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ARTICLE

Energy Consumption and Sustainable Development of the Tourism Industry: A Global Study on Regional Variations and Renewable Energy Integration

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ABSTRACT

The Tourism Industry plays a critical role in economic growth on the international scene but is equally responsible for contributing to greenhouse gas emissions and energy demand. The research analyzed the global trends of energy consumption (EC)within this industry concerning environmental performance, limits, and prospects of sustained expansion. It includes 300 tourism-related businesses across different global economic regions. Key tourism factors include EC, greenhouse gas emissions, renewable energy (RE) use, tourism's Gross Domestic Product (GDP) contribution, and energy efficiency. Statistical methods such as regression and panel data analysis assess the impact of tourism GDP, carbon emissions and RE.The regression analysis, including linear regression and panel data regression, to assess the influence of factors such as tourism GDP, carbon emissions, RE share, and energy efficiency improvements, providing a data-driven approach to understanding EC in tourism. The findings reveal regional differences, with developed regions

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consuming more energy per capita, while developing markets show progress in energy-efficient practices.The findings of the linear regression analysis show tourism GDP contribution (β = 4,200).The outcomes of the panel data regression analysis show the t-statistic values of carbon emissions (t = 5.64). The Difference-in-Differences analysis indicates that tourist GDP is greater in developed regions (β = 4,100) compared to developing regions (β = 3,500). Carbon emissions (β = 4,800) are greater, although RE (β = 4,200) and energy efficiency (β = 2,500) increase more in developing nations. The research emphasizes expanding use of RE in tourism infrastructure, especially in ecotourism and green hotels.

Keywords:Tourism Energy Consumption (EC); Sustainable Development (SD); Carbon Emissions; Renewable Energy (RE); Energy Efficiency

1. Introduction

Tourism is recognized as one of the important service industries and an essential worldwide economy. Tourism contributes to job creation, generates income, and eventually influences a country's Economic Growth (EG), especially during periods of economic disaster. The development in the domestic and international tourist arrivals enhances the income of the country and also increases EC. Among these activities, the transportation industry, particularly air transportation, makes a considerable contribution to increased energy use and emissions [1]. The process of individuals traveling from one location to another for enjoyment and spending time is known as tourism. The demand for various commodities is rising due to travel, and many cultures throughout the world are becoming more similar. The tourist business is interconnected with all areas of the global economy, which influences the GDP of a country both positively and negatively. Numerous jobs created by the TI have a significant impact on reducing poverty and enhancing global socioeconomic conditions [2].

Tourism is a vital industry of the economy, contributing significantly to economic and social well-being. Despite the benefits, the TI's fast rise has generated questions about its long-term sustainability. Inefficient EC is a major concern in the process of tourist growth and sustainability, given its significant contribution to tourism expenses and negative environmental repercussions. Energy is a crucial component of modern life and needs to be considered to reach sustainable living standards [3]. Modern economies depend heavily on energy and tourism, which are also significant components of global SD. Development in tourism and energy use boosts earnings, provides jobs, and assists in paving the way for a sustainable development for everyone. SD and reducing environmental resource management damage must be considered while satisfying rising EC. RE can help address inconsistencies in the energy mix while protecting the environment [4]. When compared to other energy sources, RE has a negligible environmental impact, which makes it an essential part of the shift to a lower-carbon economy [5].

The tourist business is critical to the global economy, but it falls short in terms of social, environmental resource management, and economic concerns. Blockchain, which acts as an Information Technology (IT), has the potential to assist in solving these difficulties and building sustainable tourism worldwide. The tourism sector boosts consumption, generates jobs, and develops a new driver of global economic development. However, tourism-driven expansion comes at the expense of environmental degradation, as tourism-related activities need more EC. The sub-sector of TI works inversely, uses various energy, has varying usage powers, executes its operations inversely, has distinct economic ramifications and has variable environmental resource management impacts [6]. Demand for EC is expected to increase as the population expands, and it is a prerequisite for economic advancement, especially in developing countries. The expansion of tourism is also influenced by the quality of institutions, since subpar institutions may keep tourists from entering a nation [7]. Tourists from all over the world evaluate a variety of factors when planning a trip to any nation. The most evident factors can include currency rate, income, infrastructure, price differential, the number of tourist attractions, population, local culture, literacy rate, poverty level, EG, political transportation expenses, stability, terrorism, tourism expenditures (TEs), EC, and institutional quality. Despite having a variety of positive benefits on the economy, the TI contributes to environmental degradation and greenhouse gas emissions as it relies primarily on existing energy sources such as fossil

fuel. When analyzing tourist demand, EC must be carefully examined, along with its impact on the country's environmental resource management [8].

The SD in tourism refers to satisfying the requirements of the host regions and present tourists when improving and protecting occasions for future generations. It emerges from the relationship between the idea of SD and TI, which serves the requirements of localities and tourists. Many international organizations and policymakers are increasingly viewing the tourist sector and its local and regional development links as high-potential vehicles for implementing sustainable development. In certain instances, the relationship between tourism and sustainable development is centered on tourism production and consumption, which is mostly driven by the TI's role in meeting the requirements of non-local people, such as tourists and visitors, with the tourism system. This production and consumption generate both positive and negative externalities for communities and the environment [9]. SD is the essential idea for encouraging the EG and humans while conserving the practical integrity of natural and social systems that support regional economies. Tourism has played an important role in promoting SD in numerous regions and nations across the world. In emerging countries, tourist growth has been utilized to boost EG, alleviate poverty, create jobs, and improve thesecurity of food [10].

