Do Energy Choices Shape Carbon Outcomes? A Study of Energy mix and CO_2 Emissions in BRICS

Rajnish Yadav[1] Prof. (Dr.) Shweta Anand[2] Dr. Kavita Singh[3]

1. *Research scholar, School of Management, Gautam Buddha University*
2. *Professor, School of Management, Gautam Buddha University*
3. *Assistant Professor, School of Management, Gautam Buddha University*

Abstract

Electric energy consumption has emerged as the fastest-growing form of energy worldwide, playing a pivotal role in driving the techno-economic and socio-economic development of nations. The debate around the role of R sources in reducing carbon emissions and fostering a cleaner environment remains active among scholars and policymakers. One of the most effective ways to diversify the energy mix is by integrating renewable sources. The study has employed the Hausman test, Breusch-Pagan test, Breusch–Godfrey test, Pesaran CD test, VIF, and Fixed Effects (Arellano robust standard errors) to assess the robustness of the model. This study focuses on BRICS nations from 1985 to 2023. The dependent variable is CE and the independent variables are NR, R, and U. The results of this study show a significant negative relationship of NR and R with CE, across all the models and Urbanisation has a positive significant relationship with CE. The study also revealed that the share of R sources is increasing in BRICS nations. The penetration of renewable sources, such as Solar and wind, is growing over time. The high coefficient highlights the importance of policies for R and NR sources. This study provides policy implications for BRICS, which can help other developing nations.

Keywords: Emission, SDG-7, Energy Mix, Non-Renewable Energy, Renewable Energy.

1. Introduction

The undeniable reality of climate change and its far-reaching effects is impacting the world without discrimination (Zhang et al., 2023). Although the consequences of climate change are evident across all continents and countries, emerging, developing, and underdeveloped economies face heightened vulnerability and climate issues are global issues, and global issues require global solutions. (Lestan et al.,2023). These nations grapple with multiple pressing challenges such as poverty, energy independence, corruption, deep development gaps, and limited access to essential resources (Signe and Mbaye, 2022). Electric energy consumption has emerged as the fastest-growing form of energy worldwide, playing a pivotal role in driving the techno-economic and socio-economic development of nations (Das et al., 2020). The debate around the role of renewable energy sources in reducing carbon emissions and fostering a cleaner environment remains active among scholars and policymakers. Nevertheless, increasing evidence underscores renewable energy's effectiveness in curbing emissions and alleviating environmental pressures (Dilanchiev et al., 2024).

Carbon emissions, largely driven by energy consumption, are accelerating the rapid degradation of the global ecological balance (Khan et al., 2023). As the United Nations highlights, energy remains one of the most significant sustainability challenges of the 21st century. Conventional energy resources, such as coal, natural gas, and oil, are no longer adequate to meet the growing demand of the global economy (Rosales et al., 2019). In response, the global energy landscape is undergoing a profound transformation, with Renewable Energy Sources (RES) like wind, solar, and hydro gaining prominence due to rising environmental concerns and technological advancements (Tudorica et al., 2024). As the transition towards exclusive reliance on renewable energy is still underway, balancing traditional and green energy sources becomes crucial. Additionally, the energy mix must emphasize improved energy efficiency, as phasing out fossil fuels will require time and could lead to increased pollution during the transition (Abban et al., 2023). The evolving energy paradigm in Asia reflects a dual challenge: growing energy demand and the persistent reliance on fossil fuel-based regimes (Lo, 2017). Crafting an optimal power generation mix is essential to ensuring the power system's security, stability, and sustainable development (Yu et al., 2019). In this context, the advancement of renewable energy technologies has become a central focus of the 21st century. Breakthroughs in engineering and material science have propelled solar, wind, hydroelectric, geothermal, and other renewable sources to the forefront of global energy solutions (Nazarov et al., 2024). Renewable electricity (RE) presents a timely, long-term, and potentially sustainable pathway for significantly reducing greenhouse gas emissions while gradually replacing non-renewable electricity worldwide (Kåberger et al., 2018). The Sustainable Development Goal (SDG) 7 advocates for increased renewable energy production, enhanced energy efficiency, and accelerated investments in cleaner energy infrastructure (UN, 2021). Ensuring the affordability and accessibility of green energy for households and businesses not only supports the achievement of SDG 7 but also contributes to SDG 13, which calls for urgent actions to combat climate change (Wang et al., 2023).

As renewable energy sources are expected to play an increasingly prominent role in global energy generation in the coming years (Bielska et al., 2020), the transition away from fossil fuels remains imperative. The widespread consensus holds that fossil fuel combustion is the primary driver of climate change due to greenhouse gas emissions (Dilmore & Zhang, 2018). With global energy demand continuing to rise, exploring strategies to reduce energy dependence while maintaining security and sustainability becomes crucial. Diversifying the energy mix by incorporating various renewable and efficient energy sources is pivotal to achieving the SDG. (Cantarero, 2020).

