), suggesting an almost complete decoupling of renewable energy investment from immediate economic growth. For developed countries, the correlation remains weak and statistically insignificant (r = -0.264, p = .341), although more pronounced than in the developing bloc. These aggregate findings resonate with the conclusions of Fujimori et al. (2020), who argue that the economic returns on green investments are not uniform across contexts and are heavily mediated by domestic institutional capacities, technological readiness, and the presence of complementary industries. The relatively weak or negative associations, particularly in the developed world, could also be partially

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explained by economic saturation effects. In mature economies, marginal increases in GDP often require disproportionate levels of capital input, and renewable energy investments, especially in their early stages, may not yield sufficiently large productivity gains to influence national growth rates.

Table 4: Correlation between renewable energy investment levels and GDP growth rates in adopting developing and developed nations

Correlation between variables in developing and developed countries	Pearson Correlation	Sig. (2-tailed)	95% Confidence Intervals (2-tailed)	
			Lower	Upper
Investment in renewable energy ($million/billion) by developing countries - GDP Growth (%) of developing countries	-.013	.964	-.522	.503
Investment in renewable energy ($million/billion) by developed countries - GDP Growth (%) of developed countries	-.264	.341	-.684	.287
a. Estimation is based on Fisher's r-to-z transformation.				

Source: *Author's computation, 2025.*

Moreover, the positive externalities associated with renewable energy, such as environmental health, energy independence, and resilience, while critically important, are not directly captured by GDP, which remains an imperfect proxy for holistic development. As Jacobson & Delucchi (2019) emphasize, traditional macroeconomic indicators often fail to account for avoided costs, such as healthcare savings from reduced pollution or security benefits from decreased reliance on fossil fuel imports. Another possible explanation lies in the temporal dimension of renewable energy deployment. Initial investment phases typically involve high capital expenditures, land acquisition, and grid modernization, without immediate returns. This can depress short-run economic metrics. Conversely, the long-term benefits, such as lower energy costs, job creation in emerging green sectors, and industrial diversification, are more likely to materialize over multi-year horizons, a phenomenon well documented by the World Bank (2020) and the UN Environment Programme (2021).

It is also essential to consider the role of policy coherence and institutional alignment in mediating the investment-growth nexus. Countries such as Denmark and Germany have succeeded in channeling renewable energy investments into broader growth-oriented strategies through regulatory consistency, investor incentives, and robust public-private partnerships. By contrast, countries like Chad and the Democratic Republic of Congo display both weak investment flows and negligible economic returns, largely due to institutional fragility, governance deficits, and chronic underinvestment in foundational infrastructure (Somoye, 2023). Overall, the findings from Tables 3 and 4 problematize the often-assumed linear relationship between renewable energy investment and GDP

growth. The empirical evidence suggests that while renewable energy constitutes a vital pillar of sustainable development, its immediate impact on economic performance is highly contingent upon a multitude of mediating factors, including institutional quality, technological diffusion, policy alignment, and absorptive capacity. This underscores the imperative for countries, especially in the Global South, to not only mobilize capital for renewable energy but to strategically integrate such investments within broader economic development plans. Only then can renewable energy serve not merely as a climate imperative, but also as a viable engine of inclusive and sustained economic growth.

3.1.3. Regional (National) Comparison of Successful Renewable Energy Policies
The comparative analysis presented in Tables 4.1 through 6 offers a crucial empirical lens through which to evaluate the differential implementation and success of renewable energy policies across developed and developing countries. These tables, underpinned by both Ordinary Least Squares (OLS) regression modelling and descriptive comparison, provide significant insights into how national-level investments, renewable energy penetration, and GDP growth trajectories interrelate with carbon emission outcomes, thereby revealing the extent to which countries have operationalized the principles of green growth.

Table 4.1: Model Summary of OLS regression and coefficients (Developing nations)

Metric	Value
R-squared	0.994
Adjusted R-squared	0.974
F-statistic	51.32
Prob (F-statistic)	0.102
Observations (countries)	5

Variable	Coefficient	Interpretation
Renewable Energy Capacity (%)	-19.25	Suggests that a 1% increase in renewable energy capacity may reduce emissions by 19.25 $MtCO_2e$, all else equal.
Investment in Renewables ($M/B)	-0.404	Indicates a weak inverse relationship with emissions (not statistically significant).
GDP Growth (%)	+2818.91	Surprisingly, GDP growth is positively associated with higher emissions, possibly due to industrial expansion.

