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Integrating Climate Finance with Circular Economy Principles to Accelerate Clean Energy Transitions in Nigeria

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ABSTRACT

The transition to clean energy in Nigeria is hindered by financing constraints, policy gaps, and reliance on a linear economic model that prioritizes resource exploitation over sustainability. This paper explores the integration of climate finance with circular economy principles as a means to accelerate Nigeria's clean energy transition. It identifies financing gaps in Nigeria's energy sector, examines key determinants of climate finance, and evaluates how circular economy practices can enhance access to climate finance. The study proposes a framework that aligns circular economy principles with green finance criteria to optimize resource use, reduce waste, and promote sustainable investment in renewable energy projects. By leveraging circular economy strategies such as resource efficiency, product lifecycle extension, and material recovery. Climate finance can be deployed more effectively to drive green growth, economic diversification, and environmental sustainability. The paper also reviews global and local case studies to highlight best practices and policy recommendations that can inform Nigeria's transition towards a low-carbon and resilient energy system. Findings underscore the need for robust regulatory frameworks, increased private-sector participation, and innovative financial instruments to bridge the climate finance gap. Ultimately, this study advocates for a paradigm shift in Nigeria's energy and financial policies, ensuring that climate finance mechanisms are designed to support circular economic activities that enhance energy security and socio-economic development.

Keywords: Climate Finance, Circular Economy, Clean Energy, Green Growth, Sustainability.

Overview Of Climate Finance and Circular Economy in Nigeria

Many developing countries have underutilized access to climate finance despite the urgency to ramp up climate change mitigation and adaptation. This is especially the case following the COVID-19 pandemic, where both public and private finance in the economy has declined across the board (Hoff et al., 2005). There are myriads of constraints to developing countries' access to climate and renewable energy finance, including political and legal contingencies, market and policy imperfections, risks, and the relatively high costs associated with renewable energy project development and technologies. Conventional accounting does not consider the value of green practices or environmental and social externalities (Borenstein, 2012). However, financing mechanisms and institutions that nurture and unlock the potentially disruptive power of renewable energy and other circular economy principles can transform developing countries towards sustainability and inclusive growth in the short and long term, and at industry and firm levels (Barbier, 2010).

Nigeria has relatively low climate change mitigation and competitiveness gains associated with integrating circular economy principles into its industrial development strategy and finance plan. Already, the energy

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IV April 2025

sector in Nigeria is positioning for a rapid low-carbon and climate-resilient transition in the national development plan

(Emodi & Boo, 2015). Green growth in Nigeria brings direct job opportunities, mainly in services, construction, and financial sectors for all employment groups. It also fosters strong links and spillovers in social, economic, and environmental justice, and significant benefits to everyone in terms of improved well-being and vibrant ecosystems. The challenge stems from how the country unlocks and scale up renewable energy and other low-carbon technologies financing. Nigerian institutions, leaders, investors, and financiers must be equipped with the right regulatory, reporting, business, technical, and financial mechanisms and information required to maximize the shift to a more sustainable and inclusive economy (Brahmbhatt et al., 2023).

BACKGROUND AND RATIONALE FOR CLIMATE FINANCE

Climate change risks and impacts are intensified by the prevailing linear economic model, which drives economic growth and employment through the continuous extraction, use, and disposal of natural resources. This take-make-dispose system has historically been strongly associated with GDP growth, reinforcing unsustainable patterns of production and consumption**.** As Nigeria increases its commitment to promoting the use of clean energy sources, it is critical to start considering the implications of growth funded by climate financing, which lie within sustainable, ecological, and circular economy principles. (Akadırı et al., 2022; Akınyemi et al., 2019). Given the substantial volume of financial support expected to flow through the system, there is a valuable opportunity to develop climate economic models grounded in principles of sustainability and ethical responsibility. However, the links between promoting the use of clean energy sources and the core components of the circular economy are completely overlooked in the present climate financing opportunity in Nigeria. (Askari & Parsa, 2024; Bhandary et al., 2021; Ozili, 2021). This research sets out to address this gap. It should be noted that the percentage of funds allocated for climate risk reduction strategies based on circular economy principles is very low. In expanding climate financing opportunities, Nigeria must be cautious not to focus solely on climate protection at the expense of broader sustainability goals, as this could lead to missed opportunities for achieving more comprehensive policy outcomes**.** While climate finance has increasingly supported clean energy transitions across sectors, including healthcare facilities, educational institutions, and individual households, there remains a notable gap in the integration of circular economy principles at the planning and implementation stages of these initiatives. Circular strategies such as resource efficiency, reuse, recycling, and sustainable product design can significantly enhance the long-term viability, cost effectiveness, and environmental impact of energy projects. However, many climate financed interventions continue to rely on traditional linear approaches that prioritize short-term carbon reduction goals without considering material circularity or lifecycle sustainability. This oversight not only limits the full potential of climate investments but also risks missing broader development objectives such as economic resilience, local job creation, and waste reduction. Therefore, a critical question arises: why have circular economy principles been largely overlooked in the design of current clean energy programs, and how can future climate finance mechanisms be structured to incorporate them more effectively?

