The Nigerian Journal of Energy & Environmental Economics
Department of Economics,
Nnamdi Azikiwe University, Awka,
Anambra State, Nigeria.
Web: www.aeeeng.org *ISSN 2006-8395*

ENERGY CONSUMPTION AND ENVIRONMENTAL DEGRADATION: EVIDENCE FROM ARDL APPROACH

[1]Mohammad Adamu, [2]Ahmad Isah Ammani & [1] Muktar Abubakar Bappaji

[1]Department of Economics, Faculty of Social Sciences, Saadu Zungur University
Bauchi State, Nigeria.
[2]Department of Economics and Development Studies, Faculty of Social Sciences,
Federal University Kashere, Gombe State, Nigeria.
[1]Department of Economics, Faculty of Social Sciences, Saadu Zungur University
Bauchi State
correspondence: talk2bom@gmail.com Tel: +2348034166818

Abstract

The study investigated the impact of energy consumption on environmental degradation in Nigeria, covering the period from 1985 to 2022 using the autoregressive distributed lag (ARDL) model. The findings show that while energy consumption had a positive but statistically insignificant long-term effect on environmental degradation, manufacturing had a significant negative impact. Urbanization is also linked to increased environmental stress in Nigeria. Based on these findings, the study recommends that efforts should focus on improving energy efficiency across various sectors. Policies should be implemented to encourage sustainable manufacturing practices, which could include regulations that require industries to adopt cleaner technologies, minimize waste, and reduce emissions. Additionally, incentives for companies that implement environmentally friendly practices would also be beneficial.

Keywords: Energy consumption, environment, environmental degradation, ARDL**.**

JEL Classification Codes: Q43, Q56, O14

1. Introduction

Global economies desire a clean environment and sustainable energy, but climate change and global warming as common and controversial environmental issues in this modern age pose threat to achieving this objective (Ahmed et al., 2021). This is because a sizable portion of the world's energy consumption need is met through fossil fuels. However, rising figures in global trade and a quick surge in economic activities around the world have caused a significant increase in environmental degradation. As heavy energy consumption and other natural resources which resulted environmental contamination, also the gas emissions from fossil consumption increases the amount of CO_2 which pollute the environment as well as inflicting irreparable damages on the atmosphere (Taghizadeh et al., 2020).

Energy consumption serves as the cornerstone of wealth creation by being the centre of operations and development driver for all sectors of the economy (Armeanu et al., 2025). The contribution of the energy sector such as electricity and petroleum products typically consolidate the activities of other sectors providing essential services to support development activities in agriculture, manufacturing, mining, commerce and other sector of the economy (Zakari, 2021). Energy consumption, mainly fossil fuel energy contributes to CO_2 emissions which are among the cause of climate change and global warming. Therefore, it was in line with this that the International Energy Agency (2020) suggested that any efforts to reduce environmental degradation in a country effectively, a strategic plan of the energy and economic sectors should be applied. The agency categorized energy users and producers of CO_2 emissions from energy burning into seven groups: industry, transportation, residential, commercial and private services, agriculture/forestry, fisheries, and undefined energy users (Asongu et al, 2019). However, the carbon dioxide released into the environment from the usage of fossil fuels such as diesel, coal and natural gas is the key gas that induces the global warming (Musa & Maijama'a 2020).

Nigeria's energy consumption is primarily dominated by fossil fuels, particularly oil and natural gas, which account for the majority of the country's electricity generation and transportation fuel needs. Despite being a major oil producer, Nigeria still grapples with energy poverty, with a significant portion of its population lacking access to reliable electricity (Musa & Maijama'a 2020). According to Imandojemu and Akinlosotu (2018) the rapid pace of industrialization, urbanization, and population growth in Nigeria has led to severe environmental degradation across various fronts. Issues such as air pollution, water contamination, deforestation, and soil degradation have become increasingly prevalent, posing significant threats to public health, biodiversity, and ecosystem integrity. Though a fugitive emission which occur from leaks and irregular release of non-renewable consumption, for instance, gases, are a significant source of GHG emissions but reduced recently, according to recent statistics smaller sources of emissions from electricity and heating generation, transportation and manufacturing and construction have increased (Koondhar, et al., 2018). The country faces numerous challenges related to environmental impacts through energy consumption patterns.

