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Van L.T.T.

THE ROLE OF GREEN ENERGY IN SUSTAINABLE DEVELOPMENT: EVIDENCE FROM THE MONTE-CARLO SIMULATION ALGORITHM USING BAYES APPROACH

Van L.T.T.*

Abstract: This research investigates the impact of green energy – power consumption from wind, solar, hydroelectric and other renewable sources (including hydro, wind, solar, geothermal, wave and tidal, and bioenergy) on sustainable development in 77 countries worldwide during the period 2005-2022. The Bayesian approach assumes that the observed data sample is fixed and the model parameters are random. The posterior distribution of the parameters will be estimated based on the observed sample and the prior distribution of those parameters, using it to interpret the results. The Bayes result shows that the average per capita energy consumption from wind, solar, hydro, and renewable energy positively affects sustainable development. The probability of a positive impact from wind, solar, and renewable energy on sustainable development is nearly 100%, while this value is relatively low at 58.35% for hydro energy, indicating that the use of hydro energy has a positive impact on sustainable development but has not fully realized its potential. Based on these findings, the author proposes appropriate policy implications for the countries and Vietnam.

Keywords: Sustainable development, green energy, Bayesian

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Introduction

In the last years of the twentieth century and the first two decades of the twenty-first century, people have witnessed many great changes in the economy, politics and many aspects of social life, such as the Asian financial crisis (1997), the dot-com bubble crisis (2000), the global financial crisis (2008), the Covid-19 pandemic (2019) and the Russian-Ukrainian political conflict (2022). These crises and conflicts have had a negative impact on the world economy. Besides, the world is also facing problems of global instability, like environmental pollution, resource depletion, climate change, energy security, and food security (Santhakumari and Sagar, 2020). Are these consequences all caused by the industrial economy? As economic growth is reaching levels that cause more destruction than real wealth creation, the world is finding new paths toward a sustainable economy that accomplishes three goals simultaneously: economic sustainability, social sustainability, and environmental sustainability (ESCAP and Scientific, 2015).

* **Le Thi Thuy Van**, Dr., National Institute for Finance, Hanoi, Vietnam;
✉ email: lethuyvan.van@gmail.com,
ORCID ID: 0000-0002-1955-9504

All economic and human activities depend heavily on energy use (Sarma and Roy, 2021). Thus, the massive use of non-renewable energy increases environmental damage. According to World Health Organization (WHO) statistics, air pollution is responsible for nearly 7 million deaths globally each year (Mackenzie and Turrentine, 2016). The Health Effects Institute (HEI) has recorded that more than 95% of the world's population faces polluted air, and over 60% of people live in environments that do not meet WHO's basic standards (Le Thanh Y, 2020). The development of the global economy leads to increased dependence on fossil fuel energy, which pollutes the environment and increases CO2 emissions (Stern, 2011). This implies that energy is considered the backbone of an economy as it is linked to economic development in all human activities (Li et al., 2022). However, energy is divided into two categories: non-renewable and renewable. The majority of developing countries rely on non-renewable energy sources to achieve rapid economic growth because they are in short supply and cannot be replaced once used, similar to fossil fuels like oil, coal, and natural gas (Hanif et al., 2019). Using non-renewable energy also generates a lot of CO2, which causes the greenhouse effect, in addition to hydrocarbons, sulfur, etc., which are the main causes of acid rain, which pollutes soil and groundwater. Climate change is taking place heavily, causing many natural disasters, unpredictable loss of people and property in the world, and threatening the lives of people and many animals in nature by excessive use of non-renewable energy.

Meanwhile, renewable energy, such as energy generated from wind, sun, and hydrogen, can be used periodically and cannot be exhausted. They are also known as green energy. Product firms are required to convert or enhance any original equipment that uses a lot of energy or generates too much pollution as technology and the economy evolve. In order to reduce the number of raw materials needed and the waste produced during production, businesses must consider the expanded functionality and repurposing of green energy in their design. Therefore, green energy is considered by the SDGs (2016) as a means of sustainable development due to its ability to reduce emissions as well as minimize undesirable impacts on the environment (Bekhet and Harun, 2017; Dogan, 2017 and Seker, 2016).

