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RESEARCH ARTICLE

IMPACT OF OPTIMAL ENERGY MIX ON ENVIRONMENTAL QUALITY IN NIGERIA

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Abstract

The paper aims at giving insight on the energy mix that is suitable for Nigeria environment between 1981 and 2021 using a technique of Fully Modified OLS (FMOLS)The results show that the level of renewable energy consumption that is environmentally friendly is higher than that of non-renewable energy consumption. Also, the two energy consumption components (renewable and non-renewable energy consumptions) had significant effect on environmental quality in Nigeria. It is recommended that greater effort should be made in enhancing environmental quality towards reducing global warming. This is as a result of the fact that renewable energy is portrayed as cleaner energy source, which could be used as alternative to non-renewable energy to curb the problem of environmental hazard arising from carbon emission in the environment.

Introduction:-

Nigeria has witnessed different eras of energy consumption overtime. This is due to the introduction of new technologies as well as discoveries of different primary sources, which have been exploited. The reason for searching for new sources of energy from time to time could be linked to craving for energy source with higher energy density and lower carbon emissions. These eras of energy transition in include pre-industrial (agricultural) era - up to mid1800s, early industrial (advanced metallurgy) era - late 1800s; industrial (steam engines) era - early to mid-1900s,; late industrial (dynamo, internal combustion engines) era - mid to late 1900s; and information (microprocessor) era - early 2000s onwards (Edomah, Foulds and Jones,2016). As noted by Edomah (2018), non-renewable energy has been the predominant energy source driving Nigerian economic process so far.

Energy is one of the factors of production important to business development and contributes to different stages of production. It enhances productivity and by implication standard of living. Households and businesses rely on energy to make some pertinent decisions (Najid and Liangsheng, 2017). Notwithstanding, different scholars have identified non-renewable energy as a source of carbon dioxide emissions leading to environmental degradation. Recent studies in literature such as Shafiei and Salim (2014), Ohlan (2015) and Uyigue (2017) revealed that these carbon dioxide emissions are responsible for global warming.

Growing concerns over the effects of global warming necessitated by climate change have placed pressure on both developed and developing economies to improve their efficiency of energy use. There are a number of hypotheses

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formulated to explain the causal relationship between energy consumption and aggregate output. They are growth, conservation, feedback, and neutrality hypotheses. The growth hypothesis implies that energy consumption contributes directly to economic growth within the production process. Unidirectional Granger-causality from energy consumption to real GDP supports the growth hypothesis with the inference that energy conservation policies could possibly reduce real GDP. Evidence supportive of the hypothesishas been provided by Akarca and Long (1979), Stern (2000), and Sari, Ewing, and Soytas (2008).

The conservation hypothesis asserts that energy conservation policies designed to reduce energy consumption and waste may not adversely impact real GDP. Unidirectional Granger-causality from real GDP to energy consumption confirms the conservation hypothesis. Studies by Kraft and Kraft (1978), Erol and Yu (1989), Abosedra and Baghestani (1991), Murray and Nan (1992), Thoma (2004), Soytas and Sari (2006), and Sari et al. (2008) support the conservation hypothesis. The feedback hypothesis proposes that energy consumption and real GDP are interrelated and may serve as complements in which case the existence of bidirectional Granger-causality between energy consumption and real GDP would substantiate the feedback hypothesis. Studies by Glasure and Lee (1996), Zarnikau (1997), Lee (2006), and Mahadevan and Asafu-Adjaye (2007) lend support to the feedback hypothesis. Finally, the neutrality hypothesis considers energy consumption as a relative minor factor in the generation of real GDP, and if such is the case, energy conservation policies may not adversely impact real GDP. The absence of Granger-causality between energy consumption and real GDP is evidence in favor of the neutrality hypothesis. Research undertaken by Soytas, Sari, and Ewing (2007), Chiou-Wei, Chen, and Zhu (2008), Narayan and Prasad (2008), Payne and Taylor (2008), Payne (2008), Riti and Shu (2016) and Nasreen (2017) are supportive of the neutrality hypothesis.

