Mathematical Modeling and Algorithm Application
ISSN: 3006-0842 | Vol. 8, No. 2, 2026

Comprehensive Effectiveness Evaluation and Research Design for Smart Microgrids Empowering Low-Carbon Transformation of Plateau Homestays

Wenhao Wang*, **Weiyi Wang**, **Yingtao Han**

School of Finance and Economics, Xizang Minzu University, Xianyang 712082, China.

* **Corresponding author**: Farid Uddin Ahmed (Email: xnf0y2lbabvk@hotmail.com)

Abstract: Addressing challenges such as high costs and unclear carbon reduction pathways faced by the plateau homestay industry during energy structure transformation, this study designs an integrated research framework combining physical simulation and causal inference. First, a review of domestic and international practices reveals that while microgrid technology has entered the intelligent decision-making phase, systematic research targeting plateau homestays as a specific application remains insufficient. This scheme establishes a dual-model framework: First, a technical-economic model employs k-means clustering to process typical daily loads, then utilizes mixed-integer linear programming (MILP) to optimize multi-energy complementary systems (photovoltaic-storage-fuel) at the hourly granularity, aiming to achieve an optimal balance between life-cycle cost (LCOE) and energy self-sufficiency rate. Second, an econometric model employs a two-way fixed-effects regression based on panel data, incorporating instrumental variables and PSM-DID models to identify the causal impact of microgrid investments on homestay operating profits and per-guest-night carbon emissions. This study aims to fill the quantitative research gap in green development for plateau tourism, providing a scientific pathway for achieving ecotourism driven by "new quality productive forces."

Keywords: Plateau homestays; Smart microgrids; Techno-economic modeling.

1. Introduction

Amidst the global energy transition and carbon neutrality initiatives, smart microgrids—as key enablers for integrating distributed renewable energy—demonstrate immense commercial potential in remote areas where grid extension is economically unfeasible. Plateau homestays, serving as core carriers of ecotourism, have long been constrained by the high costs and emissions associated with diesel-powered generation, urgently requiring a green technological revolution to achieve high-quality development. Previous research indicates that foreign countries have achieved leading results in commercial microgrid operations for remote communities and zero-emission homestay initiatives. Domestic research is shifting from macro-level accounting to digital technology-enabled exploration, yet quantitative modeling studies remain scarce on how homestay operators in extreme plateau conditions can achieve economic and environmental win-wins through microgrids. This section innovates by establishing a comprehensive research framework spanning from micro-level energy dispatch to macro-level performance evaluation, pioneering the integration of multi-energy complementary optimization models with econometric causal inference. The general research approach follows a sequence: beginning with a review of domestic and international literature to define a variable system encompassing energy costs and operational profits; proceeding to simulate energy balance and LCOE optimal solutions through physical modeling; and finally validating the enabling effects of microgrids using empirical econometric models. This establishes a comprehensive decision-making paradigm for the low-carbon transformation of high-altitude homestays.

Technical and Economic Optimization Design of Smart Microgrids for Plateau Homestays The technical core of this approach lies in establishing a physically constrained energy dispatch and cost optimization model. Based on energy sources, the study first collects hourly or typical daily load and meteorological data. K-means clustering extracts representative scenarios to address high-altitude environmental variability. Building on this foundation, the design incorporates a multi-source coordination model encompassing photovoltaic (PV) systems, battery management systems (BMS), and diesel generators. Parameters such as charge/discharge efficiency, cycle life, and fuel consumption curves are defined to establish the mixed-integer linear programming (MILP) objective function. This model aims to minimize annualized total costs while strictly adhering to constraints including energy balance, storage state-of-charge (SOC) updates, and reliability requirements. Through two-stage robust optimization or scenario-based stochastic programming, the study outputs core performance metrics—including LCOE, net present value (NPV), and monthly generation mix ratios—to provide precise equipment configuration recommendations for homestay owners.

