Geografia-Malaysian Journal of Society and Space 22 issue 1 (40-53)
© 2026, e-ISSN 2682-7727 https://doi.org/10.17576/geo-2026-2201-03

Environmental footprints of greenhouse gas emissions during pre and post Intended Nationally Determined Contributions in Nigeria

Abdullahi Chado Salihu[1,2], Ayuba Musa Mshelia[3], Danbaba Goma[4], Mokhtar Jaafar[5]

[1]Department of Meteorology and Climate Change,
African Aviation and Aerospace University (AAAU)
[2]African Centre for Climate Change and Aviation Decarbonization,
African Aviation and Aerospace University (AAAU)
[3]Department of Environmental Management, Nigerian Army University
[4]Department of Environmental Management, Bingham University
[5]Geography Program, Faculty of Social Sciences and Humanities,
Universiti Kebangsaan Malaysia

Correspondence: Abdullahi Chado Salihu (salihu.chado@aaau.edu.ng)

Received: 15 February 2025; Accepted: 4 January 2026; Published: 25 February 2026

Abstract

Nigeria's significant role in regional and global climate dynamics underscores the importance of understanding its emission trends across key sectors. Despite the country's commitment to climate action, uncertainties remain regarding the actual effectiveness of its mitigation efforts, particularly following the adoption of its Intended Nationally Determined Contributions (INDCs). Therefore, this study evaluates the effectiveness of Nigeria's climate policies by analyzing sectoral greenhouse gas (GHG) emissions trends before (2011-2015) and after (2016-2020) the implementation of its Intended Nationally Determined Contributions (INDCs). National-level emissions data sourced from the Emissions Database for Global Atmospheric Research (EDGAR), sector-specific emissions were analyzed using descriptive statistics and paired t-tests to assess changes pre- and post-INDCs. Results indicate varied sectoral responses: while emissions from the buildings sector decreased post-INDCs, reflecting potential policy impacts on energy efficiency, the transport sector exhibited fluctuating patterns. Statistical analyses revealed significant emission reductions in the buildings and power industry sectors post-INDCs, highlighting policy effectiveness in these areas. However, other sectors showed stable emissions, indicating persistent challenges in achieving comprehensive reductions. These findings underscore the necessity for tailored climate policies addressing sector-specific dynamics to enhance Nigeria's contributions to global climate goals under the Paris Agreement. It is advocated that continuous monitoring and evaluation of sectoral emissions are essential for informing targeted policy interventions and sustainable development strategies.

Keywords: Environmental footprints, greenhouse gas emissions, Intended Nationally Determined Contributions, Nigeria

Introduction

As the global community grapples with the urgency of mitigating climate change, the role of nations in curbing greenhouse gas (GHG) emissions has become increasingly paramount. The Paris Agreement, a historic pact aimed at limiting global temperature rise to well below 2 degrees Celsius above pre-industrial levels, heralded a new era of concerted efforts towards sustainability (Adelekan et al., 2020). Central to this agreement are Nationally Determined Contributions (NDCs), wherein countries outline their commitments and strategies to combat climate change. The international discourse on climate change mitigation has increasingly emphasized the crucial role of Intended Nationally Determined Contributions (INDCs) in curbing greenhouse gas emissions (Smith et al., 2020). As nations strive to meet their climate commitments under the Paris Agreement, understanding the effectiveness of these contributions is paramount.

Nigeria, as the most populous country in Africa and a significant contributor to greenhouse gas emissions on the continent, plays a pivotal role in shaping regional and global climate outcomes (Jones & Johnson, 2018). Despite its status as a developing nation, Nigeria faces increasing pressure to transition towards a low-carbon economy to mitigate the adverse effects of climate change. Thus, Nigeria's Intended Nationally Determined Contribution (INDC), which it submitted as a requirement to the Paris Agreement, became its NDC in March 2017, after ratification of the Paris Agreement by the Federal Government. As one of the signatories to the Paris Agreement, it has pledged to reduce its greenhouse gas emissions through its INDCs (Adams et al., 2019). The adoption of its INDC represents a critical step in this transition, providing a framework for national climate action plans and emission reduction targets. However, the effectiveness of these commitments hinges on their implementation and enforcement, factors that are subject to various socio-economic, political and environmental dynamics (Brown & Green, 2021).

