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# Decomposition Analysis of $CO_2$ Emissions from Electricity Generation in Nigeria

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**ABSTRACT**

This paper investigates the factors that influences the change in $CO_2$ emissions from electricity generation in Nigeria. The Logarithmic Mean Divisia Index (LMDI) method of decomposition that was used. The main result shows that: (1) $CO_2$ emission from electricity generation decreased by 0.59 Mt. (2) Electricity efficiency decreased $CO_2$ emission by 2.33 Mt. (3) Electricity intensity decreased $CO_2$ emission by 21.85 Mt. (4) Economic activity increased $CO_2$ emission by 28.27 Mt. The result from the analysis shows that $CO_2$ emission increased in Nigeria. Electricity efficiency and intensity contributed to the reduction of $CO_2$ emission while economic activity has contributed to the increase in $CO_2$ emission in Nigeria. Since economic activities can not be reduced without affecting the economic performance of Nigeria, energy efficiency improvement would be an important option to reduce $CO_2$ emissions.

**Keywords:** Nigeria, Decomposition Analysis, $CO_2$ Emission From Electricity Generation, Electricity Efficiency, Electricity Intensity
**JEL Classifications:** C01, Q41, Q43

## 1. INTRODUCTION

The issue of global warming and greenhouse gases (GHG) mitigation has been a subject of concern for both government and researchers (Shrestha et al., 2009). The issue was previously blamed on on developed economies but now involves developing countries such as China and India. The clean development mechanism as defined by the Kyoto protocol (as per Article 12) presents a lot of promise as an incentive compatible mechanism for large scale investment for technology transfer from Annex-1 countries to the developing countries with the aim of efficiently mitigating GHG emissions (Nag and Parikh, 2005).

There have been scientific eveidence to prove that the global GHG emission is still on the rise which also contributes to the increasing global temperatures. The primary source of this increase can be attributed to the rising fossil-fuel use and other human activites (Malla, 2009). The consumption of fossil-fuel occurs mostly in power generation for electrcity and heat production. Many researchers have devoted their time and resources to investigate the decomposition of $CO_2$ emissions from electrcity generation and consumption (Steenhof, 2006; Wang et al., 2010; Malla, 2009, Shrestha et al., 2009 and Zhang et al., 2013) and all came to the conclusion that the increase in economic activity raised the amount of $CO_2$ emissions which is as a result of electrcity generation and consumption.

The question this paper presents is "do the increase in economic activities really contribute to the increase in $CO_2$ emission from electricity generation in developing countries." We intend to answer this research question by applying decomposition analysis to a non-organization for economic co-operation and development (non-OECD) country, Nigeria. To our knowledge, no study has carried out the decomposition analysis used in this study to analyze the six contributing factors influencing $CO_2$ emissions in Nigeria. The factors considered in this paper are emssion coefficient, electrcity geenration efficiency, thermal power structure, electrcity structure, electrcity intensity and economic activity.

We employed the decomposition methodology used by Zhang et al. (2013) to estimate the $CO_2$ emissions from electricity generation in China and use the Logarithmic Divisia Index (LMDI) approch to decompose the change of $CO_2$ emission overtime. The rest of the paper is organized as follows. Section 2 introduce the electricity situations in the countries been analyzed. The methodology and data sources are presented in Section 3 while the results are discussed in Section 4. The policy implications and conclusions are given in Section 5 which concludes the study.

## 2. NIGERIA'S ELECTRICITY SITUATION

### 2.1. History

In Nigeria, electricity generation rose from few kilowatts that were used in Lagos by the colonial masters when the first generating plant was installed in 1898. By the Act of Parliament in 1951, the Electricity Corporation of Nigeria (ECN) was established. Niger Dams Authority was set up in 1962 to develop hydroelectricity and was merged with ECN to form the National Electric Power Authority (NEPA) in 1972. Despite various effort by NEPA (which operated a monopolized market) to manage the power sector by providing electricity to the increasing population, it became clear that NEPA was losing the battle to meet up with the electricity demand in the 1990s. Hence, in 2001, the National Electric Power Policy (NEPP) was introduced to kick-off the power sector reform and this lead to several other reforms in the past years. The NEPP in 2001 created the roadmap for Nigeria's Power Sector Privatization, but due to government bureaucracy; the policy was not signed into law until 2005. This signed document was the Electric Power Sector Reform (EPSR) Act in 2005 which was expected to level the playing ground for potential investors and improve the wellbeing of its citizens. The EPSR Act led to the incorporation of the Power Holding Company of Nigeria from NEPA, which was later defunct and divided into sub-sectors (Vincent and Yusuf, 2014).

The electricity sub-sectors in Nigeria comprises of 18 companies which include: six generating companies, eleven distribution companies and one Transmission Company. These companies have various functions which include power generation, transmission, trading, distribution and bulk supply as well as resale of electricity in the country. Electricity generation in Nigeria has been in existence for more than 100 years with various reforms of the electricity sector but its development and availability to Nigerians have been a dilemma. The electricity generated are transmitted through transmission lines that use three phases namely alternating current (AC), single-phase AC current and high-voltage direct current system. However, transmission of electricity using high voltage (110 kVA or 330 kVA used in Nigeria) aids in the reduction losses (Emodi and Yusuf, 2015).

### 2.2. Current Situation

It is generally recognized that Nigeria is vastly endowed with both renewable energy resources (e.g. solar, hydro, wind, biomass and wood fuel) and non-renewable energy resources (e.g. crude oil, natural gas, lignite and coal). However, in spite of this abundance, the country is still unable to generate enough electricity to meet its domestic demand (Akpan and Akpan 2012). According to the Worldbank, only 48% of Nigerians have access to electricity while rest of the population has to rely on personal generators to run their businesses, industries and homes. Figure 1 shows the trends of electricity production and consumption in Nigeria for the period of 1992-2011.

