Received: 1 January 2023 | Revised: 9 February 2023 | Accepted: 15 February 2023 | Published online: 17 February 2023

Green and Low-Carbon Economy
2023, Vol. 1(2) 52–59
DOI: 10.47852/bonviewGLCE3202622
BON VIEW PUBLISHING

RESEARCH ARTICLE

# $CO_2$ Emissions Decoupling from Added-Value Growth in the Chemical and Pharmaceutical (CHPH) Industry in Nigeria

**Fidelis I. Abam[1,*], Oliver Ibor Inah[2], Ekwe B. Ekwe[3], Dodeye I. Igbong[4], Samuel O. Effiom[2], Friday A. Ovat[2], Oku E. Nyong[2] and Ikem A. Ikem[2]**

[1]*Department of Mechanical Engineering, University of Calabar (Calabar), Nigeria*

[2]*Mechanical Engineering, Cross River State University (Calabar), Nigeria*

[3]*Mechanical Engineering, Covenant University, Nigeria*

[4]*Mechanical Engineering, Cross River State University, Nigeria*

**Abstract:** Nigeria's in its Third National Communication current emissions estimate that its emissions intensities will continuously increase till 2030, and mitigations measures may not be deep and adequate to meet the upper range of its national reduction goals. Analyzing the decoupling states with industrial added-value (IAV) growth, carbon emissions (CE), and the driving forces from a firm-level perspective is critical for the Nigerian state to actualize its 2030 emission reduction objective. Based on the logarithmic mean Divisia index procedure and the Tapio index approach, the drivers of CE in Nigeria's chemical and pharmaceutical (CHPH) industry were decomposed, and the decoupling states were measured between 2000 and 2020. The results show that CE increased from 4228.3 Mt in 2000 to 22,220.7 Mt in 2020, an approximately 4.3% increase. The IAV growth in this period increased by 1.667%, while the coefficient of emission contracted in 2009 with an average progression rate of 4.4%. The decomposition analysis shows that the most influencing factors of CE were the change in the energy mix (ΔEMIX) and energy intensity (ΔEI) effects. In contrast, the carbon emissions coefficient (ΔCI) effect was the significant driver that reduced $CO_2$ emission. Two decoupling states were revealed: expansive negative decoupling (END) and strong negative decoupling. Conversely, overall, the CE of Nigeria's CHPH industry demonstrated an END state with IAV growth. This suggests that the industry's energy consumption increased faster than value-added, with the resultant effect of emissions on the environment. However, the study made clear recommendations for low-carbon policy and environmental sustainability.

**Keywords:** decoupling, energy mix, low-carbon, policy, Nigeria

## 1. Introduction

Nigeria's greenhouse gas (GHG) emissions increased by 11% between 1990 and 2017 (Enerdata, 2020). Also, current emission forecasts based on the reviewed baseline and low-carbon scenario of Nigeria's Third National Communication show that the country's emission intensities will continue to increase till 2030, and mitigation procedures will not be profound enough to scale up with her national mitigation standard (FMEN, 2020; Gütschow et al., 2019). As such, Nigeria, like other countries of the world, is currently seeking sustainable measures that will foster economic growth while ensuring environmental sustainability (Inah et al., 2022). GHGs are the critical driving elements promoting global warming, of which $CO_2$ accounts for about 56% of aggregate GHGs (IPCC, 2014), which is further projected to increase by 30% in 2030 (Dong et al., 2018). Although the COVID-19 pandemic weakened consumer demand and supply chain, resulting in energy demand decline and impacting global economic advancement, the pandemic also played a decisive role in the global carbon emissions (CE) decrease in the interim and may further stall the mitigation potentials of CE in the long run (Wang & Zhang 2021; Wang & Su 2020). In Nigeria, among the 13 sub-sectors that make up the country's manufacturing sector, the chemical and pharmaceutical (CHPH) industry has been indispensable and critical in terms of value addition in the last 4 years (NESG, 2021). Nevertheless, despite the industry's role in economic progression, the associated environmental pollution accompanied by this development has not been explored and cannot be ignored. Moreover, with the continuous drive to limit emissions globally, there is a dearth of published works considering the CHPH industry in terms of their contribution to the global carbon footprint (Belkhir & Elmeligi, 2018). Similarly, intensifying the fight toward $CO_2$ emission reduction, strategic approaches involving policy, regulatory, and institutional

*Corresponding author: Fidelis I. Abam, Department of Mechanical Engineering, University of Calabar (Calabar), Nigeria. Email: fidelisabam@unical.edu.ng

frameworks and capacities are required. This highlights the need for emerging economies like Nigeria to implement more ambitious targets as pledged in the "Paris Agreement" in 2015.

Many studies have proposed different pathways for low-carbon and climate-resilient development, specifically in industrialized countries. One of which is developing emissions reduction policies targeting sectoral specifics (Gerbaulet et al., 2019; Jiang et al., 2019; Wen & Wang, 2019). Conventional production methods of the different industries are key to direct causes of CE (Yang et al., 2019) and, as such, vary significantly across industries, sectors, provinces, regions, and countries due to structural differences, technical innovation, energy consumption, and energy efficiency levels (Wang & Feng, 2017). Given the connection between economic progression and environmental sustainability, "decoupling" has recently caught scholarly attention as a crucial indicator for quantifying the interconnection between economic expansion and ecological pressure. Carbon decoupling refers to the interconnection between $CO_2$ emissions and the changes in economic development. A negative growth in $CO_2$ emission when the economy grows implies decoupling (Hua et al., 2023). "The OECD decoupling model" (OECD, 2002), Tapio decoupling model (Tapio, 2005), and the decoupling model based on the IPAT model (Zhong et al., 2010) are the commonly used decoupling approaches. However, the OECD decoupling model lacks explicit criteria as it is susceptible to decoupling elasticity (Zhao et al., 2017). Thus, the Tapio decoupling concept is preferable as the model permits a causative series decomposition of the indicators describing decoupling (Abam et al., 2021).

