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IMPACTS OF ECONOMIC VARIABLES ON SUSTAINABLE ENERGY CONSUMPTION IN VIETNAM

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ABSTRACT

Amidst the global energy crisis and Vietnam's rapid industrialization, this paper explores the imperative to transition towards sustainable energy consumption. With Vietnam's substantial surge in energy demand, the need for sustainable alternatives becomes paramount. Drawing upon an extensive review, this study examines the economic variables influencing sustainable energy consumption in Vietnam. It reveals nuanced impacts of GDP per capita, Foreign Direct Investment (FDI), industrial manufacturing (MNF), Gross Capital Formation (GCF), and Trade Openness (TO) on sustainable energy consumption. Combining these insights with the strategic policy measures outlined in Resolution No. 55-NQ/TW and Resolution No. 136/NQ-CP, the study offers actionable recommendations to expedite Vietnam's transition towards renewable energy targets set for 2030 and 2045.

Keywords: *Economic variables, Sustainable energy consumption, Vietnam*

1. INTRODUCTION

In recent years, the escalating global energy crisis has posed a formidable challenge to all countries in the world, including Vietnam. According to the General Statistics Office (GSO), Vietnam, a developing nation, ranks third in population size in Southeast Asia, with approximately 100 million inhabitants. The country is undergoing industrialization and economic modernization, resulting in a substantial surge in overall energy demand, averaging 10% annually from 2016 to 2023. Meanwhile, the ratio of sustainable energy consumption to Vietnam's total energy consumption decreased by an average annual rate of 2% during 1990-2020, from 75.91% in 1990 to only 19.11% in 2020. This trend contradicts the global trajectory, which saw an increase from 16.66% to 19.77% during the same period (WB, 2023).

Within the contemporary milieu, the imperative to recalibrate the energy matrix from conventional paradigms towards sustainable alternatives is underscored as pivotal not only for alleviating energy deficits but also for galvanizing a trajectory towards sustainable development within Vietnam's economic framework. On February 11, 2020, the Politburo promulgated Resolution No. 55-NQ/TW delineating "Strategic Directions for National Energy Development of Vietnam until 2030, with a Vision to 2045". Subsequently, on September 25, 2020, the Government promulgated Resolution No. 136/NQ-CP on Sustainable Development, articulating the pivotal role of ensuring robust national energy security as a linchpin for socio-economic advancement.

The goal regarding the proportion of renewable energy sources in energy consumption is set to reach 15-20% by 2030 and 25-30% by 2045. Achieving these objectives necessitates researching the factors influencing sustainable energy consumption in Vietnam. Based on research findings, the authors propose solutions to expedite the transition towards sustainable energy consumption in Vietnam.

The article is structured into four sections. Firstly, it provides an overview of sustainable energy. Secondly, it presents a review of research on economic variables influencing sustainable energy consumption. Thirdly, it discusses the utilization of econometric models to assess the impact of economic variables on sustainable energy consumption in Vietnam. Finally, it concludes with policy recommendations to facilitate Vietnam's rapid and efficient transition to sustainable energy consumption.

Sustainable energy

Sustainable energy refers to energy sources that meet current needs without compromising the ability of future generations to meet their own needs (Brundtland, 1987). Sustainable energy typically originates from natural sources replenished at a rate higher than consumption levels (UN, 2022). In practice, the term "renewable energy" can also be used interchangeably with "sustainable energy". According to Crawford (2018) and Smoot (2021), renewable energy becomes sustainable when the rate of replenishment compensates for the rate of extraction. Nowadays, renewable energy is increasingly becoming the primary alternative to conventional energy forms. Renewable energy sources are currently underexploited and have not suffered severe environmental damage, making them sustainable.

Sustainable energy exists in various forms, among which the following are prevalent:

a) *Solar energy*: This is the primary energy source for Earth, characterized by its clean and abundant nature across many regions (Soysal & Soysal, 2020). According to the International Energy Agency (IEA, 2023), in 2022, solar energy accounted for approximately 4.5% of global electricity generation, primarily through photovoltaic panels. Photovoltaics are expected to be the largest installed power source globally by 2027.
b) *Wind energy*: Wind energy is increasingly being harnessed and utilized worldwide. In 2022, modern wind turbines were responsible for generating approximately 7% of global electricity (IEA, 2023).
c) *Hydropower*: The energy from moving water can be converted into electricity. According to IEA (2023), hydropower still accounted for the largest share (38%) of electricity generation in 2022, surpassing all other renewable energy sources combined.
d) *Geothermal energy*: Generated by extracting heat from deep within the Earth to produce electricity or heat (László & Erika, 1981). However, geothermal energy carries the risk of inducing earthquakes and negatively impacting water sources, necessitating careful geological analysis, process design, operation, and monitoring to mitigate risks (Soysal & Soysal, 2020).
e) *Biomass energy*: Originating from plants and animals (EIA, 2021). Biomass energy plays a crucial role in the United Nations' goal of achieving net-zero emissions by 2050, accounting for over 6% of global energy supply (IEA, 2023). The utilization rate of modern biomass energy has increased by an average of about 3% per year from 2010 to 2022 and is trending upwards. The International Energy Agency predicts that this rate will continue to rise at a rate of 6% per year from 2022 to 2030 (IEA, 2023).

Sustainable energy consumption

Currently, the term "sustainable energy consumption" is increasingly being utilized, and various organizations and scholars have provided different interpretations of this term. Specifically, according to the World Bank (WB, 2023), sustainable energy consumption refers to the utilization of energy from all renewable resources, including water, wind, solar, liquid biofuels, biogas, geothermal, ocean, and waste. The European Environment Agency (EEA, 2023) defines sustainable energy consumption as the use of renewable energy for electricity, heating and cooling, transportation, or any other life activities. Moreover, sustainable energy consumption also encompasses reducing overall energy consumption and using renewable energy sources instead of fossil fuels (ICON Mainz, 2019).

Sustainable energy consumption, as an aspect of sustainable development, contributes to the global effort to combat sustainability challenges such as climate change, resource depletion, and environmental pollution.

Indeed, there are various scholars who have provided different perspectives on economic variables. According to Kim (2003), economic variables refer to the economic conditions from a national level perspective. Tarmizi et al. (2006) argue that economic variables are broadly defined as non-political factors (such as inflation rate, recession or economic growth...) that can influence other factors. Syed et al. (2022) emphasize that economic variables encompass the current state of the economy (recession or boom), inflation, fluctuations in interest rates, exchange rate fluctuations, etc. In summary, economic variables can be understood as factors related to the macroeconomic level of the economy.

To date, there have been numerous studies worldwide evaluating the impact of economic variables on sustainable energy consumption in countries, among which the following studies on the influence of common economic variables can be listed:

GDP per capita

GDP per capita can have a positive impact on sustainable energy consumption. Specifically, using Vector Error Correction Model (VECM) and Granger causality analysis to examine the relationship between economic growth and sustainable energy consumption in three North African countries during the period 1980-2012, Kais & Mbarek's study (2017) shows a positive relationship between GDP per capita and sustainable energy consumption. Similarly, through the Panel Mean Group (PMG) method and Granger causality analysis, Yazdi & Beygi (2018) also affirm a positive relationship between GDP per capita and sustainable energy consumption in some African countries during the period 1985-2015. Pegkas' study (2020) on the relationship between economic growth (the rate of change of GDP per capita) and the consumption of non-renewable energy and renewable energy in Greece during the period 1990-2016, using the Autoregressive Distributed Lag (ARDL) model, demonstrates that economic growth will help expand and increase the sustainability of renewable energy consumption rather than non-renewable energy consumption.

However, some other studies suggest that economic growth has a negative impact on sustainable energy consumption. Using the Dynamic Ordinary Least Squares (DOLS) and Error Correction Model (ECM) methods, Sadorsky (2009) argues that economic growth reduces sustainable energy consumption in G-7 countries during the period of 1980 – 2005. Specifically, the increase in per capita GDP leads to a decrease in sustainable energy consumption in countries such as Italy and the United Kingdom in the short term, and in Japan in the long term. Utilizing the PMG model for 25 OECD countries during the period of 1970-2012, Alam & Murad (2020) identify that per capita GDP negatively impacts sustainable energy consumption in some countries like the United States, Italy, Austria, Spain, Denmark, and Sweden. The research findings by Lyulyov et al. (2021) on the impact of economic growth (i.e., the growth rate of per capita GDP) on countries with different institutional arrangements during the period of 2000-2020 also reveal an inverse relationship between economic growth and the development of renewable energy sources for some countries with incomplete democratic institutions.

