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Application and Impact Assessment of Renewable Energy in Construction Projects

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Abstract. As a new type of environmentally friendly energy, renewable energy is widely used in various fields of society, and its purpose is to reduce the pollution of social production to the environment. For the research on the application effect of renewable energy, there are few cases and insufficient research depth. In order to solve the above problems, this paper proposes an improved regression analysis method, which refers to the construction engineering yearbook of 2020~2022 and the actual construction project as a case for analysis, and compares with SPSS, Mintab and other software to verify the effect of renewable energy application before and after. Among them, the complex data in renewable energy and construction projects are processed by binary classification, and the data with large field spans and low similarity are scaled to improve the unity of research content. The results of the study are realistic: renewable energy has an impact on energy consumption, cost and CO_2 emissions in construction projects, and the reduction range is between 10~20%, and there is a positive proportional relationship. At the same time, the application of renewable energy is directly affected by energy policy and environmental policy, and the impact coefficient is between 0.3~0.5. This shows that the application potential of renewable energy in construction projects is huge, and the development sustainability of construction projects is improved.

Key words. Renewable Energy, Construction Engineering, Application, Impact Assessment.

1. Introduction

With the increase of global environmental awareness, renewable energy as an environmentally friendly and long-term energy solution is gradually attracting widespread attention [1],[2]. At present, in the social and economic development, the proportion of energy consumption of construction projects is increasing, accounting for 45~50% of the total energy consumption of society [3],[4], and the urbanization process is accelerating, which further indicates the further increase of energy consumption of construction projects. As a result, there is a growing demand for the use of renewable energy in construction projects. Some scholars believe that the benefits of using renewable energy in buildings do not decrease with the increase in its application [5],[6], and its negative impact on the environment should not be underestimated, such as lead pollution, the increase of waste materials, etc. [7], so it is necessary to verify the application potential of renewable energy in construction projects with actual cases. Some scholars believe that in the process of construction project implementation, there is a shortage of energy, lack of resources and ecological environment pollution, which increases the cost of construction project implementation, so it is very important to carry out building energy conservation work [8]. In the 90s of the 20th century, all countries in the world carried out energy-saving work in construction projects, but the implementation effect was not significant. According to data research, although 65% of international construction projects are implemented in energy-saving technical standards, building energy consumption still accounts for 50% of the total energy consumption of the society [9]. For example, Finland has a high application of energy-saving technologies in its construction projects, but the total energy consumption accounts for 35% of the total energy consumption of society, so the need for renewable energy is very strong. Compared with traditional petroleum energy, renewable energy has less pollution to the ecological environment, but the application process is complex and accounts for a small proportion of construction projects, so the application effect of renewable energy in construction projects is controversial and needs more cases as support. Based on the above background, this paper proposes a regression analysis method to study renewable energy and construction engineering data, aiming to promote the sustainable development of the construction industry, expand the application scope of renewable energy, and reduce environmental pollution through the evaluation of the application of renewable energy [10],[11].

First of all, the energy consumption data of construction projects is collected, and the application indicators of renewable energy and construction projects are searched. Then, the regression analysis method was used for data processing, the domain difference was reduced, the standard processing of the data was completed, and the application effect of renewable energy was verified. Finally, the application indicators of renewable energy were found in construction projects, and energy consumption, cost, and environmental pollution were analyzed. Through a comprehensive analysis of renewable energy and construction engineering evaluation, the application effect of renewable energy is verified, and the specific implementation process is shown in Figure 1.

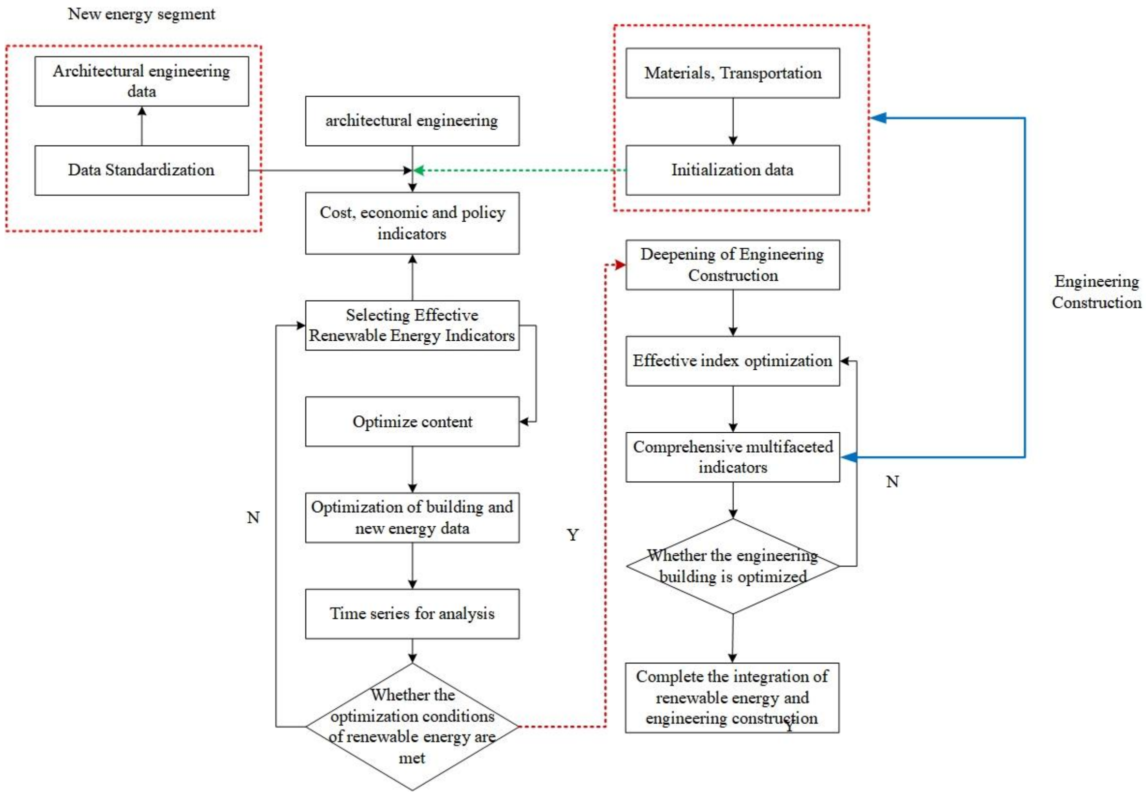

Figure 1. The Integration Process of Renewable Energy and Construction Engineering