Research Objectives

The objectives of the study can be summarized as follows:

To shed light on the current financing gaps in Nigeria's energy sector and the associated implications for Nigeria's clean energy transition.

To empirically analyze the key determinants of climate finance in Nigeria's energy sector and consider how private sector circular economy practices have improved access to climate finance, with an emphasis on three top-performing sectors in energy finance among Nigeria's ten priority sectors.

To develop a framework that integrates key principles of the circular economy into climate finance interventions, with a view to addressing the clean energy financing gap in Nigeria. This would involve the

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IV April 2025

development of design blueprints and linkages between circular economy principles and green finance criteria for the considered sectors.

By developing the blueprint from the perspective of the private sector energy conservation initiative for households, the study seeks to stimulate demand among start-ups and Small and Medium-sized Enterprises (SMEs) in Nigeria's clean energy space. This is particularly useful, given that Nigerian start-ups consider energy access to be the most critical enabling factor for the firm's operation and success, with power outages cutting down the number of business hours in a typical day to below six hours.

Climate Finance and Circular Economy: Concepts and Frameworks

Climate finance, which is a central component to address climate change, is essential to facilitate the clean energy transition needed to meet the global climate imperatives of limiting the rise in average global temperatures to well below 2°C or even 1.5°C.(Kapoor & Malviya, 2021). This research reviews the challenges and barriers to climate finance in general, and in Nigeria in particular. It enumerates key proposals that have been made to help bridge the gap between the demand and supply of climate finance, despite the presumed significant financing resources, accessible options, perceived risks, and institutional frameworks that make financing clean energy projects attractive. The central argument of this paper is that, despite significant progress and well-intentioned efforts toward sustainable transformation, Nigeria’s transition remains constrained by a structural comparative disadvantage: its position as a country still navigating the complex and resource intensive path of industrialization. This developmental stage limits the country’s ability to fully leverage advanced technologies, mobilize large scale private investments, and adopt circular and low carbon models that are more accessible to already industrialized nations.

The concept of circular economy (CE) is relatively new in climate change discourses on clean energy, and the underlying principles have not been given due attention in climate finance discourse. Although CE has gained considerable policy attention in some countries and is seen as a key strategy for sustainable transition, the influence and impact of CE on climate finance have hardly been explored (Warren, 2019, 2020). With significant institutional, legal, and policy frameworks already in place within the global community and in Nigeria on CE, this research argues that the principles should be intertwined with access to climate finance to enable an accelerated transition towards sustainable green growth in many African economies.

Mobilizing Climate Finance for Resilience: Bridging Gaps and Advancing Green Transitions in Developing Economies.

In order to fight the negative impacts of climate change as well as contribute to the development of climate resilience and lower carbon economies, many developing countries require significant resources, in addition to already available domestic resources (Edmark & Persson, 2021; Kapoor & Malviya, 2021). Such resources are anticipated to come from significant financial contributions mobilized both domestically and internationally, alongside investments that support the transfer of adaptation and mitigation technologies. As a result, climate finance is now broadly understood as funding dedicated to tackling the challenges of climate change. Moreover, cutting down on society’s greenhouse gas emissions, even with climate finance, may still drain resources towards climate change maintenance, which suggests that concrete, sustainable, and innovative climate financing can only continue when other Sustainable Development Goals (SDGs) have been guaranteed (Knudson, 2020).

Given the persistent gap in climate finance and investment, along with the completion of key international agreements, the increasing relevance of blended financial instruments, and the integration of developing countries into global markets as emerging investment destinations, it is essential to examine climate action at the regional level. Additional factors such as the growing reliance on domestic financial resources and the strategic importance of national policy frameworks further reinforce this need.

At the regional level, financing and investment strategies must be informed by local priorities and designed to advance both adaptation and mitigation efforts in response to the global climate challenge (Heidrich et al., 2015).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IV April 2025

This focus is especially important in Nigeria, where the impacts of climate change pose serious risks to the population, the environment, and socio-economic development. Attracting and directing investment flows toward building a resilient and sustainable green economy is therefore a national imperative.

Redesigning Value Chains: Circular Economy as a Catalyst for Sustainable Growth and Clean Energy Transitions.

The circular economy model capitalizes on the principles of designing out waste and pollution, retaining products, materials, and resources at their highest possible value to create a closed-loop circular system. It goes contrary to the conventional take-make-waste linear economy by replacing and expressing the wastefulness with a three-phased principle which includes: (1) sourcing materials more responsibly through a more demand-driven finance that supports sustainable practices and environmental stewardship, (2) extending the life of these resources with better regenerative finite resources and durable products respectively, and (3) at the end of product life, the recovery of the resources which will be produced to be used repeatedly through the bio-economy strategies that are deemed environmentally responsible. The circular economy is essential in achieving a sustainable economy by driving the clean energy transition. It proposes business models that are restorative and regenerative by design, based on designing out waste and pollution, retaining products, components, and materials at their highest value while regenerating natural systems (Bocken et al., 2013; Cheshire, 2019; Milios, 2017). The benefits of the circular economy have already been initiated and experienced by countries through projects that allowed the supply of affordable energy-efficient equipment, creating access to similar products in the market by investors, among others. Economic and environmental benefits from energy efficiency, reduction of input production materials, as well as reduction of pollution have been recorded from this strategy.

