OPEN ACCESS

ARTICLE HISTORY
Received: 02-07-2026
Accepted: 26-08-2026
Published: 31-08-2026

Journal Access By QR

Journal homepage: https://ssarpublishers.com/ssarjebm
Abbreviated Key Title: SSAR J Econ Bus Manage
Volume-2, Issue-4, (Jul-Aug) 2026, Page 171-180 (Total PP.10)
E-mail: ssarpublishers@gmail.com

Circular Economic Development Model Advocacy: An Integrated Model Solution of Biofil Technologies Nigeria Limited for Economic Development (A Pilot Study of the Port Harcourt Correctional Centre in Rivers State, Nigeria)

By
Author: WOKOMA Harcourt Opubo PhD
Department of Business Administration, Faculty of Management Sciences

ABSTRACT: Nigeria faces growing challenges of waste mismanagement, environmental pollution, infrastructural decay, and inadequate sustainable waste treatment systems, particularly within public institutions such as custodial centres. This study advocates the adoption of a circular economic development model using the Biofil Technologies Nigeria Limited (BTNL) integrated waste-to-resource and wealth system as a practical solution for sustainable institutional development. The study specifically examined the effectiveness of the BTNL system in converting human and organic waste into useful resources, assessed its environmental and economic benefits, examined its social and rehabilitative impacts, and identified barriers to its wider adoption in Nigeria. A qualitative case study design was adopted, focusing on the Port Harcourt Correctional Centre in Rivers State, Nigeria. Purposive sampling was used to select 10–15 key stakeholders comprising facility administrators, environmental and maintenance officers, selected inmates, and representatives of BTNL. Data were collected through in-depth interviews, participant observation, and document analysis, while thematic analysis was used for data interpretation. Findings revealed that the BTNL system effectively transformed human and organic waste into biogas, reusable water, and organic fertilizer, while improving sanitation and reducing waste-related challenges. The system also generated economic benefits through reduced energy costs and provided inmates with vocational skills and environmental awareness, thereby contributing to rehabilitation and employability. However, limited government support, inadequate investment, weak policy frameworks, poor maintenance culture, and insufficient technical capacity were identified as major barriers to wider implementation. The study concludes that the BTNL circular economic model offers a practical, environmentally sustainable, economically viable, and socially transformative approach to public infrastructure development in Nigeria. It recommends stronger policy integration, capacity building, financial incentives, public-private partnerships, and replication of the model across other custodial centres and public institutions.

KEYWORDS: Circular Economy, Biofil Technologies, Waste-to-Resource, Biogas, Sustainable Development, Correctional Centre, Green Technology

INTRODUCTION

Nigeria is currently grappling with a mounting environmental crisis driven by population growth, urbanization, unsustainable consumption patterns, and poor waste management systems. The linear economic model characterized by a "take, make, use, and dispose" approach has led to excessive resource depletion and massive generation of waste, most of which ends up in landfills or open dumps, contributing to greenhouse gas emissions, public health risks, and environmental degradation

(Nzeadibe & Ajaero, 2020). Institutional settings such as custodial centers (prisons) are particularly vulnerable due to overcrowding, poor sanitation, and limited infrastructural investment, resulting in unmanaged waste and unhygienic living conditions that further burden environmental and health systems (Adewumi & Okafor, 2022).

The global shift towards circular economy (CE) offers a transformative framework to address these challenges. Unlike the traditional linear model, the circular economy is based on principles that prioritize the minimization of waste and pollution, the continual use and reuse of resources, and the regeneration of natural systems (Ellen MacArthur Foundation, 2019). This model is increasingly recognized as essential to achieving sustainable development goals, fostering economic diversification, and ensuring environmental resilience especially in resource-constrained economies like Nigeria (Geissdoerfer *et al.*, 2017). However, in Nigeria, the CE remains largely at the advocacy and pilot stages, with few scalable, indigenous implementations in public sector infrastructure.

