

Environmental Regulation and Sustainable Materials Development in Nigeria: Challenges, Opportunities and an Integrated Regulatory Framework

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ABSTRACT

Efforts to transition towards more sustainable production and consumption in Nigeria must not only rely on technological innovation but regulatory conditions for the extraction, manufacture, use, recovery and disposal of materials as well. This mini review reviews the linkage of environmental regulation and sustainable materials development in Nigeria specifically for agricultural residues, industrial wastes and mineral wastes, plastics, electronic waste, sustainable construction materials. The review is derived from published Nigerian and international literature as well as Nigerian Environmental legislation, regulations and policy documents. It concludes that Nigeria has a strong regulatory infrastructure such as the National Environmental Standards and Regulations Enforcement Agency Act, the Environmental Impact Assessment Act, the National Policy on the Environment, sectoral environmental regulations, Extended Producer Responsibility mechanisms, the Battery Control Regulations 2024 and Plastic Waste Control Regulations 2026. This is not merely a matter of lack of regulation, however. Instead, institutional fragmentation, enforcement capability, poor waste infrastructure and testing facilities, trust in the standards for waste-derived materials, funding pressures, and research-to-industry-to-regulators chasms are all factors that affect implementation. The review advocates for an enabling regulatory approach to safeguarding environmental quality while promoting the safe recovery of resources and materials' innovation. It introduces higher standards and certification, life cycle assessment, effective EPR, green public procurement, targeted financial support and better collaboration between industry, researchers and regulators, and monitoring of material flows. The paper concludes that the drive for technological and regulatory innovation must go together if Nigeria is to progress from a linear resource system to more circular and resource efficient material systems.

Keywords: Environmental regulation, Sustainable materials, Circular economy, Nigeria.

INTRODUCTION

Societies' extraction, transformation, use and recovery of materials is a key determinant in shaping environmental sustainability. Conventional production systems are resource-intensive, and produce waste flows that are not well segregated, recovered or disposed of. These pressures are linked to urbanisation, industrialisation, infrastructure development and longstanding waste-management problems in Nigeria. Selected cities in Nigeria provide recent evidence that some of the factors that hinder scaling up of circular economy practices include regulatory fragmentation, lack of infrastructure, financial constraints, lack of market demand and institutional coordination gaps (Chukwueke & Ogbo, 2026).

Sustainable materials are a viable means for linking environmental protection and industrial and technological advancements. They encompass materials, which are designed, produced, used and managed in a manner which minimizes environmental impact throughout their life cycles. The streams of material used in Nigeria are agricultural residues, solid mineral wastes, industrial wastes, plastics, e-waste, and locally available resources. Adeniyi et al. (2021) found significant materials-to-product potential, in the Nigerian agricultural

resources, mineral resources and waste resources, and highlighted the need to harness these resources to produce value-added products. In recent years, researchers have also studied Nigerian architecture, and they have found that sustainable materials and principles of circular economy and low carbon solutions play a role (Daramola et al., 2025).

The development of such materials is not independent from the laws and regulations. Environmental rules impact extraction, processing, manufacturing, waste management, pollution control, environmental assessment, recycling and producer responsibility. Nigeria has a wide environmental regulatory framework with its management being supervised, mainly at the federal level, by the National Environmental Standards and Regulations Enforcement Agency (NESREA) with some institutions at the state level and other public institutions. There are currently 35 environmental regulations in place with NESREA which include, inter alia, sanitation and waste control, mining and industrial minerals, plastics, construction, non-metallic mineral products, electrical/electronic activities, batteries and other areas.

But regulation does not automatically ensure sustainable material production or better environmental results. Xu and Kang (2025) investigated waste disposal in Nigeria and discovered that waste-management authorities' effectiveness depends on economic and institutional factors. In more general governance literature, weak implementation, lack of institutional coordination and weak enforcement also emerge as ongoing problems (Ogunkan, 2022; Ogu & Okoye, 2025).

This paper thus investigates environmental regulation as a protective measure and potential enabler of sustainable materials development. It reflects the regulatory structure, key sustainable material flows, hurdles to implementation and policy tools that can link environmental protection to resource recovery and the innovation of industry.

In this paper, this is not a systematic review or empirical study. It collects, collates and brings together literature from the peer-reviewed and scholarly that is relevant to sustainable materials, circular economy, waste valorisation, environmental governance and sustainable construction in Nigeria, alongside official Nigerian legislation, regulations and policy documents. The discussion is intentionally confined to propositions which are supported by the quoted sources. For a regulatory proposition involving a Nigerian law and/or regulation, an official source of the law/regulation is preferred over a secondary description.

REVIEW METHODOLOGY

A structured narrative mini-review approach was used in this paper to review the relationship between environmental regulation and sustainable materials development in Nigeria. Relevant scholarly literature, Nigeria legal and policy documents were synthesized to find the regulatory mechanism, implementation challenges, resource-recovery pathway and opportunities for sustainable materials development.

Literary sources were identified using Google Scholar, ScienceDirect, SpringerLink and Wiley Online Library, along with searching of the references. The combinations of the terms environmental regulation, sustainable materials, circular economy, waste valorisation, resource recovery, extended producer responsibility, sustainable construction materials and environmental governance were the main principal search terms used with the term Nigeria. All publications prior to September 2026 were taken into account, with a focus on recent evidence and including earlier studies when they are conceptually, regulatory or historically significant.

