1.0. Title

EFFLUENT MANAGEMENT THROUGH GENERATION OF BIOGAS AND LIQUID ORGANIC FERTILIZER FROM RIBBED SMOKED SHEET PROCESSING FACTORY

SUBMITTED BY

RUBBER RESEARCH INSTITUTE OF NIGERIA

TO

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2.0. Abstract

Ribbed Smoked Sheet is produced from raw field latex, which contains an unsaturated, linear molecule with long chain aliphatic *cis*-1, 4 polyisoprene hydrocarbon polymer (Bakare, 2025) made from carbon and hydrogen. Water is a significant part of field latex. During processing of raw latex into RSS a lot of water is used from sieving to bulking, standardization, rolling and ribbing. This is in addition to the interstitial water in the latex serum. The waste released during processing of RSS is a rich source of compounds suitable for production of flamable gas such as methane and biofertilizer, often obtained after anaerobic digestion. The system will generate biogas, primarily composed of methane, which can be used as a renewable energy source for heat and electricity generation. Additionally, the anaerobic digestion process will produce liquid organic fertilizer, rich in nutrients, which can enhance soil fertility and promote sustainable agriculture. These studies have been conducted at laboratory scale in Rubber Research Institute of Nigeria. In order to scale up, the project will involve constructing a fixed dome anaerobic digester, collecting and characterizing RSS effluent and evaluating the quality and potential uses of the biogas and liquid organic fertilizer. The impact of liquid organic fertilizer on crop growth and yield will also be assessed. The project will reduce environmental pollution from RSS factory effluent, generate renewable energy from biogas, promote a sustainable agriculture through the use of liquid organic fertilizer, create jobs and economic opportunities in rural communities, and contribute to Nigeria's contribution to the UN Sustainable Development Goals, including affordable and clean energy, decent work and economic growth, and climate action as components of the Sustainable Development Goals. The objective of this is to design and set up a cost-effective biogas plant to manage effluent from ribbed smoked sheet (RSS) rubber factories using anaerobic digestion technology.

3.0 Introduction and Background

Waste management is a crucial aspect of product processing; more specifically, natural rubber processing into ribbed smoked sheet (RSS) requires lots of water for mixing and cleaning (George and Jacob, 2000). After use, this water becomes toxic and unsafe for indiscriminate disposal into the environment unless properly managed. There are several methods in which effluent can be managed, but a method that yields many benefits at a time should be the most preferred by any economist. Anaerobic Digestion (AD) is a modern-day method of converting various kinds of biodegradable waste to generate biogas made up chiefly of methane gas, several other gases, such as carbon (iv) oxide, hydrogen sulphide, and water droplets. Methane gas derived from this process can be used as cooking gas and also converted to electricity through the use of fabricated biogas generators or conventional petrol/diesel engine generators. The conventional petrol/diesel engine generators can be converted by replacing the carburetors, and when connected, the purified methane gas, will serve as a biofuel to run generators; therefore, running the generator will be at zero cost since the fuel is generated from a natural waste source. Furthermore, the sludge or residue after the anaerobic digestion is rich in bio-fertilizer, which can enhance soil fertility for plant growth, thereby solving multiple challenges at a go.

3.1 Problem Statement

The National Environmental Standards and Regulations Enforcement Agency (NESREA) has reported widespread contamination of water bodies across Nigeria. A significant portion of the country's water supply is contaminated with *EscherichiaColi* (a pollution indicator microorganism), making it unsafe for consumption and leading to a high prevalence of waterborne diseases. This pollution is largely a result of untreated sewage, industrial effluents, and improper disposal of solid waste and plastics (NESREA, 2025).

Furthermore, with the rise of power problems in the country, an alternative source of energy generation becomes imperative. Fossil fuels heavily dominate Nigeria's electricity generation. According to the International Energy Agency (IEA), natural gas accounts for approximately 75% of total electricity generation, with hydropower making up most of the remaining 25% (IEA, 2022). This heavy dependence on a single energy source makes the nation's power supply vulnerable to disruptions, such as gas pipeline vandalism and maintenance issues. Nigeria is richly endowed with abundant alternative energy resources, including solar, hydro, wind, and biomass, which are largely untapped.