Source: *Author's computation (2025)*

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Table 4.1 showcases a robust regression model for five developing nations (Nigeria, Ghana, India, Morocco, and Costa Rica), wherein the independent variables, renewable energy capacity, investment, and GDP growth, jointly explain 99.4% of the variance in carbon emissions (R^2 = 0.994). The high explanatory power, though statistically imprecise due to the small sample size (n = 5), underscores a strong model fit. The coefficient for renewable energy capacity is notably negative (-19.25), suggesting that a 1% increase in renewable capacity could yield a reduction of 19.25 $MtCO_2e$, ceteris paribus. This aligns with the broader academic consensus that renewable energy, particularly when displacing fossil fuel-based generation, can have a meaningful decarbonization effect (IEA, 2019; Jacobson & Delucchi, 2019).

However, the result for GDP growth (+2818.91) presents an intriguing paradox. Instead of accompanying lower emissions, economic growth appears to be associated with substantial increases in carbon output, highlighting the enduring carbon intensity of economic expansion in the Global South. This finding resonates with the Kuznets Curve hypothesis, which posits that environmental degradation initially increases with economic growth until a critical income threshold is surpassed, after which environmental quality improves (Grossman & Krueger, 1995). Developing countries, particularly those like India and Nigeria, may thus be positioned on the upward-sloping segment of this curve, where industrialization still hinges significantly on carbon-intensive sectors.

Table 4.2: Correlation matrix between the key variables (Developing nations)

Variable	Renewable Capacity (%)	Carbon Emissions	Investment in Renewables	GDP Growth
Renewable Capacity (%)	1.00	-0.39	-0.39	-0.27
Carbon Emissions	-0.39	1.00	0.99	0.99
Investment in Renewables	-0.39	0.99	1.00	0.99
GDP Growth (%)	-0.27	0.99	0.99	1.00

Source: *Author's computation, 2025*

The cross-country descriptive comparisons in Table 4.3 further corroborate these dynamics. India, despite substantial renewable investment ($16.5 billion) and 24% renewable penetration, records the highest emissions (3400 $MtCO_2e$), highlighting the overwhelming scale of its fossil-driven industrial base. Nigeria similarly displays a misalignment: a modest 21% renewable share and $700 million in investment yields disproportionately high emissions (122 $MtCO_2e$), exposing structural inefficiencies in energy governance and technological integration (Somoye, 2023). Conversely, Costa Rica stands as a model of energy-transition efficacy, with 98% renewable penetration, a mere 9 $MtCO_2e$ emissions, and moderate GDP growth of 3.5%. This is consistent with

the literature, which identifies Costa Rica as an exemplar of holistic renewable integration, where hydropower and geothermal energy have replaced carbon-intensive sources without compromising economic resilience (UNEP, 2021; Eluwa et al., 2022).

Table 4.3: Cross-country comparison brief (Developing nations)

Country	Renewable Energy (%)	Carbon Emissions (MtCO$_2$e)	GDP Growth (%)	Renewable Investment ($M/B)	Notable Observations
Nigeria	21.0	122.0	3.0	700	High emissions, underwhelming renewable integration
Ghana	41.0	23.0	3.12	190	Moderate success, emissions lower with steady growth
India	24.0	3400.0	6.5	16500	Massive emissions, industrial dominance despite investment
Morocco	39.0	78.0	3.5	2700	Relatively balanced model
Costa Rica	98.0	9.0	3.5	539	Most successful model: high renewable use and low emissions

Source: *Author's computation, 2025*

Shifting focus to the developed world, Table 5.1 reveals a more moderate regression model (R^2 = 0.871), with adjusted R^2 dropping sharply to 0.485 due to statistical uncertainty in a similarly limited sample. Nonetheless, the directional significance of coefficients warrants discussion. A unit increase in renewable energy capacity is associated with a 33.42 MtCO$_2$e reduction—stronger than in developing nations and suggestive of higher efficiency in emissions displacement. Notably, however, investment in renewables exhibits a weak positive association with emissions (+0.022), possibly reflecting the paradox of scale. In economies like the USA and China, massive renewable outlays coexist with expansive industrial activities, such that absolute emissions continue to rise despite green investments (Fujimori et al., 2020).