Studies were chosen based on their relevance to environmental governance in Nigeria, waste management, resource recovery, sustainable materials, circular economy, sustainable construction and/or related regulatory and technological issues. Research work of little relevance to the Nigerian context or the linkage between environmental regulation and sustainable materials development were not given priority.

The legal and policy review prioritised primary Nigerian sources, particularly those from the National Environmental Standards and Regulations Enforcement Agency (NESREA), the Federal Ministry of

Environment and other government sources. The following instruments were identified as key: NESREA Establishment Act 2007, Environmental Impact Assessment Act, National Policy on the Environment and the latest National Environmental Regulations (NER) which include those on batteries, plastics and electrical/electronic waste. Specific legal aspects were preferred in the use of official regulatory sources.

Thematic synthesis of the selected evidence was conducted on the thematic areas of: environmental governance, material and waste streams, regulatory implementation, standards and certification, market mechanisms, research-industry linkages and resource recovery. This synthesis led to the proposed integrated framework as a conceptual framework that is based on the evidence and the regulatory instruments reviewed. It is not empirically validated and is mainly used to organize the relationships found in the literature for further empirical research.

ENVIRONMENTAL REGULATION AND GOVERNANCE FOR SUSTAINABLE MATERIALS DEVELOPMENT IN NIGERIA

Environmental governance framework

Nigeria has a multi-institutional environmental governance framework. NESREA plays a strategic and central role in the enforcement of environmental laws, standards and regulations at federal level whilst the Federal Ministry of Environment has important policies and environmental-assessment functions. State environmental authorities also have important roles, especially in environmental enforcement and waste management at local level. According to the governance literature, the capacity to coordinate and implement institutions plays a significant role in determining environmental outcomes (Ogunkan, 2022; Ogu & Okoye, 2025).

NESREA's regulatory and enforcement powers are vested in the National Environmental Standards and Regulations Enforcement Agency (Establishment) Act 2007. The Environmental Impact Assessment Act sets out a framework for the assessment of environmental impacts of projects that are subject to assessment. The National Policy on the Environment (Revised 2016), gives a more general policy orientation, such as the integration of environmental issues in economic decision-making, environmental cost considerations, environmentally friendly technologies, and precautionary principles. These principles are explicitly stated in the policy documents of NESREA itself.

The relevance of this framework for sustainable materials is that it provides for consideration of various stages of the life cycle of a material. The National Environmental (Sanitation and Wastes Control) Regulations 2009 are regulations that provide a framework for controlling sanitation and waste. The National Environmental (Mining and Processing of Coal, Ores and Industrial Minerals) Regulations 2009 provide for the assessment and implementation of measures to prevent pollution from covered mining activities and mineral processing, and for cleaner production. Pollution resulting from construction, decommissioning and demolition is covered in the National Environmental (Construction Sector) Regulations 2011. Pollution from the National Environmental (Non-Metallic Minerals Manufacturing Industries Sector) Regulations 2011. The National Environmental (Domestic and Industrial Plastic, Rubber and Foam Sector) Regulations 2011 regulate pollution associated with the sector. Instead of the older 2011 instrument (which is included in the draft), NESREA registers the current Electrical/Electronic Sector Regulations as the 2022 regulations, which pertain to used and new Electrical/Electronic Equipment.

The two instruments of particular importance on the material-recovery agenda are recent. The National Environmental (Battery Control) Regulations 2024 are focused on combating pollution and disposing of waste batteries and specifically providing provisions on Extended Producer Responsibility, handling, treatment and recycling. The National Environmental (Plastic Waste Control) Regulations 2026 have now been announced by NESREA as an environmental regulation in force. The regulations were published in September 2026 and will aim to cover plastic products and plastic waste throughout the value chain, highlighting producer responsibility, recovery, recycling and resource efficiency.

The regulatory system is thus better viewed as a set of instruments than as one environmental law. For

sustainable materials that is of particular importance, since a waste-derived product could bring up the issues of waste management, environmental assessment, industrial pollution control and product standards, producer responsibility and end-of-life obligations.

Regulation across material and waste streams

The Nigerian environmental regulation is sectoral, thus providing potential avenues of addressing the various material streams. Regulations under mining and mineral-processing apply to mining and mineral processing, construction and non-metallic-mineral regulations apply to manufacture and use of materials, waste-control regulations apply to collection and disposal of waste, and product- or sector-specific regulations can affect environmental performance of specific industries. Chukwuma et al. (2020) exemplify the importance of law in relation to sustainable development in the solid mineral industry in Nigeria.

The added question of regulation that comes from waste-derived materials is when will a waste stream be considered a usable secondary resource and when will it be safe to add to a new product? The potential value of the waste generated by municipalities, agriculture, industry, plastic and electronics, is highlighted in circular-economy literature alongside the barriers to infrastructure, institutional and market. The opportunities for municipal, agricultural, industrial, plastic and electronic waste have been pointed out in the literature of the circular economy, with reference to barriers to infrastructure, institutions and markets (Ubayi, 2025; Oluwatayo & Ojo, 2024). The regulation must therefore differentiate between materials which can be recovered safely and those that need to be contained or treated in a special way.