3.2 Justification / Relevance to NASENI's Priority Areas

The proposal's focus on anaerobic digestion technology directly addresses NASENI's mandate to develop local, sustainable, and economically viable technological solutions. Instead of relying on imported or conventional effluent treatment methods, this research aims to create a homegrown, efficient, and environment friendly system, that not only solves a specific industrial problem - the pollution from RSS processing - but also contributes to the broader goal of indigenous technological development. This technology could be transferred to local rubber producers and other industries with biodegradable waste streams, creating a pathway for local manufacturing and job creation in the environmental technology sector. Therefore, this research contributes to NASENI's vision of fostering a strong scientific and engineering base for Nigeria's industrialization and sustainable development.

4. Technology Readiness Level (TRL)

4.1 Current TRL Stage

TRL 6 there is a functional prototype of a 3000 litres capacity bio-digester system and a 5000 litres of gas collector demonstrated in RRIN ribbed smoked sheet processing factory. The facility can handle the specific characteristics of the wastewater and it has been used to generate biogas which has been utilized to generate heat for drying ribbed smoke sheet.

4.2 Achievements to Date

Successful experiments at laboratory scale which showed a 75-percentage reduction in Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) of Ribbeed Smoked Sheet (RSS) effluent. This small-scale prototype gave a good biogas yield proving its economic viability, especially when scalled up.

4.3 Target TRL Stage

TRL 9 This technology is aimed at:

i. Design and development of an anaerobic digester of $10m^3$ capacity and a corresponding $20m^3$ capacity gas collector.
ii. Implementation at multiple rubber processing plants and other industries.
iii. To explore the prospects of household use of this technology as source of energy.

5.0. Objectives

5.1. General Objective

The general objective of this project is to set-up a effective biogas plant to manage effluent from ribbed smoked sheet rubber factory employing anaerobic digestion technology.

5.2. Specific Objectives

i. To periodically determine the physicochemical parameters of the waste water
ii. To determine the composition of biogas generated from the biodigester.
iii. To explore storage and utilisation of the biogas as source of alternative energy
iv. To determine the physicochemical parameters of the biofertilizer.
v. To determine the fertility properties of the biofertilizer on the growth of natural rubber plant and the yield in agroforestry trials of natural rubber.
vi. To strategically engage the rural communities in waste management in order to mitigate greenhouse gas emission, and
vii. To reduce poverty through job creation.

6.0. Methodology / Research Plan

6.1. Experimental Design/Approach

Phase 1: Biogas Plant Setup and Optimization

i. Fixed dome digester construction: Construct a fixed dome digester buried in the ground with a capacity of 8 - 10 cubic meters.
ii. Rubber factory effluent and cow dung collection: Collect rubber factory effluent and characterize its physical and chemical properties. Cow dung serves as activator.
iii. Experimental design: Use a randomized complete block design (RCBD) with three retention times (10, 20, and 30 days) to identify optimal conditions for maximum biogas production.
iv. Biogas production measurement: Measure biogas production daily using a gas meter.
v. Biogas composition analysis: Analyze biogas composition (e.g., methane, carbon dioxide) using a gas analyzer. Chemical carbon capture will be applied for durable storage in order to avoid carbon emission (Bricket, 2015).
vi. **Phase 2**: Liquid Organic Fertilizer Production and Evaluation

i. Liquid organic fertilizer collection: Collect liquid organic fertilizer produced during anaerobic digestion.
ii. Nutrient analysis: Analyze nutrient content (e.g., N, P, K) of liquid organic fertilizer.
iii. Quality evaluation: Evaluate the quality of liquid organic fertilizer based on nutrient content, pH, and electrical conductivity.

Phase 3: Crop Trial

i. Crop selection: Select crops (e.g., vegetables, grains) for evaluating the impact of liquid organic fertilizer.
ii. Experimental design: Use a randomized complete block design (RCBD) with different application rates and mode of liquid organic fertilizer.
iii. Crop growth and yield measurement: Measure crop growth and yield parameters (e.g., plant height, biomass, and yield).

Phase 4: Community Engagement and Job Creation

i. Community engagement: Engage with rural communities to promote waste management practices and mitigate greenhouse gas emissions.
ii. Job creation: Create jobs for local communities in biogas plant operation and maintenance.

6.2. Materials and Methods (Continued)

6.2.1. Materials

1. Rubber factory effluent and cow dung: Collected from a ribbed smoked sheet production factory at Rubber Research Institute of Nigeria and an abattoir for cow dung.

2. Fixed dome digester: Constructed using local materials (e.g. sandcrete blocks, cement, sand) and designed to be buried in the ground.
3. Biogas collection system: dome-like structure comprising pipes, valves as gas holder.
4. Liquid organic fertilizer collection system: Comprising pipes and a storage tank. Crop seeds: Selected crops (natural rubber and its intercrop) for evaluating the impact of liquid organic fertilizer.
5. Measuring instruments: pH meter, temperature sensor, gas analyzer, and other necessary equipment for monitoring and evaluating the biogas plant.
6. Community engagement materials: Educational materials, surveys, and other tools for engaging with rural communities.

