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Trade Openness and Renewable Energy Transition in Nigeria: Trends, Patterns and Policy Implications

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Nigeria, Renewable Energy Transition, Trade Openness

ABSTRACT

This study looks at Nigeria's trade openness and renewable energy transition trends and patterns between 2000 and 2025. The study is descriptive in nature and secondary data from the International Energy Agency and World Bank's World Development Indicators are used to analyze trade openness, GDP growth, CO2 emissions, renewable energy consumption, and renewable power output. The findings reveal that there was a high degree of fluctuation in trade openness over the period studied and generally a decline in trade openness. Renewable energy use was relatively high, but this was largely because of the use of traditional biomass rather than the widespread use of contemporary renewable technologies. Before showing a partial rebound, the output of renewable electricity fell significantly from its early-period level. However, there were different trends for GDP growth and CO2 emissions. In general, the results indicate that the improvements in the selected renewable energy indicators did not necessarily reflect the changes in the level of trade openness. The analysis comes to the conclusion that without complementing policies, trade integration might not be enough to further Nigeria's transition to renewable energy. It recommends to boost domestic production capacity, step up investment in power infrastructure, enhance access to renewable energy technologies and boost trade and energy policy cooperation.

INTRODUCTION

Energy is a key driver of economic development, industrialization and household wellbeing. The availability of energy facilitates production, transportation, communication and other productive activities; the use of fossil fuel sources is a concern regarding energy security and environmental sustainability. These concerns have led to more interest in renewable energy like hydropower, as well as solar, wind, and biomass, countries are looking for more sustainable energy systems (International Energy Agency [IEA], 2023; International Renewable Energy Agency [IRENA], 2023). But, renewable energy conversion is not achieved by nature alone. It also relies on technology, investment and infrastructure and policy to promote these cleaner forms of energy.

Trade openness is one factor that can affect this transition. International trade can help deliver renewable energy technologies and equipment that is expensive and/or not available domestically. It also can provide opportunities for technology transfer and investment. Frankel and Rose (2005) describe the general environmental effects of international economic integration; Copeland and Taylor (2004) describe how the trade and environment relationship may differ depending on the nature of economic activity and the policies used to regulate production.Therefore, trade openness does not necessarily lead to more environmentally friendly energy consumption. Its role in the development of renewable energy will be influenced in part by the type of trade it engages in, the technologies it chooses to implement and its ability to convert foreign opportunities into local investment and production.

Nigeria offers a pertinent background for the discussion of these issues. Despite the fact that the country has a huge renewable energy resources especially solar energy, hydropower and biomass, the country still has electricity supply and infrastructure problems (Ohunakin *et al.*, 2012; Oyedepo, 2012). Meanwhile, crude oil continues to be a key component of its export portfolio. This is a significant policy issue because access to renewables and resources created through international trade does not automatically translate into a significant transition to modern renewables. The extent to which trade openness is correlated with the development of Nigeria's renewable energy sector is thus worthy of further investigation.

The policy framework of Nigeria is aware of the need to diversify energy sources and increase access to cleaner energy. Renewable energy and energy diversification are key components of national energy development as captured in the National Energy Master Plan (Energy Commission of Nigeria [ECN], 2022). Likewise, the Nigeria Energy Transition Plan outlines the country's transition to universal energy access by 2030 and to net-zero emissions by 2060 (Federal Government of Nigeria, 2022). Achievement of these goals will depend on investment in renewable energy infrastructure, access to the right technologies and a policy landscape that supports them. While international trade can contribute to these efforts, especially in terms of equipment and technical expertise, this contribution should be taken

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into account in conjunction with the development of the domestic energy sector.

Although there may be a relationship between international trade and renewable energy development, it is necessary to appreciate the relationship between the two over time in Nigeria. More trade openness does not necessarily mean that a country is progressing towards renewable energy transition. Trade changes can take place at the same time as renewable energy improvements, but can also happen at the same time as reliance on conventional energy sources. Analysing trade openness in the context of renewable energy use, renewable electricity generation and other relevant indicators can help explain these trends and offer a more complete view of Nigeria's energy transition.

In this context, this study focuses on the trends and patterns of trade openness and renewable energy transition in Nigeria from 2000 to 2025. In particular, it looks at the evolution of trade openness, the evolution of renewable energy consumption and renewable electricity output, and the comparison of these evolutions with the evolution of CO2 emissions and GDP growth. The study documents changes in the selected indicators with descriptive and trend analysis, but does not attempt to estimate causal relationships. It helps to address the issue of Nigeria's energy transition by incorporating trade openness and various aspects of renewable energy development in a descriptive assessment. The results also offer a foundation for policy recommendations to facilitate the potential of international trade to contribute to more widespread access to modern renewable energy and a more sustainable energy system.

LITERATURE REVIEW

Conceptual Review

Concept of Trade Openness

Trade Openness is the degree of integration of an economy with the international markets in terms of goods and services. It is usually expressed as a percentage of GDP (exports plus imports). The higher the ratio, the more exposure to international trade. Trade openness can lead to access to foreign technology, capital goods, investment and knowledge, which can affect domestic production and energy development. But its impact depends on the nature of an economy and its trade. Economies that are highly dependent on fossil fuel exports can be more integrated internationally without necessarily having to transition to cleaner fuels.

Concept of Renewable Energy Transition

Renewable energy transition is the process of transitioning from traditional fossil fuels to increased renewable energy sources like solar, wind, hydropower, and biomass. It involves changes in energy consumption, electricity generation and installed generation capacity. The transition to a cleaner energy system is central to IRENA (2023) and the expansion of renewable energy and electrification are key. The transition is especially pertinent for Nigeria, where electricity supply is a constant issue and the country is seeking to diversify its energy mix. This study evaluates renewable energy transition based on renewable energy consumption, renewable electricity generation and installed renewable electricity capacity.