Foreign Direct Investment

Foreign Direct Investment (FDI) has been demonstrated to have a positive impact on sustainable energy consumption in many studies. Wall et al. (2019) assessed the effectiveness of policy tools in sustainable energy consumption under the influence of FDI in 137 countries worldwide during the period 2005-2014 using the Fixed Effects Model (FEM). The results showed that attracting FDI leads to the implementation of many policies supporting the production, development, and consumption of sustainable energy. Similarly, Khan et al. (2020) investigated the relationship between renewable energy and FDI in 38 countries participating in China's Belt and Road Initiative projects during the period 1995–2016, using GMM and OLS regression methods, concluding that FDI contributes significantly to initiatives and benefits related to sustainable energy consumption. Also concerning China, two studies by Huang et al. (2021) and Wye (2018) both agreed that energy consumption and energy growth rates are accelerated due to the continuous increase in FDI.

Contrary to the findings above, Ben Jabeur's (2020) study on the relationship between sustainable energy consumption and FDI in France during the period 1987–2017 using OLS, DOLS, and FMOLS models, indicates that FDI has a negative impact on sustainable energy consumption. Therefore, the author suggests that the government should consider changing foreign investment policies to benefit sustainable energy consumption. Nawaz et al. (2021), analyzing panel data from 70 countries during the period 2000-2017 using the Generalized Spatial Model (GNS) estimation method, also concluded that FDI projects negatively affect the environment, significantly impacting natural energy sources.

Industrial manufacturing

According to the findings of several researchers, the increase in industrial manufacturing requires a greater amount of sustainable energy consumption. Salim & Shafiei's (2012) study on the relationship between urbanization and consumption of renewable and non-renewable energy in OECD countries during the period 1980-2011 shows that the development of industrial manufacturing leads to growth in both renewable and non-renewable energy consumption. After examining the relationship between sustainable energy consumption and industrial manufacturing in 19 countries with complete democratic regimes during the period 2007-2014, Yahya & Rafiq (2019) suggest that economies should improve industrial manufacturing to enhance sustainable energy consumption. Recent studies by Dzwigol et al. (2020) and Kwilinski & Kuzior (2020) both provide results indicating that industrial manufacturing promotes energy consumption in general.

Contrary to that, when studying the drivers of sustainable energy development in European countries during the period 1990-2006 through the ARDL model, Marques et al. (2010) argue that the increase in industrial manufacturing will emit more $CO2$ into the environment, negatively impacting the consumption of sustainable energy sources. Malik et al. (2020) examined the long-term relationship between renewable energy and economic factors (including industrial manufacturing) in Pakistan during the period 1975-2012, revealing that industrial manufacturing negatively affects renewable energy. Consistent with the findings of the two studies above, Shahzad et al. (2021) study, based on FGLS and FMOLS estimation models using panel data from 14 G-7 and E-7 countries, indicates that industrial manufacturing is one of the factors negatively affecting renewable energy consumption.

Gross capital formation

The gross capital formation is an economic indicator reflecting total investment in production materials (such as machinery, infrastructure, transportation vehicles, etc.) and costs for refurbishing and upgrading the capacity of assets not produced by production, such as enhancing land capacity and natural resource management (GSO, 2016).

When evaluating the impact of the gross capital formation on sustainable energy consumption, various studies point out different effects. Firstly, there are positive impacts. Apergis & Payne (2012), using an ECM model, found a two-way causal relationship between renewable energy consumption and the gross capital formation in 80 countries during the period 1990–2007. Accordingly, the gross capital formation is one of the determining factors for sustainable energy consumption in the short term. Makridou et al. (2016) argue that infrastructure from public investment plays a crucial role in energy consumption efficiency in 23 European Union countries during the period 2000-2009. Samusevych et al. (2021), using the ARDL method, investigated the relationship between economic variables and sustainable energy consumption in 6 Eastern European countries including Ukraine, Moldova, Poland, Romania, Hungary, and the Republic of Slovakia during the period 2000-2019. The results indicate that the gross capital formation has a positive impact on sustainable energy consumption. However, in the long term, the gross capital formation is not statistically significant in Ukraine and Poland. Next, there are negative impacts. When studying the impact of the gross capital formation on renewable energy in Pakistan in both the short and long term through the ARDL model, Luqman et al. (2019) concluded that while acquiring an energy system, additional investment in infrastructure reduces the rate of long-term sustainable energy consumption.