The theoretical disagreement on the role of energy is matched by mixed empirical evidence. As discussed by Zachariadis (2017) and Payne (2018), the difference in results is due to the varying energy consumption and output measures. Jin-Li and Cheng-Hsun (2018) asserted that energy consumption growth is much higher than economic growth, worsening its energy efficiency. Thus, optimal energy mix is proposed as a right combination of energy sources that can minimize the risk due to future uncertainties related to the energy sources. This mix shows the maximum, technically feasible, cost-effective potential of disaggregated energy sources (renewable and non-renewable energy) under consideration and how this potential depends on the other supply alternatives and energy savings in an energy mix. Hence, the paper intends to give an insight on the energy mix that is suitable for Nigeria environment.

Literature Review:-

The study of Owusu and Asumadu-Sarkodie (2016) reviewed the opportunities associated with renewable energy sources which include: Energy Security, Energy Access, Social and Economic development, Climate Change Mitigation, and reduction of environmental and health impacts. The study concluded that despite these opportunities, there are challenges that hinder the sustainability of renewable energy sources towards climate change mitigation. These challenges include Market failures, lack of information, access to raw materials for future renewable resource deployment, and our daily carbon footprint. The study suggested some measures and policy recommendations which when considered would help achieve the goal of renewable energy thus to reduce emissions, mitigate climate change and provide a clean environment as well as clean energy for all and future generations. Also, Renewable energy sources replenish themselves naturally without being depleted in the earth; they include bioenergy, hydropower, geothermal energy, solar energy, wind energy and ocean (tide and wave) energy (Owusu and Asumadu-Sarkodie, 2016).

The technical features, energy consumption, environmental considerations, and potential of renewable energy use in driving the main desalination processes were reviewed and analyzed in the study of Al-Karaghouli and Kazmerski (2012). The study concluded that desalination continues to grow due to the increased water scarcity in many parts of the world, the increase in population, and industrial and economic growth. Desalination technologies have been in continuous rapid development during the previous decades in both system design and operation. This led to a huge savings in power consumption and a cost reduction in water. Similar to the consumer behaviour issue raised by the study above, Pacione (2003) raised a great concern over the quality of modern life as a characteristic of contemporary society. This study explains the social geographical approach to research into quality of life and urban environmental quality. The author employed five-dimensional model for quality of life research where two exemplar case studies are used to illustrate the application of the model in a real world context, so as to assess the potential usefulness of quality of life research.

Increasing the proportion of power derived from renewable energy sources is becoming an increasingly important part of many countries' strategies to achieve reductions in greenhouse gas emissions. However, renewable energy investments can often have external costs and benefits, which need to be taken into account if socially optimal investments are to be made (Bergmann, Hanley and Wright, 2004). The study estimated the magnitude of these external costs and benefits for the case of renewable technologies in Scotland, a country which has set particularly ambitious targets for expanding renewable energy. The external effects considered are those on landscape quality, wildlife and air quality. The study also considered the welfare implications of different investment strategies for employment and electricity prices while the renewable technologies considered include hydro, onshore and off-shore wind power and biomass. The study found out that renewable energy offers a partial solution to the problem of reducing greenhouse gas emissions whilst meeting future energy needs. Yet different renewable energy projects can have varying external costs in terms of impacts on the landscape, wildlife and air pollution. In addition, strategies vary in their likely impacts on jobs and electricity prices. The choice experiment method used in this paper enables these effects to be jointly evaluated in welfare-consistent terms. This enables conclusions to be drawn about the net social benefits of different renewable investment strategies.

The importance of energy to the quality of environment and state of economy cannot be over emphasized in any economy. Sulaiman et al (2015) investigated the relationship between energy consumption, carbon dioxide (CO2) emissions and GDP in Nigeria using autoregressive distributed lag approach to cointegration. The empirical results revealed that there is a long run relationship energy consumption, CO2 emissions and GDP. Both in the long run and short run, CO2 emissions has been found to have a significant positive impact on GDP, meaning that an increase in CO2 emissions facilitates GDP growth. On the other hand, energy consumption shows significant negative impact on GDP in the short run. The study concludes that renewable source of energy such as solar and wind could be explored and considered as an alternative source of energy since Nigeria is well endowed with solar energy. This will assist in reducing CO2 emissions and at the same time sustaining long run growth in GDP.