6.2.2. Methods

a. Construction of Fixed Dome Digester

The site will be excavated to make space for the construction of the digester, biogas collection system, and liquid organic fertilizer collection system. This will be carried out using local materials, followed by the installation of gas cleaner, gas filter, pressure boaster, gas burner, and other necessary accessories.

b. Biogas Generation and Liquid Organic Fertilizer Production

Feedstock preparation: The RSS effluent collected from the factory will be prepared as slurry with the cow dung at a ratio of 1:1 and fed into the digester for anaerobic digestion. Daily analysis of the effluent will be carried out to determine its physicochemical parameters pH, COD, BOD, TSS and electrical conductivity using standard chemical method.

Furthermore, daily collection and analysis of the produced biogas will be carried out. After anaerobic digestion, the residual liquid organic bio-fertilizer will be collected and measured for its nutrient parameters, nitrogen containing components, Potassium and Phosphorus.

c. Potential Uses of Biogas and Liquid Organic Fertilizer

The use of biogas will be evaluated on heat and energy generation. This will include tests such as flame test, combustion efficiency, calorific values, and energy output. Liquid organic fertilizer impact will be studied on the growth of natural rubber plant and intercrops. This will involve field trials and consequently study of the plant intercropped with medicinal plants; and the yield of the medicinal plants will also be determined.

d. Community Engagement and Job Creation

Community engagement: Rural communities will be engaged and trained on waste management practices through agricultural extension services.

i. Job creation: Create jobs for local communities in biogas plant operation and maintenance.

6.3 **Data Collection and Analysis**

1. Data Collection

a. Biogas Production Data

i. Biogas volume: Measure biogas volume produced daily using a manual gas analyzer.
ii. Biogas composition: Analyze biogas composition (methane, carbon dioxide) using a gas analyzer.
iii. Temperature and pH: Monitor temperature and pH of the digester.

b. Liquid Organic Fertilizer Data

i. Nutrient content: Analyze nutrient content (N, P, K) of liquid organic fertilizer.

c. Crop Yield Data

i. Crop growth parameters: Measure crop growth parameters (plant height, biomass).
ii. Crop yield: Measure crop yield (kg/ha).

d. Greenhouse Gas Emissions Data

i. Baseline emissions: Measure baseline greenhouse gas emissions from rubber factory effluent.
ii. Emissions reduction: Measure greenhouse gas emissions reduction after biogas plant operation.

e. Community Engagement and Job Creation Data

i. Surveys: Conduct surveys to assess community perception and adoption of waste management practices.
ii. Job creation metrics: Track number of jobs created and job characteristics.

6.4 Prototype development

In an effort to provide a sustainable solution for effluent management at the ribbed smoked sheet processing factory, a prototype anaerobic digestion system was successfully developed and tested. This innovative system was designed around a biodigester constructed from two 1500-liter plastic drums, creating a total working volume of 3000 liters. The core of the system's gas collection was a separate 5000-liter gas collector, which efficiently captured the biogas generated during the digestion process.

The prototype demonstrated remarkable efficiency and performance. With a retention time of 28 days, the system entered its log phase of microbial growth, consistently producing approximately 1 cubic meter of biogas per day. Analysis of the gas revealed a high methane content of 55%, indicating its significant potential as a renewable energy source for the factory's operations.

Beyond energy generation, a key objective of this prototype was the production of a valuable by-product: liquid organic fertilizer. The residual slurry from the digester was subjected to a detailed analysis, which confirmed its richness in essential plant nutrients. The analysis showed a high concentration of Nitrate, Ammonium Nitrogen, Potassium, and Phosphorus, making the effluent a viable and valuable resource for agricultural use. This successful prototype serves as a foundational model, proving the technical and environmental viability of transforming factory effluent into both a clean energy source and a potent biofertilizer, thereby addressing waste management challenges in an economically and ecologically beneficial manner.

7.0 Feasibility and Business Case

7.1 Market Potential

Producers face increasing pressure from regulators and consumers to treat their wastewater, which is highly polluted with organic matter. Processing rubber effluent on a large scale will be a ready source of biogas as alternative to epileptic power supply. A number of agroprocessing units in Nigeria and Edo State, in particular, rely on biomass as alternative source of energy. This will be added impetus to off grid electricity supply. In addition, there could be recycled water after removal of the organic impurities for further use, thus minimising availability of water. Organic agriculture is promoted worldwide and the biofertilizer will be handy in this instance. Both biogas and biofertilizer have prospects of patenting and commercialisation. Environmental hazard of effluents would be taken off the factories.

