International Journal on Science and Technology (IJSAT)

E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

# Drivers of Industrial Final Energy Consumption in Ghana: A Sectoral Decomposition Analysis of Energy Supply and Demand Drivers.

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**Abstract**

**Energy plays a crucial role in determining Ghana's socioeconomic growth. The rapid growth of demand and the increasing difficulties of energy supply pose a significant challenge to Ghana's efforts to achieve universal energy access.**

**This studyaims to assess the drivers of industrial final energy consumption in Ghana using a sectorial decomposition of energy demand and supply drivers. It applies the additive Logarithmic Mean Divisia Index (LMDI) to decompose industrial final energy consumption in Ghana between 2000-2022. Changes in Final Energy Consumption (FEC) were analyzed by quantifying the contributions fromthree different factors: activity effect, structure effect, and intensity effect.FEC increased significantly throughout the period with the activity effect being the major promotor. The structure effect promoted and inhibited FEC growth within the 2000-2022 period while the intensity effect largely contributed to a drop in final energy consumption. The activity effect resulted in the net growth of FEC by 136,403 TJ. The effect of the economic structure was oscillating resulting in a net growth of FEC by 9,635.45 TJ. As an inhibitor to FEC growth, the intensity effect resulted in a decline of FEC by 114,081 TJ. The results of this study can help the government to reduce energy consumption by encouragingand promoting energy-saving practices, and incentivizing the adoption of green technologies can effectively curb wasteful energy consumption and foster a culture of responsible energy usage across all sectors of the economy.**

**Keywords: LMDI decomposition analysis; energy consumption; intensity effect; activity effect; Ghana energy system.**

## 1.0 Introduction

Ghana's energy consumption is a critical factor in its economic and social development. Energy consumption patterns in the country are shaped by a mix of hydroelectric, thermal, and renewable energy sources.[1]. Hydropower, primarily from the Akosombo and Kpong dams, has historically been the backbone of Ghana's electricity supply [2];[11]. However, reliance on hydroelectricity has been complemented by thermal generation to address growing demand, particularly as the industrial sector expands. Energy demand in Ghana is expected to grow because of potential industrial expansions and households becoming richer with an increasing population. This growth is expected to increase by 7%-12% annually over the next two decades[46]; [47], and this will present a significant energy challenge to Ghana despite improvements in generation capacity [3].Thefinal energy consumption (FEC) grew steadily from 229,017.96 TJ in 2000 to 357,427 TJ in 2022, representing a 2.2% average annual growth rate with an increase of 0.2% in the total final energy consumed in 2022 compared to 2021[4]. Electricity consumption in Ghana has also seen consistent growth over the years, driven by increased electrification rates and economic activities [10]. Electricity consumptionhas consistently increased at a rate of 4.3% annually [4] within the 2000-2022 period.The introduction of natural gas from the West African Gas Pipeline and domestic fields, such as the Jubilee Field, has been instrumental in reducing reliance on expensive imported fuels like light crude oil and diesel.[50]. However, reasons, such as population and industrialization growth, economic expansion, demographic shifts, and governmental policies, continue to cause Ghana to face energy-related issues. This presents the need to assess the extent to which these drivers influence energy consumption to ensure sustainable energy consumption and production. The reliability of the energy system is undermined by persistent problems such as high transmission and distribution losses, sporadic outages, and affordability challenges [4]; [6].The energy supply-demand mismatch compels industries and businesses to invest in backup generation systems, further inflating energy costs. These challenges underscore the need for a diversified energy mix and policy-driven interventions to improve supply reliability and cost efficiency.The industrial, and service sectors play key roles in Ghana's energy landscape, having an approximate annual growth of 3.8%, and 5.3% from 2000 to 2022[4]. Figure 1 shows the main energy consumers in Ghana categorized into sectors (residential, industrial, agricultural, transport, and service).