Trade openness

Trade openness is an indicator reflecting the relative scale of foreign trade compared to the economy and is often measured by the criteria of total import and export value/GDP (WB, 2023). In some studies, trade openness has been demonstrated as one of the economic variables positively affecting sustainable energy consumption. Specifically, Omri & Nguyen (2014), when studying sustainable energy consumption in 64 countries during the period 1990–2011 using the GMM regression method, pointed out that the increase in trade openness is a key factor driving renewable energy consumption. Ari's (2020) study on Bosnia and Herzegovina during the period 1994-2015 concluded that trade openness will have a positive impact on renewable energy consumption through technology transfer. However, countries need to build infrastructure and human capacity to accommodate this transfer because achieving renewable energy requires significant technology costs and investment in infrastructure and renewable energy production plants. When examining the factors promoting sustainable energy in 43 developed and developing countries during the period 2000–2015, Uzar (2020) used the ARDL-PMG method to demonstrate that enhancing trade promotion and improving institutional quality have a positive impact on sustainable energy consumption growth.

However, some studies have shown that trade openness has a negative impact on sustainable energy consumption. Zhao et al. (2020) studied factors influencing sustainable energy consumption in 353 households in 5 cities in Pakistan during the period 1996-2014 using a structural equation modeling (SEM) framework, concluding that trade liberalization and globalization promote the growth of non-renewable energy consumption and reduce the proportion of sustainable energy consumption. Similarly, Baye et al.' (2020) study on the drivers of sustainable energy consumption in 32 countries in the Sahel region during the period 1990-2015 suggests that in countries with low energy efficiency, increased trade openness leads to a decrease in the proportion of sustainable energy consumption as these countries tend to import more cheap traditional energy sources.

2. RESEARCH METHOD

In economic analysis, examining the long-term relationships between variables is crucial. However, in empirical research results, most economic time series data do not remain stationary at their original values. Meanwhile, the stationarity of time series data determines the effectiveness of estimation methods. If the time series data are non-stationary, both the T and F estimation methods as well as the ordinary least squares (OLS) method are unreliable. In such cases, the Autoregressive Distributed Lag (ARDL) model may be considered, as this method can be implemented when all variables are stationary, or all variables are stationary at first difference, or some variables are stationary at their original series and some are stationary at first difference. Additionally, the ARDL model is suitable for time series with small observation numbers (Chien et al., 2021; Flores & Chang, 2020; Sharif et al., 2020) and provides both long-term and short-term estimation results when combined with the Error Correction Model (ECM). The combined model takes the following form:

$$\Delta y_t = \theta_0 + \theta_1 y_{t-1} + \theta_2 \Delta y_{t-1} + \theta_3 x_{t-1} + \theta_4 \Delta x_{t-1} + \theta_5 z_{t-1} + \theta_6 \Delta z_{t-1} + \ldots + \varepsilon_t$$

Where:
a) θ_0 is the intercept coefficient,
b) $\theta_1, \theta_2, \theta_3$, ... are the slope coefficients,
c) x, y, z are the variables,
d) ε is the error term.

To study the impact of economic variables on sustainable energy consumption in Vietnam in both the short and long term, the authors will use the ARDL model combined with the ECM model.

Based on theory and previous studies, the ARDL-ECM model for short-term and long-term estimation is used to assess the impact of economic variables on sustainable energy consumption in Vietnam during the period 1990-2020, as follows:

$$\Delta SEC_t = \alpha + \sum_{f=1}^{h} \varphi_1 \Delta SEC_{t-f} + \sum_{i=1}^{k} \varphi_2 \Delta GDP_{t-i} + \sum_{j=1}^{m} \varphi_3 \Delta FDI_{t-j} + \sum_{x=1}^{n} \varphi_4 \Delta MNF_{t-x} + \sum_{y=1}^{p} \varphi_5 \Delta GCF_{t-y}$$

$$+ \sum_{z=1}^{q} \varphi_6 \Delta TO_{t-z} + \theta_1 SEC_{t-1} + \theta_2 GDP_{t-1} + \theta_3 FDI_{t-1} + \theta_4 MNF_{t-1} + \theta_5 GCF_{t-1} + \theta_6 TO_{t-1} + \varepsilon_t$$

