ISSN: 2688-9323

Study on the Effect of Renewable Energy Power Generation on Carbon Emissions

Yuanyuan Cai

Southwest Petroleum University, Chengdu, China

Abstract

In the face of the dual challenges of global warming and sustainable development, cutting carbon emissions has emerged as a critical challenge for industries globally and in China. China, among the world's top carbon-emitting nations, has committed to peaking CO_2 emissions by 2030 and working toward carbon neutrality by 2060. In this context, the power industry as the main area of carbon emissions, its low-carbon transformation is particularly urgent. Although China 's power industry is Characterized by a predominance of coal-fired generation capacity, the progress in renewable power generation technologies has shown remarkable results in reducing carbon emissions. Based on the panel data of 30 provinces (municipalities and autonomous regions) in China from 2008 to 2022, this study uses a two-way fixed effect model to deeply explore the direct impact of renewable energy technologies' capacity on lower atmospheric CO_2 levels and its mechanism. The findings reveal that electricity generation from renewable sources substantially contributes to carbon emission mitigation, which provides a scientific basis for formulating and optimizing relevant policies, aiming at accelerating the expansion of clean electricity production and achieve measurable reductions in carbon output per economic unit.

Keywords

Carbon Emission Reduction; Renewable Energy Generation; Low Carbon Transformation of Power Industry; Fixed Effect Model; Policy Optimization.

1. Introduction

At present, the world 's industrialization process is accelerating. Extensive reliance on fossil fuels and substantial emissions of greenhouse gases, particularly carbon dioxide, have significantly accelerated global warming. The natural environment is facing a serious threat, which has greatly affected the sustainable development of the world [1]. In order to cope with this serious challenge, many countries and regions around the world Ratified the Kyoto Protocol in the beginning of the 20 th century, and set different levels of carbon emission reduction targets. Being one of the planet's major sources of carbon emissions, China has made binding commitments to cap its emissions by 2030 and fully decarbonize by 2060, which implies that all industries need to significantly reduce carbon emissions.

The Chinese power industry continues to rely predominantly on coal combustion for electricity production, and its power generation ranks first in the world. In 2023, China 's total power generation is 945.644 billion kWh, of which thermal power accounts for about 66.3 %, hydropower accounts for about 13.6 %, nuclear power accounts for about 4.6 %, wind power accounts for about 9.4 %, and solar power accounts for about 6.2 % [2]. Therefore, as a primary contributor to China's carbon emissions, it is particularly urgent and important to realize the low-carbon transition in power generation. In recent years, China has achieved remarkable results in carbon dioxide pollution control in electricity infrastructure by continuously enhancing the power generation capacity of renewable energy. For example, compared with

2018, in 2023, China's thermal power sector is projected to achieve a 2.38% reduction in CO_2 emission intensity, while the electricity industry as a whole will see an 8.78% decrease in carbon emission intensity. [3]. What is the internal mechanism of renewable energy power generation affecting carbon emissions? To what extent do energy portfolio optimization and consumption efficiency enhancements drive this transformation process? Delineating the dynamic interplay of renewables-based electricity infrastructure and emission reduction thresholds is pivotal to refining carbon neutrality pathways, and to provide a new perspective and analytical framework for energy transformation and environmental policy formulation. It provides strategic guidance for China to achieve the " double carbon " goal, and reveals the specific mechanism of renewable energy power generation to reduce carbon emissions, which has important practical value for promoting environmental protection and energy transformation.

2. Mechanistic Study on Renewable Energy Generation's Decarbonization Effects

2.1. Testable Hypotheses on Renewable Energy's Direct Emission Suppression Effects

In terms of externality theory, inappropriate resources production and consumption activities will lead to the deviation of resource allocation from the optimal state, and then produce negative external effects, which is usually manifested as excessive emissions of greenhouse gases [4]. When we look at the whole life cycle of energy extraction, transportation, conversion and use, renewable energy systems show more significant environmental advantages than traditional fossil fuels, and their carbon emissions are significantly reduced. In the power industry, renewable energy almost does not involve combustion in the power generation process, conserving blue carbon ecosystems from the source. This shows that renewable energy power generation has great potential in conserving blue carbon ecosystems. Building upon the preceding analysis, this study establishes:

Hypothesis 1: Green energy power generation yields quantifiable decreases in carbon output.