The primary aims of SD are to protect the environment from the negative externalities of development while also ensuring environmental resource management, community engagement, and other benefits. As a result, sustainable tourism is a vital component of SD in the TI. Its primary goal is to preserve the environment, provide economic advantages, and conserve sociocultural values [11]. Preservation of the environment, cultural authenticity, and the profitability of tourism at the destination are all necessary for the growth of sustainable tourism development, which guarantees the inverted well-being index and the social return of visited places while also giving the local population enough money through jobs, wealth, and resource availability [12]. **Figure 1** depicts the key features of the EC and SD of the TI. It provides attention to important elements affecting social impact, environmental resource management, and economic progress. It provides insights into long-term sustainability and strategic development by displaying important elements, and their relationships, and it influences sustainable development industrial practices.

Figure 1. Key Features for the EC and SD of the TI.

The TI's increasing EC and greenhouse gas emissions provide difficulties to SD, requiring a balance between EG and environmental resource management. The research focuses at global EC trends in the TI, focusing on the environmental impact, limits, and potential for sustained growth.

2. Related Works

The impact of the tourism expansion, EG, and usage of the RE on the CO_2 emissions in the Organization for Economic Co-operation and Development (OECD) countries was investigated [13]. Findings show that tourism has varying effects on emissions across countries when using the augmented mean group estimator and the bootstrap panel cointegration approach. While some countries experience an increase in emissions due to tourism, others see a decline due to cleaner energy transitions. It should be emphasized that countries with strong environmental rules are more effective in mitigating tourism-induced emissions. The relevance of technical advancements in energy efficiency for reducing tourism's carbon impact is also highlighted. Methodological presumptions that influence generalizability and data limitations are examples of limitations.Totally, 38 OECD nations were included [14], which examined how tourist development affected greenhouse gas emissions and how RE could reduce environmental costs. Results from a dynamic Gaussian mixture model (GMM) model show no discernible association between tourism and emissions, most likely as a result of a move toward RE. It showed that greater RE investments in tourism-dependent economies assist in decoupling economic development and environmental degradation. It also implies that government incentives for RE adoption in the hotel industry can result in long-term advantages. The re-

search's concentration on OECD countries limits its capacity to be applied globally.

According to socioeconomic levels, Shang et al. investigated how energy resources and tourism affected the expansion of the green economy[15].According to econometric research, tourism promotes sustainable Gross Domestic Product (GDP) development in high-income countries while impeding it in low-income. Both groups suffer when fossil fuels are used. It emphasized that policy interventions, such as carbon pricing and green infrastructure expenditures, can assist low-income countries in maximizing tourism's economic advantages while lowering emissions. It also emphasized the need for international cooperation in promoting low-carbon tourist concepts around the globe. Data limitations and possible unobserved variables are examples of limitations. Using information from Google Trends, the United Nations World Tourism Organization (UNWTO), and other research on virtual reality and human-computer interaction, the studydefined metaverse tourism and investigated its potential for sustainable tourism[16]. Metaverse tourism could promote the UNWTO SD Goals while increasing tourist resources and revenue. It underlined that metaverse tourism has the potential to dramatically minimize environmental deterioration by decreasing passengers' physical footprints. Furthermore, the use of Artificial Intelligence (AI) in virtual tourist experiences cab improves customization and accessibility. However, empirical research is required to evaluate its efficacy.

The long-term influences of natural resource rents, tourism, urbanization, and Information & Communication Technology (ICT) on environmental sustainability and per capita income in 36 OECD nations were explored [17]. Results from the two-step GMM and Augmented Mean Group (AMG) methods indicated that ICT reduces cereals, while urbanization, tourism, and revenues from natural resources increase it. This implied that smart tourism technologies, such as IoT-based monitoring systems, can help to reduce tourism-related emissions. It also emphasized that measures that combine digital transformation and sustainable urban design could successfully reduce pollution from tourism-intensive areas. Limitations include the availability of data and possible biases in the model estimate. Canonical Cointegrating Regression (CCR), Autoregressive Distributed Lag (ARDL), Fully Modified Least Squares (FMOLS), and Dynamic Ordinary Least Squares (DOLS) address were applied to analyze the effects of GDP growth, EC, urbanization, tourism, agriculture, and forest cover on the CO_2 emissions and it was found that the emissions fall with trees and RE and increase with growth and fossil fuel consumption[18]. It also underlined that government-led afforestation activities and carbon offset schemes suited for the TIcan dramatically reduce emissions. Furthermore, green certification schemes in tourist regions might encourage firms to adopt environmentally friendly practices.

The impacts of EG, tourism, RE, industrialization, urbanization, forest cover, and agriculture on carbon dioxide emissions are analyzed [19]. Granger causality, DOLS, and ARDL bounds test findings suggest that economic activity increases emissions while agriculture, forests, and RE decrease them. The study found that sustainable tourism policies, such as ecotourism incentives and stricter emission laws, can effectively balance economic development with environmental sustainability. Furthermore, public awareness efforts encouraging green tourism practices can influence travelers' environmentally beneficial behavior. Data limitations and model assumptions are used to emphasize the necessity for much more research on mitigation interventions by sector. The influences of tourism, EG, urbanization, and the usage of RE on CO_2 emissions were investigated [20], using time series data and the ARDL bounds test approach, with subsequent DOLS. Emissions are increased by tourists, urbanization, and economic expansion, but decreased by RE. It emphasized how sustainable urban planning, such as energy-efficient transit and eco-friendly lodging, can reduce tourism's environmental effects. It also implied that destination-specific carbon offset schemes might entice tourists to contribute to environmental protection. Data difficulties and potential issues with model building are among the limitations. The influences of the EG, tourism, agriculture, and EC on CO_2 emissions were investigated [21]. Emissions are lower when computed based on agriculture and RE, but greater when computed based on fossil fuels and tourism, according to the DOLS approach. It concluded that including climate-friendly tourist regulations, such as low-emission transportation and sustainable supply chains, dramatically reduces tourism-related emissions. Furthermore, it emphasized the need for cross-border partnerships in developing uniform

emission reduction objectives for the TI. This is limited by data limitations and potentially omitted variables, especially considering the strong results of FMOLS and CCR.