Channels through which Trade may Influence Renewable Energy Development

Trade can have an impact on renewable energy development primarily via technology transfer and investment and access to renewable energy equipment. International investment can give technical expertise and financing, and imports can give countries technologies and capital goods that are not readily produced domestically. Trade can also help spread knowledge and production practices of cleaner technologies (Frankel & Rose, 2005). Murshed (2020) also demonstrates that the impact of trade liberalisation on renewable energy consumption can be different for different economies, meaning that domestic conditions affect the impact of trade liberalisation on renewable energy development.

Trade, Fossil-Fuel Dependence and Environmental Sustainability

Trade can have positive and negative environmental impacts. International integration can be conducive to environmental sustainability if it helps access cleaner technologies and renewable energy investment. However, in regions where fossil-fuel production and other carbon-intensive economic activities are prevalent, economic integration can help perpetuate traditional energy reliance and environmental degradation (Copeland & Taylor, 2004). This is especially pertinent to Nigeria where crude oil is still a major export commodity despite the country's huge renewable energy potentials. The environmental impacts of trade liberalization will thus partly depend on whether trade-related investment and technology will facilitate the diversification towards cleaner energy sources.

Historical Perspective and Policy Strategies towards Renewable Energy in Nigeria

The renewable energy development in Nigeria has been transitioning from the initial concept of hydropower to an energy policy that encompasses solar, biomass, small hydropower and other alternative sources.Despite the country's potential for renewable energy, the growth of renewable energy has been hampered by lack of infrastructure, low investment and the continued reliance on petroleum in the energy and export mix.

In the 2000s, government policies to encourage the use of renewable energy increased. The Renewable Energy Master Plan (REMP) was an early master plan for increasing the use of renewable energy and diversifying the energy supply of the country, which was developed in 2005. This was further reiterated in the National Renewable Energy and Energy Efficiency Policy (NREEEP) of 2015 which emphasized more on renewable energy development, energy efficiency, electricity access and environment.

Renewable energy is now part of Nigeria's broader energy-transition plans. The Nigeria Energy Transition Plan, introduced in 2022, provides a roadmap for achieving

universal energy access by 2030 and achieving net zero emissions by 2060. Government interventions by the Rural Electrification Agency have also facilitated the installation of solar systems and mini-grids, especially in communities that have limited access to grid electricity. These are all signs of the increasing awareness that a more diversified approach to electricity generation and supply is needed to improve access to energy.

Nigeria's renewable energy policies are also in line with SDG 7 on ensuring access to affordable, reliable, sustainable and modern energy for all. This goal can be achieved with the help of renewable energy through increasing access to electricity, decreasing dependence on certain traditional energy sources and providing opportunities for productive activities. But having policies and programmes does not ensure that it is widely adopted. The implementation is still hampered by financing problems, insufficient electricity infrastructure, regulatory problems, and the lack of domestic technological capacity.

The historical experience thus reveals that Nigeria has evolved a general policy framework for renewable energy, however, implementation of policy commitments into a progressive process has been difficult. Therefore, it is salient to look at the evolution of renewable energy use and electricity generation in parallel with the trade openness. A such assessment gives a platform for the understanding of how changes in Nigeria's international trade have been correlated with changes in the renewable energy sector without necessarily implying that the observed changes are causal.

Theoretical Review

The theoretical review introduces the key theories that could account for potential interactions between international trade, technological change and environmental sustainability/renewable energy transition.It is based on international trade theory, technology diffusion theory and ecological modernisation theory.

International Trade Theory

International trade theory, especially the principle of comparative advantage as proposed by Ricardo (1817), accounts for the reasons of international trade and specialisation based on relative efficiency. Trade allows countries to gain access to goods, resources and technologies that are expensive or not available in their own country. This view implies that higher openness to trade can help to have access to renewable energy equipment, capital goods and technical inputs. It thus serves as a foundation to explore the question of whether Nigeria's integration into international markets has been accompanied by developments in renewable energy.

Technology Diffusion Theory

Technology diffusion theory, which was developed mainly by Rogers (2003), is a theory that explains the process of diffusion of technology among users and between social and economic systems. This can be done through international trade, which can help the transfer of technologies, equipment and technical knowledge. Technology transfer is also defined by Rogers (2003) as the way in which information and technological knowledge are applied. In the context of renewable energy, the theory indicates that international exposure can help to facilitate the adoption of solar, wind, hydropower and other clean-energy technologies.

Ecological Modernisation Theory

Ecological modernisation theory is the one that states that economic development and environment protection can be done hand in hand by means of technological innovation, institutional change and cleaner production. The major contributors to this perspective are Mol (1995) and Spaargaren (1997). The theory is applicable to the current study as trade can help in gaining access to technologies that can enhance the environmental performance as well as the economic activity. Therefore, international integration can help the development of renewable energy if trade helps to adopt cleaner technologies.

As a whole, these theories offer complementary explanations on the potential link between trade openness and renewable energy transition. International trade theory emphasizes access to international markets, technology diffusion theory points to the transfer and adoption of technology, ecological modernisation emphasizes the development of cleaner technologies, and the sustainable development perspective puts these processes into a wider context of economic, social and environmental goals.

Empirical Literature

Recent empirical studies increasingly show that trade openness, technological innovation and international economic integration are relevant for renewable energy development, with varying impacts depending on country and region. Khan *et al.* (2021) have found that renewable energy consumption has a positive impact on environmental quality, but the environmental impact of trade openness varies across income groups in developing and developed countries. The results indicate that an open energy transition is not necessarily an environmentally friendly one.

