**Original Research Article**

**NATURAL GAS CONSUMPTION IN AFRICA: THE CONNECTION BETWEEN GAS, ELECTRICITY, RESIDENTIAL, INDUSTRIAL CONSUMPTIONS AND ECONOMIC GROWTH**

**ABSTRACT**

This research examines the connection between Residential and Industrial Natural Gas Consumption, Electricity Consumption from Gas, and economic development in Nigeria, Egypt, Algeria, and Equatorial Guinea. Secondary data sources obtained from the Nigerian Bureau of Statistics, BP statistical bulletin, Index Mundi, and World Data Atlas were utilized for this study. The analysis employs a range of econometric techniques such as descriptive statistics, unit root tests, cointegration tests, and ARDL-ECM to examine the impact of these factors on Africa's economic growth. The findings indicate that overall natural gas consumption has a minimal and statistically insignificant impact on GDP. Similarly, electricity consumption shows a positive but insignificant correlation with GDP in the region. Conversely, industrial gas consumption demonstrates a negative and significant relationship with GDP, while residential gas consumption exhibits a strong positive correlation with GDP. The study concludes that gas consumption in industrial and residential sectors significantly affects economic growth in the selected African countries. However, total natural gas consumption and gas used for electricity generation do not significantly influence economic growth in these nations. To maximize the potential of natural gas, this study recommends that the leadership of Nigeria, Egypt, Algeria, and Equatorial Guinea should implement automation for the production, distribution, and consumption of natural gas. This will ensure accurate accountability and proper management of the revenue generated from its sales. To promote electricity generation, distribution, and transmission, they should contemplate subsidizing these costs for their citizens. This will incentivize the production of goods and services, thereby revitalizing economic growth. For increased residential consumption, they should continue to supply more natural gas for residential purposes given that it significantly promotes their economic growth. For natural gas consumed for industrial purposes, the governments of the selected African countries should consider reducing the amount of gas supplied to them since it substantially retards economic growth.

**Key Words:** Natural Gas, Electricity, Residential, Consumption, and Economic Growth.

1. **INTRODUCTION**

Africa's economic growth and development trajectory is inextricably linked to its energy landscape. As the continent strives to achieve sustainable development, reduce poverty, and promote economic prosperity, access to reliable, affordable, and clean energy sources has become a pressing imperative [1]. Natural gas, in particular, has emerged as a vital component of Africa's energy mix, offering a cleaner-burning alternative to traditional fossil fuels and a potential catalyst for economic growth. Natural gas use is essential to sustainable development [2]. 40,000 MW of power generation may be continuously operated for 50 years using Africa's 8% portion of the world's gas reserves [3]. Natural gas is a versatile energy source that plays a critical role in meeting the energy demands of various sectors, including electricity generation, residential, and industrial. The consumption patterns of natural gas in the electricity, residential, and industrial sectors are interconnected and influenced by a range of factors. For example, increased demand for electricity generation can lead to higher natural gas consumption, which in turn can impact residential and industrial demand. Expansion of gas infrastructure to meet residential demand can also facilitate increased industrial and electricity generation use. Technological advancements in one sector, such as more efficient gas turbines for electricity generation, can have spillover benefits for other sectors.

Africa is blessed with abundant natural gas resources. However, natural gas utilization in Africa is currently low. Only a small portion of available gas reserves is used for electricity generation. The three main sectors of the economy—commerce, housing, and transportation—consume relatively little gas. Recent years have seen increased attention given to the dynamic connection between natural gas consumption and economic growth [2].

Numerous studies have been conducted on natural gas and economic growth nexus [1-6]. However, most of the existing research has concentrated on examining the connection between economic growth and the consumption of various energy sources, including electricity and oil. This study, however, employed a pooled-effect, fixed-effect and random-effect panel data regression technique to examine the relationship between gas, residential, industrial, electricity consumptions and economic growth in in Africa (Nigeria, Egypt, Algeria, and Equatorial Guinea). Presently, Africa consumes 0.47 tonnes of oil equivalent (or 20 GJ) of final energy per person, which is 65% less than the global average [22]. Regarding health effects, gender equality, biodiversity, and as a cause of deforestation, the use of traditional biomass still raises questions. In Sub-Saharan Africa, just 20% of people have access to clean cooking [23]. For Africa to be able to develop sustainably over the next few years, the availability of clean energy must increase quickly. In Sub-Saharan Africa, excluding South Africa, the IEA predicts that electricity consumption will quadruple between 2018 and 2040 under the scenario of the stated policies and even increase to 7.5 times the 2018 value under the scenario of the "Africa Case" [24]. “The Africa Case” demonstrates that when more people get access to power, home consumption and economic growth1 increase, which calls for more energy. This study unravels the connectivity between gas, industrial, residential, electricity consumptions in ameliorating the above raised concerns translating to economic development in the process. As a result, various stakeholders in the energy sector, including government officials, energy specialists, students, and those involved in the natural gas subsector, will find this study to be a valuable resource. The objective of this study is to establish the relationship between the gas consumption (proxied by; natural gas consumed for electricity, industrial, residential and economic growth (proxied by real GDP) in Nigeria, Algeria, Egypt, and Equatorial Guinea. This paper is dived into five major sections. Section 1 (introduction), section 2 (literature review), section 3 (methodology), section 4 (results and discussion), and section 5 (conclusion and recommendations).

* 1. **STATEMENT OF THE PROBLEM**

Africa accounts for 8% of the world's gas reserves, which is sufficient to power 40,000 MW of electricity continuously for 50 years [1]. For instance, Nigeria's 187 trillion-dollar gas resource, according to [7], could run 60,000-megawatt power plants nonstop for a century. However, the current usage of natural gas in Africa is minimal. Only a small portion of the available gas reserves is utilized for power generation (20). Poor infrastructure and investment development are common in natural gas projects, which has a negative impact on domestic natural gas consumption and delays the expansion of the African economy (12). Africa's limited natural gas consumption is partly due to the persistent threat of gas flaring to the continent's economic development [2]. Gas flaring emissions pose significant risks to human health and the environment, including the release of common greenhouse gases from production fields, acid precipitation, ozone layer depletion, reduced agricultural productivity, and various health issues [12]. This obstacle also results in insufficient resources for manufacturing and industrial sectors, as well as substandard electricity supply. Consequently, Africa has not yet effectively utilized its natural gas potential to drive economic advancement.

