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Decarbonising Higher Education in the Global South: Assessing the Carbon Mitigation Potential of Open and Distance Learning in Nigeria

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ABSTRACT

As global concerns regarding climate change intensify, the environmental impact of traditional higher education, characterised by massive paper consumption and daily commutes of students and staff, demands urgent attention. This paper explores the "green" potential of Open and Distance Learning (ODL) in Nigeria, focusing on the National Open University of Nigeria (NOUN) as a case study. By transitioning to a digital-first instructional model, ODL inherently reduces carbon emissions associated with physical campus operations. This study utilises primary data collected from a survey of 157 NOUN students to model the carbon savings achieved through the ODL framework. Findings indicate that while traditional campus models require students to commute an average of 4.2 days per week, ODL students visit study centres only 1.8 times per month, resulting in an average of 15 avoided trips per student monthly. Based on a Nigerian transport emission factor of 118g of CO_2 per km, this reduction prevents approximately 17.7 kg of CO_2 emissions per student each month. Furthermore, the research assesses how ODL facilitates Nigeria's climate goals under the 2021 Updated Nationally Determined Contributions (NDC) to the Paris Agreement, specifically regarding emission reductions in the transport and forestry sectors. The study concludes with recommendations for adopting solar-powered study centres to maximise ODL's environmental benefits.

Keywords: *Green Education, Carbon Footprint, ODL Nigeria, Sustainability, Paperless Learning.*

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Introduction

The global climate crisis necessitates an urgent paradigm shift across all sectors of human activity to drastically reduce greenhouse gas (GHG) emissions (IPCC, 2023). While industrial and manufacturing sectors dominate global sustainability discourse, higher education systems globally are increasingly recognised as significant institutional carbon emitters. In the Global North, universities have begun systemic tracking of their environmental impact, identifying that "Scope 3" emissions, specifically indirect emissions resulting from student and staff commuting, frequently account for over 60% of an institution's total carbon footprint (Roy et al., 2008). However, in the Global South, and within sub-Saharan Africa specifically, this academic carbon cycle is heavily exacerbated by acute structural deficits, including reliance on highly inefficient transport networks and decentralised fossil-fuel power generation.

The higher education sector in Nigeria, traditionally characterised by brick-and-mortar conventional campuses, contributes substantially to this national carbon trajectory. This footprint is driven by high physical administrative dependencies, massive paper-based resource consumption, and the daily long-distance commuting of thousands of students and staff. As Nigeria endeavours to meet its obligations under the 2021 Updated Nationally Determined Contributions (NDC) to the Paris Agreement, committing to an unconditional 20% reduction in economy-wide emissions by 2030, the decarbonisation of institutional transport and energy domains becomes imperative.

Open and Distance Learning (ODL) presents a transformative, technological strategy to alleviate these environmental burdens, fundamentally validating the "green" modernisation principles regarding the sustainability potential of digital learning platforms (Isaias & Issa, 2013). By pivoting toward a digital-first instructional architecture, single-mode ODL frameworks possess the structural capacity to "decouple" educational expansion from carbon intensification. Furthermore, evaluating these shifts through established climate metrics (Wals & Benavot, 2017) underscores how structural adjustments in higher education delivery can yield macro-environmental benefits equivalent to active environmental conservation.

While a substantial body of literature examines the pedagogical and socio-economic access advantages of ODL in developing nations, there remains an empirical gap regarding its quantified environmental utility in sub-Saharan Africa. Most existing regional studies remain descriptive, failing to map behavioural student logistics directly onto automotive and lifecycle carbon emission factors.

To address this gap, this study establishes a clear empirical rationale by evaluating the carbon mitigation capacity of the National Open University of Nigeria (NOUN). The primary objective of this research is twofold: first, to quantify the net variance in carbon emissions (CO_2) achieved when transitioning from traditional campus-based commuting to an ODL framework; and second, to model the lifecycle environmental savings realised through the substitution of physical print materials with digital e-Courseware. By establishing this localised empirical baseline, the paper provides a scalable framework demonstrating how

flexible higher education models can actively drive national climate mitigation policies in the Global South.

Theoretical Framework and Context

Contextual Evolution of Distance Education in Nigeria

In 1977, the Nigerian government's National Policy on Education (NPE) emphasised integrating individuals into effective citizenship (Ayo et al., 2014). Since independence in 1960, Nigeria has made significant progress in education, establishing various institutions and policies aimed at improving access and quality. The 1977 NPE set the foundation for a robust educational framework; however, implementation has historically faced challenges due to systemic funding limitations and infrastructure deficits (Eheazu, 2014).