2. Problem Analysis of the Application of Renewable Energy in Construction Projects

A. Description of Energy Consumption Problems

In this paper, Elhorst in spatial metrics is used to analyze construction projects, and Burnett's theory in economic statistics is used to analyze renewable energy. At the same time, combined with the advantages of renewable energy, the energy consumption analysis is carried out, and the specific calculation formula is as follows:

$$PC_{it} = \alpha + \varphi \cdot PC_{it\text{-}1} + \rho \cdot wPC_{it} + x_{it} \cdot \beta + u_{it} \qquad (1)$$

$P_{Cit\text{-}1}$ represents the explanatory variable, which is constructed from the data of carbon dioxide emissions. Then, the first-order hysteresis value of PC_{it} is calculated to verify the stability of CO_2 emissions. The coefficient φ depicts the energy consumption before and after the use of renewable energy. wPC_{it} represents the energy consumption per unit floor area after the application of renewable energy; wPC_{it}, it is a random weighting of PC_{it} to improve the objectivity of the calculation; ρ represents the spatial regression coefficient of the construction project, which represents the spatial expansion of the calculation process. x_{it} represents the reduction in energy consumption after application; U_{it} is the rate of change in renewable energy applications caused by weather and seasonal changes; Complex data in renewable energy and construction projects, such as policy and construction material changes, are simplified using Rook theory to construct a simple binary weight matrix to achieve linear analysis. According to the above analysis, additional moderating factors were introduced, and a regression prediction system was constructed to improve the accuracy of the calculation results. At the same time, by drawing on historical data, the relationship between other explanatory factors is obtained, and the relationship between the indicators is shown in Table 1.

Table 1. Relationships Between Different Parameters

Variable	PC_{it}	$PC_{it\text{-}1}$	wPC_{it}	x_{it}
PC_{it}	α	φ	ρ	β
$PC_{it\text{-}1}$	φ	1	$1/\varphi$	$1/\rho$
wPC_{it}	ρ	-	1	$1/\beta$
x_{it}	β	-	-	1

From the data analysis in Table 1, it can be seen that the relationship between renewable energy and construction projects is linearly correlated.

B. Calculation of CO_2 Emissions

Through the application of renewable energy, construction projects can effectively reduce the emission of pollutants such as sulfur dioxide, nitrogen oxides and smoke (dust), and carbon dioxide accounts for the highest proportion, accounting for about 85%, while the measurement of other pollutants is difficult, so carbon dioxide is used as an indicator for the evaluation of new energy applications, and the quantity is floated on the basis of measurement to improve the verification results. According to the "2020 National Development and Reform Commission's Carbon Dioxide Evaluation Standards", the carbon dioxide emissions of renewable energy will be assessed. The formula for this estimate is:

$$CO_{2it} = \sum_{k=1}^{s} S_{it,k} * \eta_k \tag{2}$$

Among them, CO_{2it} represents the total amount of renewable energy application of the ith project of the t building, S_{it} represents the energy consumption of the ith project of the t building, and η_k represents the reduction of carbon dioxide emissions of the kth renewable energy application source. Among them, the increase coefficient of carbon dioxide emissions is between 1.77~21.67, and the average value is 10.52 (data source: actual investigation). From the 2020~2023 "Construction Enterprise Statistical Yearbook" collected from the average use of renewable energy and the average carbon dioxide emissions in all regions of the country, it can be seen that the proportion of renewable energy applications in construction projects has increased, as shown in Figure 2.

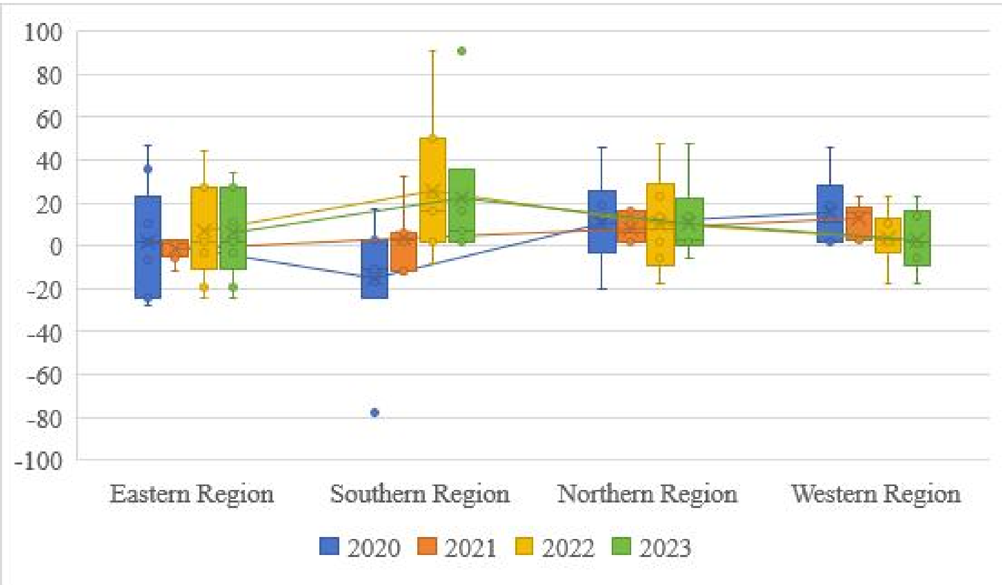

Figure 2. The Use of Renewable Energy in Different Provinces in 2020~2023 (Note: Due to limitations in data collection, the study only selected the eastern, western, southern, and northern averages.)