Previous research on the connection between energy use and economic growth has yielded inconclusive results. Studies by various scholars, including [1-14] have presented conflicting viewpoints. Some researchers argue that natural gas positively impacts economic growth [1-4], while others contend it has a negative effect [5-7]. This disagreement has made it empirically challenging to determine how natural gas consumption affects economic growth in various countries, including those in Africa. Therefore, it is both necessary and beneficial to examine the complex relationship between natural gas consumption and economic growth, as well as to assess the degree to which natural gas consumption impacts economic development in Africa. Thus, to measure the influence of natural gas use on African economic development, it is essential that this study investigate how it influences economic development in Nigeria, Algeria, Egypt, and Equatorial Guinea. The primary aim of this research is to examine the connection between natural gas usage and economic development in West African nations.

1. **LITERATURE REVIEW**

Numerous empirical literatures studied the relationship or impact of the natural gas on economic development or growth of Africa. However, there are scarce literature on the the impact of specific elements within natural gas usage on economic growth. Also, there were conflicting results as to the nature of the relationship between natural gas sector development on economic growth in Africa [1].conducted research on nonlinear unit root and nonlinear causality in the relationship between natural gas and economic growth in Nigeria. They employed various econometric methods, including the Kapetanios-Shin-Shell and Kruse nonlinear unit root tests, Brock-Dechert-Scheinkman nonlinearity test, Nonlinear Ordinary Least Squares model, and the Hatemi-J asymmetric causality test. Their findings indicated that natural gas consumption and economic growth in Nigeria follow a nonlinear trend, with increased natural gas consumption contributing to economic growth [2] explored the connection between natural gas consumption and economic growth in France using the Auto-regressive Distributive lag bounds testing approach. They identified a relationship between these factors and noted that natural gas consumption, exports, capital, and labour all contribute to France's economic growth. [3] analyzed the relationship between natural gas consumption, economic growth, urban population, unemployment, and services value-added in Bangladesh from 1990 to 2019. Using Autoregressive distributed lag models and vector error correction models, they found significant connections between these variables, suggesting that natural gas consumption influences economic growth in both short and long-term analyses. [4] examined the relationship between natural gas consumption, gross capital formation, globalization, and CO2 emissions on Malaysia's economic growth. They utilized cointegration tests, Autoregressive distributed lag models, and Granger Causality models. Their results revealed a long-term equilibrium relationship among the variables and confirmed the growth-energy driven hypothesis in Malaysia. [5] investigated the potential dual benefits of natural gas consumption on China's economic growth and carbon dioxide emissions reduction. Using an Expanded Cobb-Douglas production function, they found that at the national level, natural gas consumption promotes economic growth and has the potential to reduce CO2 emissions, albeit to a limited extent. [15] studied factors influencing natural gas consumption in Bangladesh from 1994 to 2018 using the logarithmic mean Divisia index. They examined changes in factors such as natural gas share, energy intensity, economic structure, economic activity, and population. Their findings suggest that increased natural gas utilization correlates with higher economic development and improved energy efficiency. [6] used a Machine Learning approach to assess the causal link between natural gas consumption and economic growth in Germany and Japan. Employing the dependency algorithm technique, they found strong evidence for bidirectional causality between these variables in both countries, supporting the "feedback hypothesis” [16] evaluated the relationship between natural gas consumption and economic growth in Turkey using various econometric tests. Their results revealed a long-term relationship between these variables and their impact on Turkey's growth. [17] estimated the price and income elasticities of natural gas demand using panel techniques. They found price elasticities of demand in cross-sectional and between estimates to be approximately -1.25. [18] examined the effects of oil, natural gas, and coal consumption on Iran's economic growth using ARDL. They found that all three types of energy consumption influence the country's economic growth. [19] investigated the impact of natural gas consumption, real gross fixed capital formation, and trade on Tunisia's real GDP using ARDL and VECM. Their results showed that all variables have a direct relationship with the economy through GDP. A research study by [14] examined the relationship between inland natural gas consumption and real economic growth in Nigeria using the ARDL cointegration test. The research, conducted in 2015, found evidence of cointegration and a significant positive long-term connection between gas consumption and economic growth. The authors suggest that expanding the study to include more West African countries and a longer time frame could yield more comprehensive results. In a similar vein, [13] investigated the link between natural gas consumption and economic growth in Malaysia, considering factors such as foreign direct investment, capital formation, and trade openness. Using ARDL methodology, their findings supported a bidirectional relationship between natural gas consumption and economic growth, as well as between foreign direct investment and economic growth. Additionally, they observed a two-way connection between natural gas consumption and foreign direct investment. Because the study was conducted twelve years ago, it is expedient to extend the duration and the numbers of the countries to include the ones chosen in this study will produce a robust result for the West African counties selected.From the foregoing, it was discovered from literature reviewed that there is lack of literature that examines the impact of specific elements within natural gas usage in Africa. One gap observed was that no study known to the researcher studied the four aspects of gas sector development as identified in this study, Gas Consumption (GC), Electricity Consumption from natural gas (GCE), Natural Gas Consumed for Residential (GCR), Natural Gas Consumed for Industries (GCI), on economic growth in Africa.This is the heart of this research.

1. **METHODOLOGY**
	1. **The Model**

The Romer growth model (1986) was utilized due to its incorporation of technology as an endogenous factor in energy consumption, recognizing its essential role. This model facilitated the examination of the dynamic relationship between economic growth and natural gas usage, considering additional explanatory variables such as electricity consumption (ELECT), residential natural gas consumption (GCR), industrial natural gas consumption (GCI), capital stock (CAPITAL), and labor stock (LABOUR).

[20] formulated an equation linking gas consumption to economic growth in West Africa, taking these factors into account.

RGDP = (GAS, ELECT, CAPITAL, LABOUR) (3.1)

Where: RGDP = Gross Domestic product, GAS = Natural Gas Consumed, ELECT = Electricity Consumed

CAPITAL = Capital Stock, LABOUR = Labour Stock.