In Vietnam, some data has shown that Vietnam ranks among the top 10 air-polluted countries in Asia (Le Thanh Y, 2020). Facing this situation, Resolution No. 55-NQ/TW dated February 11, 2020, of the Political Bureau on orientation of Vietnam's national energy development strategy through 2030 with a vision toward 2045 stated: After 15 years of implementing the Conclusion No. 26-KL/TW and 10 years of implementing the Resolution No. 18-NQ/TW, in all sub-sectors and fields, the energy sector in general and the power sector in particular, have evolved quickly and relatively synchronously, followed the orientation, and met the intended specific goals. In accordance with the Prime Minister's Decision No. 1658/QD-TTg of October 1, 2021, the National Strategy on Green Growth for the years 2021–2030 has established a goal to lower the intensity of greenhouse gas emissions per GDP, greening economic sectors. The main objective is to obtain 15-20% renewable energy in the overall primary energy supply by 2030 and to reduce primary energy consumption per average GDP in the 2021–2030 decade from 1.0 to 1.5% annually. This requires economical and sustainable energy consumption to ensure the sustainable development strategy is served.

Various studies conducted worldwide have suggested that green energy consumption ensures sustainable development (Narayan and Singh, 2007; Binh, 2011; Ciarreta and Zarraga, 2010; Tang et al., 2020; Li et al., 2022; Candra et al., 2023). However, the measurement of green energy has not been unified. The biggest problem is due to the limited access to data, so the results are different. Particularly for this study, the representative of green energy includes four variables: per capita energy consumption from wind energy, per capita energy consumption from solar energy, per capita energy consumption from hydroelectric power, and per capita energy consumption from renewable energy. The advantage of these metrics is that they can assess the level of green energy consumption internationally and compare the impact of each type of energy on sustainable development.

In addition, previous studies on this topic often used the traditional frequency model. However, the testing of hypotheses by this approach must be based on many assumptions that are inconsistent with reality, making it inaccurate in inference and prediction. Furthermore, the frequency statistical method considers the parameter to be an unknown but fixed value; however, this parameter will change as the sample size is updated over time. Meanwhile, the Bayesian method treats the parameter as a random variable and is assigned a distribution to indicate the confidence of the parameter. Many studies have analyzed the strengths and challenges of the Bayesian method (Gelman and Hill, 2006; Kruschke, 2014), but the most significant advantage of this method is that the model's accuracy does not depend too much on the sample size. In addition, the Bayesian method also overcomes model defects such as autocorrelation, heteroscedasticity, and endogeneity (Thach, 2020).

This study applies Bayesian method to assess the impact of green energy on sustainable development on an international scale. From the research results, the paper provides appropriate policy recommendations for countries and lessons learned for Vietnam.

Literature Review

Theory of the Impact of Green Energy on Sustainable Development

The idea that transitioning from fossil fuels to cleaner, more environmentally friendly energy sources might help us accomplish sustainable development goals is at the core of the theory of how green energy affects sustainable development. Theoretically, the production function is often used in classical and neoclassical economic theory to examine the correlational relationships between such growth and development factors and has the general form of:

$$Y = f\,(L, K)$$

Y is mainly based on labor factors (L) and capital (K). Later, in neoclassical economic theory, the production function is added with technological factors (T) to become the form of Y = f (L, K, T) and has prevailed for centuries in development management in many countries (Solow, 1956). The form of the production function (Cobb-Douglas) is

$$Y = AL^{\alpha}K^{\beta}T^{\gamma}$$

Where, Y is economic growth (usually GDP), A is Total Factor Productivity, which is all that is left to contribute to growth that is not L, K, T; and α, β, γ are coefficients satisfying the condition $\alpha + \beta + \gamma = 1$.

It can be seen in the above production function that the problems of environmental resources are not present as a contributing factor to economic growth but are unknown in A. In fact, when analyzing the economy according to the production function, the contribution of environmental resources is almost ignored. Then, there were attempts in modern economic theory to add resources and the environment (E), making the production function Y = f (L, K, T, E). The tricky thing about computing the production function Y = f(L, K, T, E) is that for E to be a variable in the production function, the first thing is that E must be quantified.