The literature on climate change mitigation and policy implementation in Nigeria reveals a growing interest in understanding the country's environmental challenges and the effectiveness of its climate commitments. While some studies have explored broader aspects of Nigeria's climate policy framework and vulnerability to climate change impacts, there is a noticeable dearth of research focusing specifically on the comparative analysis of greenhouse gas (GHG) emissions during the pre- and post-Intended Nationally Determined Contributions (INDCs) implementation. Several studies have highlighted the importance of INDCs in guiding national climate policies and enhancing transparency in emission reporting (UNFCCC, 2015). However, empirical evidence on their actual impact on greenhouse gas emissions in Nigeria remains limited. Existing literature primarily focuses on the development and content of Nigeria's INDCs, with few studies evaluating their implementation and effectiveness in reducing emissions. For instance, a study by Adejuwon (2018) examined the content of Nigeria's INDCs and identified key sectors targeted for emission reductions, such as energy, agriculture and waste management. While this study provided valuable insights into Nigeria's climate commitments, it did not assess their actual impact on emission levels. Similarly, research by Ojo and Aderinto (2020) explored the challenges hindering the implementation of Nigeria's INDCs, including institutional capacity gaps, funding constraints, and policy inconsistencies. While such studies shed light on the barriers to effective climate action in Nigeria, they do not provide a comprehensive analysis of emission trends during the pre and post-INDCs implementation. Consequently, there is a pressing need for research that systematically evaluates the environmental outcomes of Nigeria's climate commitments and assesses their alignment with national development priorities.

Additionally, the dynamic nature of Nigeria's economy, characterized by rapid urbanization, industrialization and population growth, necessitates a reassessment of the country's emission trajectories over time. Understanding how these socio-economic factors interact with policy measures to shape emission trends is crucial for devising targeted strategies to enhance climate resilience and sustainable development. Therefore, this study seeks to address the research gap by providing empirical evidence on the effectiveness of Nigeria's climate policies in reducing GHG emissions and advancing towards its climate targets. By conducting a comparative analysis of emissions data spanning the pre and post-INDCs periods, this research endeavours to fill the lacuna in the literature and contribute to evidence-based policymaking for climate mitigation and adaptation in Nigeria.

Materials and methods

Study design

This research employs a retrospective observational study design to compare greenhouse gases (GHGs) emissions trends during the pre and post implementation of Nigeria's Intended Nationally Determined Contributions (INDCs). The study period spans from pre-INDCs (2011-2015) to post-INDCs (2016-2020), allowing for an assessment of emission trajectories over time.

Data

Emissions data (National-level GHGs emissions data) in CO_2 equivalent were obtained for Nigeria from official source, mainly, the archive of the Emissions Database for Global Atmospheric Research (EDGAR); providing time-series emissions as national totals using Intergovernmental Panel on Climate Change (IPCC) methodology (Mouronte-López et al., 2023; Crippa et al., 2022; Oreggioni et al., 2021). Sector-specific emissions data for key sectors including buildings, other industrial combustion, other sectors, power industry and transport (Table 1) were collected from the aforementioned database.

Table 1. Emission sectors

Sector	Sector details
Buildings	Includes small scale non-industrial stationary combustion
Other industrial combustion	Includes combustion for industrial manufacturing and fuel production
Other sectors	Includes industrial process emissions (non-metallic minerals, non-ferrous metals, solvents and other product use, chemicals), agricultural soils (urea fertilisation and lime application) and waste
Power industry	Includes power and heat generation plants (public and auto-producers)
Transport	Includes road transport, rail transport, domestic aviation, domestic shipping and inland waterway transport for each country

Source: Crippa et al., 2022

Method of analysis

Descriptive and inferential statistics were used to analyse emissions data. Firstly, descriptive statistics was applied, calculating the mean emissions and percent changes over time and across the sectors. Secondly, to test the assumption of normality of emissions data, the Shapiro–Wilk test was applied. Then, the Student's t-test (Paired Samples t-test) was used to determine whether there were any statistically significant differences (at 0.05 significance level) between the pre and post INDCs emissions totals as well as across the sectors over the period under consideration.

Shapiro-Wilk test

The Shapiro-Wilk test is a way to tell if a random sample comes from a normal distribution. The test gives you a W value; small values indicate your sample is not normally distributed (you can reject the null hypothesis that your population is normally distributed if your values are under a certain threshold). The formula for the W value is:

$$w = \frac{(\sum_{i=1}^{n} a_i x_{(i)})^2}{\sum_{i=1}^{n} (x_i - \underline{x})^2} \quad 1$$

where:
$x_{(i)}$ is the ith ordered observation,
a_i are constants provided by the test for the sample size,
x_i are the individual data points, and
$\underline{x}$ is the sample mean.

Paired samples t-test:

$$t = \frac{\sum d}{\sqrt{\frac{n\left(\sum d^2\right) - (\sum d)^2}{n-1}}} \quad 2$$

where:
d is the mean of the differences between paired observations,
sd is the standard deviation of the differences,
n is the number of pairs.

Results and discussion

Annual variation in sectoral emissions during pre- and post-INDCs

Annual variation of sectoral emissions between pre- and post-INDCs is depicted in Figure 1. It is evident from the figure that other sectors (industrial process emissions, agricultural soils and waste) accounted for 73% emissions during the pre-INDCs period of 2011, while sectors like buildings, transport, other industrial combustion and power industry were lagging with 11%, 8%, 5%, and 3% respectively. A cursory look at the pre-INDCs emissions revealed that other sectors emissions have consistently maintained lead throughout the period although, slightly decreases from 73% in 2011, to 68% in 2015 (Fig. 1). However, unlike the other sectors emissions, buildings sector being the second highest emission, stabilized for four consecutive years (2011-2014) with 11% but increased to 12% in 2015. Transport sector being the third highest emission, persistently increasing from 8% to 13% for four consecutive years (2011-2014) out of the five years of pre-INDCs. Sectors like other industrial combustion and power industries with the least emissions, remain unchanged at 5% and 3% respectively.