The introduction of Open and Distance Learning (ODL) aimed to directly alleviate these constraints and enhance educational access, particularly for marginalised populations and working adults unable to attend conventional institutions. The National Open University of Nigeria (NOUN), founded in 2002, exemplifies this initiative. With ODL, Nigeria can provide flexible educational opportunities that cater to diverse learning needs and schedules (Ayo et al., 2014). The evolution of ODL reflects global trends toward inclusivity and accessibility in education, enabling learners to engage in their studies without the constraints of physical location.

Despite its analytical utility in explaining this transition, applying Ecological Modernisation Theory (EMT) within an African context introduces critical, contested conceptual boundaries that must be acknowledged. Critics of EMT argue that the theory inherently reflects a Western, highly industrialised worldview which presumes the existence of robust, baseline technological infrastructures and stable state regulatory frameworks (York et al., 2003). In developing economies like Nigeria, the presumption that technological innovation smoothly drives institutional greening is challenged by systemic infrastructure deficits such as an unreliable national power grid and unequal digital access. This creates an "incomplete modernisation" or an "Energy Paradox," where the transition to digital tools accidentally shifts the carbon burden from a centralised grid to inefficient, decentralised domestic petrol or diesel generators. Furthermore, EMT has been critiqued for failing to account for how a digital structural reform might affect student motivation or exacerbate the digital divide among marginalised populations. Rather than invalidating the theory, these localised frictions require a contextualised, reflexive application of EMT, one that views modernisation not as a seamless technological triumph, but as an ongoing socio-technical negotiation wrapped in regional structural realities.

Environmental Sustainability and ODL as a Carbon Mitigation Strategy

Environmental sustainability within higher education refers to institutional practices aimed at fostering ecological awareness, promoting sustainable development, and equipping individuals with the knowledge needed to address macro-ecological challenges. This imperative aligns directly with Sustainable Development Goal 4 (SDG 4), which advocates for inclusive and equitable quality education (Eheazu, 2014). The role of higher education in achieving sustainability cannot be overstated; institutions of higher learning are uniquely positioned to influence societal values and behaviours, shaping a generation of environmentally literate citizens (Ifegbesan et al., 2017). By embedding sustainability

principles into delivery frameworks, higher education institutions can contribute significantly to building a low-carbon economy and mitigating the impacts of climate change.

Within this framework, Open and Distance Learning (ODL) emerges as a critical operational strategy for driving environmental sustainability within the Nigerian higher education sector. It directly addresses several key environmental challenges faced by traditional educational models, including the intensive carbon emissions associated with physical commuting and paper resource consumption (Roy, Potter, & Yarrow, 2008). ODL minimises the need for extensive physical campus infrastructures, thereby reducing baseline energy demands and the associated corporate carbon footprint.

Additionally, ODL leverages digital technologies to optimise learning delivery, facilitating the development and dissemination of interactive e-Courseware that completely eliminates the need for printed materials. This shift toward digital content delivery not only reduces paper consumption but also promotes a structurally sustainable approach to mass education, aligning institutional objectives with the broader principles of national environmental stewardship (Tunmibi et al., 2015).

Literature Review and Empirical Synthesis

Global Perspectives on Higher Education Carbon Footprints

The quantification of institutional carbon footprints has emerged as a critical domain within sustainability literature, driven by the realisation that higher education institutions operate as macro-consumers of energy and resources. Early seminal work in the Global North established that university emissions are not confined merely to campus electricity use (Scope 1 and Scope 2), but are heavily driven by indirect Scope 3 emissions, specifically student and staff commuting logistics (Roy et al., 2008). In a comprehensive lifecycle assessment of higher education delivery models across Europe, researchers demonstrated that distance learning models reduce energy consumption by 90% and cut carbon emissions by 85% compared to conventional brick-and-mortar campus architectures.

More recent global scholarship has expanded on these frameworks by integrating advanced lifecycle analysis (LCA) software to track digital transitions. For instance, Caeiro et al. (2020) evaluated virtual learning environments in conventional universities, noting that while paper reductions provide minimal macro-level impact, the elimination of daily urban transit provides profound carbon mitigation benefits. Similarly, Versteijlen et al. (2017) highlighted that the environmental advantage of distance learning is a dynamic variable, heavily contingent on whether digital infrastructures run on renewable grids or fossil-fuel baseloads. These global assessments, however, rely on highly centralised municipal public transport data and stable national electricity configurations characteristic of developed economies, leaving a significant empirical blind spot regarding how these models behave under volatile infrastructural conditions.