The traditional economic theory considers environmental resources unlimited, providing an important input (natural resources) that are always available, while sustainable development is the opposite, considering environmental resources. There are limits, and every growth and development decision must be considered in the long run. Sustainable development places environmental resources and climate change adaptation at the heart of development decisions (Ahmed et al., 2022). The approach to sustainable development is not "economic first, environment later" as before, but environment, resources, and climate change response must be the focus rather than profit. This is also the basic thesis of the sustainable development theory (Midilli et al., 2006). It shows that green energy is an environmental protection factor (Li et al., 2022), and green energy impacts sustainable development in the following 3 ways:

Green energy mitigates climate change: Green energy sources operate with low to no greenhouse gas emissions, which reduces overall carbon emissions and fends off climate change. By transitioning to green energy, countries can contribute to the global effort to limit global warming and its dire consequences (Midilli et al., 2006).

Sustainable economic growth: Green energy can stimulate economic growth by creating new job opportunities and supporting the development of clean energy industries. This can lead to the emergence of a green economy that fosters innovation and technological progress (Narayan and Singh, 2007).

Technological advancement: The shift towards green energy is fostering innovation in clean technology and energy efficiency. This momentum is propelling the creation of novel solutions and systems that contribute to heightened sustainability and resilience. Emphasizing the significance of investing in renewable energy technologies becomes paramount in promoting green growth. Such investments not only stimulate efficient economic activity but also play a pivotal role in job creation, alleviating fuel costs, and bolstering energy security. Concurrently, these endeavors contribute to the reduction of greenhouse gas emissions, mitigating environmental pollution (Altinoz et al., 2021).

Previous Studies

Despite the fact that the idea of sustainable development has existed for a while, studying the influence of green energy on sustainable development also requires resources, including funding, expertise and time, which may be limited in some cases. In addition, this topic has not received adequate attention from researchers and policymakers during this period due to the strong process of integration and commercialization in countries where traditional GDP growth is always the top priority. Until March 2016, when the Economic and Social Sustainable Development Board (SGGs) issued new sustainable development goals, many countries had begun implementing new development strategies focusing on sustainable development (Dmuchowski et al., 2021).

Currently, several researchers have looked into the connection between economic development and the use of renewable and non-renewable energy in various countries as the study of Belaïd and Zrelli (2019) used ARDL in 9 Mediterranean countries between 1980-2014, Candra et al. (2023) used SVAR to study renewable energy consumption for sustainable development in low- and high-income countries. Also, the study of Narayan and Singh (2007), Binh (2011), Ciarreta and Zarraga (2010), Tang et al. (2020) and Li et al. (2022) also pointed out the role of green energy in sustainable development. However, the measures of green energy used in previous studies have not been unified. The biggest problem is that the results are different due to limited data access. Particularly for this study, the representative of green energy includes 4 variables: per capita energy consumption from wind, solar, hydroelectric and renewable energy. The advantage of these measures is that it is possible to assess the level of green power consumption internationally and simultaneously compare the impact of each type of energy on sustainable development.

In addition, previous studies on this topic often used the traditional frequency model. However, the testing of hypotheses by this approach must be based on many assumptions that are inconsistent with reality, making it inaccurate in inference and prediction. Furthermore, the frequency statistical method considers the parameter to be an unknown but fixed value; however, this parameter will change as the sample size is updated over time. Meanwhile, the Bayesian method treats the parameter as a random variable and is assigned a distribution to indicate the confidence of the parameter. Many studies have analyzed the strengths and challenges of the Bayesian

method (Gelman and Hill, 2006; Kruschke, 2014), but the most significant advantage of this method is that the accuracy of the model does not depend too much on the sample size. The Bayesian approach also fixes problems with the model, including endogeneity, heteroscedasticity, and autocorrelation (Thach, 2020). In this study, the author uses Bayesian method to assess the impact of green energy on sustainable development on an international scale. From the research results, the article provides appropriate policy implications for countries and lessons learned for Vietnam.
Based on the literature review and the context of countries moving towards sustainable development, we expect the following hypotheses: Hypothesis H1: Wind energy consumption positively impacts sustainable development. Hypothesis H2: Solar energy consumption has a positive impact on sustainable development. Hypothesis H3: Hydropower energy consumption has a positive impact on sustainable development. Hypothesis H4: Consumption of renewable energy positively impacts sustainable development.