2. Literature Review

In recent years, the need to adopt integrated approaches to energy policy has gained increasing attention, especially with the introduction of a wide range of policies aimed at transitioning towards a low-carbon energy system (European Commission). As global renewable energy (RE) development accelerates, optimizing the electricity generation mix has become essential. This optimization involves finding a combination of power generation sources that ensures a high level of energy security at affordable costs while considering environmental and economic scenarios (Yu et al., 2019). Given the uncertainties introduced by climate change and shifting weather patterns, assessing the robustness of the energy mix for electricity generation is increasingly important, particularly in US states (Ahmad & Derrible, 2018). The advancements in renewable energy technologies represent a paradigm shift, not only in the technical aspects of energy production but also in the global recognition of the need for sustainable and environmentally friendly energy sources (Nazarov et al., 2024). Despite the rising share of renewable sources, fossil fuels still dominate total energy production; however, the contribution of renewables continues to grow steadily (BP). The importance of renewable sources like wind and solar in reducing CO2 emissions cannot be overstated. These natural sources offer an environmentally sustainable alternative to fossil fuels and should be maximized wherever possible (Gralla et al., 2016). Achieving sustainable development and limiting the depletion of non-renewable resources, along with minimizing harmful emissions, requires a dynamic increase in the share of renewables in final energy production (Stanek et al., 2022).

Forecasting the energy mix in liberalized energy markets remains a challenge, particularly in regions with high shares of variable hydropower or strong interconnections for power import and export (Kisel et al., 2016). Countries are encouraged to increase their reliance on renewable energy and promote environmental protection to reduce CO2 emissions and combat global climate change (Yan et al., 2024). Studies show that renewable energy consumption significantly mitigates carbon emissions over time, especially in emerging economies (Nuta et al., 2024).

The detrimental environmental impact of fossil fuel-based electricity generation, primarily due to greenhouse gas emissions, underscores the need for a shift to cleaner energy sources (Das et al., 2020). Transitioning from a fossil fuel-dominated energy mix to one where renewable source predominate is essential for sustainable economic growth and environmental preservation (Nuta et al., 2024). Examining the impact of GDP, coal, oil, and environmental innovation on carbon emissions reveals that the current energy mix often leads to increased emissions both in the short and long run (Alola et al., 2024).c Energy security remains a crucial objective for national economies, defined as the market economy’s ability to meet current and future fuel and energy needs (Wyman et al., 2015; Ang et al., 2015). Fossil fuels—such as gasoline, natural gas, and coal—are the primary sources of greenhouse gas emissions (Nowotny et al., 2016). Studies emphasize the essential role of renewable energy in significantly lowering carbon emissions and enhancing environmental quality (Khan et al., 2023; Irawan et al., 2023).

One of the most effective ways to diversify the energy mix is by integrating renewable energy sources. Technologies like solar, wind, hydro, geothermal, and biomass offer cleaner alternatives to fossil fuels. Their abundance, low environmental impact, and potential for rapid technological advancement make them attractive options for reducing dependence on conventional energy sources (Bielska et al., 2020). Rapid replacement of non-renewable with renewable energy sources is crucial for ensuring long-term energy security and economic growth (Aziz et al., 2023).

(Sithole et al.,2016) in their study of the UK, the study found that the electricity supply sector accounts for about 27% of the UK's total greenhouse gas emissions. The results from the ‘Energy Optimisation Calculator’ highlight the indispensable role of nuclear, offshore wind, and CCS in achieving the decarbonization target set for 2030. A transition pathway to a near carbon-neutral electricity generation future demonstrated in this paper offers a limited role for unabated fossil fuel generation in the mix. The energy market includes the fuels of electricity generation, electric power plants, electricity transmission and distribution to the end-users, maintenance of the utilities, and a proper energy strategy to regulate the market. Among all the market parameters, energy fuels are regarded as an inevitable commodity because they determinate the associated prime cost of electricity generation. (Islam et al.,2008). (Wang et al.,2023) in their research, ASEAN nations have highlighted that it is critical to switch towards clean energy options for realizing SDG 7, which can help to achieve sustainable growth and reduce environmental pollution. (Bielska et al.,2020) Their study of Poland found that energy from solar and wind power can improve Poland's energy safety. (Kartal,2022) in his study of the top 5 CO_2 emitters of the world have found that coal, oil, and natural gas consumption are the most significant indicators for CO_2 emission generally, the adverse effects of fossil fuels on CO_2 emission in high carbon producing countries. The earth's surface is already experiencing the adverse effects of climate change across the globe, i.e., developing, transition economies, industrialized, emerging, and even developed. (Alola et al.,2024). The largest of the Nordic energy mix is in biomass and waste, used to power and generate electricity. Renewable electricity in the bloc is also derived from hydropower and the rising wind power energy share. Over half of the bloc's energy is CO_2 emission-free. (Alola et al.,2024). (Zahedi et al.,2024) in their study of Iran have highlighted that to drive toward a sustainable future far away from environmental concerns, some measures can be taken, set up an energy mix with Solar and Geothermal. To create a clean and healthy environment, renewable energy must be used. Ensuring access to affordable and reliable energy is a necessity, developed nations have started the modern energy for renewable energy systems, and developing nations have now shifted their focus to renewable energy (Parayitam,2025). (Gralla et al.,2016) study of nine nuclear countries revealed a lack of explicit definitions of sustainability in energy policies.