2.2. The Indirect Effect and Hypothesis of Green Energy Power Generation on Carbon Emissions

2.2.1. Indirect Effects of Energy Structure

The power generation mode of renewable energy helps to adjust the energy structure, thereby reducing greenhouse gas emissions. The traditional energy system is mainly dependent on carbon-intensive energy carriers including anthracite and distillate fuels. These energy sources are not only vulnerable to market fluctuations and geopolitical interference, resulting in instability of energy supply, but also the greenhouse gases and air pollution generated during their combustion pose a significant burden on the environment. With the continuous advancement of renewable energy power technology, clean energy is gradually becoming a key part of the energy structure [5]. In the field of electricity, the wide application of renewable energy can reduce the dependence on fossil energy and promote the transformation of energy structure to a more environmentally friendly and diversified direction. Large-scale integration of renewables into electrical grids substantially decreases reliance on carbon-intensive energy sources, driving structural transformations in the energy sector toward enhanced environmental sustainability and supply diversity [6]. Therefore, the advancement of clean power generation constitutes a critical pathway toward low-carbon energy transitions and climate change mitigation. Building upon the preceding analysis, this study establishes:

Hypothesis 2: Renewable penetration drives carbon intensity reduction via optimized generation portfolios.

ISSN: 2688-9323

2.2.2. The Secondary Impacts of Energy Use Efficiency

In the field of power generation, the promotion and use of renewable energy can help reduce energy consumption and control carbon emissions. First of all, Relative to traditional hydrocarbon-based energy, renewable energy systems usually use more advanced technologies and equipment, which makes the whole process from production, use to recovery can effectively reduce energy consumption, thereby reducing energy consumption intensity [7]. For instance, in the field of solar photovoltaics, the deployment of high-efficiency photovoltaic modules coupled with advanced power electronics enhances energy conversion performance. Secondly, the development of renewable energy has promoted the innovation and progress of clean energy technology, so that more energy services can be provided under the same energy supply conditions. This dual approach simultaneously expands the energy portfolio diversity while decreasing the energy-GDP ratio. In addition, reducing the intensity of energy consumption means that while maintaining the same or higher GDP output level, less energy input is required, that is, more GDP can be generated when the same energy is consumed [8]. Building upon the preceding examination, this study advances the following propositions:

Hypothesis 3: Renewable energy power generation can reduce carbon emissions by reducing energy consumption intensity.

3. Research and design of Assessing the Carbon Abatement Potential of Renewable Electricity Systems

3.1. Model Design

3.1.1. Benchmark Regression Model

To examine the causal relationship between renewable energy generation and carbon emissions, we establish the following baseline regression model:

$$CE_{it} = \alpha_0 + \alpha_1 REG_{it} + \alpha_n X_{it} + \lambda_i + \theta_t + \varepsilon_{it} \tag{1}$$

In formula (1), CEit is the carbon emission level of i province in t year, REGit represents the renewable energy generation level of i province in t year, Xit is a series of control variables, λi and θt are individual and time fixed effects respectively, εit is a random disturbance term.

3.1.2. Mediating Effect Model

To investigate the transmission mechanism through which renewable power generation affects carbon emissions, we develop the following mediation analysis framework:

$$CE_{it} = \alpha_0 + \alpha_1 REG_{it} + \alpha_n X_{it} + \lambda_i + \theta_t + \varepsilon_{it} \tag{2}$$

$$M_{it} = \beta_0 + \beta_1 REG_{it} + \beta_n X_{it} + \lambda_i + \theta_t + \varepsilon_{it} \tag{3}$$

$$CE_{it} = \eta_0 + \eta_1 REG_{it} + \eta_2 M_{it} + \eta_n X_{it} + \lambda_i + \theta_t + \varepsilon_{it} \tag{4}$$

In Equations (3) and (4), Mit is the mechanism variable, including energy structure and energy consumption intensity, and all remaining variables retain their original specifications as defined in Equation (2).