It can be seen from Figure 2 that the degree of renewable energy use in different provinces will change from decentralized to concentrated in 2020~2023, and the degree of application in different provinces will change from homogeneous to differentiated. This shows that the application of renewable energy in different provinces is more mature and the application demand is more clear, which proves that the research in this paper is objectively feasible.

C. Cost Savings from Renewable Energy

According to the application of renewable energy in building transportation, construction, lighting, etc., calculate its cost impact on construction projects, and ignore the cost of auxiliary equipment, such as water pumps and controller equipment, to ensure the accuracy of renewable energy cost accounting. In renewable energy, the CO_2 generated by photovoltaic and wind energy is the energy consumption generated during the operation of the equipment, which can also be ignored. When it is a renewable energy supply, the traditional equipment in the construction project adopts the hybrid power supply mode, and the proportion of traditional functions is calculated according to the proportion to verify the operation effect of renewable energy, and the calculation of CO_2 emissions is shown in equation (3).

$$PE = EG \times EF_{grid} + \sum_i FC_i \times NCV_i + EF_i \tag{3}$$

In equation (3), the savings of the construction project unit emission is PE , and the unit is t/m^3; Renewable energy saves electricity for EG ; The random emission factors in construction projects are EF_{grid} ; The consumption of fuel for construction works is FC_i ; The low calorific value of the heating equipment of the construction project is NCV_i ; The type of fuel used in construction activities is i . In the course of construction activities, the CO_2 emissions per unit space of fossil fuels are EF_i .

The above calculation process is used as the carbon emissions generated by renewable energy in construction projects, and the CO_2 generated in the application of renewable energy in construction projects is evaluated, so as to provide a numerical reference for subsequent evaluation.

3. Empirical Testing and Analysis

A. Add Moderating Variables in Construction Projects

In the bridge construction project, for example, the construction process includes box girders, bridge piers, asphalt pavement, etc., involving 100 people, 25 engineers, architects and supervisors, and the others are technicians and construction personnel. The bridge project is phase I~IV, located in Jiangxi, Anhui, Shaanxi and other provinces, and the specific GIS diagram is as follows (Figure 3).

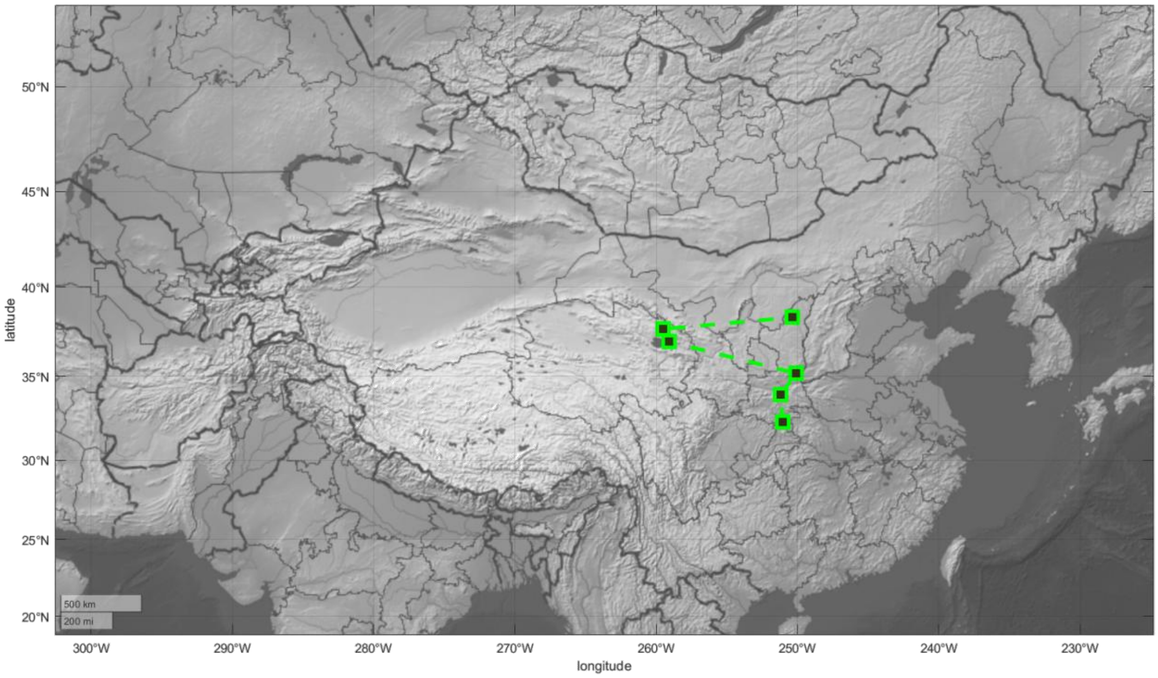

Figure 3. The Geographical Location of the Construction Project

There are specific renewable energy application plans in the project, involving lighting, curing, transportation, transmission, etc., accounting for 20~50%, and equipped with emergency equipment and tools. Overall, the use of renewable energy is in line with existing standards and is theoretically feasible.