The connection between tourism, travel, and the ecological footmark was analyzed utilizing the Environmental Kuznets Curve (EKC) [22]. The study examined how trade openness, EC, tourist development, EG, and foreign direct investment (FDI) influence environmental degradation utilizing the ARDL limits test and the Bayer and Hanck cointegration test. The results demonstrated that energy usage, foreign direct investment, and trade openness all contribute to ecological degradation, supporting the concept of tourism growth and an inverted U-shaped EKC connection. However, model reliance and data limits are among the drawbacks. Sustainable tourism, fuel diversification, and eco-friendly FDI in services should be the main priorities of representatives.

The architecture of rural tourism buildings (RTBs) was adjusted to increase energy efficiency while preserving internal comfort[23]. Three main RTB Types were identified through a field survey conducted in three villages as part of the research methodology. EC, daylighting, and thermal comfort are analyzed using Pareto-based multi-objective optimization (Octopus tool) using benchmark models created with Rhino-Grasshopper. The findings demonstrated that skylight-covered atriums lowered EC, with energy savings being crucial for heating and cooling loads. Limitations, however, include limited applicability to areas with distinct architectural conventions and variations in local temperature conditions. The results offered design recommendations for RTBs in comparable environments.

The influence of tourism on reducing inequality was examined by Shi et al. [24], who analyzed the many links among tourists, EG, CO_2 emissions, and EC across income levels. Through several panel models, such as Granger causality tests and cointegration, we experimentally investigated these interactions at different phases of development. The findings showed that while high-income nations show better feedback causation, tourism-related CO_2 emissions rise more sharply in low-income ones. Limitations, however, include the removal of other environmental variables and possible data discrepancies among nations. These results demonstrated how crucial income-based disparities are in influencing governmental regulations for environmentally friendly travel and EG.

During COP26, Shan and Ren explored how tourism and the use of RE affected HQED[25]. To examine regional variations in eastern, and central regions, as well as to confirm the geographical impacts of HQED and the mediating function of RE consumption, a spatial Durbin model is built using data from 30 regions. While tourist growth has a negative influence on the HQED due to high EC and CO_2 emissions, the outcomes showed that RE enhances HQED but has a limited influence and no regional spillover. Due to limitations such as limited sample size and unconsidered external factors that impact HQED, more study on sustainable solutions is required.

In 51 Belt & Road Initiative (BRI) nations, Khan et al. investigated the influences between natural resources, tourism, EC, income, and CO_2 emissions[26].They validated the tourist-push emission theory and found a bidirectional causal association between tourism and income using a simultaneous equations framework and difference and system GMM estimates. The findings support the natural resource curse, which holds that although natural resources have a detrimental effect on income, they also increase EC, tourism, and CO_2 emissions. Potential data discrepancies across nations and unobserved external influences are among the drawbacks, though. The results emphasized the necessity of conservation regulations and investments in green infrastructure to improve GDP growth, environmental quality, and the rise of sustainable tourism.

Panel data from 70 countries was used to examine how tourist development affects carbon dioxide emissions and environmental pollution[27]. Spatial spillover effects are evaluated using a spatial econometric approach, evaluating the direct, indirect, and total impacts using the General Nesting Spatial (GNS) model. According to the findings, tourism has a negative effect as it directly increases pollution while also indirectly reducing it. However, the connections between financial development and carbon emissions are both U-shaped and inverted U-shaped. The need for more research on long-term sustainability dynamics, unobserved geographical influences, and possible data limitations are some of the limitations.

In G20 economies, Tian et al.investigated how real GDP, tourism growth, and the use of RE affected CO_2 emissions[28]. Both the Pedroni and Kao techniques use

panel unit root tests to verify long-term cointegration between the variables. A 1% rise in tourism development lowers CO_2 emissions by 0.05% over the long term, according to FMOLS data, whereas a 1% increase in the use of RE lowers emissions by 0.15%. Additionally, the results demonstrated an inverted U-shaped link between GDP and pollution, supporting the EKC hypothesis further. Limitations, however, include geographical differences, unreported policy impacts, and possible data errors. It concludes that reducing CO_2 emissions can be facilitated by sustainable tourism.

Using an EKC paradigm, Ohajionu et al. investigated the connections between tourists, domestic credit, FDI, income, and CO_2 emissions[29].They examined Mediterranean panel data using the AMG and Method of Moment Quantile Regression (MM-QR) techniques. The findings supported the inverted U-shaped EKC hypothesis by showing that wealth has a positive correlation with emissions and that tourism lowers CO_2 emissions. The Pollution Haven Hypothesis (PHH) is supported by the fact that FDI raises pollution while domestic financing has a favorable impact on emissions. The absence of sector-specific FDI analysis and possible data heterogeneity between nations are among the limitations. To strike a balance between sustainability and EG, future studies should include the use of RE sources and legislatively mandated environmental protections. In the context of the energy-economy-environment nexus, Raihan examined how income growth, energy use, and tourism affected carbon emissions[30]. To analyze time series data, the ARDL approach was used, which captured both short-term and long-term dynamics among these variables. According to the findings, growing energy use, economic expansion, and visitor numbers all contribute to an increase in CO_2 emissions. The shortcomings, however, include the removal of additional possible environmental effects and the absence of detailed sector-by-sector EC statistics. To tackle these issues, the report recommends increasing the use of RE sources and encouraging eco-friendly travel as crucial tactics to attain carbon neutrality and environmental sustainability.