It is against this backdrop that Biofil Technologies Nigeria Limited (BTNL) has emerged as a notable innovator, introducing an integrated waste-to-resource and wealth solution tailored to Nigerian institutional and community contexts. BTNL technology processes organic and human waste into biogas (for clean cooking, energy supply and heat), clean water (for fertigation), and organic fertilizer (for sustainable agriculture), thereby closing the loop on waste and creating multiple streams of socio-economic and environmental value (BTNL, 2023). This locally adapted solution not only addresses sanitation and energy challenges but also contributes to economic development through cost savings, skill acquisition, and job creation.

This study focuses on the Port Harcourt Correctional Centre in Rivers State Nigeria, as a pilot case for assessing the feasibility, functionality, and developmental potential of the Biofil Technologies Nigeria Limited circular model. Correctional institutions are ideal testing grounds for such innovations due to their enclosed structure, predictable waste generation, and need for self-sufficiency. Moreover, deploying circular systems in these facilities can promote inmate rehabilitation through vocational training in green technologies, thereby aligning with the broader objectives of correctional reform and reintegration (Ogunlana & Ajayi, 2021).

This research is guided by several pressing questions:

a. How effective is the BTNL system in converting waste into usable resources within the custodial environment?
b. What are the environmental, social, and economic benefits of adopting such systems in public infrastructure?
c. And, what are the policy and institutional gaps limiting the broader application of circular models in Nigeria?

By exploring these questions, this study contributes to the growing body of literature on sustainable infrastructural innovation and offers empirical insight into how circular economy principles can be practically implemented in Nigeria's public institutions. It also supports the attainment of the United Nations Sustainable Development Goals (SDGs)—particularly SDG 6 (clean water and sanitation), SDG 7 (affordable and clean energy), SDG 11 (sustainable cities and communities), and SDG 12 (responsible consumption and production) (United Nations, 2015).

Importantly, this study not only documents a pilot implementation but also advocates for the institutionalization of circular economic models in national development planning. It underscores the need for enabling policy frameworks, public-private partnerships, technical training, and awareness creation to mainstream CE innovations like the BTNL model across sectors. In a nation struggling with infrastructure decay and youth unemployment, circular solutions can stimulate green entrepreneurship, reduce environmental burdens, and accelerate progress toward a regenerative and inclusive economy.

Statement of the Problem

Nigeria is currently facing a multidimensional crisis involving waste mismanagement, environmental pollution, and infrastructural decay, all of which pose serious threats to public health, sustainability, and economic growth. Despite the increasing volume of waste generated daily across urban centers and institutional settings, there remains a significant gap in effective, innovative, and scalable waste management practices (Nzeadibe & Ajaero, 2020). The traditional linear economic model—

characterized by the inefficient consumption of resources and the disposal of waste—has proven to be environmentally and economically unsustainable, especially in high-density public facilities like custodial centers, where waste generation is continuous and poorly managed (Adewumi & Okafor, 2022).

Correctional facilities in Nigeria are notably under-resourced and often lack basic sanitation infrastructure. Overcrowding, inadequate waste treatment systems, and poor energy access create unhealthy environments that undermine inmate rehabilitation and institutional functionality (Ogunlana & Ajayi, 2021). Moreover, these centers are rarely included in broader environmental sustainability or infrastructural innovation initiatives, thereby exacerbating their operational inefficiencies and socio-environmental risks. This neglect reflects a broader failure of national development strategies to integrate circular economy principles into public sector infrastructure (Okorie *et al.*, 2018).

While the circular economy (CE) has gained international attention as a pathway to sustainable development, its practical adoption in Nigeria is still minimal and poorly coordinated (Geissdoerfer *et al.*, 2017). Innovative local technologies such as the BTNL waste-to-resource system offer considerable potential to address these challenges through organic waste recycling, biogas production, and compost generation. However, there is a lack of empirical research and pilot case studies assessing the viability, effectiveness, and socio-economic impact of such circular models in institutional settings like correctional facilities.

Furthermore, policy and regulatory frameworks necessary to support circular innovation remain weak or non-existent in many sectors. This institutional void prevents the mainstreaming of CE practices and limits private-sector engagement in green infrastructure development (Onyia & Eboh, 2021). In addition, there is insufficient awareness and capacity among public administrators and facility managers regarding the economic, environmental, and social benefits of integrating circular economy technologies into public services.