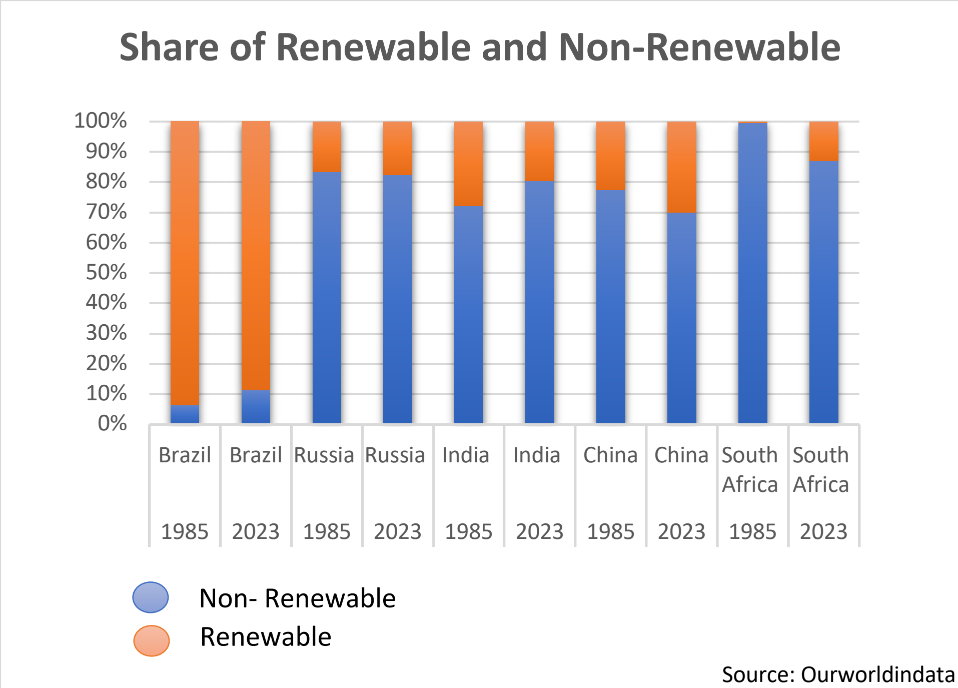

Fig. 1: Share of Renewable and Non-Renewable

Figure 1, shows a comparison of renewable and non-renewable comparison of 1985 and 2023 of BRICS nations. The graph shows how the scenario of renewable and non- renewable energy. Brazil led the renewable share in energy, South Africa has the highest proportion of non-renewable energy share but has shown a little improvement from 1985 to 2023. Russia, India and China still relying on non-renewable sources for energy production, but a shift from non-renewable to renewable can be seen from 1985 to 2023.

3. Data and Research Methodology

This section of this study focuses on the data, data sources and research methodology part.

3.1 Data and Data sources.

For this study, the variables are defined in the table 1. Where dependable variable is CE which is defined as the Total CO2 emission (in million tons). Independent variables are Coal, Gas, Hydro., Solar, Wind, Oil, Nuclear, and other renewables all are measured by their share in the total percentage of electricity.

Table 1. Variables and functions with Description.

Sl No.	Variable	Function	Description
1	Co2 Emission	CE	Total Co2 Emission
2	Non- Renewable Energy Sources	NR	Non- Renewable Share in total % electricity
3	Renewable Energy Sources	R	Renewable Share in total % electricity
4	Urbanisation	U	Urban Population (%)

Source: Authors' Compilation.

Production. The defined independent variables are part of the Energy mix or in simple words are the sources by which we can produce electricity. This includes both renewable energy sources (Wind, Solar, hydro, and Bioenergy) defined by the UN as well as Non-renewable energy sources (Coal, Oil and gas).

The current study has collected the data for BRICS countries from 1985 to 2023. The data source for this study is Ourworldindata and World Development Indicator.