One such instrument that can link the product's design with end-of-life management is Extended Producer Responsibility (EPR). We have studied the EPR implementation in Nigeria and emphasised the ability of EPR to change the responsibility for post-consumer waste from the consumers to other actors in the product chain, including the producers (Ajani and Kunlere, 2019). The current materials are also available for producers, Producer Responsibility Organisations, recyclers and collectors for registration.

From compliance to materials innovation

Prevention or control of harm has traditionally been the main thrust of environmental regulation: pollution limits, permits, waste-management requirements, environmental assessment and enforcement. These functions will continue to be vital. But the conversion to a circular economy is not possible without regulation to manage waste, as well as ensure safe re-entry of recoverable materials into productive use.

This applies especially to Nigeria, as the development of materials is frequently a problem of waste management. Agricultural residues can be fed to composite materials, mineral and industrial residues can be used as cementitious or ceramic feedstock, plastics can be recycled or used as feedstock for other plastics, and electronic waste can be used to provide secondary sources of metals. Materials to product literature supports the underlying opportunity, but it also indicates the need for improved recovery system and enhanced relationship between research and industry application (Adeniyi et al., 2021).

Evaluation should, therefore, not be based on the number of rules passed. It should also be taken into account whether it alters material flows, enhances environmental performance, establishes certain compliance conditions, facilitates the development of safe secondary-material markets and promotes innovation. In a more comprehensive review on the transitions towards the circular economy, Yuan (2026) highlights this dual nature of regulation, which can facilitate innovation and resource efficiency when it is effective, flexible, or well-integrated, but can hinder it when it is rigid, disjointed, or poorly enforced.

Figure 1 illustrates a causal relationship between environmental regulation and sustainable development of materials in Nigeria. Well-designed regulation defines the conditions under which organized resource recovery can be achieved, thus providing material innovation and research with solid secondary feedstocks. All of these materials are tested and certified for quality, safety and performance prior to their industrial uptake. Demand creation and commercialization can be done through market mechanisms, such as Extended

Producer Responsibility and public procurement that includes green procurement. Increased adoption enables circular material flows and a decrease in disposal and reliance on virgin resources. Monitoring, enforcement and stakeholder feedback are components of the pathway to ensure compliance, to measure performance and to guide ongoing improvements to regulatory and technological solutions. So, regulation provides recovery, recovery provides the resources for innovation, certification provides confidence and market mechanisms provides the adoption and circularity.