ISSN: 2688-9323

3.2. Indicator Selection

3.2.1. Explained Variables

Carbon emissions (CE) are quantified using emission intensity, calculated as total CO_2 emissions divided by nominal GDP. Total CO_2 emissions are computed by applying emission factors to the consumption of coal, coke, crude oil, gasoline, kerosene, diesel, fuel oil, LPG and natural gas. The detailed computation follows Equation (5). Energy consumption data originate from the China Energy Statistics Yearbook, while nominal GDP figures come from the China Statistical Yearbook.

$$CO_{2it} = \sum E_{ijt} \times \gamma_j \tag{5}$$

In Equation (5), CO_{2ti} denotes aggregate carbon emissions, E_{tij} represents province-level consumption of energy type j, and γ_j signifies the corresponding emission factor for energy j.

3.2.2. Core Explanatory Variables

To measure Renewable Energy Development (REG), this study adopts the established approach of using renewable power generation's share in total electricity production [9]. Data on both renewable and total electricity generation originate from the China Energy Statistics Yearbook and China Electricity Yearbook.

3.2.3. Intermediary Variables

Consistent with prior research methodologies, energy structure (Struc) is operationalized as coal consumption's share in total energy use. Energy intensity (Inten) is quantified by energy use per GDP unit. Coal and energy consumption data derive from the China Energy Statistics Yearbook, while GDP figures originate from the China Statistical Yearbook.

3.2.4. Control Variables

To more precisely assess the net impact of renewable energy on carbon emissions, this study follows established research protocols by incorporating five control variables: economic development level (GDP), openness degree (Open), government intervention extent (Gover), industrial structure upgrading (Indus), and innovation capacity (Innov) [10]. All control variable data originate from the China Statistical Yearbook, with detailed variable definitions and measurements presented in Table 1.

Table 1. Variable description and definition

variable type	variable symbol	Variable name	variable definition
variable being explained	CE	carbon emission	Carbon intensity of GDP
Core explanatory variables	REG	renewable energy generation	Proportion of renewable energy generation
Mechanism variables	Struc	energy of formation	Coal-to-total energy consumption ratio
	Inten	energy-GDP ratio	Energy intensity of GDP
	GDP	economic development level	per capita GDP
	Open	degree of opening to the outside world	(Total Cross-border goods movement * USD/ RMB exchange rate)/GDP
control variable	Gover	Level of government intervention	Government spending-to-GDP ratio
	Indus	upgrading of an industrial structure	Tertiary-to-secondary industry value-added ratio
	Innov	innovation level	R&D expenditure internal expenditure/ regional GDP

ISSN: 2688-9323

3.3. Sample Selection

This study utilizes annual provincial-level panel data spanning 2008-2022 across China's 30 administrative regions to investigate the relationship between renewable energy generation capacity and carbon emission efficiency. Owing to critical data deficiencies, Tibet, Hong Kong, Macao and Taiwan are excluded from the sample. The software used for model regression was Stata17.

4. Empirical Findings on Renewable Energy's Decarbonization Effects

4.1. Descriptive Statistics and Correlation Analysis

The summary statistics for all variables are reported in Table 2. The difference between renewable energy power generation and carbon emission levels is large, indicating that carbon emission reduction still has great potential. Pairwise Pearson correlations between variables are shown in Table 3. The results demonstrate a strongly negative association (significant at $\alpha=0.01$) linking renewable electricity generation with reduced carbon emissions, which preliminarily verifies the negative relationship between the two.