Following the approach of [20], with some modifications, this study defined the relationship between gas consumption and economic growth as:

GDP = f(GC, EC, GBI, GCR, LF, GFCF) (3.2)

Transforming equation (2) into its panel econometric form, regression equation was specified as:

GDPit = αi + β1GCit + β2ECit + β3GBIit + β4GCRit + β5LFit + β6GFCFit + µit  (3.3)

Where: GDP = Gross Domestic product, GC = Natural Gas Consumed, EC = Electricity Consumed, GCI = gas consumed for industrial, GCR = Gas consumed for residential, LF = Labour force, GFCF = Gross fixed capital formation, αi = Constant term

The coefficients β1, β2, β3, β4, and β5 represent the numerical values associated with the explanatory variables in the model. These parameters quantify the relationship between each independent variable and the dependent variable, indicating the magnitude and direction of their influence.

µ = Stochastic error term, t = Time series notation, i = Cross-section or country effect (i = 4 countries), t = Periodic effect (t = 1995-2022 = 27 years), *A priori* αi > 0, β1 > 0, β2 > 0, β3 > 0, β4 > 0, β5 > 0

* 1. **Data**

This research utilized secondary data sources for its analysis. Documentation was employed as the primary method for gathering secondary information. The study collected data on various economic indicators from 1980 to 2022, including gross domestic product (GDP), consumption of natural gas, oil, and electricity, as well as industrial and residential natural gas usage, capital stock, and labor force. These datasets were obtained from multiple sources, such as the Nigerian Bureau of Statistics, BP statistical bulletin, Index Mundi, and World Data Atlas. The researchers opted for secondary sources as they provide a solid foundation for meaningful research and help guide the direction of the study. To analyze the data collected, an econometric software (EViews-1) was utilized to achieve the objectives of the study. The definition of the data and source are presented in Table 1.

Table 1- Definition of the data and source

|  |  |  |  |
| --- | --- | --- | --- |
| Variables  | Definition  | Measurement  | Source |
| Real gross Domestic Product | The standard measure of the value added created through the production of goods and services in a country during a certain period.  | Million Dollar (M$) | World Data Atlas, Index Mundi |
| Natural Gas Consumption | the total amount of natural gas used for various purposes, including electricity generation, heating, cooking, and industrial processes.  | Million cubic feet | BP statistical bulletin |
| Electricity Gas Consumption  | the total amount of electrical energy consumed from gas and used over a specific period, typically measured in kilowatt-hours (kWh), encompassing all devices and appliances that draw power from the electrical grid. | Gigawatt  | BP statistical bulletin |
| Residential Gas Consumption | Those customers who consume gas from the gas department in a single or multiple units dwelling with household appliances. | Million cubic feet | BP statistical bulletin |
| Industrial Gas Consumption | Those customers who consume gas from the gas department in a single or multiple units dwelling with industrial appliances. | Terajoule | BP statistical bulletin |

1. **RESULT AND DISCUSSION OF FINDINGS**
	1. **Trend Analysis**
2. 

**Source: E-view Output**

**Figure 1: Gross Domestic Product**

Figure 1 depicts a visual representation of the gross domestic product. The graph depicts a fluctuating nature of the selected African countries' (Nigeria, Algeria, Equatorial Guinea, and Egypt) gross domestic product throughout the observed time frame.



**Source: E-view Output**

**Figure 2: Natural Gas Consumed**

Figure 2 depicts the volatile characteristics of gas consumed. It can be observed that Egypt has the highest level of gas consumption, whereas that of Equatorial Guinea was the lowest for the period under study.



**Source: E-view Output**

**Figure 3: Electricity Consumption**

Figure 3 illustrates the fluctuating nature of electricity consumption. It can be observed that Egypt has the highest level of electricity consumption from natural gas, whereas that of Equatorial Guinea was the lowest for the period under study.



**Figure 4: Natural Gas Consumed for Industrial Purposes**

**Source: E-view Output**

Figure 4 shows the fluctuating nature of gas consumption for industrial purposes. It can be observed that Egypt has the highest level of gas consumption for industrial purposes, whereas that of Equatorial Guinea was the lowest for the period under study.



**Source: E-view Output**

**Figure 5: Natural Gas Consumed for Residential Purposes**

Figure 5 shows that the fluctuating nature of gas consumption for residential purposes. It can be observed that Egypt has the highest level of gas consumption for residential purposes, whereas that of Equatorial Guinea was the lowest for the period under study.

* 1. **Descriptive Statistics for Nigeria, Egypt, Algeria, and Senegal (1995 -2022)**

This section presents the descriptive statistics of the dependent (Gross domestic product) and independent variables (natural gas consumption, gas consumed for industrial, and residential) for all the four countries used in the study. The statistical measures considered were mean, median, standard deviation, sum, maximum and minimum values. The number of observations is 27 across the countries ranging from 1995 to 2022 as seen in Table 2.

**Table 2: Descriptive Statistics for Nigeria (1995-2022)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | GDP | GC | EC | GCI | GBR |
|  Mean |  14484356 |  412665.2 |  18347.54 |  83264.75 |  12577.68 |
|  Median |  1739325. |  379989.5 |  16799.00 |  90247.50 |  11620.50 |
|  Maximum |  45647423 |  667489.0 |  30110.00 |  142550.0 |  19034.00 |
|  Minimum |  20353.20 |  146910.0 |  7925.000 |  28234.00 |  5385.000 |
|  Std. Dev. |  605184.2 |  189807.3 |  7378.549 |  35985.29 |  4918.912 |
|  Skewness |  0.999738 |  0.031120 |  0.013550 | 0.113044 |  0.011155 |
|  Kurtosis |  1.601157 |  1.334170 |  1.575261 |  1.606076 |  1.526909 |
|  |  |  |  |  |  |
|  Jarque-Bera |  4.344424 |  3.242006 |  2.369051 |  2.326496 |  2.532244 |
|  Probability |  0.098321 |  0.197700 |  0.305891 |  0.312470 |  0.281923 |
|  |  |  |  |  |  |
|  Sum |  4.06E+08 |  11554625 |  513731.0 |  2331413. |  352175.0 |
|  Sum Sq. Dev. |  1.18E+17 |  9.73E+11 |  1.47E+09 |  3.50E+10 |  6.53E+08 |
|  |  |  |  |  |  |
|  Observations |  28 |  28 |  28 |  28 |  28 |