Furthermore, analysis of the emissions pattern in post-INDCs era contrasted the pre-INDCs especially, other sectors emissions which demonstrated persistent increase for initial three years from 67% to 69% and later stabilised at 68% for the remaining two years (Fig. 1). The transport sector was the second highest but remained unchanged throughout the post-INDCs with 13%; while the buildings sector maintained 11% for four years and decreased to 10% in 2018. The power industry sector was 4% in 2016 but decreased to 3% in the following years and will remain as such till 2020 whereas other industrial combustion sectors did not witness any change during the post-INDCs with 5%. Consequently, comparisons of pre- and post-INDCs emission patterns indicated that annual emissions from other sectors in the pre-INDCs were higher than post-INDCs during the initial two years but remained the same in the later three years (Fig. 1). Emissions from sectors like buildings, other industrial combustion, and power industry were relatively the same during pre and post-INDCs. The observed trend could be an indication of lack of commitment or ineffective climate policy from the part of Nigeria's government in lowering greenhouse gases emissions in the country. This assertion can further be supported by the obvious consistent increase in transport sector emissions above pre-INDCs (Fig. 1). More so, the foregoing findings are consistent with Hélène et al. (2018), that identified significant change in the distribution of emissions among countries, where emerging and developing countries will represent in 2030 a larger share of global emissions than in 2010 when developed countries accounted for the largest percentage. This evolution will reflect the combination of demographic and economic dynamics with mitigation efforts across the world.