The gap between electricity demand and supply will widen up as the country has become the industrial hub of Africa and its population is increasing. The recurrent outages experienced in Nigeria has forced about 90% of the industrial sector and significant number of household customers to provide their own power through different forms of generating sets at huge cost to themselves and to the Nigerian economy. As at 2010, the total installed capacity of combined hydro and thermal power stations was 8,000 MW, whereas the power generation capacity available was approximately 4,000 MW from both PHCN and IPPs out of which only about 1500 MW was readily available to generate electricity. Figure 2 shows the electricity supply pattern to the manufacturing, service and residential sector from 1990 to 2011.

The Nigerian government is currently committed to improving the performance of the power sector by providing an enabling environment for the private investors. This includes upwards revision of the power tariff within the multi-year tariff order to a cost reflective upper limit to the end user tariffs.

## 3. METHODOLOGY AND DATA

### 3.1. Methodology

There are two methods of decomposition analysis; one is structural decomposition analysis (SDA) and the other is index decomposition analysis (IDA). These methods have been used to assess the influence of economic growth, sector shifts and technology changes on a variety of environmental and socio-economic indicators. SDA uses the input–output model and data to decompose changes in indicators while IDA uses only sector level data (Hoekstra and Van den Bergh, 2003). The IDA is used in this report. Especially, based on IDA, many specific decomposition methods can be developed and LMDI is one of them.

### 3.2. Data Source

All electricity data used for the decomposition analysis were obtained from National Control Center, Osogbo, Nigeria. The data for Nigeria's Gross Domestic Product (GDP) in 2005 USD and GDP deflator were obtained from the United Nations Statistics-National Account.

### 3.3. $CO_2$ Emission Estimation

Following the Revised IPCC (1996) method, the total $CO_2$ emissions from electricity generation in a year is estimated by

$$CO=\sum_{ft} EC_{ft}\times CEF_{ft}\times COD_{ft}\times MWR \qquad (1)$$

Where subscript ft represent fuel type. $EC_{ft}$ denotes energy consumption based on fuel type ft; $CEF_{ft}$ is the carbon emission factor of the $ft^{th}$ fuel; $COD_{ft}$ is the fraction of the carbon oxidized dioxide from fuel type ft; and MWR is the molecular weight ratio of carbon dioxide to carbon (44/12). The carbon emission factors for diesel oil which is the fuel used in the oil power plants was 20.2 and fractions of carbon oxidized is 0.98. Natural gas which is used in gas plants have the carbon emission factor of 15.3 while its fraction of carbon oxidized is 0.98 (IPCC, 1996).

**Figure 1:** Electricity production and consumption pattern in Nigeria

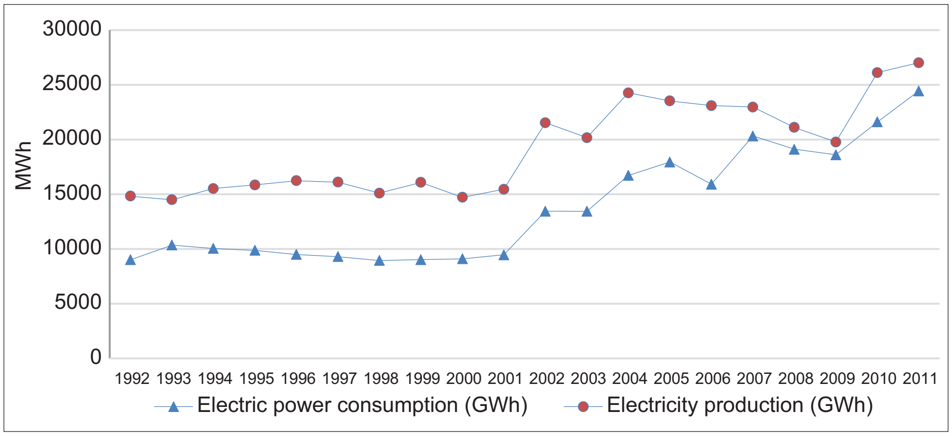
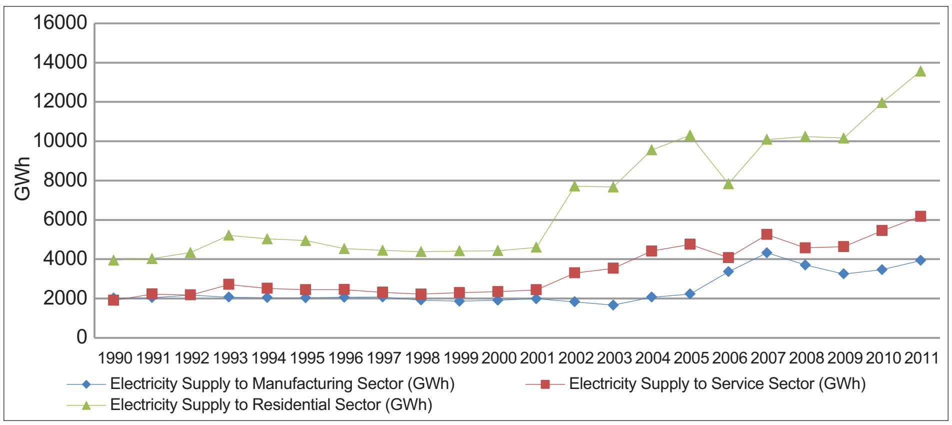



**Figure 2:** Electricity supply to manufacturing, service and residential sector in Nigeria




### 3.4. Decomposition of $CO_2$ Emission

The $CO_2$ emissions from electricity generation can be shown as following equation (Zhang et al, 2013).