Thus, the central problem this study addresses is the absence of practical, evidence-based, and locally adaptable circular economy models in Nigeria's public infrastructure system, with a particular focus on custodial centers (Prisons) in Nigeria. By evaluating the BTNL integrated circular waste system at the Port Harcourt Correctional Centre in Rivers State, Nigeria. This research seeks to fill the empirical and policy knowledge gap while advocating for scalable, green development strategies that can support sustainable economic transformation in Nigeria.

Research Objectives

The primary objective of this study is to explore the practical implementation and impact of the BTNL integrated circular waste management system as a sustainable development model within Nigeria's custodial infrastructure.

Specifically, the study seeks to:

1. Assess the effectiveness of the Biofil Technologies integrated waste-to-resource and wealth model in managing waste and generating reusable resources (biogas, compost, and water) in the custodial center.
2. Examine the environmental and economic benefits of applying circular economy principles in institutional settings in Nigeria.
3. Evaluate the social and rehabilitative impacts of green technology deployment on inmates and custodial facility staff.
4. Identify institutional, technical, and policy-related barriers hindering the adoption and scalability of circular economy innovations in Nigeria's public infrastructure.
5. Propose a scalable framework or model for integrating circular economy technologies into Nigeria's broader national development strategy.

Conceptual Review

Circular Economy (CE)

The concept of a Circular Economy (CE) has gained significant global traction as a transformative model aimed at reducing waste and promoting sustainability. CE replaces the traditional linear economic model (take–make–dispose) with a regenerative framework that emphasizes resource efficiency, waste minimization, and product life extension (Geissdoerfer *et al.*, 2017). According to the Ellen MacArthur Foundation (2013), CE is not just an environmental strategy but a viable economic development pathway that enhances material productivity and reduces dependence on finite resources.

In Nigeria, the transition toward CE is still emerging, hindered by limited infrastructure, policy enforcement, and public awareness. However, innovations such as the BTNL integrated system—converting organic waste into biogas and organic fertilizer reflect the practical implementation of CE ideals in real-world institutional settings, such as custodial centers. This system is aligned with Sustainable Development Goals (SDGs) 6, 7, 11, and 12, which focus on clean water, affordable energy, sustainable cities, and responsible consumption (UNDP, 2022).

Integrated Waste Management (IWM)

Integrated Waste Management (IWM) combines various waste management practices like collection, processing, recycling, composting, and energy recovery to optimize efficiency and environmental impact (Wilson *et al.*, 2012). IWM is holistic, encompassing the entire waste stream and promoting the recovery of resources. The BTNL system exemplifies IWM by integrating anaerobic digestion and bio-filtration to transform waste into energy and organic fertilizer, thereby enhancing sustainability, reducing pollution and GHG emissions.

The BTNL Integrated Waste Treatment Plant (BTNL IWTP)

The Biofil Integrated Waste Treatment Plant (BTNL IWTP) represents an innovative and sustainable approach to waste management, specifically designed for processing sewage, all types of grey water, biodegradable municipal solid waste (MSW), and biomedical waste from hospitals. This system not only conserves water but also ensures zero wastewater discharge into the environment while producing renewable energy in the form of biogas.

The IWTP features a primary digester for initial sewage treatment, followed by cutting-edge enzyme technology that significantly reduces chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), fats, oils, and grease (FOG), enhancing the clarity of the biogas effluent and managing non-sewer wastewater. This system also includes a tertiary treatment stage with carbon filters and disinfection, allowing for the recycled water to be used for irrigation. Any remaining unused fractions can be safely discharged into storm drains or provided to local farmers for irrigation purposes. The IWTP has been chosen based on its proven effectiveness, with successful installations in various reputable churches, hotels, institutions, and shopping malls across Ghana and Nigeria.

BTNL Biogas System

Globally, biogas production is increasingly recognized as a dual-benefit strategy, generating clean energy while addressing waste management challenges (Makhura et al., 2022). This renewable energy source is produced through the anaerobic digestion of organic materials such as food waste, animal manure, and sewage, thereby contributing to both greenhouse gas (GHG) emission reduction and resource recovery.