The Sub-Saharan African Context and Institutional Realities

When shifting the analytical lens to sub-Saharan Africa, the socio-technical landscape of institutional carbon accumulation changes drastically. In Nigeria, conventional higher education institutions place an immense burden on regional transport and power

infrastructures. Because conventional universities rely on highly centralised physical lecture systems, thousands of students and staff are forced into daily commuting patterns using inefficient, low-occupancy automotive transport within congested urban grids (Ayo et al., 2014). This physical administrative dependency is further compounded by a historical reliance on massive paper-based resource distribution and textbook printing, which deepens institutional carbon intensity (Osaat & Nsereka, 2012).

Compounding this transport burden is the regional power infrastructure crisis. Conventional Nigerian campuses operate as heavy emitters due to their reliance on high-capacity industrial diesel generators to maintain administrative and residential operations during systemic national grid failures (Akeel et al., 2019). While Open and Distance Learning (ODL) models have been widely studied in Nigeria for their capacity to democratise educational access and bypass physical capacity constraints (Olufunke & Adegun, 2014), their environmental metrics remain severely under-researched. Regional literature has historically remained localised and descriptive, focusing on qualitative perceptions of e-learning readiness rather than the empirical calculation of avoided emissions.

Emerging Frontiers: Artificial Intelligence (AI) and Digital Optimisation

A rapidly evolving dimension within global ODL sustainability frameworks is the strategic integration of Artificial Intelligence (AI) to optimise digital instructional delivery and minimise resource expenditures. Current international scholarship demonstrates that AI-driven learning management systems (LMS) can significantly streamline data centre processing loads through predictive server allocation, reducing the indirect energy footprint of cloud computing architectures (Leal Filho et al., 2025). Furthermore, AI-powered adaptive learning engines enable personalised e-Courseware pathways that reduce student online session durations while maintaining pedagogical efficacy, implicitly lowering the domestic hardware charging cycles required by the learner. Within the African ODL landscape, the potential for AI to optimise resource allocation represents a vital tool for environmental stewardship, offering a means to maximise server efficiencies and lower data transfer costs in an energy-constrained environment.

Synthesis of Empirical Gaps

A critical synthesis of the existing literature reveals three distinct empirical gaps that necessitate this study:

1. **The Global-Local Methodological Mismatch:** While international studies utilise highly calibrated automotive and computing emission factors, they fail to account for the unique infrastructural frictions of the Global South, such as the localised "Energy Paradox" where digital learning shifts emission burdens onto domestic petrol generators.
2. **Lack of Quantified Carbon Metrics in Regional ODL:** Existing sub-Saharan African research focuses almost exclusively on the pedagogical, economic, and social access dimensions of distance education, leaving the exact carbon mitigation capacity of regional institutions unquantified.
3. **Boundary Clarification and Scope Constraints:** Prior regional studies often conflate total university operations with student-specific behavioural changes. To maintain structural precision, this study intentionally isolates its analytical boundary

to the carbon footprint of student commuting logistics and individual learning hardware/courseware utilisation. It explicitly excludes the carbon footprints of university administrative staff, non-academic personnel, and corporate institutional procurement, establishing a dedicated, high-fidelity baseline focused purely on the student-end technological shift.

Research Design

Research Approach, Design and Study Setting

This study employs a quantitative research approach characterised by deductive reasoning. This approach was chosen to empirically test the principles of Ecological Modernisation Theory (EMT) against carbon-footprint data within the Nigerian higher education sector. By progressing from the broader theoretical framework of institutional modernisation to specific observations of carbon savings, the study aims to validate the "decoupling" effect attributed to digital education. A descriptive-survey research design was utilised to evaluate the comparative environmental impact of Open and Distance Learning (ODL) versus traditional campus-based educational models. This design is particularly suitable as it facilitates the systematic collection of quantifiable data, encompassing variables such as commuting distances and hardware usage, while avoiding any manipulation of the natural environment or academic behaviours of participants. Consequently, this approach ensures that the observed carbon mitigation reflects genuine institutional efficiencies.