Recent empirical studies have investigated the link between trade openness and renewable energy use. Huang and Liu (2022) examined the impact of trade openness, eco-innovation and human capital on renewable energy consumption in G20 economies for the period 1995-2019. They found that all three factors were positively related to renewable energy use. The authors recommend that eco-innovation and human-capital development may be able to bolster the role of international trade in renewable energy adoption (Huang & Liu, 2022).

The relationship is further complicated by evidence from emerging economies. Using the period 1995-2022, Suleman *et al.* (2025) investigated the determinants of trade and renewable energy consumption in the MINT economies, namely Mexico, Indonesia, Nigeria and Türkiye. Their results showed that the trade balance, trade reserves and labour force participation positively affected renewable

energy consumption while exchange rates and population growth negatively affected renewable energy consumption. The study underscores the need to account for the general macroeconomic environment in understanding the connection between trade dynamics and renewable energy use in emerging economies (Suleman *et al.*, 2025).

African evidence is also key. Berhe *et al.* (2025) investigated the potential of China's trade and investment to boost renewable energy uptake in Africa and found that the evidence on the impact of international trade and foreign investment on renewable energy uptake is still scarce. Their study highlights the need to consider trade dynamics not only from an economic growth perspective, but also in the context of Africa's energy transition. A recent study of 33 African countries also revealed that renewable energy policies, especially market incentives, RPS, risk mitigation and grid connection policies support renewable energy innovation. The study also found that trade openness is an important factor in determining renewable energy technological innovation.

It is also evident from country-specific evidence that the trade openness-renewable energy connection is not uniform. Hussein and Abdullahi (2024) discovered that trade openness positively influenced the renewable energy consumption in Somalia in the long run, indicating that enhanced international trade integration could be a pathway for renewable energy adoption. However, Maluleke (2024) reported asymmetric effects in South Africa, where a decrease in renewable energy consumption in the long run is linked to an increase in total trade and exports. A recent study by Seraj *et al.* (2025) investigated the relationship between trade openness and renewable energy consumption in 14 countries in Southern Africa from 2000 to 2022. The study used cointegration analysis and method of moments quantile regression to determine that trade openness had a positive relationship with renewable energy consumption at various quantiles of the distribution. This result indicates that international market integration can help facilitate renewable energy adoption, perhaps by making energy technologies more available, energy investment and technical knowledge. The results, however, are for a wide range of economies and do not on their own prove that trade openness will have the same effects on Nigeria.

The empirical literature thus indicates that trade openness can be conducive to renewable energy development by providing access to technology, investment and integration into international markets, although this is not always the case. A lot of the literature available is based on econometric estimation of determinants or causal relationships. The descriptive evolution of trade openness with various indicators of renewable energy transition in Nigeria has garnered relatively less attention. This serves as the foundation for the current study which focuses on the trends and patterns of trade openness, renewable energy consumption, renewable electricity generation and renewable electricity capacity in Nigeria between 2000 and 2024.

Empirical Synthesis

The empirical literature shows that the relationship between trade openness and renewable energy development is mixed. Some research indicates that trade openness promotes the use of renewable energy resources via technology transfer, investment, and access to international markets, while others suggest weak, negative, or asymmetric effects. The discrepancies seem to be due to the different economic structures, energy policies, institutional conditions and fossil fuel dependency of the countries. The evidence from African countries is also inconclusive and there is relatively limited country-specific research on Nigeria.

Another drawback of the literature is that it is highly econometric in nature and provides causal or statistical effects of trade openness on renewable energy use. Few studies have focused on the actual evolution of trade openness in conjunction with several aspects of renewable energy transition in a single African country. This study attempts to fill this gap by conducting a descriptive analysis of Nigeria's trade openness and renewable energy development between 2000 and 2025, with the key indicators of renewable energy transition: renewable energy consumption, renewable electricity generation, CO_2 emissions, GDP growth and renewable electricity capacity to assess Nigeria's changing energy pattern and the policy implications.

MATERIALS AND METHODS

This section presents the methods used to analyze trends and patterns in trade openness and Nigeria's renewable energy transition It outlines the research design, data sources, variable measurement and descriptive approach used in the analysis from 2000-2025.

Research Design

The study is descriptive in nature, which aims to analyze the trends of trade openness and renewable energy transition in Nigeria. The design is suitable as the study is about finding trends, changes and patterns in the variables over time, not about estimating causal relationships. Data from 2000 to 2025 is analyzed annually to present a coherent picture of the developments in Nigeria's trade and renewable energy sectors.

Data Sources and Measurement

The study is based on secondary data for the years 2000-2015 collected from World Bank, World Development Indicators and International Energy Agency (IEA).

Trade openness is measured as the sum of exports and imports of goods and services as a percentage of GDP. Four indicators are used to assess renewable energy transition: Renewable Energy Consumption (REC) as % of Total Final Energy Consumption (TFEC), Renewable Electricity Output, CO2 Emissions and GDP Growth. Multiple indicators allow a more comprehensive picture of the renewable energy transition, including changes to renewable energy use, electricity generation, environmental emissions and overall economic performance.

Analytical Approach

Descriptive statistics and trend analysis are used for the analysis. Tables and graphical presentations are used to examine the annual changes in the selected indicators. Where appropriate, developments over different periods are compared using average values and percentage changes. In addition, major changes in Nigeria's energy and trade policies are taken into account and movements in the data are interpreted in the context of those changes. No regression, correlation or other causal estimation techniques are used in the analysis. For this reason, the changes in the values of the trade openness and renewable energy indicators observed over the period are interpreted as trends and patterns rather than as evidence that the change in one indicator caused the change in another. This method is in line with the descriptive problem of the study.

Scope of the Study

The study is conducted in Nigeria from the year 2000 till 2025. The time frame reflects key achievements in Nigeria's trade integration, electricity sector reforms and renewable energy policy. The year 2000 is also selected as a starting point to ensure that changes in trade openness and the development of renewable energy can be observed over a long enough time for the analysis. In the case where an indicator is only available annually for a limited period, the moving average method is used to provide estimates for the missing observations and to keep the data series continuous.