Nigeria is experiencing severe environmental deterioration, which is made worse by things like industrial activity, urbanization, and energy use. Studies reveal that energy consumption has a statistically negligible impact on environmental degradation, raising doubts about its long-term implications despite the increased concern over environmental issues. However, the industrial sector has a significant detrimental effect on the environment even though it boosts economic growth. Nigeria's environmental resources are also under more stress due to the country's fast urbanization. The intricate relationship between energy use, industrialization, and urbanization emphasizes how urgently sustainable practices and regulations are needed to lessen the negative effects on the environment.

This study offers important insights into how various industries, especially, manufacturing and energy use, impact the environment using data from 1985 to 2022. The results can help policy makers and environmentalists understand which important issues need to be addressed in order to lessen environmental stress. Along with providing helpful suggestions for reducing adverse environmental effects, the report emphasizes the significance of enhancing energy efficiency and encouraging sustainable manufacturing methods. In the end, this research will provide a basis for formulating strategies and policies that will assist Nigeria in attaining sustainable economic growth while preserving its natural resources for posterity.

2. Literature Review

Theoretical Review

Environmental Kuznets Curve (EKC) hypothesis or theory was formulated by economist Simon Kuznet in 1950s and 1960s. The theory suggest that economic development initially leads to a decline in the environment, but after a certain level of economic growth, a society begins to improve its relationship with the environment and levels of environmental degradation reduces (Ibrahim & Cudjoe 2021). Energy consumption increases as economies get more industrialized, which increases pollution and depletes resources. As a result of companies' exploitation of natural resources, environmental damage is common throughout this phase. Environmental concerns start to take precedence in society when per capita income reaches a particular threshold. There is a rise in public awareness and demand for greener technologies. After the tipping point, environmental quality improves as a result of additional economic expansion. Investments in sustainable technologies and stricter environmental regulations typically increase, driven by both market demand and policy interventions.

Energy use in the early phases of development is mostly derived from fossil fuels, which raises emissions and pollution levels. Renewable energy sources may become more popular as income levels rise and environmental concerns gain traction in society.

The Environmental Kuznets Curve (EKC) theory offers a useful framework to understand the relationship between energy consumption, and environmental degradation. According to this theory, as an economy grows, environmental degradation initially worsens, primarily due to increased energy consumption that typically comes from polluting sources like fossil fuels. However, after a certain level of economic development, the trend reverses, and further economic growth leads to environmental improvements (Musa et al., 2021).

Empirical Literature Review

The reviewed studies provide evidence of varying relationships between energy consumption, economic growth, and environmental quality across different regions. A key theme that emerges is the contrasting impacts of different energy sources on CO_2 emissions. For instance, Ibrahim and Cudjoe (2021) found that while gas oil consumption in Nigeria has a negative impact on CO_2 emissions, suggesting it might reduce emissions, natural gas and fuel oil consumption exacerbate CO_2 emissions. Hydroelectricity, on the other hand, has a long-run negative impact, improving environmental quality by reducing emissions. In the OECD countries, Zakari et al. (2021) observed that higher energy consumption generally leads to more CO_2 emissions, though renewable energy sources help mitigate this impact by reducing emissions in the long run.

The review also touches on the EKC hypothesis which proposes that environmental degradation initially increases with economic growth but improves once a certain threshold is reached. Hasnisah (2019) confirmed the EKC in 13 Asian countries, where the rise in GDP per capita and conventional energy consumption leads to environmental degradation, but further development and the transition to cleaner energy sources offer opportunities for emission reduction. In contrast, Armeanu et al. (2019) in Central and Eastern Europe highlighted the potential of renewable energy consumption to stimulate economic growth while minimizing environmental damage, suggesting a more positive relationship between renewable energy use and economic development.