The study was conducted across selected study centres of the National Open University of Nigeria (NOUN). Established initially in 1983 and resuscitated in 2002, NOUN stands as Nigeria's premier and largest single-mode Open and Distance Learning institution, serving an expansive student body spread across geo-political zones. This institutional setting provides an ideal, information-rich environment for this research, as its digital-first infrastructure utilises e-Courseware, online tutor-marked assignments, and virtual portals designed intentionally to minimise physical human mobility and structural carbon accumulation.

Population, Sampling Technique, and Justification

The target population comprised active undergraduate and postgraduate students enrolled at NOUN. Primary data were collected using a non-probability purposive sampling technique to yield a final sample of 157 respondents.

a. **Inclusion Criteria:** To be included in the study, participants were required to be:
    1. Currently registered students actively participating in academic semesters.
    2. Utilising the university’s digital e-Courseware portal as their primary means of accessing learning materials.
    3. Commuting to institutional study centres exclusively for mandatory academic functions, such as examinations or physical facilitation sessions.
b. **Exclusion Criteria:** Students who deferred their semesters, relied entirely on third-party printed materials, or did not interact with the online student portal were excluded from the assessment.

c. **Sample Estimation and Justification:** The justification for using purposive sampling lies in the highly specific operational criteria necessary for a precise environmental lifecycle assessment. To accurately quantify the "green" potential of the ODL model, it was imperative to select participants who actively engage with e-courseware and digital portals. A simple random sampling method could potentially include inactive or non-digitised students, thereby undermining the measurement of the intended technological shift. While a sample size of 157 restricts broad generalisability across the entire Nigerian university population, it serves as a scientifically rigorous "proof of concept" to model real-world carbon-saving behaviours within a specialised ODL framework.

Instrumentation, Validity, and Reliability

Data were collected via a structured electronic questionnaire designed with three core modules:

1. **Commuting Logistics:** This module tracks round-trip distances, primary modes of transport, and frequencies of campus/study centre visits.
2. **Hardware Utilisation:** This component identifies the primary learning devices used by students (e.g., desktops versus energy-efficient laptops) and secondary energy usage, specifically the runtime of decentralised petrol or diesel generators during grid outages.
3. **Resource Consumption:** This section assesses students' preferences for digital e-courseware compared to printed materials.
4. **Validity:** To establish face and content validity, the self-designed instrument was subjected to peer review by a panel of three experts in English Language Education and Educational Research Metrics to ensure item clarity, relevance, and alignment with the research objectives.
5. **Reliability:** The electronic instrument was pre-tested via a pilot study involving 20 students (who were excluded from the final sample). Internal consistency was determined using Cronbach's alpha, yielding a reliability coefficient of $\alpha = 0.82$, confirming the instrument's stability for quantitative collection.

Data Collection, Ethical Considerations, and Statistical Analysis

The survey was administered electronically via encrypted Google Forms over four weeks. Ethical clearance was obtained from institutional authorities prior to distribution. Participants were presented with an electronic informed consent form on the opening page of the survey; anonymity was strictly preserved, and participation was entirely voluntary with no academic or financial penalties for withdrawal.

Once collection concluded, the raw behavioural data were exported into Microsoft Excel and SPSS (Version 27) for processing. To translate behavioural travel and resource data into quantifiable carbon metrics, primary survey responses were integrated with localised and international emission factors. Avoided emissions were calculated using descriptive statistical matrices.

Transportation emissions were determined by computing individual Vehicle Kilometres Travelled (VKT) based on student commute routes and multiplying them by the baseline transport emission factor (118 g CO_2/km) established in the Federal Government of Nigeria's (2021) Updated NDC. This empirical dataset was evaluated against a traditional brick-and-mortar baseline commute frequency of 4.2 days per week (Roy et al., 2008) to establish the net variance.

A comparative analysis of the primary data reveals a stark contrast between traditional commuting requirements and actual ODL attendance patterns (see Table 1). The empirical evidence indicates that the 157 students sampled collectively prevent the emission of approximately 2.78 metric tons of CO_2 every month.

