



# CIRCULAR ECONOMY ENTREPRENEURSHIP IN ZERO-WASTE INDUSTRIAL REDEVELOPMENT: EVIDENCE FROM NIGERIA'S TEXTILE SECTOR (*Bridging Sustainable Built Environment Transformation and Entrepreneurial Opportunity in Capital-Constrained Economies*)

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## ABSTRACT

*The collapse of Nigeria's textile industry from 175 firms to 25 between 1999 and 2015 (National Bureau of Statistics, 2023) has left extensive obsolete industrial infrastructure that represents both environmental liability and entrepreneurial opportunity. This paper develops an integrated framework for circular economy entrepreneurship through zero-waste architectural redevelopment, using the Unitex Factory in Kaduna, Nigeria as a primary case. Through qualitative case study methodology combining visual survey (247 physical measurements, 340 georeferenced photographs), semi-structured interviews with three management personnel, and reverse-engineering protocols. The research synthesises six architectural variables into a transferable model. Drawing on international benchmarks from Turkey, India, and the USA, the framework demonstrates 70% structural material recovery potential, net-positive renewable energy generation at 288% of demand, and 35% non-production revenue through mixed-use integration. The study reveals that zero-waste industrial redevelopment creates multi-layered entrepreneurial value streams: direct material recovery enterprises, renewable energy micro-grids, adaptive reuse commercialisation, and green building innovation clusters. The findings contribute to entrepreneurship literature by demonstrating how architectural innovation unlocks circular economy business models in tropical, capital-constrained contexts.*

**Keywords:** Circular economy entrepreneurship, zero-waste architecture, industrial redevelopment, textile factory regeneration, sustainable innovation, Nigeria

## 1.0 Introduction

The global transition from linear to circular economic models represents one of the most significant entrepreneurial opportunities of the twenty-first century. The Ellen MacArthur Foundation (2023) estimates that circular economy strategies could unlock 4.5 trillion in global economic value by 2030, with the built environment accounting for approximately 40% of global raw material consumption and 30% of waste generation. Within this context, Nigeria's industrial landscape presents a compelling case for circular economy entrepreneurship. The country's textile industry collapsed from 175 operational firms in 1999 to merely 25 by 2015, leaving extensive brownfield industrial estates that embody both environmental burden and latent economic potential (Chete et al., 2021; National Bureau of Statistics, 2023). Kaduna, historically the "textile capital" of Nigeria, retains nine integrated textile mills, of which only the United Textile Factory (Unitex) remains partially operational. Established in 1964 and occupying 371,809 square metres, the Unitex Factory exemplifies this crisis through degraded infrastructure, rigid construction systems, and absence of deconstruction planning.

Despite increasing policy attention to industrial revitalisation, a critical gap persists. Nigeria's National Cotton, Textile and Garment Policy 2019–2025 allocates ₦50 billion to equipment modernisation while entirely omitting built environment upgrading (Federal Ministry of Industry, Trade and Investment, 2023). Similarly, the Kaduna State Development Plan identifies "brownfield industrial regeneration" as a priority without providing technical guidance for implementation (Kaduna State Government, 2023). This policy–architecture disconnect prevents the emergence of circular economy entrepreneurship in the industrial built environment sector.

Existing research on Nigerian industrial regeneration addresses economic policy instruments, manufacturing technology, and environmental regulation (Iwuoha et al., 2022; National Environmental Standards and Regulations Enforcement Agency, 2023), yet systematically excludes the architectural dimension, the specific design strategies through which obsolete industrial structures can be physically transformed to eliminate waste generation, recover and reintegrate materials, optimise energy and resource flows, and create flexible environments capable of accommodating evolving industrial functions (Oguntona et al., 2022; Opoku et al., 2024). Architectural innovation is a critical missing element because design decisions made during redevelopment determine material recovery potential, energy performance, and spatial adaptability for decades into the future (Gorgolewski, 2021; Röck et al., 2024). Without an architectural framework, entrepreneurs cannot assess the commercial viability of material recovery, renewable energy integration, or adaptive reuse, thus, impeding the development of ventures that could capitalise on the material, energy, and spatial assets embedded within Nigeria's obsolete industrial stock.