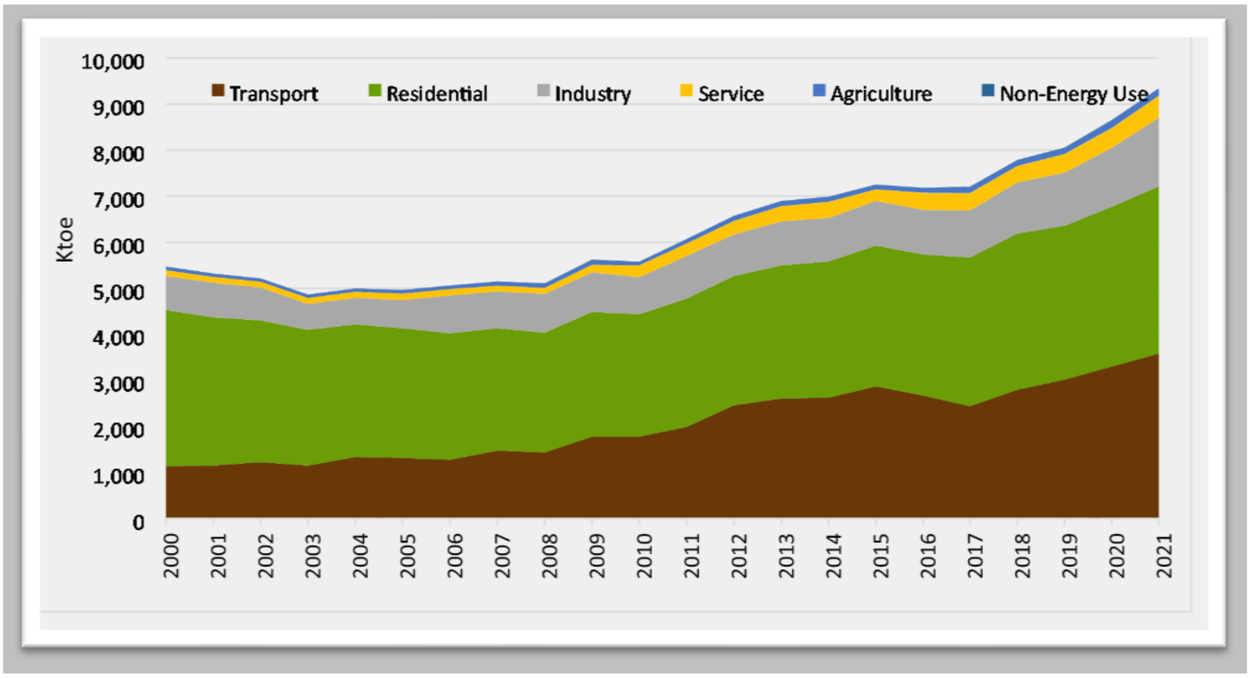


**Figure 1: Total energy consumed by sectors**

Source: [4]

This study employs a sectoral decomposition analysis of energy supply and demand drivers to identify the key factors contributing to changes in energy consumption in different industrial sectors of the Ghanaian economy. Thestudy seeks to answer the following main questions: What are the main drivers of the energy demand and supply in Ghana?How do these drivers affect a country's energy demand and supply?What policy recommendations will promote sustainable energy consumption, production, and integration of green hydrogen and its derivatives in Ghana?

This analysis will provide insights into the most effective policy interventions to promote sustainable energy consumption and production in Ghana and the possible integration of renewable energy into the final energy mix. Furthermore, this study contributes to the literature on energy demand and supply in Ghana and provides a basis for future research in this area.