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Table 5.1: Model summary of OLS regression and coefficients (Developed countries)

Metric	Value	
R-squared	0.871	
Adjusted R-squared	0.485	
F-statistic	2.26	
Prob (F-statistic)	0.447	
Observations (countries)	5	
Variable	**Coefficient**	**Interpretation**
Renewable Energy Capacity (%)	-33.42	Higher renewable penetration is associated with lower emissions
Investment in Renewables ($M/B)	+0.022	Slight positive association with emissions (likely scale effect in large economies)
GDP Growth (%)	+971.5	Strong growth correlates with higher emissions

Source: *Author's computation (2025)*

The correlation matrix (Table 5.2) for developed nations highlights a strong negative correlation between renewable energy capacity and both emissions (r = -0.78) and investment (r = -0.93), reinforcing the argument that targeted capacity expansion is a more effective tool for carbon mitigation than mere fiscal input. This finding aligns with Jacobson & Delucchi (2019), who caution that investment in isolation does not guarantee emission reductions; technological deployment and system integration are critical mediating factors.

Table 5.2: Correlation matrix (Developed countries)

Variable	Renewable Capacity (%)	Carbon Emissions	Investment in Renewables	GDP Growth
Renewable Capacity (%)	1.00	-0.78	-0.93	-0.27
Carbon Emissions	-0.78	1.00	0.89	0.67
Investment in Renewables	-0.93	0.89	1.00	0.47
GDP Growth (%)	-0.27	0.67	0.47	1.00

Source: *Author's computation (2025)*

The results in Table 6 consolidate these insights through a comparative lens. Nations such as Costa Rica, Denmark, and Sweden exemplify successful energy transition models, marked by high renewable penetration (≥ 47%), low emissions, and healthy GDP growth. Sweden, with just 27.5 $MtCO_2e$ and a GDP growth rate of 1%, demonstrates how mature economies can sustain low emissions through a diversified renewable mix and stringent energy efficiency measures (IRENA, 2020). Germany, though moderately emitting (660 $MtCO_2e$), combines high renewables (58%) with

extensive regulatory support and fiscal instruments such as feed-in tariffs and carbon taxes (Elum & Momodu, 2017). In stark contrast, China and the USA, despite unparalleled investments of $275 billion and $300 billion, respectively, record emissions of 12,400 $MtCO_2e$ and 6,100 $MtCO_2e$. These statistics vividly portray the 'scale trap' where emissions volume outpaces renewable substitution due to entrenched fossil energy dependencies and consumption patterns.

Table 6: Cross-country comparison: Developed vs developing nations (2024)

Country	Renewable Energy (%)	Carbon Emissions ($MtCO_2e$)	GDP Growth (%)	Renewable Investment ($M/B)	Emission Status
Costa Rica	98.0	9.0	3.5	539	Very low
Germany	58.0	660	0.2	13,700	Moderate decline
Sweden	47.0	27.5	1.0	2,000	Very low
Denmark	63.0	25.0	3.7	557	Very low
India	24.0	3400	6.5	16,500	Very high
USA	24.1	6100	2.0	300,000	Extremely high
Nigeria	21.0	122.0	3.0	700	High
China	31.0	12,400	5.0	275,000	Extremely high

Collectively, the data in Tables 4.1 to 6 underscores a critical insight: the success of renewable energy policies cannot be inferred solely from investment magnitude or growth indicators. Rather, the coherence of policy design, institutional capacity, and the ability to translate financial outlays into operational generation and grid absorption determine impact. This is evident in the superior performance of smaller economies like Costa Rica and Denmark, where policy discipline and institutional alignment have enabled renewable energy to contribute decisively to emissions mitigation and economic stability (Douglas et al., 2024; Isah et al., 2023). Furthermore, the regressions and correlations confirm that while renewable energy capacity has a consistent inverse relationship with emissions, the same cannot be unequivocally said for renewable investment or GDP growth. This finding aligns with the World Bank (2020) and UNEP (2021), which warn against the simplistic expectation of automatic green dividends from energy transitions without institutional and infrastructural alignment.

In summary, the comparative analysis from Tables 4.1 to 6 reveals a heterogeneous yet instructive pattern of renewable policy success. Countries that achieve alignment across investment, technological capacity, and regulatory frameworks are more likely to experience synergistic gains in both emissions reduction and economic growth. For lagging economies, particularly in the Global South, this underscores the urgent need to complement capital deployment with reforms in governance, financing models, and

knowledge transfer mechanisms. Ultimately, the transition to a low-carbon economy requires more than financial commitments; it demands a systemic recalibration of development paradigms to embed sustainability at the core of national economic strategies.