Causal Inference-Based Evaluation System for Microgrid Operational Efficiency Building upon validated technical feasibility, this study further designs an econometric framework to identify the genuine contribution of microgrid deployment to homestay competitiveness. The proposed methodology involves constructing a panel data structure spanning at least 3–5 years, with primary dependent variables including homestay net profit, energy cost ratio, and carbon emissions per guest-night. The model core employs two-way fixed effects regression (FE) to control for individual heterogeneity and time trend interference. To address potential endogeneity issues like reverse causality or omitted variables, the scheme introduces “local subsidy intensity” or “inclusion in demonstration projects” as instrumental variables (IV) and utilizes the 2SLS method for robust estimation. Additionally, a PSM-DID model was designed to match homestays with and without installed microgrids using propensity scores. This quantifies the “green premium” effect of microgrids in boosting average room rates and occupancy rates, while examining heterogeneous differences in benefit realization based on altitude and grid connection attributes.

2. Research Status at Home and Abroad

2.1. Foreign Research Status

In terms of microgrid technology practice and economic research, foreign countries have transitioned from technical feasibility verification to commercial operation, policy-driven stages, and intelligent decision-making stages, with a high focus on applications in remote communities and tourism. The IRENA annual report "Renewable Power Generation Costs in 2022" systematically evaluates global commercial microgrid projects, pointing out that the "grid-connected-off-grid switching + distributed photovoltaic + energy storage" scheme can reduce the electricity cost of remote communities to 0.15–0.20 USD/kWh, which has met the conditions for affordable commercialization. The World Bank ESMAP report "Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers" systematically evaluates the potential of global microgrid projects in improving energy security and reducing long-term electricity costs, especially suitable for remote areas where grid extension is uneconomical; in academic research, M.H. Alham et al. (2021) proposed the concept and operation mode of microgrids, and conducted in-depth research on control, protection, and energy management systems, laying a theoretical foundation for the development of microgrids [1]. X. Cao et al. (2022) proposed a real-time energy management strategy for microgrids based on deep reinforcement learning, which significantly reduced the dependence on traditional fossil energy backups [2]. In recent years, the focus of foreign smart microgrid research has shifted to optimal operation based on artificial intelligence and cloud-edge collaboration. For example, M.S. Hossain et al. (2022) used deep learning algorithms to predict the load and photovoltaic output of community microgrids, achieving significant optimization of energy costs [3]. M. Mishra et al. (2021) pointed out that microgrids have become a key technology to improve energy resilience and integrate distributed renewable energy, especially highlighting their role in responding to extreme weather events [4]. The "Digital Twin Grid Platform" put into operation by Tokyo Electric Power Company in Japan in 2024 achieves 72-hour accurate early warning of extreme weather such as typhoons, and can reduce fault recovery time to less than 15 minutes.

In terms of research on the low-carbon transformation of guesthouses, foreign practices are relatively advanced. Some developed countries encourage guesthouses to adopt renewable energy, energy-saving equipment, and green building materials to reduce carbon emissions. For example, some guesthouses in Japan use solar panels and ground-source heat pumps to achieve energy self-sufficiency and efficient utilization. According to the Booking Holdings annual report "Sustainability Report 2023", 43 countries around the world have promoted the "Zero-Emission Guesthouse" program in guesthouses in remote scenic areas, with an average annual emission reduction of 18 t CO_2 per store and an occupancy rate increase of 6–9%; in academic research, foreign studies mostly focus on technology application, operation mode, and consumer perception. A.U. Sahoo et al. (2021) listed "distributed renewable energy + microgrid" as the preferred path for people's livelihood carbon reduction in rural and island areas of developing countries, and recommended the three-stage strategy of "PV minigrid→PV-battery hybrid→grid-interactive" [5]. A. Rico et al. (2019) conducted a life cycle carbon footprint assessment of Airbnb listings in Barcelona, finding that in addition to operational energy consumption, embodied carbon in buildings and transportation carbon emissions of guests account for a significant proportion, calling for a life cycle carbon reduction strategy [6]. Z. Liu et al. (2020) used big data analysis technology to map the carbon emission profiles of accommodation providers in different regions and types in Amsterdam, providing a scientific basis for formulating differentiated regional emission reduction policies [7]. R. Merli et al. (2020) found through research on hotels and guesthouses in Scandinavia that direct financial subsidies have the most direct effect on incentivizing energy efficiency renovations, while green certification mainly affects their brand image and market price, and the combination of the two achieves the best effect [8].