Where:
$\varphi_1, \varphi_2, \varphi_3, \varphi_4, \varphi_5, \varphi_6$ represent short-term coefficients
$\theta_1, \theta_2, \theta_3, \theta_4, \theta_5, \theta_6$ represent long-term coefficients
SEC: Sustainable energy consumption, measured as the proportion of renewable energy consumption to total energy consumption (%)
GDP: GDP per capita, calculated by dividing the GDP by the population (USD).

a) FDI: Net foreign direct investment, calculated as the difference between inward FDI and outward FDI (USD).
b) MNF: Industrial manufacturing, measured by the annual growth rate of industrial manufacturing (%).
c) GCF: Gross capital formation, measured by the annual growth rate of gross capital formation (%).
d) TO: Trade openness, measured by the ratio of total import and export value to GDP (%).
e) ε: White noise

Based on previous studies and theoretical foundations, the authors propose the following hypotheses:

Hypothesis H1: GDP per capita has a negative impact on sustainable energy consumption.
Countries, including Vietnam, heavily rely on non-renewable energy sources (such as coal, oil, natural gas). Therefore, as GDP per capita increases, the proportion of sustainable energy consumption to total energy consumption decreases. Additionally, in Vietnam, income inequality among regions hinders people's access and the government's implementation of policies promoting renewable energy use.

Hypothesis H2: FDI has a positive impact on sustainable energy consumption.
Sustainable energy consumption can be improved through attracting FDI projects related to sustainable energy sources such as solar panels, offshore wind farms, etc. Moreover, FDI enterprises often bring modern technologies, contributing to efficient exploitation and consumption of sustainable energy.

Hypothesis H3: Industrial manufacturing has a negative impact on sustainable energy consumption.
Generally, industrial manufacturing often requires higher energy consumption compared to agriculture and services. Industrial plants typically use a large amount of energy to operate machinery and equipment in production, transportation, and distribution of products. In developing countries, environmental regulations and waste management practices for industrial plants are often lax, leading to a large amount of waste generated from industrial activities negatively impacting sustainable energy sources. Moreover, the pursuit of rapid economic growth in some countries leads them to prioritize the use of low-cost non-renewable energy sources regardless of environmental consequences.

Hypothesis H4: Gross capital formation has a positive impact on sustainable energy consumption.
Gross capital formation plays a crucial role in economic growth, reflecting the investment in new production capacity. Investing in infrastructure for the exploration and utilization of sustainable energy will enhance the efficiency of exploitation and utilization, while reducing the cost of using sustainable energy sources. As the cost of utilizing sustainable energy decreases, it will stimulate the transition from traditional energy sources to environmentally beneficial energy sources.

Hypothesis H5: Trade openness has a positive impact on sustainable energy consumption.
Trade openness can help developing countries like Vietnam access advanced technologies from other countries to develop and exploit sustainable energy quickly and effectively. Additionally, setting high environmental standards by trading partner countries during the integration process also creates pressure for businesses and governments of countries to seek solutions towards sustainable energy use.

3. RESULTS AND DISCUSSIONS

The data used in this study is secondary data collected from the World Development Indicators of the World Bank (WB, 2023) up to February 2024. However, the data on sustainable energy consumption in Vietnam is only available from 1990 and has been updated until 2020. Therefore, the study utilizes data for the period 1990-2020 and proposes solutions for the period 2024-2030, with a vision until 2045, according to Vietnam's National Energy Development

Strategy issued in 2020. Below is the descriptive statistics table for the 6 variables used in the model.

Table 1. Descriptive statistics of variables in the model
Source: Authors' compilation

Variables	*Observations*	*Mean*	*Standard deviation*	*Minimum value*	*Maximum value*
SEC	31	47,3971	16,89662	19,11	75,91
GDP	31	1257,278	1157,203	96,7193	3586,347
FDI	31	5.69E+09	5,27E+09	1,80E+08	1,61E+10
MNF	31	8,67354	6,60088	-21,83876	13,72238
GCF	31	11,82413	11,27006	-7,693058	44,24928
TO	31	119,6708	30,58372	66,21227	164,7042

Next, the correlation between variables has been examined through a correlation matrix. The matrix shows the findings from the correlation analysis between the variables, allowing the determination of dependence (degree and direction of linkage) between them.