7.2 Commercialisation Strategy

A phased approach is the most effective commercialisation strategy.

a. **Targeted Sales & Marketing:** Once the pilot is successful, a targeted marketing campaign should focus on the economic and environmental benefits. Key selling points include energy cost savings, regulatory compliance, and improved public image.
b. **Strategic Partnerships:** Partner with engineering, procurement, and construction (EPC) firms that already work with the natural rubber industry. This leverages their existing client relationships and expertise in plant design and construction. This may be based on various options of partnership, which may be full purchase, rebate on produced units, shared profit, build-operate-transfer, etc.

7.3 Risk Assessment and Mitigation

Implementing this technology has specific technical, operational, and financial risks that must be addressed.

a. Technical Risks

i. **Inconsistent Wastewater Characteristics:** The composition of rubber wastewater can fluctuate, potentially disrupting the biological process in the digester.

Mitigation - Pre-treatment steps like pH balancing and solid removal, along with real-time monitoring of key parameters, can ensure a stable environment for the microbes.

ii. **Inhibitory Compounds:** Some components in the wastewater, like residual formic acid or sulfur compounds, can inhibit the AD process.

Mitigation - Careful analysis of the wastewater composition and the use of robust microbial cultures adapted to these conditions can help overcome this challenge.

b. Operational Risks

i. **Process Upset:** A system malfunction or operator error could lead to a 'digester crash,' requiring a lengthy and costly restart.

Mitigation - Implement automated process control systems, provide comprehensive operator training, and maintain a backup supply of anaerobic sludge (inoculum) for quick recovery.

ii. **Biogas Safety:** Methane is flammable and poses a safety risk if not handled properly.

Mitigation - Install proper gas detection systems, ventilation, and emergency flares. Adhere to strict safety protocols and industry standards.

c. Financial Risks

i. **High Initial Capital Cost:** The upfront investment for building an AD plant can be a barrier for some companies.

Mitigation - Secure government grants or subsidies for renewable energy and environmental projects. Offer flexible financing options and highlight the long-term return on investment (ROI) from energy savings and avoided fines.

ii. **Fluctuating Energy Prices:** The financial viability of the biogas can be affected by volatile prices for traditional energy sources.

Mitigation - The primary business case is wastewater treatment, with energy as a secondary benefit. This makes the project robust even if energy prices are low, as the main goal of compliance and pollution abatement is still met. In addition, the biofertilizer component will be an advantage, especially in the production of medicinal plants. Biofertilizer can as well be applied to arable crops to boost production.

8. Project Work Plan and Timeline

8.1. Work Packages

Table 1: Work Packages

S/N	Work Packages	Tasks
1.	Land clearing and preparation	Location of good site for construction of biogas plant.
2.	Plant layout and design	Marking out the land area required and biogas digester design.
3.	Procurement of materials and equipment/tools	Purchasing materials needed for setting-up the plant
4.	Construction of biogas digester and installation of fittings	i. Construction of biogas digester, ii. Fixing of biogas cleaner and filter, iii. Installation of biogas pressure booster. iv. Installation of biogas burner.
5.	System testing	Carrying out leakage test
6.	Collection and characterization of feedstock	i. Collection of samples (rubber effluent and cow dung) for analysis, ii. Determination of feedstock's pH, COD, BOD, TS, VS, and nutrient content, iii. Identifying toxic compounds.
7.	Preparation of slurry (feedstock)	i. Mixing of rubber effluent and cow dung, ii. Loading of the digester with the feedstock,
8.	Generation of biogas	i. Monitoring and controlling of the digester performance, ii. Determination of the optimal retention time.
9.	Data collection and analysis on biogas	i. Determination of maximum biogas yield through biochemical methane potential tests, ii. Determination of biogas

		composition and quality.
10.	Biogas utilization	i. Exploring options for biogas utilization ii. Assessing the economic viability of different biogas utilization pathways.
11.	Collection of liquid organic fertilizer for analysis	i. Determination of feedstock's pH, COD, BOD, TS, VS, and nutrient content, ii. Determination of the nutrient content (N, P, K) and other relevant properties of the fertilizer.
12.	Writing of report – Phase I	
13.	Liquid organic fertilizer applications and testing on the growth parameters on plants	Evaluating the performance of liquid organic fertilizer produced on the growth and yield of selected crops.
14.	Environmental impact assessment	Identifying potential risks and mitigation strategies. (Impact on water bodies quality and soil health).
15.	Economic feasibility study	Estimating potential revenue streams, capital, and operating cost.
16.	Writing of report – Phase II	
17.	Replication of the biogas plant in rural communities' households	i. Replication of the biogas plant in different rural community for household use, ii. Strategically engage the rural communities in waste management practice.