Research Methodology

Variables and Dataset

The sustainable development variable is calculated based on the integration of 17 indicators (table 3) according to SGDs (Economic and Affairs, 2022) (Appendix 2). Green energy variables include per capita energy consumption from wind energy (EW), per capita energy consumption from solar energy (ES), per capita energy consumption from hydroelectricity energy (EH), and per capita energy consumption from renewables (ER). In addition, some control variables are added to the research model, such as urban population rate (UR), trade openness (OPE), inflation rate (INF), population growth rate (POP), and economic growth (TGDP). The measurement methods and data sources of the variables are presented in Table 1. The research model is as follows:

$$\mathrm{SDGI}_{i,t} = \beta_o + \beta_1 ESi,t + \beta_2 EH_{i,t} + \beta_3 EW_{i,t} + \beta_4 ER_{i,t} + \beta_x X_{i,t} + \varepsilon_{i,t} \quad (1)$$

wherre i = 1, 2, … is the country and N = 1, 2, … is the year.
$X_{i,t}$ is the vector of control variables.

Research data were collected across 77 countries for the period 2005-2022. The data has been collected from various sources, including SDGindex.org, ourworldindata.org, and data.worldbank.org.

Table 1. Description of variables

Variable	Sign	Measure	Research	Data source
Dependent variable				
Sustainable development	SDGI	Integrate 17 indicators in Table 3 (Points)	Economic and Affairs (2022)	SDGI
Independent variable				
Energy consumption per capita from wind energy	EW	Annual growth rate of energy consumption per capita from wind energy (%)		Ourworldindata
Energy consumption per capita from solar energy	ES	Annual growth rate of energy consumption per capita from solar energy (%)	Tang et al. (2020); Li et al. (2022) Candra et al. (2023).	Ourworldindata
Energy consumption per capita from hydroelectric energy	EH	Annual growth rate of energy consumption per capita from hydroelectric energy (%)		Ourworldindata
Energy consumption per capita from renewable energy	ER	Annual growth rate of energy consumption per capita from renewable energy (%)		Ourworldindata
Control variable				
Urban population	UR	Urban population/Total population (%)	Guo et al. (2022)	WDI
Trade openness	OPE	(Exports imports)/GDP	Guo et al. (2022)	WDI
Inflation rate	INF	Annual CPI growth rate (%)	Saydaliev and Chin (2022)	WDI
Population growth rate	POP	Annual population growth rate (%)	Saydaliev and Chin (2022)	WDI
Economic growth	TGDP	Annual GDP growth rate (%)	Ngo et al. (2021	WDI

Methodology

In Bayesian statistics, research data is combined with a priori information to compute a posterior distribution, and the results are interpreted as a probability distribution of parameter values, regardless of sample size. Therefore, the Bayesian method can overcome the small sample disadvantage in the studies. Bayesian and frequency methods have very different philosophies about considering what is fixed, so the interpretation of research results also differs. The Bayesian approach is based on the presumption that the model parameters are random and the observed data sample is fixed. The observed sample and the a priori distribution of the parameter will be used to estimate the posterior distribution of the parameter, which will then be used to interpret the findings. The frequency distribution assumes that the observed samples repeat at random, that this parameter is unknown, but that it is fixed and constant due to sample repetition. The interpretation is dependent on the data's statistical properties or sample distribution. In other words, the distribution of the conditional parameter of the observed sample is used by Bayesian analysis to provide the answer. The three steps Bayesian regression will take to examine the fictitious relationship between marginal interest income and explanatory variables are as follows. First, we make the a priori assumption that the coefficients are normally distributed, with a mean of zero for each coefficient. According to such an a priori specification, the coefficients obtained by Bayesian analysis are more likely to have near zero values than nonzero values. Most importantly, the author does not influence the outcome of the analysis—positive or negative Bayesian examination of research ideas. Second, the study assumes normal distributions with the parameters given in equation (1) for the likelihood functions of the coefficients. Finally, using 12,500 cycles of estimate and simulation selected from the posterior distribution, we employ the Markov Chain Monte Carlo (MCMC) and Gibbs Sampler procedures to determine the corresponding posterior distributions of the coefficients. As usual, the first 2,500 withdrawals will disqualify us. In several disciplines, complicated models are tuned using the MCMC method (Levy, 2020).