## 2.0 Decomposition Analysis

Several studies have used index decomposition analysis (IDA) frameworks to analyze drivers of changes in energy consumption, CO2 emissions, energy efficiency, and many other variable indicators [13];[14];[15];[16][17][18]. [20] used the Logarithmic Mean Divisia Index (LMDI) approach of IDA frameworks to examine the factors influencing CO2 emissions from the industrial sector of Fujian province, China. Decomposition analysis between 2005 and 2016 revealed industrial scale effect was the main driving factor of CO2 emissions, while the energy intensity effect was the main inhibitor. This structural effect had a minimal impact on CO2 emissions in the Fujian industrial sector. [21] focused on examining CO2 emissions from electricity generation in China during the 1991-2001 time period using the LMDI approach. The findings showed that the economic activity effect was the main contributor to CO2 emissions from electricity generation, whereas the generation efficiency effect was the main inhibitor of CO2 emissions. [22] explored the changes in energy intensity in Latvia using LMDI methods for the energy sectors. The increased energy intensity is attributed to the expansion of the energy-demanding sectors. The scale, composition, emission regulation, and production efficiency influence CO2 emissions in the production of Indian exports [23]. The study decomposed data within the 1995-2009 period and found that the scale effect increased CO2 emissions by more than 184%. However, the other three effects had a dampening effect on CO2 emissions. [24] discussed the factors affecting changes in energy consumption and investigated energy intensity across the Indonesian manufacturing sector from 1980 to 2015. The results showed that limited changes in the industrial structure contributed to a 65% reduction in energy intensity over the study period. Energy efficiency improvements and financial shocks also influence energy intensities. Other studies have employed a similar methodology to investigate trends in other variable indicators, as shown in Table 1.

**Table 1: Representative literature for LMDI decomposition analysis**

| Indicator | Frameworks | | | Driving effects | | | | Source(s) |
|---|---|---|---|---|---|---|---|---|
| | Region | Study period | Sector | Activity effect | Structure effect | Intensity effect | Others | |
| Energy Intensity | Australia | 1978-2009 | Economy-wide | X | √ | X | Efficiency effect | [25] [26] |
| | Ghana | 2000-2020 | | X | √ | X | Labor productivity | |
| Electricity Consumption | China | 1995-2014 | Economy-wide | √ | X | √ | Energy consumption effect | [27] [28] |
| | | 1990-2015 | Manufacturing | X | √ | √ | Transfer effect | |
| | 46 cities | 1960-2001 | Transport | X | √ | X | urbanization effect | [29] [30] [31] |
| $CO_2$ Emissions | 40 countries | 1995-2009 | Economy-wide | X | √ | √ | X | [32] [33] |
| | USA | 2000-2016 | | X | √ | √ | Labor input effect | |
| | Thailand | 2005-2017 | Manufacturing | X | √ | √ | X | |
| | China | 2009-2018 | Power | √ | √ | √ | X | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | China | 1985-2009 | Transport | √ | √ | √ | Transportation modal shifting effect | [34] |
| | Shanghai, China | 1996-2007 | Industrial | X | √ | √ | industrial output | [35] |
| | Korea | 1991-2009 | Manufacturing | √ | √ | √ | Emission-factor effect. | [36] |
| Energy Consumption | Kerala, India | 2007-08 to 2016-17 | power and petroleum sector | √ | X | √ | X | [37] [38] [39] [40] |
| | South Africa | 1970-2016 | Manufacturing | √ | √ | √ | X | [41] |
| | EU Countries | 2005-2016 | Economy-wide | √ | X | X | Demographic effects, changes in lifestyle, weather | |
| | Korea | 1991-2001 | Manufacturing | √ | √ | √ | X | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | China | 2000-2014 | Non-ferrous metal industry | X | √ | √ | Labor productivity effect and industrial scale effect. | |
| Carbon Intensity | China | 2001-2015 | Urban residential | X | X | √ | urban sprawl, and land demand | [42] |
| Water and Energy Consumption | China | 2011-2015 | Economy-wide | √ | √ | √ | industrial water consumption | [43] |

## 2.0 Data and Methodology

### 2.1 General Formulae of LMDI

The LMDI decomposition analysis method is widely used because of its desirable features, including the ability to provide perfect decomposition, consistency in aggregation, and the ability to express components in additive or multiplicative forms[44].