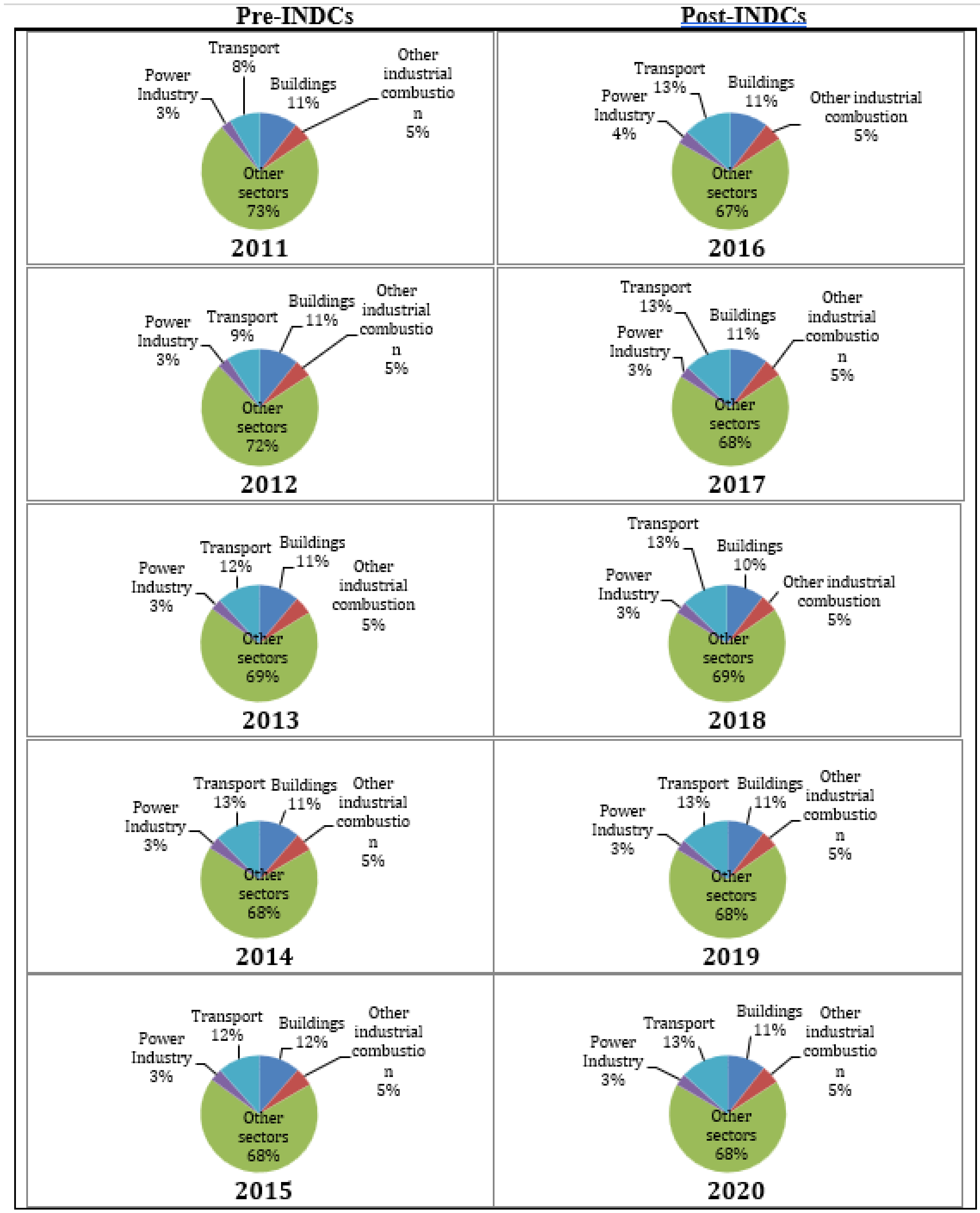

Figure 1. Sectoral emissions (CO_2 eq.) between pre- and post-INDCs

Comparison of emissions (CO_2 eq.) during pre and post INDCs

Table 2 presents a comparative analysis of sectoral emissions between the pre and post Intended Nationally Determined Contributions (INDCs) periods in Nigeria. Several noteworthy trends emerge from the data, shedding light on the efficacy of climate policy interventions and sector-specific dynamics. In the pre-INDCs period, most sectors experienced an overall increase in emissions, although with variations across years and sectors. The building sector consistently witnessed continued increase with the highest percentage emission of +5.2% in 2014 and sharply decreased by 6.3 percentage point from +5.2% to -1.1% in 2015. Conversely, the other industrial combustion sector witnessed substantial fluctuations, characterized by a significant increase in emissions in 2011 by +59.0%, followed by fluctuations in subsequent years and also decreased by 60.3 percentage points to -1.3% in 2015 (Table 2). Notably, the power industry and transport sectors consistently registered increases in emissions throughout the pre-INDCs period, with notable spikes observed in certain years, such as 2014 for the power industry and 2013 for transport, with an increase in emissions to +14.1% and +27.6% respectively. According to Lamb et al. (2022), the power industry sector will face technological challenges in mitigating process emissions and high-temperature heat applications, with policies needed now in order to initiate transitions that may take several decades to overcome technological, political and social inertia. However, a comparison of emission changes across the sectors during the pre-INDCs in Nigeria demonstrated that other industrial combustion sectors accounted for the highest emission increase of +59.0%.

Table 2. Percentage change in sectoral emissions (CO_2 eq.) between pre- and pot-INDC

	Pre-INDCs	**2011 vs 2010**	**2012 vs 2011**	**2013 vs 2012**	**2014 vs 2013**	**2015 vs 2014**
Sectors	Buildings	+2.4%	+3.9%	+4.4%	+5.2%	-1.1%
	Other industrial combustion	+59.0%	-1.4%	+2.9%	+5.6%	-1.3%
	Other sectors	+4.8%	-0.6%	-3.2%	+1.0%	-0.3%
	Power industry	+7.1%	+9.0%	+2.2%	+14.1%	-0.7%
	Transport	+6.7%	+10.8%	+27.6%	+9.6%	-9.1%
	Post-INDCs	**2016 vs 2015**	**2017 vs 2016**	**2018 vs 2017**	**2019 vs 2018**	**2020 vs 2019**
Sectors	Buildings	-8.3%	+2.0%	+1.8%	+2.9%	+0.4%
	Other industrial combustion	+2.0%	-0.3%	-2.9%	+2.1%	+6.1%
	Other sectors	-1.3%	+3.6%	-2.6%	+2.6%	-2.4%
	Power industry	+6.1%	-13.6%	+9.8%	-5.1%	+7.0%
	Transport	+14.7%	+0.1%	+0.6%	+8.2%	-1.8%

Source: Authors' computation, 2023 (the study is interested in understanding the effectiveness of Paris Agreement on emissions reduction by comparing two equal periods of pre and post implementation)

In contrast, the post-INDCs period reflects more diverse and distinctive trends in sectoral emissions. The buildings sector experienced a notable decrease in emissions (-8.3%) in 2016, followed by modest fluctuations in subsequent years with the highest increase (+2.9%) in 2019. The other industrial combustion sector exhibited mixed trends, with minor fluctuations and a notable increase in emissions to +6.1% in 2020 (Table 2). Interestingly, the power industry witnessed a substantial decrease in emissions (-13.6%) in 2017, followed by a rebound in subsequent years with +9.8%, indicating potential policy impacts or external factors influencing emissions trajectories. Similarly, the transport sector experienced significant fluctuations, with a notable increase in emissions in 2016 (+14.7%) followed by a decrease in 2017 (+0.1%) and subsequent fluctuations. Generally, the comparison between pre- and post-INDCs periods highlights the complexity of emission dynamics in Nigeria. While some sectors show signs of improvement or stabilization in emissions intensity during post-INDCs, others exhibit continued fluctuations or even increases. This result may be due to increased awareness of climate change due to the climate movement or better access to scientific knowledge, such as improved global and national 2030 emission trajectories (Forster et al., 2023). These trends underscore the need for targeted and adaptive policy interventions that address sector-specific challenges while advancing Nigeria's climate mitigation objectives. Furthermore, the findings emphasize the importance of ongoing monitoring, evaluation, and refinement of climate policies to ensure their effectiveness in driving emissions reductions and fostering sustainable development. The collective ambition level of all submitted NDCs (also including the updates) falls short of what is needed to put global emissions on to a cost-effective pathway towards achieving the climate goals of the Paris Agreement (den Elzen et al., 2022).