The relationship between urbanization and CO_2 emissions is examined in the context of the EKC hypothesis. The empirical results show that renewable energy consumption has a negative and significant effect on CO_2 emissions. In line with the above, (Riti and Shu, 2016) confirmed the existence of co-integration among the variables both in long- and short-run paths. However, an economic growth impact on environmental degradation in the long run invalidates the environmental Kuznets curve (EKC) hypothesis for CO_2 emission in Nigeria. The study concluded that the adoption of renewable and alternate energy resources will support sustainable growth with reduced adverse environmental impacts and ensure an eco-friendly environment in Nigeria. An autoregressive distributed lag (ARDL) bounds testing approach to co-integration and the vector error correction model (VECM)-Granger causality test were applied to estimate both long- and short-run parameters as well as the direction of causation.

Methodology:-

The study is premised on the theory of sustainable energy development. The effort to put the ideals of sustainable development into practice gave rise to the philosophy of sustainable energy. Energy access is a vital element in the growth of modern societies' society. As a result, the energy market should be one of the first to undergo transformation in the direction of sustainable growth. It is not always clear in which direction the transition should take place. As a result, it is important to identify what constitutes a sustainable energy future now and in the future.

Model Specification:-

In line with the sustainable energy development, the functional relationship between environment and disaggregated energy consumption is given by

$$E = F(R, N, Y) \qquad 1$$

whereE represents environmental quality, R represents renewable energy, N represents non-renewable energy and Y represents income.

Using constant return to scale assumption we have equation 2 as

$$f\left(\frac{R}{Y}, \frac{N}{Y}\right) \equiv f(r, n) \qquad 2$$

wherer $= \frac{R}{Y}$ and n = $\frac{N}{Y}$. Using Taylor series expansion, equation 2 becomes

$$\frac{E}{Y} = \varphi_0 + \varphi_1 r + \varphi_2 n + R_m \qquad 3$$

In order to determine the real effect of energy consumption on the environment, the variables in the model are transformed to per capita as follows:

$$e_t = \varphi_0 y_t + \varphi_1 \tilde{r}_t + \varphi_2 \tilde{n}_t + \epsilon_t \qquad 4$$

Sequel to the Equation 4, the Environmental Kuznets Curve (EKC) Hypothesis states that as an economy's per capita income increases, the total amount of environmental impact of economic activities initially grows, reaches a maximum and then falls. The EKC was promoted by the World Bank's World Advancement Report 1992 (IBRD, 1992), which contended that: "The view that more prominent economic activity definitely harms the environment is in light of static assumptions about technology, tastes and environmental ventures" also, that "As incomes rise, the interest for enhancements in environmental quality will increase, as will the assets accessible for venture". Others have clarified this position much more commandingly with Beckerman (1992) asserting that "there is clear confirmation that, albeit economic development as a rule prompts environmental degradation in the early phases of the procedure, at last the best and most likely the only approach to accomplish a fair environment in many nations is to turn into rich." The earliest EKCs were straightforward quadratic elements of the levels of income. Therefore, following the EKC assumption, equation 3.5 becomes an estimable form as

$$e = \alpha + \alpha_1 y + \alpha_2 y^2 + \alpha_3 \tilde{r} + \alpha_4 \tilde{n} + \alpha_5 \tilde{r}.\tilde{n} + \alpha_6 \tilde{r}^2 + \alpha_7 \tilde{n}^2 + \epsilon \qquad 5$$

where e represents environment per capita, yrepresents income per capita, y^2 represents square of income per capita, $\tilde{r}$ represents renewable energy consumption per capita, $\tilde{r}^2$ represents square of renewable energy consumption per capital, $\tilde{n}$ represents non-renewable energy consumption per capital, $\tilde{n}^2$ represents square of non-renewable energy consumption per capital, $\tilde{r}.\tilde{n}$ represents interaction between renewable and non-renewable energy consumption per capita.