However, the situation in Nigeria presents a more complex dynamic. Musa and Maijama'a (2020) found that economic growth and energy consumption both contribute to environmental degradation, supporting the early phase of the EKC. Additionally, they noted that crude oil prices, which influence energy consumption patterns, have a negative effect on pollution in the long run, suggesting that policy interventions such as adjustments in crude oil prices could potentially help reduce emissions. Sharif et al. (2019) argued that renewable energy consumption can influence environmental degradation, but the effects vary significantly across different levels of energy use and local environmental conditions. While there is an overall dependence between the two factors, the relationship is not uniform, suggesting that more nuanced approaches are needed to understand the role of renewable energy in environmental sustainability. Shahbaz (2021) provides evidence that clean energy consumption did not have a significant long-term impact on reducing CO_2 emissions in France, particularly when considering the role of economic policy uncertainty (EPU). This suggests that while clean energy may contribute to sustainability, external factors such as economic policy and growth dynamics can complicate its potential to reduce emissions.

Nathaniel et al. (2021) emphasized that natural resource exploitation, globalization, and urbanization are key drivers of increased CO_2 emissions in Latin American and Caribbean countries. The study highlights the importance of addressing these drivers while also recognizing that human capital development could mitigate some of the negative environmental impacts. This implies that a holistic approach to sustainable development is necessary, beyond just focusing on energy consumption. Khan et al. (2020) argued that both energy consumption and economic growth contribute to environmental degradation, particularly in the form of increased CO_2 emissions. They advocate for promoting renewable energy sources to replace fossil fuels as a strategy to support economic growth while mitigating environmental harm.

Ahmed (2022) assert that economic growth tends to increase the ecological footprint, but that democracy and environmental regulations play a crucial role in reducing it. This highlights the importance of governance and policy frameworks in promoting sustainability, emphasizing that the adoption of renewable energy and stricter environmental regulations can mitigate the negative impacts of economic growth on the environment. Ajayi and Alaka (2022) contribute to the argument by demonstrating the potential of advanced machine learning models, particularly deep learning (ANN), to predict energy consumption in buildings. Their findings underscore the role of technological innovation in enhancing energy efficiency and guiding sustainable energy practices, particularly in building design.

3. Methodology

The study used secondary data for relevant variables sourced from the World Development Indicators of the World Bank. The data covers the period from 1982 to 2022, and the variables are expressed in their natural logarithm.

Theoretical Framework

A theoretical framework for comprehending the connection between energy consumption and environmental degradation is the environmental Kuznets curve. Economic progress, technical breakthroughs, and environmental policies can help reverse the tendency as countries mature, even though initial increases in energy consumption may result in higher environmental costs (Ammani et al., 2025). The EKC hypothesis emphasizes how crucial it is to use innovation, regulation, and the adoption of cleaner energy technology to strike a balance between environmental sustainability and economic growth.

Empirical Model Specification

This study adopts the empirical model from Mahmood et al. (2019), which is grounded in the Environmental Kuznets Curve, with slight modifications to incorporate the impact of trade openness. The model is formulated as follows:

$$CO2_t = f(ENC_t, \mathrm{URB}_t, \mathrm{MNF}_t) \qquad (3.1)$$

Where CO_2 stand for environmental degradation which is the dependent variable, ENC_t is energy consumption at time t, URB_t is stand for urbanization at time and MNF stand for manufacturing at time t. Subsequently, Equation (3.1) can be specified in the econometrics form as follows:

$$CO2_t + \beta_0 + \beta_1 ENC_t + \beta_2 URB_t \beta_3 MNF_t + \mu_t \qquad (3.2)$$

Where: $CO2_t$ stand for environmental degradation and serve as dependent variable. the The independent variables are ENC_t= the energy consumption; MNF_t= manufacturing; $URB_t =$ urbanization, while μ_t is the residual or error term. Transforming Equation (3.2) into natural logarithm form it becomes:

$$lnCO2_t + \beta_0 + \beta_1 \ln E\,NC_t + \beta_2 \ln U\,RB_t + \beta_3 \ln M\,NF_t + \mu_t \qquad (3.3)$$

Where: $InCO2_t$ stand for natural log of environmental pollution, $\ln E\,NC_t$is the natural log of energy consumption; $\ln M\,NF_t$is the natural log of manufacturing; $\ln U\,RB_t$is the natural log of urbanization and μ_t is the residual or error term.