$$CO=\sum_{ft} CO_{ft}=\sum_{ft}\frac{CO_{ft}}{EC_{ft}}\times\frac{EC_{ft}}{TPG_{ft}}\times\frac{TPG_{ft}}{TPG}\times\frac{TPG}{TEG}\times\frac{TEG}{GDP}\times GDP$$
$$=\sum_{ft} COCF_{ft}\times EGEF_{ft}\times SEG_{ft}\times STPG\times EI\times GDP \quad (2)$$

Wherec $CO_{ft}$ denotes $CO_2$ emissions based on fuel type ft; $TPG_{ft}$ denotes thermal power generation based on fuel type ft; TPG denotes thermal power generation; TEG denotes total electricity generation; GDP as the gross domestic production; $COCF_{ft}=CO_{ft}/EC_{ft}$ is the $CO_2$ emissions coefficient of fuel type ft; $EGEF_{ft}=EC_{ft}/TPG_{ft}$ is the electricity generation efficiency based on fueltype ft; $SEG_{ft}=TPG_{ft}/TPG$ is the share of electricity generation based on fuel type ft in total thermal power generation; STPG=TPG/TEG is the share of thermal power generation in total electricity generation; EI=TEG/GDP is the electricity intensity.

In the logarithmic mean weight scheme, the change of $CO_2$ emissions from electricity generation between a base year 0 and a target year t, can be expressed as $\Delta C_{total}$ which is can be decomposed into six effects as follows:

(i) the changes in the emissions coefficient effect (denoted by $\Delta C_{COCF}$);

$$\Delta C_{COCF}=Log\left(CO_{ft}^{t}, CO_{ft}^{0}\right)\ln\left(\frac{COCF_{ft}^{t}}{COCF_{ft}^{0}}\right) \quad (3)$$

(ii) the changes in the electricity generation efficiency effect (denoted by $\Delta C_{EGEF}$);

$$\Delta C_{EGEF}=Log\left(CO_{ft}^{t}, CO_{ft}^{0}\right)\ln\left(\frac{EGEF_{ft}^{t}}{EGEF_{ft}^{0}}\right) \quad (4)$$

(iii) the changes in the thermal power structure effect (denoted by $\Delta C_{SEG}$);

$$\Delta C_{SEG}=Log\left(CO_{ft}^{t}, CO_{ft}^{0}\right)\ln\left(\frac{SEG_{ft}^{t}}{SEG_{ft}^{0}}\right) \quad (5)$$

(iv) the changes in the electricity structure effect (denoted by $\Delta C_{STPG}$);

$$\Delta C_{STPG}=Log\left(CO_{ft}^{t}, CO_{ft}^{0}\right)\ln\left(\frac{STPG_{ft}^{t}}{STPG_{ft}^{0}}\right) \quad (6)$$

(v) the changes in electricity intensity effect (denoted by $\Delta C_{EI}$); and

$$\Delta C_{EI}=Log\left(CO_{ft}^{t}, CO_{ft}^{0}\right)\ln\left(\frac{EI_{ft}^{t}}{EI_{ft}^{0}}\right) \quad (7)$$

(vi) the changes in the economic activity effect (denoted by $\Delta C_{GDP}$);

$$\Delta C_{GDP} = \text{Log}\left(CO_{ft}^{t}, CO_{ft}^{0}\right)\ln\left(\frac{GDP_{ft}^{t}}{GDP_{ft}^{0}}\right) \quad (8)$$

All the effect (Equation 3-8) can be placed on the right hand side and arranged in additive form as shown below;

$$\Delta C_{total} = \Delta C_{COCF} + \Delta C_{EGEF} + \Delta C_{SEG} + \Delta C_{STPG} + \Delta C_{EI} + \Delta C_{GDP} \quad (9)$$

Each effect in the right hand side of equation can be computed as follow:

The superscripts t and 0 represent a year, respectively. In the index number, we form

$$\left(\frac{\Delta C_{COCF}}{\Delta C_{TOTAL}} + \frac{\Delta C_{EGEF}}{\Delta C_{TOTAL}} + \frac{\Delta C_{SEG}}{\Delta C_{TOTAL}} + \frac{\Delta C_{STPG}}{\Delta C_{TOTAL}} + \frac{\Delta C_{EI}}{\Delta C_{TOTAL}} + \frac{\Delta C_{GDP}}{\Delta C_{TOTAL}}\right) \times 100\% = 100\% \quad (10)$$

## 4. RESULTS AND DISCUSSIONS

The result of the decomposition analysis of the three countries will be presented in this section and we made some comparison with the work of Zhang et al. (2013) and compared the $CO_2$ emission intensity from the countries we analyzed with Korea, Japan, Germany, France and the United States.

### 4.1. Analysis of $CO_2$ Emissions

The consequential $CO_2$ emission from electricity generation in Nigeria from 1992 to 2011 are presented in Figure 3. There have been a slow increase in $CO_2$ emission from electricity generation with 8.76 Mt in 1992 to 18.30 Mt in 2011. From Figure 3, we can observe that $CO_2$ emission increased between the period of 1995 and 1997 which is due to the additional capacity of gas plants in Nigeria. Oil power plants were also converted to gas combined cycle and this is evident in Figure 4 which shows the emission by fuel type. A notable drop in $CO_2$ emission from power plants can be clearly observed in Figure 4 in the year 2000 which was the same year the national utility body NEPA was unbounded into various companies. However, gas plants still functioned normally and increased from 2002 onwards.

It is important to note that the thermal power plants in Nigeria consist of oil and gas according to fuel types with gas having the most number of power plants and at present, only two oil power plants are in operations in Nigeria besides the numerous gas plants. However, the $CO_2$ emission by fuel source (Figure 4) shows that the increasing number of gas plants have contributed to the increase in $CO_2$ emissions. The $CO_2$ emission of oil power plants have remain at very low level.