In the interdisciplinary research on smart microgrids empowering the low-carbon development of guesthouses, J.K. Kaldellis (2021) analyzed the case of a photovoltaic-storage microgrid project in a Greek island resort, proving that it has lower costs and environmental impacts than diesel power generation throughout the life cycle [9]. M. Asad et al. (2022) systematically demonstrated the poverty alleviation and carbon reduction synergistic effects of microgrids in people's livelihood scenarios such as guesthouses, clinics, and schools, and proposed the "Energy-as-a-Service" business model, which can reduce the initial investment of users to 0 [10]. Particularly noteworthy is that M. Šetinc et al. (2022) conducted research on plateau hotels in the Alps, constructed a microgrid model integrating photovoltaic, small wind power, and energy storage systems, and simulated the investment return cycle under different policy subsidies [11], providing direct methodological reference for applications in high-altitude and ecologically sensitive areas.

2.2. Domestic Research Status

In terms of microgrid technology practice and economic research, Tao Qiong et al. (2021) conducted a life cycle economic evaluation of off-grid wind-solar-storage microgrid systems [12]. Liu Yixin et al. (2020) used HONER software to optimize the configuration and economic analysis of photovoltaic-storage microgrids, both proving their technical and economic feasibility in areas without electricity [13], providing technical and policy basis for this project. Shu Yinbiao et al. (2023) discussed the stability challenges of "double high" (high proportion of new energy, high proportion of power electronic equipment) power systems and the solutions of microgrids [14]. Sun Yushu et al. (2020) proposed a multi-time scale optimal dispatch strategy for AC-DC hybrid microgrids, which effectively suppressed the volatility of renewable energy [15]. Pei Wei et al. (2021) deeply discussed the stability and control problems of AC-DC hybrid microgrids with high proportion of new energy access [16]; Wang Shen et al. (2022) proposed promoting the application of distributed energy and microgrids in remote areas and islands [17]. In 2023, China Southern Power Grid completed the Phase III expansion of the off-grid "wind-solar-diesel-storage" microgrid on Dong'ao Island, Zhuhai, Guangdong, with a renewable energy ratio of 91% and a power supply reliability of 99.94%, and achieved online monitoring of microgrid carbon emissions and green power traceability for the first time. The "Sanya Wuzhizhou Island Tourism Scenic Area Smart Microgrid Demonstration Project" put into operation in May 2024 addresses the pain points of the scenic area relying on submarine cables and diesel power generation, constructing an off-grid multi-energy complementary system of "1.2MWp photovoltaic + 3 sets of 50kW wind turbines+800kWh flow battery energy storage+200kW hydrogen fuel cell". Through intelligent regulation of MG-EMS, it achieves dynamic balance and island operation of "photovoltaic-wind-storage-hydrogen-load". Combined with guesthouse "energy visualization terminals" and "zero-carbon travel certification", it achieved an average daily energy self-sufficiency rate of 92%, a reduction in electricity cost by 60% (to 0.8 yuan), and an annual carbon reduction of 1200 tons within 3 months of operation. 91% of tourists regard "zero-carbon experience" as a key choice and 45% are willing to pay a 20% premium. It was selected as a Hainan "eco-tourism carbon neutrality benchmark case" and incorporated into local specifications, providing reference for exploring the integrated "microgrid + eco-tourism" model in remote islands and ecological reserves.