Assume $Z$ is an aggregate variable, and there are m factors (X1, X2, X3…Xm) that influence Z over some time. The general IDA identity is given by

$$Z = \sum_{j} Z_j = \sum_{j} Z_1, jZ_2, jZ_3, j \ldots Z_3, j \quad [1]$$

The contribution of the $m$th factor to the change in the aggregate from a reference time, t to a time, T is expressed as;

$$\Delta Z_{xm} = \sum_{j} L(Z_j^T, Z_j^t) In[\frac{X_{m,j}^T}{X_{m,j}^t}] = \sum_{i} \frac{Z_j^T - Z_j^t}{InZ_j^T - InZ_j^t} In\left[\frac{X_{m,j}^T}{X_{m,j}^t}\right] \quad [2]$$

Where L (a, b) = (a-b) / (lna - lnb)

### 2.2 Decomposition of Energy Consumption

The general IDA identity for the decomposition of energy consumption is given by

$$E = \sum_{i} E_i = \sum_{i} Q \frac{Q_i}{Q} \frac{E_i}{Q_i} = \sum_{i} Q S_i I_i \quad [3]$$

Where i denotes the sector, E is the total energy, Q is the economic activity (gross domestic output or gross added value), $and\ S_i = \frac{Q_i}{Q}$ Represents the proportion of the economic activity relative to the whole economy in which the structural effect is captured. $I_i = \frac{E_i}{Q_i}$ is the total energy intensity of sector i which captures the intensity effect.

In the additive LMDI approach, the change in energy consumption due to the activity, structure, and intensity effects from a reference time t to time T is calculated as follows:

$$\Delta E = E^T - E^t = \Delta Eact + \Delta Estr + \Delta Eint \quad [4]$$

Where;

ΔEact, ΔEstr, and ΔEint are the changes due to activity, structure, and intensity effects which are respectively represented by Q, $S_i$, and $I_i$ in equation [3] above. The following formulae were used to quantify the above effects:

$$\Delta Eact = \sum_i w_i \, In\left(\frac{Q^T}{Q^t}\right) \quad [5a]$$

$$\Delta Estr = \sum_i w_i \; In\left(\frac{S_i^T}{S_i^t}\right) \quad [5b]$$

$$\Delta Eint = \sum_i w_i \; In\left(\frac{I_i^T}{I_t^t}\right) \quad [5c]$$

Where $wi = \frac{E_i^T - E_i^t}{InE_i^T - InE_i^t}$

**2.2.1 Decomposition of Final Energy Consumption.**

The consideration of industrial subsectors was performed based on available disaggregation data on energy consumption and value-added. As a result, this study consideredthree industrial subsectors (manufacturing, construction, and non-mining industries,commerce and public services, andagriculture, forestry, and fishing). Due to data unavailability and restrictions, it was not possible to treat all industrial sectorswithin the economy. The equation used to decompose the final energy consumption in the industrial sector is as follows:

$$\text{FEC} = \sum_i GVA \frac{GVA_i}{GVA} \frac{FEC_i}{GVA_i} = GVA \frac{GVA_{man}}{GVA} \frac{FEC_{man}}{GVA_{man}} + +GVA \frac{GVA_{agr}}{GVA} \frac{FEC_{agr}}{GVA_{agr}} + GVA \frac{GVA_{ser}}{GVA} \frac{FEC_{ser}}{GVA_{ser}} \quad [7]$$

Where i represents the disaggregated subsectors, and FEC and GVA are the final energy consumption and gross added value of the industrial sector, respectively. Similarly, $GVA_i$ and $FEC_i$ are the gross added values and final energy consumptions for the different subsectors of the industrial sector considered.