At the core of the biogas system is the anaerobic digestion, which facilitates a controlled biological breakdown of organic materials in an oxygen-free environment, enabling the efficient capture and use of biogas, which typically consists of approximately 50 – 70% methane, 25 – 45% carbon dioxide, and trace amounts of other gases. This biogas is upgraded to Biomethane which contains 90 – 98% biomethane, 0.1 – 5% carbon dioxide, readily available for energy supply (cooking, electricity, heat).

The BTNL biogas system at the Port Harcourt Correctional Centre exemplifies this dual-benefit approach. Beyond energy generation, it forms a holistic circular economy model by converting the institution's organic waste streams into a valuable energy resource, reducing reliance on fossil fuels and lowering waste disposal costs.

Integration of biogas technology into correctional institutions has been identified as a viable model for promoting environmental sustainability, reducing operational costs, and fostering economic development in underserved communities (Ojolo et al., 2007). Such systems can be replicated in similar institutional settings, offering a scalable pathway toward achieving climate goals and enhancing local resilience.

BTNL Organic Fertilizer From The Correctional Facility

BTNL Organic Fertilizer is a practical solution to Climate-Smart Agriculture, supporting its three (3) core pillars: increase productivity, enhance climate resilience and reduce GHG emission associated with dependence on chemical fertilizers. The use of Organic fertilizers has been shown to reduce GHG

emission intensity in crop cultivation (Anuga et al., 2022). According to BTNL handbook (2023), the BTNL Organic fertilizer is made from carefully sourced organic waste materials. It can be used for all crops including vegetables (tomatoes, lettuce, cucumber), cereals (rice, millet, maize), fruits (strawberries, grapes, citrus) and cash crops (grass, flowers cocoa, cashew, palm oil, etc). Environmentally friendly to the soil, crops, and humans, it supplies the essential macro and micronutrients needed by plants for high-quality produce and improved yield. Its organic matter content helps to promote soil fertility, by improving the soil physical properties and sustaining beneficial microbial life.

Sustainable Correctional Infrastructure

Institutions like prisons often generate large amounts of waste and consume substantial energy and water. Greening such spaces through CE models introduces sustainability in overlooked sectors. Sustainable correctional infrastructure is now recognized as vital for not only environmental conservation but also for reducing operational costs and improving inmate rehabilitation (Okonkwo & Ajayi, 2021). By embedding green technologies like the BTNL system, custodial centers can serve as models for institutional circularity in developing economies.

THE PORT HARCOURT CORRECTIONAL CENTRE IN RIVERS STATE

Port Harcourt Prison, officially known as the Port Harcourt Correctional Centre, located in Port Harcourt, the capital of Rivers State, Nigeria. It is one of the several correctional facilities in the country and has garnered attention for challenges related to overcrowding and poor conditions resulting in unsanitary conditions that pose health risks to both inmates and staff. Among its facilities, the correctional center in Port Harcourt **(**Maximum prison) is often cited as one of the largest prisons in West Africa in terms of population density. However, specific numbers can fluctuate over time due to various factors such as policy changes, legal reforms, and conditions in the justice system. The prison facility has implemented basic waste management practices, but these systems often struggled under the weight of overcrowding until the BTNL circular economic system was put in place.

Theoretical Review

Ecological Modernization Theory (EMT)

Ecological Modernization Theory posits that technological innovation, institutional reform, and policy alignment can lead to both environmental protection and economic development (Mol & Sonnenfeld, 2000). EMT challenges the notion that industrial development is inherently environmentally harmful. In the case of BTNL, waste-to-resource and wealth systems exemplify EMT's principles—using technological advancements not only to solve environmental problems but also to create new value chains, skills, and employment.

Systems Theory

Systems Theory views institutions as interconnected subsystems working together to maintain stability and achieve goals (Bertalanffy, 1968). The application of BTNL circular economic systems in custodial settings represents a systemic approach to sustainability. Waste management, sanitation, energy production, and training become interlinked, showing that interventions in one area (e.g., waste) can positively influence others (e.g., inmate health, vocational skills, cost reduction). Such systemic transformation reflects the comprehensive benefits of adopting circular models.