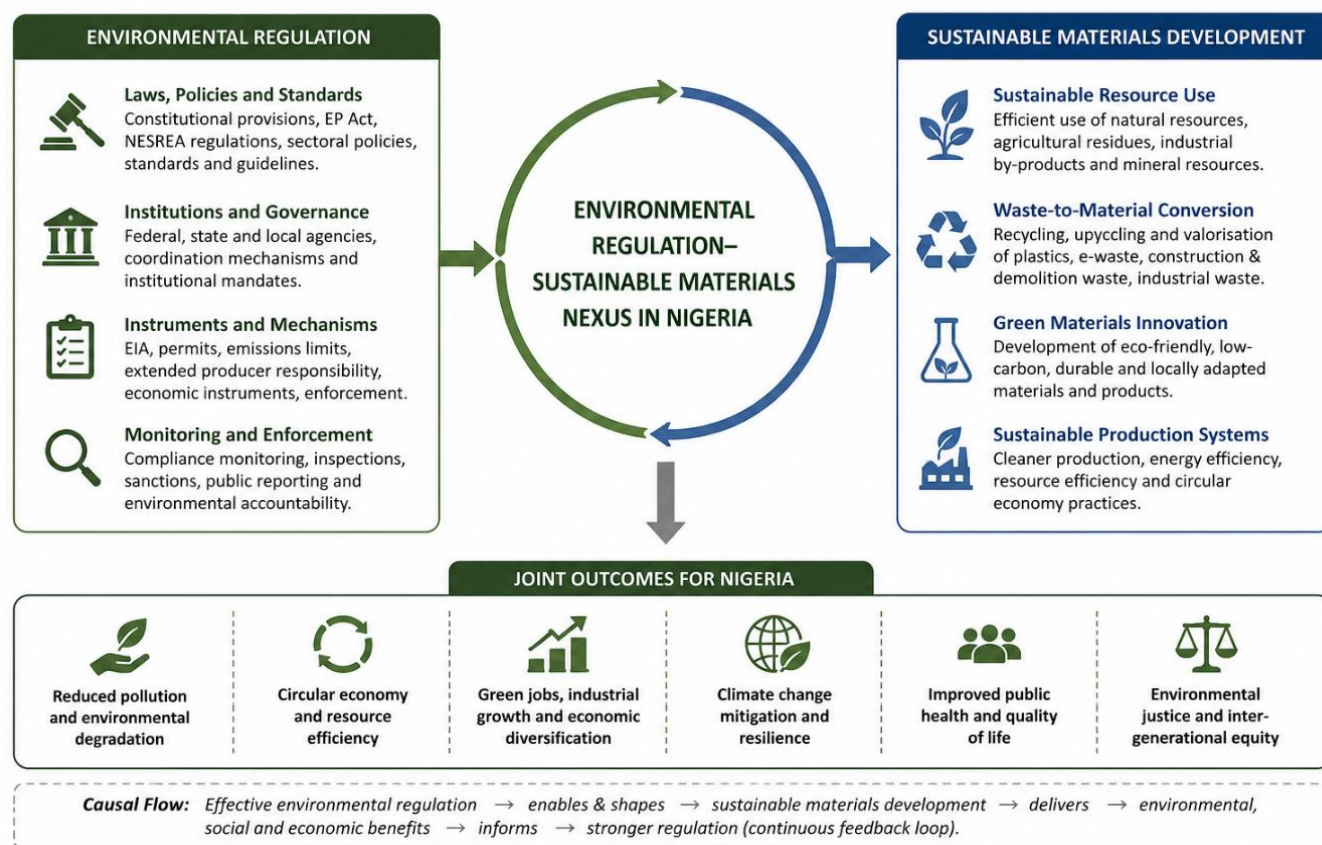


Figure 1. Environmental regulation–sustainable materials development nexus in Nigeria.

Regulatory effectiveness and implementation

Implementing environmental regulation is the key to its effectiveness. Persistent concerns in environmental governance research in Nigeria include weak enforcement and institutional fragmentation and limited implementation capacity (Ogunkan, 2022; Ogu & Okoye, 2025). Sustainable materials have obvious relevance to these problems. If waste streams are not well segregated or if there are deficient collection services, the cost of recovering recyclable feedstock increases and they become contaminated.

This is also highlighted by Nigeria's evidence. In their study on household waste-disposal practices and the operations of waste-management authorities, Xu and Kang (2025) showed that economic and institutional circumstances have an impact on waste-management authorities. Legal requirements must be enacted at an even lower level—physical system by which compliance can be attained. The collection centres, sorting systems, recycling plants, testing laboratories, monitoring equipment and trained personnel are thus complementary and not substitutes for environmental regulation.

In the case of sustainable materials, it is therefore appropriate to evaluate the effectiveness of regulations based on operational measures like recovery rates, adherence to the environmental requirements, the share of certified secondary materials available in the market, the functioning of EPR systems, material-flow analysis and the extent to which technically viable innovations are commercialized.

SUSTAINABLE MATERIALS DEVELOPMENT PATHWAYS IN NIGERIA

There are significant agricultural, mineral and industrial resources in Nigeria, and there are also waste streams which have potential secondary value. The problem isn't just identification of resources, but also the creation of safe and economic ways of scaling up the transformation of these resources into useful material (Adeniyi et al., 2021). Of particular interest are four pathways: agricultural residues and bio-based materials, industrial and mineral waste, plastic and polymer waste, electronic waste and other complex waste streams. Sustainable construction materials span across these pathways as construction can represent a large market for recovered and low impact materials.



Figure 2. Sustainable materials pathways from Nigerian resources and waste streams.

Agricultural residues and bio-based materials

Agriculture in Nigeria produces wastes like rice husks, groundnut shells, cassava residues, palm residues, maize cobs and bagasse. Jekayinfa et al. (2020) point to significant biomass resources in Nigeria and Adeniyi et al. (2021) explore the general potential for Nigeria's resources and wastes to be transformed into value-added products.

Agricultural residues can be used as reinforcement, fillers or feedstocks for composites and other engineered materials. Residues can be utilized in particle boards, insulation materials, bricks, ceramics, adsorbents and other uses depending upon their chemical and physical properties. The environmental value is generated in part by using secondary feedstocks, instead of virgin, and by decreasing the uncontrolled disposal.

Assessment of the sustainability claim should be undertaken with care though. Agricultural residues are scattered, seasonal and sometimes contaminated and poorly stored. Economic and environmental costs may be incurred in the collection, transportation, drying and preprocessing. Products made from such residues also need to meet the performance and safety requirements before they can be introduced on the market. Collection and recovery can be facilitated by regulation, but standards and certification are required to ensure that recovered feedstock can be accepted in certain applications.

Industrial and mineral-waste valorisation

Quarry dust, mine tailing, ash, slag and other processing residues are all examples of industrial and mineral

wastes. The opportunities for secondary use of these materials exist in the Nigerian mineral sector, and legal regulation is applicable to the control of environmental consequences of extraction and processing (Chukwuma et al., 2020).

Potential applications are cementitious materials, geopolymers, bricks, ceramics, refractories and aggregates. Similarly, waste-derived and low-carbon materials are among the sustainability agenda in the built environment in Nigeria, as identified by Daramola et al (2025). These applications can decrease the amount of waste that needs to be disposed of and can decrease the demand for virgin mineral input where technically applicable.

Just replacing a virgin material with a waste derived material does not make it sustainable. Some industrial waste may contain hazardous constituents and significant amounts of energy or chemicals are needed for processing. A life cycle assessment is then key to assessing the actual reduction in environmental loads that would result from what appears to be an environmental benefit. Unegbu et al. (2025) show how life cycle assessment is relevant to Sustainable building materials in Nigeria.