**Table 2: Overview of decomposition identities used in this study**

| Sector | Industry |
|---|---|
| (Index=i) | Manufacturing, construction, and non-mining industries<br>Agriculture, forestry, and fishing<br>Commerce and public services |
| Activity effect | Gross Value Added (GVA) |
| Structure effect | $GVAi/GVA$ |
| Intensity effect | $FECi/GVAi$ |

i denote the subsector

FEC = final energy consumed in the residential sector

GVA = total gross added value
GVAi = gross added value per each subsector
FECi = final energy consumed per each subsector

## 2.3 Data Sourcesand Overview

Primary and Final energy consumption data were obtained from the Ghana Energy Commission (EC) and the UN Statistics website, a public database that provides time-series data for different sectors between 2000 and 2022. UN Data comprises data from various national sources that have been harmonized to enable comparability of data across different countries. Economic activity data were obtained from the World Bank's database. Data from the Ghana Statistical Service (GSS) were used to cover specific data needs, such as population and population with access to electricity.

The Gross Value Added (GVA) of the corresponding sub-industrial sectors was used as the activity for the analysis. Owing to data unavailability and restrictions, simplifications and approximations were performed to fill out missing data. FEC for the manufacturing, construction, and non-fuel mining industries was used. However, its corresponding activity data was unavailable. Therefore, activity data for manufacturing alone was used.

## 3.0 Results and Discussion

The additive LMDI analysis was performed using Excel 2016. Final Energy Consumption (FEC) with the various industry sectors was decomposed and analyzedin terms of activity, structure, and intensity effects between 2000-2022.The activity effect was the GVA growth rate of the industrial sector and the structure effect was the proportion of the industrial sector. The intensity effect included energy efficiency measures put in place to reduce FEC. FEC increased from 229,017.96 TJ in 2000 to 357,427 TJ in 2022. This increase alignswith the projections of [46] and [47] that estimate final energy consumption growth by 7%-12% annually over the next two decades. As shown in Table 3, the effect of economic activities contributed 75,719.10 TJ increase in final energy consumption between the periods 2000-2001 and 2011-2012. In the same period, both structure and intensity effects were negative, -15,705.59 TJ and -73,828.20 TJ respectively, playing inhibitory roles in the growth of final energy consumption. The intensity effect was approximately 5 times larger than the structure effect which implies that the role played by the intensity effect in inhibiting final energy consumption growth was stronger. In effect, the increase in GVAis a promoter of final energy consumption while improvements in technologies and energy utilization efficiency measuresare inhibitors of final energy consumption growth.This is consistent with the findings of [12] which showed that the growth of industrial GVA will lead to an increase in industrial energy consumption.

**Also, there was a sharp rise in FEC as a result of high economic activities between the periods 2005-2006 and 2012-2013.This acceleration was in part due to higher prices for Ghana's main commodity exports, notably gold and cocoa, and the start of commercial oil production in 2011[51].However, the effect as a result of economic structure remained fairly stable. Within this period, services emerged as the largest sector, surpassing agriculture. In line with a larger trend of urbanization and labor shifting from agriculture to services and industry, services accounted for more than 50% of Ghana's GDP by 2012 [52]. Between 2013-2014 and 2014-2015, the effect of economic actives rather led to a drop in final energy consumption by 14,997.46 TJ. In the same period, the effect of economic structure also inhibited final energy consumption growth by**

**1,039.72 TJ.The effect of energy intensity on the other hand increased final energy consumption. This was so because of the power crisis, popularly called 'dumsor' which spanned 2012-2015 impacting economic activities. Also, the decline in energy consumption due to the effect of the economic structure implies that there was a shift in the structure of the Ghanaian economy towards a less energy-consuming sector.**

The activity effect was positive and contributed to an increase in final energy consumption by 32,406.26 TJin the period 2015-2016 to 2020-2021. This increase in final energy consumption is linked to the improvements in the industrialization of the economy. Within this period, the structure effect had an oscillating effect on energy consumption resulting in a decline in final energy consumption by 3,122 TJ. The intensity effect led to an increase in final energy consumption by 3,075.60 TJ. This trend is consistent with the findings of [25] which showed energy consumption intensity has a positive relationship with economic growth. The effect of energy intensity could not offset the increase caused by the increase in economic activities. This increase in energy consumption by the effect of energy intensity could indicate worsening impacts of transformational losses, which could be a signal of aging energy infrastructure. In 2021-2022, the effect of both economic activities and energy intensity led to a decline in FEC by 3,596.14 TJ and 11506.16 TJ respectively. Table 3 and Figure 3 below show the decomposition results.