Different authors have presented decoupling studies. For instance, Zhao et al. (2016) decoupled CE ($CO_2$) and industrial progress from 1993 to 2013 in China: Their findings revealed a weak decoupling state, with the investment scale effects promoting $CO_2$ emissions significantly and inhibiting decoupling. Meng et al. (2021) decoupled $CO_2$ emissions in Chinese industries from economic growth between 1995 and 2019. The result indicates a continuous improvement in the decoupling states of industrial $CO_2$ emissions from economic expansion. Also, between 2016 and 2019, all provinces achieved industrial decoupling of $CO_2$ emissions from direct economic progression. The study by Hang et al. (2019) conducted from 1995 to 2015 shows that China's manufacturing industry experienced a decoupling growth trend between 1995 and 2015. Energy intensity (EI) is the potential dominant factor promoting the decoupling development. At the same time, the study of Liu et al. (2015) from 1996 to 2012 shows that energy-intensive sectors were weakly decoupled, and non-intensive sectors were strongly decoupled.

Additionally, several studies have employed decomposition methods, namely structural decomposition analysis (SDA) and Index decomposition analysis (IDA), to explore the driving forces of CE (Sun et al., 2019). The Index decomposition analysis (IDA) method proves to be widely applied compared to SDA techniques because of its advantages of (1) applicability where data are limited and (2) necessitating cumulative data for a selected industrial sector (Wang & Feng, 2017). The SDA model lacks a complete input–output table Ang & Zhang, (2000). The famous Index decomposition analysis (IDA) includes the IPAT model, Kaya identity, and the Laspeyres decomposition technique (Meyers et al., 2016). Numerous scholars (Zhao et al., 2017) have utilized these approaches to analyze energy-related CE at different levels. Also, the extended Kaya identity built on the logarithmic mean Divisia index (LMDI) method is more adaptable in recent times and is now widely employed in diverse fields of study, mainly in energy-related emissions studies covering the global manufacturing industry (Zhao et al., 2017; Zuo et al., 2020) due to its advantages. Furthermore, the LMDI proves more reliable than other index analysis methods due to its ability to ignore the residual term problem (i.e., perfect in decomposition), more flexible, and better suited to results explanation.

Moreover, Nigeria recently committed to cutting down approximately 20% of its GHGs emissions by 2030 with 45% transnational support. On the net-zero commitment, Nigeria is keen to reach net-zero emissions by 2060, whereas on the international methane pledge, the country aims to cut methane emissions by approximately 30% by 2030. Conversely, to achieve these objectives, Nigeria will require an adequate appraisal of her economic sectors in terms of emission trajectory and decoupling states for effective low-carbon initiatives. However, such studies are limited, as energy data at the firm level are scarce in Nigeria. To bridge the gap, this study aims to analyze the decoupling states between CE and industrial added-value (IAV) growth. In addition, the CHPH industry's driving forces from a firm-level standpoint between 2000 and 2020 are explored. The latter will enhance the practical policy framework in the CPHI in Nigeria.

## 2. Methodology and Data Description

### 2.1. Estimation of industrial energy-related $CO_2$ emissions

In this paper, the energy-related $CO_2$ emissions were calculated following the 2006 Intergovernmental Panel on Climate Change Gas Inventories (IPCC, 2006), as shown in Equation (1)

$$C^{tot} = \sum E_i * NCV_i * CEF_i * COF_i * \frac{44}{12} \tag{1}$$

where $C^{tot}$ is the total carbon emissions, $Mt$, $E_i$ is the terminal energy consumption of $i$ energy mix, $GJ$, $NCV_i$ is the average low calorific value (KJ/Kg), $CEF_i$ is the carbon emission coefficient (KgC/GJ), $COF$ is the carbon oxidation factor (%), and $\frac{44}{12}$ is the conversion coefficient between carbon and $CO_2$ (as shown in Table 1).

### 2.2. Kaya identity and the LMDI decomposition model of emissions drivers

The Kaya identity presents the relationship between $CO_2$ emissions and their influencing drivers: carbon emission coefficient (CEC), energy mix (EMIX), EI, IAV-per capita, and industrial scale (IS) (Kaya, 1989), respectively. The basic formulation of $CO_2$ emissions from the base year $C^{to}$ to the target year $C^T$ can be expressed as:

$$C^{tot} = \frac{C_i}{E_i} \times \frac{E_i}{E} \times \frac{E}{Q} \times \frac{Q}{P} \times P = CI \times EMIX \times EI \times IAV \times IS \tag{2}$$

where $C^{tot}$ is the total $CO_2$ emissions, $E_i$ is the share of i energy consumption, $E$ is the annual aggregate energy consumption, $Q$ is the annual added-value, and $P$ is the annual employees.

The LMDI decomposition technique has been extensively useful in the extant body of literature due to its robust hypothetical basis of consistency in aggregation and perfect decomposition (Ang & Liu, 2001). Applying the LMDI technique, the change in $CO_2$ emissions from a base year $C^{to}$ to a target year $C^T$ $\Delta C^{tot}(\Delta C^{tot} = C^T - C^{to})$ can be decomposed into five effects in the addictive form:

**Table 1**
**Emission factors for the different energy mix (SMCDR., 2022)**

| Energy source | NCV (KJ/Kg, KJ/m$^3$) | CEF (KgC/GJ) | COF (%) |
|---|---|---|---|
| Fuel | 43,070 | 18.90 | 98 |
| Diesel | 42,652 | 20.20 | 98 |
| Kerosene | 43,070 | 19.60 | 98 |

$$\Delta C^{tot} = C^T - C^{to} = \Delta C_{CEC} + \Delta C_{EMIX} + \Delta C_{EI} + \Delta C_{IAV} + \Delta C_{IS} \quad (3)$$

among which

$$\Delta C_{CEC} = (C^T,\ C^{to}) \times In\left[\frac{CEC^T}{CEC^{to}}\right] \quad (4)$$

$$\Delta\Delta C_{EMIX} = (C^T,\ C^{to}) \times In\left[\frac{EMIX^T}{EMIX^{to}}\right] \quad (5)$$

$$\Delta C_{EI} = (C^T,\ C^{to}) \times In\left[\frac{EI^T}{EI^{to}}\right] \quad (6)$$

$$\Delta C_{IAV} = (C^T,\ C^{to}) \times In\left[\frac{IAV^T}{IAV^{to}}\right] \quad (7)$$

$$\Delta C_{IS} = (C^T,\ C^{to}) \times In\left[\frac{IS^T}{IS^{to}}\right] \quad (8)$$

where $L(C^T,\ C^{to}) = \frac{C^T - C^{to}}{In(C^T - C^{to})}$ is called the logarithmic mean weight, and the contribution of the effect in (Equation (3)) is defined in Equation (11)

$$\sum_i \left(\frac{\Delta C_{CEC}}{\Delta C^{tot}} + \frac{\Delta C_{EMIX}}{\Delta C^{tot}} + \frac{\Delta C_{EI}}{\Delta C^{tot}} + \frac{\Delta C_{IAV}}{\Delta C^{tot}} + \frac{\Delta C_{IS}}{\Delta C^{tot}}\right) \times 100 \quad (9)$$

The variables on the right-hand side of Equation (3) are explained as follows:

(i) CEC effect ($\Delta C_{CEC}$), which denotes the changes in $CO_2$ emissions for each unit of energy consumed.
(ii) Energy mix effect ($\Delta C_{EMIX}$), which represents the changes in the relative shares of energy types in aggregate energy consumed.
(iii) EI effect ($\Delta C_{EI}$), which denotes the changes in the energy consumption ratio to its industrial value added.
(iv) IAV-per capita ($\Delta C_{IAV}$), which indicates the fractional changes in industry value-added to the labor population.
(v) The IS effect ($\Delta C_{IS}$) signifies the changes in the labor force.

## 2.3. Decoupling indicator

The measures to mitigate $CO_2$ emissions encompass $\Delta C_{CEC}$, $\Delta C_{EMIX}$, $\Delta C_{EI}$ , and $\Delta C_{IS}$. The decoupling indicator, $D^t$, for the sector is estimated as the proportion of the summation of all the drivers, which can decrease $CO_2$ emissions to the rise of CE. From Tapio (2005), the decoupling index of $i - th$ industry from year $T$ to year $t^0$ can be evaluated from Equation (10) and $\Delta Z^t$ is estimated as in Equation (11)

**Table 2**
**Measures of decoupling index**

| $\Delta Z^t$ | $\Delta C_{IAV}$ | $D^t$ | Decoupling status |
|---|---|---|---|
| $> 0$ | $> 0$ | $D^t 0$ | Expansive negative decoupling (END) |
| $< 0$ | $> 0$ | $0 > D^t - 0.4$ | Expansive coupling (EC) |
| $< 0$ | $> 0$ | $-0.4 > Dt - 0.1$ | Weak decoupling (WD) |
| $> 0$ | $> 0$ | $-1 > D^t$ | Strong decoupling (SD) |
| $> 0$ | $< 0$ | $D^t \leq 0$ | Strong negative decoupling (SND) |
| $< 0$ | $< 0$ | $0.4D^t > 0$ | Weak negative decoupling (WND) |
| $< 0$ | $< 0$ | $1D^t > 0.4$ | Recessive coupling (RC) |
| $< 0$ | $< 0$ | $D^t > 0$ | Recessive decoupling (RD) |

$$D^t = \frac{\Delta Z^t}{\Delta C_{IAV}} \quad (10)$$

$$\Delta Z^t = D^t \Delta C_{CEC} + D^t \Delta C_{EMIX} + D^t \Delta C_{EI} + D^t \Delta C_{IS} \quad (11)$$

where $\Delta C_{CEC}$, $\Delta C_{EMIX}$, $\Delta C_{EI,}$ and $D^t \Delta C_{IS}$ measure the effects of each indicator. Accordingly, the Tapio decoupling criteria are presented in Table 2 (Song et al., 2019).

The $CO_2$ emission of the CHPH industry that is driven by the energy mix effect ($\Delta C_{EMIX}$) is expressed as theoretical energy consumption share. Consequently, the mitigation or reduction rate of $CO_2$ ($MRC^t$), according to Peng et al. (2022) of the CHPH industry during ($C^T$, $C^{to}$), is expressed in Equation (12), and the following rules in Table 3 apply:

$$MRC^t = \frac{-\Delta Z^t}{C^{to} + \Delta C_{IAV}} \times 100 \quad (12)$$

## 2.4. Data description

The research used annual time series data of industrial energy consumption collected from the Manufacturing Association of Nigeria annual reports (MAN, 2000) from 2000 to 2020. The data for energy, the share of labor, and industrial value added are obtained from the CHPH industry periodic financial report listed in the NBS (National Bureau of Statistics bulletin).