Empirical Review

Empirical Evidence in Nigeria

Empirical studies in Nigeria show promising trends in localized circular economy practices, particularly in urban sanitation and agriculture. Akinyele and Alade (2021) studied decentralized bio-waste treatment systems in Lagos and found that community-level bio-digesters significantly reduced organic waste by 45% and produced enough biogas for communal cooking needs. This points to the feasibility of replicating such systems in custodial centers.

Similarly, a pilot BTNL installation in a secondary school in Enugu reduced waste disposal frequency by 60% and generated biogas for the school kitchen and compost for the garden (Biofil Technologies Nigeria Ltd, 2021). Feedback from students and staff highlighted improved hygiene and cost savings. These findings underscore the value of BTNL's systems as scalable CE solutions for institutional settings.

Eze and Nwankwo (2022) conducted a qualitative study on green technology adoption in Nigerian prisons. Their interviews with prison officials revealed strong support for renewable energy and waste reuse, citing potential benefits like improved inmate morale and reduced disease outbreaks. However, they identified barriers such as funding, policy inertia, and lack of technical capacity, all of which need to be addressed to scale innovations like Biofil circular economic system.

International Studies and Comparisons

Globally, correctional facilities in South Africa have adopted bio-digester systems to process food and human waste into methane gas, which powers kitchens and lighting systems (Mokoena & Sibanda, 2020). These initiatives have led to energy savings and improved inmate hygiene, validating CE technologies in the African correctional context.

In India, Kumar et al. (2019) documented the transformation of hospital waste into renewable energy in over 40 public health institutions. Their study found a 22% reduction in energy costs and a 50% decrease in hospital waste accumulation. The model's success is attributed to strong public-private partnerships and policy support.

The UNEP (2020) stresses that integrating CE into institutional infrastructure can yield multiple development dividends—job creation, carbon reduction, and local economic revitalization. Their global review advocates for embedding CE principles in schools, prisons, and hospitals as part of national sustainable development strategies.

Research Gap and Rationale for the Study

While numerous global studies confirm the effectiveness of circular economy models in public institutions, very few have focused on their implementation within Nigeria's correctional sector. Most existing literature addresses urban waste systems or industrial circularity, overlooking the potential of institutional innovation. This study fills that gap by assessing the application and outcomes of Biofil's circular economic model in a custodial center in Port Harcourt, Rivers State. It aims to contribute empirical evidence on how CE models can promote sustainable public infrastructure in developing contexts.

Methodology

Research Design

This study adopted a qualitative research design, which is appropriate for exploring the processes, perceptions, and contextual relevance of circular economic practices within institutional settings. The qualitative approach allows for a rich, in-depth understanding of how BTNLs' integrated circular model is implemented and experienced in the Nigeria Custodial Center in Rivers State. This design is most suitable for capturing insights, motivations, and real-world dynamics that cannot be quantified easily (Creswell & Poth, 2018).

Research Approach

A case study approach was utilized, focusing on the Nigeria Custodial Center where the BTNL circular model has been piloted. This approach enabled an intensive, context-specific exploration of the circular economy model as applied within a controlled institutional environment. Yin (2014) emphasizes that a case study is most effective when examining contemporary phenomena within their real-life context, especially where boundaries between context and the phenomenon are blurred.

Study Area

The research was conducted at the Port Harcourt Correctional Centre in Rivers State, one of the pilot sites for the implementation of Biofil Technologies Nigeria Limited's integrated circular economic model. The site was chosen because it offers a practical example of a closed-loop system within a public institution—making it ideal for analyzing the intersection of circular economy, sustainability, and infrastructural innovation.

Population and Sampling

The **target population** comprised stakeholders directly involved in the installation, management, and usage of the BTNL system, including:

- Facility administrators
- Environmental/maintenance officers
- Selected inmates participating in the maintenance
- Representatives from Biofil Technologies Nigeria Limited

A **purposive sampling** technique was adopted to select 10–15 key informants with in-depth knowledge or hands-on experience related to the system. According to Palinkas et al. (2015), purposive sampling is suitable in qualitative research where the goal is to access knowledgeable participants who can provide rich, relevant data.