RESULTS AND DISCUSSION

In this section, the data and trends of trade openness, renewable energy consumption, renewable electricity output, CO2 emissions and GDP growth in Nigeria from 2000 to 2025 are presented and discussed. The analysis focuses on the trends in these indicators, and the potential impact on the Nigeria renewable energy transition.

Table 1: Descriptive Patterns in Trade Openness, Renewable Energy Consumption, Renewable Electricity Output, CO_2 Emissions and GDP Growth in Nigeria (2000-2025)

Year	Trade Openness (% GDP)	Renewable Energy Consumption (% TFEC)	Renewable Electricity (% total)	CO_2 Emissions (metric tonnes per capita)	GDP Growth (%)
2000	49	86	42.76	0.79	5.02
2001	49.68	84.5	39.24	0.82	5.92
2002	40.04	84.5	29.30	0.72	15.33
2003	49.33	82.9	37.84	0.78	7.35
2004	31.9	84	32.91	0.74	9.25
2005	33.06	83.9	54.66	0.71	6.44
2006	42.57	85.8	44.94	0.62	6.06
2007	39.34	87.1	32.90	0.55	6.59
2008	40.8	85.7	33.01	0.58	6.77
2009	36.06	88.1	35.07	0.50	8.04
2010	43.32	86	26.12	0.57	8.01
2011	53.28	84.1	18.21	0.61	5.31
2012	44.53	83.90	17.14	0.58	4.23
2013	31.05	81.40	18.04	0.63	6.67
2014	30.89	79.90	15.02	0.66	6.31
2015	21.33	81.30	14.35	0.62	2.65
2016	20.72	81.10	15.66	0.63	-1.62
2017	26.35	81.60	22.28	0.58	0.81
2018	33.01	80.80	21.18	0.59	1.92
2019	34.02	80.10	23.39	0.60	2.21
2020	25.4	81.80	20.19	0.56	-6.37
2021	27.39	80.30	22.23	0.60	1.11
2022	26.89	81.00	19.90	0.58	4.32
2024	27.68	80.96	20.69	0.55	3.33
2024	28.68	80.94	21.41	0.57	4.06
2025	29.01	80.84	21.29	0.57	4.00

Source: World Bank World Development Indicators (WDI, 2026); International Energy Agency (IEA, 2026).

Analysis of Descriptive Patterns in Trade Openness, Renewable Energy Consumption, Renewable Electricity Output, CO_2 Emissions and GDP Growth in Nigeria

Table 1 shows the trend of trade openness, renewable energy consumption, renewable electricity generation, CO2 emissions and GDP growth in Nigeria for the period 2000-2025. The figures show significant variations in trade openness and economic growth, as well as in renewable energy indicators and carbon emissions.

Although there were fluctuations during the period, trade openness has decreased from 49.00% of GDP in 2000 to 29.01% in 2025. It peaked in 2011 at 53.28% and dropped to 20.72% in 2016, and has been slowly recovering since. This trend suggests that Nigeria's vulnerability to international trade fluctuated significantly during the period. This drop since 2011 could be due to the change in the trade flows relative to GDP, but more evidence would be captured in the trend movement to determine the factors behind this. More significantly, the slow recovery in trade openness since 2016 has not been matched by a commensurate rise in renewable electricity generation, implying that increased trade openness cannot be expected to drive a significant renewable energy transition.

The share of renewable energy in total final energy consumption was also high, ranging from 79.90% to 88.10% of total final energy consumption in the observations reported. It increased from 86.00% in 2000 to 88.10% in 2009, before generally declining to approximately 80.84% in 2025. Traditional biomass (fuelwood, charcoal) is included in this indicator, as it still plays a significant role in household energy consumption. Therefore, a high share of renewable energy consumption does not necessarily reflect a modern renewable energy transition to cleaner and more efficient renewable technologies. The downward trend could be due to shifts in the composition of energy use, but this trend alone does not provide evidence of the reasons for the change. The interactive trends between trade openness and renewable energy consumption will demonstrate more.

Renewable electricity generation is more strongly downward trending than total renewable energy consumption. It declined from 42.76% in 2000 to 14.35% in 2015, before recovering to 21.29% in 2025. The indicator stayed below the starting level in the subsequent years despite some improvement between 2016 and 2017. This difference between the level of renewable energy consumption and the smaller proportion of renewable electricity generation indicates that Nigeria's energy profile is different when it comes to end-use energy consumption and electricity generation. The results highlight the need to differentiate the utilization of traditional biomass from the development of renewable electricity systems for the country's energy transition.

The CO2 emissions indicator was not stable during the period, as it decreased from 0.79 in 2000 to 0.50 in 2009 and then increased to 0.66 in 2014. It then fluctuated in a fairly small range, peaking at 0.57 in 2025. This pattern indicates that the reported emissions measure had undergone changes and not an upward or downward trend. The relatively small variations in the reported figures should therefore not be interpreted as proof of an improvement in environmental sustainability, if the emissions measure, energy structure and overall economic activity are not also taken into account.

There were also significant variations in GDP growth. Growth increased from 5.02% in 2000 to 15.33% in 2002, but subsequently varied considerably. There were two downturns in the economy in 2016 (-1.62%) and 2020 (-6.37%), with rebounds in the following years. GDP growth reached 4.32% in 2022 and stood at 4.00% in 2025. The differences are indicative of the volatility of the economy during the study period. The data, in combination with measures of trade openness and renewable energy, reveal that gains in economic growth were not necessarily matched by gains in renewable electricity generation.