B. Analyze the Application Accuracy of Renewable Energy

In order to evaluate the accuracy of the results, the robustness and correlation of carbon dioxide emissions, construction costs and energy consumption were selected as the analysis content during the regression analysis. The accuracy of the evaluation results is ensured by analyzing not only the first-order and second-order sequences of lighting, piers and box girders, but also the correlation between the random perturbation terms and the sequences. Finally, in order to verify the reliability of the prediction results, this paper uses the two-stage mean comparison and the parameter estimation of the spatial model, and the detailed prediction of accuracy is shown in Table 2.

Table 2. Regression Models and their Results

	CO_2 emissions	Construction costs	Energy consumption
Box girders	1.0734*** (43.67)	.7327*** (8.21)	.7913*** (32.37)

Pier	-.0002 (1.97)	.1437 (1.79)	.3735*** (9.84)
Transport	.0001 (2.44)	.0001* (2.12)	.0001*** (4.01)
Cement curing	-6.01e-10*** (-2.79)	-7.46e-10** (-2.45)	-9.53e-10*** (-4.81)
Illuminating	-.0103 (-1.86)	-.0118 (0.53)	.01912** (1.93)
Opening	-.0062 (-2.17)	-.0054 (-0.79)	-.0261*** (-2.90)
Monitor	-.0101 (-1.41)	.0417 (1.09)	-.0071*** (-4.57)
Refrigeration	.6904* (2.33)	-1.7771 (-0.91)	-1.9737** (-3.28)

According to the data in Table 2, CO_2 emissions, construction costs, and energy consumption are calculated at a significance level of 1%. In-depth comparison of cement curing, lighting, box girder and other data shows that the accuracy of the calculation results is also 1%, and the error change is 0.4621, which means that the integration of renewable energy and construction engineering in terms of space energy conservation is better. According to the autoregressive test results of the error term, the P values of construction cost and energy consumption reached 0.08 and 0.35, respectively, indicating that there was no correlation between construction cost and energy consumption, and there was independence between the verification results, but the continuous detection of carbon dioxide emissions could not be initially predicted. Therefore, in order to make a better analysis and ensure the validity of the parameter estimation of the calculation results, this study performed a regression analysis of energy consumption, cost and carbon dioxide emissions, and the results are shown in Figure 4.

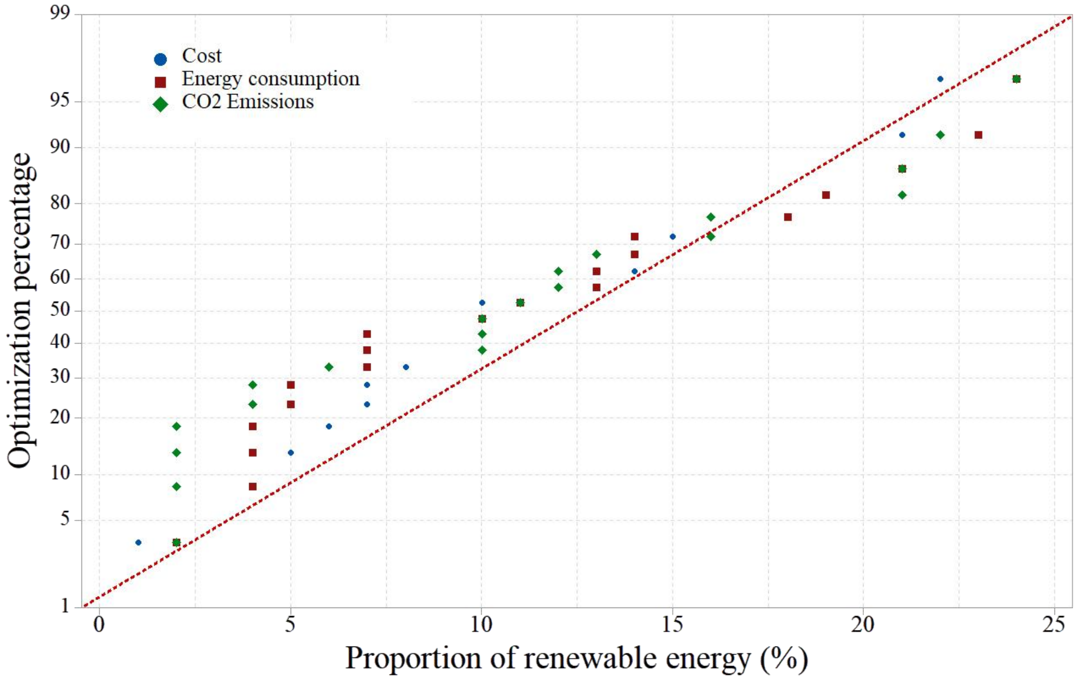

Figure 4. Regression Results for Cost, Energy Consumption and CO_2 Emissions

As can be seen from Figure 4, the regression results of cost, energy consumption and carbon dioxide emissions are concentrated around the center line, indicating that the proportion of renewable energy will reduce the energy consumption and cost of construction projects.

C. Correlation Analysis Between Renewable Energy and Energy Consumption and Cost

In order to verify the sustainability of the application of renewable energy, combined with the historical data of construction projects, the forecast value of renewable energy, and comparative analysis, the results show that the saving rate of renewable energy is between 33~70%. Moreover, there is no significant correlation between the two predictions, and there is also independence between energy consumption and cost, and the difference between the front and back is obvious. This result means that each unit increase in renewable energy use will lead to a decrease in energy consumption and cost, with a decrease ratio of 1.2~1.6, and the specific energy consumption, cost and carbon dioxide emissions are compared, as shown in Table 3.