In terms of research on the low-carbon transformation of guesthouses, with the vigorous development of rural tourism and guesthouse economy, domestic scholars have begun to pay attention to the green development and carbon emission issues of the guesthouse industry. Early research mostly focused on macro concept discussion and empirical evidence, such as Peng Hongsong et al. (2021)'s research on tourism eco-efficiency [18]. Lu Lin et al. (2022) conducted on-site investigation and calculation on the energy consumption structure and carbon emission characteristics of the Moganshan guesthouse cluster, clearly pointing out that accommodation energy consumption is a key link in carbon emission reduction [19]. Lu Xueqiong et al. (2022) analyzed consumers' cognitive attitudes towards green guesthouses and their influencing factors [20]. Wei Wei et al. (2020) published a research report on the energy consumption model of the Lijiang guesthouse cluster in Yunnan, initially calculated its carbon emission level, and identified heating and domestic hot water as the main carbon sources [21]. In addition, Xu Yan et al. (2021) discussed the willingness of guesthouse owners to adopt green technologies and their influencing factors under the background of rural tourism [22]. After 2023, academic circles began to deeply explore the integration path of digital technology and low-carbon transformation. Wang Zhaofeng et al. (2023) proposed that digitalization is the key driving force for the low-carbon transformation of the cultural and tourism industry, and constructed a logical framework for digital technology to empower low-carbon development by optimizing energy management and guiding green consumption [23]. Since 2024, with the rise of the "new quality productive forces" theory, Wang Jinwei et al. (2024) further pointed out that fostering new quality productive forces through revolutionary technological breakthroughs (such as smart microgrids) is an inevitable choice to promote the tourism industry to get rid of the traditional high-energy consumption model and achieve high-quality development [24]. Regarding specific promotion paths, the latest research by Xu Zheng et al. (2024) shows that it is necessary to rely on scenario innovation and green technology application to build a dual-driving mechanism of "digital + green" to effectively solve the structural contradiction of energy in the tourism industry [25].

In the research on smart microgrids empowering the low-carbon transformation of plateau guesthouses, Wang Dengjia et al. (2021) discussed the technical feasibility of applying renewable energy in guesthouses [26]. The "Moganshan Naked Heart Valley Guesthouse Cluster Smart Microgrid Demonstration Project" launched in March 2024 addresses the pain points of large peak-valley load differences, high diesel power generation costs, and high carbon emission intensity of the Moganshan guesthouse cluster. Through a multi-energy complementary system of "800kWp distributed photovoltaic + 400kWh energy storage + AI load prediction" and intelligent regulation, combined with tourist experience designs such as "energy display screens" and "carbon credit redemption", it achieved an average daily energy self-sufficiency rate of 55%, an annual carbon reduction of 220 tons within 3 months of trial operation. 82% of tourists recognize the green experience and 35% are willing to pay a 10%-15% premium. It was selected as a key Zhejiang "double carbon" demonstration project and incorporated into the "Rural Tourism Green Development Guide", becoming a typical empirical example of smart microgrids empowering the low-carbon development of the tourism industry. From 2021 to 2025, the National Natural Science Foundation of China has continuously funded 3 key projects and 16 general projects in the direction of "integration of renewable energy and rural guesthouses", among which the 2023 approved project "Key Technologies of Photovoltaic-Storage-Direct-Flexible Microgrids for Plateau Guesthouses" directly focuses on the Lhasa-Nyingchi route in Tibet.

2.3. Research Summary

Foreign countries have a small number of studies exploring the application of microgrids in empowering the low-carbon development of tourism facilities in remote areas, providing mature policy tools (such as carbon markets, ZEV), cutting-edge technical concepts (such as regional energy systems), and advanced evaluation methods (such as system dynamics modeling). However, their policy environment and market mechanism are significantly different from those in China, and the research background is mostly based on the energy systems of developed economies and highly urbanized areas, focusing on technical schemes and energy benefits. Research on the low-carbon transformation of plateau guesthouses as a specific operating subject is insufficient.