The advantages of sustainable tourism for communities, local governments, the environment, and visitors were the main emphasis by Tien et al[31], who assessed the successes and difficulties of this development in Vietnam's coastal districts. To analyze how policy planning, socioeconomic issues, and institutional frameworks influence the implementation of sustainable tourism, the research uses a qualitative method. Although the results show the benefits of sustainable tourism, socioeconomic limitations and governance concerns show a large discrepancy between the goals of the policy and its actual implementation. Economic pressures, environmental concerns in emerging countries, and challenges enforcing policies are some of the main constraints. Based on the outcomes, the research makes first recommendations for improving culture and ecotourism to bridge the gap between practice and policy for long-term sustainability.

Using data from 30 provinces, Rauf explored the long-term relationships between tourist growth, EG, transportation, EC, and environmental degradation[32]. To evaluate the relationships, the methodology comprises the CD test for cross-sectional dependency, CIPS unit root tests, and sophisticated panel estimate techniques (DOLS, FMOLS, and PMG). The findings demonstrated that while tourist expansion has a mixed impact on ecological deterioration, EC, transportation, and hotel food services all considerably increase CO_2 emissions. The causality test demonstrates that there are reciprocal relationships between environmental quality and energy use, tourism, transportation, and EG. Potential data discrepancies between provinces and the omission of other environmental elements affecting CO_2 emissions are among the limitations. Differing sustainability approaches among tourism entrepreneurs and stakeholders influence the growth of nature tourism in a nature park setting was examined by Sørensen and Grindsted[33]. According to their findings, sustainability viewpoints are not easily grouped into theoretical frameworks; rather, they create their sustainability DNA, which causes disputes because of incommensurate viewpoints. Deeply held ontological views on sustainability and its place in corporate strategy are the fundamental causes of these disputes. To tackle these issues, a root-cause model is suggested. Nevertheless, the research's narrow emphasis on a single instance limits its applicability to other tourism environments, necessitating more research. A framework for sustainable ecotourism was proposed by Baloch et al.[34], which examined the connection between environmental sustainability and tourism development. Data from

650 respondents including visitors, local government representatives, hotel owners, tour operators, and civil administrators were subjected to hierarchical regression analysis. According to the findings, the rise of tourism contributes to socioeconomic advantages like jobs, business possibilities, and infrastructural development, but it also causes pollution, social vulnerability, and environmental deterioration because of overuse of land and cultural intrusion from outside sources. Potential response bias and findings that are peculiar to a certain place are among the limitations that restrict generalizability.

The connection between the transportation, commercial, and public services industries, and the overall economy's final energy use and the tourism industry in the 15 nations with the greatest number of foreign visitors worldwide between 2000–2019 were examined by Pablo-Romero et al[35]. Their findings demonstrated that rather than being related to the money spent by visitors, the positive correlation between energy consumption and tourism appears to be related to increasing consumption produced by the growing population of the tourist area.

The factors of carbon emissions were described by-Shah et al. as being tourism, financial complexity, ICT, FDI, and renewable energy usage[36]. The econometric findings supported the economic difficulty index-induced environment Kuznets curve theory for the chosen Asian nations by confirming an inverted U-shaped relationship between carbon emissions and economic difficulty.

A selection of the top 20 tourist countries from 2005 to 2020 was analyzed by Qamruzzaman to examine the relationship between tourism, the use of renewable energy, and environmental effects[37]. The findings demonstrated a statistically significant and beneficial connection between tourism growth and renewable energy utilization, supporting the theory that increased tourism activity leads to increased use of renewable energy sources.

To achieve the UN Sustainable Development Goals (SDGs), it was possible to improve the quality of tourism destinations as explained by Mason et al[38].They showed that a small percentage of the SDGs were primarily concerned with quality, while the majority were mostly focused on quantity.It maintained a beneficial relationship between improving destination quality and dealing with the SDGs at tourist sites.

The challenges include data limits, possibly unobserved factors, and geographical differences that may affect the result's generalizability. The worldwide application of many of the assessments was limited because the findings were limited to certain countries or areas, such as OECD or BRI countries.The findings might be influenced by econometric model assumptions, such as neglecting sector-specific elements or outside environmental variables.The results were further limited by possible biases in model assessments and variations in the quality of the data. Dependence on certain methodological techniques, such as ARDL or GMM, could not account for all the variables influencing the connection between emissions, renewable energy, and tourism.The approach was important since it focused on how energy consumption varies by location in the tourist industry and emphasized the importance of integrating renewable energy sources.It addresses the problem of achieving a balance between the expansion of tourism and environmental sustainability, encouraging eco-friendly behaviors in a variety of geographical areas.

2.1. Problem Statement

The tourism sector plays a vital role in the expansion of the world economy, but its effects on the environment, especially energy use, make sustainable development challenging.The global expansion of tourism creates greater pressure on energy supplies, increasing environmental damage, emission of greenhouse gases, and unsustainable consumption procedures. The tourism industry faces specific challenges and possibilities due to local shifts in energy consumption patterns. These variations are influenced by economic, geographical, and infrastructure factors that impact energy management and use. The carbon footprint of the tourist industry is increased by considering that certain areas are making progress in incorporating renewable energy into their infrastructure, while others keep depending mostly on non-renewable sources.

3. Methodology

The method includes research sample and design, data collection, and statistical analysis such as regression analysis, descriptive statistics and panel data regressionto identify patterns and influencing variables for the industry's SD.