Results and Discussion

Descriptive Statistics

Table 2. Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
SDGI	71.7421	10.3783	38.4500	86.4800
EW	17.4570	20.8742	-97.8700	141.4954
ES	38.5002	25.1326	-100.000	6580.894
EH	4.1813	3.3514	-87.1325	425.135
ER	4.1618	2.0132	-65.46	187.2030
UR	53.6908	13.7834	19.1740	79.0440
OPE	88.6355	26.9595	24.7016	157.9743
INF	6.5596	7.3977	-1.5841	59.2197
POP	0.3416	1.1468	-1.8543	2.4246
GDP	4.3630	5.0168	-15.1365	34.5000

Table 2 shows that the average SDGI of the studied countries is 71.7470, with a standard deviation of 10.3783. The average growth in energy consumption per capita from wind, solar, hydropower, and renewables is 17.4521, 38.5002, 4.1813, and 4.1618, respectively. These findings suggest that the growth rate of ES consumption is higher than that of EH and EW. In addition, the results show that the standard deviations of EW, ES, and EH are quite high, showing that countries have strong fluctuations in energy use. Furthermore, the average values and standard deviations for the variables UR, OPE, INF, POP, and GD are as follows: UR: 53.6908 (standard deviation: 13.78) OPE: 88.6355 (standard deviation: 26.95) INF: 6.5596 (standard deviation: 7.397) POP: 0.3416 (standard deviation: 1.146) GDP: 4.3630 (standard deviation: 5.016). These values indicate a relatively large variability in INF, POP, and GDP during the research period.

Bayesian Regression Results and Discussion

The Metropolis-Hastings (MH) method, utilized in the Bayesian approach, simulates the regression model 10,000 times and provides us with a regression coefficient each time, in contrast to the frequency method, which provides a table of regression results indicating the regression coefficients. The regression results table will, therefore, show the mean. In addition, Bayes provides the standard deviation (Std. Dev.) and Monte-Carlo standard error for the regression coefficient. Table 3's results show that the lowest average acceptance rate is 0.9113, more than the necessary limit of 0.1, and the lowest model efficiency is 0.3618, higher than the permitted level. The aforementioned model satisfies the specifications. According to Flegal et al. (2008), the Monte-Carlo Standard Error (MCSE) of all parameters is very small. The closer the MCSE is to zero, the stronger the MCMC series. The author also believes that MCSE values less than 6.5% of the standard deviation and less than 5% of the standard deviation are acceptable. The ideal level has been attained. Because all of the maximum Rc values of the coefficients are 1, as shown by the analysis findings in Table 3, it can be said that the MCMC series satisfies the convergence requirements. As a result, it can be claimed that the outcomes of a Bayesian simulation are reliable.

Table 3. Bayesian regression results for the period 2005-2022

SDGI	Mean	Std. Dev	MCSE
EW	1.3511	0.0331	0.0003
ES	1.1612	0.0017	0.0000
EH	0.6935	0.3841	0.0040
ER	0.2390	0.0235	0.0003
UR	0.2136	0.0101	0.0001
OPE	0.0456	0.0236	0.0002
INF	-0.0612	0.0113	0.0001
POP	-2.8163	0.0193	0.0002
GDP	-0.1699	0.0238	0.0002
Average acceptance rate	0.9113		
Avg efficiency min	0.3618		
Max Gelman-Rubin Rc	1.0000		

Table 2 illustrates that the variables EW, ES, ER, and EH positively affect SDGI, with corresponding coefficients of 1.3511, 1.1612, 0.2390, and 0.6935, respectively. This implies that per capita energy consumption from wind, solar, hydropower and renewables promotes sustainable development, in the same opinion as the earlier studies by Tang et al. (2020), Li et al. (2022) and Candra et al. (2023). However, Table 4 indicates that the likelihood of positive effects for EW, ES, and EH on SDGI is 100%, 98.13%, and 96.03%, respectively—approaching certainty. However, the probability of a positive impact from EH on SDGI is notably lower at 58.35%. Hydroelectricity, as a renewable energy source, operates by converting energy from flowing water, including tides, rivers, and lakes, into electricity. Although hydroelectricity offers some benefits, such as providing renewable energy and reducing greenhouse gas emissions, it can also cause some environmental pollution problems: i) construction of hydroelectric facilities often requires large-area flooding, leading to changes in natural ecosystems, loss of habitats for species, and impacts on the movement and livelihoods of fish and other organisms living in flooded areas; ii) Construction of hydropower plants is often accompanied by changes in river flows. This can affect the movement of sand, gravel, and sand in the river bed, cause structural changes in river flow and affect the ecological environment. It is shown that although water consumption promotes sustainable development, the probability of a positive impact is very low.