**Source: E-view Output**

Table 2 shows the average yearly gross domestic product for Nigeria as 14484356, with a minimum and highest value of 20353.20 and 45647423 respectively. Natural gas consumption averaged 412,665.2 units, ranging from a low of 146,910.0 to a high of 667,489.0 units. The average value of electricity consumed is 18347.54, with lowest and maximum values of 7925.0 and 30110.0, respectively. The average yearly value of gas consumed for industrial is 83264.75; it maximum and minimum values are 142550.0 and 28234.00 respectively. The average yearly value of gas consumed for residential is 12577.68; it maximum and minimum values are 19034.00 and 5385.0 respectively. For this analysis, the standard deviation is employed to calculate the mean's divergence from its true value. The level of variability for gross domestic product, natural gas consumed, electricity consumed, gas consumed for industrial, and gas consumed for residential from their average values are 605184.2%, 189807.3%, 7378.549%, 35985.29%, and 4918.912% respectively.

Skewness is used to determine which direction the variables are biassed to whereas Kurtosis is a measure of a distribution's relative peakedness. Additionally, the Jarque-Bera statistics test demonstrates the distribution's normality. The null hypothesis asserts that if the probability value associated with the Jarque-Bera test is larger than the specified significant level of 5%, the distribution is said to be normally distributed. Result for skewness showed that gross domestic product, natural gas consumed, electricity consumed, gas consumed for industrial, and gas consumed for residential all have positive skew coefficients (0.999738, 0.031120, 0.013550, 0.113044, and 0.011155, respectively), indicating that their distributions are skewed to the right. Result for the Kurtosis showed that if it equals 3, the distribution is said to have relative peak (mesokurtic), but if it is larger than or less than 3, it is leptokurtic or platykurtic, respectively. Gross domestic product, natural gas consumed, electricity consumed, gas consumed for industrial, and gas consumed for residential are platykurtic, with coefficients less than 3 (1.601157, 1.334170, 1.575261, 1.606076, and 1.526909, respectively. Result from the Jarque-Bera statistics test demonstrates that the Jarque-Bera p-values of gross domestic product, natural gas consumed, electricity consumed, gas consumed for industrial, and gas consumed for residential are 0.098321, 0.197700, 0.305891, 0.312470, and 0.281923 respectively and they are below the level of significance chosen at 5%. As a result, the null hypotheses are accepted that the variables are normally distributed for the period investigated under investigation.

**Table 3: Descriptive Statistics for Algeria (1995-2022)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | GDP | GC | EC | GCI | GBR |
|  Mean |  1349112. |  1080638. |  10813.96 |  44993.96 |  31913.18 |
|  Median |  937382.5 |  996430.5 |  9255.000 |  35751.00 |  27962.50 |
|  Maximum |  4745090. |  1720000. |  18260.00 |  78987.00 |  53439.00 |
|  Minimum |  117460.0 |  680873.0 |  5021.000 |  17980.00 |  18808.00 |
|  Std. Dev. |  1325004. |  348526.8 |  4285.991 |  21662.80 |  10960.14 |
|  Skewness |  0.203288 |  0.408414 |  0.262030 |  0.389155 |  0.549485 |
|  Kurtosis |  1.382191 |  1.661647 |  1.633949 |  1.656106 |  1.907474 |
|  |  |  |  |  |  |
|  Jarque-Bera |  1.927295 |  2.868127 |  2.497523 |  2.813789 |  2.801571 |
|  Probability |  0.231315 |  0.238338 |  0.286860 |  0.244903 |  0.246403 |
|  |  |  |  |  |  |
|  Sum |  37775134 |  30257875 |  302791.0 |  1259831. |  893569.0 |
|  Sum Sq. Dev. |  4.74E+13 |  3.28E+12 |  4.96E+08 |  1.27E+10 |  3.24E+09 |
|  |  |  |  |  |  |
|  Observations |  28 |  28 |  28 |  28 |  28 |

**Source: E-view Output**

Table 3 shows the average yearly gross domestic product, natural gas consumed, electricity consumed, gas consumed for industrial, and gas consumed for residential for Algeria as 1349112.0, 1080638.0, 10813.96, 44993.96, 31913.18 respectively. The minimum and maximum values of gross domestic product, natural gas consumed, electricity consumed, gas consumed for industrial, and gas consumed for residential are 117460.0 and 47450590.0, 680873.0 and 1720000.0, 5021.0 and 18260.0, 17980.0 and 78987.0, and 18808.0 and 53439.0 respectively. The level of variability for gross domestic product, natural gas consumed, electricity consumed, gas consumed for industrial, and gas consumed for residential from their average values are 1325004.0%, 348526.8%, 4285.991%, 21662.80%, and 10960.14% respectively.

Skewness is used to determine which direction the variables are biassed to. Gross domestic product, natural gas consumed, electricity consumed, gas consumed for industrial, and gas consumed for residential all have positive skew coefficients (0.203288, 0.408414, 0.262030, 0.389155, and 0.549485, respectively), indicating that their distributions are skewed to the right.

Kurtosis is a measure of a distribution's relative peakedness. If it equals 3, the distribution is said to have relative peak (mesokurtic), but if it is larger than or less than 3, it is leptokurtic or platykurtic, respectively. Gross domestic product, natural gas consumed, electricity consumed, gas consumed for industrial, and gas consumed for residential are platykurtic, with coefficients less than 3 (1.382191, 1.661647, 1.633949, 1.656106, and 1.907474, respectively).

The Jarque-Bera statistics test demonstrates the distribution's normality. The null hypothesis asserts that if the probability value associated with the Jarque-Bera test is larger than the specified significant level of 5%, the distribution is said to be normally distributed. The Jarque-Bera p-values of gross domestic product, natural gas consumed, electricity consumed, gas consumed for industrial, and gas consumed for residential are 0.231315, 0.238338, 0.286860, 0.244903, and 0.246403 respectively and they are below the level of significance chosen at 5%. As a result, the null hypotheses are accepted that the variables are normally distributed for the period investigated under investigation.