Powering The Future: Unlocking Clean Energy Transitions in Nigeria

Nigeria has significant potential for clean energy development. The country is home to the largest natural gas reserves in Africa while receiving sunlight all year round. Despite its impressive resources, access to electricity is a significant challenge for Nigeria, as approximately 50% of its population is off the grid. This results in over-reliance on wood for heating, with associated harmful health impacts as well as more disturbing climate consequences (Ibitoye, 2013; Williams et al., 2019). The energy sector is ranked as the one of the worst in the world due to low performance in providing energy access and environmental sustainability.

This has spurred efforts to redesign the national energy policy framework, as evidenced by recent shifts in government policy direction. It also includes a robust energy policy document, the Vision 30:30:30 Energy Policy for Nigeria, which seeks to provide 30 gigawatts of electricity by 2030, with a 30 percent contribution from renewables. The policy is being updated to perform well as an enabling framework for investment in clean energy. This policy is contained in the Vision for Nigeria. (Adeyanju et al., 2020; Nwozor et al., 2021).

Energy Poverty and Power Paradox: Navigating Nigeria's Current Energy Landscape.

Nigeria, as the most populous country in Africa with a population of over 200 million inhabitants, is one of the most energy poverty-stricken countries in the world, with over 100 million people without access to electricity. The country has an energy challenge, as its energy consumption per capita stands at 150 kWh/capita, which is a quarter of the world average. Even at that, only about 60% of Nigerians have access to electricity. The majority rely on off-grid and backup diesel generators, which are expensive and emit the harmful greenhouse gas CO2 (Ekpe & Umoh, 2019; Kayode et al., 2018; Oyedepo et al., 2018). Petrol stations in Nigeria run secondary generators to power their businesses because of the unreliable supply from the grid. Nigeria also has immense power generation challenges. With a total installed capacity of over 13 GW, the nation only generates about 4 gigawatts of power, and only 50% of this is grid-connected.

This unreliable supply means that most businesses use diesel generators to power their operations. However, a lack of adequate power supply and the high cost of diesel generators will cost Nigeria's economy 600 billion USD over a 20-year period in an 8-hour power loss. Further stalls access to more technologies that remain out of reach for millions, and the loss from lack of electricity means a 7% loss in GDP (Aliyu et al., 2013; Ekpe &

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IV April 2025

Umoh, 2019). While Nigeria is faced with an energy and power crisis, the world is making revolutions in alternative, innovative, climate-friendly solutions in the exploitation of renewable energy. Such options are clean, climate-friendly, sustainable, and economically viable alternative energy sources in the areas of hydropower, wind, solar, bioenergy, and geothermal. Furthermore, a more climate-friendly solution arises in technology that uses energy more efficiently, such as light-emitting diodes, fuel-efficient vehicles, smart grids, and energy storage. These technologies help promote sustainable development with built-in co-benefits such as reduced air pollution, localized job creation, and lower costs of energy services.

Bridging Policy Gaps and Systemic Barriers in Circular Public Procurement.

At the subnational level, some challenges and opportunities can be highlighted in implementing circular economic principles in public procurement processes. In addition to the policy vacuum and the absence of institutional capacity for circular procurement currently discussed in the Nigerian context, several other factors impede its widespread adoption. These include limited peer benchmarking, entrenched rent-seeking practices, internal corporate politics, and a strong inclination toward preserving the status quo. Together, these challenges constrain the implementation of circular procurement guidelines at both the national and state levels (Hartley et al., 2020).Whereas the use of lifecycle costing and benefit estimation approaches can be highlighted as an opportunity for states that already conduct their procurement processes with life-cycle perspectives, there is a

committed group of environmentalists in government and in wider society that understand existing knowledge or can be trained to identify the steps that can be taken immediately to streamline public procurement processes. It is difficult to resolve some of the incentives and purchase rules that prefer low purchase costs due to harsh economic climate in Nigeria. The lack of domestic circular economy policies themselves, and insulation of domestic operations and economics from external policies that could create new niches and platforms along with the disconnected protocols and usability provisions in standards and environmental labels, play a role in limiting the adoption of circular economy models in Nigeria. Whether there would be market incentives remains unclear, given the existence of infrastructure that may reduce or eliminate the need for auxiliary systems and services such as battery storage units, inverters, monitoring software, grid integration tools, and maintenance or installation services. Although the public is willing to cooperate proactively and is willing to make trade-offs and pay higher costs for eco-friendly products, the absence of information in public procurement documents results in miscommunication whereby contractors are forced to offer or supply less sustainable products or services (Michelsen & Boer, 2009).