Table 2. Correlation matrix of variables in the model
Source: Authors' compilation

Variables	*SEC*	*GDP*	*FDI*	*MNF*	*GCF*	*TO*
SEC	1					
GDP	-0,9042	1				
FDI	-0,9004	0,9687	1			
MNF	0,0692	-0,0966	-0,0998	1		
GCF	0,4055	-0,3551	-0,3033	0,2657	1	
TO	-0,9301	0,7814	0,8056	0,0806	-0,3957	1

The results show that SEC has a negative correlation with GDP, FDI, and TO, and a positive correlation with MNF and GCF. Regarding the correlation between the dependent variable and the independent variables, SEC exhibits high correlations with GDP (0.90), FDI (0.90), and TO (0.93). Regarding the correlation between independent variables, the pairs of variables GDP-FDI and FDI-TO demonstrate high correlations (0.9687 and 0.8056), which may lead to multicollinearity. However, studies by Polcyn et al. (2021) and Oluoch et al. (2021) have suggested that these variables play an important role in sustainable energy consumption, so they should be retained in the model despite the high correlation. Furthermore, according to Farrar & Glauber (1967), Goldberger (1991), and Shabbir et al. (2019), researchers often ignore multicollinearity when implementing ARDL models because multicollinearity in this model only distorts the regression error term without affecting the regression coefficients.

The authors used the Augmented Dickey–Fuller (ADF) test and the Phillips-Perron (PP) test to check the stationarity of the variables. The specific results are presented in the table below:

Table 3. Results of ADF and PP Tests
Source: Authors' compilation

	ADF Test		*PP Test*		
Variables	*z-statistic*	*P-value*	*z-statistic*	*P-value*	*Choice*
SEC	-5,367	0,0000	-5,53	0,0000	I(1)
GDP	-4,093	0,0065	-4,198	0,0045	I(1)
FDI	-4,425	0,0020	-4,34	0,0027	I(1)
MNF	-4,898	0,0003	-4,911	0,0003	I(0)
GCF	-4,281	0,0034	-4,315	0,0030	I(0)
TO	-5,411	0,0000	-5,451	0,0000	I(1)

The results indicate that only the variables MNF and GCF are stationary at the original values with a significance level of 1%. However, when taking first-order differences, the remaining variables, namely SEC, GDP, FDI, and TO, are all stationary at a significance level of 1%. It can be concluded that the data series exhibit a mixed order of integration, I(0) and I(1).

To test the cointegration among the variables, the authors used the bounds test (Pesaran et al., 2001) with the F-statistic. The results are presented in the table below:

Table 4. Bounds Test Results
Source: Authors' compilation

				Critical value	
Model	***F-statistic***	***Number of lags***	***Degree of freedom***	***I(0)***	***I(1)***
SEC/(GDP, FDI, MNF, GCF, TO)	4,405	5	10%	2,26	3,35
			5%	2,62	3,79
			1%	3,41	4,68

With the null hypothesis H_0 stating that there is no long-run relationship among the variables in the model, based on the results, it can be observed that the F-statistic exceeds the critical value. Therefore, it can be affirmed that there exists cointegration, and the authors can proceed to use the ARDL model.

To assess the adequacy of the model, the authors conducted Jarque-Bera tests for normal distribution of data, Breusch-Godfrey tests, and White tests for heteroscedasticity. The results indicate that the model does not suffer from these defects.

Table 5. Results of Model Deficiency Tests
Source: Authors' compilation

Test	***Hypothesis H0***	***P-value***	***Conclusion***
Jarque-Bera	Data follows normal distribution	0,9836	Data does not follow normal distribution
Breusch - Godfrey	No autocorrelation present	0,897	No autocorrelation presents in the model
White	Homoskedasticity	0,4125	No heteroscedasticity presents in the model

The estimation results of the ARDL-ECM model in the short run and long run are presented in the tables below:

Table 6. Short-run estimation results
Source: Authors' compilation

Variable	***Coefficient***	***Standard Error***	***t-statistic***	***P-value***
D(GDP)	0,0155027	0,0054634	2,84	0,012
D(FDI)	-1,72e-09	5,25e-10	-3,26	0,005
D(MNF)	-0,2165622	0,0734986	-2,95	0,009
D(GCF-1)	0,1215063	0,0475309	2,56	0,021
D(GCF-2)	0,1154009	0,0433441	2,66	0,017
D(TO)	0,2467592	0,0760785	3,24	0,005
ECM(-1)	-0,6102517	0,156966	-3,89	0,001

Based on the results, it can be observed that the coefficient of ECM (-1) is statistically significant at the 1% level, ensuring the existence of long-run relationships among the variables as indicated by the bounds testing. This coefficient is negative, indicating the adjustment back to equilibrium state (Engle & Granger, 1987). It represents the speed of adjustment of the short-run coefficients towards long-run equilibrium in the model. The value of the ECM(-1) coefficient is (-0.61), implying that when short-term fluctuations lead the sustainable energy consumption away from long-term equilibrium, in the following year, this impact tends to return to equilibrium with an adjustment rate of 61%.