Plastic waste and recycled polymer materials

Plastic waste is especially pertinent because plastics are so ubiquitous and long-lasting in the environment. Problems have been identified on both production and consumption side in Nigeria, as well as on collection, segregation and end-of-life management (Ezeudu et al., 2024; Nyakuma & Ivase, 2021).

The plastic waste can be mechanically recycled into new products made of polymers or be used for making composite products. Other processes can process plastic waste either thermally or chemically to make fuels, chemical feedstocks or carbon-based materials. They must be assessed on their use of energy, contamination, emissions, process efficiency and residual waste management (Nyakuma & Ivase, 2021).

A new dedicated policy instrument is introduced in this area with the introduction of the National Environmental (Plastic Waste Control) Regulations 2026. The regulations are included in the current environmental regulatory framework, as mentioned by NESREA, and in current reporting of the implementation of the regulations, a value chain approach in production, recovery, recycling and producer responsibility is described. The significance of the regulations for sustainable materials is that they can enhance the quality of recovered plastic feedstock and provide an incentive for plastic product redesigning and recycling.

A circular plastics system isn't just about collecting plastics. Recycling capacity and markets for recovered polymers may result in stockpiling if collection is increased but not accompanied with proper sorting. Recycling, on the other hand, can't function effectively without a steady stream of feed stocks. Thus, the development of regulation and infrastructure must go hand in hand with the development of standards and market.

Electronic waste and recovery of valuable materials

Waste electrical and electronic equipment has valuable and hazardous components. Nigeria has a huge informal e-waste sector, studies reveal environmental and health hazards that result from primitive dismantling and burning methods (Abogunrin-Olafisoye and Adeyi, 2025). A review of similar nature also points out the gaps in legislation, infrastructure and environmentally friendly recycling technologies (Abogunrin-Olafisoye et al., 2025).

A material-based approach considers e-waste as an urban secondary resource with metals and recoverable materials. Mechanical separation, hydrometallurgical and pyrometallurgical processes are some of the technologies used for recycling. In contrast, Smith and Behdad (2025) have noted that recycling technologies should be evaluated based on environmental, economic and social considerations, and not only on recovery yield.

Therefore, the regulatory framework for Nigeria should ensure the protection of workers or communities and facilitate responsible material recovery. Regulatory entry points for this are provided by the current Electrical/Electronic Sector Regulations that are listed by NESREA and EPR. To transform e-waste from an environmental liability to a safer source of secondary materials, it is necessary to have formal collection, technical standards, producer responsibility, safe recycling facilities, and appropriate treatment of the hazardous fractions.

Sustainable construction materials as an application pathway

Infrastructure and construction are some significant areas of opportunity for sustainable material because construction activity and infrastructure have significant consumption of aggregates, binders, blocks, panels, polymers and other material inputs. Technical, financial, institutional and knowledge barriers have been established by research in Nigeria as the factors affecting the adoption of sustainable building materials (Eze et al., 2023; Agboola et al., 2024).

The study shows that the construction industry in Nigeria is increasingly focused on sustainability and smart materials, with recent studies emphasizing the significance of these developments. Similarly, Adebawale et al. (2025) point out challenges from the use of innovative sustainable construction materials, and they suggest solutions aimed at tackling the adoption's constraints. Osuolale et al. (2026) also found that awareness is linked to adoption of sustainable materials in the built-environment among the built-environment professionals in Nigeria and noted the challenges of economic, regulatory and supply chain constraints.

Construction may thus offer an important pathway to scale sustainable materials, however, only when performance, safety, and durability and environmental attributes are demonstrated. Alongside environmental regulation, standards and testing and certification play a vital role in establishing consumer, engineer, contractor and regulatory confidence.

From laboratory innovation to commercial material systems

One of the consistent problems found throughout literature is the gap between innovation in the technical and the commercialization of the technology. Even the best materials can fail to go to industry due to inconsistent feedstock, unavailable processing equipment, unclear standards, limited financing and/or uncertain markets. Adeniyi et al. (2021) point to the need to shift from resource and research to value-added products, and Ubayi (2025) pinpoint gaps in implementing a circular construction industry in Nigeria.

The transition from research to market therefore requires defined feedstock sources, processing infrastructure, testing, certification, environmental assessment, financing and identifiable end-use markets. Environmental regulation can provide part of the institutional structure connecting these components, but it cannot substitute for technical validation or commercial feasibility.

REGULATORY CHALLENGES AFFECTING SUSTAINABLE MATERIALS DEVELOPMENT IN NIGERIA

Fragmented institutional responsibilities

Material lifecycles span multiple regulatory areas. Collection, transport, processing and environmental assessment of waste, industrial operation, end-of-life management, product testing and market approval are all aspects of a waste-based construction product. Responsibilities may vary depending on the stage of the project by different authorities. Institutional fragmentation and poor institutional coordination are recurring issues that have been identified in the environmental-governance literature in Nigeria (Ogunkan, 2022; Ogu & Okoye, 2025).

Sustainable materials may result in uncertainty regarding applicable permits, applicable standards and compliance responsibilities. There is a need for more coherent coordination between all the concerned

organisations, such as environmental regulators, standards institutions, waste management authorities, research institutions, industry and state environmental agencies.