### 4.2. Decomposition Analysis

Applying the decomposition methodology from Zhang et al. (2013), we present the results in Tables 1 and 2 for the percentage. Improvement in the overall electricity sector aids to reduce $CO_2$ emission and the rise in standard of living may increase the emission of $CO_2$ since it will require more electricity which is vital for socioeconomic growth. The complete decomposition of $CO_2$ emission change from 1992 to 2011 is shown in Figure 5.

From the result of the analysis, the emission coefficient effect ($\Delta C_{COCF}$) partially decreased the emission of $CO_2$ in most period of observation except 1992-1993, 1993-1994, 1994-1995, 1997-1998, 1998-1999, 2000-2001, 2004-2005 and 2008-2009. The accumulated (period-wise) effect leads to the decrease of 0.591Mt

**Table 1: Complete decomposition result of $CO_2$ emission from 1992 to 2011**

| Year | $\Delta C_{COCF}$ | $\Delta C_{EGEF}$ | $\Delta C_{SEG}$ | $\Delta C_{STPG}$ | $\Delta C_{EI}$ | $\Delta C_{GDP}$ | $\Delta C_{TOTAL}$ |
|---|---|---|---|---|---|---|---|
| 1992-1993 | 0.57 | 0.32 | 0.00 | 0.37 | 5.27 | −5.47 | 1.06 |
| 1993-1994 | 2.24 | −1.41 | 0.00 | 0.39 | −0.64 | 1.28 | 1.86 |
| 1994-1995 | 0.55 | 1.00 | 0.00 | 0.18 | −4.40 | 4.61 | 1.93 |
| 1995-1996 | −0.58 | −0.27 | 0.00 | 0.13 | −1.89 | 2.15 | −0.46 |
| 1996-1997 | −0.01 | −1.04 | 0.00 | −0.14 | −0.33 | 0.25 | −1.26 |
| 1997-1998 | 0.00 | −1.47 | −0.01 | −0.54 | 0.47 | −1.11 | −2.65 |
| 1998-1999 | 0.03 | 0.50 | 0.00 | 0.00 | −0.49 | 1.10 | 1.13 |
| 1999-2000 | −0.07 | 0.04 | −0.02 | 0.00 | −3.22 | 2.40 | −0.87 |
| 2000-2001 | 0.00 | −0.74 | 0.01 | 0.00 | 0.91 | −0.46 | −0.28 |
| 2001-2002 | −0.01 | 2.04 | 0.10 | 0.00 | 0.43 | 3.22 | 11.79 |
| 2002-2003 | −0.02 | −4.11 | −0.02 | 0.26 | −2.51 | 1.69 | −4.70 |
| 2003-2004 | −0.01 | 0.39 | 0.02 | 0.77 | −1.09 | 3.73 | 3.81 |
| 2004-2005 | 0.06 | −0.53 | 0.00 | 0.10 | −4.40 | 3.91 | −0.87 |
| 2005-2006 | −0.01 | −2.86 | 0.00 | 1.37 | −4.52 | 4.22 | −1.79 |
| 2006-2007 | −0.01 | 0.16 | 0.00 | 0.00 | −2.36 | 2.27 | 0.05 |
| 2007-2008 | −0.05 | −2.36 | 0.00 | 0.00 | −4.95 | 3.58 | −4.88 |
| 2008-2009 | 0.98 | −1.81 | −0.03 | 0.79 | 1.98 | −2.90 | −0.99 |
| 2009-2010 | −0.02 | 1.20 | 0.06 | −0.23 | −5.97 | 5.29 | −3.97 |
| 2010-2011 | −0.04 | 0.65 | −0.04 | 0.41 | −0.90 | 1.31 | 9.92 |
| 1992-2011 | −0.59 | −2.33 | −0.48 | 3.01 | −21.85 | 28.27 | 7.21 |