Estimation Technique

To assess the association between $C0_2$, ENC, URB, and MNF, this work used the autoregressive distributed lag (ARDL) limits test approach to co-integration, which was proposed by Pesaran, Shin, and Smith (2001).

Compared to previous co-integration methods, the ARDL approach has a few desirable statistical advantages. The ARDL test procedure yields reliable results whether the variables are I(0), I(1), or mutually co-integrated, and it produces very effective and consistent estimates in both small and large sample sizes, whereas other co-integration techniques require all the variables to be integrated of the same order (Pesaran, Shin & Smith, 2001). Since every series is either I(0) or I(1), this method so becomes pertinent to this investigation.

$$\Delta lnCO2_{t_t} = \beta_0 + \sum_{i=1}^{S} \phi_i \Delta \ln C\,O2_{t_{t-1}} + \sum_{i=0}^{S} \varphi_i \Delta \ln E\,NC_{t-1} + \sum_{i=0}^{S} \lambda_i \Delta \ln U\,RB_{t-1} + \sum_{i=0}^{S} \delta_i \Delta \ln M\,NF_{t-1} + \theta_1 \ln C\,O2_{t_{t-1}} + \theta_2 \ln E\,NC_{t-1} + \theta_3 \ln U\,RB_{t-1} + \theta_4 \ln M\,NF_{t-1} + \varepsilon_t \qquad (3.4)$$

ARDL Long-Run Model

After discovering the evidence of cointegration, the long-run ARDL model is specified as:

$$lnCO2_t = \beta_0 + \sum_{i=1}^{S} \phi_i \ln C\,O2_{t-1} + \sum_{i=0}^{S} \varphi_i \ln E\,NC_{t-1} + \sum_{i=0}^{S} \lambda_i \ln U\,RB_{t-1} + \sum_{i=0}^{S} \delta_i \ln M\,NF_{t-1} + \varepsilon_t \qquad (3.5)$$

ARDL Error Correction Term Model

Sequel to the existence of long run relationship, the error correction model for the estimation of the short run relationships is specified as;

$$\Delta lnCO2_t = \beta_0 + \sum_{i=1}^{S} \phi_i \Delta \ln C\,O2_{t-1} + \sum_{i=0}^{S} \varphi_i \Delta \ln E\,NC_{t-1} + \sum_{i=0}^{S} \lambda_i \Delta \ln U\,RB_{t-1} + \sum_{i=0}^{S} \delta_i \Delta \ln M\,NF_{t-1} + \varepsilon_t \qquad (3.6)$$

Where the ECT in Equation 3.6 is defined as:

$$ECT_t = lnCO2_t - \alpha_o - \sum_{i=1}^{S} \psi_i \ln C\,O2_{t-1} - \sum_{i=0}^{S} \varphi_i \ln E\,NC_{t-1} - \sum_{i=0}^{S} \lambda_i \ln U\,RB_{t-1} - \sum_{i=o}^{S} \phi_i \ln M\,NF_{t-1} \qquad (3.7)$$

How much of the disequilibrium is being corrected, or how much of any disequilibrium from the prior period is being adjusted in yt, is shown by the ECT, which is the long-run residual. Whereas a negative coefficient denotes convergence, a positive coefficient denotes divergence. 100% of the adjustment occurs during the interval, or the adjustment is instantaneous and complete, if the estimate of ECT = 1. Additionally, 50% of the adjustment occurs each period or year if the estimated ECT is equal to 0.5. It no longer makes sense to assert that there is a long-term association since ECT = 0 indicates that there is no adjustment.