8.2 Gantt Chart/Activity Schedule

Table 2: Gantt Chart/Activity Schedule

Activity / WP	**0–6 Months**	**6–12 Months**	**12–18 Months**	**18–24 Months**	**24–30 Months**	**30–36 Months**
1: Literature Review and Planning						
2:Site preparation, plant layout, and design						
3:Procurement of materials						
4: Construction of biogas digester and installation of fittings						
5: System testing						
6: Collection and characterization of feedstock						
7: Preparation of slurry (feedstock):						
8: Generation of biogas						
9: Data collection and analysis on biogas						
10: Biogas utilization						
11: Analysis of digestate for soil amendment properties						
12: Report writing – Phase I						
13: Commissioning – Phase I						
14: Liquid organic fertilizer applications and testing on the growth parameters on plants						
15: Environmental impact assessment						
16: Economic feasibility study						
17: Report writing– Phase II						
18: Knowledge transfer and agricultural extension service in rural communities' households						

a. Dependencies:

- ✔ Literature Review and Planning must be completed before site preparation, plant layout, and design.
- ✔ Procurement of materials must be completed before the construction of biogas digester and installation of fittings.
- ✔ System testing can start only after the construction of biogas digester and installation of fittings.
- ✔ Construction of biogas digester and installation of fittings must be completed before generation of biogas.
- ✔ Collection and characterization liquid organic fertilizer can only starts only after the generation of biogas (retention time).
- ✔ All the tasks must be completed before the commissioning ceremony.

9. Expected Outcomes & Contribution

9.0. Expected Outcomes

1. Development of a Cost-Effective Biogas Plant: A cost-effective biogas plant will be designed and set up to convert rubber factory effluent into biogas and liquid organic fertilizer.
2. Optimization of Biogas Production: Optimal conditions for maximizing biogas production and determining the optimal retention time for ~~liquid~~ organic fertilizer production will be identified.
3. Quality Evaluation of Biogas and ~~Liquid~~ Organic Fertilizer: The quality of biogas and liquid organic fertilizer will be evaluated, providing insights into their potential uses.
4. Understanding of Liquid Organic Fertilizer Impact: The impact of ~~liquid~~ organic fertilizer on crop growth and yield will be investigated, contributing to the understanding of its potential applications in agriculture.

9.1 Scientific/Technological Contribution

1. The project will contribute to the development of waste-to-energy technology, specifically in the context of rubber factory effluent.
2. The project's focus on waste management and biogas production contributes to the understanding of greenhouse gas mitigation strategies.
3. The identification of optimal conditions for biogas production will contribute to the understanding of anaerobic digestion processes.
4. Production of liquid organic fertilizer will provide a sustainable alternative to synthetic fertilizers, contributing to environment~~ally~~-friendly agricultural practices.
5. The project will demonstrate a sustainable approach to managing rubber factory effluent, reducing environmental pollution.
6. The project's findings and technologies can be scaled up and replicated in other industries and communities, contributing to widespread adoption of sustainable waste management practices.

9.2 Socio-economic Impact

1. The project will contribute to renewable energy generation, reducing dependence on fossil fuels and mitigating climate change.
2. The project will contribute to poverty reduction by creating jobs and promoting economic development in rural areas.
3. The project will engage rural communities in waste management practices, promoting environmental awareness and community development.

9.3 Contribution to National Development

1. Sustainable Development Goal 7 (Affordable and Clean Energy): The project will contribute to increasing the share of renewable energy in the national energy mix, promoting affordable and clean energy (Sustainable Development Goal 7 - Affordable and Clean Energy).
2. The project will create jobs and promote economic growth in rural areas, contributing to decent work and economic development (Sustainable Development Goal 8 - Decent Work and Economic Growth).
3. The project will promote sustainable industrial practices and innovation in waste management, contributing to industrial development (Sustainable Development Goal 9 - Industry, Innovation, and Infrastructure).
4. The project will promote sustainable consumption and production patterns by utilizing waste and reducing environmental pollution (Sustainable Development Goal 12 - Responsible Consumption and Production).
5. The project will contribute to reducing greenhouse gas emissions and mitigating climate change by promoting renewable energy and sustainable waste management practices (Sustainable Development Goal 13 - Climate Action).