Integration Of Climate Finance and Circular Economy in Clean Energy Transitions

Clean energy transitions cut across different sectors of the economy, thereby requiring significant investment funds for effective implementation. It is essential that the growing demand for investment in clean energy transitions is coupled with the necessary tools and financial infrastructure to ensure a uniform approach to measuring the necessary investment (Chavarot & Konieczny, 2020). In response to growing concern not only about the adequacy of existing funds for clean energy transitions but also about the appropriateness of their deployment, governments and multilateral development finance institutions have emphasized the need for a unified and clearly defined framework for clean energy investment. The need for climate action from businesses and the financial sector has never been more urgent, and global commitments by countries and regions to net zero emissions are increasing. There is significant growth in interest and investments in clean energy technologies, particularly in renewables like wind, solar, and biomass (Gielen et al., 2019).

Clean energy transition refers to a shift in energy production from fossil fuels to renewable forms of energy. It typically involves switching to electric energy networks and mobility. The transition to clean energy, however, is a prerequisite for almost all efforts to mitigate climate change as it involves reducing the amount of energy consumed, changing diets, and adopting measures that are less carbon intensive. The circular economy is a business model that focuses on the importance of maintaining the values of products, materials, and resources in the economy for as long as possible and the generation of low or zero negative impacts. It ensures that products, materials, and resources are resistant, renewable, and environmentally friendly, minimizing resource consumption and waste. Climate finance is the financial capital deployed to support emission reductions and

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IV April 2025

the adaptation efforts of countries, companies, and other types of entities aiming to contribute to the overall effort in reducing growth.

Policy and Regulatory Instruments Guiding Nigeria's Energy Transition.

In Nigeria, several policies, guidelines, regulations, and incentives direct the country's energy landscape. The predominant energy policies include the 2015 Executive Order for Transparent and Efficient Management of Nigerian Public-Private Partnership projects (PPP Projects), which allows for the execution of joint venture arrangements in view of the prevailing realities of the Nigerian petroleum sector, leveraging circular economy principles and Nigeria's ailing downstream infrastructure. The Nigerian Gas Flare Commercialization Program aims to eliminate routine gas flaring by supporting technically and commercially sustainable gas utilization projects developed by competent investors. These projects are designed to reduce carbon emissions while providing accessible financial returns to their developers. Similarly, the Petroleum Industry Bill aims to regulate the allocation and development of oil exploration areas in the frontier basins to ensure environmental and economic sustainability. Nigeria's ongoing energy transition is further guided by the National Renewable Energy and Efficiency Policy developed by the Federal Government, which aims to demonstrate that by rapidly scaling renewable energy, energy efficiency, and energy access, the country can reduce the cost of energy consumption while simultaneously driving economic development. The Nigerian Electricity Regulatory Commission's primary function is to ensure an efficient transition from public sector electricity to a viable private sector model (Olujobi, 2020). Central to its role are financial and other technical constraints, including a lack of an integrated framework that aligns the strategic policy goals and directions of the energy technologies. The commission's asset reform, however, is central to the process through which this financing is finalized, and consequently, it provides governments the confidence to assume responsibility for covering the costs especially if other critical reforms are to be undertaken**.** The overall energy supply and consumption system model has shown that using renewable energy for single or multiple energy purposes can indeed prove to be very efficient and cost-effective.

The Circular Economy Cycle: A Framework for Sustainable Clean Energy.

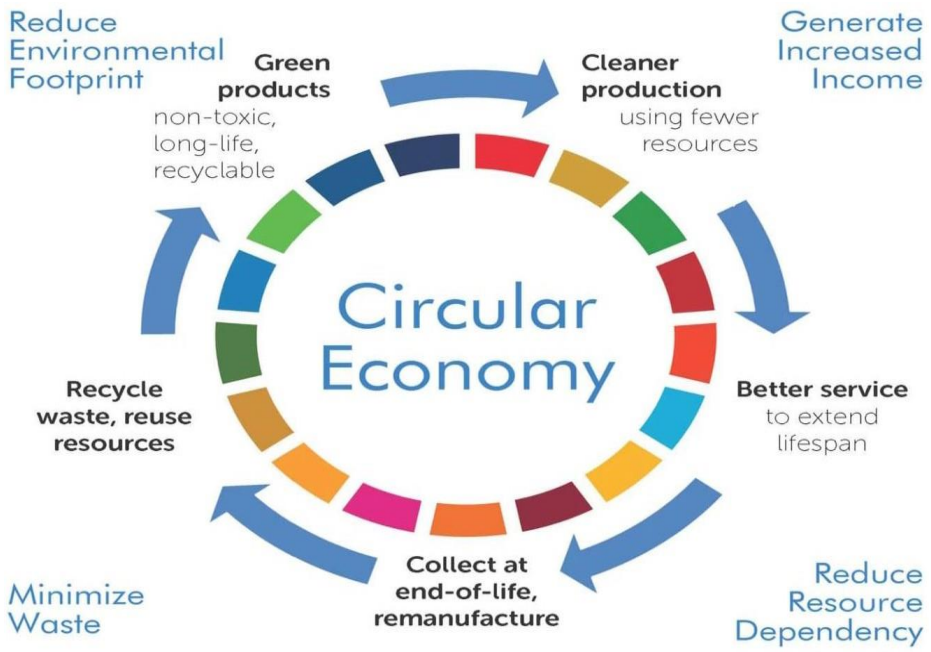

Figure 1

The circular economy cycle (Figure 1) captures essential principles such as green product design, cleaner production, extended product lifespan, remanufacturing, and resource reuse. These elements are vital for maximizing the impact of climate finance in clean energy transitions. For example, designing renewable