Most significantly, the table 1 shows three patterns. First, there was a significant drop in the level of trade openness from its early period value, although some recovery was seen in later years. Second, the use of renewable energy was high, and the electricity generation from renewable energy sources dropped significantly over the long term and partially recovered. Third, CO2 emissions and GDP growth fluctuated, indicating that changes in environmental and economic conditions were not uniform. Overall, these trends indicate that Nigeria's engagement in international

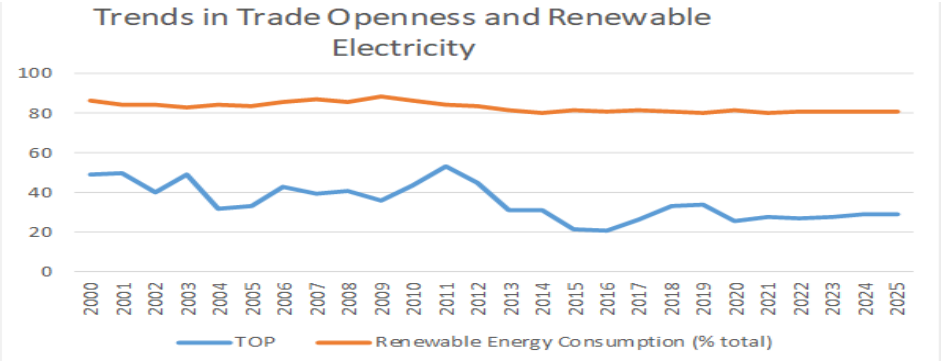


Figure 1: Trends in Trade Openness and Renewable Energy Consumption in Nigeria

Source: Researchers' computation (2026)

Data sourced fromWorld Bank World Development Indicators (WDI, 2026) and International Energy Agency (IEA, 2026).

trade has not been correlated with a steady improvement in all the selected indicators of renewable energy transition. The results show that policies linking international trade with renewable energy technology acquisition, investment in electricity infrastructure and expansion of modern renewable energy sources are important.

The figure 1 shows the trend of trade openness and renewable energy consumption in Nigeria from 2000 to 2025. There are different trends between the two indicators over the period. Trade openness saw significant variations and overall decreased, while renewable energy use was relatively high but decreased from its previous level.

Trade openness was approximately 49% of GDP in 2000 and 2001, before declining to 40.04% in 2002 and rising to 49.33% in 2003. It then varied, peaking at 53.28% in 2011. This was followed by a significant drop, as the trade openness dropped to 21.33% in 2015 and then to the lowest level of 20.72% recorded in 2016. The indicator recovered to 34.02% in 2019 before declining to 25.40% in 2020. The estimated values show a gradual increase from 27.39% in 2021 to 29.01% in 2025.

The use of renewable energy, on the other hand, was significantly greater than trade openness during the period. It rose from 86.00% of total final energy consumption in 2000 to reach 88.10% in 2009 (the maximum recorded value).The indicator has since generally decreased, to 79.90% in 2014, and has hovered in the 80-82% range since 2015. The estimated values for 2022-2025 show a relative stability in the consumption of renewable energy, which will be 80.84% in 2025. But this high percentage does not necessarily reflect significant development of modern renewable energy technologies, since it also covers traditional biomass, which is used for cooking and other domestic purposes. This means that Nigeria's high share of renewable energy consumption may be obscuring the slow progress towards cleaner, more efficient and more sustainable energy sources and technologies.

The two trends are compared and it is found that there is no consistent parallel movement between trade openness and renewable energy consumption. In 2011, for instance, there was a significant increase in trade openness and a decrease in renewable energy consumption from its previous peak. In a similar manner, the trade openness decreased significantly during 2013–2016, while the renewable energy consumption was relatively unchanged. These differences indicate that the changes in Nigeria's trade integration were not always in line with the share of renewable energy in total *final energy consumption.*

Figure 1 also reveals that Nigeria had a high share of renewable energy consumption with significant fluctuations and an overall decrease in trade openness throughout most of the period. This trend is an indicator of the importance of separating renewable energy's share of total energy consumption from the growth of modern renewable energy systems. It also indicates that trade integration alone is not enough to drive Nigeria's renewable energy transition, as additional policies to facilitate clean-energy technology transfer, investment and energy infrastructure are needed.

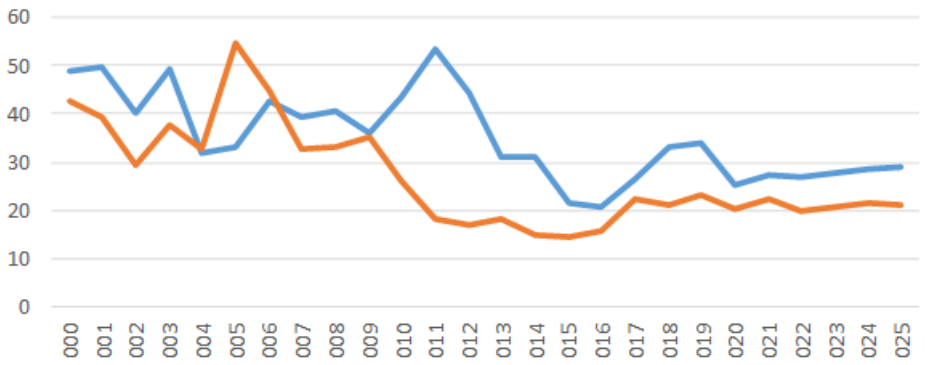


Figure 2: Trends in Trade Openness and Renewable Electricity Consumption in Nigeria
Source: Researchers' computation (2026)
Data sourced fromWorld Bank World Development Indicators (WDI, 2026) and International Energy Agency (IEA, 2026).