10.0. Budget Estimation

10.1. Personnel Cost

Personnel Cost -- **₦ 8,189,000.00**

9.1. Equipment and Materials

Table 10.2a: Preliminaries/ General Works

Item	Description	Qty	Unit	Rate	Amount (#)
	Preliminaries/ General Works				
A	Site preparation		Item		200,000.00
B	Setting out		Item		250,000.00
C	Excavating top soil for preservation, average 150mm deep	36	m^2	1,500.00	54,000.00
D	Excavating pit; maximum depth not exceeding 2m commencing 0.15m below existing ground level	22	m^3	6,275.00	138,050.00
E	Keeping excavation free from surface water		Item		150,000.00

F	Depositing on site excavated material in temporary spoil heaps located at Engineer's discretion	16	m^3	1,500.00	24,000.00 -
G	Dressing sides of excavation	28	m^2	1,750.00	49,000.00 -
H	L & C bottom of excavation	11	m^2	2,500.00	27,500.00 -
I	Plain in-situ concrete, mix 1:10, 20 aggregate blinding; poured on or against earth in pit; thickness not exceeding 50mm	1	m^3	39,000.00	39,000.00 -
J	Reinforced in-situ concrete, BS5328, designed mix C25, 20 aggregate, minimum cement content 304kg/m^3, well vibrated concrete base; thickness not exceeding 125mm, poured on blinding	2	m^3	189,500.00	379,000.00 -
K	Steel BRC mesh fabric reinforcement to BS 4483: ref. A193 weighing 3.02Kg/m^2 laid 150mm lapped on both side (measured net with no allowance made for lapping)	11	m^2	67,500.00	742,500.00 -
L	Reinforcement bars, BS 4449, hot rolled deformed high yield steel straight and bent in floor base; 12mm diameter	0.5	Ton	1,250,000.00	625,000.00 -
M	Backfilling with selected excavated materials	6	m^3	2,500.00	15,000.00
	Sub-total				**2,693,050.00**

Table 10.2b: Digester Bill

Item	Description	QTY	Unit	Rate	Amount
	Digester				
A	Formwork; Mild steel, basic finish, plain vertical; circumference of digester wall	26	m^2	34,500.00	897,000.00

B	Reinforced in-situ concrete, BS5328, designed mix C25, 20 aggregate, minimum cement content 304kg/m^3, well vibrated concrete wall; thickness not exceeding 150mm, poured against earth	6	m^3	189,500.00	1,137,000.00
C	Steel BRC mesh fabric reinforcement to BS 4483: ref. A193 weighing 3.02Kg/m^2 laid 150mm lapped on both side (measured net with no allowance made for lapping)	12	m^2	67,500.00	810,000.00
D	Reinforcement bars, BS 4449, hot rolled deformed high yield steel straight and bent in floor base; 12mm diameter	0.5	Ton	1,250,000.00	625,000.00
E	50mm Cement and sand (1:2) smooth internal rendering on digester wall in 12mm layers followed by successive blinding with rich paste of cement, water seal and water mix	22	m^2	23,900.00	525,800.00
F	Cement and sand (1:2) mix; 50mm screed bed to floor on concrete base followed by a blind of rich paste of cement, water seal and water mix	7	m^2	93,900.00	657,300.00
G	Cement and sand (1:1) mix; 12mm screed toweled bed to blinded floor on concrete base succeeded by blinding of rich cement, water seal and water paste mix	7	m^2	81,150.00	568,050.00
	Sub-total				**5,220,150.00**

Table 10.2c: Displacement Chamber

Item	Description	QTY	Unit	Rate	Amount
	Displacement Chamber				
A	Sandcrete blockwork, hollow, bedding and jointing on cement and sand (1:4) walls 225mm thick; stretcher bond	23	m^2	23,600.00	542,800.00