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IV April 2025

energy systems with recyclability in mind reduces long-term waste and emissions. Cleaner production methods reduces energy intensity, while extending product lifespans lowers the demand for raw materials.

At the end of their lifecycle, clean energy technologies like batteries and solar panels can be remanufactured or recycled, reducing environmental footprints and enhancing resource efficiency. This model not only minimizes waste and resource dependency but also generates new economic opportunities, such as jobs in recycling and local manufacturing.

Integrating circular practices into climate-financed projects ensures that such investments are not only sustainable but also scalable. In Nigeria, sectors such as waste management, energy, and the production or manufacturing industries present promising entry points for this integration. Directing climate finance toward circular initiatives like waste-to-energy systems and modular solar units with reusable components can enhance investment returns while supporting Nigeria's broader development goals. By aligning financing strategies with circular economy principles, Nigeria can accelerate its energy transition while advancing resource efficiency, local value creation, and environmental sustainability.

The Role of Banks in Advancing Circular Climate Finance for Clean Energy Transitions in Nigeria.

Banks in Nigeria are uniquely positioned to catalyse the transition to clean energy systems by mobilizing and directing climate finance toward circular economy solutions. The evolving financial landscape, driven by environmental sustainability imperatives and low-carbon development goals, requires banking institutions to move beyond traditional lending. They must adopt innovative financial instruments, support emerging circular business models, and facilitate market creation for clean energy investments that promote resource efficiency, reduce waste, and enhance socio-economic resilience.

One crucial pillar of circular climate finance is the deployment of tailored financial instruments and mechanisms. Such financing is indispensable for clean energy deployment, improving access to sustainable water sources, and upgrading waste management infrastructure. These interventions not only transform Nigeria's urban environment but also generate employment, promote food security, and reduce ecological degradation (Berg et al., 2012). In particular, financial support directed at African small and medium-sized enterprises (SMEs) developing circular goods, services, and business models can unlock actions that target resource-rich waste streams. This fosters the creation of local circular markets, which are essential for achieving the economies of scale necessary to make circular business models economically viable.

Banks have a strategic role to play in shaping these markets by providing financial products that address the unique needs of circular enterprises. Financing for modular solar units, waste-to-energy systems, and battery refurbishment centers are examples of how banks can align lending portfolios with climate and circular objectives. Banks such as the Bank of Industry and Development Bank of Nigeria, in partnership with multilateral agencies, can structure concessional finance and blended capital instruments to support projects that embed recyclability, lifecycle management, and local content into their operating models.

Banks and private financial institutions must begin to explore ways of accelerating climate-aligned lending for circular economy investments in key sectors, including energy materials, water, environmental services, and the built environment (Park and Kim, 2020). This approach supports policymakers in integrating circular economy principles into national policy strategies, while enabling financial institutions to identify new areas of competitive advantage.

Banks should also educate businesses, especially at early stages of engagement, on the financial and operational benefits of adopting cradle-to-cradle models across their value chains. These models emphasize sourcing inputs with high durability, minimal ecological harm, and cost-effectiveness, ultimately reducing long-term supply chain risks. Bank loan portfolios should reflect a commitment to sustainability principles by ensuring that financed projects incorporate circular economy practices (Ozili, 2021).

Moreover, the economic rationale for circular investment is becoming increasingly compelling. Energy efficiency initiatives—such as decentralized solar systems, solar-powered refrigeration units, and industrial

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IV April 2025

process optimization—can deliver operational savings that often pay for themselves within one to three years (Ozili, 2021). This reinforces the case for increased financial support toward resource-efficient clean energy systems.

To enhance their impact, Nigerian banks must also build internal capacity. This includes training credit and risk officers to assess circular business models, understanding the lifecycle economics of clean energy technologies, and developing evaluation tools that account for long-term resource efficiency and carbon reduction. Collaborations with research institutions, universities, and international development partners can aid in building technical knowledge and expanding bankable project pipelines.

Banks also play a role in shaping the broader financial ecosystem by advocating for regulatory reforms and participating in policy dialogue. Through engagement with institutions such as the Central Bank of Nigeria, the Securities and Exchange Commission, and the Federal Ministry of Finance, banks can support the development of green finance taxonomies, offer input on fiscal incentives for circular investments, and promote regulatory frameworks that encourage long-term climate-aligned lending (Park and Kim, 2020; Ozili, 2021).