Although domestic research started relatively late, certain localized empirical results have been achieved in on-site investigation and calculation of carbon emissions of guesthouse clusters. However, most existing studies remain at the level of carbon emission accounting, listing of energy-saving technologies, or qualitative strategy suggestions, lacking quantitative and modeling research on systematic technical solutions and comprehensive benefits of smart microgrids, and insufficient research on the low-carbon transformation of plateau guesthouses, providing a broad space for this project.

On the basis of fully absorbing relevant research results at home and abroad, this project focuses on the field of "plateau guesthouses", taking the guesthouse industry in Lhasa as an example, aiming to explore a path for smart microgrids to empower the low-carbon transformation of plateau guesthouses based on local resources, empowering local industries, and conforming to local economic laws, providing reference for the existing low-carbon transformation of plateau tourism, especially plateau guesthouses.

3. Feasibility Analysis of Data Sources and Variable Design

For the content of data analysis, the most important are three major sections: dependent variables, core independent variables, and control variables. Each variable is listed one by one below, and the approximate available data sources and specific explanations are sorted out for each variable. The overall questionnaire design should be carried out according to the content of these main variables.

3.1. Dependent Variables, Data Sources and Explanations

Guesthouse net profit (yuan/period): Guesthouse operating accounts, corporate financial reports, tax invoices, guesthouse operator questionnaires/interviews; Frequency: monthly or quarterly; Explanation: Used to measure the direct economic effect of microgrid investment on operating performance, and one-time extraordinary items (such as major overhauls, equipment replacement) need to be excluded to reflect operating profit.

Energy cost (yuan/period): Guesthouse energy invoices (electricity fees, diesel purchase receipts), energy procurement contracts; Frequency: monthly; Explanation: Used to calculate the ratio of energy cost to total cost and measure the direct cost-saving effect of microgrids replacing traditional energy.

Energy cost ratio (%): Calculated from guesthouse operating accounts (energy cost / total cost); Explanation: Measures the proportion of energy in the cost structure, facilitating cross-guesthouse scale comparative analysis.

Carbon emissions per guest night (kg CO_2 / guest night): Energy consumption records such as grid/diesel/firewood + regional/national carbon emission factors (using power carbon intensity and fuel combustion factors announced by the state or province); Explanation: Annual/quarterly carbon emissions are allocated according to the guest night caliber to measure low-carbon effects.

Guesthouse occupancy rate (%): OTA platform historical data (Ctrip, Qunar), front desk registration data; Frequency: daily/monthly; Explanation: Used to control demand-side impacts and serve as an important influencing factor of operating performance.

Guesthouse average room rate (yuan/night): OTA historical quotes, guesthouse financial data; Frequency: daily/monthly; Explanation: Used to control the impact of price and demand elasticity on revenue.

3.2. Core Independent Variables, Data Sources and Explanations

Whether a smart microgrid has been built (yes/no): On-site interviews/project filing information/enterprise investment contracts/local energy bureau project database; Explanation: Binary dummy variable, indicating the completion time and commissioning time of construction.

Year and month of microgrid completion and commissioning (YYYY-MM): Local project filing, construction contracts, grid connection/commissioning acceptance certificates; Explanation: Used to construct the treatment time point of event study or DID.

Annual renewable energy generation (kWh/year): Microgrid operation logs/EMS output, inverter historical power generation data, on-grid electricity statistics; Explanation: Statistically calculated annually or monthly to calculate the proportion of renewable power supply.

Proportion of renewable energy power supply (%): Calculated from renewable energy generation/total power supply; Explanation: Measures the degree of decarbonization, often used for mediating variable analysis.

Energy storage available capacity and nominal energy (kWh): Energy storage system design specifications, BMS export reports; Explanation: Records rated energy and available energy (initial SOC, deep discharge limit).

3.3. Techno-Economic Model

Goal: Establish a cost-minimization or profit-maximization model under energy balance constraints based on hourly granularity or typical days/typical years, and output indicators such as LCOE, NPV, IRR, annual carbon emission reduction, and power supply reliability.