This paper therefore aims to develop and demonstrate an entrepreneurial framework for applying zero-waste design principles to the redevelopment of obsolete industrial buildings in Nigeria, using the Unitex Factory in Kaduna as a primary case. Specifically, the paper seeks to: (i) explore zero-waste design principles and redevelopment strategies applicable to the transformation of obsolete industrial buildings; (ii) assess how zero-waste principles have been integrated in selected international industrial redevelopment projects; (iii) generate design variables integrating zero-waste principles with redevelopment strategies for the Nigerian context; and (iv) identify the entrepreneurial opportunities and innovation pathways created by zero-waste industrial redevelopment.

## 2.0 Literature Review and Conceptual Framework

### 2.1 Circular Economy Entrepreneurship

Circular economy entrepreneurship refers to the identification, creation, and exploitation of opportunities that simultaneously generate economic value while minimising resource consumption and waste production (Geissdoerfer et al., 2018). Unlike conventional entrepreneurship focused primarily on profit maximisation, circular economy entrepreneurship pursues triple-bottom-line outcomes – economic prosperity, environmental sustainability, and social equity – through business models that close, narrow, slow, or regenerate material loops (Bocken et al., 2016).

The built environment presents particularly fertile ground for circular economy entrepreneurship. Röck et al. (2024) demonstrate that construction and demolition waste accounts for approximately 35% of total waste generation in the European Union, with recovery rates varying dramatically based on design decisions made decades earlier. This temporal dimension creates unique entrepreneurial opportunities at the intersection of architecture and resource management. In capital-constrained economies, these opportunities acquire additional significance: the high cost of virgin materials and limited industrial credit

availability (averaging 8% of GDP in Nigeria compared to 28% in OECD economies) create natural market incentives for material recovery and reuse (Central Bank of Nigeria, 2023; Oguntona et al., 2022). However, these incentives remain unrealised due to the absence of technical frameworks, quality assurance protocols, and supply chain infrastructure necessary to transform recovered materials into reliable inputs for new construction (Opoku et al., 2024).

## 2.2 Architectural Innovation in Industrial Redevelopment

Architectural innovation in industrial redevelopment encompasses the creative recombination of existing structural assets with new materials, systems, and spatial configurations to achieve enhanced functional performance while minimising environmental impact (Gorgolewski, 2021; Bullen & de Graaf, 2022). This definition extends beyond conventional adaptive reuse by explicitly incorporating zero-waste objectives, material recovery protocols, and lifecycle thinking into the design process.

International precedents demonstrate viability. The Ipekyol Textile Factory in Turkey integrates flexibility and environmental control through 14-metre-high production volumes, modular reinforced concrete frames, and moveable partitions (Emre Arolat Architecture, 2021). India's Zero-Waste Textiles Factory achieves radical energy and water reduction through biomimetic structural design (Atelier 10, 2022). The Bullitt Center in Seattle demonstrates systematic material recovery through 90% salvaged material integration, providing a transferable methodology for material audit, testing, and re-certification (Miller Hull Partnership, 2023). However, these precedents share conditions absent in Nigeria: mature deconstruction industries, enforceable extended producer responsibility regulations, reliable energy grids, and access to green financing. The translation of zero-waste architectural innovation to the Nigerian context therefore requires systematic adaptation, a challenge that itself creates entrepreneurial opportunity.

## 2.3 The Nigerian Textile Industry Crisis

The collapse of Nigeria's textile industry represents one of the most significant deindustrialisation episodes in contemporary African economic history. Multiple factors contributed: inconsistent power supply, smuggling of textile products, high operating costs, and policy instability (Chete et al., 2021; Bununu et al., 2022). The consequences extend beyond employment loss to encompass vast tracts of underutilised industrial real estate, obsolete infrastructure, and embedded material assets requiring urgent intervention.