Figure 2 shows the trade openness and renewable electricity consumption in Nigeria from 2000 to 2025. The level of trade openness varied significantly during the period and renewable electricity use was relatively high, but has shown a slight downward trend. The contrasting patterns indicate that Nigeria's international trade was not necessarily associated with the use of renewable energy. The trade openness indicators were relatively high in the early years, with a value of 49.00% of GDP in 2000 and 53.28% in 2011. It subsequently declined to 20.72% in 2016 before recovering to 34.02% in 2019 and falling again to 25.40% in 2020. The estimated values for the years 2021-2025 show a gradual improvement, with the value in 2025 projected to be 29.01%.

As shown in Figure 2, renewable use of electricity was relatively high during the time period, but declined in general from previous levels. A slight decrease was observed in the intermediate years, followed by a few fluctuations, and partial recovery towards 2021. Looking

at the two series together, it is seen that movements were not consistently in line. The increase in trade openness was significant and there were significant declines as well, while the renewable energy indicator had a much more gradual path. This divergence implies that trade openness could not fully account for the Renewable energy development changes in Nigeria. Other considerations might be energy infrastructure, investment, technology uptake and policy implementation.

As observed from Figure 2, Nigeria experienced an unequal trade and renewable energy development over the study period. The results indicate that policies that promote access to renewable energy technologies and equipment via international trade, and enhance domestic investment and infrastructure, are all important. This may contribute to Nigeria realizing the potential gains from trade into more tangible improvements in its energy mix and clean energy transition.



Figure 3: Trends in Trade Openness and CO_2 Emissions in Nigeria
Source: Researchers' computation (2026)
Data sourced fromWorld Bank World Development Indicators (WDI, 2026) and International Energy Agency (IEA, 2026)

Figure 3 shows the Nigeria's trade openness and CO2 emissions from the year 2000 to 2025. There are significant variations in the series for Trade Openness, and the series for CO2 emissions is fairly stable and near to the horizontal axis. Trade openness has been quite volatile, having increased from around 50% in 2000 to its highest level of around 53% in 2011. It then dropped off precipitously to around 21% in 2016. The situation slowly improved until around 34% of the population was open to trade in 2019, but declined to roughly 25% in 2020. The series exhibits a slight upward trend starting from 2021, which peaks at around 29% in 2025.

By comparison, there are relatively small fluctuations in CO2 emissions compared with trade openness. The emission series is just above the horizontal axis all the way through. This is reflective of the significant fluctuations in trade openness compared to CO2 emission which was relatively stable. The comparison underscores the need to pay attention to environmental performance in addition to trade integration in examining Nigeria's progress towards sustainable development.

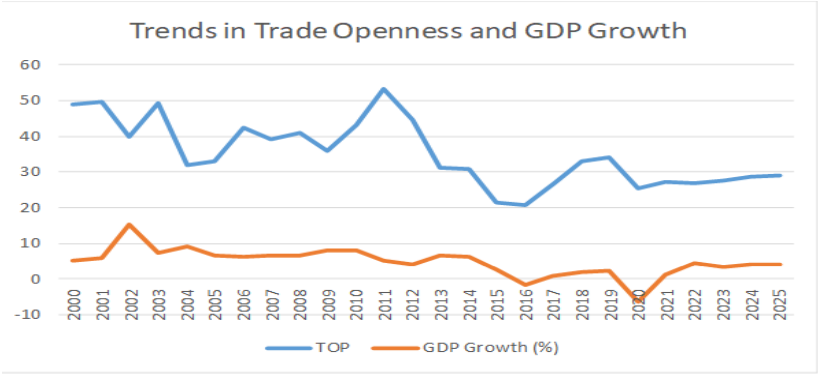


Figure 4: Trends in Trade Openness and GDP Growth in Nigeria
Source: Researchers' computation (2026)
Data sourced fromWorld Bank World Development Indicators (WDI, 2026) and International Energy Agency (IEA, 2026).

The figure 4 shows the trade openness and GDP growth in Nigeria in the period 2000-2025. The two indicators exhibit considerable fluctuations, although their movements do not consistently follow the same pattern. There was a general downward trend in the degree of trade openness from high levels and GDP growth had phases of expansion, contraction and recovery.

Trade openness was highly volatile, increasing from 49.00% of GDP in the year 2000 to 53.28% in the year 2011. It then dropped sharply to 20.72% in 2016, and increased to 34.02% in 2019. The indicator fell again to 25.40% in 2020. The estimated values for the years 2021

to 2025 indicate a gradual recovery, with the value in 2025 estimated at 29.01%.

There was also significant variation in GDP growth over the period. In 2002, it rose to 15.33%, up from 5.02% in 2000, but it has since varied over the years. Growth slowed down in 2015 to 2.65% and fell into negative territory in 2016 at -1.62%, marking an economic contraction. Although growth recovered to 0.81% in 2017 and 2.21% in 2019, the economy contracted again in 2020, when GDP growth fell to -6.37%. Reported figures show a recovery in the following year with growth of 4.32% in 2022. The values for the two rows with the label 2024 are 3.33% and 4.06%, and the value for the row with the label 2025 is 4.00%. The year labels on the duplicate documents should be fixed prior to the final interpretation.

A comparison of the two indicators shows that there was no consistent pattern of change in trade openness and GDP growth. For example, in the period 2011-2016, the decline in trade openness was significant, and GDP growth slowed down and turned negative in 2016. Conversely, both indicators were rather weak around 2020 during the economy's significant contraction due to the COVID-19 pandemic. However, these co-movements do not prove that the changes in trade openness led to the changes in economic growth. It is possible that other factors such as domestic production conditions, macroeconomic policies or external shocks may have had an impact on economic performance.

Lastly, Figure 4 shows Nigeria's economic growth and trade openness which are not constant over the study period. The patterns indicate that more open trade does not necessarily lead to higher economic performance; nor do less open trade necessarily lead to lower economic performance. The trends are important for Nigeria, where policies are needed to increase domestic productive capacity, diversify exports and boost the ability of local industries to take advantage of international trade. These can contribute to promoting more trade that is conducive to stable and sustained economic growth to support renewable energy transition programme.