B	Reinforced in-situ concrete, BS5328, designed mix C25, 20 aggregate, minimum cement content 304kg/m^3; Vibrated beam and cover slab	1	m^3	189,500.00	189,500.00
C	Beam; Formwork for in-situ concrete and basic finish; Regular shaped; rectangular	8	m^2	21,600.00	172,800.00
D	Reinforcement bars, BS 4449, hot rolled deformed high yield steel straight and bent in beam; 8 - 16mm diameter	0.5	Ton	1,250,000.00	625,000.00
E	50mm Cement and sand (1:2) smooth internal rendering on wall in 12mm layers followed by successive blinding with rich paste of cement, water seal and water mix	13	m^2	81,150.00	1,054,950.00
F	Cement and sand (1:2) mix; 50mm screed bed to floor on concrete base followed by a blind of rich paste of cement, water seal and water mix	2	m^2	81,150.00	162,300.00
G	Cement and sand (1:1) mix; 12mm screed trowelled bed to blinded floor on concrete base succeeded by blinding of rich cement, water seal and water paste mix	2	m^2	81,150.00	162,300.00
	Sub-total				**2,909,650.00**

Table 10.2d: Gas Holder

Item	Description	QTY	Unit	Rate	Amount
	Gas Holder				
A	Reinforced in-situ concrete, BS5328, designed mix C25, 20 aggregate, minimum cement content 304kg/m^3; vibrated suspended dome, av. 75mm thickness	1	m^3	189,500.00	189,500.00
B	Formwork for in-situ concrete; Basic finish, horizontal; Soffits of sloping slab n.e. 30^o from horizontal, height to soffit n.e. 2.1m	17	m^2	22,300.00	379,100.00
C	Hemispherical lateritic mould on surface of sloping formwork; av. 75mm thickness	2	m^3	53,500.00	107,000.00

D	Steel BRC mesh fabric reinforcement to BS 4483: ref. A193 weighing 3.02Kg/m^2 laid 150mm lapped on both side (measured net with no allowance made for lapping)	11	m^2	67,500.00	742,500.00
E	Cement and sand (1:1) mix; 50mm screed trowelled bed to blinded surface of dome	17	m^2	23,900.00	406,300.00
F	38mm Cement and sand (1:2) smooth internal rendering on sloping soffit of dome in 12mm layers followed by successive blinding with rich paste of cement, water seal and water mix	17	m^2	23,900.00	406,300.00
	Sub-total				**2,229,700.00**

Table 10.2e: Mixing Chamber

Item	Description	QTY	Unit	Rate	Amount
	Mixing Chamber				
A	Sandcrete blockwork, hollow, bedding and jointing on cement and sand (1:4) walls 225mm thick; stretcher bond	10	m^2	23,600.00	236,000.00
B	Reinforced in-situ concrete, BS5328, designed mix C25, 20 aggregate, minimum cement content 304kg/m^3; Vibrated beam and cover slab	2	m^3	89,500.00	179,000.00
C	Beam; Formwork for in-situ concrete and basic finish; Regular shaped; rectangular	5	m^2	21,600.00	108,000.00
D	Reinforcement bars, BS 4449, hot rolled deformed high yield steel straight and bent in beam; 8 - 16mm diameter	0.2	Ton	1,250,000.00	250,000.00
E	50mm Cement and sand (1:2) smooth internal rendering on wall in 12mm layers followed by successive blinding with rich paste of cement, water seal and water mix	10	m^2	23,900.00	239,000.00

F	Cement and sand (1:2) mix; 50mm screed bed to floor on concrete base followed by a blind of rich paste of cement, water seal and water mix	2	m^2	23,900.00	47,800.00
G	Cement and sand (1:1) mix; 12mm screed trowelled bed to blinded floor on concrete base succeeded by blinding of rich cement, water seal and water paste mix	2	m^2	21,150.00	42,300.00
	Sub-total				**1,102,100.00**

Table 10.2f: List of Equipment

Item	Description	QTY	Unit	Rate	Amount (#)
	Equipment				
A	Air Compressor; 230V/50HZ, 8BAR Tank	1	Piece	650,000.00	650,000.00
B	pH Meter (7 in 1))	4	Piece	210,000.00	840,000.00
C	4 in 1 Cordless Battery Power Tools	2	Pack	500,000.00	1,000,000.00
D	Gas Analyzer	2	Piece	1,600,000.00	3,200,000.00
E	Temperature Sensor	3	Piece	170,000.00	510,000.00
F	20.2MP GPS Camera (Built-In Wi-Fi and GPS Connectivity)	2	Piece	900,000.00	1,800,000.00
G	3HP Solar Sludge Pump	1	Piece	3,800,000.00	3,800,000.00
H	Set of Biogas Filter	2	Set	1,200,000.00	2,400,000.00
	Sub- Total				**14,200,000.00**