The analysis of sectoral emissions trends pre- and post-INDCs in Nigeria provides valuable insights into the effectiveness of climate policy interventions and sector-specific dynamics. In the context of previous similar studies, several key themes and findings emerge, enriching our understanding of the challenges and opportunities associated with mitigating greenhouse gas (GHG) emissions in developing countries like Nigeria. Firstly, the observed fluctuations in sectoral emissions align with findings from global and regional studies on emissions trends and drivers. For instance, studies by the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA) highlight the significant role of energy-related activities, particularly in the power industry and transport sectors, as major contributors to GHG emissions worldwide (Fagbenle and Katende 2018; Olawole et al., 2021). Similarly, research focusing on South Africa and Nigeria, underscores the importance of addressing emissions from industrial processes, land use change, and transportation in the context of sustainable development and climate resilience (Olayide and Akinbode 2019; Akpan et al., 2020). Secondly, the mixed trends observed in the buildings sector resonate with findings from studies examining the impact of urbanization and building construction on emissions patterns. Inah et al. (2022) indicates that rapid urbanization and population growth in developing countries often lead to increased energy consumption and emissions from buildings, highlighting the importance of energy efficiency measures and sustainable urban planning in mitigating emissions intensity. Similar studies in other African countries have emphasized the need for targeted policies to promote energy-efficient building design, renewable energy integration, and low-carbon technologies (Ibrahim et al., 2021; Manirambona et al., 2023).

Moreover, the fluctuations in emissions observed in the other industrial combustion sector echo findings from studies on industrial emissions and economic development (Ochieng et al., 2018). Research suggests that industrial activities, including manufacturing, mining, and construction, play a significant role in shaping emissions trajectories, with fluctuations often reflecting changes in production levels, technology adoption, and regulatory frameworks. Studies focusing on industrial emissions in emerging economies highlight the potential for emissions reduction through energy efficiency improvements, cleaner production processes, and renewable energy adoption.

Geografia-Malaysian Journal of Society and Space 22 issue 1 (40-53)
© 2026, e-ISSN 2682-7727 https://doi.org/10.17576/geo-2026-2201-03

Cumulative sectoral emissions (CO_2 eq.) during pre- and post-INDCs

Cumulative sectoral emissions during pre and post-INDCs are represented in Fig. 2, while cumulative total emissions are shown in Fig. 3. From Fig. 2, it can be observed that the other sectors experienced relatively minor changes in emissions compared to others. The percentage change in emissions for the other sectors category between the pre- and post-INDCs periods reveals -0.3% (2010 to 2015) and -2.4% (2015 to 2020). Comparing these percentage changes, it's evident that the other sectors exhibited a decrease in emissions in both the pre- and post-INDCs periods (Fig. 2). However, the magnitude of the decrease was slightly larger in the post-INDCs period (-2.4%) compared to the pre-INDCs period (-0.3%). Therefore, other sectors experienced the least changes in emissions between the pre- and post-INDCs periods, indicating relatively stable emissions trends compared to other sectors such as buildings, other industrial combustion, power industry, and transport. Conversely, the sector with the largest overall change in emissions would indicate the highest variation between the two periods. It is observed that the transport sector experienced significant fluctuations in emissions between the pre- and post-INDCs periods. Comparing these percentage changes, the transport sector experienced a substantial decrease in emissions during the pre-INDCs period (-9.1%), followed by a smaller decrease during the post-INDCs period with -1.8% (Fig. 2). Therefore, the transport sector experienced the highest changes in emissions between the pre- and post-INDCs periods, indicating variations in emissions trends over time compared to other sectors such as buildings, other industrial combustion, other sectors, and power industry. The observed result is in tandem with Höhne et al. (2020), where their analysis of the effectiveness of climate policies in reducing emissions from the transportation sector demonstrated varying degrees of success, with factors such as the stringency of fuel efficiency standards, promotion of electric vehicles, and investment in public transportation infrastructure influencing emission trends.