4. Presentation of Results and Discussions

Descriptive statistics

Table 4.1: Descriptive statistics

Variables	CO_2	ENC	URB	MNF
Mean	3.445	6.431	4.514	0.343
Median	3.527	6.800	4.642	4.310
Maximum	4.492	9.455	8.499	18.180
Minimum	2.651	2.415	0.000	-65.85
Std. Dev.	0.532	2.179	2.344	.618
Skewness	0.054	-0.302	-0.061	-2.633
Kurtosis	2.029	1.879	1.958	12.236
JarquBera	1.550	2.637	1.787	183.720
Probabily	0.060	0.027	0.009	0.022
Sum	134.37	250.825	176.064	13.389
Sq.Dev.	10.772	180.526	208.838	8120.966
Observation	**37**	**37**	**37**	**37**

Results from Table 4.1 shows that the mean value of all the variables is low during the study period. The low mean value of manufacturing and environmental degradation highlights the problems associated with the Nigerian environmental quality. The maximum value of all the variables appears to be low except for manufacturing, hence the value of environmental degradation, within the study period proves low. The low values of standard deviation of all variables are low means that the values of all the variables are closer to mean. The skewness result shows that all the variables are fairly symmetrical as all the values fall between -0.5 to 0.5 except for environmental degradation that exceeded the threshold showing evidence of heavy tails. The heavy tail means that the distribution of the variable is not exponentially bounded, heavy-tailed distributions approach zero at a slower rate and can have outliers with very high values. The result also depicts that none of the variables kurtosis value exceeds 3. These shows the data sets of all the variables have no heavy tails.

Unit Root Test

The unit root test was carried out using Augmented Dickey Fuller (ADF, 1981) test to check stationary among the variables. The unit root tests were conducted at level and at first difference using constant and the results of the test is presented in Table 4.2

Table 4.2: ADF Unit Root Test Result

Variables	Order of Integration	Augmented Dickey Fuller Test Critical value			ADF Statistics	Prob.
		1%	5%	10%		
lnCO_2	I(1)	-3.610453	-2.938987	-2.607932	-6.800613	0.0000
lnENC	I(0)	-3.605593	-2.936942	-2.606857	-5.131483	0.0001
lnMNF	I(1)	-3.605593	-2.936942	-2.606857	-7.503474	0.0000
lnURB	I(0)	-3.610453	-2.938987	-2.607932	-6.686424	0.0000

Source: Author's Computation using E-views 9

The unit root test result in Table 4.2 shows that, the natural log of environmental degradation is stationary at first difference at 1% level of significance. Similarly, the coefficient of manufacturing is stationery at first difference at 1% level of significance. But the natural logarithm of energy consumption and urbanization were found stationary at both level and first difference at 1% level of significance.

Optimum Lag Selection Test

It is paramount to identify the optimum lag length to be used in order to avoid spurious regression. Before conducting cointergration test, the optimal lag length was determined through the VAR model and empirically using five lag selection criteria. These are the log likelihood method (LR), Akaike Information Criterion (AIC), final prediction error (FPE), Swartz Bayesin Criterion (SC) and the HannanQuin (HQ) criterion as such, optimal lag selection result present in Table 4.3.

Table 4.3: Optimum Lag Selection Result

Lag	LogL	LR	FPE	AIC	SC	HQ
0	36.86	NA	1.906	-1.77	-1.60	-1.715
1	177.03	242.44	2.44*	-8.48*	-7.61*	-8.18*
2	183.08	9.15	4.31	-7.95	-6.38	-7.39
3	203.45	26.43 *	3.71	-8.18	-5.92	-7.38
4	215.75	13.29	5.38	-7.98	-5.02	-6.94

Source: Author's Computation using E-views 9

From Table 4.3, the optimum lag selection result shows that all the criteria indicate lag length of lag one (1) except (LR) which choose lag three. The best lag for this analysis is one (1) as shown in Akaike Information Criterion (AIC), final prediction error (FPE), Swartz Bayesian Criterion (SC) and the HannanQuin (HQ) criterion.