Risk perception remains a significant constraint in the financing of circular clean energy projects. Banks can address this by implementing de-risking instruments such as loan guarantees, co-lending facilities, and partial risk-sharing mechanisms. Drawing from the success of frameworks like the Nigeria Incentive-Based Risk Sharing System for Agricultural Lending (NIRSAL), similar models can be adapted to clean energy and circular economy sectors to improve creditworthiness and project viability (Berg et al., 2012).

Consequently, the Nigerian banking sector is a critical enabler of circular climate finance. By mobilizing resources, promoting sustainable lending practices, supporting enterprise development, and shaping policy, banks can accelerate the clean energy transition in a way that advances environmental sustainability, economic inclusion, and long-term resilience. Their evolving role is essential for ensuring that climate finance contributes not only to decarbonization goals but also to a regenerative and circular economic future for Nigeria.

Learning From Cases: Circular Solutions Driving Climate Finance Impact

Case-based evidence underscores the transformative potential of aligning climate finance with circular economy principles to advance clean energy transitions. Projects implemented across Nigeria and other regions provide practical illustrations of how this integration can deliver multidimensional benefits, including emissions reduction, enhanced resource efficiency, and inclusive economic development.

In Nigeria, Green Climate Fund (GCF)-supported projects have contributed to strengthening institutional capacity and expanding the country's renewable energy landscape. These projects include efforts to enhance data infrastructure for climate risk management in agriculture, promote deforestation-free value chains in the cocoa sector, and develop Nigeria's solar and wind energy potential. Additionally, they have supported national and subnational entities in improving land and water resource governance (Emodi & Boo, 2015). Although not always explicitly framed as circular economy initiatives, many of these interventions embed resource efficiency and long-term sustainability, making them highly relevant to circular transition objectives.

Complementing these national-level projects are emerging local initiatives that illustrate the practical application of circular principles. In Lagos, a waste management company has successfully implemented systems to collect, sort, and recycle non-biodegradable post-consumer waste. This reduces landfill pressure and enables the recovery of materials that can be reintroduced into production cycles, thereby supporting local circular value chains (Ismanto et al., 2010). Similarly, a local cassava starch mill has adopted a waste-to-value model by converting cassava waste into industrial starch, generating multiple product lines while minimizing environmental externalities (Wang et al., 2022). These cases exemplify circular economy practices in action, particularly in terms of waste valorisation, closed-loop production, and resource-efficient manufacturing.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IV April 2025

Internationally, models such as the upcycling of single-use plastics into durable materials and the conversion of fibrous agricultural waste into clean energy provide further insights into the effectiveness of circular strategies. These initiatives, implemented in regions across East Asia and Europe, demonstrate how circular innovations can simultaneously address waste challenges, improve energy access, and generate employment (Hiraga et al., 2019; Wei & Zimmermann, 2017). Such projects offer Nigeria replicable blueprints that can be adapted to its socio-economic context and resource endowment.

Crucially, these case studies highlight the enabling role of climate finance in advancing circular innovation when structured effectively through green bonds, concessional lending, blended finance, or public-private partnerships. Climate finance can de-risk investments and incentivize the adoption of circular models across sectors. Embedding circularity into the design and implementation of climate-financed projects can also improve project performance by extending asset lifecycles, reducing environmental impacts, and increasing the overall return on investment.

Furthermore, the application of advanced technologies such as artificial intelligence (AI) and machine learning (ML) can amplify the efficiency and impact of these interventions. For example, AI-powered systems can optimize waste sorting and recycling operations, enhance energy demand forecasting, and facilitate real-time emissions tracking. These technologies support better data-driven decision-making, improve project monitoring and evaluation, and increase transparency for investors and stakeholders alike.

Despite these promising developments, significant gaps remain in terms of awareness, institutional coordination, and access to finance, particularly for small and medium-sized enterprises (SMEs) operating within Nigeria's informal sector. Addressing these barriers will require stronger policy coherence, increased stakeholder collaboration, and targeted capacity-building efforts.

Conclusively**,** the case studies reviewed affirm that the integration of circular economy principles into climate finance strategies holds considerable promise for accelerating Nigeria's clean energy transition. These initiatives demonstrate that circularity can be operationalized through practical interventions that enhance environmental sustainability, support industrial competitiveness, and drive inclusive growth. Leveraging these lessons to inform national policy, investment frameworks, and sectoral strategies will be critical in positioning Nigeria for a resilient and climate-smart future.

Measuring Transformational Outcomes and Spillover Effects in Circular Clean Energy Projects

In Nigeria, the measurement of outcomes from circular clean energy interventions, particularly those supported by climate finance, requires a methodological framework that captures both direct and indirect effects. The selection of appropriate impact evaluation methods depends on the nature of the intervention, the scale of implementation, and the quality and availability of data. However, many interventions produce **spillover effects** that extend beyond immediate beneficiaries, calling for more comprehensive evaluation approaches.