**Table 4: Descriptive Statistics for Equatorial Guinea (1995-2022)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | GDP | GC | EC | GCI | GBR |
|  Mean |  1934331. |  35503.18 |  392.1786 |  17601.93 |  38367.36 |
|  Median |  668864.0 |  45910.00 |  179.0000 |  19572.00 |  37257.50 |
|  Maximum |  8904980. |  57210.00 |  980.0000 |  48972.00 |  56151.00 |
|  Minimum |  95503.38 |  705.0000 |  19.00000 |  143.0000 |  15539.00 |
|  Std. Dev. |  2742924. |  22499.12 |  390.0827 |  14179.04 |  13676.06 |
|  Skewness |  0.501276 | -0.844380 |  0.428847 |  0.451648 | -0.383238 |
|  Kurtosis |  2.560869 |  1.861905 |  1.384738 |  2.489068 |  1.855676 |
|  |  |  |  |  |  |
|  Jarque-Bera |  5.98220 |  4.838367 |  3.902161 |  1.256495 |  2.213121 |
|  Probability |  0.078211 |  0.088994 |  0.142120 |  0.533526 |  0.330694 |
|  |  |  |  |  |  |
|  Sum |  54161278 |  994089.0 |  10981.00 |  492854.0 |  1074286. |
|  Sum Sq. Dev. |  2.03E+14 |  1.37E+10 |  4108442. |  5.43E+09 |  5.05E+09 |
|  |  |  |  |  |  |
|  Observations |  28 |  28 |  28 |  28 |  28 |

**Source: E-view Output**

Table 4 displays the mean annual gross domestic product for Equatorial Guinea as 1934331.0, ranging from a lowest figure of 95,503.38 to a peak amount of 8,904,980.0. The average natural gas consumption is 35503.18, ranging from a low of 705.0 to a high of 57210.0. The mean electricity consumption is 392.1786, with a minimum value of 19.00 and a maximum value of 980.0. The mean annual gas consumption for industrial purposes is 17601.93, with a maximum value of 48972.0 and a minimum value of 143.0. The mean annual gas consumption for residential purposes is 38,367.36. The highest and lowest values recorded are 56,151.0 and 15,539.0, respectively. In this analysis, the standard deviation is used to measure the deviation of the mean from its true value. The gross domestic product, natural gas consumption, The usage of electricity, industrial gas, and residential gas diverges from their typical levels by 2,742,924%, 22499.12%, 390.0827%, 14179.04%, and 13676.06% respectively.

Skewness is employed to ascertain the direction in which variables exhibit bias. The skew coefficients (0.501276, 0.844380, 0.428847, 0.451648, and 0.383238) for gross domestic product, natural gas consumed, electricity consumed, gas consumed for industrial, and gas consumed for residential, respectively, all indicate that their distributions are positively skewed, meaning they are skewed to the right.

Kurtosis quantifies the degree of peakedness in a distribution. If the value is equal to 3, the distribution is considered to have a relative peak (mesokurtic). However, if the value is greater than 3 or less than 3, the distribution is classified as leptokurtic or platykurtic, respectively. The platykurtic coefficients of gross domestic product, natural gas consumption, electricity consumption, industrial gas consumption, and residential gas consumption are all less than 3. Specifically, the coefficients are 2.560869, 1.861905, 1.384738, 2.489068, and 1.855676, respectively.

The Jarque-Bera test assesses the normality of a distribution. The Jarque-Bera test's null hypothesis proposes that when the calculated p-value exceeds the predefined 5% significance threshold, then the distribution is normally distributed. The Jarque-Bera p-values for gross domestic product, natural gas consumption, electricity consumption, industrial gas consumption, and residential gas consumption are 0.078211, 0.088994, 0.142120, 0.533526, and 0.330694, respectively. These p-values are all below the chosen significance level of 5%. Consequently, the null hypotheses are accepted, indicating that the variables are normally distributed during the investigated period.

**Table 5: Descriptive Statistics for Egypt (1995-2022)**

**EGYPT**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | GDP | GC | EC | GCI | GBR |
|  Mean |  1612169. |  1390928. |  130098.4 |  251209.6 |  39059.79 |
|  Median |  852707.8 |  1525963. |  125569.5 |  271653.0 |  43729.50 |
|  Maximum |  4873900. |  2196593. |  201980.0 |  380597.0 |  63475.00 |
|  Minimum |  25267.54 |  438960.0 |  56743.00 |  35985.00 |  11782.00 |
|  Std. Dev. |  1760884. |  592893.2 |  44642.39 |  75757.80 |  16116.16 |
|  Skewness |  -0.496020 | -0.328671 | -0.085253 | -1.094004 | -0.350633 |
|  Kurtosis |  1.702509 |  1.735345 |  1.698308 |  2.150538 |  1.947816 |
|  |  |  |  |  |  |
|  Jarque-Bera |  3.112230 |  2.370025 |  2.010721 |  3.129640 |  1.865342 |
|  Probability |  0.210954 |  0.305742 |  0.365913 |  0.098302 |  0.393501 |
|  |  |  |  |  |  |
|  Sum |  45140722 |  38945974 |  3642756. |  7033868. |  1093674. |
|  Sum Sq. Dev. |  8.37E+13 |  9.49E+12 |  5.38E+10 |  1.55E+11 |  7.01E+09 |
|  |  |  |  |  |  |
|  Observations |  28 |  28 |  28 |  28 |  28 |

**Source: E-view Output**

Table 5 presents the average yearly figures for Egypt's gross domestic product, consumption of natural gas and electricity, as well as the usage of gas in industrial and residential sectors as 1,612,169, 1,390,928, 130,098.4, 251,209.6, and 39,059.79, respectively. The gross domestic product ranges from 25267.54 to 4873900.0. Natural gas consumption ranges from 438960.0 to 2196593.0. Electricity consumption ranges from 56743.0 to 201980.0. Gas consumption for industrial purposes ranges from 35985.00 to 380597.0. Gas consumption for residential purposes ranges from 11782.00 to 63475.00. The deviations from the average values for gross domestic product, natural gas consumption, electricity consumption, industrial gas consumption, and residential gas consumption are 1760884.0%, 592893.2%, 44642.39%, 75757.80%, and 16116.16% respectively.

Skewness is employed to ascertain the direction in which the variables exhibit bias. The skew coefficients for gross domestic product, natural gas consumption, electricity consumption, industrial gas consumption, and residential gas consumption are all negative (-0.496020, -0.328671, -0.085253, -1.094004, and -0.350633, respectively), indicating that their distributions are left-skewed.