ARDL Bound Test

As the best optimal lag is chosen, the ARDL bounds test was conducted to find the evidence of the long-run cointegration among the variables. The result of the bound test is presented in Table 4.4.

Table 4.4: Cointegration Test Result

Model	F-statistic	lag	Level of Significance	Bound test critical values (constant level)	
CO2=f(ENC, LMNF,LURB)	**6.32**	**1**		**1(0)**	**1(1)**
			10%	2.72	3.77
			5%	3.23	4.35
			2.5%	3.69	4.89
			1%	4.29	5.61

Source: Author's Computation using E-views 9

The bounds test result in Table 4.4 shows that the calculated F-statistic value of 6.32 is greater than the upper bound critical value 3.77 at 10%, 4.35 at 5%, 4.89 at 2.5% and at 1% is 5.61 level of significance. This implies the presence of strong cointegration among the variables and therefore rejects the null hypothesis of no co-integration among CO_2, ENC, LMNF and URB i.e. a long-run cointegration exists among the variables.

Table 4.5: Estimated Long-run Coefficients Results

		InCO2		
Variables	**Coefficient**	Std. Error	**T-statistic**	Prob*
InENC	0.259735	0.238953	0.884893	0.0034***
lnMNF	0.009859	0.224160	0.102142	0.0092***
lnURB	0.221238	0.035487	3.236519	0.0026***
Constant	-0.171923	0.026814	-0.126391	0.9001

Note: ***, **, * Denotes 1%, 5% and 10% significance level respectively

Source: Author's Computation using E-views 9

The ARDL long-run estimate, as presented in Table 4.5, indicates that, over the long term, energy consumption (InENC) has a positive and statistically significant effect on environmental degradation ($InCO_2$). Implying increase in energy consumption is associated with increase in environmental degradation. This finding is contrary to environmental kuznet hypothesis which posits an inverted U-shaped relationship between economic development and environmental degradation but is consistent with the findings from Ezenwa et al. (2021); Zakari et al. (2021). Similarly, at the 1% level of significance, the coefficient of manufacturing (InMNF) has a long-term positive and statistically significant impact on environmental degradation ($InCO_2$). Over time, there is a 0.009859 rise in environmental damage for every 1% growth. The result further reveals that coefficient of urbanization (InURB) found positive and significant effect on environmental degradation ($InCO_2$) in the long run. A percentage increase in urbanization will lead to 0.22 increase in environmental degradation in the long run.

Table 4.6: Short-run ARDL Results

	InCO2	
Regressors	**Coefficients/Probability**	**T-statistics**
D(lnENC)	0.087763 (0.3008)	1.050308
D(lnMNF)	0.003331 (0.9209)	0.099986
D(lnURB)	0.074755 (0.0332)	2.217795
Coint Eq(-1)	- 0.337896 (0.0237)	-2.365079

Note: ***, **, * denote 1%, 5% and 10% significance level respectively.

Source: Author's Computation using E-views 9

As shown in Table 4.6, the ARDL short run estimate indicated that, the natural log of energy consumption had positive and insignificant effect on environmental degradation in the short run form. A percent increase in energy consumption will lead to 0.088 increase in environmental degradation. However, coefficient of manufacturing had positive and statistically insignificant effect on environmental degradation in the short run. A percent increase in manufacturing is associated with 0.0033 increase in environmental degradation in the short run. The coefficient of urbanization had a positive and statistically significant effect on environmental degradation, at 5 % level of significance. In the short run a 1% increase in urbanization will lead 0.075 increases in environmental degradation in the short run.

The error correction term (ECT) is negative, less than one (in absolute value) and significant. The coefficient of the ECT is -0.34 and the probability value is 0.0237. This confirms the earlier long run relationship among the data series and also shows the speed of adjustment of towards long run equilibrium to be 34% in the first year. The speed of adjustment is slow because only 34% of the short-term disequilibrium between the explained and the explanatory variables will converge to equilibrium in the long-run.