**Table 3: Decomposition Results**

| Years | Total effect | Activity effect | Structure effect | Intensity effect |
|---|---|---|---|---|
| 2000-2001 | -2908.05 | 3176.24 | -213.98 | -5870.31 |
| 2001-2002 | -49.39 | 7331.35 | 96.10 | -7476.84 |
| 2002-2003 | -11698.12 | 8907.81 | -723.36 | -19882.58 |
| 2003-2004 | -1156.94 | 4876.89 | -1160.03 | -4873.80 |
| 2004-2005 | 2056.94 | 6973.22 | -133.77 | -4782.50 |
| 2005-2006 | 4972.51 | 32500.67 | 402.78 | -27930.94 |
| 2006-2007 | -7090.89 | 3762.34 | -3365.73 | -7487.50 |
| 2007-2008 | -3661.67 | 1680.91 | -4193.25 | -1149.34 |
| 2008-2009 | 823.28 | -7561.07 | -4704.92 | 13089.27 |
| 2009-2010 | 83.06 | 7418.72 | -769.79 | -6565.87 |
| 2010-2011 | 4498.07 | 8638.34 | 3101.74 | -7242.01 |
| 2011-2012 | 316.52 | -1986.33 | -4041.37 | 6344.22 |
| 2012-2013 | 28898.13 | 46871.24 | 26136.71 | -44109.82 |
| 2013-2014 | 18.98 | -10708.56 | 463.41 | 10264.14 |
| 2014-2015 | -3768.21 | -4288.89 | -1503.13 | 2023.82 |
| 2015-2016 | 1678.05 | 7099.58 | -2946.26 | -2475.27 |
| 2016-2017 | 1604.33 | 1353.35 | -1056.74 | 1307.71 |
| 2017-2018 | 4068.16 | 6424.46 | 818.59 | -3174.89 |
| 2018-2019 | 3729.30 | 1578.48 | -48.68 | 2199.50 |
| 2019-2020 | 6062.29 | 5691.93 | 1757.25 | -1386.90 |
| 2020-2021 | 15217.72 | 10258.45 | -1646.17 | 6605.45 |
| 2021-2022 | -11736.24 | -3596.14 | 3366.05 | -11506.16 |