Table 3. Comparison of Indicators Before and After the Application of Renewable Energy in Construction Projects

Time	Energy Consumption (kJ)	Cost (100 million yuan)	CO_2 Emissions (tons)
Before regenerative energy source fusion	1578.56	12.62	2145.62
After the integration of	465.32	8.44	652.78

renewable energy			
Difference	1113.24	4.18	1492.84
Percentage	29.48	66.88	30.42
Savings rate	70.52	33.12	69.58

Note: The data is from actual tests.

After the two-stage evaluation, it is found that the parameter prediction of energy consumption is of great significance in the range of 1%, and the corresponding coefficient ρ is predicted to be 0.374, which means that renewable energy will not only have an impact on the cost of construction projects, but also have an indirect impact on energy consumption. Through the parameter values before and after, it can be seen that renewable energy is widely used in construction projects, and mainly solar energy and wind energy, so the impact of renewable energy is also related to its own technology and application degree, which needs to be further evaluated. In the core project of the building, regardless of whether the nature of the construction project adopts green building standards, photovoltaic and wind energy can reduce energy consumption and cost. Among them, photovoltaic renewable energy is the mainstay, and the construction effect is shown in Figure 5.

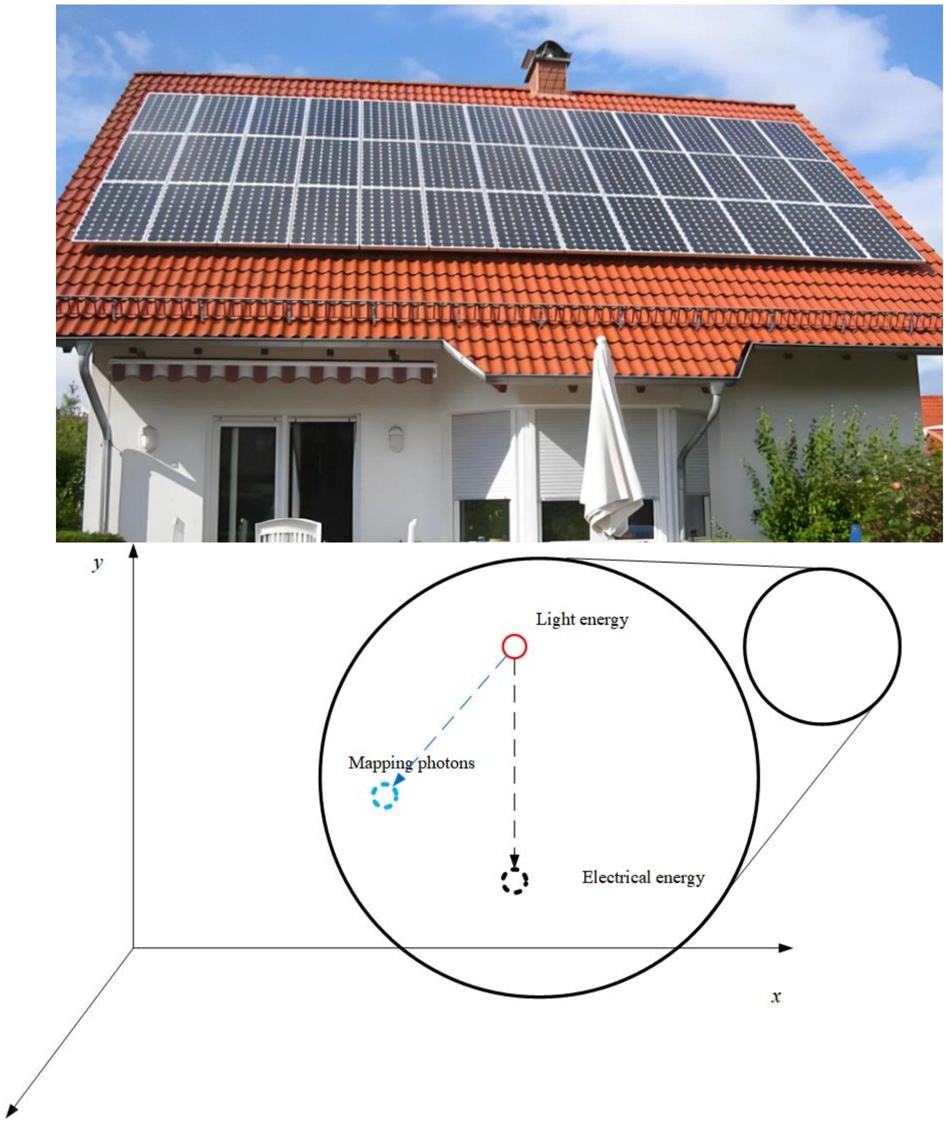

Figure 5. The Application Effect of Photovoltaic Renewable Energy in Buildings

As can be seen from Figure 5, solar energy is mapped in a large number of photovoltaic tubes through the monocrystalline silicon medium, and generates electrical energy, which can effectively save electrical energy in the construction project, and the effective time is 12~16 hours, especially in southern China. Therefore, it is necessary to adopt different technical means for different construction projects, select the best renewable energy technology solutions, and effectively apply them to construction projects. The results show that the application of renewable energy in construction projects can save construction costs, reduce environmental pollution, and improve building efficiency, as shown in Table 4.

Table 4. The Overall Impact of Renewable Energy on Construction Projects

	Building efficiency (%)		Environmental pollution (%)	t	p	Construction cost (10,000 thousand)	
	Outcome	Standard error	Randomness			Base cost	Deviation
Constant	65.090	0.864	-	5.892	0.002**	-	-
Solar energy	60.324	0.180	10.398	-1.801	0.132	124.001	0.999
Wind energy	60.130	0.191	10.151	0.682	0.526	1.003	0.997
Geothermal energy	60.642	0.192	10.741	-3.348	0.020*	1.004	0.996
R^2	0.756						
Adjust R^2	0.610						
F	F (3,5)=5.166, p=0.054						
D-W values	2.638						
Dependent variable: Construction work							
*p<0.05 **p<0.01							

As can be seen from Table 4, the impact of renewable energy on construction projects is relatively large, the impact on building efficiency and environment is large, the impact on construction cost is relatively small, and the overall effect is better.

