Mainstreaming Clean Innovative Technologies into Nigeria's Agricultural Sector:

Reducing Waste, Enhancing Product Value, Easing Labour Burdens, and Urging Policy and Political Commitment to a Just Transition

RENEWABLE ENERGY ASSOCIATION OF NIGERIA (REAN)

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Foreword

Nigeria stands at a defining moment in its agricultural and energy transition journey. Its food systems are under growing pressure from the realities of climate change, persistent rural poverty, and energy insecurity, to the social inequities that continue to burden women and youth who form the backbone of production and processing. Yet, within these challenges lies a profound opportunity – the chance to reimagine the country's agricultural future through clean, inclusive, and innovative technologies that not only enhance productivity but also protect people and the planet.

This study, "Mainstreaming Clean Innovative Technologies into Nigeria's Agricultural Sector", responds directly to this opportunity. It provides evidence that the necessary technologies required to transform Nigeria's agriculture already exist and are being successfully deployed by small enterprises, women's cooperatives, and young innovators, across the country in form of solar dryers, mini-grids, biogas systems and climate-smart irrigation, among others. Furthermore, it emphasises the enabling policies, financing frameworks, and institutional coordination required to scale up these solutions.

At Heinrich Böll Stiftung Nigeria, we believe that a just transition must address structural inequalities and create real economic value for communities, going beyond energy access. The integration of clean technologies in agriculture aligns perfectly with this vision: It reduces post-harvest losses, alleviates labour burdens, and strengthens local economies, all the while cutting emissions and improving resilience.

I would like to commend the partners, stakeholders, researchers and consultants who contributed to this study for their thorough analysis and inclusive methodology. Their findings provide a roadmap for policymakers, development partners, and private investors seeking to align agricultural modernization with climate justice principles.

We hope that this work will inspire bold, coordinated action, with public and private actors channelling existing agricultural and climate finance to scale renewable-energy solutions that benefit farmers, processors, and traders alike.

With the necessary political will and sustained investment, Nigeria could lead the way in Africa by demonstrating that sustainable agriculture and clean energy are two sides of the same transition.

Sophie von Knebel
Country Director
Heinrich Böll Stiftung (hbs) Nigeria

Executive Summary

Nigeria's agriculture is the backbone of rural livelihoods but continues to face low productivity, high post-harvest losses, and unsustainable energy dependence. Many value-chain processes drying, milling, irrigation, and preservation still rely on outdated, inefficient, or polluting systems. These "dirty" agricultural practices not only limit profitability but also worsen greenhouse gas emissions, deforestation, and rural pollution. This study assesses how clean and innovative technologies such as solar dryers, cold-storage systems, biogas digesters, mini-grids, and solar irrigation can transform Nigeria's agri-food system by reducing waste, easing labour burdens, increase profits and driving a just agricultural and energy transition.

The study adopted mixed-methods, participatory approach across key agro-ecological zones. It combined desk research, field surveys, interviews, and stakeholder consultations with farmers, women and youth cooperatives, innovators, and policy actors. The goal was to identify unsustainable processes, assess the socio-economic and environmental benefits of clean technologies, and propose feasible strategies for scaling up their adoption.

Key Findings

- Dirty agricultural practices such as open-sun drying, diesel-powered milling, and inefficient irrigation remain widespread, contributing to high food losses (up to 40% of perishables) and rural pollution.

- Clean-energy innovations like solar dryers, mini-grids, and cold rooms are emerging, cutting post-harvest waste by 30–50% and reducing diesel use by 40%. Youth and women entrepreneurs increasingly lead these solutions.

Key Findings

- Economic and social gains include higher yields, better produce quality, and improved incomes for adopters; however, uptake is slowed by high upfront costs, limited finance, and poor awareness.

- Policy and institutional gaps persist: fragmented mandates, weak enforcement of product standards, and limited training within extension services.

- Energy poverty and gender inequality compound the problem most rural women lack access to affordable, reliable energy for processing and storage, despite being the majority of smallholders.