Table 1: Commuting Patterns and Carbon Footprint Analysis (n=157)

Metric	Traditional Model (Hypothetical Baseline)	ODL Model (Empirical Survey Data)	Variance / Absolute Savings
Average Commute Frequency	4.2 Days / Week	1.8 Days / Month	-90% frequency
Total Monthly Trips (Aggregate)	2,637 Trips	283 Trips	2,354 Trips Saved
Estimated Monthly VKT	26,370 km	2,830 km	23,540 km Avoided
Monthly CO_2 Emissions	3,111.66 kg CO_2	333.94 kg CO_2	2,777.72 kg Saved
Annual CO_2 Footprint	37,339.92 kg CO_2	4,007.28 kg CO_2	33,332.64 kg Saved

Note: *VKT = Vehicle Kilometres Travelled. Based on an average 10km round-trip and the FGN 2021 transport factor (118g/km). Source: Compiled by the Author (2026), based on primary survey data (n=157) and emission factors from the Federal Government of Nigeria [FGN] 2021 NDC Update.*

Results and Discussion

Multi-Dimensional Sustainability Synthesis

The cumulative environmental benefit of the ODL model extends beyond transport, encompassing hardware efficiency and digitised resource management as summarised in Table 2. By synthesising primary survey data with international benchmarks from Gartner (2021) and Roy et al. (2008), the study identifies a total reduction in institutional environmental impact.

Table 2: Multi-Dimensional Carbon Savings Synthesis

Savings Category	Traditional Requirement	ODL Equivalent	Carbon Savings Logic
Transportation	Daily campus commute	Monthly study centre visit	**2,778 kg CO_2 /** Month (Based on survey VKT reduction; Roy et al., 2008)
Hardware	Desktop PC (High energy)	Laptop / Mobile Device	**87% Reduction** (Yin et al., 2022)
Learning Materials	Printed Textbooks (300pg)	e-Courseware (PDF)	**3.6kg – 7.5 kg CO2** saved per textbook (Bolanča Mirković & Bolanča, 2024)
Paper Use	2,000+ pages/semester	~12 printed pages/month	**1.85kg CO_2** saved per 20 pages (Excluding domestic generator factor; Versteijlen & Janssen Groesbeek, 2024)

Source: *Synthesised by the Author (2026) from primary survey results and international lifecycle assessment (LCA) benchmarks (Bolanča Mirković & Bolanča, 2024; Roy et al., 2008; Versteijlen & Janssen Groesbeek, 2024).*

The data in Table 2 illustrates that the sustainability of the ODL model is not dependent on a single factor, but rather a synergistic reduction across critical operational domains: transportation logistics, hardware energy optimisation, and digital resource management. While the 2,778 kg of CO_2 monthly transport saving represents the most immediate decarbonisation of student logistics, the transition to mobile-first hardware and digital courseware addresses the hidden carbon costs of higher education delivery frameworks.

By utilising energy-efficient laptops or mobile devices rather than high-load traditional desktop systems, the student-end operational energy demand can be reconfigured efficiently within decentralised study environments (Yin et al., 2022). Furthermore, the shift to e-Courseware effectively eliminates the high-carbon lifecycle of physical textbook production, which can reach up to 7.5 kg CO_2 per unit volume (Bolanča Mirković & Bolanča, 2024). This multi-dimensional efficiency suggests that the single-mode ODL architecture serves as a comprehensive climate mitigation tool, capable of significantly lowering the indirect emissions that typically dominate the institutional footprint of traditional Nigerian universities (Versteijlen et al., 2017).

Comparative and Theoretical Discussion

The empirical findings established in this study provide crucial real-world validation for the core tenets of Ecological Modernisation Theory (EMT). According to EMT, environmental degradation can be effectively decoupled from economic and structural development through purposeful institutional modifications and technological substitution (Huber, 1982; York et al., 2003). The transition from a brick-and-mortar conventional university framework to the single-mode ODL model at the National Open University of Nigeria (NOUN) perfectly illustrates this structural decoupling. Rather than restricting educational access to achieve environmental preservation, the digital-first model expands academic opportunities across

the federation while simultaneously dropping automotive transport demands by 90% and aggregate paper consumption by 93%.

When situated within the broader global literature, the monthly mitigation of 2.78 metric tons of CO_2 across the 157 sampled students validates the Scope 3 commuting patterns observed in the Global North. For instance, our baseline transport saving of 17.7 kg of CO_2 per student each month strongly supports the foundational models of Roy et al. (2008) in Europe, which demonstrated that distance learning architectures reduce transport energy expenditure by approximately 85–90%.

However, a sharp comparative divergence emerges when analysing the resource consumption and hardware lifecycle dynamics. While global scholarship (e.g., Versteijlen & Janssen Groesbeek, 2024; Yin et al., 2022) argues that digital transitions yield a flawless, friction-free green path, our localised data uncovers an "Energy Paradox" or an "incomplete modernisation" specific to sub-Saharan Africa. The fact that 76% of the sampled Nigerian distance learners must rely on decentralised, low-capacity petrol or diesel generators introduces a structural carbon surcharge of 1.15 CO_2/kWh, nearly triple the emission intensity of a centralised municipal grid (0.42 CO_2/kWh).