Weak enforcement and implementation capacity of the law and policy.

Detailed rules are not guarantees for compliance. According to Oruonye and Ahmed (2020), enforcement is a key challenge in environmental protection in Nigeria, whereas Ogunkan (2022) refers to weak implementation and institutional coordination as environmental governance issues. Inadequacies in enforcement may diminish the incentive for businesses to invest in cleaner production processes and resource recovery.

Enforcement of sustainable materials should apply not just disposal but also recovery, recycling, producer responsibility, environmental permits and compliance with applicable standards. Labs, monitoring tools, data and staff need to be available and properly trained to implement enforcement effectively. Capacity for regulation and enforcement is thus dependent on each other.

Limited standards and certification for waste-derived materials

Standards play a key role as a link between regulation and materials innovations. A material that has good laboratory characteristics can be commercially unfeasible if it does not meet the recognized standard for quality, durability, safety, or environmental attributes. Technical and institutional uncertainty are identified to be important obstacles to the adoption of sustainable building materials in Nigeria (Eze et al., 2023; Agboola et al., 2024).

The requirements for waste-derived materials need to cover not only traditional engineering characteristics but also environmental protection safety. Depending on the material and application, parameters that can be relevant are strength, durability, thermal performance, chemical composition, leachability, contaminant levels, emissions and end-of-life behaviour. Life Cycle Assessment can be used together with product standards to assess the cumulative environmental impacts (Unegbu et al., 2025).

This is the place where also the regulation must steer clear of two dangers. Hazardous materials can be introduced to applications where they could pose a hazard to people or the environment, if precautions are not sufficient, while if they are too cautious, the innovations may not be carried out and prove useful in the market. Proportionate certification and evidence-based standards will minimize both risks.

Financial and market barriers

The economic conditions play a significant role in the use of sustainable materials. The collection, sorting, cleaning, preprocessing, testing and certification of waste can make secondary materials more expensive than conventional materials, and conventional materials can have established supply chains and predictable quality. Some barriers highlighted in Nigerian studies on sustainable construction include cost, financing, and market acceptance (Eze et al., 2023; Agboola et al., 2024).

Compliance with regulation may lead to higher cost of compliance in the short term, especially for small businesses, but it can also generate markets. Demand for materials with proven environmental benefits can be boosted through EPR, recycled-content regulations, green public procurement and specific fiscal measures. These instruments will only be valuable if rules are transparent, monitoring is reliable and the actual capacity of the market is available.

Inadequate infrastructure and technological capacity

Research laboratories are not enough for sustainable development of materials. To produce consistent feedstocks and reliable products, it is important to have collection, sorting, transportation, preprocessing, recycling, material characterisation and quality-control systems. A major factor that emerged from the Nigerian circular economy research is the infrastructure constraint (Oluwatayo and Ojo, 2024; Ubayi, 2025).

For regulation there must be infrastructure as well. Laboratories, monitoring equipment, data systems, and trained personnel are essential for environmental agencies to verify compliance of regulated activities to environmental requirements. Thus, there is a possibility that investment in infrastructure can aid not only in material innovation, but also in regulatory enforcement.

Limited awareness and stakeholder acceptance

The adoption of sustainable materials requires the efforts of government, manufacturer, architect, engineer, contractor, investor and consumers. But even if technically appropriate products are available, their adoption can be hampered by a lack of knowledge or uncertainty of material performance. The Nigerian studies have concluded that awareness and knowledge are factors that can be considered when dealing with the issue of adoption (Agboola et al., 2024; Osuolale et al., 2026).

Awareness shouldn't be limited to the general environmental message. Specifications, performance, environmental characteristics and certification requirements are important pieces of information for professionals. The regulators also need technical expertise to create realistic standards and evaluate new technologies.

Weak research–industry–regulator linkages

Research institutions produce knowledge about the use of agricultural residues, recycling of waste, renewable construction materials with reduced carbon emissions, etc. but laboratory research does not necessarily lead to commercial production. Technical, financial and regulatory aspects are part of the gap. Industry requires evidence on cost and scalability; regulators require evidence for standards and environmental controls and researchers need to understand industrial and regulatory requirements.

Greater cooperation between research and industry, between industry and regulators, and more direct connections from the proof of concept to commercialization may lead to common pilot facilities, coordinated testing programmes, and faster translation from proof of concept to commercialization. This would help to limit duplication and enhance the evidence base for regulators and investors.

The central regulatory dilemma

Sustainable materials need to be available for experimentation, innovation and investment to prevent harm in environmental regulation. Either too much or too little, too little and too much, or too much and too little regulation can deter investment, and technological progress without environmental protection can generate new risks. The answer is not deregulation, but enabling regulation: clear environmental boundaries, reasonable, predictable compliance standards, robust enforcement and systems in place to support safe resource recovery.

In line with the broader circular economy literature, this approach emphasizes the interdependency of the three pillars of regulation, infrastructure, and markets and innovation (Oluwatayo & Ojo, 2024; Yuan, 2026).

