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Digital Carbon Footprint in Nigeria: Awareness, Emissions, and Sustainable Mitigation Strategies

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Abstract

The accelerating pace of digital transformation has significantly reshaped communication, commerce, education, governance, and financial systems worldwide. While Information and Communication Technologies (ICT), cloud computing, artificial intelligence, and digital services have enhanced productivity and economic development, their growing dependence on electricity-intensive infrastructure has raised concerns regarding environmental sustainability. This study assessed the level of awareness of digital carbon footprints among Nigerians and estimated carbon dioxide (CO_2) emissions associated with common digital activities. A descriptive research design incorporating quantitative and qualitative approaches was adopted. Data were collected from 500 internet users across major Nigerian cities, including Lagos, Abuja, Port Harcourt, Kano, and Enugu, using structured online questionnaires. Results revealed relatively low awareness of digital carbon footprints, with only 48.4% of respondents indicating awareness, while 51.6% lacked knowledge of the environmental consequences of digital technologies. Analysis of internet usage patterns showed an average daily online engagement of approximately 3.2 hours per user. Applying internationally recognized emission factors for digital activities yielded an estimated annual emission of approximately 46.7 tonnes of CO_2 for the sampled population. The findings reveal a substantial knowledge gap regarding the environmental implications of digitalization despite increasing internet penetration in Nigeria. The study recommends public awareness campaigns, sustainable digital practices, green ICT investments, and policy interventions to support environmentally responsible digital transformation in Nigeria.

Keywords

Digital Carbon Footprint,
Climate Change,
ICT,
Carbon Emissions,
Digital Sustainability,
Nigeria.

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1. Introduction

The Fourth Industrial Revolution has ushered in an era of unprecedented digital transformation characterized by the widespread adoption of Information and Communication Technologies (ICT), artificial intelligence (AI), cloud computing, big data analytics, blockchain technologies, smart manufacturing systems, and digital financial services. These technological innovations have fundamentally altered the way societies communicate, learn, conduct business, and access public services. The digital economy has emerged as a major driver of economic growth, innovation, and global competitiveness.

Despite the numerous socio-economic benefits associated with digitalization, increasing concerns have been raised regarding its environmental implications. The operation of digital technologies requires extensive physical infrastructure, including data centres, telecommunication networks, cloud servers, internet exchange points, and billions of connected electronic devices. These infrastructures are heavily dependent on electricity, much of which is still generated from fossil fuel-based energy sources. Consequently, digital activities contribute indirectly to greenhouse gas emissions and climate change.

The environmental impact associated with the use of digital technologies is commonly referred to as the digital carbon footprint. Digital carbon footprint represents the total amount of carbon dioxide and other greenhouse gases emitted as a result of internet usage, data processing, cloud storage, online communication, video streaming, social media interactions, video conferencing, online gaming, and other digitally mediated activities. Although individual digital actions may appear environmentally insignificant, their cumulative effects across millions of users can result in substantial carbon emissions.

Recent studies estimate that the global ICT sector contributes between 1.5% and 4% of worldwide carbon emissions, a proportion comparable to or exceeding emissions from the aviation industry. As internet penetration, cloud computing adoption, and artificial intelligence applications continue to increase globally, the carbon footprint of digital technologies is projected to rise substantially in the coming decades.

Nigeria possesses one of the largest and fastest-growing digital markets in Africa. According to the Nigerian Communications Commission (NCC), the country currently has more than 103 million internet users and over 36 million active social media users. Digital technologies have become central to banking, e-commerce, education, entertainment, healthcare, governance, and social interactions. However, while considerable attention has been devoted to expanding digital inclusion and connectivity, limited research has examined the environmental consequences of digital activities among Nigerian internet users.

Understanding public awareness of digital carbon footprints is essential for developing sustainable digital policies and encouraging environmentally responsible online behaviour. Therefore, this study investigates awareness levels of digital carbon footprints among Nigerians and estimates the carbon emissions associated with common internet-based activities.

2. Methodology

2.1 Research Design

The study adopted a descriptive survey research design incorporating both quantitative and qualitative approaches. The design was considered appropriate because it enabled the collection of data from a large and diverse population while providing insights into internet usage patterns and awareness of environmental sustainability issues associated with digital technologies.