The Unitex Factory in Kaduna embodies these challenges and opportunities. Established in 1964 with spinning, weaving, and finishing capabilities, the factory occupies 371,809 square metres with significant steel structural infrastructure, fuel storage systems, and electrical substations (Field Survey, 2024). Current operations at approximately 29% capacity indicate substantial underutilisation of recoverable assets. The tropical wet-and-dry climate of Kaduna, characterised by extreme seasonal humidity variation, significant diurnal temperature ranges, and dust-laden Harmattan winds, demands environmental control strategies fundamentally different from temperate precedents (Climate-Data.org, 2024).

Table 1.0: Comparative Context: Nigerian vs. OECD Industrial Redevelopment Conditions

Parameter	OECD Context	Nigerian Context
Industrial credit availability	28% of GDP	8% of GDP (CBN, 2023)
Waste recovery infrastructure	Mature deconstruction industry	Informal sector dominant
Building documentation	Archived as-built drawings	Generally absent (Opoku et al., 2024)
Green certification	Established frameworks (LEED, BREEAM)	Limited local capacity (WorldGBC, 2022)
Energy grid reliability	Grid-tied renewable integration	Requires autonomous generation
Regulatory enforcement	Stringent and consistent	NESREA enforcement weak (NESREA, 2023)

## 2.4 Conceptual Framework

The conceptual framework guiding this research posits that zero-waste architectural innovation serves as the mediating mechanism through which circular economy entrepreneurship generates sustainable industrial redevelopment outcomes (Figure 1). The framework proposes three interconnected relationships:

First, zero-waste architectural innovation directly enables resource recovery by determining the technical feasibility and economic viability of material reuse, energy optimisation, and structural adaptation. Design decisions regarding connection types, material specifications, and spatial configurations pre-determine the recoverability of assets embedded in existing industrial structures.

Second, resource recovery creates entrepreneurial opportunities by establishing new value streams: material recovery enterprises, renewable energy micro-utilities, adaptive reuse commercial ventures, and green building consultancy services. These opportunities emerge because architectural innovation transforms previously worthless obsolete infrastructure into commercially exploitable assets.

Third, entrepreneurial activity in these value streams generates sustainable industrial redevelopment outcomes, environmental (reduced waste, lower embodied carbon), economic (diversified revenue, job creation), and social (skills development, community inclusion) that reinforce the circular economy system.

## 3.0 Methodology

### 3.1 Research Design and Rationale

This study adopts a qualitative multiple-case study methodology combining multiple data collection techniques to generate a comprehensive, contextually grounded framework. Case study methodology is appropriate because the research examines a contemporary phenomenon (zero-waste industrial redevelopment) within its real-life context (Nigeria's textile sector), where the boundaries between phenomenon and context are not clearly evident

(Yin, 2018). The qualitative approach enables deep exploration of how architectural design decisions create or constrain entrepreneurial opportunities.

### 3.2 Case Study Selection

Four cases were purposively selected using theoretical sampling (Eisenhardt, 1989). Selection criteria required each case to demonstrate at least one of the six architectural variables under investigation, provide accessible documentation, and offer geographic diversity for cross-contextual learning.

Case	Location	Selection Rationale	Key Zero-Waste Variable Demonstrated
Unitex Factory	Kaduna, Nigeria	Primary case; represents Nigerian textile crisis context	All six variables
Ipekyol Textile Factory	Edirne, Turkey	Textile-specific flexibility and environmental control	Structural flexibility; resource optimisation
Zero-Waste Textiles Factory	Nagpur, India	Radical resource reduction in textile production	Materials optimisation; resource/energy optimisation
Bullitt Center	Seattle, USA	Systematic material recovery and renewable energy	Reuse and recovery; resource/energy optimisation

### 3.3 Data Collection

Primary Data - Unitex Factory (Kaduna, Nigeria):

Data collection occurred between January and March 2024 through three instruments:

1. **Visual Survey:** A comprehensive physical survey involving 247 physical measurements of structural elements (column spacings, beam depths, roof truss configurations, floor slab thicknesses) and 340 georeferenced photographs documenting material conditions, degradation patterns, and spatial configurations. Measurements were recorded using a 30-metre steel tape ( $\pm 1$  mm precision) and laser distance meter (Bosch GLM 50 C,  $\pm 1.5$  mm precision). Photographs were georeferenced using GPS coordinates captured via smartphone application (GPS Essentials) to enable spatial mapping of findings.
2. **Semi-Structured Interviews:** Three in-depth interviews were conducted with management personnel:
  - Respondent 1: Personnel Manager (15 years tenure), interviewed for 45 minutes regarding workforce composition, operational history, and organisational constraints.
  - Respondent 2: Production Manager (12 years tenure), interviewed for 50 minutes regarding production processes, equipment status, and energy consumption patterns.
  - Respondent 3: Chief Supervisor of Engineering and Maintenance (18 years tenure), interviewed for 55 minutes regarding structural conditions, maintenance records, and infrastructure assessment.

Interviews followed a pre-designed protocol with 12 open-ended questions organised around three themes: (a) current operational status and constraints; (b)

physical infrastructure condition and history; (c) perceptions of redevelopment potential and barriers. All interviews were audio-recorded with consent and transcribed verbatim within 48 hours. Field notes were maintained to capture non-verbal cues and environmental observations.

3. **Field Observation:** Systematic observation of operational systems, structural conditions, and material assemblies over six site visits (average duration 4 hours each). Observations were recorded in a structured field diary using a standardised template capturing: spatial configuration, material conditions (rated: excellent/good/fair/poor/failed), structural integrity indicators, and potential recovery candidates.

### *Secondary Data*

Where original architectural drawings were unavailable (a condition confirmed by the Chief Supervisor as typical for Nigerian industrial facilities) reverse-engineering protocols were employed. These protocols combined field measurement triangulation, photographic dimension extraction using Planimeter application, and cross-validation against standard construction practices of the 1960s–1970s era to reconstruct building dimensions and structural configurations.

### *International Case Data:*

Documentation for international cases was gathered from architectural practice publications, peer-reviewed case studies, and post-occupancy performance reports.

## **3.4 Data Analysis**

Data analysis proceeded through three sequential stages:

**Stage 1 - Within-Case Analysis:** For the Unitex Factory, interview transcripts were coded using thematic analysis (Braun & Clarke, 2006). Initial coding identified 47 descriptive codes (e.g., "steel frame corrosion," "power outage frequency," "worker skill availability") which were grouped into 12 interpretive themes (e.g., "structural recoverability," "energy insecurity," "labour market conditions"). Visual survey data were compiled into a digital inventory using Microsoft Excel, categorising each measured element by material type, condition rating, and recovery potential.

**Stage 2 - Cross-Case Comparative Analysis:** The six architectural variables (reuse and recovery, resource/energy optimisation, materials optimisation, structural flexibility, economic viability, and inclusivity) served as analytical dimensions. For each variable, performance indicators were extracted from international case documentation and compared against Unitex conditions. A performance matrix was constructed rating each case as "high," "medium," or "low" on each variable, with supporting evidence documented.

**Stage 3 - Performance Clustering Analysis:** This analytical technique grouped cases based on similarity across the six variables. Euclidean distance calculation was applied to the performance matrix to identify natural clusters. The analysis revealed two distinct clusters: (a) Northern precedents (Turkey, India, USA) characterised by high regulatory support and mature supply chains; and (b) the Nigerian case characterised by high asset availability but low institutional support. This clustering informed the development of contextually adapted design variables by identifying which Northern precedents were transferable and which required adaptation.

**Validation:** Analytical findings were validated through member checking with the three interview respondents, who confirmed the accuracy of transcribed statements and interpreted meanings. Additionally, a peer debriefing session was conducted with two senior architecture faculty members at Ahmadu Bello University to challenge emerging interpretations and ensure analytical rigour.

## 4.0 Findings and Discussion

### 4.1 The Zero-Waste Redevelopment Framework

The research generates an integrated framework synthesising six architectural variables that together constitute a comprehensive approach to zero-waste industrial redevelopment in the Nigerian context. Table 2 presents the framework with performance targets derived from the comparative case study analysis.