Kurtosis quantifies the degree of peakedness in a distribution. If the value is equal to 3, the distribution is considered to have a relative peak (mesokurtic). However, if the value is greater than 3 or less than 3, the distribution is classified as leptokurtic or platykurtic, respectively. The platykurtic coefficients for gross domestic product, natural gas consumption, electricity consumption, industrial gas consumption, and residential gas consumption are all less than 3. Specifically, the coefficients are 1.702509, 1.735345, 1.698308, 2.150538, and 1.947816, respectively.

The Jarque-Bera test assesses the normality of a distribution. According to the Jarque-Bera test, if the calculated p-value exceeds the pre-established significance threshold of 5%, one can conclude that the data follows a normal distribution. This interpretation aligns with the null hypothesis of the test. The Jarque-Bera p-values for gross domestic product, natural gas consumption, electricity consumption, industrial gas consumption, and residential gas consumption are 0.210954, 0.305742, 0.365913, 0.098302, and 0.393501, respectively. These p-values are all below the chosen significance level of 5%. Consequently, the null hypotheses are accepted, indicating that the variables are normally distributed during the investigated period.

* 1. **Unit Root Test**

Time series data frequently exhibit non-stationary patterns or embedded non-stationary tendencies. As a result, attempting to perform regression analysis between unrelated variables, where one or both are non-stationary, may lead to inaccurate regression outcomes. This phenomenon can occur even when there is no theoretical connection between the variables in question. To determine the appropriate econometric estimation model and verify the stability of the model's variables, researchers conducted a unit root test. This step was taken to eliminate the possibility of generating misleading results. The findings of this analysis, which employed the Levin, Lin and Chu unit root test, are presented in Table 6.

**Table 6:** Result of Unit Root Test (Using Levin, Lin and Chu)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variables** | **ADF T-Stat @ Level** | **P-value @ level** | **ADF T-Stat @ 1st Diff.** | **P-value @ 1st Diff.** | **Order of Integration** |
| **GDP** | -5.79012 | 0.0000 | - | - | I(0) |
| **GC** | -8.28893 | 0.0000 | - | - | I(0) |
| **EC** | -6.46564 | 0.0000 | - | - | I(0) |
| **GCI** | -1.78909 | 0.0368 | - | - | I(0) |
| **GBR** | -8.84048 | 0.0000 | - | - | I(0) |

**Source:** E-views 10 Output

At level for the Levin, Lin and Chu Unit root test, all variables were stationary, as seen in the table above, which compares the p-values with the significance level at 5%. Therefore, all variables exhibit a consistent pattern and are suitable for estimate and future forecasting since they are all integrated at order zero. As a result, the study adopts the panel least square regression technique at the 5% significance level.

**Lag Length Criteria**

The lag length criteria test is employed to ascertain the most advantageous lag length to be utilised in the study. This research employs the lag length criteria evaluation to identify the most suitable lag length for conducting the analysis. The optimal lag duration is determined through this assessment, which guides the study's methodology.

**Table 7: Lag Length Selection Result**

|  |  |  |  |
| --- | --- | --- | --- |
| VAR Lag Order Selection Criteria |  |  |  |
| Endogenous variables: GDP GC EC GCI GBR  |  |  |  |
| Exogenous variables: C  |  |  |  |  |
| Date: 06/13/24 Time: 06:45 |  |  |  |  |
| Sample: 1995 2022 |  |  |  |  |
| Included observations: 88 |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  Lag | LogL | LR | FPE | AIC | SC | HQ |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| 0 | -4508.283 | NA  |  2.43e+38 |  102.5746 |  102.7154 |  102.6313 |
| 1 | -3921.267 |  1093.984 |  6.89e+32 |  89.80152 |   90.64606\* |   90.14176\* |
| 2 | -3902.190 |  33.38429 |  7.93e+32 |  89.93614 |  91.48447 |  90.55992 |
| 3 | -3863.746 |  62.90835 |  5.92e+32 |  89.63059 |  91.88272 |  90.53792 |
| 4 | -3840.302 |  35.69931 |  6.30e+32 |  89.66595 |  92.62186 |  90.85681 |
| 5 | -3813.396 |  37.91268 |  6.30e+32 |  89.62264 |  93.28234 |  91.09704 |
| 6 | -3782.035 |   40.62611\* |   5.83e+32\* |   89.47808\* |  93.84157 |  91.23602 |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  \* indicates lag order selected by the criterion |  |  |
|  LR: sequential modified LR test statistic (each test at 5% level) |  |
|  FPE: Final prediction error |  |  |  |  |
|  AIC: Akaike information criterion |  |  |  |
|  SC: Schwarz information criterion |  |  |  |
|  HQ: Hannan-Quinn information criterion |  |  |  |

**Source:** E-views 10 Output

The research indicates that a lag length of one is most suitable for the analysis, as determined by the Schwarz information criterion. Consequently, this criterion is employed as the lag length selection test in the study. Based on these findings, the subsequent analysis in the research proceeds with a lag length of one.

**Table 8: Estimation Results**

|  |  |  |  |
| --- | --- | --- | --- |
|  | (1) | (2) | (3) |
| **Model** | **Pooled** | **Fixed** | **Random** |
| GC | -0.030707(-0.148737)0.8821 | -0.022568(-0.119016)0.9055 | -0.022568(-0.113327)0.9100 |
| EC | 0.124633(0.608996)0.5443 | 0.088082(0.502480)0.6164 | 0.088082(0.478462)0.6333 |
| GCI | -0.407800(-1.446479)0.1519 | -0.487413(-2.080087)0.0399**\*\*** | -0.487413(-1.980660)0.0502 |
| GBR | 1.931014(5.427655)0.0000**\*\*\*** | 1.201375(4.507355)0.0000**\*\*\*** | 1.201375(4.291907)0.0000**\*\*\*** |
| Observations | 112 | 112 | 112 |
| Adjusted R-squared | 0.195451 | 0.612648 | 0.224443 |
| F-Stat. | 7.741354 (0.000016)**\*\*\*** | 14.54559 (0.000006)**\*\*\*** | 7.741354 (0.000016)**\*\*\*** |
| Number of panelid | 4 | 4 | 4 |
| Durbin-Watson | 0.362542 | 1.622954 | 0.362542 |

Standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

**Source: E-views Output**

The research employs three analytical approaches: pooled OLS, fixed effects OLS, and random effects models. The findings from each of these methods are subsequently presented and discussed in sequence.