Policy Implications of the Findings

The implications of this study have significant policy implications for Nigeria's trade policy, renewable energy development and environmental sustainability. The observed reduction in trade openness from 49.00% of GDP in 2000 to 29.01% in 2025 but with some improvement in the recent years, is a sign that the ability of the Nigerian economy to gain from international trade needs to be enhanced. Trade policy should be more than facilitating increased imports and exports; it should promote the purchase of renewable energy technologies such as solar panels, inverters, batteries and other necessary equipment. Through the use of appropriate tariff arrangements, customs procedure and targeted incentives for renewable energy imports, the cost of accessing these technologies could be lowered and help to promote their uptake. Such measures, however, should be framed in a way that would promote technology transfer and increase the country's productive capacity and not render permanent dependence on imported equipment.

Secondly, the relatively high percentage of renewables consumed should not be interpreted as a full switch to modern renewable energy systems, as the percentage of renewables consumed remained at around 80-88% throughout the study period. Total renewable energy consumption includes traditional biomass (fuelwood and charcoal) which can mask reliance on inefficient and potentially damaging household energy practices. This discovery suggests a differential policy in government to encourage modern renewable energy use over traditional biomass use. More resources need to be committed to solar energy, modern bioenergy, clean cooking technologies and decentralised electricity systems for the more sustainable and improved energy use. The adoption of policies to increase access to affordable clean cooking options may also decrease the use of traditional biomass and contribute to household well-being.

Third, the significant drop in renewable electricity generation from 42.76% in 2000 to 14.35% in 2015 and subsequent increase to 21.29% in 2025 indicates a need for more consistent investments in renewable electricity generation. Partial recovery indicates some improvement, albeit not to the same level as the indicator was in the beginning. Investment in hydropower, solar power, mini-grids and other viable sources of renewable electricity should be strengthened, therefore, as a part of the efforts of the government. Improvements in transmission and distribution infrastructure and financing arrangements and regulatory certainty are also very important. Public-Private Partnerships, Concessional financing and risk sharing can help mobilise investments needed to scale up renewable electricity generation, especially in underserved and rural communities.

Fourth, the ups and downs of CO2 emission show that environmental performance needs to be continuously addressed by policy. The emissions per capita series does not create a trend of continuous improvement of environmental sustainability although emissions per capita decreased from 0.79 metric tonnes in 2000 to 0.57 metric tonnes in 2025. Nigeria should incorporate environmental factors in its trade, industrial and energy policies through the promotion of cleaner production processes, energy efficiency and investments with low carbon intensity. It could also be possible to diversify the economy's production towards less carbon-intensive activities to reduce the economy's reliance on fossil-fuel related activities as an export source. Furthermore, environmental policies ought to be based on overall emissions and not on changes in emissions per capita.

Lastly, the volatility of GDP growth, especially negative growth in 2016 and 2020, highlights the need for a stable macroeconomic environment in which to invest in renewables. Low economic growth can make financing more difficult, and can deter investment in energy

infrastructure, due to the capital costs. Thus, the policies should be adopted to enhance the productive capability at home, to ensure long-term financing and to create a stable regulatory framework for renewable energy companies. Trade diversification could be coupled with domestic manufacturing, technical and vocation trainings and renewable energy investment to create jobs and to increase the country's ability to engage in the international clean-energy market.

Most importantly, the results indicate that the opening up of trade is not enough to ensure the transition towards renewable energy in Nigeria. Policy focus should be given to enhancing the connection between international trade, the transfer of technology and domestic investment and deployment of modern renewable energy. Nigeria's energy diversification and trade policy can be harmonised to better the prospect of having a reliable, affordable and sustainable energy system.

CONCLUSION

This study examined the trends and patterns of trade openness and renewable energy transition in Nigeria from 2000 to 2025. The findings revealed fluctuations in trade openness, which declined from 49.00% of GDP in 2000 to 29.01% in 2025. Although renewable energy consumption remained relatively high, this did not necessarily indicate progress towards modern renewable energy technologies because traditional biomass was included. Renewable electricity output declined significantly before experiencing partial recovery, while CO□ emissions and GDP growth also fluctuated. The study concludes that trade openness alone does not guarantee renewable energy transition in Nigeria. Although international trade can facilitate access to renewable energy technologies, equipment, investment and technical knowledge, the actual benefits depend on domestic infrastructure, financing, technology adoption and effective policy implementation. Therefore, Nigeria needs stronger integration of trade and energy policies to translate trade opportunities into sustainable energy development. Promoting affordable modern renewable technologies, improving electricity infrastructure and strengthening institutional coordination are essential for advancing energy security, economic development and environmental sustainability.

Recommendations

Based on the findings, the study recommends the following:

1. Align trade policies with renewable energy development: The Nigerian government should reduce barriers to importing essential renewable energy equipment, including solar panels, inverters and batteries, while promoting local manufacturing and assembly.
2. Promote modern renewable energy: Policies should encourage solar energy, modern bioenergy and cleaner cooking alternatives to reduce dependence on traditional biomass, fuelwood and charcoal.
3. Expand renewable electricity infrastructure: Federal and state governments should collaborate with private investors to develop solar and hydropower projects, mini-grids, electricity storage and reliable transmission and distribution systems.
4. Integrate environmental objectives into trade policies: Nigeria should encourage energy-efficient production, cleaner technologies and economic diversification while strengthening monitoring of carbon emissions.
5. Improve financing and policy coordination: Government should establish consistent regulations, strengthen cooperation among relevant institutions and encourage financial institutions to provide affordable, long-term financing for renewable energy projects.
6. Strengthen energy data collection: Relevant agencies should improve the regular collection and publication of reliable data on renewable energy consumption, electricity generation, installed capacity, trade and emissions to support evidence-based policymaking.