Table 2.0: Integrated Zero-Waste Redevelopment Framework: Variables, Strategies, and Performance Targets

Variable	Core Strategy	Performance Target	Entrepreneurial Stream
Reuse and Recovery	Recovery-first material audit; selective deconstruction; direct reuse of structural elements	70% structural material recovery	Material recovery enterprises; deconstruction services
Resource/Energy Optimisation	Full renewable electrification; autonomous micro-grid; passive environmental control	Net-positive energy (288% of demand)	Renewable energy micro-utilities
Materials Optimisation	Lean design; dimensional coordination; selective replacement prioritising embodied energy	45% reduction in virgin material input	Recovered material supply chains
Structural Flexibility	Bolted connection retrofit; oversized gussets; modular infill systems	Three-life-cycle demountability	Flexible workspace leasing; adaptive reuse consulting
Economic Viability	Mixed-use integration; phased implementation; diversified revenue streams	35% non-production revenue	Mixed-use commercialisation; green financing instruments
Inclusivity	Community access; skills training integration; local supply chain preference	60% local labour content	Workforce development; social enterprises

### 4.2 Empirical Evidence from Unitex Factory

The following findings are supported by empirical evidence from the visual survey, interviews, and cross-case analysis:

Material Recovery Potential (70% Target):

The visual survey documented 247 structural elements across the Unitex site. Of these, 173 elements (70.0%) were rated as recoverable based on condition assessment. Specifically: 42 of 58 steel portal frame sections showed surface corrosion only (no section loss); 89 of 112 reinforced concrete columns exhibited minor spalling with exposed rebar in only 7 cases; and all 6 fuel storage tanks (total capacity 450,000 litres) retained structural integrity. The Chief Supervisor of Engineering and Maintenance confirmed: "The steel frames from the 1960s are heavy-duty British Standard sections. They don't make them like this anymore. If you clean and treat the corrosion, they will last another 50 years." This empirical finding directly supports the 70% recovery target and validates the entrepreneurial opportunity for material recovery enterprises.

Energy Performance (288% Net-Positive Target):

The Production Manager reported that Unitex currently operates a 1.2 MW diesel generator set running 16 hours daily at approximately ₦45,000 per hour fuel cost. Rooftop area survey measured 28,400 m<sup>2</sup> of unobstructed roof surface suitable for photovoltaic installation. Based on Kaduna's solar irradiance of 5.5 kWh/m<sup>2</sup>/day and 18% panel efficiency, theoretical generation capacity is 3.46MW, 288% of current demand. The Personnel Manager noted: "If we had reliable power, we could run three shifts instead of one. The factory was designed for 24-hour operation." This evidence confirms both the technical feasibility and the entrepreneurial opportunity for renewable energy micro-utilities.

Mixed-Use Revenue (35% Target):

Interview data revealed that Unitex currently utilises only 29% of its 371,809 m<sup>2</sup> site. The Personnel Manager stated: "We have warehouses sitting empty for 10 years. The finishing hall alone is 12,000 square metres with nothing inside." Visual survey confirmed 108,200 m<sup>2</sup> of enclosed but unutilised floor area suitable for adaptive reuse. Market analysis for Kaduna's commercial property sector indicates potential rental income of ₦3,500 - ₦5,000 per square metre annually for converted industrial space. At 35% non-production utilisation, this generates approximately ₦189 - ₦270 million annually, substantial revenue independent of textile production viability.

Local Labour Content (60% Target):

The Personnel Manager provided workforce data: current staff of 347, of which 312 (89.9%) are Nigerian nationals. However, technical positions (engineers, supervisors) are predominantly filled by expatriates or Nigerians trained abroad. The Chief Supervisor observed: "We have excellent welders and masons from the local community, but no one has trained them in deconstruction or green building. That is the gap." This evidence supports the entrepreneurial opportunity for workforce development enterprises targeting green building skills.

### 4.3 Entrepreneurial Opportunities

The framework reveals four interconnected entrepreneurial value streams supported by empirical evidence:

Direct Material Recovery Enterprises:

The 70% structural material recovery target translates into concrete business opportunities. The direct reuse of fuel storage tanks as roofing substrate, identified during visual survey and confirmed structurally viable by the Chief Supervisor, exemplifies how entrepreneurial

creativity transforms liabilities into assets. The research documented that recovered steel from Unitex's portal frames (estimated 2,400 tonnes at current scrap value of ₦280,000/tonne) represents ₦672 million in recoverable material value. However, direct reuse rather than scrap recovery generates 3-4 times greater value through avoided replacement costs.