D. Policy Implications for Renewable Energy Applications

Renewable energy is affected by policy, so in construction projects, the impact of policy is very significant. After a two-phase evaluation, it was found that the policy impact on renewables reached 15.03 and 17.03, both of which differed within the 1% range, with values marked as positive and all other conditions remained stable. The correlation between the two values in the previous and subsequent stages showed fluctuating changes, and the change range was similar, which means that the application of renewable energy in construction projects is related to environmental protection policies and renewable energy policies. In other words, the increase in the use of renewable energy is not only related to construction projects, but also affected by policies. Figure 6 illustrates the relationship between the use of renewable energy and local policies and the economy.

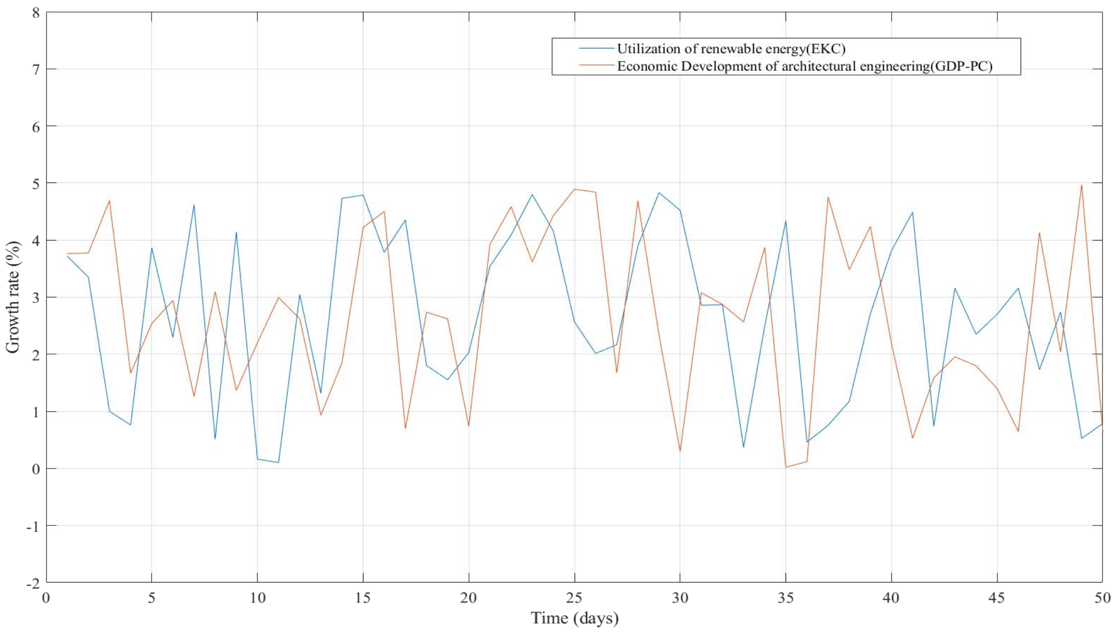

Figure 6. Relationship Between Renewable Energy and the Economics of Construction Projects

In addition, the relationship between renewable energy and the construction economy is also related to industrialization, opening up and urbanization. The results show that industrialization has a significant negative effect on CO_2 reduction, and the application of renewable energy can change this value. Industrial progress and the high use of renewable energy sources have an impact on CO_2 emissions from construction projects. From the perspective of policy, industrialization and urbanization, the role of renewable energy in construction projects is analyzed, and the development of different regions is shown in Figure 7.

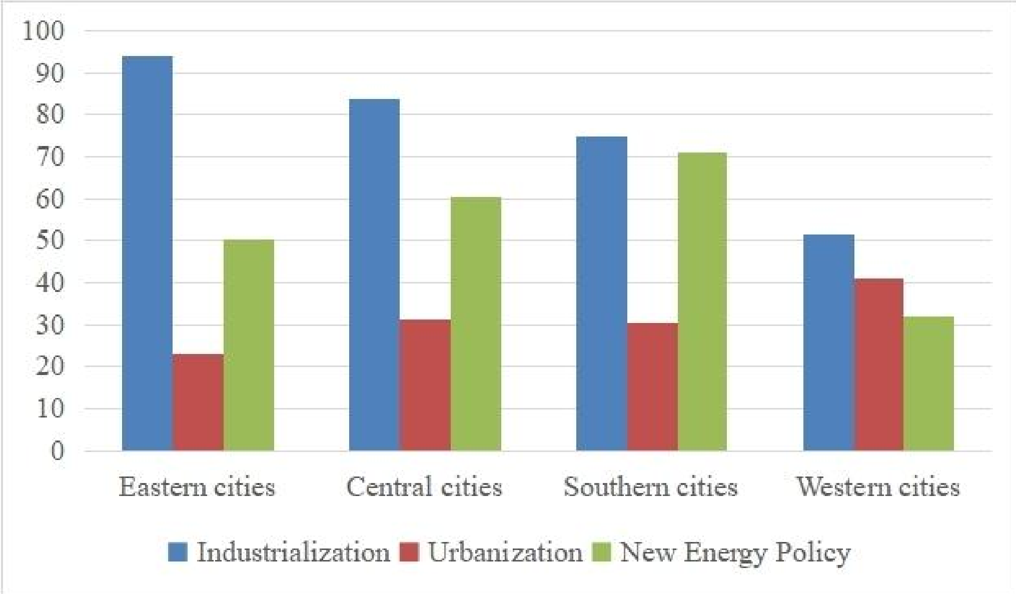

Figure 7. Development of Construction Projects in Different Cities

As can be seen from the last column of Figure 7, the predictors of opening up and urbanization are significantly negative, and opening up and urbanization have not led to an increase in carbon dioxide emissions from construction projects, mainly due to the increase in the application of renewable energy, which also indirectly indicates that the impact of the policy is obvious. Among them, the degree of impact of different policies is different, as follows (Figure 8).