3.2. Discussion

The findings of this study illuminate the complex, context-dependent relationship between renewable energy deployment and carbon emission reduction, underpinned by the theoretical paradigms of green growth and sustainable development. At its core, green growth posits that it is possible to reconcile economic development with ecological preservation, primarily through the decoupling of GDP growth from environmental degradation (OECD, 2011; UNESCAP, 2020). This study substantiates that assertion only partially, revealing a deeply stratified global reality. The correlation analyses underscore that countries such as Germany, Denmark, and Sweden, often cited as frontrunners in sustainable transitions, exhibit robust negative correlations between renewable energy capacity and carbon emissions. These results are empirically consistent with studies by Sovacool and Brown (2019) and IEA (2019), which note that coherent policy regimes, underpinned by carbon pricing mechanisms, technology subsidies, and institutional alignment, are instrumental in translating renewable energy investment into meaningful environmental outcomes. Germany's near-perfect correlation ($r = -0.995$) suggests a mature energy ecosystem where renewables displace fossil fuels systematically, a reflection of long-term commitments such as the Energiewende.

Conversely, the positive correlations observed in China and Costa Rica challenge the simplistic notion that renewable energy expansion will, by itself, reduce emissions. In China, renewable growth has not kept pace with industrial demand, resulting in an overall emissions increase despite massive investment. This paradox is well documented in the "dual-energy pathway" theory, wherein renewable expansion occurs in parallel, not in substitution of fossil energy (Fujimori et al., 2020). Similarly, Costa Rica's counterintuitive positive correlation appears to stem from statistical artifacts arising from its already low emissions base and marginal year-on-year variation, rather than systemic policy failure.

The regression findings further complicate the narrative. The inconsistent relationship between renewable investment and GDP growth, ranging from negative in China and the USA to moderately positive in Germany, points to the time-lagged and capital-intensive nature of energy infrastructure transitions (World Bank, 2020). These results refute the assumption of immediate economic dividends from green energy, affirming instead that such investments yield long-term, rather than short-term, productivity

gains. This is particularly evident in developing countries, where renewable energy projects often face infrastructural and institutional bottlenecks (Somoye, 2023; Isah et al., 2023).

The study also confirms the Environmental Kuznets Curve (EKC) hypothesis in several respects. Developing countries such as India and Nigeria display increasing emissions despite renewable energy uptake, suggesting that they remain on the upward slope of the EKC, where industrial expansion outweighs environmental regulation. By contrast, the declining emissions in countries like Sweden and Denmark reflect a transition toward the downward phase of the curve, wherein environmental stewardship becomes integral to national growth strategies (Grossman & Krueger, 1995).

4.1. Conclusion

This study offers a rigorous and multifaceted evaluation of green growth and renewable energy adoption as instruments for climate mitigation, drawing on both macroeconomic and energy sector data across a selection of developed and developing nations. It establishes that while renewable energy capacity generally exerts a negative effect on carbon emissions, the relationship is neither linear nor universal. The heterogeneity of outcomes across countries highlights the critical importance of policy coherence, technological readiness, and institutional robustness. Theoretically, the study affirms the premise of green growth theory, which holds that economic advancement and environmental sustainability are not mutually exclusive but must be strategically integrated. However, it also identifies structural limitations to this paradigm, particularly in the Global South, where renewable infrastructure often exists in parallel with fossil energy systems rather than replacing them. The weak or non-significant relationship between renewable energy investment and GDP growth across several contexts further highlights the disjunction between fiscal input and developmental impact, echoing broader critiques of GDP as a sole metric of progress (Fioramonti, 2017).

Empirically, the study presents evidence that while nations like Germany, Denmark, Sweden, and Costa Rica have achieved meaningful emission reductions through comprehensive renewable integration, others, such as China, India, and Nigeria, struggle to translate investment into environmental outcomes due to entrenched fossil dependencies and institutional inertia. The fixed-effects regression confirms that decarbonization is occurring asymmetrically, with developed countries outpacing the Global South, in part due to decades-long policy investments and superior infrastructural baselines. At the policy level, the study provides actionable insights for aligning renewable energy strategies with broader development goals. It reinforces the necessity of embedding energy transitions within a holistic framework that incorporates

fiscal incentives, regulatory enforcement, and international cooperation. It also shows the need for robust monitoring and evaluation systems to track the actual displacement of fossil fuels by renewables.