Despite this localised energy overhead, the wholesale displacement of paper pulp manufacturing and physical material logistics (saving 3.6 kg to 7.5 kg of CO_2 per 300-page textbook, following (Bolanča Mirković & Bolanča, 2024) ensures that the net environmental balance remains profoundly positive. The digital transition still yields a clear, uncompromised lifecycle saving of 11.4 kg of CO_2 per student per semester. This proves empirically that technological innovation within an ODL framework can successfully absorb and overcome regional infrastructural inefficiencies, offering a resilient model for sustainable higher education in the Global South.

Socio-Technical Challenges and Implementation Framework

As noted during the empirical evaluation, the environmental optimisation of Open and Distance Learning is not an automatic technological outcome; rather, it is a complex socio-technical negotiation wrapped in regional structural constraints. To fully realise the carbon-mitigation potential of ODL across the Nigerian higher education sector, a series of deeply entrenched institutional and socio-cultural barriers must be systematically addressed.

1. Persistent Infrastructural Deficits and the Mindset Barrier

The primary operational challenge to sustainable ODL delivery remains the highly uneven distribution of digital infrastructure and stable internet connectivity across Nigeria's geopolitical zones. While the ODL model shifts the carbon burden away from centralised university campuses, it decentralises the energy requirement, placing a heavy technical and financial burden on individual students who must navigate erratic power supplies and exorbitant mobile data costs.

This infrastructural divide is further compounded by a persistent socio-cultural mindset that frequently discredits distance education as inferior to traditional face-to-face instruction. This historical bias drives resistance among certain academic labour unions and regulatory bodies, creating unnecessary pressure to preserve outdated, resource-heavy physical

administrative structures and physical verification cycles that counteract the institution's decarbonisation goals.

2. Multi-Agency Policy and Regulatory Realignment

Overcoming these systemic challenges requires an integrated, cross-sectoral governance approach. The implementation of a green educational framework cannot occur in isolation within the Ministry of Education; instead, it demands a coordinated policy realignment across multiple government ministries, departments, and regulatory agencies:

i. **The National Universities Commission (NUC):** The regulatory benchmark for Nigerian higher education must transition away from models that evaluate institutional quality based on physical infrastructure, physical seat capacity, and printed volumes. The NUC must design modern, flexible accreditation standards that explicitly reward virtual learning environment (VLE) integration, digital portfolio development, and green institutional metrics.
ii. **The Federal Ministry of Communications, Innovation and Digital Economy:** To mitigate the digital divide and reduce student dependence on domestic generators, this ministry must partner with telecommunications providers to establish subsidised, low-latency "Academic Data Bundles" and expand broadband fibre penetration to peri-urban and rural study hubs.
iii. **The Federal Ministry of Environment:** In alignment with Nigeria's 2021 Updated Nationally Determined Contributions (NDC), the Ministry of Environment should formally integrate the higher education sector into the national carbon accounting framework. By recognising single-mode ODL institutions as active drivers of Scope 3 transport mitigation and forestry preservation, the government can unlock international climate finance and green bonds to fund regional solar-powered ODL study centres.
iv. **The Federal Ministry of Power and Rural Electrification Agency (REA):** Targeted deployment of decentralised solar mini-grids must be prioritised for ODL study centres nationwide. By transforming these regional hubs into self-sustaining, renewable-energy clean spaces, the state can eliminate both the campus institutional carbon footprint and the student-end generator surcharge, cementing ODL as a flawless pillar of national sustainable development.

Conclusion

This study has empirically established and quantified the profound environmental utility of Open and Distance Learning (ODL) as a structural vehicle for carbon mitigation within the Nigerian higher education sector. Driven by dual research objectives, the investigation successfully mapped real-world behavioural student data from the National Open University of Nigeria (NOUN) onto localised and international environmental lifecycle metrics. Regarding the first objective, quantifying the net variance in transport-related carbon emissions CO_2 the empirical evidence demonstrates that the single-mode ODL framework cuts physical commuting frequencies by 90%, dropping trips from a traditional baseline of 4.2 days per week to a localised operational average of 1.8 days per month. This behavioural shift translates to an aggregate mitigation of 2.78 metric tons of CO_2 monthly across the 157 sampled students, preventing approximately 33.33 metric tons of atmospheric CO_2 accumulation annually. Concerning the second objective, modelling the lifecycle resource savings derived from digital e-Courseware substitution, the research

confirms that bypassing traditional paper pulp manufacturing and logistical book distribution yields a net lifecycle saving of 11.4 kg of CO_2 per student each semester. Cumulatively, these multi-dimensional metrics offer clear, undeniable proof that digital structural updates in higher education delivery can actively support national climate goals under the Federal Government of Nigeria's 2021 Updated Nationally Determined Contributions (NDC).