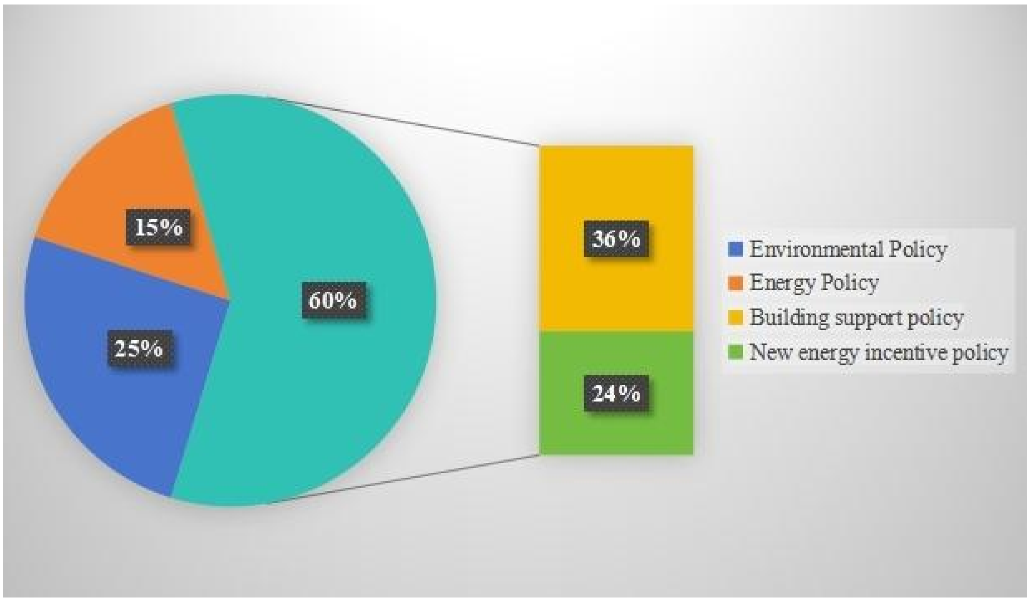

Figure 8. The Impact of Different Policies on Renewable Energy and Construction Projects

As can be seen from Figure 8, environmental policy, energy policy and new energy policy have a great impact on renewable energy, promote the development of construction projects, and have an optimization effect on their structure.

4. Inspiration and Suggestions

A. Propose Promotion Policies to Promote Renewable Energy

This empirical study reveals two important implications: (1) although the application of renewable energy is an inevitable result of construction projects, its final effect depends on the depth of integration between the two; (2) The application of renewable energy has a strong positive correlation with environmental protection policy and industrialization. The government's policy of adopting low environmental standards will increase the carbon emissions of construction projects, and it will increase the cost of construction. The combination of environmental policy and renewable energy has a 1+1>2 effect, so renewable energy should be combined with reasonable policies to meet the needs of construction projects. In order to ensure the balanced development of the integration of construction projects and renewable energy, this study finds that the structure of policy and renewable energy can reduce the energy consumption and cost of construction projects, so the following directions are proposed when formulating policy recommendations: (1) promote the application of renewable energy, promote the application of renewable energy, reduce energy consumption and cost, (2) promote the structural optimization of industrialization and renewable energy, through the reform of construction projects and the innovation of renewable energy technology, Continuously optimize energy use; (3) Strengthen support for renewable energy and increase the application of photovoltaic, wind and geothermal. (4) Research on the need to establish a mechanism for the application of renewable energy, promote the joint efforts of the government in the application of renewable energy, and encourage the joint efforts of construction projects and the government in environmental management.

B. Break Through the Limits of Renewable Energy Applications

Based on the above analysis, there are some problems and challenges in the evaluation of renewable energy grid integration and sustainability, which mainly cover the following aspects:

Upgrading technical and policy constraints, although the integration of renewable energy into the grid relies on cutting-edge technology, there are still technical bottlenecks and areas that have not yet been fully developed. Another major issue comes from government policies, including how to design and enforce relevant laws, and how to build an efficient market system. To raise the awareness of renewable energy in society, the promotion of renewable energy integration is inseparable from the help of enterprises and the active participation of the public. However, in the specific implementation, this study may encounter problems such as a lack of corporate awareness and conflict of rights and interests, so this study must improve the awareness and enthusiasm of enterprises with the help of education popularization and participation in system construction.

The development of renewable energy usually requires a large amount of financial investment and financial assistance, and the initial implementation of construction projects is usually inefficient. On the other hand, in order to promote the progress of the market, this study must also construct a sound market system and its corresponding economic stimulus strategies to attract more individual input. Integrating renewable energy requires a major upgrade of the renewable energy system, which requires a comprehensive regulatory and oversight framework. This includes building capabilities and processes in the areas of renewable energy engineering applications, operational monitoring, scientific standard development, and data processing.