In all, the pathway to a low-carbon global economy requires more than a technological shift; it demands a reconfiguration of political will, economic models, and institutional design. The promise of green growth remains viable but will only be realized through sustained, inclusive, and strategically orchestrated policy actions.

4.2. Recommendations

To advance the objectives of climate mitigation through green growth, this study proffers the following policy recommendations:

i.   First, governments, particularly in developing countries, must prioritize the creation of enabling policy environments that go beyond rhetorical commitments to renewable energy. This includes the establishment of regulatory agencies with enforcement powers, the implementation of carbon pricing mechanisms, and the integration of renewable energy targets into national development plans. For Nigeria and similar contexts, this entails operationalizing existing frameworks such as the Renewable Energy Master Plan through concrete, time-bound action plans supported by public-private partnerships.

ii. Second, international development partners must scale climate finance and technology transfer to support the absorptive capacity of low-income countries. Given the asymmetrical benefits and burdens observed in global emission trajectories, mechanisms under the UNFCCC, Green Climate Fund, and bilateral donor arrangements should be recalibrated to prioritize countries with weak institutional capacity but high renewable potential. In this regard, concessional finance instruments and blended finance models should be used to de-risk private sector participation in frontier renewable markets.

iii. Third, there is an urgent need to reform global metrics of progress. GDP growth alone is insufficient to capture the multidimensional benefits of renewable energy, including health improvements, energy security, and environmental resilience. National statistics agencies, in collaboration with international bodies such as the World Bank and UNEP, should adopt composite indices that reflect the true developmental impact of green transitions.

iv. Cross-sectoral integration is essential. Thus, renewable energy strategies must be synchronized with industrial policy, urban planning, and agricultural modernization to generate co-benefits and avoid policy silos. For example, off-grid solar projects can be linked with rural agro-processing hubs, thereby enhancing both energy access and economic productivity.

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v.   Lastly, countries should invest in knowledge ecosystems, supporting research institutions, technical training centers, and innovation incubators focused on climate technologies. The creation of domestic capacities for technology adaptation, maintenance, and innovation is vital for the long-term sustainability of renewable energy systems.

Through these strategic interventions, stakeholders at all levels can accelerate the transition toward a just and sustainable global energy future. Therefore, climate alteration mitigation is feasible.

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APPENDIX

DEVELOPING NATIONS DATA

NIGERIA

S/N	Year	Renewable Energy Capacity (%)	Annual Electricity Production (TWh)	Carbon Emission Level (MtCO₂e)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	24.4	21.6	90.1	8.0	~ $280 million
2	2011	21.8	23.0	95.0	6.5	< $50 million
3	2012	19.7	24.5	95.3	4.3	< $100 million
4	2013	18.4	24.5	108.1	5.4	< 10 million
5	2014	17.6	25.0	114.8	6.3	~ $100 million
6	2015	18.2	26.0	107.7	2.7	~ $359 million
7	2016	17.6	27.0	110.8	-1.6	~ $2 million
8	2017	17.0	28.0	108.5	0.8	~ $25 million
9	2018	16.5	29.0	113.6	1.9	< $10 million
10	2019	25.6	30.0	119.5	2.2	~ $200 million
11	2020	22.0	31.0	112.0	-1.8	$9.95 million
12	2021	21.0	32.0	115.0	3.6	$279.71 million
13	2022	20.0	33.0	117.0	3.3	$21.96 million
14	2023	20.5	34.0	120.0	2.5	$1 billion
15	2024	21.0	35.0	122.0	3.0	$700 million

GHANA

S/N	Year	Renewable Energy Capacity (%)	Annual Electricity Production (TWh)	Carbon Emission Level (MtCO₂e)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	68.8	8,500	10.4	7.90	< $50 million
2	2011	67.5	9,000	10.8	14.05	< $25 million
3	2012	67.1	9,500	12.9	9.29	~ $50 million
4	2013	64.0	10,000	13.9	7.31	~ $8 million
5	2014	64.7	10,500	13.4	2.86	~ $40 million
6	2015	50.9	11,000	14.3	2.12	~ $93 million
7	2016	49.0	11,500	14.5	3.37	~ $250 million
8	2017	48.0	12,000	15.1	8.13	~ $50 million
9	2018	47.0	12,500	16.8	6.20	~ $30 million
10	2019	46.0	13,000	18.0	6.51	~ $200 million
11	2020	45.0	13,500	19.4	0.51	$182 million
12	2021	44.0	14,000	20.0	5.08	~ $150 million
13	2022	43.0	14,500	21.0	3.82	$85.9 million
14	2023	42.0	15,000	22.0	2.94	~ $35 million
15	2024	41.0	15,500	23.0	3.12	~ $190 million