3.2 Model specification

The current study employs an econometric model with the variables. Before starting to apply the econometric model, this study will test the stationary test by employing the panel unit root test. (Haini,2021). The variables employed in Equation 1 are highlighted in Table 1, which also highlights the full model specification.

$$CE = f(NR, R, U) \qquad (1)$$

In the equation 1, CE symbolizes Carbon emission, NR is non-renewable energy sources, R is renewable energy sources and U is urbanisation. Equation 1 can be specified as

$$CE=\beta_0+\beta_1 NR+\beta_2 R+\beta_3 U+\epsilon \qquad (2)$$

More specifically equation 2 can be written as

$$CE_{it}=\beta_0+\beta_1 NR_{it}+\beta_2 R_{it}+\beta_3 U_{it} +\epsilon_{it} \qquad (3)$$

Where i is the country, t is the time and ϵ *is* the error term. $\beta 0$ = Intercept term, β is used to designate the coefficient value.

For this study we have first used the Descriptive analysis of data representing its mean and standard deviation, after that Correlation matrix test, the study used the panel unit root test, to check the stationarity of the time series, the study employed ADF and PP tests to examine the stationarity of variables, then we have used heteroskedasticity test to check whether the variance of the error terms is constant in the regression model. We have used the Hausman test to choose between the FE and RE tests. VIF for multicollinearity and Pesaran CD test for cross-sectional dependency. Finally, the Driscoll-Kraay SEs test due to autocorrelation and the presence of heteroskedasticity in panel data.

Table 2: Test Table Summary.

Test	Purpose	Finding
Hausman test	Choose between FE & RE	$p < 0.01$ → FE preferred
Breusch-Pagan (BP)	Checked heteroskedasticity	$p < 0.001$ → heteroskedasticity present
Breusch–Godfrey Test	Serial correlation in panel errors	$p < 0.001$ → serial correlation present
Pesaran CD test	Cross-sectional dependence	$p = 0.86$ → no cross-sectional dependence

VIF (via OLS)	Multicollinearity	Multicollinearity found between NR and R.

Source: Authors' Compilation.

Table 2, shows the summary of all the tests Hausman test is used to select the model and FE is preferred for the study. Breusch-Pagan (BP), is applied to check the heteroskedasticity and it was found that there is a heteroskedasticity present in the data. Breusch–Godfrey Test and VIF are applied for the correlation and Multicollinearity check and the data has serial correlation as well as Multicollinearity found between NR and R. Pesaran CD test, is applied to check the Cross-sectional dependence between the panel data and no cross-sectional dependency is found.

4.Results and Discussion

This section highlights the results of the study. The tests and their results are described in Table 2. Table 3 shows the Descriptive Statistics; the results of the study show that the Mean value

Table 3: Descriptive Statistics

	CE	NR	R	U
Mean	2034.07	70.93	28.90	53.46
Median	1133.82	82.43	17.59	57.96
Maximum	11902.5	99.46	93.33	75.33
Minimum	180.11	4.59	0.083	22.87
Std. Dev.	2676.69	30.18	29.93	17.26

Source: Authors' Compilation.

Of CE, NR, R, and U are 2034.07, 70.93,28.90 and 53.46 respectively. Whereas the range for CE is 11902.5 to 180.11 which shows the variation of emission in different countries. The standard deviations for CE (2,676.69), NR (30.18), and R (29.93) highlight the large variability in emissions and energy sources both in NR and R.

Table 4 represents the correlation coefficients between carbon emissions (CE), natural resource

Table 4: Correlation Matrix

	CE	NR	R	U
CE	1			
NR	0.191	1		
R	-0.178	-0.999	1	
U	-0.066	-0.208	0.210	1

Source: Authors' Compilation.

use (NR), renewable energy share (R), and urbanization (U). The correlation matrix shows CE has a weak correlation with NR, R, and U. There is a strong negative correlation between NR and R, which shows the Energy Substitution Theory, which posits that as the new technology grows economies substitute renewable sources for non-renewables.

Table 5 shows the panel unit root tests for the variables of the study. The Levin-Lin-Chu (LLC),

Table 5: Unit root tests.

	LLC	ADF	PP
CE	0.0010	0	0
NR	0	0	0
R	0	0	0
U	0	0	0

Source: Authors' Compilation.

Augmented Dickey-Fuller (ADF), and Phillips-Perron (PP) tests were applied to check the stationarity. The H0 is the series is non-stationary and H1 is the series is stationary and as all the variables are 0 or near to 0, this indicates stationarity at level at conventional significance levels.

Table 6 shows the result of the Hausman test, which is used to determine whether a Fixed Effects (FE) or Random Effect (RE) model is appropriate for the panel data. H0 is the preferred.