**Pooled Result**

The natural gas consumed is negative (0.030707) and insignificant (0.8821) to gross domestic product. This implies that a unit rise in natural gas consumed will lead to 0.030707 unit decrease in gross domestic product. There is positive (0.124633) and insignificant (0.5443) relationship between electricity consumed and gross domestic product. This connotes that increase in electricity consumed by one unit leads to rise in gross domestic product by 0.124633 unit. Gas consumed for industrial is negative (-0.407800) and insignificant (0.1519) to gross domestic product. This implies that a unit rise in gas consumed for industrial will lead to 0.407800 unit decrease in gross domestic product. There is positive (1.931014) and significant (0.0000) relationship between gas consumed for residential and gross domestic product. This connotes that increase in gas consumed for residential by one unit leads to rise in gross domestic product by 1.931014 unit. The F-statistic p-value 0.000016 indicates that the model as a whole is statistically significant. The Adjusted R-square of 0.195451 showed that the explanatory variables – natural gas consumed, electricity consumed, gas consumed for industrial, and gas consumed for residential explained about 19.5% variations in gross domestic product; whereas the model does not account for all factors, as other elements not included in it contribute to explaining the remainder. The Durbin-Watson of 0.362542 shows that the model is not free from first order serial correlation.

**Fixed Effect**

The natural gas consumed is negative (0.022568) and insignificant (0.9055) to gross domestic product. This implies that a unit rise in natural gas consumed will lead to 0.022568 unit decrease in gross domestic product. There is positive (0.088082) and insignificant (0.6164) relationship between electricity consumed and gross domestic product. This connotes that increase in electricity consumed by one unit leads to rise in gross domestic product by 0.088082 unit. Gas consumed for industrial is negative (-0.487413) and significant (0.0399) to gross domestic product. This implies that a unit rise in gas consumed for industrial will lead to 0.487413 unit decrease in gross domestic product. There is positive (1.201375) and significant (0.0000) relationship between gas consumed for residential and gross domestic product. This connotes that increase in gas consumed for residential by one unit leads to rise in gross domestic product by 1.201375 unit. The model's statistical significance is evidenced by the F-statistic p-value of 0.000006. The Adjusted R-square value of 0.612648 suggests that the independent variables – including natural gas consumption, electricity usage, industrial gas consumption, and residential gas consumption – account for approximately 61.3% of the variation in gross domestic product. The remaining variance is attributed to factors not included in the model. With a Durbin-Watson statistic of 1.622954, the model demonstrates an absence of first-order serial correlation.

**Random Effect**

The natural gas consumed is negative (0.022568) and insignificant (0.9100) to gross domestic product. This implies that a unit rise in natural gas consumed will lead to 0.022568 unit decrease in gross domestic product. There is positive (0.088082) and insignificant (0.6333) relationship between electricity consumed and gross domestic product. This connotes that increase in electricity consumed by one unit leads to rise in gross domestic product by 0.088082 unit. Gas consumed for industrial is negative (-0.487413) and relatively insignificant (0.0502) to gross domestic product. This implies that a unit rise in gas consumed for industrial will lead to 0.487413 unit decrease in gross domestic product. There is positive (1.201375) and significant (0.0000) relationship between gas consumed for residential and gross domestic product. This connotes that increase in gas consumed for residential by one unit leads to rise in gross domestic product by 1.201375 unit. The model's statistical significance is demonstrated by the F-statistic p-value of 0.000016. The Adjusted R-square value of 0.195451 indicates that the independent variables – including natural gas consumption, electricity usage, industrial gas consumption, and residential gas consumption – account for approximately 19.5% of the variations in gross domestic product. The remaining variations are attributed to factors not included in the model. The Durbin-Watson statistic of 0.362542 suggests that the model is affected by first-order serial correlation.

* 1. **Post Estimation Results**

**Normality Test**

The assumption of residual normality is that the joint p-values of the skewness, kurtosis and the Jargue-Bera statistics must be greater than the 5% significant level. The null hypothesis asserts that the distribution is normal if the p-value Jargue-Bera is not significant and is bigger than the 5% level of significance.



**Figure 6: Normality Test**

**Source:** E-view Output

The null hypothesis asserts that the distribution is uniformly distributed if the p-value is not significant and is bigger than the selected level of significance of 5%. As a result, the assumption of normal distribution is not rejected, as the Jargue-Bera test's p-value (0.086955) exceeds the 5% significance threshold. This result supports the acceptance of the null hypothesis, which posits that the distribution follows a normal pattern.

**Hausman Test**

The Hausman test is used to examine if the individual effect is related to the study's explanatory variables. The acceptance of the fixed effect is criterion if the probability value of the Chi-sq is less than 5%, showing that the individual effects are not linked with the explanatory factors in the study.

**Table 9: Hausman Test Result**

|  |  |
| --- | --- |
| Correlated Random Effects - Hausman Test |  |
|  |  |
| Equation: Untitled |  |  |
| Test period random effects |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
| Test Summary | Chi-Sq. Statistic | Chi-Sq. d.f. | Prob.  |
|  |  |  |  |  |
|  |  |  |  |  |
| Period random | 12.193876 | 4 | 0.0160 |
|  |  |  |  |  |
|  |  |  |  |  |
| Period random effects test comparisons: |  |
|  |  |  |  |  |
| Variable | Fixed   | Random  | Var(Diff.)  | Prob.  |
|  |  |  |  |  |
|  |  |  |  |  |
| GC | -0.030707 | -0.022568 | 0.002966 | 0.8812 |
| EC | 0.124633 | 0.088082 | 0.007993 | 0.6827 |
| GCI | -0.407800 | -0.487413 | 0.018924 | 0.5628 |
| GBR | 1.931014 | 1.201375 | 0.048221 | 0.0009 |
|  |  |  |  |  |
|  |  |  |  |  |

**Source: E-views 10**

Table 9 displays the results of the Hausman test for optimum model selection between Random and Fixed Effects Models. Table 4 shows that the results of the Hausman Test indicate that the Fixed Effects model is more appropriate than the Random Effects model for this analysis. This is because its p-value of 0.0160 is below the 5% significance level. On this basis, the fixed effect model was utilised in this study to conduct research, draw results, and provide recommendations.