Data Collection Methods

Primary data were collected through the following methods:

a. In-depth Interviews

Semi-structured interviews were conducted with stakeholders using open-ended questions to elicit detailed responses. This allowed for flexibility, probing, and follow-up, enabling the researcher to understand individual perspectives (Kvale & Brinkmann, 2015).

b. Participant Observation

Non-intrusive observations were conducted to understand the actual functioning of the Biofil system, staff interactions, waste input-output flow, and energy reuse. Observations were documented through field notes.

c. Document Analysis

Secondary data, including project implementation reports, environmental impact assessments, and internal memos from BTNL and the custodial center, were reviewed to complement the primary data and provide a comprehensive perspective.

Data Analysis Technique

Data were analyzed using thematic analysis, which involves identifying, analyzing, and interpreting patterns or themes within qualitative data (Braun & Clarke, 2006). Transcripts from interviews and notes from observations were coded manually, and emergent themes were classified under categories such as sustainability outcomes, system efficiency, challenges, and stakeholder perception.

Trustworthiness of the Study

To ensure the credibility, transferability, dependability, and confirmability of the study:

- **Triangulation** was employed by using multiple data sources (interviews, observation, documents).
- **Member checking** was done by allowing participants to verify the accuracy of the interpreted data.
- **Thick description** was used to ensure findings are transferable to similar institutional contexts.

Ethical Considerations

Ethical clearance was obtained from relevant authorities, and participants were informed of the purpose of the study. Participation was voluntary, and informed consent was secured. Anonymity and confidentiality were guaranteed to all participants, and sensitive information was handled with care in line with ethical research practices (Orb *et al.*, 2001).

Data Presentation and Analysis

This chapter presents and analyzes the qualitative data collected from interviews, field observations, and document analysis. The data are organized into thematic categories based on the research objectives and questions.

Thematic Analysis

Theme 1: Effectiveness of the Biofil Integrated System

Respondents confirmed that the BTNL system effectively processes human and organic waste through biological digestion, converting it into usable by-products such as biogas and bio-fertilizer. One senior maintenance officer noted:

"Before the BTNL system, waste disposal especially sewage was unhygienic as we use conventional septic system which get filled in no time because of the crowd of inmates. Now, we reuse water, generate gas, and there is zero odor."

Observation verified this claim as visible infrastructure included underground dome digesters, gas outlets for cooking in the kitchen of the facility, and filtration systems for water treatment. This aligns with the findings of Ijomah et al. (2020), who highlighted the effectiveness of decentralized bio-digester systems in developing countries.

Theme 2: Environmental and Economic Benefits

Stakeholders reported improved sanitation, reduced water contamination, and lower energy costs. According to a BTNL representative:

"The biogas is now used for cooking in the kitchen. We've saved over 30% of the usual LPG cost monthly."

Organic fertilizer from the digester is used in prison gardens, reducing the need for chemical fertilizers supporting food sustainability and supply of fertilizer to farms across the nation. These observations support Kirchherr et al. (2017), who argue that circular systems minimize ecological footprints while enabling economic efficiency through resource recovery.

Theme 3: Social and Rehabilitative Impact

Interviews with correctional officers revealed that inmates involved in the system's operation gained vocational skills, training and environmental awareness.

"This project is not just green; it's reformative. Inmates now learn plumbing, system maintenance, and even gardening," said one facility trainer. And they get gainfully employed working at the factory." This social component reinforces the potential of circular economic models to deliver both ecological and rehabilitative benefits, as proposed by Geissdoerfer et al. (2017).

Theme 4: Barriers to Broader Implementation

Despite its success, participants pointed out Key constraints including limited government support, epileptic maintenance culture, policy gaps, and insufficient investment in green technologies.

"This innovation is scalable, but without policy support, poor maintenance culture and education, many institutions will ignore it," lamented a project implementation officer. This echoes findings by Geng et al. (2012) and Akinbami et al. (2016), who noted that policy inertia and underinvestment are major setbacks to green innovation diffusion in Nigeria.

Discussion of Findings

The findings from the Port Harcourt Correctional Centre in Rivers State pilot study align with broader academic perspectives on circular economy models. The BTNL system illustrates how institutional waste can be a resource when processed through a closed-loop system—an outcome consistent with Kirchherr et al. (2017) who argue that circular economy practices promote environmental and economic resilience.