Table 6: Hausman Test

Test Statistic	Degrees of Freedom	p-value	Decision
16.445	3	0.0009	Preferred FE model as RE Model is inconsistent

Source: Authors' Compilation.

model is Random Effects (RE) and H1 is the preferred model is Fixed Effects (FE) or RE is inconsistent. As the p-value is less than 0.05, This result rejects the null hypothesis of no correlation between individual effects and regressors, indicating that the random effects model is inconsistent. Therefore, the fixed effects model is preferred for the analysis.

Table 7 shows the results of the multiple tests of cross-sectional dependence. The Breusch-Pagan LM (statistic = 226.49, $p < 0.001$) and Pesaran Scaled LM (statistic = 48.41, $p < 0.001$)

Table 7: Cross-sectional dependency test

Test	Statistic	Degree of Freedom	P- Value
Breusch-Pagan LM	226.49	10	0.000
Pesaran Scaled LM	48.41		0.000
Pesaran CD	-0.4710		0.6376

Source: Authors' Compilation.

indicated significant cross-sectional dependence among the panel units, and the Pesaran CD test (statistic = -0.471, $p = 0.6376$) did not detect significant dependence. This mixed evidence suggests potential cross-sectional correlations.

Table 8: Heteroskedastic test

	Period	Cross-Section
F-statistic	37.238	290.02
Prob(F-statistic)	0.000	0.000

Durbin-Watson stat	0.07018	0.2663

Source: Authors' Compilation.

Table 8 shows the heteroscedasticity results, and shows that there is a significant heteroskedasticity across periods (F = 37.238, p < 0.001) and cross-sections (F = 290.02, p < 0.001). The low Durbin-Watson stat reflects the presence of correlation in residuals.

Table 9 shows the results of the Fixed Effects model with two robust methods, Arellano robust standard errors, and Driscoll-Kraay standard errors, to address the heteroskedasticity & autocorrelation, and cross-sectional dependence respectively. Researchers have used the Hausman test to test the validity of the RE model, which indicated that the RE mode is inconsistent (highlighted in Table 2). Due to the inconsistency of the RE model, researchers preferred the FE model for the study. The FE model can address the heterogeneity, cross-sectional dependence, and correlation problems. The study has also estimated robust standard error corrections.

The results of this study show a significant negative relationship of NR and R with CE, across all the models. The results of FE show that NR and R both have negative effect on CE (-632.39, p < 0.001) and R (-586.46, p < 0.001) respectively. On the other hand, the coefficient of U is

Table 9: Model Estimations: Results (Dept. Variable: CE)

Test	Fixed Effects	Fixed Effects (Arellano robust SE)	Fixed Effects (Driscoll-Kraay SE)
NR	-632.39*** (0.0001)	-632.39*** (0.0002)	-632.39* (0.014)
R	-586.46*** (0.0001)	-586.46** (0.0031)	-586.46* (0.026)
U	221.55*** (0.0001)	221.55*** (0.0001)	221.55*** (0.0001)
R-squared	0.77	0.77	0.77
Adjusted R-squared	0.76	0.76	0.76

Source: Authors' Compilation.
*Note: Significance levels: *** p < 0.001, ** p < 0.01, * p < 0.05*

positive and highly significant (+221.55, p < 0.001). This shows that urbanization is increasing the CE. The significant results show that both renewable and non-renewable energy have a negative effect on carbon emissions. These results suggest that both renewable and non-renewable energy policies play a significant role in shaping national energy outcomes.

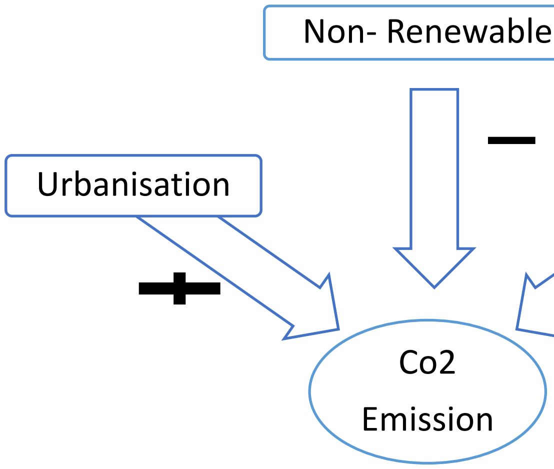

Fig. 2 Graphical abstract of the main results.

5.Conclusion & Policy Implications

This study examined the impact of energy mix both renewable and non-renewable (Coal, nuclear, hydro, gas, Solar, Wind, and other renewable energy sources) percentage in electricity on Carbon emission (CE). To investigate the interdependencies over the long run, the time frame is from 1985 to 2023 using a range of econometric techniques in BRICS countries. The research has used the ADF and PP unit root tests to establish the series' integration order. The study has used Fixed Effects (FE) and extends to robust standard error corrections such as Arellano robust standard errors and Driscoll-Kraay standard errors.