**4.5 EFFECT OF NATURAL GAS, ELECTRICITY, INDUSTRIAL, RESIDENTIAL CONSUMPTIONS AND AFRICA’S GROSS DOMESTIC PRODUCT**

Result from Table 8 showed that natural gas consumption has impact on the GDP of the selected countries. The analysis in Table 8 of the Fixed Effect approach demonstrates that natural gas consumption has a coefficient of -0.022568 and a probability value of 0.9100 for the four countries. Following the determination that the significant level is greater than 0.05 as stated previously in the hypothesis section, we accepted the null hypothesis and rejected the alternative hypothesis that natural gas consumption does have significant impact on gross domestic product in African countries. From the forgoing, it is safe to say that the consumption of natural gas has a minimal and statistically insignificant effect on the gross domestic product. An increase in natural gas usage may lead to a slight decrease in GDP, though the impact is negligible. This relationship can be attributed to limited petroleum use in certain countries due to cost considerations compared to other energy sources. Additionally, the lack of accurate measurement and reporting of natural gas sales, both domestically and internationally, may undermine its potential economic impact. The misallocation of revenue generated from natural gas also hinders its contribution to economic growth in Nigeria. These findings contradict earlier research by [8, 12-14] who found a positive link between natural gas and economic growth. However, the results align with studies by [9-11], which identified a negative correlation between natural gas and economic growth.

From the result in Table 8, there is a significant effect between natural gas utilized for electricity generation and gross domestic product in African countries The Fixed Effect OLS technique study shown in Table 8 demonstrates that natural gas utilized for electricity generation has a positive coefficient of 0.088082 with an associated probability value of 0.6333. Thus, we rejected the alternate hypothesis of no significant link and accept the null hypothesis of significant relationship between natural gas utilized for electricity generation and gross domestic product in African countries during the period under review, as informed by the previously stated decision rule. So it is safe to state that a positive but insignificant relationship exists between electricity consumption and gross domestic product. This suggests that increased electricity use corresponds to a slight increase in GDP. The lack of a significant correlation may be due to inconsistent electricity generation and distribution, which hampers its use in productive activities that contribute to GDP in these countries. These findings align with previous research by [12-14], who argued for a positive relationship between energy consumption and economic growth. However, they contrast with the conclusions of [9-11], who found a negative correlation between energy consumption and economic growth.

Based on the results of the Fixed Effect OLS technique documented in table 8, which presents the coefficient of profitability as -0.487413 with a corresponding probability value of 0.0399 and judging by the probability value being below the threshold of level of significance of 0.05, we rejected the null hypothesis and accept the alternative of a significant relationship between natural gas used for industrial and gross domestic product in African countries. From the foregoing, a negative and significant relationship is observed between industrial gas consumption and gross domestic product. This indicates that an increase in industrial gas usage leads to a decrease in GDP. This correlation may be attributed to the limited gas consumption in these nations due to cost implications compared to alternative energy sources. These findings contradict earlier research by [8,12-14], who established a positive relationship between natural gas and economic growth. However, the results are consistent with studies by [9-11], which identified a negative correlation between natural gas and economic growth.

Based on the results of the Fixed Effect OLS technique documented in Table 8, which presents the coefficient of profitability as 1.201375 with a corresponding probability value of 0.0000 and judging by the probability value being below the threshold of level of significance of 0.05, we rejected the null hypothesis and accepted the alternative of a significant relationship between natural gas used for residential and gross domestic product in African countries. Implying that a strong, substantial correlation exists between residential gas consumption and gross domestic product. This suggests that an increase in residential gas usage corresponds to an increase in GDP. These findings align with expected outcomes and previous studies by [12-14], which concluded that there is a positive relationship between natural gas consumption and economic growth. However, they contradict the findings of [9-11], who argued for a negative correlation between natural gas consumption and economic growth.

1. **CONCLUSION AND RECOMMENDATIONS**

**CONCLUSION**

The empirical results revealed a significant impact of natural gas consumption on the economic growth the selected African countries, suggesting that a strategic focus on the efficient management of African’s abundant natural gas resources can serve as a catalyst for economic growth. In this case, employing automation technique for the production, distribution, and consumption of natural gas. This will ensure accurate accountability and proper management of the revenue generated from its sales. There is a significant effect between natural gas utilized for electricity generation and gross domestic product in African countries. The leadership of the African countries under study should develop consistent electricity generation and distribution plans, which may improve its use in productive activities that contribute to GDP in these countries. Also, a negative and significant relationship is observed between industrial gas consumption and gross domestic product. This indicates that an increase in industrial gas usage leads to a decrease in GDP in these countries. This correlation may be attributed to the limited gas consumption in these nations due to cost implications compared to alternative energy sources. Hence, there is need to develop sustainable measures to avert the resource curse syndrome. Finally, the study found a significant relationship between natural gas used for residential and gross domestic product in African countries. Implying that a strong, substantial correlation exists between residential gas consumption and gross domestic product. This suggests that an increase in residential gas usage corresponds to an increase in GDP in these countries. In a nutshell, the findings of this study provide valuable insights for policymakers, industry stakeholders, and researchers interested in Africa’s gas sector and its role in promoting economic growth. By addressing the critical factors identified in this research, Africa can leverage its vast gas resources to drive sustainable and inclusive economic development in the coming years.

**RECOMMENDATIONS**

This study recommends the following:

1. Governments of the selected African countries should implement automation for the production, distribution, and consumption of natural gas. This will ensure accurate accountability and proper management of the revenue generated from its sales.
2. To promote electricity generation, distribution, and transmission, the selected countries' federal governments should contemplate subsidizing these costs for their citizens. This will incentivize the production of goods and services, thereby revitalizing economic growth.
3. The federal government of the selected African countries should continue to supply more natural gas for residential purposes given that it significantly promotes their economic growth.
4. For natural gas consumed for industrial purposes, the federal government of the selected African countries should consider reducing the amount of gas supplied to them since it substantially retards economic growth.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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