To investigate the impact of optimal energy mix on environmental quality in Nigeria, the study employed the Fully Modified OLS (FMOLS) technique. The technique modifies least squares and is designed to provide optimal estimates of the existence of a cointegrating relationship in order to account for both serial correlation effects and endogeneity in the regressors (Phillips and Hansen, 1990). It is a long-run model that can be used to examine the existence or otherwise of long-run relationship among the variables. The simplicity and ability of this technique to produce estimated parameters that are consistent (like ordinary least square (OLS)), asymptotically efficient and median unbiased makes it to be preferred to other single equation estimators. This technique also has ability to eliminate sample bias and also take into account simultaneity bias, non-normality problems that are common in economic and financial data. These attributes are technically important because the presence of any of them e.g. simultaneity can result in biased standard errors which will then bring about deceptive inference. The study made use of dataset from 1981 to 2018 and the estimated model in Equation 5 was used to determine the optimal estimates of renewable energy consumption per capital ($\tilde{r}$) and non-renewable energy consumption per capita ($\tilde{n}$) in Equations 10 and 11 respectively

Measurement and Sources of Data:-

The study made use of annual time series secondary data over the study period. The description and measurement of variables and the sources of data are presented in Table 1 below.

Table 1:- Description and Measurement of Variables.

VARIABLES	DESCRIPTION	MEASUREMENTS	Sources
E	Environmental quality	$C0_2$ emission per capita	Central Bank of Nigeria Statistical Bulletin (CBN, 2018).
R	Renewable energy consumption	Renewable energy consumption per capita	World Development Indicator (WDI)
N	Non-renewable energy consumption	Fossil fuel consumption	World Development Indicator (WDI)
Y	Gross Domestic Product.	GDP per capita	Central Bank of Nigeria Statistical Bulletin (CBN, 2018).

Examining the Impact of optimal Energy mix on Environmental quality in Nigeria

The impact of optimal energy mix on environmental quality in Nigeria was investigated by the use of Fully Modified OLS (FMOLS) to estimate equation 5. The results are presented in Table 2.

Table 2:- Impact of optimal Energy mix on Environmental quality (1981 – 2021).

Dependent Variable: ELOG				
Method: Fully Modified Least Squares (FMOLS)				
Variables	**Coefficient**	**Std. Error**	**t-Statistics**	**Prob.**
NLOG	-1.335062	17.55606	-0.076046	0.9399
RLOG	0.462244	16.37447	0.028230	0.9777
NRLOG	0.768327	12.30131	0.062459	0.9506
YLOG	2.055054	4.319667	0.475744	0.6377
$NLOG^2$	-0.524892	0.524892	-0.087731	0.9307
$RLOG^2$	-0.231183	6.641787	-0.034807	0.9725
$YLOG^2$	-0.243719	0.360790	-0.675515	0.5045
R^2 = 0.908882			**Adjusted R^2 = 0.890658**	

Source: Authors' computation

The results in Table 4.8 show a negative relationship between nonrenewable energy consumption and environmental quality in Nigeria. It was revealed that 1% increase in nonrenewable energy consumption (NLOG) leads to about1.34% decrease in environmental quality (ELOG). This is an indication that nonrenewable energy consumptionhas negative effect on environmental quality in Nigeria. The results of this finding supported the empirical work of (Edomah, 2018) which found out that non-renewable energy has been the predominant energy source driving Nigeria economic process so far.

Similarly, positive relationship is found to exist between renewable energy consumption and environmental quality in Nigeria. It was revealed that 1% increase or decrease in renewable energy consumption (RLOG) leads to 0.46% increase or decrease in environmental quality (ELOG). This is an indication that judicious use of renewable energy consumption has ability toimprove environmental quality in Nigeria.