Table 2. Descriptive statistics

Variables	N	mean	sd	min	max
CE	450	2.679	2.044	0.227	9.338
REG	450	0.255	0.242	0.000366	0.918
GDP	450	5.254	3.082	0.970	19.00
Indus	450	1.286	0.722	0.527	5.283
Gover	450	0.239	0.0998	0.0874	0.643
Innov	450	0.0171	0.0113	0.00227	0.0684
Open	450	0.284	0.307	0.00763	1.597
Inten	450	0.876	0.528	0.166	2.834
Struc	450	0.392	0.155	0.00564	0.724

Table 3. Correlation analysis

Variables	(CE)	(REG)	(Struc)	(Inten)	(GDP)	(Open)	(Gover)	(Indus)	(Innov)
CE	1.000								
REG	-0.261***	1.000							
Struc	0.505***	0.023	1.000						
Inten	0.898***	-0.025	0.484***	1.000					
GDP	-0.423***	0.120**	-0.532***	-0.444***	1.000				
Open	-0.382***	-0.378***	-0.561***	-0.395***	0.309***	1.000			
Gover	0.311***	0.421***	-0.013	0.488***	0.039	-0.409***	1.000		
Indus	-0.308***	-0.067	-0.612***	-0.324***	0.619***	0.432***	0.124***	1.000	
Innov	-0.435***	-0.332***	-0.529***	-0.486***	0.586***	0.715***	-0.410***	0.613***	1.000
*** p<0.01, ** p<0.05, * p<0.1									

4.2. Multicollinearity Test

This study conducts additional multicollinearity diagnostics using variance inflation factor (VIF) analysis. The VIF diagnostic results presented in Table 4 reveal that all variables exhibit tolerance levels within acceptable limits (VIF range: 1.62-4.16), substantially below the

ISSN: 2688-9323

conventional threshold of 10. This confirms the absence of problematic multicollinearity that could distort our regression estimates.

Table 4. Variance inflation factor test

Variables	VIF	1/VIF
REG	1.62	0.616
Struc	2.52	0.396
Inten	2.50	0.399
GDP	2.40	0.417
Open	2.74	0.365
Gover	3.05	0.328
Indus	2.66	0.377
Innov	4.16	0.241
Mean VIF	2.71	

4.3. Baseline Regression Analysis

4.3.1. Hausman Test

The Hausman test findings are displayed in Table 5. When the computed p-value falls below the 1% significance threshold, we reject the null hypothesis in favor of the fixed effects specification.

Table 5. Hausman test

Variables	CE
REG	-2.734***
	(0.333)
GDP	-0.246***
	(0.0188)
Open	-1.607***
	(0.238)
Gover	-3.575***
	(0.677)
Indus	0.0354
	(0.118)
Innov	6.793
	(8.671)
Constant	5.816***
	(0.351)
Observations	450
Number of province	30
Prob>chi2	0.000762

Note: Parentheses contain standard error estimates. Asterisks indicate statistical significance (*p<0.1, **p<0.05, ***p<0.01), following the same convention throughout subsequent tables.

4.3.2. F Test

To determine the most appropriate model specification between two-way and one-way fixed effects approaches, this study employs an F-test for comparative model selection. Statistical significance of time fixed effects is confirmed when the p-value falls below the 1% threshold, leading to rejection of the null hypothesis. The analysis justifies the adoption of a two-way fixed effects framework.

4.3.3. Benchmark Regression Analysis

This study employs a two-way fixed effects model selected through Hausman and F tests, implementing a stepwise regression approach with progressively added control variables. As demonstrated in Table 6, the negative coefficient for renewable energy generation's impact on carbon emissions remains statistically significant ($p<0.01$) across all model specifications. The final specification (Column 6) yields a coefficient of -2.728 for REG, significant at the 1% level, confirming renewable energy's substantial emission reduction effect and thereby validating Hypothesis 1. The robustness of these findings throughout the sequential modeling process reinforces the conclusion that renewable power generation significantly curbs carbon emissions. These consistent results across alternative model specifications provide compelling evidence supporting our primary hypothesis regarding renewable energy's decarbonization potential.