3.1. Research Sample and Design

The research employs 300 tourism-related businesses across different global economic regions to analyze energy use patterns in the TI. The regions were chosen based on their intensity in tourism, energy consumption patterns, and sustainability policies. Some quantitative approaches were employed to analyze the relationship between tourism development, energy use, and sustainability efforts through statistical modeling.

3.2. Data Collection

The research employed a dataset that included records from 300 tourism-related businesses across different economic regions and covers several tourism sectors. Utilizing random sampling, 300 tourism-related businesses were selected based on specific standards:Businesses with developed sustainability strategies, high tourism intensity, and unique energy consumption patterns were selected from a variety of global economic locations.The selection method utilized characteristics such as business type, location, and size to guarantee an extensive and representative sample.Furthermore, sectors like resorts, hotels, and transportation services, which have high-energy requirements, receive emphasis. The association between tourism growth, energy usage, and sustainability initiatives was extensively investigated due to this method, which made it possible to make insightful comparisons between areas with different economic and environmental resource management circumstances. The demographic information of the participants, including region, income level, tourism sector, and other pertinent criteria, are shown in **Table 1** and **Figure 2**.These characteristics assist in comprehending the composition of the sample and offer a basis for examining the potential effects of these demographics on the results.

Table 1. Demographic Features.

Variables	Category	Frequency (n)	Percentage (%)
Region	Developed Regions	120	40%
	Emerging Economies	100	33.3%
	Developing Regions	80	26.7%
Income Level	High Income	100	33.3%
	Middle Income	120	40%
	Low Income	80	26.7%
Tourism Sector	Accommodation	100	33.3%
	Transportation	90	30%
	Food & Beverage	60	20%
	Entertainment	50	16.7%
Tourism Contribution to GDP	Low (<5%)	90	30%
	Moderate (5–10%)	120	40%
	High (>10%)	90	30%
Energy Source in Tourism	Renewable Energy	110	36.7%
	Mixed (Renewable & Non-renewable)	130	43.3%
	Fossil Fuels	60	20%
Energy Consumption (MWh)	Low (<50 MWh)	80	26.7%
	Medium (50–150 MWh)	140	46.7%
	High (>150 MWh)	80	26.7%
Carbon Emission Level	Low (<50 tons CO_2)	100	33.3%
	Medium (50–150 tons CO_2)	120	40%
	High (>150 tons CO_2)	80	26.7%
Sustainability Initiatives	Renewable Energy Use	110	36.7%
	Energy Efficiency Measures	130	43.3%
	Carbon Offsetting Programs	60	20%

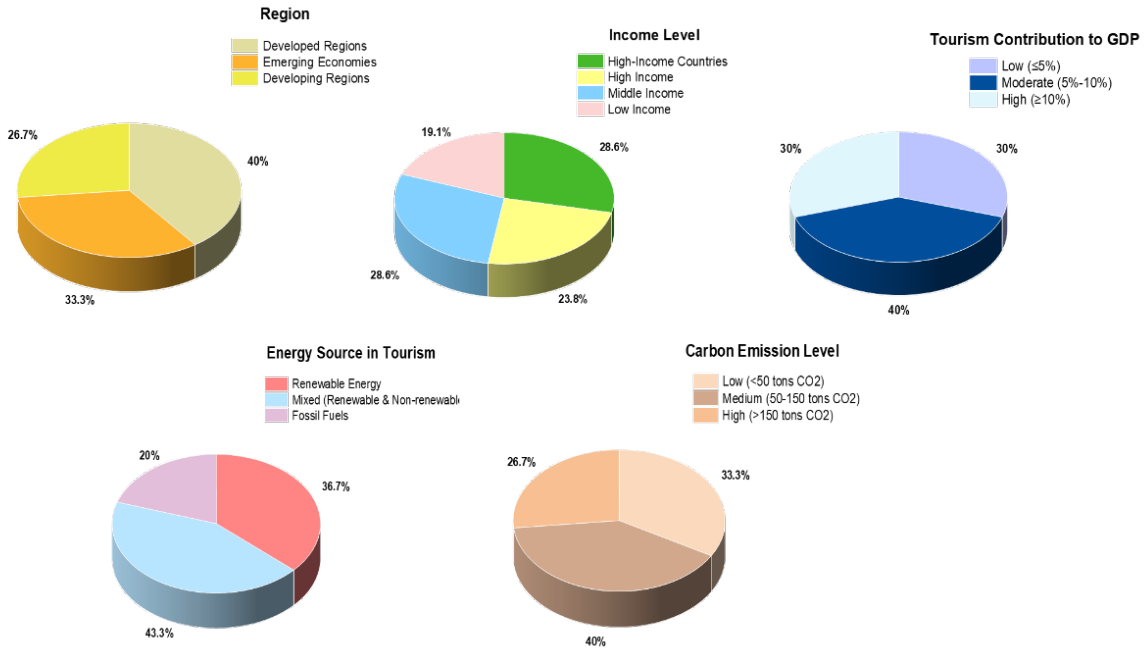

Figure 2. Graphical Representation of the Demographic Features.

3.3. Statistical Analysis

The research utilizes a variety of statistical measures to examine tourist development and EC, including descriptive statistics, regression analysis, and Panel Data Regression. Descriptive statistics is used in summarizing key trends in EC, including mean, Standard Deviation (SD), median and percentage change over time. Regression analysis is used in examining the relationships between tourism development, GDP, and EC and determining the most influential contributing factors. Panel Data Regression is used to observe the dynamic link between the EC, EG, and SD in the tourist sector across various countries.

4. Result

This section presents the outcomes of the research, which analyzes the correlation between the SD and energy use in the TI. Different statistical methods, including descriptive statistics, linear regression, and panel data regression, are employed to analyze patterns, determinants, and regional differences. The results offer critical information on energy efficiency, carbon emissions, and the role of RE in guiding policy recommendations for SD.