Furthermore, the relationship between energy mix (NRLOG) and environmental quality (ELOG) in Nigeriais positive. This is an implication that a unit increase or decrease in energy mix in Nigeria increase or decreases environmental quality respectively. Thus, a rise in the consumption of energy mix to reduce environmental hazard in the country. Similar to the results above is the relationship between gross domestic output (YLOG) and environmental quality(ELOG). It was revealed that 1% increase or decrease in YLOG leads to 2.055054% decrease or increase in ELOG respectively. This implies that an improved gross domestic output necessitated by routine productive activity in the economy provide opportunity for purchase of pollution abate equipment.

The relationships discussed above are linear in nature. Thus, there are also non-linear relationships among renewable energy consumption, nonrenewable energy consumption, gross domestic output and environmental quality. The non-linear relationship between renewable energy consumption, non-renewable energy consumption, gross domestic output and environmental quality are negative. These results also corroborated the findings of Shafiei and Salim (2014), Ohlan (2015) and Uyigue (2017) which revealed that non-renewable energy as a source of carbon dioxide emissions leading to environmental degradation and these carbon dioxide emissions are responsible for global warming.

Testing for Optimal Energy Mix: -

The coefficients obtained from FMOL results were extracted and a Wald test was conducted on it. The result obtained from the Wald test is presented in Table 3.

Table: 3:- Wald Tests Results.

Variable	**Value**	**P-value**
W_r	-5.150534	-
W_n	-2.497879	-
F_r	0.002878	0.9576
F_n	0.000844	0.9770
t_r	-0.053642	0.9576
t_n	-0.029056	0.9770
$x^2{}_r$	0.002878	0.9572

x^2_n	0.000844	0.9768

Source: Authors' computation

$W_r$and$W_n$refer to the Wald test of long-run symmetry which represent the optimal renewable energy consumption per capital and optimal non-renewable energy consumption per capital respectively. $F_r$andF_n are the respective F-statistic for the optimal renewable energy consumption per capital and optimal non-renewable energy consumption per capital proposed by Pesaran et al. (2001). Also, t_r and t_n represent the respective t-statistic of the variables developed by Banerjee et al. (1998) while x^2_r and x^2_n refer to the respective variables ARCH-LM heteroscedasticity and serial correlation LM tests.

From the results In Table 3 it was indicated that the optimal value ofrenewable energy consumption per capital on environmental quality in Nigeria does not exceed-5. 150534.This implies the optimal level of renewable energy consumption that is favourable to environment as it produces minimum secondary wastes which are sustainable for both the current and future economic and social needs.

Similarly, the results also indicated that the optimal value of non-renewable energy consumption per capital on environmental quality in Nigeria and does not exceed -2.497879. Comparing absolute value of optimal level of renewable energy consumption (5.150534) with the optimal absolute value of non-renewable energy consumption (2.497879) shows that the renewable energy has the higher level of optimal consumption. In other words, the level of renewable energy consumption that is environmentally friendly is higher than that of non-renewable energy consumption. This is in line with the findings of Panwar, Kaushik and Kothari, (2011) which revealed that renewable energy provides an exceptional opportunity for mitigation of greenhouse gas emission and reducing global warming through substituting conventional energy sources (fossil fuel based). Thus, the findings of this study support the fact that renewable energy is portrayed as cleaner energy, which could be used as alternative to fossil fuel to curb the problem that carbon emission is causing in the environment as claimed by Panwar, Kaushik, and Kothari, (2011).

Conclusion:-

From the results above it was revealed that the impact of renewable energy consumption per capital on environmental quality in Nigeria did not exceed 5.15 %. This is the optimal estimate of renewable energy consumption per capital. This implies that the optimal use of these renewable energy help to improve environmental quality. This is an indication that that the renewable energy has the higher level of optimal consumption. In other words, the level of renewable energy consumption that is environmentally friendly is higher than that of non-renewable energy consumption. The results therefore revealed that the two energy consumption components (renewable and non-renewable energy consumptions) had significant effect on environmental quality in Nigeria. This is an indication that the optimal use of energy mix will significantly improve environmental quality in Nigeria. It is recommended that greater effort should be made in enhancing environmental quality towards reducing global warming. This is as a result of the fact that renewable energy is portrayed as cleaner energy source, which could be used as alternative to non-renewable energy to curb the problem of environmental hazard arising from carbon emission in the environment.

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