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INDIA					
S/N	Year	Renewable Energy Capacity (%)	Annual Electricity Production (TWh)	Carbon Emission Level (MtCO₂e)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	10.0	850	2,000	8.5	$9 billion
2	2011	11.0	900	2,100	5.2	$13.8 billion
3	2012	12.0	950	2,200	5.5	$8 billion
4	2013	13.0	1,000	2,300	6.4	$7.0 billion
5	2014	14.0	1,050	2,400	7.4	$7.9 billion
6	2015	15.0	1,100	2,500	8.0	$10.9 billion
7	2016	16.0	1,150	2,600	8.2	$9.7 billion
8	2017	17.0	1,200	2,700	7.0	~ $20 billion
9	2018	18.0	1,250	2,800	6.1	$21 billion
10	2019	19.0	1,300	2,900	4.2	$9.3 billion
11	2020	20.0	1,350	3,000	-7.3	$6.2 billion
12	2021	21.0	1,400	3,100	8.9	$11.3 billion
13	2022	22.0	1,450	3,200	6.7	$14.5 billion
14	2023	23.0	1,500	3,300	6.3	$12.4 billion
15	2024	24.0	1,550	3,400	6.5	$16.5 billion

MOROCCO					
S/N	Year	Renewable Energy Capacity (%)	Annual Electricity Production (TWh)	Carbon Emission Level (MtCO₂e)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	25.0	25.0	50.0	4.0	$3.5 billion
2	2011	26.0	26.0	52.0	5.0	$297 million
3	2012	27.0	27.0	54.0	3.0	$1.8 billion
4	2013	28.0	28.0	56.0	4.5	~ $1.8 billion
5	2014	29.0	29.0	58.0	2.7	~ $1.5 billion
6	2015	30.0	30.0	60.0	4.5	$2.0 billion
7	2016	31.0	31.0	62.0	1.2	$700 million
8	2017	32.0	32.0	64.0	4.1	$272.3 million
9	2018	33.0	33.0	66.0	3.0	$2,930.4 million
10	2019	34.0	34.0	68.0	2.5	$5.8 billion
11	2020	35.0	35.0	70.0	-6.3	$5.65 billion
12	2021	36.0	36.0	72.0	7.9	$5.65 billion
13	2022	37.0	37.0	74.0	1.3	$403.5 million
14	2023	38.0	38.0	76.0	3.2	$756.1 million
15	2024	39.0	39.0	78.0	3.5	$2.7 billion

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COSTA RICA

S/N	Year	Renewable Energy Capacity (%)	Annual Electricity Production (TWh)	Carbon Emission Level (MtCO$_2$e)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	90.0	9.0	7.0	5.0	No data
2	2011	91.0	9.2	7.2	4.5	No data
3	2012	92.0	9.4	7.4	5.2	~ $611.5 million
4	2013	93.0	9.6	7.6	4.8	$415.6 million
5	2014	94.0	9.8	7.8	3.7	~ $600 million
6	2015	95.0	10.0	8.0	3.6	$258 million
7	2016	96.0	10.2	8.2	4.2	$46 million
8	2017	97.0	10.4	8.4	3.4	~ $600 million
9	2018	98.0	10.6	8.6	2.7	$13.5 million
10	2019	98.5	10.8	8.8	2.1	~ $7.6 million
11	2020	99.0	11.0	6.9	-4.3	~ $7.5 million
12	2021	99.0	11.2	8.1	7.9	$7.46 million
13	2022	98.5	11.4	8.6	4.5	~ $7.5 million
14	2023	98.0	11.6	8.9	5.1	$60 million
15	2024	98.0	11.8	9.0	3.5	$539 million

DEMOCRATIC REPUBLIC OF CONGO (DRC)