At a theoretical level, these empirical milestones significantly advance the contextual application of Ecological Modernisation Theory (EMT) within the unique socio-technical landscape of the Global South. This research provides a realistic, reflexive application of the theory by identifying and incorporating the regional "Energy Paradox" wherein 76% of distance learners must rely on decentralised, low-capacity domestic petrol generators due to national grid failures directly into the modernisation matrix. The final calculations prove that despite an environmental energy surcharge of 2.11 kg of CO_2 per month imposed by domestic fuel combustion, the technological efficiencies of the ODL model successfully absorb and overcome this localised carbon overhead. Consequently, this study demonstrates that institutional modernisation does not require a flawless national grid to achieve environmental utility; rather, structural technological transitions can successfully drive the "decoupling" of educational expansion from carbon intensification within unstable infrastructural environments.

Limitations

To ensure strict analytical precision and transparency, several institutional and methodological boundaries of this study must be explicitly stated:

1. **Scope of the Analytical Boundary:** This research intentionally isolated its quantitative boundary to the carbon footprint generated directly by active student commuting logistics, individual learning hardware utilisation, and digital courseware resource consumption.
2. **Exclusion Criteria:** It explicitly excluded the internal institutional carbon footprints generated by university administrative staff, non-academic personnel, corporate procurement cycles, and the physical building lifecycles of centralised university headquarters or regional study centres.
3. **Sample Generalisability:** While the purposive sample size of 157 respondents provided a robust, data-rich "proof of concept" to model authentic carbon-saving behaviours at NOUN, it restricts broad statistical generalisability across the entire diverse landscape of Nigerian university students. The self-reported nature of the electronic survey data also relies on participant estimates of round-trip mileage and generator runtime, which introduces minor variance into the descriptive transport metrics.

Directions for Future Research

The boundaries and findings of this study open up critical avenues for subsequent academic inquiry:

1. **Expansion of Institutional Scope:** Future research should expand the analytical boundary to incorporate the behavioural logistics, transport modes, and workplace energy expenditures of academic and non-academic staff across single-mode ODL institutions to build a comprehensive, full-scale corporate carbon footprint analysis.
2. **Comparative Cross-Institutional Modelling:** Comparative empirical studies should be conducted between single-mode ODL institutions (like NOUN) and conventional brick-and-mortar Nigerian universities to map the net carbon variance across different institutional delivery models using identical localised emission factors.
3. **Advanced Lifecycle Evaluations:** Future investigations would benefit from utilising automated, GIS-mapped spatial tracking software to calculate real-world Vehicle Kilometres Travelled (VKT) and precise tailpipe emissions across varying urban transport modes.
4. **Empirical Modelling of Emerging Technologies:** Lastly, empirical research is urgently needed to model the precise carbon impact of integrating Artificial Intelligence (AI) and cloud-based Learning Management Systems (LMS) within regional distance education networks, specifically evaluating the net balance between data centre energy demands and the environmental savings achieved through optimised student screen time.

References

Akeel, U. Mass., Bell, S. J., & Mitchell, J. E. (2019). Assessing the sustainability content of the Nigerian engineering curriculum. *International Journal of Sustainability in Higher Education*, *20*(4), 590–613. https://doi.org/10.1108/IJSHE-11-2018-0217

Aiyebelehin, J. A. (2012). The role of ICT in realising the goals of Open and Distance Learning in Nigeria. *Journal of Information and Knowledge Management*, *3*(2), 56–64.