**Figure 3:** $CO_2$ Emission from electricity generation in Nigeria

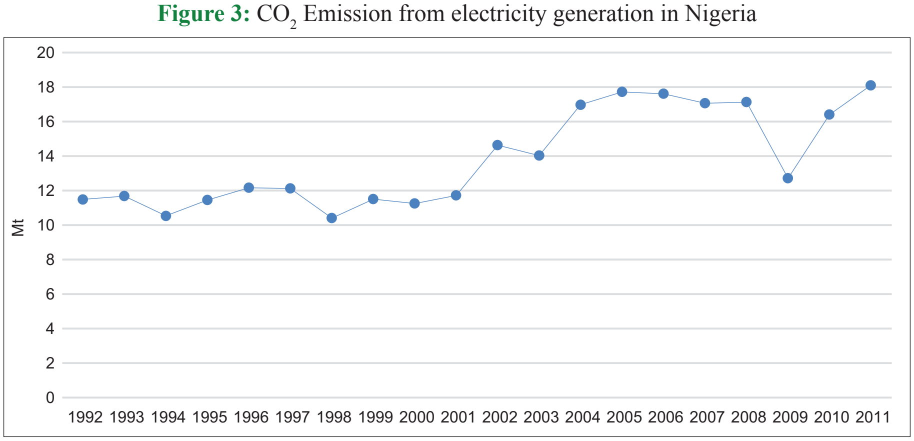


**Figure 4:** $CO_2$ emission from electricity generation by fuel type

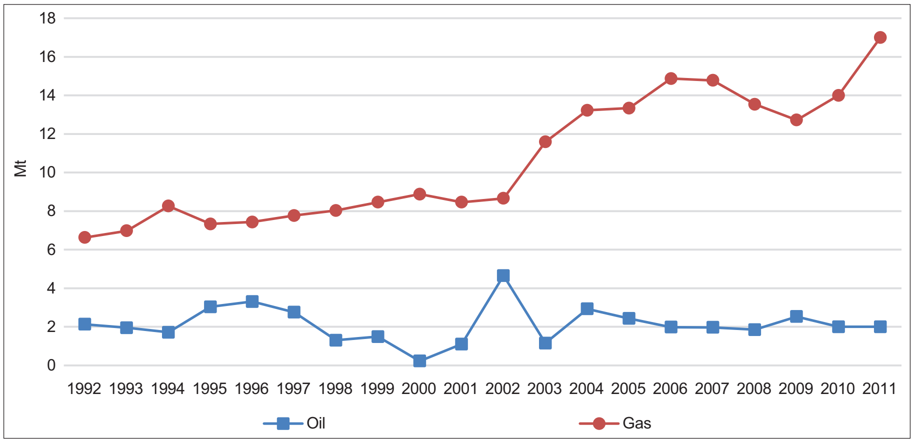



**Figure 5:** Complete decomposition of $CO_2$ emission change (1992-2011)

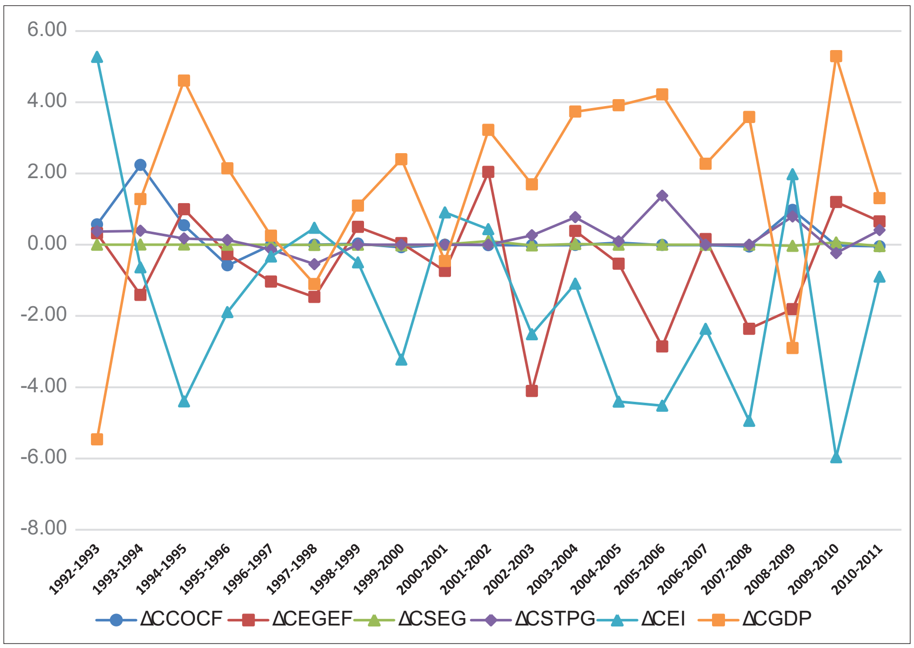



**Table 2: Complete decomposition result of $CO_2$ emission from 1992 to 2011 (in percentage)**

| Year | $\Delta C_{COCF}$ | $\Delta C_{EGEF}$ | $\Delta C_{SEG}$ | $\Delta C_{STPG}$ | $\Delta C_{EI}$ | $\Delta C_{GDP}$ | $\Delta C_{TOTAL}$ |
|---|---|---|---|---|---|---|---|
| 1992-1993 | 53.50 | 30.28 | 0.04 | 34.83 | 495.65 | −514.30 | 100.00 |
| 1993-1994 | 120.25 | −75.98 | 0.09 | 20.98 | −34.22 | 68.87 | 100.00 |
| 1994-1995 | 28.25 | 51.60 | 0.19 | 9.10 | −227.81 | 238.68 | 100.00 |
| 1995-1996 | 125.84 | 57.71 | −0.02 | −28.63 | 409.52 | −464.42 | 100.00 |
| 1996-1997 | 0.74 | 82.00 | −0.04 | 10.76 | 26.33 | −19.79 | 100.00 |
| 1997-1998 | −0.05 | 55.32 | 0.28 | 20.53 | −17.86 | 41.77 | 100.00 |
| 1998-1999 | 2.45 | 43.96 | 0.01 | 0.10 | −43.67 | 97.15 | 100.00 |
| 1999-2000 | 8.34 | −4.90 | 2.07 | 0.05 | 368.85 | −274.43 | 100.00 |
| 2000-2001 | 0.00 | 262.39 | −2.03 | −0.09 | −323.53 | 163.26 | 100.00 |
| 2001-2002 | −0.10 | 17.33 | 0.87 | −0.01 | 3.69 | 27.32 | 100.00 |
| 2002-2003 | 0.35 | 87.41 | 0.43 | −5.64 | 53.51 | −36.07 | 100.00 |
| 2003-2004 | −0.26 | 10.17 | 0.54 | 20.27 | −28.72 | 98.00 | 100.00 |
| 2004-2005 | −6.65 | 61.19 | 0.03 | −10.97 | 505.41 | −449.02 | 100.00 |
| 2005-2006 | 0.45 | 159.65 | −0.03 | −76.81 | 252.45 | −235.71 | 100.00 |
| 2006-2007 | −20.82 | 316.20 | 0.00 | 0.46 | −4811.59 | 4615.76 | 100.00 |
| 2007-2008 | 1.07 | 48.44 | 0.00 | 0.00 | 101.42 | −73.50 | 100.00 |
| 2008-2009 | −98.42 | 182.04 | 3.28 | −79.74 | −199.09 | 291.93 | 100.00 |
| 2009-2010 | 0.62 | −30.22 | −1.61 | 5.91 | 150.16 | −133.06 | 100.00 |
| 2010-2011 | −0.43 | 6.58 | −0.38 | 4.13 | −9.04 | 13.17 | 100.00 |
| 1992-2011 | −8.19 | −32.29 | −6.62 | 41.71 | −302.94 | 391.95 | 100.00 |

which accounts for 8.12% of the total change ($\Delta C_{TOTAL}$) in absolute values. The period 2000-2001 recorded zero which as earlier stated was the same period of the unbounding of the country's electricity utility body and another notable period was 2004-2005, which is the same period that the Nigerian Electric Power Reform Act was passed into law and lead to the formation of the Nigerian Electricity Regulatory Commission. However, a decrease is observed for 11 years and the accumulated (period-wise) effect reduce the $CO_2$ emission.