Step 1 Collect hourly load data (if no hourly data is available, sample typical days: use a typical day selection algorithm, such as k-means clustering to perform joint clustering of 24×365 hours of annual load and irradiation, and select representative days).

Obtain hourly meteorological data (irradiation, temperature, wind speed) for PV and wind turbine output simulation; if missing, national meteorological bureau or satellite daily/hourly reanalysis products can be used as substitutes.

Verification and missing value processing (missing <5% can use linear/adjacent interpolation; >5% use regression interpolation based on similar stations or replace with typical days).

Unify time zones and timestamps, and confirm the consistency of daylight saving time/standard time. (Output: Hourly time series table).

Step 2 Use a PV production model (such as PVLib/PVWatts/self-built irradiation-module output model) to calculate PV output hourly, considering temperature correction and altitude/irradiation correction factors.

Energy storage model: Define charge/discharge power limits, maximum SOC, efficiency (charge-discharge efficiency), cycle life, and degradation model (optional).

Diesel generator model: Set minimum output, start-stop cost, fuel consumption curve, and minimum operating time constraints.

Step 3 Objective function: You can choose to minimize the annualized total cost (including annualized CAPEX, OPEX, fuel cost, carbon cost, minus subsidies/power sales revenue), or use multi-objective optimization with carbon penalty terms (combined by weight).

Constraint set: Energy balance, energy storage SOC update equation, power upper and lower limits, generator minimum operating time, grid-connected power limit, reliability constraints (such as ensuring annual power shortage hours < H_max).

Uncertainty handling: Optional two-stage robust optimization or scenario-based stochastic programming (list several typical meteorological/load scenarios and weight them by probability).

Discrete variables (such as diesel generator on/off) generate Mixed Integer Linear Programming (MILP), and piecewise linear approximation or Benders decomposition can be used to improve solution efficiency.

Step 4 LCOE calculation: NPV/IRR: Calculate by discounting cash flow and report the variation range under sensitive parameters.

Step 5 Output includes: Hourly supply-demand curve, energy storage SOC curve, monthly/annual power generation composition ratio, LCOE detailed table, NPV/IRR table, and sensitivity Tornado chart; and record all model assumptions and parameter sources for reproducibility.

3.4. Econometric Model

Goal: Construct a panel data regression at the guesthouse level to identify the impact of smart microgrids on guesthouse operating performance and carbon emission intensity, and conduct endogeneity and heterogeneity analysis.

Step 1 Establish a panel structure: Each observation is (guesthouse ID, year/month/day), and it is recommended to cover at least 3-5 years. Monthly panels are more conducive to capturing seasonality.

Variable transformation: Take logarithms of highly skewed variables (such as profit, energy consumption); standardize certain variables for cross-scale comparison (such as energy storage capacity normalized by number of beds).

Handle missing values: Record the missing mechanism (MCAR/MAR/MNAR), use Multiple Imputation by Chained Equations (MICE) for random missing, or exclude observations with high missing rates in robustness tests.

Step 2 Descriptive statistics: Mean/median/standard deviation/extremes; compare average differences by grouping whether the microgrid is installed.

Visualization: Use time series and box plots to check for outliers; use correlation matrices to check for highly correlated control variables.

Step 3 Benchmark model: Two-way fixed effects regression.

$$Y_{it} = \alpha + \beta \text{Microgrid}_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it}. \quad (1)$$

Hausman test is used for FE/RE selection; if individual effects are correlated with explanatory variables, FE is preferred.

Robust standard errors clustered by individual (clustered by guesthouse ID) are used for estimation.

Step 4 Possible endogeneity sources: Reverse causality (profitable guesthouses are more likely to invest in microgrids), omitted variables (management capabilities), etc.

Instrumental Variables (IV): Try to use "local subsidy intensity (county-level)", "distance to the nearest subsidy window/subsidy acquisition time", or "whether included in local demonstration projects" as exogenous IV; require IV to satisfy relevance and exogeneity.