Table 4. Probability results of the impact of SDGI on the remaining variables

Variable	Mean	Std. Dev	MCSE
Prob (SGDI: EW) >0	1.0000	0.0000	0.0000
Prob (SGDI: ES) >0	0.9813	0.1335	0.0010
Prob (SGDI: ER) >0	0.9603	0.0935	0.0010
Prob (SGDI: EH) >0	0.5835	0.4913	0.0049
Prob (SGDI: OPE) >0	0.7943	0.3063	0.0031
Prob (SGDI: INF) <0	0.9530	0.4940	0.0049
Prob (SGDI: POP) <0	0.9080	0.3939	0.0040
Prob (SGDI: GDP) >0	0.8008	0.2119	0.0021

Figures 1, 2 and 3 show that the per capita consumption of solar and wind energy in Vietnam is much higher than the world and Asian averages, while the energy consumed from the wind has not been utilized well (lower consumption compared to Asia and the world).

In Vietnam in the period 2005-2022, per capita energy consumption from wind increases from 0 kWh in 2005 to 213 kWh in 2021, per capita energy consumption from solar increases from 0kWh to 700 kWh and per capita energy consumption from hydroelectricity increases from 623kWh to 1994 kWh. Although wind renewable energy (Figure 2) has significantly contributed to environmental protection and sustainable development, consumption is still low compared to Asia and the world. The reason is that many wind power projects have been completed but have not been allowed to connect to sell electricity to the system due to the expiration of the validity period of Decision 39/2018 and Circular 02 on wind power project development.

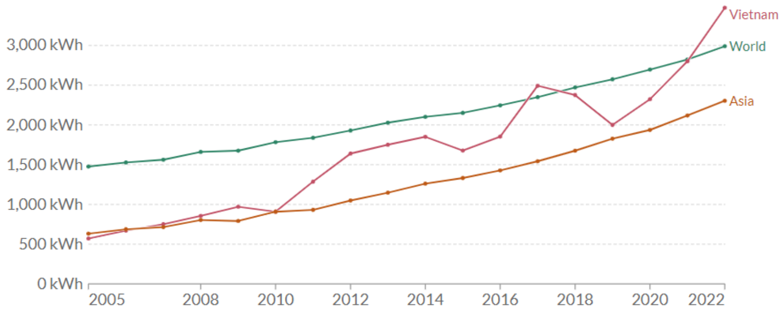

Figure 1: Per capita energy consumption from renewable energy
Source: Energy Institute Statistical Review of World Energy, 2023

According to "The Economist", in the four years to 2021, the share of solar power in Vietnam has increased from practically zero to nearly 11%. This growth is faster than almost anywhere in the world, and the share is higher than in major economies like France or Japan. In 2020, Vietnam became the 10th largest solar power producer in the world. According to Vietnam Electricity, the system as a whole produced 24.55 billion kWh of power in July 2022. The total electricity produced over the past seven months has increased by 4.2% to 158.02 billion kWh. Hydropower output has increased by 33.3%, to 52.58 billion kWh, while coal thermal power has increased by 40.5% to 63.94 billion kWh, and gas turbines have increased by 11% to 17.39 billion kWh. Renewable energy sources reached 22.06 billion kWh, accounting for 14%; solar power alone reached 16.54 billion kWh, and wind power reached 5.24 billion kWh. Data analysis in 2021 also shows that the capacity of Vietnam's electricity system is about 76,620MW. Hydroelectricity reached 22,111MW, coal-fired thermal power 25,397MW, and gas thermal power 7,398MW. The total capacity of wind and solar power sources reached 20,670MW, accounting for nearly 27% of the total capacity of the whole system. 31.5 billion kWh of electricity was produced by wind and solar energy, making about 12.27% of the system's overall electricity output. With a share of up to one-third of total electricity output, coal power plays a significant role in Vietnam's electricity grid today.