The electricity generation efficiency effect ($\Delta C_{EGEF}$) decreased $CO_2$ emission except for 1992-1993, 1994-1995, 1998-1999, 1999-2000, 2001-2002, 2003-2004, 2006-2007, 2009-2010 and 2010-2011. The accumulated (period-wise) effect is a decrease of 2.33 Mt, which accounts for 32.29% of the total change ($\Delta C_{TOTAL}$) in absolute value. The improvement in electricity generation efficiency could be attributed to the conversion of single turbine power plants to CCGT which has higher efficiency and also the conversion of oil power plants to CCGT. Figure 6 shows the trends of electricity generation efficiency in Nigeria.

The thermal power structure effect ($\Delta C_{SEG}$) did not play a role in the reduction of $CO_2$ emission except for 1997-1998, 1999-2000, 2002-2003, 2008-2009 and 2010-2011. The accumulated (period-wise) effect is a decrease of 0.48 Mt which accounts for 6.62% of the total electricity change ($\Delta C_{TOTAL}$) in absolute value. The notable period of reduced $CO_2$ emission (1997-1998, 1999-2000, 2002-2003, 2008-2009 and 2010-2011) were the period of various power sector reforms in Nigeria.

Under the observed period, the electricity structure effect ($\Delta C_{STPG}$) did not reduce $CO_2$ emissions except for 1996-1997, 1997-1998 and 2010-2011 with accumulated (period-wise) effect of 3.01 Mt which accounts for 41.71% in the total $CO_2$ emission change ($\Delta C_{TOTAL}$) in absolute value. This may be due to the long reliance of the Nigerian power sector on thermal power plants and hydro power which has not change since the 1980s. There has not been any addition of hydro power within the study period as shown in Figure 7.

The results for electrcity intensity effect ($\Delta C_{EI}$) showed that electrcity intensity played a dominat role in the reduction of $CO_2$ emissions except for 1992-1993, 2000-2001, 2001-2002 and 2008-2009. The accumulated (period-wise) is a decrease of 21.85 Mt, which accounts for 302.94% of the total change ($\Delta C_{TOTAL}$) in absolute value. Figure 8 shows the electrcity intensity for Nigeria under the studied period and showed a steady decrease from 1993 to 1998, and then decreased to 2000 which then steadly increased from 2009 to 2011.

This may be due to the effect of privitization of the electricity sector which has seen the huge influx of private firms into the electrcity sector which inturn comes with new process, new technology and new equipments. Hoever, it is important to n ote that Nigeria's energy intensity may be low but in the real sense, the intensity maybe high because most companies who contributes to the growth of the economy (GDP) depend on their own source of electricity. This is evident in Figure 2 which shows that electricity supplied to the manufacturing sector is the lowest in Nigeria. So what this actually imply is that our data did not capture the electricity generated by the manufacturers thgrough their own generators.

The economic activites effects ($\Delta C_{GDP}$) played a vital role in the increase of $CO_2$ over the studied period except for 1992-1993, 1997-1998, 2000-2001 and 2008-2009. During the privious mentioned period, some political activities took place in the country, the then civilian president Ernest Shonekan was overthowned in 1993 by General Sani Abacha, and Abacha died in office 1998. Also 2000-2001 saw the return to civilian rule while 2008-2009 was the period of the global financial crisis. All these events may have had some effect in the reduction of $CO_2$ since the was a change in governement. In the case of Nigeria, $CO_2$ from electrcity generation is not linked to economic growth, but the $CO_2$ emission and GDP increased together throughout the period under observation but at different rates. Electricity production which was 14834 GW in 1992 had not faired well through the period observed in this study which ended with just 27034 GW in 2011.