The environmental improvements and biogas generation validate previous empirical findings from Ghisellini et al. (2016) that organic waste reuse significantly reduces ecological footprints. Socially, the skill acquisition and behavioral change among inmates support the idea that circular practices have rehabilitative and educational value in institutional settings.

However, systemic limitations such as absence of enabling policies, funding challenges, poor maintenance culture and bureaucratic bottlenecks mirror the challenges documented by Geissdoerfer et al. (2017) and Ijomah et al. (2020) regarding the institutionalization of green innovations in developing nations.

Conclusion

This study concludes that the Biofil Technologies Nigeria Limited's integrated circular economic model presents a practical and replicable approach to sustainable waste management and green economic development within public institutions in Nigeria. The pilot implementation at the Port Harcourt Correctional Centre in Rivers State demonstrates significant environmental, economic, and social benefits. The system effectively transforms waste into reusable energy and bio-fertilizer, reduces operational costs, and equips inmates with life skills.

While the outcomes are promising, the broader adoption of such models requires intentional policy support, public-private collaboration, and increased advocacy for circular economy principles. The study confirms that circular economy innovations are not only ecologically necessary but also socially transformative and economically viable for Nigeria's development future.

Recommendations

1. **Policy Integration:**
   Government agencies should mainstream circular economy principles into national frameworks for waste management, prison reform, and infrastructure development (Akinbami *et al.*, 2016).

2. **Capacity Building**
   Custodial facilities should receive training and resources to manage and maintain green technologies (Geissdoerfer *et al.*, 2017)

3. **Financial Incentives:**
   Create funding schemes and tax incentives like tax rebates, or incentives to organizations implementing circular economy technologies like the BTNL model for public-private collaborations in green innovation (Geng *et al.*, 2012).

4. **Public-Private Partnerships (PPP):**
   Encourage strategic partnerships between government agencies, green technology firms, like Biofil Technologies Nigeria Limited to extend circular solutions across correctional institutions and other public facilities nationwide.

5. **Awareness Campaigns:**
   Launch awareness programs at institutional and community levels to promote the socio-economic benefits of circular economy models in public systems. (Ellen MacArthur Foundation, 2013).

6. Replication Studies:
Further research should be conducted in other custodial centers and public institutions to test the model's scalability and long-term impact across diverse settings. (Lieder & Rashid, 2016).

REFERENCES

Adewumi, I., & Okafor, C. (2022). Waste Management Challenges in Nigerian Institutions: Toward a Sustainable Solution. *Journal of Environmental Studies*, 19(3), 112–127.

Akinbami, J.-F. K., Akinbami, T., & Salami, A. O. (2016). Developing a framework for promoting renewable electricity in Nigeria: The potential of feed-in tariff policy. *Renewable Energy*, 88, 258–276. https://doi.org/10.1016/j.renene.2015.11.036

Akinyle, B., & Alade, T. (2021). Circular waste solutions for urban sustainability in Nigeria: A case study of Lagos State. *Journal of Waste Management and Circular Economy*, 4(2), 88–104.

Anuga, S. W., K. O. Agyeman, R. B. Zougmore, and R. B. Zougmoré. 2022. "Climate-Smart Agriculture: Greenhouse Gas Mitigation in Climate-Smart Villages of Ghana." *Environmental Sustainability* 5 (3): 303–313. https://doi.org/10.1007/s42398-022-00243-8.

Bertalanffy, L. von. (1968). *General System Theory: Foundations, Development, Applications*. George Braziller.

Biofil Nigeria Ltd. (2021). *Biofil Pilot Projects Report: Sustainable Sanitation for Institutional Facilities*.

Biofil Technologies Nigeria Limited. (2023). *Corporate Profile and Technical Guide*. Lagos: Biofil Technologies.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101.

Creswell, J. W., & Poth, C. N. (2018). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches* (4th ed.). SAGE Publications.

Ellen MacArthur Foundation. (2013). *Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition*.

Ellen MacArthur Foundation. (2019). *Completing the Picture: How the Circular Economy Tackles Climate Change*. https://ellenmacarthurfoundation.org

Eze, C., & Nwankwo, M. (2022). Exploring green innovation in correctional facilities: The Nigerian case. *African Journal of Environmental Policy and Sustainability*, 9(1), 77–91.