Table 4.7: Diagnostics Tests Results

Test Statistics	F(Prob)	Probability
Autocorrelation	F(2,16) = 0.4367	0.3755
Hetroskedasticity	F(1,37)= 0.5222	0.5095
Normality	0.623396	0.732202

Source: Author's Computation using E-views 9

The serial correlation result in Table 4.7 was conducted using Breusch-Godfrey serial correlation. The null hypothesis for no serial correlation was not rejected since p-value is greater than 5%. Heteroscedasticity was also estimated using Breusch-Pagan-Godfrey test and from the test result reported in Table 4.7, the null hypothesis of variance is constant (homoscedasticity) because the probability value is greater than 5%. The study also tested for the normality of the errors in the model through the Jarque-Bera and its probability values as reported in Table 4.7. The result revealed that the Jarque-Bera p-value was insignificant which implies the acceptance of null hypothesis that errors were normally distributed in the ARDL model.

5. Conclusion and Recommendation

The broad objective of this paper is to investigate the impact of energy consumption on environmental degradation in Nigeria. Following the findings, the study concludes that there are nuanced relationships between energy consumption, manufacturing, and urbanization in relation to environmental degradation. Energy consumption and manufacturing had positive and statistically significant long-run effect, highlighting the urgent need for sustainable industrial practices. Urbanization, on the other hand while linked to increased environmental stress, shows varying effects depending on the time frame, with significant short-run implications. Based on the findings, the following recommendations are made to address the environmental implications of energy consumption, manufacturing, and urbanization:

Since the long-run effect of energy consumption on environmental degradation is positive yet significant, efforts should focus on improving energy efficiency across various sectors. This can be achieved through investments in renewable energy technologies and promoting energy-saving practices among consumers and businesses.

The significant positive effect of the manufacturing sector on environmental degradation underscores the need for policies that encourage sustainable manufacturing practices. This could include regulations that require industries to adopt cleaner technologies, minimize waste, and reduce emissions. Incentives for companies that implement environmentally friendly practices could also be beneficial.

The short-run significant impact of urbanization on environmental degradation highlights the urgency for sustainable urban planning. Local governments should prioritize green spaces, efficient public transport systems, and sustainable infrastructure to mitigate environmental stress. Comprehensive urban development policies that incorporate environmental considerations will be crucial.

Raising awareness about the environmental impacts of energy consumption, manufacturing, and urbanization can lead to more responsible behaviour among individuals and businesses. Public campaigns and education programs can promote sustainable practices and encourage community involvement in environmental initiatives.

References

Ahmad, M. I., Waziri, S. I., Abdullahi, M. M., & Chindo, S. (2021). Energy consumption, environmental pollution, and economic growth in Nigeria. *International Journal of Intellectual Discourse (IJID), 4*(4).

Ahmed, Z., Ahmad, M., Rjoub, H., Kalugina, O. A., & Hussain, M. (2021). Economic growth, renewable energy consumption, and ecological footprint: Exploring the role of environmental regulations and democracy in sustainable development.*Wiley Online Library* https://onlinelibrary.wiley.com/doi/full/10.1002%2Fsd.2251

Alege, P. O., Adediran, O. S., & Ogundipe, A. A. (2016). Pollutant emissions, energy consumption, and economic growth in Nigeria. *International Journal of Energy Economics and Policy*.