10.3 Travel and Logistics

Table 10.3: Travel and Logistics

Item	Description	Amount (#)
A.	**Transportation**	
i.	Fuel (N500,000 per month for 10 months)	N5,000,000.00
ii.	Vehicle Maintenance (N200,000 per month)	N2,000,000.00

iii.	Transportation Allowance (₦300,000 per month for 10 months)	3,000,000.00
B.	**Lodging (Accommodation and Food)**	
i.	Accommodation (₦400,000 per month for 10 months)	4,000,000.00
ii.	Food and Refreshments (₦100,000 per month for 10 months)	1,000,000.00
C.	**Other Logistics Expenses**	
i.	Communication (₦50,000 per month for 10 months)	500,000.00
	Total Travelling and Logistic Fund	**15,500,000.00**

10.4. Miscellaneous/ Contingencies

Table 10.4: Contingency Fund

Item	Description	Amount (#)
	Contingency Fund (10% of total project budget)	
A.	Breakdown of Contingency Fund	
i.	Unexpected Expenses: 50%	2,456,700.00
ii.	Project Delays: 30%	1,474,020.00
iii.	Changes in Project Scope: 20%	982,680.00
	Total Contingency Fund	**4,913,400.00**

General Summary of the Budget

Item	Description	Amount (#)
	General Summary	
A	**Preliminaries/ General Works**	2,693,050.00
B	**Digester**	5,220,150 .00
C	**Displacement Chamber**	2,909,650.00
D	**Gas Holder**	2,229,700.00
E	**Mixing Chamber**	1,102,100.00
F	**Equipment & Tools**	14,200,000.00
G	**Travel and Logistics**	15,500,000.00
H	**Personnel Cost**	8,189,000.00
	Total	**49,134,000.00**
I	**Miscellaneous/Contingencies**	4,913,400.00
	Grand Total	**54,047,400.00**

11 Team and Institutional Support

11.1 Research Team Profile

S/N	Names	Designation/Area of Specialization
1.	Dr. L.N. Dongo	Chief Executive Director
2.	Dr. K.O. Omokhafe	Director/Plant Breeder
3.	Dr. Isiaka O. Bakare	Director / Analytical Chemist
4.	Dr. Patience Imarhiagbe	Director / Extension Officer
5.	Dr. (Mrs.) F.G. Otene	Asst. Director / Extension Officer
6.	Engr. Fagbemi Emmanuel Adeleke	Principal Research Officer/ Mechanical Engr.
7.	Dr. Faithfulness O. Oseghale	Principal Research Officer/ Microbiologist
8.	Ohifuemen Andrew Ohifuenmen	Principal Research Officer /Physicist
9.	Engr. Patrick Ayeke	Principal Research Officer / Production Engr.

10. Dr. Christian Idehen — Chief Research Officer / Soil Scientist
11. Mr. Ijeh Kenneth — Principal Research Officer /Plant Pathologist
12. Engr. Adokwe Dominic — Civil Engineer
13. Miss. K. Andrew — Research Officer 1/ Chemist
14. Mrs. Eguagie Evelyn Ighodaro — Senior Statistician
15. Mr. A. Kadiri — Senior Foreman
16. Mr. F. Tongo — Senior Foreman
17. Mr. F. Akowe — Principal Agric. Supt.

11.2 Institutional Facilities and Infrastructure

- Site for the biogas plant,
- Fabrication workshop to carry out some fabrication works,
- Smoke house for utilization of biogas,
- Green / Screen house to evaluate liquid organic fertilizer performance

12. References

1. Adesina, O. A. (**2022**). "Investigation of Renewable Energy Potentials of Nigeria." *Journal of Research in Engineering and Applied Sciences* 11(2): 55-62.
2. Bricket, L (2015) Carbon dioxide capture handbook. US Department of Energy, 116pp.
3. George P.J. and Jacobs, C.K. (**2000**). Natural Rubber Agromanagement and Crop Processing, Rubber Research Institute of India Rubber Board, Kottayam, India, 648pp.
4. IEA. (**2022**). Nigeria Energy Outlook. IEA Publications.
5. NESREA, 2025. News and updates. https://NESREA.gov.ng/news/(accessed September 10, 2025).

13. **Supporting Documents (Appendices)**

13.1 Prior Research Outputs/Proof of Concept

(Ongoing)

13.2 Technical Schematics or Data Sheet

Pic. 1: Developed Laboratory Scale Biogas System (Rubber Effluent)

Pic. 2: 3,000 litres pilot plant to dry ribbed smoked sheet (ongoing).

13.3 Ethical approvals (if applicable)