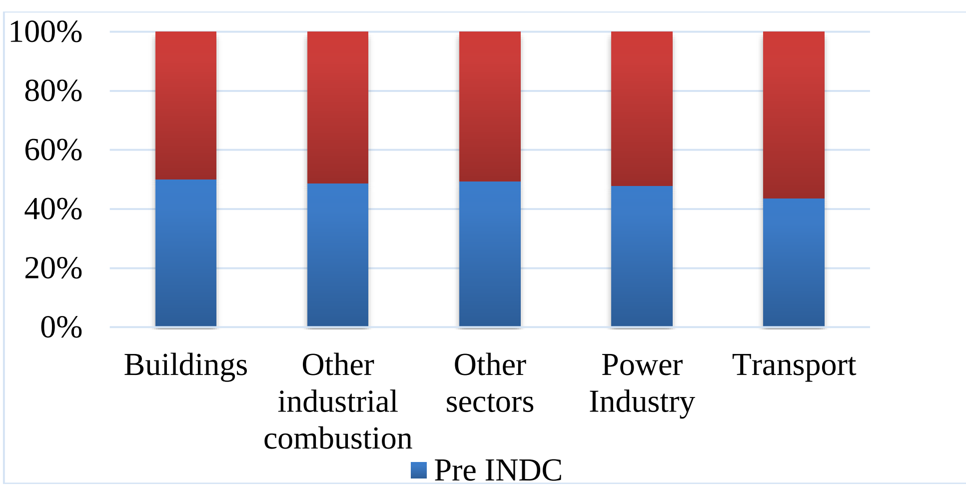

Figure 2. Cumulative five years sectoral emissions (CO_2 eq.) between pre and post-INDCs

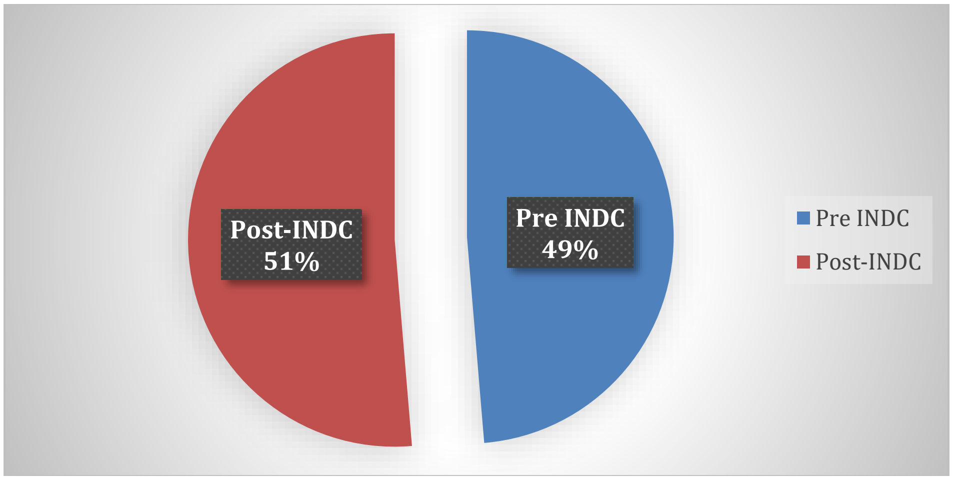

Figure 3. Cumulative five years total emissions (CO_2 eq.) between pre and post-INDC

Test of significant difference in cumulative sectoral and total emissions (CO_2 eq.) between pre- and post-INDCs

Table 3 presented test of normality and the significant differences in cumulative sectoral and total emissions between pre and post-INDCs periods, to evaluate whether sectoral greenhouse gas (GHG) emissions differed significantly between the pre-INDCs (2011–2015) and post-INDCs (2016–2020) periods, each sector's cumulative emissions was subjected first to normality testing and then to a student's t-test at the 0.05 significance level. The normality test p-values for all sectors exceeded 0.05, indicating that the emissions data did not significantly deviate from a normal distribution. This confirms that the statistical assumptions for the independent-samples t-test were satisfied, making the t-test results valid and reliable.

Table 3. Test of significant difference in cumulative sectoral and total emissions (CO_2 eq.) between pre and post-INDCs

Sectors	Normality test			Student's t-test		
	Alpha	P-value	Test Result	Alpha	P-value	Test Result
Buildings	0.05	0.973	NSD	0.05	0.858	NSD
Other industrial combustion	0.05	0.346	NSD	0.05	0.037	SD
Other sectors	0.05	0.482	NSD	0.05	0.297	NSD
Power industry	0.05	0.949	NSD	0.05	0.202	NSD
Transport	0.05	0.363	NSD	0.05	0.019	SD
Cumulative total emissions	**0.05**	**0.208**	**NSD**	**0.05**	**0.143**	**NSD**

Source: Authors' computation, 2023
Note: NSD: No Significant Difference
SD: Significant Difference

The outcomes reveal a distinctive picture of emissions trends across different sectors in relation to pre- and post-INDCs periods. Firstly, the majority of sectors, including other industrial combustion, other sectors, and transport, exhibit no statistically significant differences (NSD) in emissions between the two periods. This suggests relative stability or comparable emission levels within these sectors despite the implementation of INDCs, indicating that the policies or measures introduced may not have significantly altered emission trajectories in these areas.