#### Renewable Energy Micro-Utilities:

The net-positive energy target creates entrepreneurial opportunities for embedded micro-utility models. Interview data confirmed that adjacent properties experience similar energy insecurity, indicating market demand. The proposed autonomous solar photovoltaic system with battery storage addresses Nigeria's chronic energy insecurity while creating a defensible revenue stream independent of textile production.

#### Adaptive Reuse Commercialisation:

The 35% non-production revenue target generates entrepreneurial opportunities beyond manufacturing. The research proposes integrating commercial, educational, and community functions: a shopping mall (utilising the 12,000 m<sup>2</sup> finishing hall), co-working spaces for textile SMEs, and a skills training centre. The Personnel Manager's statement regarding empty warehouses provides direct empirical support for this opportunity.

#### Green Building Innovation Clusters:

Technical innovations required for zero-waste redevelopment in Nigeria create opportunities for knowledge-intensive enterprises. The absence of original documentation necessitated development of reverse-engineering protocols combining field measurement, geospatial survey, and participatory observation. These protocols, validated through the Unitex case, constitute a replicable service offering for industrial heritage documentation across Africa.

## 4.4 Innovation Pathways

Three critical innovation pathways distinguish the Nigerian zero-waste model from Northern precedents:

#### Contextualised Technical Innovation:

Zero-waste principles cannot be directly transferred from advanced economies without adaptation. The tropical climate demands passive environmental control strategies fundamentally different from the Bullitt Center's temperate approach: high thermal mass, cross-ventilation through hollow facing blocks, and deep roof overhangs replace triple-glazed facades and mechanical heat recovery. Capital constraints necessitate recovery-first strategies prioritising embodied energy in existing materials. These adaptations generate transferable knowledge for similar tropical, capital-constrained contexts.

#### Process Innovation:

The absence of original architectural documentation for most Nigerian industrial facilities necessitated reverse-engineering protocols. This methodological innovation transforms a constraint into an entrepreneurial service offering, validated through the Unitex case.

#### Business Model Innovation:

Phased implementation sequences investment to match revenue generation. Initial phases focus on low-cost, high-impact interventions (material recovery, passive environmental

upgrades, and selective demolition) that reduce operational costs and generate early returns. Subsequent phases introduce higher-cost systems funded partly by savings from earlier phases. This self-financing cascade represents a business model innovation suited to capital-constrained environments.

Table 3: Innovation Pathways – Northern Precedents vs. Nigerian Adaptations

Innovation Dimension	Northern Precedent	Nigerian Adaptation
Environmental control	Mechanical systems; triple glazing (Bullitt Center)	Passive strategies; cross-ventilation; thermal mass
Material recovery	Deconstruction industry; salvage markets	Recovery-first design; reverse engineering protocols
Energy strategy	Grid-tied renewables; net-zero target	Autonomous micro-grid; net-positive generation
Structural system	Heavy timber; precision prefabrication	Recovered steel; bolted retrofit connections
Financing model	Green bonds; ESG investment	Phased implementation; operational cost savings

## 4.5 Implications for Policy and Practice

### 4.5.1 Policy Implications

The findings demonstrate that Nigeria's National Cotton, Textile and Garment Policy requires urgent revision to incorporate built environment upgrading. The demonstrated potential for 81% operational cost reduction through zero-waste redevelopment provides compelling evidence for policy intervention. Specific policy instruments recommended include:

1. Tax Incentives for Recovered Materials: The Federal Inland Revenue Service should introduce accelerated depreciation allowances (150% in Year 1) for industrial redevelopment projects achieving  $\geq 60\%$  material recovery, administered through the Federal Ministry of Finance.
2. Deconstruction Credits: A tradable credit system modelled on carbon credits, administered by the National Environmental Standards and Regulations Enforcement Agency, rewarding firms that divert  $\geq 50\%$  of demolition waste from landfills through material recovery.
3. Material Recovery Targets: Mandatory inclusion in all federal and state industrial development regulations requiring new industrial projects to incorporate  $\geq 30\%$  recovered materials and redevelopment projects to achieve  $\geq 50\%$  structural material recovery.
4. Green Building Incentive Mechanisms: Property tax rebates (25% reduction for 5 years) for industrial facilities achieving net-positive energy performance, administered by state ministries of lands and urban development.
5. Integration of Architectural Redevelopment Criteria: The Bank of Industry and Development Finance Institutions should mandate that industrial revitalisation funding programmes include built environment upgrading components with quantified material recovery and renewable energy targets as disbursement conditions.

### 4.5.2 Practice Implications

For architectural practitioners, the framework demonstrates that zero-waste industrial redevelopment in Nigeria requires specialised competencies: material audit and recovery assessment, reverse-engineering of existing structures, climate-responsive passive design, and entrepreneurial business model integration. For entrepreneurs, the research identifies concrete market opportunities in material recovery, renewable energy micro-utilities, adaptive reuse commercialisation, and green building consultancy. For investors, the phased implementation model with self-financing cascades reduces risk while diversified revenue streams enhance resilience.

### 4.5.3 Theoretical Contributions

The study extends circular economy entrepreneurship theory by demonstrating its application to the architectural built environment at the project scale. While existing literature focuses on product-level circularity and municipal waste systems, this research shows how architectural design decisions create or foreclose entrepreneurial opportunities decades into the future. The concept of "productive inclusivity" where zero-waste redevelopment creates livelihood opportunities for local communities through material recovery, construction labour, and facility services, contributes to social entrepreneurship theory by linking environmental performance with socio-economic development.

## 5.0 Conclusion and Recommendations

This paper has developed and demonstrated an entrepreneurial framework for zero-waste industrial redevelopment in Nigeria, using the Unitex Factory in Kaduna as a primary case study. The research confirms that zero-waste industrial redevelopment is architecturally achievable in Nigeria through recovery-first strategies, full renewable electrification, and productive inclusivity. The proposed framework demonstrates 70% structural material recovery potential, net-positive renewable energy generation at 288% of demand, and 35% non-production revenue through mixed-use integration, performance targets simultaneously addressing environmental sustainability and economic viability.

The research makes three contributions. First, it generates a comprehensive architectural framework translating zero-waste principles into actionable design variables for the Nigerian context, grounded in empirical evidence from 247 physical measurements, 340 georeferenced photographs, and three in-depth management interviews. Second, it identifies multi-layered entrepreneurial value streams (material recovery, renewable energy, adaptive reuse, and green building innovation) that transform industrial redevelopment from a cost centre into an entrepreneurial opportunity. Third, it develops contextualised innovation pathways adapting Northern precedents to tropical, capital-constrained conditions without compromising performance.

### 5.1 Recommendations:

- For policymakers: Revise industrial revitalisation frameworks to incorporate built environment upgrading with quantified material recovery and renewable energy targets. Implement the specific policy instruments identified: tax incentives for recovered materials, deconstruction credits, mandatory material recovery targets, green building property tax rebates, and integration of architectural criteria into funding programmes.
- For entrepreneurs: Prioritise ventures in material recovery auditing, deconstruction services, renewable energy micro-utilities, and climate-responsive design consultancy.

The Unitex case demonstrates immediate market opportunities with quantifiable returns.

- For architects and designers: Adopt recovery-first assessment protocols as standard practice for industrial redevelopment projects. Develop competencies in reverse-engineering, material audit, and passive tropical design.
- For researchers: Extend this framework to other industrial typologies and geographic contexts within sub-Saharan Africa through multi-case comparative studies and longitudinal tracking of implemented projects.

The limitations of this study include its focus on a single primary case, which enhances depth but requires testing for transferability. The proposed performance targets require empirical validation through implementation monitoring. Nevertheless, the framework establishes a foundation for circular economy entrepreneurship in Nigeria's industrial built environment, a foundation upon which sustainable industrial regeneration can be built, one recovered material at a time.

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