2.2 Study Area

The research was conducted in five major Nigerian cities with relatively high levels of digital connectivity and internet penetration:

- Lagos
- Abuja
- Port Harcourt
- Kano
- Enugu

These cities represent major economic, administrative, educational, and commercial centres where digital technology usage is widespread.

2.3 Population and Sampling Technique

A stratified random sampling technique was employed to ensure adequate representation across different demographic categories, including age groups, educational levels, occupations, and geographical locations. A total of 500 internet users participated in the study.

The sampling strategy ensured that respondents represented diverse socio-economic backgrounds and varying levels of digital literacy, thereby improving the reliability and representativeness of the findings.

2.4 Data Collection

Primary data were collected using structured online questionnaires administered through Google Forms. The questionnaire was designed to obtain information on:

- Frequency of internet usage
- Daily online activity duration
- Video streaming habits
- Cloud storage utilization
- Device usage patterns
- Social media engagement
- Awareness of digital carbon footprints
- Awareness of environmental impacts of digital technologies

The online mode of administration facilitated rapid data collection and enabled participation from respondents located in different regions of the country.

2.5 Data Analysis

Descriptive statistical methods including percentages, frequencies, and weighted averages were employed to analyze the data. Carbon emission estimates were derived using internationally recognized emission benchmarks reported by The Shift Project (2021), the International Energy Agency (IEA), and other relevant studies on digital sustainability.

3. Results and Discussion

3.1 Awareness of Digital Carbon Footprints

The results indicate relatively low awareness of digital carbon footprints among Nigerian internet users. Approximately 48.4% of respondents reported awareness of the concept, whereas 51.6% indicated little or no knowledge of the environmental impacts associated with digital technologies.

Further analysis revealed that:

- 48.4% were aware of digital carbon footprints.

- 31.1% were unaware of the environmental consequences of digital technology.
- 20.5% had never heard of digital carbon footprints.

These findings suggest that although internet adoption is widespread, environmental literacy relating to digital technology remains limited. The relatively low awareness observed may be attributed to inadequate environmental education, insufficient public discourse on digital sustainability, and limited integration of climate-related digital literacy into educational curricula. Similar findings have been reported in developing economies where digital inclusion policies often prioritize access and connectivity while neglecting environmental sustainability considerations.

3.2 Estimation of Carbon Emissions from Digital Activities

The estimation of carbon emissions associated with digital activities was based on internationally recognized emission factors reported by The Shift Project (2021), the International Energy Agency (IEA), and related studies on digital sustainability. These benchmarks account for energy consumption across the entire digital ecosystem, including data centres, telecommunication infrastructure, network transmission systems, cloud computing services, and end-user devices such as smartphones, tablets, laptops, and desktop computers.

Although digital activities are often perceived as environmentally benign due to their virtual nature, they rely on extensive physical infrastructure that requires substantial amounts of electricity. Every internet search, video stream, online meeting, cloud storage operation, or gaming session involves data transmission through servers and communication networks that consume energy and indirectly generate greenhouse gas emissions. Consequently, the cumulative environmental impact of billions of daily digital interactions worldwide has become a growing concern in climate change and sustainability discourse.

Table 1 presents average carbon emission estimates for common digital activities.

Table 1: Average Carbon Emissions from Selected Digital Activities

Activity	**Estimated CO_2 Emissions**
Video Streaming (1 hour)	55–100 g CO_2
Web Browsing (1 hour)	10–20 g CO_2
Video Conferencing (1 hour)	150 g–1 kg CO_2
Online Gaming (1 hour)	50–75 g CO_2

The results indicate considerable variation in emissions among different digital activities. Video conferencing exhibits the highest carbon footprint, ranging from 150 g to 1 kg CO_2 per hour depending on video resolution, internet connectivity, number of participants, and the energy efficiency of supporting infrastructure. High-definition and ultra-high-definition video conferencing platforms require continuous transmission of large volumes of data, resulting in elevated energy consumption.