Priority Recommendations

1. Launch a National Agri-Energy Acceleration Program (NAEAP): Establish clear national and state targets for deploying solar irrigation systems, dryers, and cold-storage units, linked to Nigeria's Just Energy Transition Plan (JET-P).

2. Create a Green Agribusiness Fund (GAF): Provide concessional naira-based credit and results-based grants to farmers, cooperatives, and clean-tech enterprises adopting renewable energy for agricultural operations. Otherwise –

3. Establish a Clean Agriculture Finance Integration Framework (CAFIF): Instead of creating a new fund, align and re-purpose existing agricultural, climate, and renewable-energy financing mechanisms such as the CBN's Anchor Borrowers' Programme, BOI's Solar Energy Fund, REA's Performance-Based Grant, and the NCCC's Climate Fund to finance clean agricultural technologies.

The CAFIF will coordinate these institutions under one umbrella, set clear renewable-agriculture investment quotas (e.g., 10–15% of annual disbursements), and create a joint eligibility and monitoring framework for solar dryers, cold rooms, irrigation systems, and biogas units.

4. Promote Public-Private Partnerships (PPP) for Clean Agro-Processing Hubs: Develop regional “Agro-Energy Hubs” combining solar drying, cold storage, and mechanized processing managed by women and youth cooperatives under pay-as-you-use or lease-to-own models.

5. Strengthen Policy and Standards Alignment: Develop a unified Agri-Energy Framework integrating mandates of FMAFS, REA, NASENI, SON, and State Ministries of Agriculture; establish and enforce equipment quality standards to eliminate sub-standard imports.

6. Build Local Capacity and Gender Inclusion: Train technicians and farmers on the use and maintenance of clean technologies; reserve at least 40% of program assets for women- and youth-led enterprises.

Clean, inclusive technologies offer Nigeria’s agricultural sector a pathway to higher productivity, reduced waste, and improved resilience against climate and energy shocks. With coordinated policy action, accessible finance, and local participation especially of women and youth Nigeria can transition from a labour-intensive, waste-prone system to one that is productive, climate-smart, and justly powered for the future.

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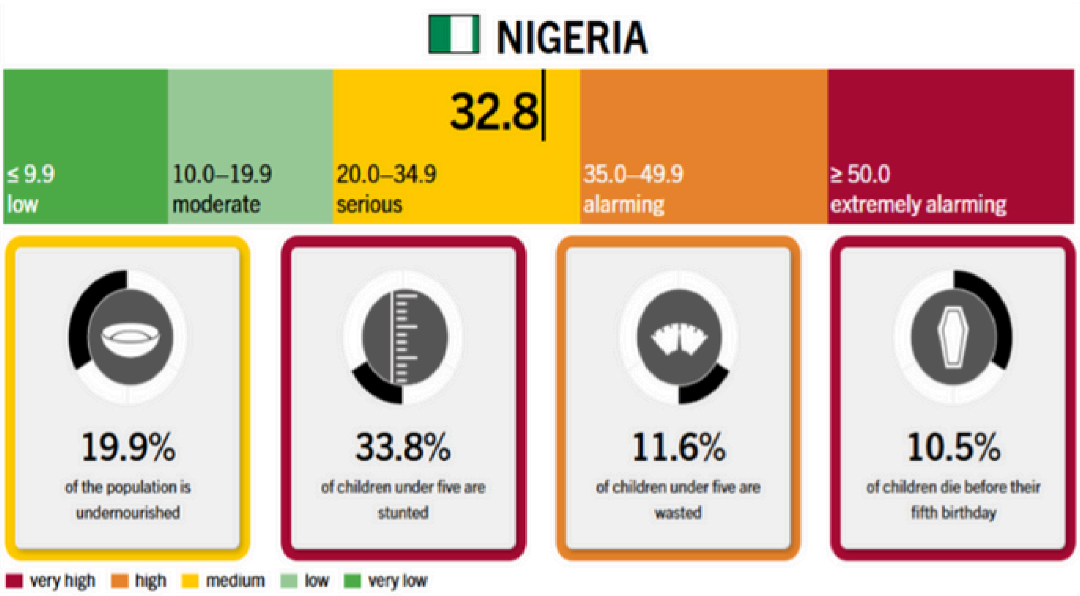
Chapter One: Introduction