4.1. Descriptive Statistics

Descriptive statistics characterize and interpret data to expose patterns, trends, and variations in a dataset. It facilitates an understanding of the distribution of carbon emissions, energy use, and the uptake of RE in several countries. The statistics provide a detailed description of the economic advantages to the tourists and operational efficiency gains that allow policymakers to determine trends, imbalances, and specific areas that require intervention for continued tourism development. The mean provides the average value of all of the variables, hence aiding the interpretation of overall trends in tourism EC. The median, embodying the value at the midpoint, tends to lessen the impact of extreme numbers and thus gives a fair image. Standard Deviation (*Std. Dev.*) quantifies data dispersion, revealing considerable variation in total energy consumption (TJ) between nations. Carbon emissions range from 3.5 to 18.6 Mt CO_2, showing the need for sustainable development strategies suited to diverse levels of EC. The descriptive statistical analysis of important elements, such as tourism GDP, carbon emissions, and RE, is shown in **Table 2** and **Figure 3**.It provides insights into their patterns and

connections while highlighting their growth and significance. The results contribute to a better understanding of how these elements influence environmental resource management and economic trends.

Table 2. Descriptive Statistic's Outcomes.

Variables	*Mean*	*Median*	*Std. Dev.*	*Min*	*Max*
Total Energy Use in Tourism (TJ)	85,000	80,500	25,000	40,000	150,000
Carbon Emissions from Tourism (Mt CO_2)	10.5	9.8	4.2	3.5	18.6
Share of Renewable Energy (%)	35.4	32.0	10.8	10.0	65.0
Tourism GDP Contribution (%)	8.2	8.0	2.5	3.5	14.5
Energy Efficiency Improvement (%)	12.5	12.0	4.1	5.0	22.0

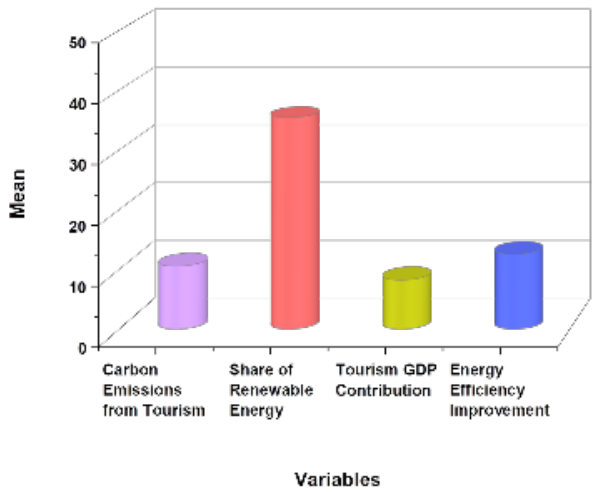

Figure 3. Descriptive Statistic'sGraphical Representation.

Table 2 reveals that the Total Energy Use in tourism is 85,000 TJ (Terajoule), with values ranging from 40,000 to 150,000 TJ, indicating regional differences. Carbon emissions average 10.5 Mt CO_2 (Megaton of Carbon Dioxide), with industrialized countries having larger emissions. RE represents 35.4% of tourist infrastructure on average but can reach 65% in eco-tourism-driven countries. Tourism generates 8.2% of GDP on average, while energy efficiency gains average 12.5%, indicating an increasing movement toward sustainability.

4.2. Linear Regression Analysis

Linear Regression is a statistical technique that models the connection between the dependent and independent variables. It aids in identifying significant drivers of energy usage in tourism. It analyzes how variables such as tourism GDP contribution, carbon emissions, RE adoption, and energy efficiency improvements affect total EC, allowing policymakers to support sustainable development practices. The Coefficient (β) evaluates the effect of independent factors on EC. The Standard Error (*SE*) helps measure accuracy by indicating diversity in β estimations. The *t-statistic* determines the relevance of each variable by demonstrating how strongly it affects energy usage. The *p-value* indicates statistical significance, with values less than 0.05 indicating substantial impacts. R^2 indicates that the model explains the variance in energy usage, whereas *Adjusted* R^2 measures the number of predictors to avoid overfitting. Finally, the *F-Statistic* evaluates the entire model's significance, confirming the substantial explanatory power of tourism GDP, carbon emissions, and sustainability metrics in predicting EC patterns. The effects of variables such as tourism GDP, carbon emissions, and RE on economic and environmental resource management consequences are demonstrated using Linear Regression analysis in **Table 3**.It provides substantial information for the establishment of environmental resource management and tourism policies by demonstrating the correlations between these variables and assisting in the assessment of their impact on economic development and environmental resource management.

Tourism GDP contribution considerably increases EC (β = 4,200, p = 0.0001), indicating that increased tourism-related economic activity leads to greater energy demand. Carbon emissions have a significant positive influence (β = 6,500, p = 0.00001), indicating that greater emissions lead to increased energy use. Renewable energy share (β = –1,800, p = 0.013) and energy efficiency improvements (β = –2,100, p = 0.018) lead to lower EC, illustrating the advantages of sustainability initiatives. The model explains 78% of the variance in EC (R^2 = 0.78), making it a strong predictor of tourism-related energy changes.

Table 3. Outcomes of the Linear Regression Analysis.