Ammani, A. I., Gamba, S. L., Mohammed, A., & Isah, A. M. (2025). Testing environmental Kuznets curve in Nigeria (1990-2022): The role of trade openness on environmental pollution. *GRS Journal of Arts and Educational Sciences*, 1(1). 1-9

Armeanu, D. S., Gherghina, C., & George, P. (2019). Exploring the causal nexus between energy consumption, environmental pollution, and economic growth: Empirical evidence from Central and Eastern Europe. *Energies,12*(19), 3704. https://www.mdpi.com/1996-1073/12/19/3704

Asongu, S., Iheonu, C. O., & Odo, K. O. (2019). The conditional relationship between renewable energy and environmental quality in Sub-Saharan Africa. *AGDI Working Paper, No. WP/19/074*. African Governance and Development Institute (AGDI). http://www.econjournals.com

Hasnisah, A. A., Azlina, C. M., & Imran, C. T. (2019). Impact of renewable energy consumption on carbon dioxide emissions: Empirical evidence from developing countries in Asia. *International Journal of Energy Economics and Policy, 9*(3), 135–143.

Ibrahim, A. S., & Cudjoe, D. (2021). The environmental impact of energy consumption in Nigeria: Evidence from CO2 emissions. *Research*

Square https://assets-eu.researchsquare.com/files/rs-420727/v1_covered.pdf

Imandojemu, K., & Akinlosotu, N. T. (2018). Renewable energy consumption and economic growth in Nigeria: A co-integration and Granger causality approach. *CBN Bulletin, 42*(2), 50–67.

Khan, M. K., Khan, M. I., & Rehan, M. (2020). The relationship between energy consumption, economic growth, and carbon dioxide emissions in Pakistan. *Financial Innovation, 6*(1). https://doi.org/10.1186/s40854-019-0162-0

Koondhar, M. A., Lingling, Q., Houjian, L., & Weiwei, L. (2018). Nexus between air pollution, energy consumption, and growth of economy: A comparative study between the USA and China based on the ARDL bound testing approach. *Agricultural Economics Czech, 64*. https://doi.org/10.17221/101/2017-AGRICECON

Musa, K. S., & Maijama'a, R. (2020). Economic growth, energy consumption, and environmental pollution in Nigeria: Evidence from ARDL approach. *Energy Economics Letters, 7*(2), 61–73.

Nathanie, S. P., Nnandi, N., & Bekun, F. (2021). Natural resource, globalization, urbanization, human capital, and environmental degradation in Latin American and Caribbean countries. *Environmental Science and Pollution Research, 28*, 6207–6221. https://doi.org/10.1007/s11356-020-10850-9

Ojonugwa, E. (2021). The effects of economic growth and renewable energy consumption on environmental quality in Nigeria: Does the role of structural breaks matter? *International Journal of Innovative Environmental Studies Research, 9*(3), 64–75.

Olu-Ajayi, R., & Alaka, H. (2022). Building energy consumption prediction using deep learning. *Big Data Technologies and Innovation Laboratory, University of Hertfordshire*. https://r.olu-ajayi@herts.ac.uk

Pesaran, M. H., & Pesaran, B. (1999). The role of economic theory in modelling the long run. *The Economic Journal, 107*, 178–191. https://www.jstor.org/stable/2235280

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics, 16*(3), 289–326. https://www.jstor.org/stable/2678547

Sharif, A., Mishra, S., Sinha, A., Jiao, Z., Shahbaz, M., & Afshan, S. (2019). The renewable energy consumption-environmental degradation nexus in top-10 polluted countries: Fresh insights from quantile-on-quantile regression approach. *MPRA Paper No. 97908*. https://mpra.ub.uni-muenchen.de/97908/

World Development Indicator (WDI). (2024). Trade (% of GDP) [Dataset]. Retrieved from http://databank.worldbank.org/data/reports.aspx?source=2&series=NE.TRD.GNFS.Z

Xue, C., Shahbaz, M., Ahmed, Z., Ahmad, M., & Sinha, A. (2021). Clean energy consumption, economic growth, and environmental sustainability: What is the role of economic policy uncertainty? *MPRA Paper No.*

110945. https://mpra.ub.uni-muenchen.de/110945/

Zakari, A., Festus, F. A., & Festus, V. B. (2021). Effect of energy consumption on the environment in the OECD countries: Economic policy uncertainty perspective. *Environmental Science and Pollution Research.* *https://doi.org/10.1007/s11356-021-14463-8*