Table 6. Benchmark regression results

	(1)	(2)	(3)	(4)	(5)	(6)
	FE1	FE2	FE3	FE4	FE5	FE6
Variable	CE	CE	CE	CE	CE	CE
REG	-6.535***	-3.279***	-3.346***	-2.702***	-2.746***	-2.728***
	(0.778)	(0.778)	(0.634)	(0.589)	(0.616)	(0.616)
GDP		-0.204***	-0.233***	-0.232***	-0.240***	-0.256***
		(0.0432)	(0.0342)	(0.0312)	(0.0355)	(0.0438)
Open			-1.359***	-1.579***	-1.500***	-1.445***
			(0.319)	(0.284)	(0.296)	(0.315)
Gover				-4.117***	-4.303***	-4.214***
				(1.236)	(1.272)	(1.324)
Indus					0.110	0.111
					(0.184)	(0.183)
Innov						13.84
						(14.87)
Constant	4.345***	4.587***	5.141***	6.017***	5.952***	5.757***
	(0.198)	(0.191)	(0.247)	(0.241)	(0.230)	(0.377)
Observations	450	450	450	450	450	450
R-squared	0.443	0.655	0.680	0.709	0.709	0.711
Number of province	30	30	30	30	30	30

4.4. Endogenous Treatment and Robustness Test

For the purpose of further verify the main research conclusions, this paper adopts the following measures for endogeneity correction and specification testing. In terms of endogeneity, this paper uses three methods to deal with. One is to lag the core explanatory variable REG by one period; additionally, we instrument the key independent variable REG using its temporal lag and implement a two-stage least squares estimation procedure. The third is to use the system GMM to re-return. In terms of robustness test, this paper also uses three methods to test. The analysis employs dual verification strategies: utilization of gross renewable generation as an alternative dependent variable, followed by sample restriction through the elimination of special administrative regions. the third is to add control variables urbanization (UR). A series

ISSN: 2688-9323

of test results show that renewable energy power generation can always inhibit carbon emissions, which verifies the robustness of the research conclusions.

4.5. Mediation Effect Test

Building upon the theoretical framework, this study empirically examines the dual mechanisms through which renewable energy generation contributes to carbon reduction - namely energy structure optimization and energy intensity reduction. Following established methodological approaches, we operationalize these pathways as mediating variables and employ a sequential regression analysis to test their effects. The mediation analysis results, presented in Tables 14 and 15, provide systematic evidence supporting these hypothesized transmission channels. The empirical verification confirms that renewable energy deployment achieves emission reductions both directly and indirectly through these structural and efficiency improvements in the energy system.

4.5.1. Energy Structure Struc as an Intermediary Variable

The mediation analysis employs a two-way fixed effects model to ensure robust estimation results. The baseline regression confirms a statistically significant negative relationship between renewable energy generation and carbon emissions at the 1% level ($p<0.01$). Subsequent analysis reveals that renewable power development significantly improves energy structure (coefficient = -0.0195, $p<0.01$), while structural deterioration conversely increases emissions (coefficient = 3.291, $p<0.01$). The comparative reduction in absolute coefficient values between models indicates partial mediation, demonstrating that renewable energy's emission reduction effect operates partially through energy structure optimization. These results confirm the mediating role of structural transformation in renewable energy's decarbonization pathway while maintaining direct negative impacts on emissions. The consistent significance levels across all specifications ($p<0.01$) validate the robustness of these mediation effects.