Variables	β	*SE*	*t-Statistic*	*p-Value*	R^2	*Adjusted* R^2	*F-Statistic*
Tourism GDP Contribution (%)	4,200	950	4.42	0.0001			
Carbon Emissions (Mt CO_2)	6,500	1,200	5.42	0.00001			
Renewable Energy Share (%)	–1,800	700	–2.57	0.013	0.78	0.75	27.5
Energy Efficiency Improvement (%)	–2,100	850	–2.47	0.018			
Constant (Intercept)	30,000	8,500	3.53	0.002			

4.3. Panel Data Regression Analysis

Panel Data Regression is a statistical approach for analyzing datasets with both cross-sectional (various regions) and time-series (over years) components. It contributes to capturing country-specific and time-dependent changes in tourist energy usage. This technique gives more detailed insights into how factors such as tourism GDP, carbon emissions, renewable energy share, and energy efficiency gains affect EC over time while accounting for country-specific variations. Fixed Effects (*FE*) Coefficient modifies for country-specific factors influencing EC, whereas Random Effects Coefficient (*REC*) allows for fluctuations over time and between countries. The *SE* evaluates the accuracy of coefficient estimates, which provides statistical dependability. The *t-statisic* tests the significance of each independent variable's contribution to EC, and the *p-value* tests statistical significance, with results below 0.05 showing significant correlations. The Hausman Test validates the *FE* model by pointing out the significance of country-specific variables on sustainable tourism EC. The findings of a Panel Data Regression analysis, which was used to evaluate the influence of factors including carbon emissions, tourism GDP, and RE on the research outcomes, are shown in **Table 4**.The panel data regression model assesses the connections among these variables, offering information on how energy sources, tourism, and environmental issues affect the overall ecological and economic growth.

The *FE* model ($R^2 = 0.81$, $p = 0.005$) reveals significant country-specific impacts on EC. Tourism's GDP contribution ($\beta = 3{,}800$, $p = 0.0002$) and carbon emissions ($\beta = 6{,}200$, $p = 0.00001$) considerably impact energy use. Adopting RE ($\beta = -1{,}700$, $p = 0.012$) and improving energy efficiency ($\beta = -2{,}000$, $p = 0.008$) lead to reduced energy usage. These findings highlight the need of sustainable energy policy in tourism in balancing growth and environmental resource management responsibility.

Table 4. Outcomes of the Panel Data Regression.

Variables	*FE*	*REC*	*SE*	*t-Statistic*	*p-Value*
Tourism GDP Contribution (%)	3,800	4,100	920	4.13	0.0002
Carbon Emissions (Mt CO_2)	6,200	6,450	1,100	5.64	0.00001
Renewable Energy Share (%)	–1,700	–1,850	680	–2.50	0.012
Energy Efficiency Improvement (%)	–2,000	–2,150	780	–2.69	0.008
Constant (Intercept)	28,500	30,000	8,200	3.48	0.001
R^2 (Overall)	0.81	0.78	-	-	-
Hausman Test (χ^2 test statistic)	12.45	-	-	-	0.005

4.4. Difference-in-Differences (DiD) Analysis

DiD analysis is a statistical method that compares changes in results over time between the treated group and a control group to assess the causal influence of a strategy. DiD evaluates pre- and post-intervention patterns across tourism-related businesses to investigate whether the expansion of tourism affects energy consumption and sustainability.The findings demonstrate an increase in tourism-related GDP and carbon emissions, advancements in energy efficiency, and the usage of renewable energy.It ensures a more accurate comprehension of the economic and environmental impact of tourism by helping to recognize the actual impact of changes in the market or policy.

To indicate a statistically significant correlation between variables, the p-value must be smaller than the selected significance threshold, which is usually 0.05 or 0.01. Utilizing the DiD approach, **Table 5** and **Figure 4a,b** contrast the GDP contributions from tourism, carbon emissions, energy efficiency, and renewable energy across developed and developing regions. This provides an understanding of sustainability and growth trends across different areas by highlighting differences in economic and environmental resource management impacts.

Tourism-related energy and economic aspects are compared across developed and developing regions using the DiD analysis.In developed regions, tourism GDP contributesmore (β = 4,100) than in developing ones (β = 3,500), with a DiD estimation of 600 (p = 0.035).There is a considerable difference in carbon emissions between the developed region (β = 7,200) and the developing region (β = 4,800), with a DiD calculation of 2,400 (p = 0.002).Developing regions have a greater percentage of RE (β = 4,200), with a DiD estimation of 3,500 (p = 0.001).A DiD estimation of 1,000 (p = 0.045) indicates that energy efficiency improvements are more prevalent in developing regions (β = 2,500).

Table 5. Outcomes of the DiD Analysis Comparison Across Developed and Developing Regions.

Variables	Developed Regions		Developing Regions		DiD Estimate (β)	*SE* (DiD)	*t-Statistic* (DiD)	*p-Value*
	(β)	*SE*	(β)	*SE*				
Tourism GDP Contribution (%)	4,100	920	3,500	850	600	400	1.50	0.035*
Carbon Emissions (Mt CO_2)	7,200	1,150	4,800	900	2,400	800	3.00	0.002**
Renewable Energy Share (%)	3,800	920	4,200	950	3,500	900	3.11	0.001**
Energy Efficiency Improvements (%)	1,500	650	2,500	720	1,000	500	2.00	0.045*