# 3. Results and Discussion

## 3.1. Nigeria's CHPH industry characteristics and emissions trajectory

Figure 1 presents the energy consumption and $CO_2$ emissions of Nigeria's CHPH industry between 2000 and 2020. The $CO_2$ emissions

**Table 3**
**Criteria for $CO_2$ emissions reduction (Peng et al. 2022)**

| $\Delta Z^t$ | $MRC^t$ | Remarks |
|---|---|---|
| $< 0$ | $> 0$ | $CO_2$ emission has been alleviated in time |
| $> 0$ | $< 0$ | $CO_2$ emission has not been effectively mitigated |
| | If $MRC^t$ is minimal | Implying that the mitigation rate of $CO_2$ is lower and the problem of $CO_2$ emission has not been improved |

**Figure 1**
**Energy consumption variation and $CO_2$ emissions of Nigeria's CHPH**

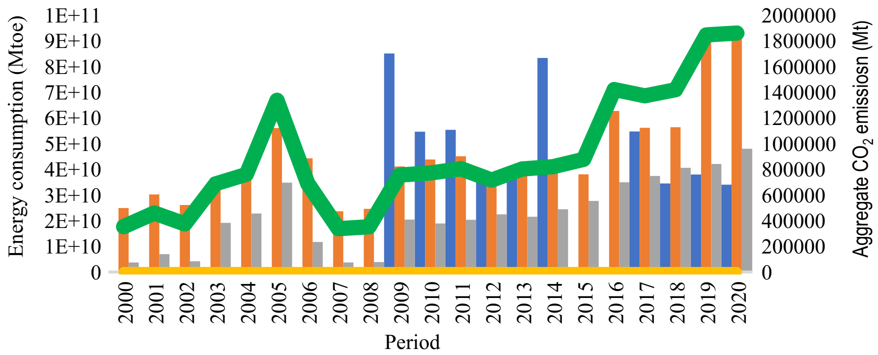
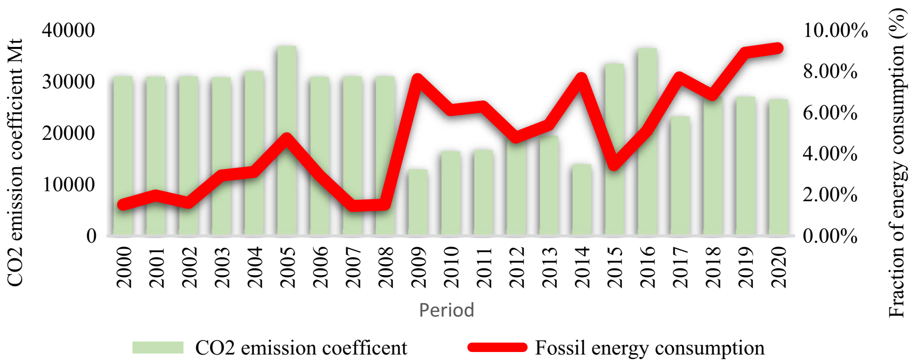



**Figure 2**
**$CO_2$ emission coefficient (CEC) and fossil fuel energy share in the CHPH**




increased by approximately 4.3% increase from 2000 to 2020. The $CO_2$ curve is divided into three phases: the initial sharp growth phase (2000–2005), the sharp decline phase (2005–2007), and the slow growth phase (2008–2020). In that order, the annual average $CO_2$ emissions growth rate for the three phases was 0.04%, 0.04%, and 0.06%. Figure 2 presents the CEC and fossil fuel energy share in the CHPH industry. The CEC was sustained between 2000 and 2008 and decreased from 0.00332 Mt/Mtoe in 2010 to 0.00308 Mt/Mtoe in 2014. Overall, the highest CEC values were obtained at 0.00879 Mt/Mtoe in 2005 and the lowest at 0.003084 Mt/Mtoe in 2009. The latter implies that during these periods, little effort has been made in clean energy development and utilization, as well as enhancement in fuel quality, type and technology by the sector.

Figure 3 shows that between 2000 and 2020, Nigeria's CHPH industry value-added expanded, although with some fluctuations across the periods. The economic productivity increased from 25,232,108 in 2000 to 35,028,102 billion Naira in 2020, resulting in a 1.66% rise. Moderate growth was observed from 2000 to 2005, slow growth from 2006 to 2012, rapid growth from 2012 to 2017, and a sharp decline from 2017 to 2020. From 2006 to 2012, the $CO_2$ emissions intensity decreased slowly. During this period, the industrial value-added grew more rapidly than the rate of energy consumption levels, which further translated into a decrease in $CO_2$ emissions intensity. The technological progression between 2017 and 2020 promoted energy efficiency, as the industry value-added increased from 20,790,736 billion Naira to 35,028,102 billion Naira. While Figure 4 shows that the industrial value added (IVA) IS of the CHPH industry demonstrated a varying trend between 2000 and 2007, then rose slowly from 4.37% in 2008 to 5.40% in 2014. The industry observed an improvement in production efficiency (labor productivity) ascribed to the technological drive in 2017, as 5.76% of the labor force was engaged in the CHPH industry.

## 3.2. Decomposition analysis of $CO_2$ emissions influencing factors

Figure 5 shows that the energy mix effect ($\Delta$EMIX) was the major driving factor that promoted $CO_2$ emissions in the CHPH industry. The effect of energy intensity ($\Delta$EI) also promoted $CO_2$ emissions by 40.40%. The effect caused by $\Delta$EMIX was about 205.24%, while the carbon emissions coefficient ($\Delta$CEC) was the critical driver that inhibited $CO_2$ emissions by −172.24%. The result is inconsistent with the conclusion of Peng et al. (2022). They concluded that the EI effect was the most significant factor that inhibited $CO_2$ emissions. However, the IAV effect ($\Delta$IAV) and the IS effect ($\Delta$IS) were weak in promoting $CO_2$ emissions. Also, the $\Delta$EI only reduced $CO_2$ emissions from 2000 to 2005 by about −6.671E-9 GJ, equivalent to −49.43%, with economic output expanded by 4.7%. Thus, this period could be described as having higher production and energy efficiency. In the subsequent periods of 2005–2010, the role of $\Delta$IS, $\Delta$IAV effects in mitigating $CO_2$ emissions was weaker.