Table 7. The mediating effect test results of renewable energy power generation based on energy structure

	(1)	(2)	(3)
Variables	CE	Struc	CE
Struc			3.291***
			(1.173)
REG	-2.728***	-0.0195***	-2.664***
	(0.616)	(0.0801)	(0.571)
GDP	-0.256***	-0.0298***	-0.158***
	(0.0438)	(0.00371)	(0.0427)
Open	-1.445***	-0.126**	-1.030***
	(0.315)	(0.0496)	(0.275)
Gover	-4.214***	-0.153	-3.709***
	(1.324)	(0.162)	(1.096)
Indus	0.111	-0.00613	0.131
	(0.183)	(0.0297)	(0.188)
Innov	13.84	-1.737	19.56
	(14.87)	(1.827)	(15.10)
Constant	5.757***	0.664***	3.574***
	(0.377)	(0.0476)	(0.886)
Observations	450	450	450
R-squared	0.711	0.689	0.748
Number of province	30	30	30

ISSN: 2688-9323

4.5.2. Energy Consumption Intensity Inten as an Intermediary Variable

The mediation analysis presented in Table 8 demonstrates the pathway through which renewable energy generation influences carbon emissions via energy consumption intensity. The benchmark regression confirms a statistically significant negative relationship ($p<0.01$) between renewable power generation and carbon emissions. Further examination reveals that renewable energy development significantly reduces energy consumption intensity (coefficient = -0.636, $p<0.01$), while higher energy intensity conversely increases emission levels (coefficient = 2.504, $p<0.01$). The comparative analysis of coefficients between models indicates the presence of partial mediation, where renewable energy's emission reduction effect operates both directly and indirectly through lowering energy intensity. These findings collectively validate the dual mechanisms of energy structure optimization and consumption intensity reduction as critical pathways for renewable energy to achieve carbon mitigation, thereby supporting Hypotheses 2 and 3 of this study. The results underscore the importance of considering both direct and mediated effects when evaluating renewable energy's environmental benefits.

Table 8. Test results of the mediating effect of renewable energy power generation based on energy consumption intensity

	(1)	(2)	(3)
Variables	CE	Inten	CE
Inten			2.504***
			(0.242)
REG	-2.728***	-0.636***	-1.136***
	(0.616)	(0.221)	(0.260)
GDP	-0.256***	-0.104***	0.00465
	(0.0438)	(0.0172)	(0.0220)
Open	-1.445***	-0.436***	-0.354*
	(0.315)	(0.125)	(0.203)
Gover	-4.214***	-1.781***	0.247
	(1.324)	(0.434)	(0.728)
Indus	0.111	0.115	-0.178*
	(0.183)	(0.0706)	(0.101)
Innov	13.84	5.098	1.075
	(14.87)	(6.258)	(6.752)
Constant	5.757***	1.899***	1.002**
	(0.377)	(0.147)	(0.482)
Observations	450	450	450
R-squared	0.711	0.711	0.933
Number of province	30	30	30

5. Research Outcomes and Governance Proposals

This study employs a two-way fixed effects model to analyze provincial-level panel data from China's 30 administrative regions spanning 2008-2022, investigating the relationship between renewable energy generation and carbon emission reduction. The empirical findings reveal three interconnected dimensions of renewable energy's decarbonization effects.

The analysis demonstrates robust evidence that renewable electricity generation directly contributes to carbon mitigation, with statistical significance confirming its positive environmental impact. The expansion of clean energy capacity shows measurable effectiveness

ISSN: 2688-9323

in lowering emission intensity through displacement of carbon-intensive power sources. Beyond direct effects, the research identifies secondary pathways where renewable deployment facilitates structural transformation of energy systems - notably through gradual phasing out of fossil fuel dependence and systemic improvements in energy productivity. These transitional mechanisms operate through progressive optimization of regional energy portfolios and enhanced efficiency in energy utilization patterns.