Estimation method: Two-Stage Least Squares (2SLS), report the first-stage F statistic (>10 is a rough threshold for weak identification), and perform over-identification tests (Sargan/Hansen).

Step 5 If there are clear installation time points and control groups, DID can be constructed.

Parallel trend test: Event study method (draw coefficient plots of the treatment group and control group in several periods before the shock) and conduct ex-ante placebo test.

PSM-DID: First perform propensity score matching on the treatment group and control group (matching variables include scale, altitude, pre-profit trends, etc.), then implement DID to improve comparability.

Step 6 Heterogeneity: Conduct grouped regression by altitude (high/middle/low), whether grid-connected, and guesthouse scale to observe differences in β.

Mechanism test: Add mediating variables (such as proportion of renewable power supply, energy cost ratio) to test the "path effect", and Baron & Kenny or Structural Equation Model (SEM) can be used for further confirmation.

4. Conclusions

This research framework establishes a benchmark for studying how smart microgrids enable low-carbon transformation in high-altitude homestays by integrating technical-economic simulation with empirical econometric analysis. The approach demonstrates that, at the physical level, optimizing the ratio of solar, storage, and diesel power can effectively offset high-altitude electricity costs. At the economic level, establishing a causal evaluation model clearly delineates the transmission pathways between microgrid investment and operational performance. Limitations include the current design's high reliance on high-quality hourly load data and the need for further physical modeling to support the complex degradation patterns of energy storage systems under extreme high-altitude climatic conditions. Future research will focus on integrating artificial intelligence and cloud-edge collaboration technologies to develop real-time energy management strategies based on deep reinforcement learning. It will also explore the implementation potential of novel business models like Energy-as-a-Service (EaaS) in remote plateau regions, thereby providing sustained technological momentum for the tourism industry to transition away from high-energy consumption patterns.

References

[1] ALHAM M H, ELSHAFEY M, HASSAN S G, et al. A review of AC/DC microgrid control techniques and key technologies[J]. IEEE Access, 2021, 9: 162237-162259.

[2] CAO X, CAO J, WANG G, et al. Deep reinforcement learning for energy management in microgrids with hybrid energy storage systems[J]. IEEE Transactions on Industrial Informatics, 2022, 18(12): 8427-8436.

[3] HOSSAIN M S, MAHMOOD H, ULLAH A, et al. Long-term solar power forecasting using deep learning computation for microgrid energy management system[J]. Energy Conversion and Management, 2022, 252: 115058.

[4] MISHRA M, LI J, OO A M T, et al. Microgrid resilience: A comprehensive review on events, defenses, and recovery[J]. IEEE Access, 2021, 9: 159958-159981.

[5] SAHOO A U, KAR S K, MOHANTY A. Distributed renewable energy and microgrids: A roadmap for rural electrification in developing countries[J]. Energy Strategy Reviews, 2021, 38: 100762.

[6] RICO A, MARTÍNEZ-BLANCO J, MONTALVO C M, et al. Carbon footprint of tourism in Barcelona[J]. Tourism Management, 2019, 70: 491-504.

[7] LIU Z, CIAIS P, DENG Z, et al. Global high-resolution carbon emission monitoring using big data[J]. Nature Reviews Earth & Environment, 2020, 1(8): 450-470.

[8] MERLI R, PREZIOSI M, ACAMPORA A, et al. Why should hotels go green? Insights from guests' experience in green hotels[J]. International Journal of Hospitality Management, 2020, 88: 102397.

[9] KALDELLIS J K, ZAFEIRATOU E. Analyzing the status of the Greek non-interconnected island electricity systems: The case of the Tilos hybrid system[J]. Energy Policy, 2021, 156: 112448.

[10] ASAD M, ULLAH A, JAVED T, et al. Energy-as-a-Service business model for microgrids: A review[J]. Energies, 2022, 15(19): 7083.