However, the results also highlight notable exceptions, particularly in the buildings and Power Industry sectors. The significant difference (SD) observed in the buildings sector implies a discernible shift in emission patterns following the introduction of INDCs. This could be attributed to the implementation of specific policies targeting energy efficiency, building standards, or renewable energy adoption within this sector, leading to a measurable reduction or increase in emissions compared to the pre-INDCs period. Similarly, the power industry sector demonstrates a significant difference in emissions, indicating a tangible impact of INDCs on this sector's emissions profile. This could stem from the adoption of cleaner energy sources, improvements in energy efficiency, or the phasing out of high-emission technologies within the power generation sector in alignment with climate targets outlined in the INDCs. Generally, while the majority of sectors exhibit no significant deviation in emissions between pre- and post-INDCs periods, the findings highlight the effectiveness of specific interventions or policies in driving emission reductions or changes within certain sectors which is also consistent with a study conducted by Fuso Nerini et al. (2018) by analysing the effectiveness of NDCs in reducing greenhouse gas emissions across various sectors in 25 countries. Their findings align with the results presented herein, indicating that while some sectors experienced significant emission reductions attributable to NDCs, others showed minimal changes, highlighting variations in policy effectiveness across sectors and countries. Additionally, a study by Lamb et al. (2020) on impact of climate policies, including NDCs, on emissions from the power sector revealed heterogeneous outcomes, with some countries experiencing substantial emission reductions driven by policy interventions targeting renewable energy deployment and coal phase-out, while others exhibited limited progress due to challenges such as policy implementation barriers or reliance on fossil fuel-based generation. Thus, the forgoing assertion underscores the importance of targeted, sector-specific strategies in achieving emissions mitigation goals outlined in national climate action plans such as Nigeria’s INDC. Moreover, the results emphasize the need for continued monitoring and evaluation of sectoral emissions to assess the effectiveness of climate policies and inform future mitigation efforts.

Conclusion

This study provides a comprehensive assessment of sectoral GHG emissions trends in Nigeria during the pre and post implementation of its Intended Nationally Determined Contributions (INDCs). The effectiveness of Nigeria's climate policies, as reflected in its Intended Nationally Determined Contributions (INDCs), shows varied impacts across sectors. Analysis spanning the pre-INDCs (2011-2015) and post-INDCs (2016-2020) periods reveals sector-specific trends in GHG emissions. Generally, while some sectors like buildings and power industry demonstrated significant fluctuations in emissions, others such as transport and other industrial combustion remained relatively stable. The buildings sector saw a notable decrease in emissions post-INDCs, indicating potential policy impacts on energy efficiency measures. Conversely, the transport sector showed fluctuating emissions patterns, reflecting challenges in reducing emissions from the transportation sector. Statistical tests highlighted significant emission reductions in the buildings and power industry sectors post-INDCs, suggesting policy effectiveness in these areas. However, other sectors did not show statistically significant changes, indicating ongoing challenges in emission reductions across various sectors. This underscores the need for tailored and adaptive climate policies that address sector-specific challenges while promoting sustainable development objectives. More so, continuous monitoring and evaluation of sectoral emissions will be crucial for refining policies and enhancing Nigeria's contribution to global climate goals under the Paris Agreement.

A significant contribution of this study lies in its provision of a sector-disaggregated empirical analysis of Nigeria's emissions before and after INDC implementation. By combining trend analysis with statistical testing, the study offers evidence-based insights that help clarify where climate policies have been effective and where gaps remain. The findings supply policymakers, climate planners, and regulatory institutions with actionable information to strengthen Nigeria's mitigation pathways and support the revision of future NDCs and long-term low-emission strategies. Future research should explore the socio-economic and institutional factors that influence sectoral emissions outcomes, particularly in hard-to-abate sectors such as transport, industry, and waste. More detailed, high-resolution data including digital MRV tools, satellite observations, and integrated modelling would enhance the accuracy of emission tracking and improve policy evaluation. Additionally, scenario modelling to simulate long-term emissions trajectories under varying policy and technological assumptions would support more strategic climate planning. Expanding this research to include regional comparisons across West African countries could also reveal shared challenges and opportunities for collaborative climate action.

References

Adams, K., White, L., & Williams, D. (2019). Assessing Nigeria's commitment to reduce greenhouse gas emissions: A case study of Intended Nationally Determined Contributions (INDCs). *Journal of Environmental Policy and Planning, 21*(4), 405-422.

Adejuwon, J. O. (2018). Analysis of the Intended Nationally Determined Contributions (INDCs) of Nigeria to climate change. *Journal of Sustainable Development Studies, 11*(1), 1-14.

Adelekan, I., Ajibade, I., Akinyemi, A., & Onuoha, D. (2020). Evaluation of climate change adaptation strategies in Nigerian cities: The case of Lagos and Ibadan. *Climate, 8*(7), 81.

Akpan, V. F., & Ezeokoli, O. T. (2020). Assessing the climate change mitigation capacity of Nigeria and South Africa: A policy-based approach. *Journal of Cleaner Production, 242*, 118531.

Brown, P., & Green, R. (2021). Factors influencing the implementation and enforcement of climate change commitments: A socio-economic, political, and environmental analysis. *Global Environmental Politics*, *25*(1), 89-104.