OPPORTUNITIES AND PROPOSED REGULATORY FRAMEWORK

Transitioning from waste control to resource recovery

Carefully managed resource recovery can complement waste-control goals for strengthening Nigeria's environmental framework. Where technically and environmentally feasible, agricultural residues, plastics, industrial waste and e-waste should not only be viewed as disposal issues, but also as potential secondary sources. Resource recovery is identified as an opportunity for resource recovery in the circular-economy research conducted in Nigeria (Oluwatayo & Ojo, 2024).

Not all waste streams can be recovered, and the recovery process can produce emissions or hazardous residues. These should be the criteria that the regulation should be based on contamination, composition, processing

requirements, and intended use.

Developing standards and certification for waste-derived materials

Nigeria should create or revise standards for recycled and waste-based materials of appropriate categories. These standards would establish minimum performance, safety, durability and environmental quality requirements and would help decrease uncertainty for manufacturers and users.

Construction material requirements could include strength, durability, thermal, leachability and contaminant limits. As far as possible, LCA should be used to avoid transferring environmental impacts from one phase to another (Unegbu et al., 2025). Regulators, standards bodies, materials scientists, engineers, and manufacturers and end users should all participate in standard-setting.

Strengthening Extended Producer Responsibility

EPR can link design to consumption and end-of-life management of products. Nigeria is proof of the importance of producer responsibility to Sustainable Waste Management (Ajani & Kunlere, 2019). Recent developments in this direction have been introduced by the 2024 Battery Control Regulations and the 2026 Plastic Waste Control Regulations.

Measurable recovery targets, producer registration, transparent financing, reporting requirements, reliable data and monitoring should support EPR. If these conditions are not adhered to, EPR could turn into an administrative rather than a transformational tool for material flows. As properly implemented, it can enhance the reliability of secondary feedstocks and promote easier to repair, dismantle, reuse and recycle products.

Using green public procurement to create markets

Government is a significant buyer of building and infrastructure, furniture and packaging and other intensive material goods, and can drive demand for sustainable materials. Recycled content, local resource recovery, and demonstrated life-cycle performance may be considered in procurement criteria, if backed by proven evidence.

Green procurement shouldn't be based on fuzzy definitions, such as the term 'green'. Criteria should be measurable, verifiable based on applicable standards, testing, life-cycle assessment or environmental product information. This would eliminate market uncertainty and generate a demand for materials which can prove their environmental and technical performance.

Financial incentives for sustainable-material innovation

The costs of research, pilot production, testing and certification are high, especially for small and new businesses. Purposeful grants, concessionary financing, tax benefits and other support measures can thus be helpful if they are linked to tangible environmental and technical results.

However, financial support should not be intended to foster dependency on public funding, unless that is essential for the project to be implemented. There are different levels of support, for example, in the early stages of research funding, pilot scale support, testing and certification and then commercial scale funding with technical and market viability proven.

Stronger research–industry–regulator partnerships

Materials development, materials characterisation and environmental and technical assessment can be offered by universities and research centres, cost, manufacturing requirements and scalability, as well as market demand, can be offered by industry, and the translation of evidence into appropriate environmental and technical requirements can be offered by regulators. This is supported by the research findings on sustainable construction and circularity in Nigeria, which indicate the need for enhanced implementation pathways (Adebowale et al., 2025; Ubayi, 2025).

A practical model could consist of shared pilot facilities, consensus on testing procedures, regulatory sandboxes or controlled demonstration projects, if allowed by law, and structured interaction between researchers, industry and regulators. These systems may help reduce the time lag between laboratory testing and commercialization.

Establishing a life-cycle approach to material regulation

The LCA should consider the following stages of the material life cycle: extraction or waste generation, processing, manufacturing, transportation, use, maintenance, recovery, recycling and final disposal. Material that helps to cut down waste in one step can contribute to energy use or contamination in another. Life-cycle assessment can be used to help identify such trade-offs (Unegbu et al., 2025).

The choices of regulation, procurement and investment, therefore, should be based on a life-cycle approach. It would also enable the distinction between those improvements that are truly environmentally friendly and those that are burden shifting, especially if the waste-derived materials can be compared with alternative materials that are not derived from waste.

Proposed integrated framework

The framework proposed in this paper is a conceptual synthesis derived from the reviewed scholarly literature, legislation, regulation and policy documents. It is not empirically validated. Based on this synthesis, the framework comprises six interacting factors which are: (1) environmental regulation, (2) resource-recovery systems, (3) materials research and innovation, (4) standards and certification, (5) economic and market instruments, and (6) monitoring and enforcement.

The components must be connected in such a way that they work as a coordinated system. Environmental boundaries and obligations are set by regulation. Reliable secondary feedstocks are provided by recovery systems. Research takes those feedstocks and turns them into technically viable materials. Confidence in quality and safety from standards and certification. The creation and strengthening of markets are achieved through EPR, procurement and financial instruments. Monitoring and enforcement ensure environmental and technical requirements are met.

The pathway can be summarized as: environmental regulation; resource recovery; materials innovation; testing and certification; industrial adoption; market development; circular materials flows, and monitoring, research, industry and stakeholder feedback can act throughout the pathway.

The plan does not mandate specific technologies for the regulators. Instead, regulation should establish environmental goals, minimum performance standards and accountability provisions, and allow for technology-specific and place-based solutions.