1.1 Background and Context:

As at the third quarter of 2024, Agriculture contributed about 25.01% to Nigeria's GDP.[1] Nigeria is ranked 107 out of 113 on the Global Food Security Index (2022)[2]. Indications are that food security will worsen as the nation's population doubles from over 200 million to around 400 million by 2050, and its urbanized population increases to reach approximately 70% by 2050.[3] In addition, the 2025 Global Hunger Index, Nigeria ranks 115th out of 123. With a score of 32.8 in the 2025 Global Hunger Index, Nigeria has a level of hunger that is serious.

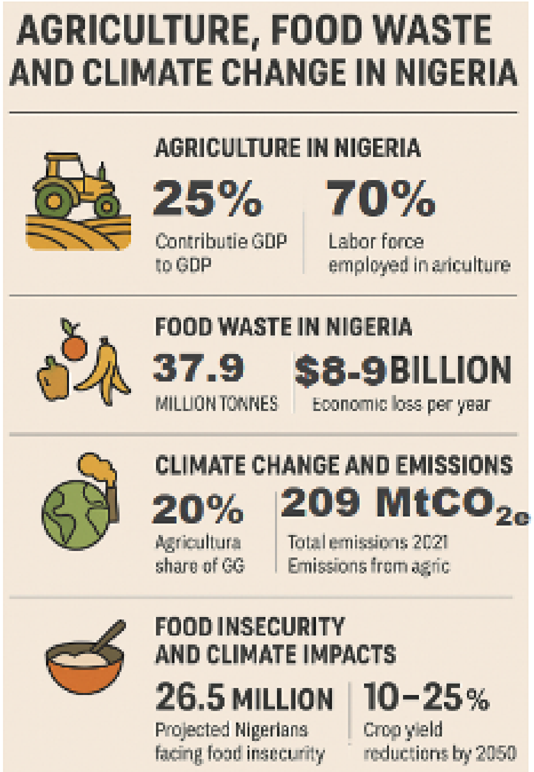


According to a recent joint analysis by the Food and Agriculture Organization (FAO) and the Federal Ministry of Agriculture and Food Security (FMAFS), as many as 34.7 million Nigerians, including over 650 000 internally displaced persons, are expected to experience acute food insecurity (Phase 3 or worse) between June and August 2026.

[1] National Bureau of Statistics (NBS) Q3 Report 2024: National Gross Domestic Product Q3 2024. https://www.nigerianstat.gov.ng/elibrary/read/1241593
[2] Economist Impact - Global Food Security Index (2022): Accessed 10.29.2025 https://impact.economist.com/sustainability/project/food-security-index/resources/Economist_Impact_GFSI_2022_Global_Report_Sep_2022.pdf
[3] The World Bank (2020). Food Smart Country Diagnostic - Nigeria. International Bank for Reconstruction and Development / The World Bank

The report points to multiple drivers including conflict and displacement, rising food and agricultural input costs, transport challenges, and climate shocks as key factors deepening the crisis.

Nigeria's total CO2 emissions are estimated at approximately 122.7 million tonnes (122,750,410 tons) for the year 2022, with trends showing persistent growth in overall greenhouse gas emissions, driven mainly by energy sector activities.