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The circular economy – A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Geng, Y., Fu, J., Sarkis, J., & Xue, B. (2012). Towards a national circular economy indicator system in China: An evaluation and critical analysis. *Journal of Cleaner Production*, 23(1), 216–224.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, 114, 11–32.

Ijomah, W., Mensah, A., & Oseghale, I. (2020). Evaluating decentralized bio-digester systems for urban sanitation: A study of Biofil in West Africa. *Sustainability*, 12(13), 5437.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, 127, 221–232.

Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular economy: The concept and its limitations. *Ecological Economics*, 143, 37–46.

Kumar, S., Jain, S., & Sharma, P. (2019). Biogas generation from hospital waste: A circular approach in India. *Journal of Environmental Management*, 245, 285–291.

Kvale, S., & Brinkmann, S. (2015). *Interviews: Learning the Craft of Qualitative Research Interviewing*. SAGE.

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: A comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, 115, 36–51.

Makhura, R. R., Muzenda, E., & Zawada, P. K. (2022). Biogas production from organic waste: A review of opportunities and challenges in South Africa. *Journal of Energy in Southern Africa,*

33(1), 43–55. https://doi.org/10.17159/2413-3051/2022/v33i1a10740

Mokoena, L., & Sibanda, M. (2020). The role of biogas in promoting energy sustainability in South African prisons. *Energy and Environment Research*, 10(3), 44–58.

Mol, A. P. J., & Sonnenfeld, D. A. (2000). *Ecological Modernisation Around the World: Perspectives and Critical Debates*. Frank Cass.

Murray, A., Skene, K., & Haynes, K. (2017). The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *Journal of Business Ethics*, 140, 369–380.

Nzeadibe, T. C., & Ajaero, C. K. (2020). Solid Waste Governance in Nigerian Cities: Policy Gaps and Prospects for Circular Economy. *African Journal of Environmental Policy*, 7(1), 33–45.

Ogunlana, A., & Ajayi, T. (2021). Correctional Facility Reforms in Nigeria: Challenges and Opportunities. *Nigerian Journal of Policy Studies*, 15(1), 65–79.

Ojolo, S. J., Oke, S. A., Animasahun, K., & Adesuyi, B. K. (2007). Utilisation of poultry, cow and kitchen wastes for biogas production: A comparative analysis. *Iranian Journal of Environmental Health Science & Engineering, 4*(4), 223–228.

Okonkwo, I., & Ajayi, T. (2021). Promoting Green Infrastructure in Nigerian Correctional Institutions. *Journal of Built Environment and Sustainability*, 6(1), 22–36.

Okorie, O., Salonitis, K., Charnley, F., Turner, C., Tiwari, A., & Moreno, M. (2018). Digitalisation and the Circular Economy: A Review of Current Research and Future Trends. *Sustainability*, 10(12), 4839. https://doi.org/10.3390/su10124839

Onyia, A. I., & Eboh, E. C. (2021). Regulatory and Institutional Barriers to Circular Economy in Nigeria: Policy Reforms and Innovation Gaps. *African Journal of Public Administration*, 11(2), 94–107.

Orb, A., Eisenhauer, L., & Wynaden, D. (2001). Ethics in qualitative research. *Journal of Nursing Scholarship*, 33(1), 93–96.

Palinkas, L. A., et al. (2015). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and Policy in Mental Health and Mental Health Services Research*, 42(5), 533–544.

UNDP. (2022). *Sustainable Development Goals Overview*. United Nations Development Programme.

UNEP. (2020). *Circular Economy in Institutional Infrastructure: Opportunities and Barriers*. United Nations Environment Programme.

United Nations. (2015). *Transforming Our World: The 2030 Agenda for Sustainable Development*. https://sdgs.un.org

Wilson, D. C., Velis, C., & Cheeseman, C. (2012). Role of informal sector recycling in waste management in developing countries. *Habitat International*, 30(4), 797–808.

Yin, R. K. (2014). *Case Study Research: Design and Methods* (5th ed.). SAGE Publications.