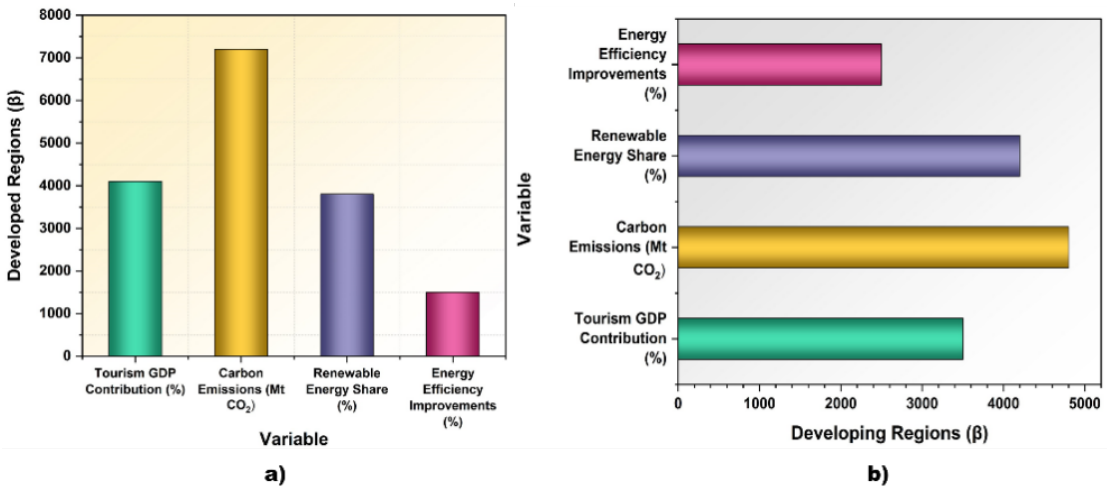

Figure 4. DiD Analysis Outcomes of(**a**)Developed Regions and(**b**)Developing Regions.

5. Discussion

The findings reveal that the EC of countries differs widely, with higher tourist-oriented GDP contributions translating to higher energy use. The environmental resource management implications of growing tourism have also been amplified by a close correlation between the rise in CO_2 emissions and energy use. While tourism generates additional GHG emissions, enhanced policy measures like promoting energy efficiency and the use of RE can lessen resultant negative environmental changes. The FE model highlights the importance of distinct national policies in driving sustainable EC. This approach provides insight into how these tourism-dependent economies need to consume more energy, but incorporating sustainability with renewable sources and energy efficiency programs will decrease the negative environmental fallout, thus requiring policy prescriptions, technological advancements, and cross-

sector partnerships for sustainable tourism growth over sustainability.

The challenges include the possibility of data errors, the assumption of uniform connections across nations, the disregard of factors like technological advances, and the failure to account for regional differences in tourism practices. These factors might fail to fully represent the intricacy of the energy impact of tourism [35].The constraints include the use of certain econometric models that could not adequately represent dynamic, long-term environmental consequences across varied Asian countries, the possibility for biases resulting from regional economic variations, and the failure to account for all variables affecting carbon emissions [36].Disadvantages include possible biases from focusing only on the top 20 tourism destinations, a lack of analysis for local contexts, dependence on general information that may ignore sector-specific variances, and a lack of ability to account for additional environmental problems influencing sustainability [37].

The average amount of energy used in tourism is 85,000 TJ, according to descriptive statistics, with emissions of 10.5 Mt CO_2 and a 35.4% adoption rate for renewable energy share. The results of linear regression show that EC is considerably increased by tourism GDP contribution (β = 4,200, p = 0.0001) and carbon emissions (β = 6,500, p = 0.00001) while it is decreased by RE adoption (β = –1,800, p = 0.013), and energy efficiency (β = –2,100, p = 0.018).There are notable country-specific impacts on energy consumption, as shown by the panel data regression analysis (R^2 = 0.81, *Hausman test* p = 0.005). EC is increased by carbon emissions (FE = 6,200, p = 0.00001) and tourism GDP contribution (FE = –3,800, p = 0.0002), but it is decreased by the RE share (FE = –1,700, p = 0.012), and energy efficiency improvements (FE = –2,000, p = 0.008), highlighting sustainable development policy initiatives.The DiD analysis evaluates the environmental resource management and economic effects of tourism in various regions.In contrast to developing regions (β = 3,500), developed regions had a larger tourism GDP (β = 4,100).Developed regions had higher carbon emissions (β = 7,200) compared to developing regions (β = 4,800).The development of energy efficiency (β = 2,500) and renewable EC (β = 4,200) is greater in developing nations.

6. Conclusion

The environmental impact, challenges, and chances for sustainable development were emphasized in this research's investigation of the TI's global energy usage. The results indicated notable differences, with wealthy countries using more energy per person while poor countries made advances in energy efficiency. With carbon emissions averaging 10.5 Mt CO_2 and a 35.4% adoption rate for RE, the average tourism EC was 85,000 TJ. According to regression analysis, energy demand rose in response to tourism GDP and carbon emissions, but decreased in response to efficiency gains and RE. The FE model confirmed significant country-specific impacts. This research was constrained by data availability, as several nations lacked extensive energy records, and external influences such as policy changes were not thoroughly considered. Future studies on tourism's energy consumption and sustainable development might concentrate on how policy changes affect energy consumption, how renewable energy sources are incorporated, and how new technologies like smart grids, energy-efficient structures, and environmentally friendly transportation options contribute to the sustainability of the tourismindustry. Need to Highlights the need for targeted policies promoting renewable energy adoption and energy-efficient technologies in tourism. Future research should focus on enhancing energy performance in developing regions, while policymakers should incentivize green tourism infrastructure to foster sustainable growth.

Author Contributions

Conceptualization, N.N. and A.S.; methodology, A.S.; software, K.P.; validation, A.S., K.P. and K.B.N.; formal analysis, A.S.; investigation, K.B.N.; resources, B.N.; data curation, K.P.; writing—original draft preparation, A.S.; writing—review and editing, N.N.; visualization, K.B.N.; supervision, N.N.; project administration, B.N.; funding acquisition, N.N. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

All data supporting the findings of this study are included in the article.

Conflicts of Interest

The authors declare no conflict of interest.

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