Table 7. Long-run estimation results
Source: Authors' compilation

Variable	*Coefficient*	*Standard error*	*t-statistic*	*P-value*
GDP	-0,0123403	0,0026292	-4,69	0,000
FDI	1,49e-09	5,99e-10	2,48	0,025
MNF	0,6507837	0,1890394	3,44	0,003
GCF	-0,0994231	0,1092094	-0,91	0,376
TO	-0,3486671	0,0426094	-8,18	0,000

The estimation results of the model are significant at a level of P-value = 0.0000. The R-squared value is 72.93%, indicating that the economic variables explain 72.93% of sustainable energy consumption. However, the short-term results are contrary to the long-term results. Specifically:

Firstly, an increase in GDP per capita stimulates sustainable energy consumption in the short term. As GDP per capita increases, people tend to consume more energy, including sustainable energy. However, in the long term, a $1 increase in GDP per capita leads to a 0.01% decrease in the ratio of sustainable energy consumption to total energy consumption, at a statistically significant level of 1%. For developing countries like Vietnam, rapid growth in GDP per capita, coupled with a lack of policies to protect sustainable energy sources, negatively impacts their consumption. Moreover, the pursuit of rapid economic growth leads countries to rely heavily on non-renewable energy sources to save costs, resulting in air pollution and climate change.

Secondly, an increase in FDI initially decreases sustainable energy consumption in the short term but will eventually promote it in the long term. Specifically, if FDI increases by 1 USD, the ratio of sustainable energy consumption to total energy consumption increases by 1.4910^{-9}% (or if FDI increases by 1 billion USD, the ratio of sustainable energy consumption to total energy consumption increases by 1.49%) at a statistically significant level of 5%. In Vietnam, the structure of FDI by sector is not yet optimal. Most FDI projects are concentrated in industrial sectors, while the energy sector has not received much attention from foreign investors. This leads to inefficient development and exploitation of these energy sources due to outdated technology and inadequate infrastructure. In the long term, when the government implements appropriate policies to attract FDI projects, focusing on industries that use renewable energy sources and promote advanced energy technologies, FDI will have a positive impact on sustainable energy consumption.

Thirdly, an increase in industrial manufacturing (MNF) has a negative impact on sustainable energy consumption in the short term. Currently, in Vietnam, environmental regulations are still lax, and manufacturing enterprises are not under pressure to invest in modern technology or use sustainable energy. However, over time, with the global trend and the pursuit of Vietnam's National Energy Development Strategy and strict compliance with environmental regulations, industrial manufacturing will significantly increase the proportion of sustainable energy consumption. Specifically, when industrial manufacturing grows annually at a rate of 1%, the ratio of sustainable energy consumption to total energy consumption increases by 0.65%.

Fourthly, in the short term, an increase in Gross Capital Formation (GCF) promotes sustainable energy consumption in Vietnam. Investments in sustainable energy development infrastructure such as wind power plants, solar power plants, and other renewable energy projects enhance the capacity for sustainable energy production. Additionally, investments in research and development of new sustainable energy technologies will bring advancements and create cleaner and more efficient energy development solutions, thus stimulating sustainable energy consumption. However, once the economy has fully transitioned to using renewable energy sources and the infrastructure serving sustainable energy production and consumption is completed, GCF will no longer have a significant impact on sustainable energy consumption.

Fifthly, the higher the Trade Openness (TO), the more it increases the level of sustainable energy consumption in the short term. Trade openness allows Vietnam to access modern sustainable energy production technologies from other countries, thereby enhancing the efficiency of sustainable energy production, reducing the cost of energy products, and promoting sustainable energy consumption. However, in the long term, excessive trade openness without strict regulations and commitments to environmental protection will lead to rampant importation of non-renewable energy sources at low costs to serve domestic production, thereby reducing sustainable energy consumption and causing negative impacts on the environment.