Based on the empirical evidence we can say that both renewable and non-renewable energy sources have negative and significant effects on CO2 emission. The study also revealed that the share of renewable energy sources is increasing in BRICS nations. Penetration of renewable energy sources such as Solar and wind is increasing over time. The coefficient is high for both energy sources. This shows that both policies whether it is for renewable or non-renewable have an impact on the co2 emissions.

Countries all over the world are facing the challenge to combat emissions as the energy sector is one of the most polluting sectors. A Universal policy and guidelines are needed, and common goals need to be set, there are some significant steps taken by world agencies and groups around the world but still, the challenge of emissions remains the same. With this study, we can suggest some policy solutions to the developing and emerging countries. We have studied BRICS as one of the strongest groups of emerging economies in terms of GDP, Population, and area. Some of the suggestions are: -

1. The share of coal in the energy mix is still a persistent problem for developing countries. BRICS with high growth rate and most of the countries around the world still rely on

NR for energy sources. Governments can push for cleaner fuels and can make separate departments for clean energy, so we can tackle the problem of emissions from NR.

2. Low investment in the Renewable energy sector. A low investment for RE is hindering the process of shifting from RE to non-renewable energy sector in BRICS countries such as China and India which are also the top 5 economies of the world still struggling to divert the funds for RE from fossil fuels.
3. Green finance such as green bonds and carbon tax can help to generate funds for renewable energy and a transition to green economic growth. As suggested by the study of (Desai & Patel, 2025), green finance can help in advancing sustainability.
4. Long-term commitments. Long-term commitments with already existing projects in developing countries are also hindering the process of shift from RE to NRE.
5. Countries such as South Africa, India, and China can work on solar power generation countries such as Brazil can rely on Wind energy for clean fuel.
6. CABM can be a solution for emission control, proposed by the EU in 2021 and adopted in 2023. The study of (Lestan et al.,2023) suggested that the integration of CBAM has a very minimal role to play in creating a carbon-neutral economy.
7. The role of government is also very crucial in climate change as suggested by the study of (Tewary et al.,2024) Governments can take climate action by embedding both mitigation and adaptation measures within their fiscal frameworks. It can encourage stakeholders to consider the climate impacts of their decisions. Such efforts can be effectively implemented through carefully designed and strategic interventions.

Some previous studies have also suggested some solutions for RE; more investments could be channelled towards green energy R&D and pricing strategies could be revisited to make green energy more affordable and limit the usage of conventional energy by imposing taxes. (Wang et al.,2023). As the costs of renewable technologies continue to fall, the economic argument for renewables over fossil fuels will become indisputable. The shift towards a more sustainable energy sector will also be influenced by policy and market forces (Nazarov et al.,2024).

This study provides some insightful outcomes for BRICS nations; it also has some limitations. The other studies can include more developing countries, with the more time frame the results can be changed, as countries start shifting towards the RE, and coming years can provide more insightful results of RE on CE. This study only focused on CO2 emission; other studies can take emissions from electricity only. Additionally, employing sophisticated econometric methods for individual city or country comparisons and cross-study analysis could enhance understanding in this field.

6.Acknowledgment

We would like to acknowledge Gautam Buddha University for providing us with constant research support and a working environment.