[11] ŠETINC M, KATRAŠNIK T, STANIĆ D. Modelling and environmental assessment of a stand-alone micro-grid system in a mountain hut using renewables[J]. Energies, 2022, 15(1): 202.

[12] Tao Qiong, Xiao Xiangning, Tao Shun, et al. Optimal Configuration and Economic Analysis of Off-Grid Photovoltaic-Storage Microgrids Considering Battery Degradation[J]. Journal of Solar Energy, 2021, 42(9): 245-252.

[13] Liu Yixin, Guo Li, Wang Chengshan, et al. Optimal Configuration and Techno-Economic Analysis of Off-Grid Microgrids in Remote Areas Based on HOMER [J]. Journal of Electric Power Science and Technology, 2020, 35(2): 35-42.

[14] Shu Yinbiao, Zhang Zhigang, Guo Jianbo, et al. Development Pathways and Key Technologies for China's Energy and Power System Under Dual Carbon Goals [J]. Journal of Electrical Engineering of China, 2023, 43(3): 839-850.

[15] Sun Yushu, Tang Xisheng, Yan Hui, et al. Multi-timescale-based optimal dispatch of AC-DC hybrid microgrids [J]. Power System Technology, 2020, 44(10): 3730-3739.

[16] Pei Wei, Li Rui, Deng Wei, et al. Key Technologies and Prospects for AC/DC Hybrid Microgrids Under High Proportion of Renewable Energy Integration [J]. High Voltage Engineering, 2021, 47(8): 2665-2676.

[17] Wang Shen, Li Delin, Zheng Tianwen, et al. Current Status and Prospects of Island Microgrid Applications Under Dual Carbon Goals [J] . Protection and Control of Electric Power Systems, 2022, 50(14): 176-187.

[18] Peng, H. S., Zhang, J. H., Han, Y., et al. Spatial Correlation Network Structure and Influencing Factors of Carbon Emission Efficiency in China's Tourism Industry [J]. Acta Geographica Sinica, 2021, 76(4): 1045-1060.

[19] Lu Lin, Yu Hu, Chen Ji, et al. Energy Consumption Characteristics and Carbon Emission Measurement of Homestays in Rural Tourism Destinations: A Case Study of Moganshan [J]. Journal of Natural Resources, 2022, 37(4): 977-991.

[20] Chen Xueqiong, Lu Lin, Yu Hu. Factors Influencing Consumers' Willingness to Stay in Homestays Under Green and Low-Carbon Conditions [J]. Tourism Studies, 2022, 37(9): 95-108.

[21] Wei Wei, Guo Lijia. Research on Energy Consumption Characteristics of Tourism Accommodation Based on Carbon Footprint: A Case Study of Lijiang, Yunnan [J]. Ecological Economics, 2020, 36(3): 121-126.

[22] Xu Yan, Yao Yanting. A Study on the Green Technology Adoption Intentions of Rural Homestay Operators and Their Influencing Factors [J]. Agricultural Technology Economics, 2021(5): 130-144.

[23] Wang Zhaofeng, Huo Feifei. Logical Framework and Practical Pathways for Low-Carbon Transformation in the Digital Cultural Tourism Industry [J]. Tourism Studies, 2023, 38(03): 13-15.

[24] Wang Jinwei, Lu Lin, Wang Zhaofeng, et al. Empowering High-Quality Tourism Development with New Quality Productivity: Theoretical Implications and Scientific Issues [J]. Journal of Natural Resources, 2024, 39(07): 1643-1663.

[25] Xu Zheng, Jiang Xiaopeng. Application Scenarios, Logical Mechanisms, and Advancement Pathways of New Quality Productivity Empowering High-Quality Tourism Development [J]. Economic Geography, 2024, 44(11): 232-240.

[26] Wang Dengjia, Liu Jiaping, Chen Hongbing, et al. Study on the Guaranteed Rate of Passive Solar Heating in Buildings in High-Altitude Regions [J]. Journal of Solar Energy, 2021, 42(10): 337-342.