Expanding the application scope of renewable energy, for energy reform, the integration of renewable energy is an important part of it, in the process, there will be problems such as supply and demand balance, energy storage methods, grid design and so on. In addition, this study must also integrate it into the traditional renewable energy system to cope with the continuous disappearance and replacement of traditional energy sources. There are many difficulties and challenges in energy consumption and cost assessment of renewable energy and construction projects, including technical and policy constraints, the practicability and market progress of construction project implementation, the structure of management and supervision, public awareness and participation, and energy transformation. In order to solve these dilemmas, this study must unite all members of government, companies and enterprises to promote technological innovation, optimize market operation, and increase public participation through some scientific policies and laws, so as to promote the sustainable development of renewable energy integration. In the execution of construction projects, the integration and continuous evaluation of renewable energy sources are crucial. This will reduce the need for traditional energy sources, reduce the use of renewable energy, and promote green and sustainable development. In addition, sustainability assessment also helps to improve the environmental, social and economic benefits of construction projects to achieve more effective sustainable development.

C. Provide a Development Direction for the Development of Renewable Energy

After new energy has been widely recognized in many fields, the state has also made mandatory provisions on energy conservation in the construction industry, and construction engineering designers attach great importance to energy conservation. The government can work with renewable energy equipment companies and product developers to actively explore environmentally friendly products for the construction industry. Engineers in construction projects should integrate environmental protection concepts into construction projects. Combining renewable energy technology with low-carbon trading, through the effective calculation of energy consumption, construction projects can not only realize technical value, but also realize the economic value of renewable energy applications and construction projects. In the execution of construction projects, the integration and continuous evaluation of renewable energy sources are crucial. This will not only reduce the need for conventional energy and reduce the use of renewable energy, but it will also promote green and sustainable development. In addition, sustainability assessments can help improve the environmental, social, and economic benefits of construction projects, leading to more effective sustainable development.

5. Conclusion

As a kind of clean energy, renewable energy can save costs and reduce energy consumption, which is a hot topic of current research. As a major industry of social energy consumption, construction engineering has obvious value in integrating with renewable energy. Based on renewable energy, this study combined historical data and yearbook data to conduct regression analysis to find out the integration points with construction projects, and analyze their energy consumption and cost. The results show that there is a direct correlation between renewable energy sources that optimize energy consumption in construction projects, reduce costs and CO_2 emissions. At the same time, environmental policies and the degree of industrialization will also have an impact on the application of renewable energy, so it is the focus of the government's attention. New energy can reduce the cost of buildings by 35~25% and reduce energy consumption by 10~20%, but it has less impact on carbon dioxide emissions, at 10~15%. Therefore, renewable energy has great potential to optimize energy consumption in lighting, transportation, cement curing and other aspects of construction projects. However, in the course of the research, some difficulties were still encountered. For example, it is difficult to solve the analysis of technical and policy constraints, mainly because of strong randomness and subjectivity, and in the future, the analysis will be carried out through follow-up investigation, so as to realize the continuous research of construction projects and improve the authenticity of the research.

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References

[1] L. Deng, "Modeling the role of natural resources, renewable and non-renewable energy, and technological innovation on the economic growth of China," *Environ. Eng. Manage. J.*, vol. 23, no. 1, pp. 113-122, 2024, doi: 10.30638/eemj.2024.010.

[2] H. Elba, H. Hegazy, J. Zhang, I. M. Mahdi, I. Abdel Rashid, and H. M. Hassan, "Exploring critical barriers towards the uptake of renewable energy usage in Egypt," *Innovative Infrastruct. Solutions*, vol. 9, no. 7, Jun. 2024, doi: 10.1007/s41062-024-01578-3.

[3] C. Gusain, U. Nangia, and M. M. Tripathi, "Optimal sizing of standalone hybrid renewable energy system based on reliability indicator: A case study," 2024, doi: 10.2139/ssrn.4750504.

[4] Q. Hassan *et al.*, "The renewable energy role in the global energy transformations," *Renewable Energy Focus*, vol. 48, p. 100545, Mar. 2024, doi: 10.1016/j.ref.2024.100545.

[5] N. N. Ibrahim, J. J. Jamian, and M. Md Rasid, "Optimal multi-objective sizing of renewable energy sources and battery energy storage systems for formation of a multi-microgrid system considering diverse load patterns," *Energy*, vol. 304, p. 131921, Sep. 2024, doi: 10.1016/j.energy.2024.131921.

[6] Y. Jiang *et al.*, "Dynamics islanding control for power grid with high penetration of renewable energy," *IEEE Trans. Power Syst.*, vol. 39, no. 3, pp. 5297-5309, May 2024, doi: 10.1109/tpwrs.2023.3324424.

[7] Z. Liao *et al.*, "Comprehensive analysis of renewable hybrid energy systems in highway tunnels," *Front. Energy Res.*, vol. 12, Jan. 2024, doi: 10.3389/fenrg.2024.1365532.

[8] Y. Lin, M. A. Mahmood, W. Meng, and Q. Ali, "Green economy transition in Asia Pacific: A holistic assessment of renewable energy production," *J. Cleaner Prod.*, vol. 437, p. 140648, Jan. 2024, doi: 10.1016/j.jclepro.2024.140648.

[9] A. Rahman, S. M. W. Murad, A. K. M. Mohsin, and X. Wang, "Does renewable energy proactively contribute to mitigating carbon emissions in major fossil fuels consuming countries?," *J. Cleaner Prod.*, vol. 452, p. 142113, May 2024, doi: 10.1016/j.jclepro.2024.142113.

[10] A. K. Sampene, C. Li, and T. K. Nsiah, "Catalyzing renewable energy deployment in the Mercosur economies: A synthesis of human capital, technological innovation and green finance," *Energy Strategy Rev.*, vol. 53, p. 101388, May 2024, doi: 10.1016/j.esr.2024.101388.

[11] B. Xiao, Z. Gao, H. Peng, K. Chen, Y. Li, and K. Liu, "Robust optimization of large-scale wind-solar storage renewable energy systems considering hybrid storage multi-energy synergy," *Sustainability*, vol. 16, no. 1, p. 243, Dec. 2023, doi: 10.3390/su16010243.