Similarly, video streaming contributes substantially to digital emissions because of the large data volumes required for continuous audio-visual content delivery. Streaming services such as YouTube, Netflix, Amazon

Prime, TikTok, and other social media platforms have become major drivers of internet traffic globally. The increasing popularity of high-definition (HD) and 4K content further amplifies energy demands and associated emissions.

Online gaming also contributes significantly to carbon emissions due to prolonged user engagement, intensive graphics processing, cloud gaming services, and real-time data exchange. In contrast, web browsing generally exhibits the lowest carbon footprint because it requires relatively smaller data transfers and lower computational resources.

These findings demonstrate that digital carbon emissions are highly dependent on the nature, duration, and intensity of online activities. Consequently, understanding user behaviour is essential for developing strategies aimed at reducing the environmental impacts of digital technology usage.

3.3 Internet Usage Patterns

Analysis of survey responses revealed substantial engagement with internet-based services among respondents. Daily internet usage duration was categorized into three groups to facilitate the assessment of digital activity intensity and corresponding carbon emissions.

Table 2: Internet Usage Patterns among Respondents

Daily Usage Duration	Percentage (%)
Less than 1 hour	24.6
Approximately 3 hours	44.0
Greater than 6 hours	27.0

The results indicate that internet use has become deeply integrated into the daily lives of many Nigerians. Approximately 44.0% of respondents reported spending about three hours online daily, representing the largest user category. This finding reflects the growing reliance on digital platforms for communication, education, entertainment, banking, business transactions, and social networking.

Furthermore, 27.0% of respondents reported spending more than six hours online per day. This category likely includes students engaged in online learning, professionals working remotely, digital entrepreneurs, content creators, and individuals who depend heavily on digital platforms for occupational and social activities. Extended internet usage among this group suggests a potentially higher contribution to digital carbon emissions due to prolonged interaction with energy-intensive digital services.

Only 24.6% of respondents reported internet usage below one hour daily, indicating that low-intensity digital engagement constitutes a relatively small proportion of the surveyed population.

To estimate the average duration of internet use across all respondents, weighted average calculations were employed:

Average Daily Usage

= (0.5 \times 24.6%) + (3 \times 44.0%) + (6.5 \times 27.0%

=12.3 + 132 + 175.5

=319.8/100

approx. 3.2 \text {hours per user per day}

The calculated weighted average indicates that respondents spend approximately 3.2 hours online each day. This level of engagement reflects moderate to high digital activity and demonstrates the increasing centrality of internet technologies in contemporary Nigerian society. The result also provides a basis for estimating associated carbon emissions from routine digital activities.

3.4 Estimated Carbon Emissions

To quantify the environmental implications of respondents' digital behaviour, a conservative average emission factor of 80 g CO_2 per hour was adopted. This value represents a blended estimate derived from common digital activities including web browsing, social media engagement, video streaming, online communication, cloud storage access, and virtual meetings.

Based on the calculated average daily internet usage of 3.2 hours, the average carbon emission per user was estimated as follows:

CO_2 Emission per User per Day

$$3.2 \text{ hours/day} \times 80 \text{ g } CO_2\text{/hour}$$

$$= 256 \text{ g } CO_2\text{/day}$$

For the entire sample population of 500 respondents:

Daily Emissions

$$500 \times 256 \text{ g}$$

$$= 128{,}000 \text{ g/day}$$

$$= 128 \text{ kg/day}$$

Annual Emissions

$$128 \text{ kg/day} \times 365 = 46{,}720 \text{ kg/year}$$

$$= 46.7 \text{ tonnes } CO_2\text{/year}$$

The analysis reveals that the surveyed population collectively generates approximately **46.7 tonnes of carbon dioxide annually** through internet-related activities alone.

Although this quantity may appear relatively small when compared to emissions from heavy industries, transportation systems, or fossil fuel power generation, it becomes environmentally significant when considered at larger scales. Nigeria currently has more than 103 million internet users, and if similar consumption patterns are assumed nationwide, the cumulative carbon footprint associated with digital activities could reach several million tonnes of CO_2 annually.