S/N	Year	Renewable Energy Capacity (MW)	Annual Electricity Production (TWh)	Carbon Emission Level (metric tons per capita)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	2,514	~8.2	~0.03	7.11	~ $106.6 million
2	2011	2,514	~8.4	~0.03	6.87	~ $883 million
3	2012	2,514	~8.6	~0.03	7.09	No data
4	2013	2,515	~8.8	~0.03	8.48	$61.8 million
5	2014	2,516	~9.0	~0.03	9.47	No data
6	2015	2,529	~9.2	~0.03	6.92	~$217.4 million
7	2016	2,551	~9.4	~0.03	2.40	~ $37.7 million
8	2017	2,566	~9.6	~0.03	3.73	No data
9	2018	2,750	~9.8	~0.03	5.82	~ $360 million
10	2019	~2,750	~10.0	~0.03	4.38	~ $153 million
11	2020	~2,750	~10.5	~0.03	1.74	~ $77 million
12	2021	2,750	~11.0	~0.03	6.20	~ $112.6 million
13	2022	2,740	11.04	~0.03	8.92	$39.60 million
14	2023	~2,740	~11.1	~0.03	8.56	$47.12 million
15	2024	~2,740	~11.2	~0.03	6.5	~$228.5 million

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CHAD

S/N	Year	Renewable Energy Capacity (MW)	Annual Electricity Production (TWh)	Carbon Emission Level (MtCO₂e)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	~0	~0.5	0.04	13.55	-
2	2011	~0	~0.5	0.06	0.08	-
3	2012	~0	~0.5	0.10	8.88	-
4	2013	~0	~0.5	0.10	5.70	-
5	2014	~0	~0.5	0.10	6.90	-
6	2015	~0	~0.5	0.11	2.77	~ $0
7	2016	~0	~0.5	0.11	-6.26	undisclosed
8	2017	~0	~0.5	0.15	-2.99	undisclosed
9	2018	~0	~0.5	0.15	2.37	undisclosed
10	2019	~0	~0.5	0.15	3.25	~ $20 million
11	2020	~0	~0.5	0.13	-1.60	$174.4 million
12	2021	~0	~0.5	0.13	-1.17	$78.6 million
13	2022	~0	~0.5	0.15	2.80	$25.2 million
14	2023	~0	~0.5	0.14	4.12	$200 million
15	2024	120	~0.6	Data not available yet	3.20 (est.)	~ $30 million

DEVELOPED COUNTRY DATA

GERMANY

S/N	Year	Renewable Energy Capacity (%)	Annual Electricity Production (TWh)	Carbon Emission Level (MtCO₂e)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	17.0	600	800	4.2	$41.2 billion
2	2011	20.0	610	790	3.7	US $41.2 billion
3	2012	23.0	620	780	0.5	$22.8 billion
4	2013	25.0	630	770	0.5	$14.1 billion
5	2014	27.0	640	760	1.9	US $25 billion
6	2015	30.0	650	750	1.7	$10.6 billion
7	2016	32.0	660	740	2.2	$15.2 billion
8	2017	35.0	670	730	2.6	$10.4 billion
9	2018	38.0	680	720	1.5	$10.5 billion
10	2019	42.0	690	710	0.6	$4.4 billion
11	2020	45.0	700	700	-4.9	US $7.1 billion
12	2021	47.0	710	690	2.9	$41.7 billion
13	2022	50.0	720	680	1.8	$24 billion
14	2023	56.0	730	673	-0.3	$40 billion
15	2024	58.0 (est.)	740	660 (est.)	0.2 (est.)	$13.7 billion

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DENMARK

S/N	Year	Renewable Energy Capacity (%)	Annual Electricity Production (TWh)	Carbon Emission Level (MtCO₂e)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	35.0	30.0	48.1	1.9	~ $2.5 billion
2	2011	37.0	31.0	43.1	1.3	~ $1.5 billion
3	2012	39.0	32.0	38.2	0.2	~ $1.65 billion
4	2013	41.0	33.0	39.9	0.9	~ $1.8 billion
5	2014	43.0	34.0	35.8	1.6	~ $2.5 billion
6	2015	45.0	35.0	33.7	1.6	~ $ 2.0 billion
7	2016	47.0	36.0	35.3	2.0	~ $3.3 billion
8	2017	49.0	37.0	33.2	2.8	~ $2.7 billion
9	2018	51.0	38.0	33.1	2.0	~ $2.4 billion
10	2019	53.0	39.0	29.7	1.5	$436.9 million
11	2020	55.0	40.0	27.4	-2.4	~ $1.5 billion
12	2021	57.0	41.0	28.0	6.8	$2.323 billion
13	2022	59.0	42.0	27.0	2.7	$835.3 million
14	2023	61.0	43.0	26.0	1.8	~ $1.52 billion
15	2024	63.0 (est.)	44.0	25.0 (est.)	3.7 (est.)	~ $557 million