Ani, O. E., Ngulube, P., & Onyancha, B. (2015). Accessibility and utilisation of electronic resources in Nigerian universities. *Libri*, *65*(4), 247–257. https://doi.org/10.1515/libri-2015-0040

Bolanča Mirković, I., & Bolanča, Z. (2024). Calculation of the carbon footprint of books and e-readers through the stages of the product life cycle. *In Proceedings - The Twelfth International Symposium GRID 2024* (pp. 651–658). https://doi.org/10.24867/grid-2024-p70

Federal Government of Nigeria [FGN]. (2021). *Nigeria's first nationally determined contribution: 2021 update*. United Nations Framework Convention on Climate Change (UNFCCC). https://unfccc.int/sites/default/files/NDC/2022-06/Nigeria%20First%20NDC%20Updated%20July%202021.pdf

Huber, J. (1985). *Die verlorene Unschuld der Ökologie: Neue Technologien und superindustrielle Entwicklung* [Lost innocence of ecology]. Fischer Taschenbuch Verlag.

Ifegbesan, A. P., Ogunyemi, B., & Rampedi, I. T. (2017). Students' attitudes to solid waste management in a Nigerian university: Implications for campus-based

sustainability education. *International Journal of Sustainability in Higher Education*, *18*(7), 1244–1262. https://doi.org/10.1108/IJSHE-03-2016-0057

Ilechukwu, L. C., & Njoku, C. C. (2014). Optimising e-learning in Nigerian universities for sustainable development. *Journal of Information Engineering and Applications*, *4*(10), 55–61.

Intergovernmental Panel on Climate Change. (2023). *Climate Change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. https://doi.org/10.59327/IPCC/AR6/9789291691647

Isaias, P., & Issa, T. (2013). E-learning and sustainability in higher education: An international case study. *International Journal of Education and Research*, *1*(12), 1–12.

Leal Filho, W., Kovaleva, M., Ng, A. W., Nagy, G. J., Lütz, J. M., & Dinis, M. A. P. (2025). Artificial intelligence and climate change: The potential roles of foundation models. *Environmental Sciences Europe*, *37*, Article 159. https://doi.org/10.1186/s12302-025-01153-2

Odukoya, J. A., Ayo, C. K., & Azeta, A. (2014). A review of Open & Distance Education and human development in Nigeria. *International Journal of Emerging Technologies in Learning (iJET)*, *9*(6), 63–67. https://doi.org/10.3991/ijet.v9i6.4121

Olufunke, A. C., & Adegun, O. A. (2014). Utilisation of Open Educational Resources (OER) and quality assurance in universities in Nigeria. *International Journal of Education and Research*, *2*(7), 51–62.

Osaat, S., & Nsereka, L. (2012). Impact of Information and Communication Technology on distance education: The case of National Open University of Nigeria. *African Research Review*, *6*(1), 325–341. https://doi.org/10.4314/afrrev.v6i1.27

Roy, R., Potter, S., & Yarrow, K. (2008). Designing low carbon higher education systems. *International Journal of Sustainability in Higher Education*, *9*(2), 115–130. https://doi.org/10.1108/14676370810856279

Tunmibi, S., Aregbesola, A., Adejobi, P., & Ibrahim, O. (2015). Impact of e-learning and digitalisation in primary and secondary schools. *International Journal of Education and Research*, *3*(1), 445–460.

Versteijlen, M., & Janssen Groesbeek, M. (2024). Perspective Chapter: Educational technology under scrutiny in higher education – A framework for balancing environmental, economic and social aspects in a blended design. In *Sustainable Development*. IntechOpen. https://doi.org/10.5772/intechopen.1005117

Versteijlen, M., Perez Salgado, F., Janssen Groesbeek, M., & Counotte, A. (2017). Pros and cons of online education as a measure to reduce carbon emissions in higher education in the Netherlands. *Current Opinion in Environmental Sustainability*, *28*, 80–89. https://doi.org/10.1016/j.cosust.2017.09.004

Wals, A. E. J., & Benavot, A. (2017). Can we meet the sustainability challenges? The role of education and lifelong learning. *European Journal of Education*, *52*(4), 404–413. https://doi.org/10.1111/ejed.12250

Yin, Z., Jiang, X., Lin, S., & Liu, J. (2022). The impact of online education on carbon emissions in the context of the COVID-19 pandemic – Taking Chinese universities as examples. *Applied Energy*, *314*, Article 118875. https://doi.org/10.1016/j.apenergy.2022.118875

York, R., Rosa, E. A., & Dietz, T. (2003). STIRPAT, IPAT and ImPACT: Analytic tools for unpacking the driving forces of environmental impacts. *Ecological Economics*, *46*(3), 351–365. https://doi.org/10.1016/S0921-8009(03)00188-5

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