Moreover, ongoing increases in internet penetration, smartphone ownership, cloud computing adoption, artificial intelligence applications, online education, and digital entertainment services are likely to further increase future digital emissions. Therefore, digital consumption patterns should be recognized as an emerging component of national carbon inventories and sustainability planning.

The findings highlight the hidden environmental costs associated with seemingly intangible online activities and reinforce the importance of promoting carbon-conscious digital behaviour among internet users.

3.5 Implications for Sustainable Digital Development

The findings of this study have important implications for sustainable development and environmental management in Nigeria's rapidly expanding digital economy. While national policies have largely focused on increasing internet access, digital literacy, financial inclusion, and technological innovation, relatively little attention has been paid to the environmental sustainability of digital transformation.

The estimated annual emissions associated with internet use demonstrate that digital technologies, although less visibly polluting than traditional industrial activities, are not environmentally neutral. As Nigeria continues to experience growth in cloud computing, e-commerce, digital banking, artificial intelligence, smart cities, Internet of Things (IoT) technologies, and online education systems, the energy demand associated with digital infrastructure will inevitably increase.

Of particular concern is the rapid growth of data centres, which represent one of the most energy-intensive components of the digital ecosystem. Data centres operate continuously to support cloud services, online platforms, and digital communications, requiring substantial electricity for both computing operations and cooling systems. In regions where electricity generation remains heavily dependent on fossil fuels, increased digital activity translates directly into higher greenhouse gas emissions.
The results further reveal a significant gap between digital adoption and awareness of its environmental consequences. Despite widespread internet use among respondents, more than half lacked knowledge of digital carbon footprints. This knowledge deficit suggests that sustainability considerations have not yet been fully integrated into digital literacy programs, educational curricula, or public awareness initiatives.

To achieve sustainable digital development, environmental considerations must be embedded within Nigeria's digital transformation strategy. Government agencies, educational institutions, telecommunications companies, and technology providers should collaborate to promote green ICT practices, improve energy efficiency, encourage renewable-energy-powered digital infrastructure, and educate citizens about environmentally responsible online behaviour.

Furthermore, investments in renewable energy, energy-efficient data centres, sustainable cloud computing technologies, and digital carbon accounting systems will be essential for reducing the environmental footprint of Nigeria's growing digital economy. By integrating sustainability principles into digital development planning, Nigeria can continue to harness the benefits of technological innovation while minimizing its contribution to climate change and environmental degradation.

4. Conclusion

Digital technologies have become indispensable drivers of socio-economic development in Nigeria. However, the environmental consequences associated with digital activities remain largely overlooked. This study demonstrates that awareness of digital carbon footprints among Nigerians is relatively low despite substantial engagement with internet-based services.
The estimated annual emission of approximately 46.7 tonnes of CO_2 generated

by the surveyed population illustrates the hidden environmental cost of digital activities. As Nigeria continues to expand its digital economy, integrating sustainability considerations into technology adoption and digital infrastructure development will become increasingly important.

Creating awareness, encouraging responsible digital behaviour, promoting renewable energy utilization, and implementing supportive environmental policies are essential for ensuring that digital transformation contributes to sustainable national development.

5. Recommendations

5.1 Public Awareness and Education

- Implement nationwide awareness campaigns on digital carbon footprints.
- Integrate digital sustainability concepts into primary, secondary, and tertiary educational curricula.
- Promote environmental literacy through social media and traditional media platforms.

5.2 Sustainable Digital Practices

Internet users should be encouraged to:

- Reduce unnecessary screen time.
- Optimize device energy settings.
- Stream content at lower resolutions when appropriate.
- Download frequently accessed content.
- Shut down unused devices and applications.

5.3 Government and Regulatory Actions

Relevant agencies including NCC, NITDA, and NESREA should:

- Develop national digital sustainability guidelines.
- Promote renewable-energy-powered data centres.
- Encourage green ICT investments.
- Establish carbon reporting frameworks for digital service providers.

5.4 Research and Green Technology Development

- Support local research on digital carbon accounting.
- Develop digital carbon monitoring systems.
- Encourage innovation in energy-efficient computing technologies.
- Promote sustainable cloud computing infrastructure.

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