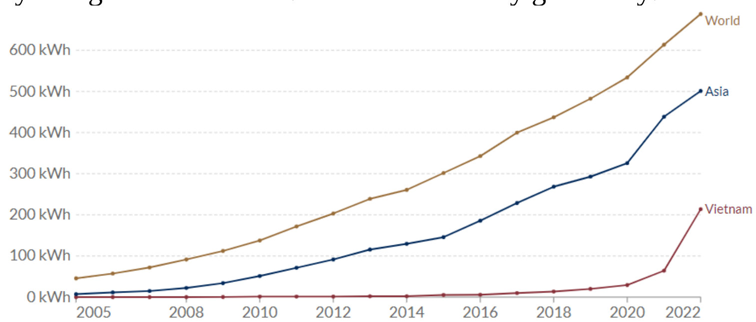

Figure 2: Energy consumption per capita from wind energy
Source: Energy Institute Statistical Review of World Energy, 2023

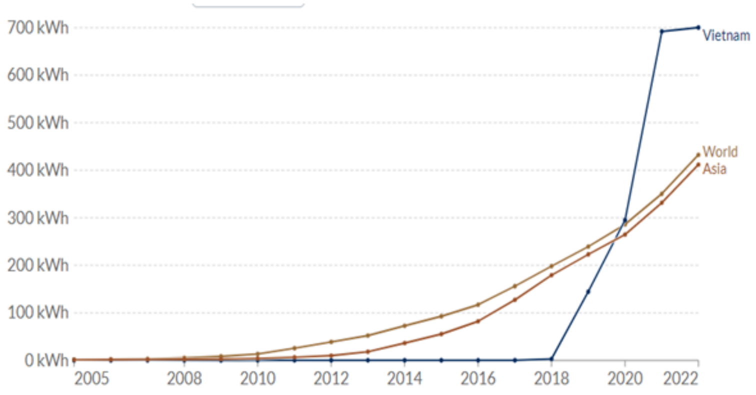

Figure 3: Energy consumption per capita from solar energy
Source: Energy Institute Statistical Review of World Energy, 2023

As stated in the Prime Minister's Decision No. 2068/QDTTg dated November 25, 2015, which approved Vietnam's renewable energy development strategy for the period to 2030 with a vision toward 2050, the share of electricity produced from renewable sources (including large and small hydroelectricity) in the nation's total electricity production should reach 32% by 2030 and 43% by 2050. By 2030, it is predicted under the revised Power Master Plan VII that renewable energy sources, such as small hydro, wind, solar, and biomass, will supply 21% of the nation's total power capacity. According to Political Bureau Resolution No. 55-NQ/TW dated February 11, 2020, the percentage of renewable energy sources in the total primary energy supply will be between 15% and 20% in 2030 and 25% to 30% in 2045, respectively. The percentage of renewable energy in the total amount of electricity generated nationwide will be between 30% and 40% in 2030. Vietnam needs to put forth numerous necessary processes and solutions in order to reach the aforesaid aim.

Conclusion

This research examines the influence of green energy, encompassing wind, solar, hydro, and various renewable sources such as hydroelectricity, wind, solar, geothermal, wave and tidal, and bioenergy, on the sustainable development of 77 countries globally from 2005 to 2022. Employing Bayesian regression, the findings reveal a positive correlation between per capita energy consumption derived from wind, solar, hydroelectricity, and renewable energy and the enhancement of sustainable development. The probability of a positive impact of wind, solar and renewable energy on sustainable development is almost 100%, while this value for hydropower is quite low, only 58.35%. The use of energy from hydroelectricity, although positively affecting sustainable development, has not yet fully exploited its potential. From the above results, the author proposes appropriate policy implications for the countries, especially Vietnam.

Policy Implication

Governments worldwide can play a pivotal role in mitigating climate change by implementing strategic measures to limit fossil energy use. By establishing regulations and strict limits on sources like coal, oil, and gas, they can expedite the transition to green energy. Additionally, fostering the development of sustainable energy projects is crucial. Governments can create an environment conducive to such projects by simplifying licensing procedures, ensuring steady progress in electricity consumption, and providing support for emerging green technologies. These proactive steps contribute to a global shift towards cleaner and renewable energy sources, aligning with the imperative to address environmental challenges and promote a sustainable future.