The sectoral contribution is led overwhelmingly by energy (including power, transport, and fossil fuels), followed by agriculture, waste, and industry.[4] The agriculture sector in Nigeria contributed approximately 1.68 million tonnes of CO_2 equivalent in 2023, increasing from 1.46 million tonnes in 2022. This sector accounts for about 18-20% of Nigeria's total greenhouse gas emissions, making it the second largest contributor after energy – contributing to the climate change effects.[5]

Climate change is expected to reduce Nigeria's major crop yields by 10 – 25% by 2050, especially in the North.[6] Between July and December 2022, devastating floods affected over 4.4 million people across Nigeria. The disaster displaced more than 2.4 million individuals and claimed over 660 lives. In addition, about 174,000 homes were rendered uninhabitable, while more than 676,000 hectares of farmland — much of it during the harvest season were destroyed. These losses have further aggravated the country's already critical levels of hunger and malnutrition.[7]

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[4] WorldoMeter (Accessed 30.10.2025): https://www.worldometers.info/co2-emissions/nigeria-co2-emissions/
[5] C.E.I.E (Accessed 30.10.2025): Nigeria Total CO2 Emissions: Tonnes of CO2 Equivalent per Year: Agriculture
[6] UNEP/World Bank Climate Change Nigeria Country Profile
[7] ReliefWeb (14.12.2022): Nigeria - Floods Response: Flash Update 4 (Last Updated: 14 December 2022). https://reliefweb.int/report/nigeria/nigeria-floods-response-flash-update-4-last-updated-14-december-2022

Yet each year, the country loses and wastes 40% of its total food production, equal to 31% of its total land use and producing 5% of the country's GHG emissions. By implication, this is equivalent to $8–$9 billion in economic losses each year.[8] These makes the country rank among the top nations in food waste with a per capita waste of 189 kilograms and an annual total of 37.9 million tons.[9]

These loses are dues to:

1. Production and harvest: Inefficient practices and lack of mechanization.
2. Storage & processing: Inadequate cold chains and rural infrastructure, and
3. Retail and consumption: Spoilage in markets and homes due to power issues and poor planning.

Nigeria's NDC 3.0 targets, submitted in September 2025, commit to an ambitious 32% reduction in greenhouse gas emissions by 2035 compared to 2018 levels, with an interim target of 29% below 2018 by 2030. This economy-wide pledge covers all greenhouse gases in the national inventory and aligns with Nigeria's net-zero goal for 2060. (Climate Promise – UNDP/ Nigeria)

The Country's NDC 3.0 among many targets to –

- reduce deforestation by 60% and plant at least 20 million trees annually.
- grow renewables' share in electricity generation to 50% by 2030; pursue 100% electricity access by 2030.

[8] Global Hunger Index (Accessed 11.08.2025): Nigeria.https://www.globalhungerindex.org/nigeria.html
[9] Adekunle Agbetiloye (26 September 2024:): Top 10 African countries with the highest food waste. Business Insider Africa. https://africa.businessinsider.com/local/markets/top-10-african-countries-with-the-highest-food-waste/98vyylb

Implementation of the Country’s past NDC is slow, especially in agriculture-related mitigation and food system transformation. The scale of waste and environmental damage in Nigeria's agricultural sector demands urgent intervention through sustainable farming practices, renewable energy solutions for production and processing, improved post-harvest infrastructure, better water management, and comprehensive policy reforms to address these systemic inefficiencies.

1.2 Rationale and Objective of the Study

This study seeks to assess and promote the integration of clean, inclusive, and innovative technologies within Nigeria’s agricultural sector in order to reduce post-harvest losses, enhance product value chains, alleviate labour burdens, and strengthen policy and political commitment toward a just agricultural and energy transition.

The specific objectives of the study are;

1. To assess the extent and impacts of environmentally unsustainable (“dirty”) agricultural processes and value-chain operations, and to propose clean, innovative alternatives that enhance efficiency, improve user profitability, and contribute to Nigeria’s climate resilience and energy transition goals.

2. Map and document existing clean and innovative agricultural technologies being deployed in Nigeria including solar dryers, cold storage systems, biogas digesters, mini-grids, irrigation systems, and efficient agro-processing equipment.

3. Showcase successful models and pilot interventions that demonstrate how renewable energy and climate-smart innovations can enhance value addition and inclusive economic growth in the agric-food system.