Furthermore, the study quantifies important mediating processes whereby renewable energy adoption enables broader decarbonization. The gradual restructuring of generation assets toward cleaner sources, coupled with technological advancements that reduce energy inputs per economic output, creates synergistic effects that amplify emission reductions. These findings suggest that renewable energy development simultaneously addresses both supply-side and demand-side aspects of carbon mitigation, with structural changes in energy systems and efficiency gains collectively contributing to measurable climate benefits. The results underscore the multifaceted role of renewable energy in achieving sustainable energy transitions through combined technological, economic and systemic transformations.Based on the above research conclusions, this paper puts forward the following policy recommendations: First, increase investment in renewable energy. The government should increase investment in renewable energy power generation projects, especially in the fields of wind, solar and hydropower, in order to increase the proportion of renewable energy power generation and reduce dependence on fossil energy; second, optimize the energy structure. Promote the transformation of energy structure, reduce the use of high-carbon energy such as coal, and increase the proportion of clean energy and renewable energy to achieve low-carbon energy consumption; third, strengthen technological innovation. Encourage and support the research and development of renewable energy technologies, improve the efficiency of renewable energy power generation, reduce costs, and enhance their market competitiveness.

Drawing upon the empirical findings, this study proposes a comprehensive policy framework to accelerate the low-carbon energy transition. The analysis suggests prioritizing enhanced financial commitments to renewable energy infrastructure, with particular emphasis on scaling up wind, solar, and hydroelectric generation capacity to systematically displace fossil fuel dependence. Concurrently, strategic energy system restructuring should be pursued through coordinated measures that phase down coal consumption while expanding clean energy penetration in the national energy mix.

Critical to this transition is the advancement of technological innovation through targeted research and development initiatives. Such efforts should focus on improving renewable energy conversion efficiencies, driving down levelized costs of electricity production, and strengthening the commercial viability of sustainable power solutions. The integration of these policy dimensions - financial mobilization, structural transformation, and technological advancement - can collectively enhance the decarbonization potential of renewable energy deployment while ensuring energy security and economic competitiveness.

This integrated approach recognizes the synergistic relationship between investment scaling, market design reforms, and innovation ecosystems in achieving China's dual carbon objectives. The policy recommendations specifically address the need for balanced development across different renewable energy technologies while creating enabling conditions for systemic energy transition.

References

[1] Wang L, Xie Y, Hafeez M, et al. Assessing the dynamic linkage between energy efficiency, renewable energy consumption, and CO2 emissions in China[J]. Environmental Science and Pollution Research, 2022: 1-13.

ISSN: 2688-9323

[2] Ehigiamusoe K U, Dogan E. The Role of Interaction Effect Between Renewable Energy Consumptionand Real Income in Carbon Emissions: Evidence from Low-income Countries[J]. Renewable and Sustainable Energy Reviews, 2022, 154: 111883.

[3] E. J P, Diep H H T, Khanh L C, et al. The effect of economic complexity and energy security on measures of energy efficiency: Evidence from panel quantile analysis[J]. Energy Policy, 2023, 177.

[4] Qi S, Peng H, Tan X. The Moderating Effect of R& D Investment on Income and Carbon Emissions in China: Direct and Spatial Spillover Insights[J]. Sustainability, 2019, 11(5): 1235.

[5] Alfred A. Haug, Meltem Ucal. The role of trade and FDI for CO2 emissions in Turkey: Nonlinear relationships[J]. Journal of Energy Finance and Development, 2019, 81: 297-307.

[6] Dong F, Qin C, Zhang X, et al. Towards Carbon Neutrality: The Impact of Renewable Energy Development on Carbon Emission Efficiency[J]. International Journal of Environmental Research and Public Health, 2021, 18(24): 13284.

[7] Renata D. Influence of negative and positive perceptions about Renewable energy on intention to use bio-and other renewable energy sources[J]. Environment, Development and Sustainability, 2023, 26(2): 3081-3095.

[8] Kasperowicz R, Bilan Y, Štreimikienė D. The renewable energy and economic growth nexus in European countries[J]. Sustainable Development, 2020, 28(5): 1086-1093.

[9] Salari M, Kelly I, Doytch N, et al. Economic growth and renewable and non-renewable energy consumption: Evidence from the U.S. states[J]. Renewable Energy, 2021, 178: 50-65.

[10] Li Q, Cherian J, Shabbir M S, et al. Exploring the Relationship between Renewable Energy Sources and Economic Growth. The Case of SAARC Countries[J]. Energies, 2021, 14(3): 520.