**Figure 3**
**Industrial value-added and $CO_2$ emissions intensity**

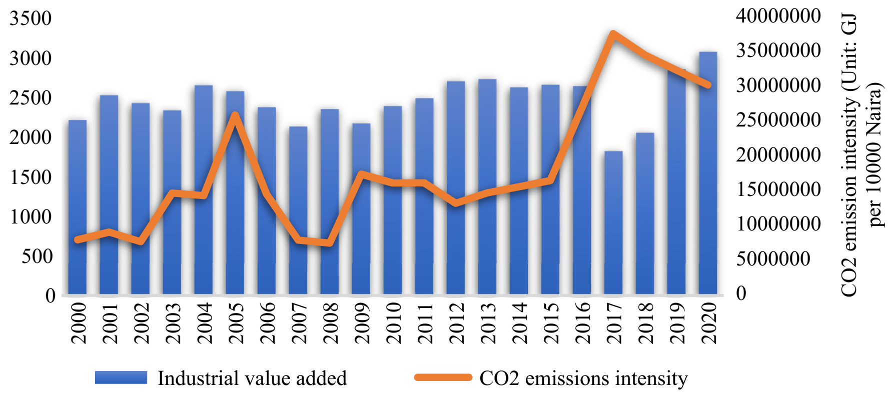



**Figure 4**
**Share of labor and industrial value-added**

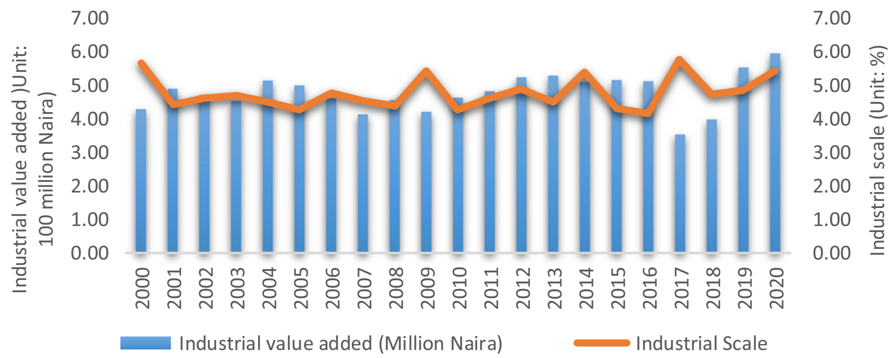



**Figure 5**
**Decomposition of carbon emissions ($CO_2$) from Nigeria's CHPH from 2000 to 2020**

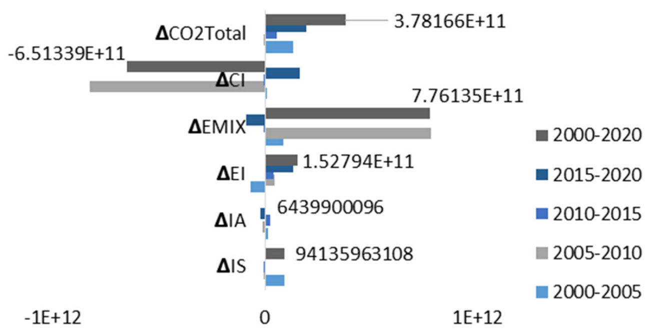



**Table 4**
**Decoupling results of $CO_2$ emissions from Nigeria's CPHI**

| Period | $\Delta Z^t$ | $\Delta C_{IAV}$ | $Dt$ | $Dt$ | Decoupling status |
|---|---|---|---|---|---|
| 2000–2005 | 1.19E-10 | 1.56E-10 | 7.67 | 7.669 | END |
| 2005–2010 | 5.7E-9 | −1.29E-10 | −0.44 | −0.442 | SND |
| 2010–2015 | 2.89E-10 | 2.66E-10 | 1.09 | 1.088 | END |
| 2015–2020 | 2.18E-11 | −2.28E-10 | -9.53 | -9.529 | SND |
| 2000–2020 | 3.72E-11 | 6.4E-9 | 57.72 | 57.722 | END |

## 3.3. Decoupling analysis, drivers' contribution to decoupling and mitigation possibilities

Table 4 presents the decoupling results of CE from Nigeria's CHPH industry from 2000 to 2020. Two decoupling states were observed: expansive negative decoupling (END) and strong negative decoupling (SND). From 2000 to 2005 and 2010 to 2015, the CHPH industry went through an END state, decoupling values at 7.67 and 1.09, respectively. The latter suggests that the energy consumption (EC) of the CHPH industry increased faster than value-added, which rein to the increase and decrease in $CO_2$ emissions in these periods. Similarly, the industry transited into an SND state from 2005 to 2010 and 2015 to 2020, with decoupling values at −0.44 and −9.53, respectively. The period indicates that $CO_2$ emissions increased faster while industrial value addition declined. Overall, from 2000 to 2020, the $CO_2$ emissions of Nigeria's CHPH industry show an END state with economic expansion and the decoupling index estimated at 58.7. Similarly, the decoupling degree of the IS effect ($Dt_{\Delta IS}$) was between 0 and 5 for the whole research period, which suggests that the $CO_2$

emission growth rate caused by the IS effect was higher than the value-added. The value of $Dt_{\Delta EI}$ ranges between −0 and 1. The average contribution rate of the decoupling indicator for EI is 41.1%; the decoupling indicator for $Dt_{\Delta EMIX}$ was −0 to 5, thus playing the same role as $Dt_{\Delta IS.}$ However, the average contribution rate was 208.8%. The value of $Dt_{\Delta CEC}$ maintained 0.5 to 65, with an average contribution rate of −175.2%. Indicating a decline in $_{\Delta CEC}$ promoted the decoupling of $CO_2$ emissions and industrial value-added in the CHPH industry. However, during the sub-periods 2000–2005, 2005–2010, 2010–2015, and 2015–2020, the mitigation rates of CE were 49.97%, 0.61%, 14.94%, and 70.56%. CHPH industry grew faster than value addition as environmental pollution was propelled by direct emissions from fossil-based energy: fuel oil, diesel, and kerosene, which collectively accounted for 0.923 Mtoe, about 99.98% of the aggregate $CO_2$ emissions. Hence, optimizing the energy mix through energy efficiency improvement and reducing workforces resulting from the industrial transformation remain significant in mitigating $CO_2$ emissions (Peng et al., 2022).