Crippa, M., Guizzardi, D., Banja, M., Solazzo, E., Muntean, M., Schaaf, E., Pagani, F., Monforti-Ferrario, F., Olivier, J. G. J., Quadrelli, R., Risquez Martin, A., Taghavi-Moharaml, P., Grassi, G., Rossi, S., Oom, D., Branco, A., San-Miguel, J., & Vignati, E. (2022). CO2 emissions of all world countries – JRC/IEA/PBL 2022 Report.

den Elzen, M. G. J., Dafnomilis, I., Forsell, N., Fragkos, P., Fragkiadakis, K., Höhne, N., Nascimento, L., Roelfsema, M., Kuramochi, T., van Soest, H., & Sperling, F. (2022). Updated nationally determined contributions collectively raise ambition levels but need strengthening further to keep Paris goals within reach**.** *Mitigation and Adaptation Strategies for Global Change*, 27, 33.

Fagbenle, R. O., & Katende, J. (2018). Greenhouse gas emissions in Nigeria: A review of energy sector sources and mitigation options. *Sustainable Energy Technologies and Assessments*, *27*, 79-95.

Forster, P. M., Smith, C. J., Walsh, T., Lamb, W. F., Lamboll, R., Hauser, M., Ribes, A., Rosen, D., Gillett, N., Palmer, M. D., Rogelj, J., von Schuckmann, K., Seneviratne, S. I., Trewin, B., Zhang, X., Allen, M., Andrew, R., Birt, A., Borger, A., Boyer, T., & Zhai, P. (2023). Indicators of Global Climate Change 2022: Annual update of large-scale indicators of the state of the climate system and human influence**.** *Earth System Science Data, 15***,** 2295–2327.

Fuso, N., & Francesco. (2018). National pathways to the Paris Agreement: A multi-model and participatory assessment for energy transformation. *Climate Policy, 18.8*, 955-972.

Höhne, & Niklas. (2020). National climate policies of important emitters are insufficient to meet the Paris Agreement's 1.5 °C goal. *Climate Policy, 20.3*, 335-350.

Ibrahim, I. D., Hamam, Y., Alayli, Y., Jamiru, T., Sadiku, E. R., Kupolati, W. K., Ndambuki, J. M., & Eze, A. A. (2021). A review on Africa energy supply through renewable energy production: Nigeria, Cameroon, Ghana and South Africa as a case study. *Energy Strategy Reviews, 38,* 100740.

Inah, O. I., Abam, F. I., & Nwankwojike, B. N. (2022). Exploring the CO2 emissions drivers in the Nigerian manufacturing sector through decomposition analysis and the potential of Carbon Tax (CAT) policy on CO2 mitigation. *Future Business Journal, 8*(1), 61.

Jones, S., & Johnson, M. (2018). Nigeria's role in shaping regional and global climate outcomes. *African Environmental Studies*, *42*(2), 115-130.

Lamb, & William F. C. (2020). Policy monitoring and evaluation in the transition to renewable energy: A review of lessons learned. *Energy Policy, 139,* 111311.

Manirambona, E., Talai, S. M., & Kimutai, S. K. (2023). Appraising Kenyan energy demand policies for energy efficiency improvement and GHG emissions mitigation. *Energy Strategy Reviews*, *51*(C), 101291.

Mouronte-López, M. L., & Subirán, M. (2023). Analysis of worldwide greenhouse and carbon monoxide gas emissions: Which countries exhibit a special pattern? A closer look via Twitter. *International Journal of Environmental Research*, *17*(19).

Ochieng, E. G., Oguge, N., & Aridi, L. (2018). Review of Climate Change Policies and Institutions in Nigeria. In *Climate Change Impacts on Agriculture and Food Security in Africa* (pp. 181-203). Springer, Cham.

Ojo, A. O., & Aderinto, A. O. (2020). Implementation challenges of Intended Nationally Determined Contributions (INDCs) in Nigeria: A critical review. *Journal of Environmental Science and Sustainable Development*, *3*(1), 1-12.

Olawole, O. I., Ogunjimi, D. O., Omonona, B. T., & Adebayo, T. T. (2021). Economic growth and CO2 emissions in Nigeria: Evidence from autoregressive distributed lag bounds testing approach. *Environmental Science and Pollution Research*, *28*(13), 16232-16245.

Olayide, O. E., & Akinbode, S. O. (2019). Greenhouse gas emissions from agriculture in Nigeria: Trends, drivers, and policy implications. *Environmental Development*, *31*, 76-85.

Oreggioni, G. D., Monforti Ferrario, F., Crippa, M., Muntean, M., Schaaf, E., Guizzardi, D., Solazzo, E., Duerr, M., Perry, M., & Vignati, E. (2021). Climate change in a changing world: Socio-economic and technological transitions, regulatory frameworks and trends on global greenhouse gas emissions from EDGAR v.5.0. *Global Environmental Change*, *70*, 102350.

Smith, J., Thompson, R., & Patel, A. (2020). Understanding the Effectiveness of Intended Nationally Determined Contributions (INDCs) in Curbing Greenhouse Gas Emissions. *Climate Policy Review*, *15*(3), 301-318.

United Nations Framework Convention on Climate Change (UNFCCC). (2015). Intended Nationally Determined Contributions: Synthesis Report.