7.Declaration of conflicting interest

The author(s) declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

8.Funding statement

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

- Abban, O.J., Xing, Y.H., Nutaˇ, A.C., Nuta ˇ, F.M., Borah, P.S., Ofori, C., Jing, Y.J., 2023. Policies for carbon-zero targets: Examining the spillover effects of renewable energy and patent applications on environmental quality in Europe. Energy Econ. 126, 106954.
- Ahmad, N., & Derrible, S. (2018). An information theory-based robustness analysis of energy mix in US States. Energy Policy, 120, 167-174.
- Alola, A. A., Bekun, F. V., Obekpa, H. O., & Adebayo, T. S. (2024). Explaining the environmental efficiency capability of energy mix innovation among the Nordic countries. Energy Reports, 11, 233-239.
- Al-Mulali, U., Fereidouni, H. G., Lee, J. Y., & Sab, C. N. B. C. 2013. Exploring the relationship between urbanization, energy consumption, and CO2 emission in MENA countries. Renewable and Sustainable Energy Reviews, 23, 107-112.
- Ang, B.W.; Choon, W.L.; Ng, T.S. Energy security: Definitions, dimensions and indexes. Renew. Sustain. Energy Rev. 2015, 42, 1077–1093.
- Aziz, G., Sarwar, S., Waheed, R., & Khan, M. S. (2024, August). The significance of renewable energy, globalization, and agriculture on sustainable economic growth and green environment: Metaphorically, a two-sided blade. In Natural resources forum (Vol. 48, No. 3, pp. 763-783). Oxford, UK: Blackwell Publishing Ltd.
- Baul, T. K., Datta, D., & Alam, A. (2018). A comparative study on household level energy consumption and related emissions from renewable (biomass) and non-renewable energy sources in Bangladesh. Energy Policy, 114, 598-608.
- British Petroleum, Energy Data, https://www.bp.com/en/global/corporate/ energy-economics/statistical-review-of-world-energy/downloads.html
- Cantarero, M. M. V. (2020). Of renewable energy, energy democracy, and sustainable development: A roadmap to accelerate the energy transition in developing countries. Energy Research & Social Science, 70, 101716.
- Das, N. K., Chakrabartty, J., Dey, M., Gupta, A. S., & Matin, M. A. (2020). Present energy scenario and future energy mix of Bangladesh. Energy Strategy Reviews, 32, 100576.
- Desai, R., & Patel, S. (2025). Analysing the Research Development in Green Finance: Performance Analysis and Directions for Future Research. *FIIB Business Review*, 23197145241306838.
- Díaz, A., Marrero, G. A., Puch, L. A., & Rodríguez, J. (2019). Economic growth, energy intensity and the energy mix. Energy Economics, 81, 1056-1077.
- Dilanchiev, A., Sharif, A., Ayad, H., & Nuta, A. C. (2024). The interaction between remittance, FDI, renewable energy, and environmental quality: a panel data analysis for the top remittance-receiving countries. Environmental Science and Pollution Research, 31(10), 14912-14926.

- Dilmore, R., & Zhang, L. (2018).Greenhouse gases and their role in climate change. Greenhouse Gases and Clay Minerals: Enlightening Down-to-Earth Road Map to Basic Science of Clay-Greenhouse Gas Interfaces, pp. 15–32.
- Energy governance in the context of energy service security: A qualitative assessment of the electricity system in Bangladesh.
- European Commission. A 2030 framework for climate and energy policies, COM (2013) 169 final. Brussels, 27.3.2013; 2013.
- Gralla, F., John, B., Abson, D. J., Møller, A. P., Bickel, M., Lang, D. J., & von Wehrden, H. (2016). The role of sustainability in nuclear energy plans—What do national energy strategies tell us?. Energy research & social science, 22, 94-106.
- Haini, H. 2021. Examining the impact of ICT, human capital and carbon emissions: Evidence from the ASEAN economies. International Economics, 166, 116-125.
- Ikevuje, A. H., Kwakye, J. M., Ekechukwu, D. E., & Benjamin, O. (2024). Optimizing the energy mix: Strategies for reducing energy dependence. Open Access Research Journal of Multidisciplinary Studies, 8(01), 094-104.
- Irawan, C. A., Jones, D., Hofman, P. S., & Zhang, L. (2023). Integrated strategic energy mix and energy generation planning with multiple sustainability criteria and hierarchical stakeholders. European Journal of Operational Research, 308(2), 864-883.
- Kåberger, T. (2018). Progress of renewable electricity replacing fossil fuels. Global Energy Interconnection, 1(1), 48-52.
- Kartal, M. T. (2022). The role of consumption of energy, fossil sources, nuclear energy, and renewable energy on environmental degradation in top-five carbon producing countries. Renewable Energy, 184, 871-880.
- Kevin, L. O. (2017). Asian energy challenges in the Asian century. Journal of Asian Energy Studies, 1(1), 1-6.
- Khan, S. A. R., Zia-Ul-Haq, H. M., Ponce, P., & Janjua, L. (2023). Re-investigating the impact of non-renewable and renewable energy on environmental quality: A roadmap towards sustainable development. Resources Policy, 81, 103411.
- Kisel, E., Hamburg, A., Härm, M., Leppiman, A., & Ots, M. (2016). Concept for energy security matrix. Energy Policy, 95, 1-9.
- Lestan, F., Kabiraj, S., & George, B. (2023). Preliminary impact assessment of carbon border adjustment mechanism on Russian economy. *FIIB Business Review*, 23197145221143033.
- M. Rofiqul Islam, M. Rabiul Islam, M. Rafiqul Alam Beg, Renewable energy resources and technologies practice in Bangladesh, Renew. Sustain. Energy Rev. 12 (2) (February 2008) 299–343.
- Marks-Bielska, R., Bielski, S., Pik, K., & Kurowska, K. (2020). The importance of renewable energy sources in Poland's energy mix. Energies, 13(18), 4624.
- Molazadeh, M., Ahmadzadeh, H., Pourianfar, H. R., Lyon, S., & Rampelotto, P. H. (2019). The use of microalgae for coupling wastewater treatment with CO2 biofixation. Frontiers in Bioengineering and Biotechnology, 7, 42.
- Nazarov, A., Sulimin, V., & Shvedov, V. (2024). Renewable energy sources: global implementation experience. In E3S Web of Conferences (Vol. 474, p. 01030). EDP Sciences.