**Figure 6:** Nigeria electricity generation efficiency

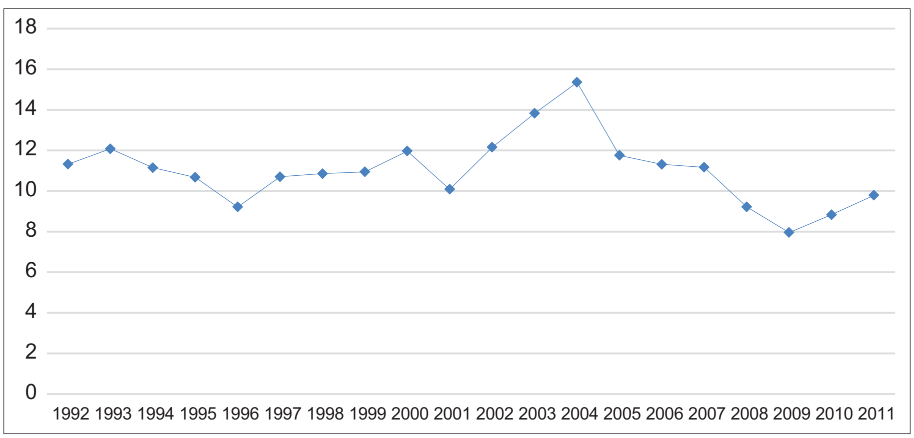
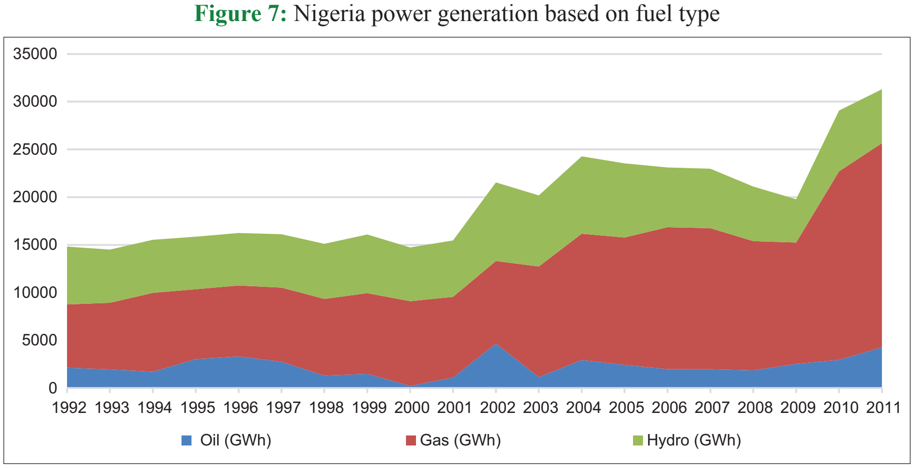



**Figure 7:** Nigeria power generation based on fuel type



## 4.3. Results Comparision with Zhang et al. (2013)

In Zhang et al. (2013) results from the "Decomposition analysis of $CO_2$ emission from electrcity generation in China," we can observe that a lot of factors contributed to the reduction in $CO_2$ emission. Starting with the emission coefficient where the accumulated (period-wise) effect leads to a decrease of nearly 3.92 Mt as compared to the 0.59 Mt recorded in the Nigerian decomposition result in Table 3. China actually has 52 coal power plants and 7 nuclear plant as compared to Nigeria's 20 gas power plants (SCGT and CCGT) and 2 oil power plants in terms of thermal power generations in the two countries.

The electrcity generation efficiency effect played a major role in $CO_2$ emssion reduction of 303.55 Mt in China while in the case of Nigeria, it was 2.33 Mt (accumulated) and this implies that electrcity efficiency measures contributed to the reduction of $CO_2$ emission in both countries. It is important to note that China is now converting some of its coal plants to CCGT and this contributed to the high-efficiency recorded in Zhang et al. (2013).

The thermal power structure effect played a minor role in increasing $CO_2$ emission from generating plants in China and decreased with only 1.92 Mt (acccumulated). The results from Nigeria showed little change as it recorded 0.48 Mt (accumulated) of $CO_2$ emission change.

The electrcity structure effect in China decreased $CO_2$ emission to 41.00 Mt (accumulated) but Nigeria showed no reduction but just a change of 3.01 Mt (accumulated) as compared to China which has a very large number of power plants and renewable energy generation source (hydro power and wind). Nigeria still depends on large hydro power and thermal power plants through out the studied period.

The electrcity intensity effect from Zhang et al. (2013) results showed that an accumulated effect decrease of 48.56 Mt and in the Nigerian results showed 21.85 Mt decrease. This implies that new process, new technologies and new equipment in electrcity generating facilities aids in the reduction of the emission of $CO_2$ emission. It could also mean that Nigeria use less amount of electricyt to improve its economic growth which we refuse to accept as explanied in the Decomposition result (Section 4.2).

The economic activity effect in China increased the emission of $CO_2$ to 2256.75 Mt (accumulated) while Nigeria recorded 28.27 Mt (accumulated). This implies that $CO_2$ emission and electrcity generation is closely linked to economic development in China but not in Nigeria since the supply of electrcity from the national utility grid is not sufficient to foster economic growth which has caused both the manufacturing, service and residential sectors to depend heavly on private generating plants. Table 3 gives a summary of the comparison between Nigeria and China by showing the dominant effect in both countries.

## 4.4. Nigeria's $CO_2$ Intensity Comparisons with Korea, France, Germany, Japan, and the USA

From Figure 9, we can oberve that France has the lowest carbon intensity due to the country's electricity generation from Nuclear

**Figure 8:** Electricity intensity in Nigeria

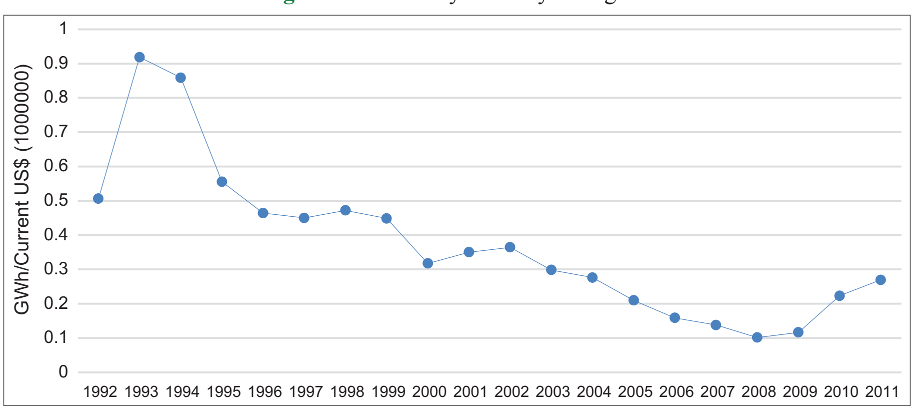
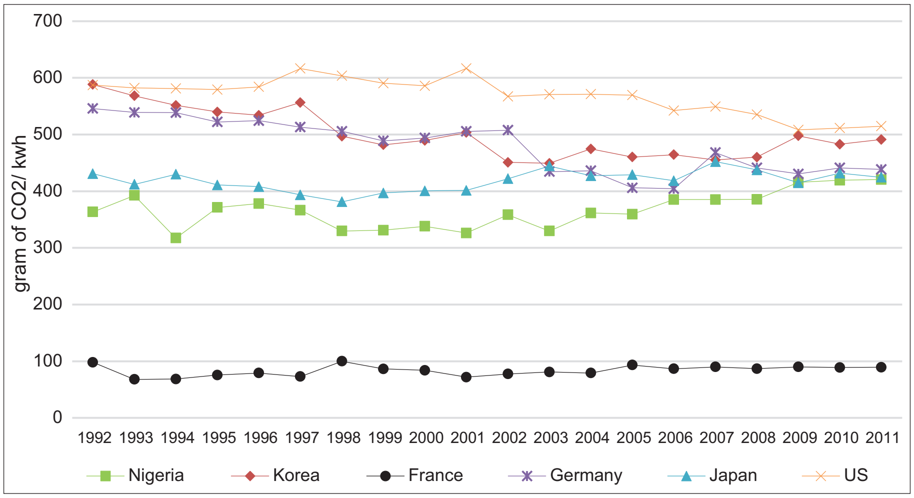