4. CONCLUSION AND SUGGESTIONS

Based on the quantitative research results and the potential as well as the strategic direction of Vietnam’s national energy development, the authors propose the following solution groups:

Promoting economic growth along with research and development of sustainable energy exploitation technologies

It can be seen that Vietnam belongs to the group of countries with high economic growth rates in the region and the world. Specifically, the average economic growth rate is 5.91% for the period 2010-2015 and 5.98% for the period 2016-2020. However, when compared with other countries in the region, Vietnam's per capita GDP is still relatively low. In 2020, the per capita GDP of Singapore, Brunei, and Thailand was respectively 21.86 times, 11.57 times, and 2.33 times higher than that of Vietnam (GSO, 2021). These figures indicate that the standard of living of the Vietnamese people is still relatively low. This limits people's access to and use of sustainable energy sources, as they tend to use cheaper non-renewable energy sources. Therefore, the government needs to implement policies to promote economic growth and increase income for the people.

In addition, to promote the consumption of sustainable energy, it is necessary to increase efficiency and reduce the production costs of sustainable energy. To achieve this, the Vietnamese government needs policies to develop advanced technologies in the exploitation and storage of the country's potential sustainable energy. Currently, Vietnam has great potential in exploiting various sustainable energy sources such as solar energy, wind energy, hydro energy, and bioenergy. Among these, bioenergy accounts for the largest proportion of all renewable energy sources, followed by wind, solar, and hydroelectric power. Energy conversion from waste is also beginning to develop (EVN, 2022). Furthermore, the government also needs to train and enhance the knowledge of experts and workers in the field of sustainable energy so that they can adopt and use advanced technologies.

Encouraging FDI in sustainable energy

Attracting FDI into sustainable energy will promote the transfer of advanced exploitation technologies from abroad, helping to shorten the development time and improve the efficiency of sustainable energy exploitation. To attract FDI into sustainable energy, the government needs to create a favorable investment environment (such as simplifying investment registration and licensing procedures, reducing taxes and fees, etc.), ensuring political and legal stability, and ensuring fairness and transparency in the investment process. However, it is also important to note that investment attraction policies should not relax for FDI projects that bring significant economic benefits but have serious environmental and energy implications in the future.

Promoting the use of sustainable energy in industrial manufacturing

To promote the use of sustainable energy in industrial manufacturing, in the short term, the government needs to introduce favorable and incentive policies (such as tax reduction policies or financial support packages) for industrial enterprises using renewable energy sources. In the long term, the government needs strict regulations on environmental protection to compel enterprises to limit the use of traditional energy sources and switch to sustainable energy. Additionally, the government needs mechanisms for monitoring, inspection, and severe penalties for enterprises that do not comply with the state's policies and legal regulations.

Boosting investment in sustainable energy infrastructure

To attract FDI into the field of sustainable energy and encourage businesses and individuals to use sustainable energy, the government also needs to invest in infrastructure and physical facilities for the development of the sustainable energy sector, such as upgrading the power grid system, infrastructure for energy exploitation and transportation, research and development facilities for technology... Additionally, the government needs to build a national energy storage system with new technologies. Investing in research and deployment of energy storage technologies such as lithium-ion batteries, thermal storage batteries, electromagnetic energy storage systems, and other energy storage technologies can help address climate change issues and ensure stable energy supply from renewable energy sources.

Participation in trade agreements or establishment of international cooperation related to sustainable energy

In the international market, to promote the purchase, sale, and exchange of products produced from the use of sustainable energy in the production process, the Vietnamese government should actively participate in trade agreements to establish international standards and rules on the use of sustainable energy. The government can also collaborate with other countries to share experiences and technologies related to sustainable energy development.

For the domestic market, the government needs appropriate foreign trade policies to encourage businesses to use sustainable energy to produce export goods. At the same time, strong barriers should be in place to limit domestic enterprises from importing non-renewable energy sources such as coal, oil, and gas for use in the production process. In reality, during the period from 1990 to 2020, Vietnam's import ratio of non-renewable energy sources has decreased annually but still remained at a high level. On average, the import ratio of these items accounted for 7% of the import structure (WB, 2023). This indicates that Vietnam still heavily relies on cheap energy imports for production processes.

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