- Nowotny, J., Hoshino, T., Dodson, J., Atanacio, A. J., Ionescu, M., Peterson, V., ... & Alim, M. A. (2016). Towards sustainable energy. Generation of hydrogen fuel using nuclear energy. International Journal of Hydrogen Energy, 41(30), 12812-12825.
- Nuţă, F. M., Sharafat, A., Abban, O. J., Khan, I., Irfan, M., Nuţă, A. C., ... & Asghar, M. (2024). The relationship among urbanization, economic growth, renewable energy consumption, and environmental degradation: A comparative view of European and Asian emerging economies. Gondwana Research, 128, 325-339.
- Parayitam, S. (2025). Why Going 'Green'has Become Order of the Day? Sustainability Consciousness. *FIIB Business Review*, *14*(1), 7-11.
- Rosales-Calderon, O., & Arantes, V. (2019). A review on commercial-scale high-value products that can be produced alongside cellulosic ethanol. Biotechnology for biofuels, 12(1), 240.
- Signe, L., Mbaye, A. A. (2022). Renewing global climate change action for fragile and developing countries (WP#179; Global Economy and Development at Brookings).
- Sithole, H., Cockerill, T. T., Hughes, K. J., Ingham, D. B., Ma, L., Porter, R. T. J., & Pourkashanian, M. (2016). Developing an optimal electricity generation mix for the UK 2050 future. Energy, 100, 363-373.
- Stanek, W. (2022). Thermo-Ecological Cost (TEC)–comparison of energy-ecological efficiency of renewable and non-renewable energy technologies. Energy, 261, 125152.
- Stanek, W. (2022). Thermo-Ecological Cost (TEC)–comparison of energy-ecological efficiency of renewable and non-renewable energy technologies. Energy, 261, 125152.
- Talib, M. N. A., Hashmi, S. H., Aamir, M., & Khan, M. A. 2022. Testing non-linear effect of urbanization on environmental degradation: Cross-country evidence. Frontiers in Environmental Science, 10, 971394.
- Tewary, T., Jain, V., Gopalakrishnan, B. N., & Anand, A. (2024). Climate mitigation investments: An economic and policy outlook. *FIIB Business Review*, *13*(2), 220-231.
- Tudorică, B. G., Bucur, C., Panait, M., Oprea, S. V., & Bâra, A. (2024). Energetic Equilibrium: Optimizing renewable and non-renewable energy sources via particle swarm optimization. Utilities Policy, 87, 101722.
- UN, 2021. UNITED nations, department of economic and social affairs sustainable development, the 17 goals. Available at: https://sdgs.un.org/goals.
- United Nations, Draft Outcome Document of the United Nations Summit for the Adoption of the Post-2015 Development, 2015.
- Wang, Z., Chandavuth, Y., Zhang, B., Ahmed, Z., & Ahmad, M. (2023). Environmental degradation, renewable energy, and economic growth nexus: Assessing the role of financial and political risks?. Journal of Environmental Management, 325, 116678.
- Wyman, C. E., & Dale, B. E. (2015). Producing biofuels via the sugar platform. Chem. Eng. Prog, 111(3), 45-57.
- Yan, X., Abdalla, A. A., Zhu, G., Uslu, Y. D., Mohamed, M. A. A., Muhammad, T., & Shabbir, M. S. (2024). Does natural resources matter? Nexus among renewable energy policies, technological innovation, environmental protection, and economic growth. Energy Strategy Reviews, 51, 101272.
- Yu, S., Zhou, S., Zheng, S., Li, Z., & Liu, L. (2019). Developing an optimal renewable electricity generation mix for China using a fuzzy multi-objective approach. Renewable Energy, 139, 1086-1098.

- Zahedi, R., Sadeghitabar, E., Khazaee, M., Faryadras, R., & Ahmadi, A. (2024). Potentiometry of wind, solar and geothermal energy resources and their future perspectives in Iran. Environment, Development and Sustainability, 1-27.
- Zaman, R., & Brudermann, T. (2018). Energy governance in the context of energy service security: A qualitative assessment of the electricity system in Bangladesh. Applied Energy, 223, 443-456.
- Zhang, X., Ji, C.E., Zhang, H., Wei, Y., Jin, J., 2023. On the role of the digital industry in reshaping urban economic structure: the Case of Hangzhou, China. J. Econ. Analysis 2 (4), 123–139.
- https://www.un.org/en/climatechange/what-is-renewable-energy