For example, in rural Nigerian communities where biogas systems have replaced traditional biomass cooking fuels, the resulting improvement in indoor air quality can significantly reduce respiratory illnesses. These health benefits often reach beyond individual households to the broader community. In such cases, conventional evaluation tools may undervalue the full impact of the intervention. The principle of **benefit sharing** requires that these positive externalities—such as reduced public health expenditures, improved maternal health, and enhanced school attendance due to better family health—are identified, measured, and reflected in the impact assessment process (Bourey et al., 2015).

In the Nigerian context, appropriate indicators for capturing such spillover effects may include changes in household healthcare costs, incidence of respiratory diseases, school enrolment or attendance rates, and community-level data on nutrition and stunting. These metrics provide a clearer picture of the wider social and economic effects of clean energy and circular economy projects, beyond their immediate technical or environmental outputs.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IV April 2025

Evidence of co-benefits can also justify scaling interventions or adapting them across sectors. For instance, the successful deployment of decentralized solar systems with recyclable components in peri-urban areas could inform similar applications for rural electrification, agricultural processing, or water access solutions. Demonstrating transformational outcomes in one domain such as public health or economic productivity can provide a foundation for replicating those benefits in other sectors, thereby maximizing the value of circular climate investments.

Nonetheless, Nigeria currently lacks a coherent and consistent framework for conducting independent impact evaluations, particularly in the area of climate finance and circular economy. The absence of structured evaluation mechanisms makes it difficult to establish causal links between interventions and observed changes. This challenge is compounded by limited access to disaggregated data, short project cycles, and inconsistent monitoring practices. Without robust attribution analysis, project outcomes may be either overstated or underestimated, leading to skewed interpretations of effectiveness.

Moreover, reliance on a narrow set of methodological tools, without accounting for Nigeria's diverse social and economic realities, often leads to partial or superficial conclusions. Such rigidity reduces the accuracy and relevance of evaluations and limits opportunities for institutional learning. When compounding biases and measurement gaps go unaddressed, impact assessments risk becoming detached from the practical realities on the ground.

To strengthen the evidence base for circular climate finance in Nigeria, stakeholders must adopt flexible and adaptive evaluation frameworks capable of capturing both measurable impacts and intangible co-benefits. This includes mixed method approaches that combine quantitative indicators with qualitative insights from local communities and project stakeholders. By contextualizing evaluation within Nigeria's unique development landscape, it becomes possible to support better policy design, enhance resource allocation, and inform the replication and scaling of high-impact clean energy initiatives.

Metrics and indicators for measuring circular climate finance impacts.

In Nigeria's ongoing transition toward a climate-resilient and circular economy, the development and application of measurable indicators are essential to track progress and guide decision-making. These metrics are particularly vital for aligning socio-economic and developmental priorities with the country's net-zero commitments and broader sustainability goals. Introducing a circular performance measurement framework will require the establishment of operational indicators that capture key dimensions such as material flows, waste reduction, emissions avoidance, and lifecycle environmental impacts (Sassanelli et al., 2019).

Sustainable finance efforts, including those emerging in Nigeria's green bond market and climate-related investment initiatives, increasingly advocate for simplified, standardized, and consistent reporting tools. Such instruments are crucial for aligning public and private investments with national development strategies and international climate obligations. Yet the transition to a fully circular economy requires more than financial disclosure—it demands a collaborative approach to designing, validating, and harmonizing impact measurement standards. This process must involve statutory and non-statutory stakeholders, including the Central Bank of Nigeria (CBN), the Securities and Exchange Commission (SEC), the Federal Ministry of Environment, and private sector actors (Mullan, 2017).

A nationally endorsed quality assurance framework that integrates both environmental and financial dimensions of risk and return is indispensable. In the circular economy and climate finance context, this involves translating environmental objectives—such as emissions reduction, pollution control, and resource conservation—into robust financial indicators that can be used to assess investment performance. Strengthening existing metrics and developing new ones that can dimension both positive and negative externalities will provide decision-makers with a more accurate understanding of long-term project value. These should account for environmental impacts across the project lifecycle, including emissions avoided, resource recovery rates, and social inclusion outcomes (Christensen et al., 2021).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IV April 2025

Ensuring that financial decisions align with circular and climate goals will also require collaboration with national statistics agencies, international reporting bodies, academic institutions, and civil society organizations. These entities can contribute data, analytical methodologies, and validation processes that ensure reliability and transparency. Once harmonized standards are in place, stakeholders will be able to apply consistent tracking codes, data systems, and evaluation frameworks. This consistency will promote trust among investors, reduce information asymmetry, and improve the transparency of climate and circular investments (Steuer and Tröger, 2022).

Advancing this agenda in Nigeria also means addressing data limitations and institutional fragmentation. Many climate-related projects in the country still rely on generic or externally imposed metrics that do not reflect the local policy environment, sectoral dynamics, or developmental needs. By grounding indicators in Nigeria's specific regulatory, environmental, and socio-economic contexts, projects will become more bankable, outcomes more measurable, and impacts more scalable.