Priority policy actions

Drawing from the evidence considered, six priority actions are suggested to enhance the role of environmental regulation in sustainable materials development in Nigeria. The actions are designed to operate as an interconnected policy package rather than isolated interventions.

Table 1 Priority policy actions for strengthening environmental regulation and sustainable materials development in Nigeria

Priority action	Principal responsible institutions	Implementation mechanism	Proposed measurable indicators
1. Strengthen regulatory coordination and	Federal Ministry of Environment, NESREA and relevant	Develop and periodically update a consolidated inventory of applicable environmental laws,	Updated regulatory inventory; clearly defined institutional responsibilities;

maintain an updated regulatory inventory	state environmental agencies	regulations and institutional responsibilities	frequency of regulatory updates
2. Strengthening monitoring and enforcement capacity	NESREA and relevant state environmental agencies	Improve laboratory capacity, inspection systems, technical staffing, monitoring infrastructure and compliance reporting	Number of inspections; compliance rate; number of enforcement actions; monitoring coverage
3. Develop standards and certification systems for secondary materials	Standards and regulatory institutions, relevant professional bodies and industry stakeholders	Establish measurable quality, safety and environmental-performance requirements for priority recycled and waste-derived materials	Number of standards developed; number of certified secondary materials; proportion of compliant materials
4. Improve the performance and transparency of extended producer responsibility (EPR)	NESREA, producers, and recyclers	Strengthen producer registration, collection and recovery targets, reporting and verification mechanisms	Producer registration rate; recovery rate; verified quantities collected and recovered; EPR reporting compliance
5. Promote sustainable public procurement and market demand	Federal and state procurement authorities and relevant regulatory institutions	Incorporate measurable environmental and recycled-material criteria into appropriate public procurement processes	Proportion of eligible procurement meeting sustainability criteria; recycled-material procurement volumes
6. Strengthening research-to-market and commercialisation support	Universities, research institutions, government funding agencies and industry	Support pilot-scale demonstration, testing, certification, technology transfer and commercialisation of technically viable materials innovations	Number of technologies reaching pilot stage; number tested/certified; number progressing to commercial application

These measures align with the governance and circular economies literature reviewed in this paper, which shows that Ogunkan (2022), Oluwatayo & Ojo (2024) and Yuan (2026) have noted that such measures exist.

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

Environmental regulation and sustainable materials development in Nigeria are closely related. Nigeria has a significant regulatory framework for waste management, mining and mineral processing, construction, plastics, electrical/electronic, batteries and other sectors as well as the general policy framework provided by the National Policy on the Environment. The recent Battery Control Regulations 2024 and Plastic Waste Control Regulations 2026 are further evidence of the ongoing evolution of environmental law in the sectors.

Nevertheless, the review reveals that the main challenge is not only that there are no environmental rules. Impediments to implementation include institutional fragmentation, enforcement capacity, poor infrastructure, unclear standards, lack of funding, and lack of research–industry linkages and weak markets. All these can hinder technically feasible sustainable material from scaling up from the lab or pilot level (Eze et al., 2023; Adebowale et al., 2025; Ubayi, 2025).

The regulatory opportunity is to transition away from a pollution control/disposal-focused model and to a more integrated model that supports safe recovery of resources and innovative materials for sustainability. There are practical mechanisms for this transition such as EPR, standards and certification, life-cycle

assessment, green public procurement, targeted financial support and research–industry–regulator partnerships.

Additional research is needed to produce Nigerian specific evidence on the environmental and economic performance of waste-derived materials; research the implementation and effectiveness of EPR schemes; research life cycle impact of locally developed materials; research regulatory requirements for commercialisation; and to develop reliable data on material flows. Research should also rate the effect of regulations on behaviour, environmental outcomes and resource recovery to distinguish between the presence of a regulation and its effect on these.

In summary, Nigeria's shift towards sustainable materials must go hand in hand with technological innovation as well as regulatory innovation. A good framework ought to ensure environmental quality and ensure conditions are predictable and evidence-based for safe recovery, innovation, investment and industrial adoption.

LEGAL AND POLICY INSTRUMENTS

- Environmental Impact Assessment Act, Cap E12, Laws of the Federation of Nigeria 2004 (originally enacted 1992).
- National Environmental Standards and Regulations Enforcement Agency (Establishment) Act, 2007.
- National Policy on the Environment (Revised 2016).
- National Environmental (Sanitation and Wastes Control) Regulations, S.I. No. 28 of 2009.
- National Environmental (Mining and Processing of Coal, Ores and Industrial Minerals) Regulations, 2009.
- National Environmental (Domestic and Industrial Plastic, Rubber and Foam Sector) Regulations, S.I. No. 17 of 2011.
- National Environmental (Construction Sector) Regulations, S.I. No. 19 of 2011.
- National Environmental (Non-Metallic Minerals Manufacturing Industries Sector) Regulations, S.I. No. 21 of 2011.
- National Environmental (Electrical/Electronic Sector) Regulations, S.I. No. 79 of 2022.
- National Environmental (Battery Control) Regulations, 2024.
- National Environmental (Plastic Waste Control) Regulations, 2026.

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