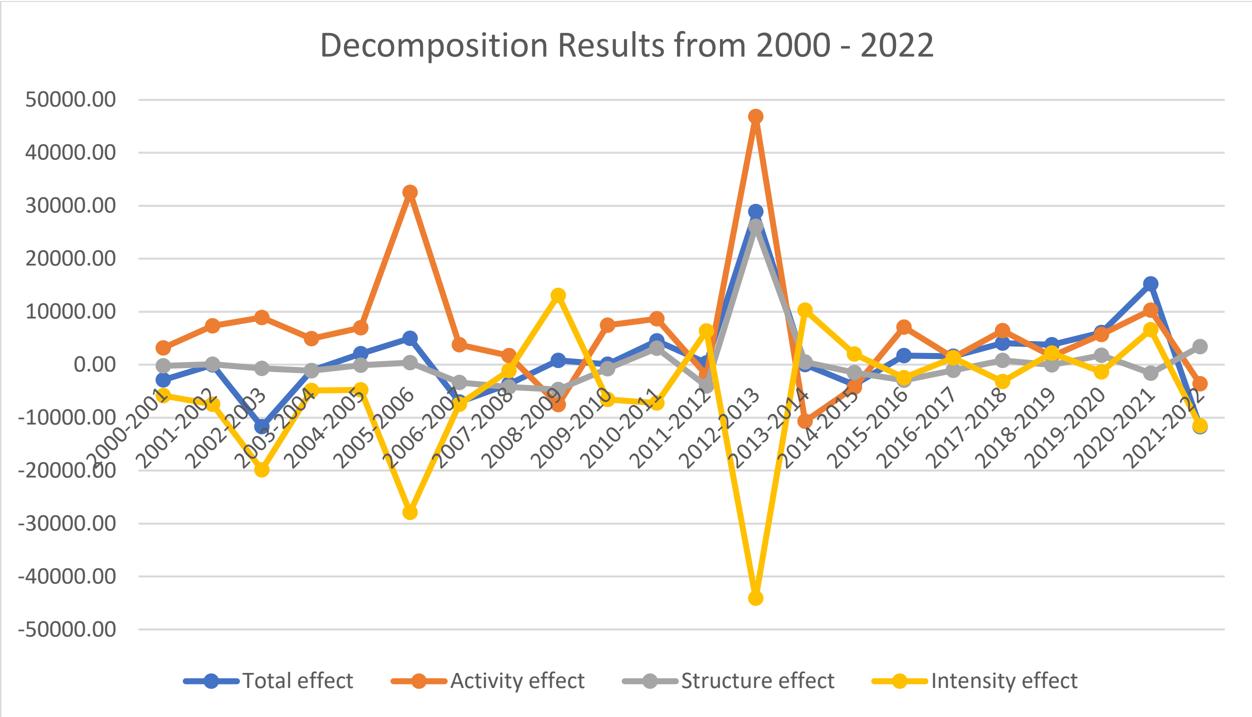


**Figure 2: Decomposition results**

### 3.1 Policy Recommendations

Even though the activity effect is the major promoter of energy consumption, reducing the activity effect to reduce Ghana's energy consumption is not the best approach. Based on the above results, the following policy recommendations for reducing energy consumption in Ghana should be encouraged.

1. Enforcing strict energy efficiency policies: Energy inefficiency in the industrial sector is a major concern. Many Ghanaian industries have high energy intensity, with many firms relying on outdated machinery and inefficient processes. There is a potential for energy savings through the adoption of modern energy-efficient technologies and practices. Energy usage in manufacturing and agro-processing, for example, might be significantly decreased via waste heat recovery systems and process optimization. This can be achieved by incentivising energy saving industries.

2. Encouraging the integration of renewable energy, green hydrogen, and its derivatives into the energy mix: Renewable energy adoption within Ghana's industrial sector remains limited, despite the country's significant potential for solar energy. High upfront costs, insufficient policy incentives, and technical challenges have slowed the integration of renewables into industrial operations. Policies that promote the usage of renewable energy systems in both residential and industrial sectors should be adopted. Encouraging the public could go hand in hand with stronger policy support, financial incentives, and public-private partnerships to drive large-scale adoption.

3. Changing the economy's structure from high-intensive sectors (manufacturing, mining) to less intensive (service) ones. This could be done by targeting sectors whose economic activities have higher added value compared to energy consumption.

## 4.0 Conclusion

The findings of this study showed several key drivers, including economic growth, population expansion, industrial development, and the relative lack of energy-efficient technologies. Acknowledging these factors is pivotal for formulating effective energy policies that can address the growing energy demand while concurrently ensuring sustainable development and environmental conservation. The analysis also indicates an oscillating pattern in energy intensity promoted by structural effect. This implies energy efficiency has not been the main focus of energy policies. Policymakers can use this information to develop policies that promote energy efficiency to reduce energy consumption in Ghana.

Moreover, the identified disparities in energy consumption among different sectors emphasize the need for tailored, sector-specific strategies. While the industrial sector appears to be the major contributor to overall energy consumption, other sectors also play a significant role, necessitating targeted interventions to promote energy efficiency and conservation at all levels.

Addressing issues such as high energy costs, inefficiencies, and supply unreliability requires a multi-faceted approach involving technological innovation, policy reforms, and stakeholder collaboration. Leveraging renewable energy and improving efficiency in industrial processes will not only bolster the sector's competitiveness but also contribute to Ghana's sustainable energy future.

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