### 3.4. Discussion

Nigeria recently committed at the COP26 of 2021 to limit 30% of her emissions by 2030 and net-zero emissions by 2060 in compliance with the Paris Agreement. As a nation, fossil energy constitutes about 25% of its energy mix, with per capita GHG emissions estimated at 3.37 $tCO_2eq$ as of 2017. In line with the commitment, the Federal Executive Council recently signed into law the country's Energy Transition Plan (ETP), which sought to define a pathway to attaining its 2060 net-zero target. The ETP seek to pull over 100 million citizens from poverty line via economic expansion, linking her citizens to modern energy services, and dealing with potential job loss in the oil sector owing to the global decarbonization needs. However, following Nigeria's over-dependence on fossil-based energy in the past two eras, it thus beholds that the 2030 emissions reduction target is unrealistic. The effects of energy choice and substitution might be promising; however, a single choice is insufficient to accomplish the targeted emission reduction benchmark. As demonstrated in our result, energy mix and EI effects were the primary drivers that increased $CO_2$ emissions, which agrees with previous studies (Fatima et al., 2019; Shao et al., 2014). Although the CHPH industry's high dependence on fossil fuels makes it a great task to transition from fossil-based energy to renewable energy even when the possibility of utilizing renewable energy sources is vast in the country. Thus, even though the ETP is yet to be fully implemented, it calls for the Nigerian government to make substantial efforts through strong political willingness, public sensitization of low-carbon régime, and administrative capacities through policy implementation, energy mix diversification, and broader integration of renewable energy as earlier suggested by Zhang et al. (2020).

## 4. Conclusion and Policy Recommendations

As an indispensable and critical industry of the manufacturing sector and Nigeria's economic growth in value creation, the CHPH industry is also one of the significant users of Nigeria's energy mix. Also, to foster economic expansion while guaranteeing the environmental sustainability of the CHPH industry, the paper studied the drivers of $CO_2$ emissions, decoupling states, and emissions decrease possibilities of Nigeria's CHPH industry. Using the LMDI technique, the influencing drivers of $CO_2$ emissions from the CHPH industry were analyzed between 2000 and 2020. The results indicate that the $CO_2$ emissions of the CHPH industry increased by approximately 4.3% from 2000 to 2020. The $CO_2$ emissions were divided into three phases. Overall, the annual average $CO_2$ emissions growth rate for the three phases was 0.04%, 0.04%, and 0.06%, in that order. From 2000 to 2008, the CEC was sustained and decreased from 0.00332 Mt/Mtoe in 2010 to 0.00308 Mt/Mtoe in 2014. The highest CEC values were obtained at 0.00879 Mt/Mtoe in 2005 and the lowest at 0.003084 Mt/Mtoe in 2009. Nonetheless, the economic productivity increased from 25,232,108 in 2000 to 35,028,102 billion Naira in 2020, resulting in a 1.66% rise, while moderate growths were observed from 2000 to 2005, slow growth from 2006 to 2012, rapid growth from 2012 to 2017, and a sharp decline from 2017 to 2020. Furthermore, the technological progression between 2017 and 2020 promoted energy efficiency, as the industry value-added increased from 20,790,736 billion Naira to 35,028,102 billion Naira. Accordingly, the findings show that the energy mix effect was the significant driver that promoted $CO_2$ emissions, while the carbon emissions coefficient was the critical driver that inhibited $CO_2$ emissions. The study reveals two decoupling states: END and SND. Overall, the $CO_2$ emissions of Nigeria's CHPH industry demonstrated an END state with value-added economic expansion. During the sub-periods 2000–2005, 2005–2010, 2010–2015, and 2015–2020, the mitigation rates of CE were 49.97%, 0.61%, 14.94%, and 70.56%. Signifying that the growth rate of fossil energy consumption grew faster than value-added, as direct emissions from fossil-based energy propelled environmental pollution: fuel oil, diesel, and kerosene, which collectively accounted for 0.923 Mtoe, about 99.98% of the aggregate $CO_2$ emissions. Finally, strengthened mitigation measures of $CO_2$ emissions in the CHPH industry are of the essence as it is evident from our results that the Nigeria space and, in particular, the CHPH industry are over-dependent on fossil fuel energy as a significant energy carrier.

In conclusion, and based on our findings, some salient approaches to reducing CE in the CHPH industry are suggested as follows:

1. Expanding ISs and improving economic expansion are of significance. But, in addition, diversification, energy structure adjustment, and vigorously promoting optimization through technological drive are the most significant path to curbing CE in the interim.
2. From our results, EI has increased, resulting in an up-shoot in emissions levels. Thus, compared with other developed countries studies, Nigeria's CHPH industry energy and carbon intensity with respect to value-added remains high. Therefore, new strategies such as the development of low-carbon initiatives through a highly energy-efficiency technology drive will be the most effective approach to promote a change in industries' $CO_2$ emissions from an END to a strong decoupling state.
3. Other approaches include reducing the ratio of industries depending on fossil fuel consumption by strictly controlling the expansion of production capacity in high-energy-consumption industrial firms and implementing different energy consumption policies for them. This could be achieved by awarding environmental tax and financial incentives to industries willing to be "green."
4. Finally, there are several prospects for the paper. First, further studies could enrich the present study by integrating more firm-level drivers, such as capacity utilization, into the CHPH industry decomposition model. In addition, the research methods of this study could be enhanced by considering the multiplicative LMDI and econometrics approaches.

## Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

## References


Abam, F. I., Ekwe, E. B., Diemuodeke, E. O., Ofem, M. I., Okon, B. B., Kadurumba, C. H. . . . , & Ukueje, W. E. (2021). Environmental sustainability of the Nigeria transport sector through decomposition and decoupling analysis with future framework for sustainable transport pathways. *Energy Reports*, *7*, 3238–3248. https://doi.org/10.1016/j.egyr.2021.05.044

Ang, B. W. (2015). LMDI decomposition approach: A guide for implementation. *Energy Policy*, *86*, 233–238. https://doi.org/10.1016/j.enpol.2015.07.007

Ang, B., & Liu, F. (2001). A new energy decomposition method: Perfect in decomposition and consistent in aggregation. *Energy*, *26*(6), 537–548. https://doi.org/10.1016/S0360-5442(01)00022-6

Ang, B., & Zhang, F. (2000). A survey of index decomposition analysis in energy and environmental studies. *Energy*, *25*(12), 1149–1176. https://doi.org/10.1016/S0360-5442(00)00039-6

Belkhir, L., & Elmeligi, A. (2019). Carbon footprint of the global pharmaceutical industry and relative impact of its major players. *Journal of Cleaner Production*, *214*, 185–194. https://doi.org/10.1016/j.jclepro.2018.11.204

Dong, F., Long, R., Yu, B., Wang, Y., Li, J., Wang, Y. . . . , & Chen, H. (2018). How can China allocate $CO_2$ reduction targets at the provincial level considering both equity and efficiency? Evidence from its Copenhagen accord pledge. *Resource Conservation and Recycling*, *130*, 31–43. https://doi.org/10.1016/j.resconrec.2017.11.011

Peng, D., Yi, J., Chen, A., Chen, H., & Yang, J. (2022). Decoupling trend and emission reduction potential of $CO_2$ emissions from China's petrochemical industry. *Environmental Science and Pollution Research*, 30, 23781–23795. https://doi.org/10.1007/s11356-022-23869-x.

Enerdata. (2020). Global energy and CO2 data. Retrieved from https://www.enerdata.net/research/energymarket-data-co2-emissions-database.html

Fatima, T., Xia, E., Cao, Z., Khan, D., & Fan, J. (2019). Decomposition analysis of energy-related $CO_2$ emission in the industrial sector of China: Evidence from the LMDI approach. *Environmental Science Pollution Research*, *26*, 21736–21749. https://doi.org/10.1007/s11356-019-05468-5.

FMEN. (2020). Third National Communication (TNC) of the Federal Republic of Nigeria under the United Nations Framework Convention on Climate Change (UNFCCC). Retrieved from https://newsroom.unfccc.int/documents/226453.

Gerbaulet, C., von Hirschhausen, C., Kemfert, C., Lorenz, C., & Oei, P. (2019). European electricity sector decarbonization under different levels of foresight. *Renewable Energy*, *141*, 973–987. https://doi.org/10.1016/j.renene.2019.02.099

Gütschow J., Jeffery L., Gieseke R., & Günther A. (2019). The PRIMAP hist national historical emissions time series (1850–2017). V. 2.1. Retrieved from: https://dataservices.gfz-potsdam.de/pik/showshort.php?id=escidoc:4736895.

Hang, Y., Wang, Q., Zhou, D., & Zhang, L. (2019). Factors influencing the progress in decoupling economic growth from carbon dioxide emissions in China's manufacturing industry. *Resources, Conservation & Recycling*, *146*, 77–88. https://doi.org/10.1016/j.resconrec.2019.03.034

Hua, J., Gao, J., Chen, K., & Li, J. (2023). Driving effect of decoupling provincial industrial economic growth and industrial carbon emissions in China. *International Journal of Environmental Research and Public Health*, *20*(1), 145. https://doi.org/10.3390/ijerph20010145

Inah, O. I., Abam, F. I., & Nwankwojike, B. N. (2022). Exploring the $CO_2$ emissions drivers in the Nigerian manufacturing sector through decomposition analysis and the potential of carbon tax (CAT) policy on $CO_2$ mitigation. *Future Business Journal*, *8*, 61. https://doi.org/10.1186/s43093-022-00176-y

IPCC. (2006). *IPCC Guidelines for National Greenhouse Gas Inventories*. UK: Cambridge University Press.

IPCC. (2014). Greenhouse gas inventory: IPCC guidelines for national greenhouse gas inventories.

Jiang, M., Gao, X., Guan, Q., Hao, X., & An, F. (2019). The structural roles of sectors and their contributions to global carbon emissions: A complex network perspective. *Journal of Cleaner Production*, *208*, 426–435. https://doi.org/10.1016/j.jclepro.2018.10.127

Kaya, Y. (1989). Impact of carbon dioxide emission control on gnp growth: Interpretation of proposed scenarios. *Intergovernmental Panel on Climate Change/Response Strategies Working Group, May*.

Liu, Q., Liu, S., & Kong, L. (2015). Decomposition and decoupling analysis of energy-related carbon emissions from China manufacturing. *Mathematical Problems in Engineering*, *2015*. http://dx.doi.org/10.1155/2015/268286.

Lu, M., Wang, X., & Cang, Y. (2018). Carbon productivity: Findings from industry case studies in Beijing. *Energies*, *11*(10), 2796.

MAN. (2000). Manufacturers Association of Nigeria-Membership profile available. Retrieved from https://www.manufacturersnigeria.org/membership.htm.