**Table 3: Results comparison with Zhang et al. (2013)**

| Factors | Nigeria | China |
|---|---|---|
| Changes in emission coeffficient | The accumulated effect lead to an increase in $CO_2$ emission to 0.59 Mt (8.19%) | The accumulated effect leads to decrease in $CO_2$ emission 3.92 Mt (0.21%) |
| Changes in electrcity generation efficiency | The accumulated effect lead to a decrease in $CO_2$ emission to 2.33 Mt (32.29%) | The accumulated effect leads to decrease in $CO_2$ emission 303.55 Mt (16.31%) - Dominant effect |
| Changes in thermal power structure effect | The accumulated effect lead to minor increase in $CO_2$ emission to 0.48 Mt (6.62%) | The accumulated effect leads to decrease in $CO_2$ emission 41 MT (2.2%) |
| Changes in electricity structure effect | The accumulated effect lead to a change in $CO_2$ emission to 3.01 Mt (41.71%) | The accumulated effect leads to decrease in $CO_2$ emission 41.0 Mt (2.20%) |
| Changes in electricity intensity effect | The accumulated effect lead to a decrease in $CO_2$ emission to 21.85.13 Mt (302.94%) - Dominant effect | The accumulated effect leads to decrease in $CO_2$ emission 48.56 Mt (2.61%) |
| Changes in economic activity effect | The accumulated effect lead to an increase in $CO_2$ emission to 28.27 Mt (391.95%) - Dominant effect | The accumulated effect leads to increase in $CO_2$ emission 2256.75 Mt (121%) - Dominant effect |

**Figure 9:** Carbon intensity from 1992 to 2011




energy. Nuclear energy contributes 77.1% electricity production while fossil fuel contributes only 8.2% (www.indexmundai.com) which is very less than other OECD courtiers. Carbon intensity in Nigeria seems not changing that much during1992-2008 but increased from 2009 to 2011. Slightly growth rate of carbon intensity in Nigeria may be cause of generation increase from the natural gas and oil. United Sates has highest carbon intensity, but the trend looks decreasing. Untied states electricity generation is mainly from the coal and natural may be cause for highest carbon intensity.

## 5. POLICY RECOMMENDATIONS AND CONCLUSIONS

### 5.1. Policy Recommendations

The analysis carried out on the Nigerian electrcity generation sector shows that economic activities contributed the most to the increase in $CO_2$ emission. Electricity demand is very high in Nigeria but supply is very low, so we cannot link the increase in power generation to economic growth but link the increase in economic activities to the increase in $CO_2$ emission. Another factor that contributed to the increase in $CO_2$ emission is the structure effect which is due to the long relance on thermal power plants and a single renewable energy source which is large hydro power with no additional facilities throughout the study period. However, the electrcity generation efficiency contributed to the reduction of $CO_2$ emission while electrcity intensity played a majoy role in $CO_2$ emission reduction. From these results, some policy implication could be drawn and they include;

- Improvement in energy efficiency practice and implementation of energy efficiency policies in the power sector by the Nigerian Government.
- The Nigerian government should ensure the security of fuel source for power generation by mandating oil companies to channel their flarred gasses to power plant.
- Initiate energy conservation measures in the residential sectors to reduce the increasing energy demand by Nigeria's growing populations.
- Promoting electrcity rationing will be a good move while efforts should be intesified by the governemnt to improve the performance and capacity of the power sector in Nigeria.
- The Nigerian government should diversify the nations energy source by considering large scale renewable energy projects such as wind farms in various locations in the country, small hydro power projects and solar power system provisions in off-grid areas especially in rurla areas.
- The complete conversion of single cycle gas turbine and oil plants to CCGT which is more efficient in power generation and less $CO_2$ emission will be a good move by the government.
- The governemnt should increase private sector participation in electricity generation as well as improve the public awareness of energy efficiency and conservation.

## 6. CONCLUSIONS

This paper investigated the factors influcing the increase in $CO_2$ emissions in Nigeria. The LMDI method of decomposition was employed and the main results showed that $CO_2$ emission from electrcity generation decreased in Nigeria by 0.59 Mt. Electricity efficicency improvement reduced $CO_2$ emission by 2.33 Mt. Electricity intensity effect reduced $CO_2$ emission by 21.85 Mt. Economic activity increased $CO_2$ emission by 28.27 Mt. We came to the conclusion that since economic activities contributed the most to the increase in $CO_2$ emissions from electrcity generations, energy efficiency improvement and diversification of energy souces to include renewable energy options should be encouraged by the countries government.

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