In Vietnam, the absence of a market-driven approach to electricity rates poses a challenge for renewable energy sources to compete with traditional fossil fuel-based prices. To establish equitable benefits for all stakeholders, it is imperative to delineate and implement acceptable electricity tariffs specifically tailored for renewable sources like wind and solar power. Developing short-, medium-, and long-term strategies with well-defined goals at each stage of economic progress is crucial for fostering the growth of renewable energy. Early promulgation of national and local plans for renewable energy development not only expedites investor due diligence but also facilitates efficient resource deployment and the timely completion of project documentation. By taking these measures, Vietnam can accelerate its transition to sustainable energy sources, addressing both economic and environmental imperatives.

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APPENDIX 1: List of countries

United Arab Emirates; Argentina; Australia; Austria; Azerbaijan; Belgium; Bangladesh; Bulgaria; Belarus; Brazil; Canada; Switzerland; Chile; China; Colombia; Czech Republic; Germany; Denmark; Algeria; Ecuador; Egypt, Arab Rep.; Spain; Estonia; Finland; France; United Kingdom; Greece; Hong Kong;

Croatia; Hungary; Indonesia; India; Ireland; Iran, Islamic Rep.; Iceland; Israel; Italy; Japan; Kazakhstan; Korea, Rep.; Kuwait; Sri Lanka; Lithuania; Luxembourg; Latvia; Morocco; Mexico; North Macedonia; Malaysia; Netherlands; Norway; New Zealand; Oman; Pakistan; Philippines; Peru; Poland; Portugal; Qatar; Romania; Russian Federation; Saudi Arabia; Singapore; Slovak Republic; Slovenia; Sweden; Thailand; Turkmenistan; Trinidad and Tobago; Turkey; Ukraine; United States; Uzbekistan; Venezuela, RB; Viet Nam; South Africa.

APPENDIX 2: 17 indicators for calculating the sustainable development index

Indicator 1	No Poverty	**Indicator 10**	Reduced Inequalities
Indicator 2	No Hunger	**Indicator 11**	Sustainable Cities and Communities
Indicator 3	Good Health and Well-Being	**Indicator 12**	Responsible Consumption and Production
Indicator 4	Quality Education	**Indicator 13**	Climate Action
Indicator 5	Gender Equality	**Indicator 14**	Life Below Water
Indicator 6	Clean Water and Sanitation	**Indicator 15**	Life on Land
Indicator 7	Affordable and Clean Energy	**Indicator 16**	Peace, Justice and Strong Institutions
Indicator 8	Decent Work and Economic Growth	**Indicator 17**	Partnerships for the Goals
Indicator 9	Industry, Innovation and Infrastructure		

ROLA ZIELONEJ ENERGII W ZRÓWNOWAŻONYM ROZWOJU: DOWODY Z ALGORYTMU SYMULACJI MONTE CARLO Z WYKORZYSTANIEM PODEJŚCIA BAYESOWSKIEGO

Streszczenie: Niniejsze badanie analizuje wpływ zielonej energii - zużycia energii wiatrowej, słonecznej, wodnej i innych źródeł odnawialnych (w tym energii wodnej, wiatrowej, słonecznej, geotermalnej, fal i pływów oraz bioenergii) na zrównoważony rozwój w 77 krajach na całym świecie w latach 2005-2022. Podejście bayesowskie zakłada, że obserwowana próbka danych jest stała, a parametry modelu są losowe. Późniejszy rozkład parametrów zostanie oszacowany na podstawie obserwowanej próbki i wcześniejszego rozkładu tych parametrów, wykorzystując go do interpretacji wyników. Wynik Bayesa pokazuje, że średnie zużycie energii na mieszkańca z energii wiatrowej, słonecznej, wodnej i odnawialnej pozytywnie wpływa na zrównoważony rozwój. Prawdopodobieństwo pozytywnego wpływu energii wiatrowej, słonecznej i odnawialnej na zrównoważony rozwój wynosi prawie 100%, podczas gdy wartość ta jest stosunkowo niska i wynosi 58,35% dla energii wodnej, co wskazuje, że wykorzystanie energii wodnej ma pozytywny wpływ na zrównoważony rozwój, ale nie w pełni wykorzystało swój potencjał. Na podstawie tych ustaleń autor proponuje odpowiednie implikacje polityczne dla krajów i Wietnamu.

Słowa kluczowe: Zrównoważony rozwój, zielona energia, Bayesian