Limitations and Directions for Further Research

This study has some limitations. First, missing observations in the dataset were estimated using moving averages to maintain continuity through 2025. These estimates may not accurately reflect actual developments and should therefore be interpreted cautiously. Second, the indicators used do not fully capture the renewable energy transition, particularly the distinction between traditional biomass consumption and modern renewable energy technologies. Third, the descriptive and trend analysis identifies patterns over time but cannot establish a causal relationship between trade openness and renewable energy transition in Nigeria. Future research should address these limitations by using more comprehensive and reliable datasets covering renewable energy consumption, installed capacity, electricity generation, clean cooking access and carbon emissions. Researchers should also employ econometric techniques to examine the direction, magnitude and statistical significance of the relationship between trade openness and renewable energy transition. Further studies could investigate the effects of renewable energy investment, technology imports, financing and government policies on Nigeria's energy transition. Comparative studies involving other African countries would also help determine whether Nigeria's observed patterns are country-specific or reflect broader regional trends. These approaches would provide stronger empirical evidence to guide energy and trade policymaking.

REFERENCES

Berhe, M. W., Dossou, T. A. M., Huang, J., & Wedajo, A. D. (2025). Can China's trade and investment facilitate renewable energy consumption in Africa? *Energy & Environment, 36*(7), 3244–3267. https://doi.org/10.1177/0958305X231215320

Copeland, B. R., & Taylor, M. S. (2004). Trade, growth, and the environment. *Journal of Economic Literature, 42*(1),

7–71.https://doi.org/10.1257/002205104773558047

Energy Commission of Nigeria. (2022). National energy policy (Revised ed.). *Federal Ministry of Science, Technology and Innovation.* https://energy.gov.ng/Energy_Policies_Plan

Federal Government of Nigeria. (2022). *Nigeria energy transition plan*. https://www.energytransition.gov.ng/

Frankel, J. A., & Rose, A. K. (2005). Is trade good or bad for the environment? Sorting out the causality. R*eview of Economics and Statistics, 87*(1), 85–91. https://doi.org/10.1162/0034653053327577

Huang, Z., & Liu, Y. (2022). The role of eco-innovations, trade openness, and human capital in sustainable renewable energy consumption: Evidence using CS-ARDL approach. *Renewable Energy, 201*, 131–140. https://doi.org/10.1016/j.renene.2022.10.039

Energy Agency. (2023). *World energy outlook 2023*. https://www.iea.org/reports/world-energy-outlook-2023

International Energy Agency. (2026). Nigeria: *Energy mix*. https://www.iea.org/countries/nigeria/energy-mix

International Renewable Energy Agency. (2023). *World energy transitions outlook 2023: 1.5*°C pathway https://www.irena.org/Publications/2023/Mar/World-Energy-Transitions-Outlook-2023

Khan, H., Liu, W., Khan, I., & Khamphengxay, S. (2021). Renewable energy consumption, trade openness, and environmental degradation: A panel data analysis of developing and developed countries. *Mathematical Problems in Engineering, 2021, Article* 6691046. https://doi.org/10.1155/2021/6691046

Maluleke, G. (2024). The asymmetric impact of trade openness on renewable energy consumption in South Africa. *Journal of Smart Economic Growth, 9*(2), 95–113.

Mol, A. P. J. (1995). The refinement of production: Ecological modernization theory and the chemical industry. International Books.

Murshed, M. (2020). Are trade liberalization policies aligned with renewable energy transition in low- and middle-income countries? An instrumental variable approach. *Renewable Energy, 151,* 1110–1123. https://doi.org/10.1016/j.renene.2019.11.106

Nyiwul, L., & Koirala, N. P. (2024). Renewable energy policy performance and technological innovation in Africa: A Bayesian estimation. *Energy Policy, 193,* Article 114279. https://doi.org/10.1016/j.enpol.2024.114279

Ohunakin, S. Olayinka & Ojolo, S. Joshua & Ogunsina, S. Babatunde & Dinrifo, R. Rufus, 2012. Analysis of cost estimation and wind energy evaluation using wind energy conversion systems (WECS) for electricity generation in six selected high altitude locations in *Nigeria Energy Policy, Elsevier, vol. 48*(C), pages 594-600. https://doi.org/10.1016/j.enpol.2012.05.064

Oyedepo, S. O. (2012). Efficient energy utilization as a tool for sustainable development in Nigeria. *International Journal of Energy and Environmental Engineering,* 3, Article 11. https://doi.org/10.1186/2251-6832-3-11

Ricardo, D. (1817). *On the principles of political economy,* and *taxation*. John Murray.

Rogers, E. M. (2003). *Diffusion of innovations (5th ed.). Free Press.*

Seraj, M., Siakamba, A., & Özdeşer, H. (2025). The impact of economic indicators on renewable energy consumption in Southern Africa: Evidence from residual augmented least squares cointegration and method of moments quantile regression models. *Sustainability, 17*(8), Article 3496. https://doi.org/10.3390/su17083496

Spaargaren, G. (1997). *The ecological modernization of production and consumption: Essays in environmental sociology.* Landbouwuniversiteit Wageningen.

Suleman, S., Nawaz, F., Kayani, U., Aysan, A. F., Sohail, M., Thaker, H. M. T., & Haider, S. A. (2025). Drivers of trade market behavior effect on renewable energy consumption: A study of MINT (Mexico, Indonesia, Nigeria, and Turkey) economies. *Discover Sustainability*, 6, Article 141. https://doi.org/10.1007/s43621-024-00715-3

World Bank. (2026 *World development indicators.* https://databank.worldbank.org/source/world-development-indicators