Taken together, the development of a nationally relevant indicator system is a foundational step in scaling circular climate finance. When designed collaboratively and implemented consistently, such a framework will not only improve project accountability and resource allocation but also position Nigeria as a credible and attractive destination for international climate finance. This approach offers a pathway toward aligning investment flows with long-term sustainability objectives and ensuring that the transition to a circular economy delivers measurable value for people, planet, and prosperity.

Barriers And Enablers to Integrating Circular Economy Principles with Climate Finance

Integrating circular economy principles with climate finance in Nigeria faces several barriers. Key among them are fragmented financing mechanisms, information asymmetries, weak enforcement of environmental policies, and limited incentives for private-sector participation (Hartley et al., 2020). Additionally, most climate finance frameworks currently overlook micro, small, and medium enterprises (MSMEs), which dominate Nigeria's informal economy (Ozili, 2021).

However, enablers do exist. These include the potential for lifecycle costing in public procurement, the presence of an environmentally conscious segment within government and civil society and growing public willingness to pay for eco-friendly solutions (Michelsen & Boer, 2009). With better coordination and targeted reforms, Nigeria could harness these enablers to advance sustainable, circular finance models.

Strategic Pathways for Integrating Circular Economy Principles into Climate Finance

Nigeria must intensify efforts to embed circular economy principles into its development strategies, particularly as the availability of international climate finance becomes more constrained. Managing non-concessional climate funds responsibly is essential to ensure the sustainability of local development outcomes. The country's ability to unlock high-quality, climate-linked concessional finance will largely determine its competitiveness in the emerging green economy. Programs like the Zero Percent Pledge, which emphasize equitable benefit-sharing in emission reduction efforts, should be prioritized and institutionalized as models of long-term collaboration. Nigeria must also work with the international community to secure guarantees that can enhance the attractiveness of climate-related investments, ensuring each fund adds measurable domestic value. Furthermore, linking short-term financial instruments with long-term funding commitments will allow the country to sustain progress through the entire project life cycle. Aligning climate finance strategies with broader development cooperation frameworks will also enable access to larger capital pools.

To complement these efforts, Nigeria should take concrete steps to align existing policy frameworks such as the Industrial Revolution Plan, the Economic Recovery and Growth Plan, and the Nationally Determined Contributions with circular economy principles (Cheshire, 2019). This includes updating industrial strategies to target high-impact sectors like cement, steel, and consumer goods, which are economically strategic and well-positioned to adopt circular practices (Goyal et al., 2016). These sectors should receive access to sustainable financing, technical support, and procurement incentives, along with the right to recover and recycle materials from end-of-life products. Each industry should be guided by a tailored circular economy

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IV April 2025

framework, with results tracked through environmental indicators and the Sustainable Development Goals (Ezeudu & Ezeudu, 2019). Addressing current gaps in research and data is also crucial. Nigeria needs more empirical evidence on the long-term relationships between energy use, emissions, and industrial specialization, as well as better assessments of the carbon intensity of different technologies (Sarma & Zabaniotou, 2021). These efforts will enable the design of more effective policies and reduce vulnerability in energy and industrial systems. A robust research agenda will support policy innovation, investment prioritization, and progress toward national climate goals (Essers, 2013).

CONCLUSION: ALIGNING CLEAN ENERGY TRANSITION WITH CIRCULAR ECONOMY PRINCIPLES

This study examined two critical and interrelated transitions facing Nigeria: the clean energy transition, essential for meeting the country's net-zero commitments under the Nationally Determined Contributions (NDC), and the shift from a linear to a circular economy to achieve broader economic diversification. While Nigeria possesses abundant renewable energy potential, particularly in solar and wind, investments in these sectors remain inadequate, and the economy continues to rely heavily on fossil fuels. Aligning clean energy development with circular economy principles presents multiple co-benefits, including emissions reductions, improved energy security, resource efficiency, and inclusive growth. Financial intermediaries and policy institutions have a pivotal role in ensuring that financing mechanisms support this alignment and are structured to deliver scale, resilience, and measurable outcomes.

Key findings from this study demonstrate that integrating climate finance with circular economy principles can unlock significant economic opportunities and accelerate Nigeria's green transition in the post-COVID context. Redirecting a portion of oil and gas subsidies and international development funds toward renewable energy and circular infrastructure can mitigate carbon lock-ins and stranded assets while creating jobs and improving industrial competitiveness. The study identified Nigeria's energy and waste value chains as priority areas for circular reform, which collectively account for nearly 60 percent of the country's greenhouse gas emissions. Practical implications include the need to reconceptualize clean energy investment as a market-driven opportunity that can attract private capital and accelerate access to electricity and modern energy services (Oyedepo et al., 2018; Jacome et al., 2019). Policymakers, financial institutions, and development actors must adopt innovative, context-specific approaches that consider Nigeria's socio-economic realities while aligning with global sustainability principles. Ultimately, this alignment will empower Nigeria to meet its climate goals and developmental objectives simultaneously.

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