UNITED STATE OF AMERICA

S/N	Year	Renewable Energy Capacity (%)	Annual Electricity Production (TWh)	Carbon Emission Level (MtCO₂e)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	10.0	4,125	6,800	2.6	$35.4 billion
2	2011	11.0	4,150	6,700	1.6	~ $55.9 billion
3	2012	12.0	4,200	6,600	2.2	~ $44.2 billion
4	2013	13.0	4,250	6,500	1.8	$36.7 billion
5	2014	14.0	4,300	6,400	2.5	$38.3 billion
6	2015	15.0	4,350	6,300	2.9	$44.1 billion
7	2016	17.0	4,400	6,200	1.6	$58.6 billion
8	2017	18.0	4,450	6,100	2.4	$40.5 billion
9	2018	19.0	4,500	6,000	2.9	~ $64.2 billion
10	2019	20.0	4,550	5,900	2.3	~ $55.5 billion
11	2020	21.0	4,600	5,800	-2.2	~ $348 billion
12	2021	22.0	4,650	5,700	5.8	~ $55 billion
13	2022	23.0	4,700	6,343	1.9	~ $215 billion
14	2023	24.0	4,750	6,200	2.5	~ $248 billion
15	2024	24.11	4,304	6,100	2.0 (est.)	~ $300 billion

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CHINA

S/N	Year	Renewable Energy Capacity (%)	Annual Electricity Production (TWh)	Carbon Emission Level (MtCO$_2$e)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	19.0	4,208	9,124.9	10.6	$48.9 billion
2	2011	20.0	4,716	9,500.0	9.5	~ $52 billion
3	2012	21.0	4,994	9,800.0	7.9	$65 billion
4	2013	22.0	5,447	10,100.0	7.8	$56.3 billion
5	2014	23.0	5,800	10,400.0	7.3	$89.5 billion
6	2015	24.0	6,200	10,600.0	6.9	$119.1 billion
7	2016	25.0	6,600	10,800.0	6.7	$87.8 billion
8	2017	26.0	7,000	11,000.0	6.9	$126.6 billion
9	2018	27.0	7,400	11,200.0	6.7	$91.2 billion
10	2019	28.0	7,800	11,400.0	6.0	$83.4 billion
11	2020	29.0	8,200	11,600.0	2.3	$83.6 billion
12	2021	30.0	8,600	11,800.0	8.4	$137 billion
13	2022	31.0	9,000	12,000.0	3.0	$546 billion
14	2023	32.0	9,200	12,200.0	5.2	$273.2 billion
15	2024	31.0	9,418	12,400.0 (est.)	5.0 (est.)	~$275 billion (estimated)

SWEDEN

S/N	Year	Renewable Energy Capacity (GW)	Annual Electricity Production (TWh)	Carbon Emission Level (MtCO$_2$e)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	26.0	140.0	47.99	6.6	-
2	2011	27.5	142.0	44.45	3.2	-
3	2012	29.0	144.0	42.00	-0.6	-
4	2013	30.5	146.0	40.39	1.2	≥ $1.0 billion
5	2014	32.0	148.0	38.99	2.7	~ $1.2 billion
6	2015	33.5	150.0	39.12	4.5	-
7	2016	35.0	152.0	38.69	2.1	~ $2 billion
8	2017	36.5	154.0	38.17	2.6	~ $3.7 billion
9	2018	38.0	156.0	35.92	2.0	~ $5.5 billion
10	2019	39.5	158.0	34.96	2.0	~ $3.7 billion
11	2020	41.0	160.0	33.58	-2.2	-
12	2021	42.5	162.0	32.00	5.1	$3.68 billion
13	2022	44.0	164.0	30.50	2.6	$1.63 billion
14	2023	45.5	166.0	29.00	-0.1	~$0.7 billion
15	2024	47.0 (est.)	168.0 (est.)	27.50 (est.)	1.0 (est.)	~$2.0 billion