Meng, D., Li, Y., Zheng, J., Li, Z., Ye, H., & Li, S. (2021). Decoupling analysis of $CO_2$ emissions in the industrial sector from economic growth in China. *Energies*, *14*(16), 5099. https://doi.org/10.3390/en14165099

Meyers, S., Schmitt, B., Chester-Jones, M., & Sturm, B. (2016). Energy efficiency, carbon emissions, and measures towards their improvement in the food and beverage sector for six European countries. *Energy*, *104*, 266–283. https://doi.org/10.1016/j.energy.2016.03.117

NESG. (2021). Sectoral Reforms and Investments in Nigeria: A focus on the Manufacturing Sector.

OECD. (2002). Indicators to measure decoupling of environmental pressure from economic growth.

Raza, M. Y., & Lin, B. (2022). Analysis of Pakistan's electricity generation and $CO_2$ emissions: Based on decomposition and decoupling approach. *Journal of Cleaner Production*, *359*, 132074. https://doi.org/10.1016/j.jclepro.2022.132074

Shao, W., Keim, B. D., Garand, J. C., & Hamilton, L. C. (2014). Weather, Climate, and the Economy: Explaining Risk Perceptions of Global Warming, 2001–10. *Weather, Climate, and Society*, *6*(1), 119–134. https://doi.org/10.1175/WCAS-D-13-00029.1

SMCDR. (2022). Method of Accounting and Reporting Greenhouse Gas emissions in Shanghai Electric Power and Thermal Power Production Industry. Retrieved from: http://www.shdrc.gov.cn/jw_admin/upload/myupload_2206.doc

Song, Y., Zhang, M., & Shan, C. (2019). Research on the decoupling trend and mitigation potential of $CO_2$ emissions from China's transport sector. *Energy*, *183*, 837–843. https://doi.org/10.1016/j.energy.2019.07.011

Sun, Z, Liu Y., & Yu, Y. (2019). China's carbon emission peak pre-2030: Exploring multi-scenario optimal low-carbon behaviors for China's regions. *Journal of Cleaner Production*, *231*, 963–979. https://doi.org/10.1016/j.jclepro.2019.05.159

Tapio, P. (2005). Towards a theory of decoupling: Degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001. *Transport Policy*, *12*, 137–151. https://doi.org/10.1016/j.tranpol.2005.01.001

Wang M., & Feng C. (2017). Decomposition of energy-related $CO_2$ emissions in China: An empirical analysis based on provincial panel data of three sectors. *Applied Energy*, *190*, 772–787. https://doi.org/10.1016/j.apenergy.2017.01.007

Wang, Q., & Su, M. (2020). A preliminary assessment of the impact of COVID-19 on environment -A case study of China. *Science of the Total Environment*, *728*, 138915. https://doi.org/10.1016/j.scitotenv.2020.138915

Wang, Q., & Zhang, F. (2021). The effects of trade openness on decoupling carbon emissions from economic growth-evidence from 182 countries. *Journal of Cleaner Production*, *279*, 123838. https://doi.org/10.1016/j.jclepro.2020.123838.

Wen, W., & Wang, Q. (2019). Identification of key sectors and key provinces at the view of $CO_2$ reduction and economic growth in China: Linkage analyses based on the MRIO model. *Ecological Indicators*, *96*, 1–15. https://doi.org/10.1016/j.ecolind.2018.08.036

Wu, Y., Tam, V. W., Shuai, C., Shen, L., Zhang, Y., & Liao, S. (2019). Decoupling China's economic growth from carbon emissions: Empirical studies from 30 Chinese provinces (2001–2015). *Science of The Total Environment*, *656*, 576–588. https://doi.org/10.1016/j.scitotenv.2018.11.384

Yang, K., Yi, J., Chen, A., Liu, J., & Chen, W. (2021). ConDinet++: Full-scale fusion network based on conditional dilated convolution to extract roads from remote sensing images. *IEEE Transactions on Geoscience and Remote Sensing*, *19*, 1–5. https://doi.org/10.1109/LGRS.2021.3093101

Zhang, J., Fan, Z., Chen, Y., Gao, J., & Liu, W. (2020). Decomposition and decoupling analysis of carbon dioxide emissions from economic growth in the context of China and the ASEAN countries. *Science of the Total Environment*, *714*, 136649. https://doi.org/10.1016/j.scitotenv.2020.136649

Zhao, X., Zhang, X., & Shao, S. (2016). Decoupling $CO_2$ emissions and industrial growth in China over 1993–2013: The role of investment. *Energy Economics*, *60*, 275–292. https://doi.org/10.1016/j.eneco.2016.10.008.

Zhao, X., Zhang, X., Li, N., Shao, S., & Geng, Y. (2017). Decoupling economic growth from carbon dioxide emissions in China: A sectoral factor decomposition analysis. *Journal of Cleaner Production*, *142*, 3500–3516. https://doi.org/10.1016/j.jclepro.2016.10.117

Zhao, Y., Li, H., Zhang Z., Zhang, Y., Wang, S., & Liu, Y. (2017). Decomposition and scenario analysis of $CO_2$ emissions in China's power industry: Based on LMDI method. *Natural Hazards*, *86*, 645–668. https://doi.org/10.1007/s11069-016-2710-5

Zhong, T. Y., Huang, X. J., & Wang, B. Y. (2010). Analysis of decoupling between economic growth and construction land expansion. *Natural Resources*, *25*, 18–31.

Zuo, Z., Guo, H., & Cheng, J. (2020). An LSTM-STRIPAT model analysis of China's 2030 $CO_2$ emissions peak. *Carbon Management*, *11*(6), 577–592. https://doi.org/10.1080/17583004.2020.1840869

**How to Cite:** Abam, F. I., Inah, O. I., Ekwe, E. B., Igbong, D. I., Effiom, S. O., Ovat, F. A., Nyong, O. E., & Ikem, I. A. (2023). $CO_2$ Emissions Decoupling from Added-Value Growth in the Chemical and Pharmaceutical (CHPH) Industry in Nigeria. *Green and Low-Carbon Economy* 1(2), 52–59, https://doi.org/10.47852/bonviewGLCE3202622