4. Analyze the socio-economic and environmental impacts of these technologies on smallholder farmers, women, and youth agropreneurs focusing on productivity, waste reduction, income generation, and labour intensity.

5. Identify key policy, institutional, and market barriers hindering the widespread adoption of clean technologies in the agricultural sector, and proffer viable recommendations.

1.3. Methodology

The study adopts a mixed-methods, participatory and evidence-based research approach to capture data across Nigeria's agricultural value chains. The methodology is designed to ensure rigor, inclusivity, and practical policy relevance.

Study Design

- Descriptive–analytical design combining desk research, field surveys, and stakeholder consultations.
- The study will cover key agro-ecological zones (Northwest, North-Central, Southwest, and South-South) to capture geographical diversity and technology adoption patterns.
- Both qualitative and quantitative data will be collected to analyze social, technical, economic, and environmental aspects of technology integration.

Chapter Two: Resource Inefficiencies and Environmental Impacts in Agro-Processing

2.1 Overview of Post-Harvest Losses and Food Waste in Nigeria

Post-harvest losses refer to the measurable decrease in both the quantity and quality of food crops from the time of harvest until they are consumed, occurring at various points in the supply chain, including harvesting, handling, storage, processing, transportation, and marketing. Quantitative losses are a reduction in weight, while qualitative losses involve a decline in acceptability, nutritional value, or edibility of the food.

Post-harvest losses and food waste in Nigeria constitute a significant challenge across the agricultural value chain, negatively impacting food security, farmer livelihoods, and national economic growth. In Nigeria, estimates indicate that between 40% and 60% of perishable foods are lost before reaching consumers, amounting to an annual value loss of approximately ₦3.5 trillion. Post-harvest losses for grains range between 5% and 20%, are about 20% for fish, and climb as high as 50% to 60% for tubers, fruits, and vegetables. These losses can reduce farmers' incomes by at least 15% for millions of smallholder farmers, many of whom already contend with food insecurity and poverty.[10]

The major causes of post-harvest losses in Nigeria are poor transportation infrastructure, inadequate storage facilities, lack of cold storage, insufficient value addition, pest and disease infestations, and inefficient market logistics.

[10] Usman, A, H et al (2023). Chapter Seven - Food loss and waste in Nigeria: Implications for food security and environmental sustainability. Marc J. Cohen (Ed), Advances in Food Security and Sustainability (2025). Elsevier (8)217 -233

Furthermore, limited farmer training in modern post-harvest handling and environmental factors such as excessive heat and humidity raise the level of spoilage, especially for highly perishable crops like tomatoes. Premature harvesting, improper packaging, and poor processing capabilities also exacerbate the issue, resulting in both physical waste and economic losses across the food supply chain. Food waste not only undermines efforts to achieve food security but also increases commodity prices, contributes to higher rates of malnutrition, and boosts greenhouse gas emissions through decomposing food.

The extent of post-harvest losses varies dramatically by crop type:[11]
- Fresh produce experiences losses of nearly 50%,
- Grains suffer losses between 5-20%,
- Tubers, fruits, and vegetables lose 50-60% of total production,
- Fish loses approximately 20% during post-harvest handling,
- Out of 1.5 million tons of tomatoes harvested annually, approximately 700,000 tons are lost due to post-harvest delays and inadequate storage facilities.

This pattern is replicated across other perishable crops, with some estimates suggesting that 25% of peasant farmers' annual income is lost to food wastage.

[11]Businessday Newspaper (September 4, 2024): Annual N3.5trn post-harvest loss swallows five-year agric budget https://businessday.ng/agriculture/article/annual-n3-5trn-post-harvest-loss-swallows-five-year-agric-budget/ see also - The National Horticultural Research Institute (NHRI)'s Horti-Nigeria – "Scoping and Mapping of Postharvest Losses and Tuta Absoluta Related losses and the technologies for combating the losses (May 1, 2023) led study by Aderibigbe O. R and Oke Abiola.

2.2 Water Resource Waste and Mismanagement

Nigeria's water crisis represents a catastrophic waste of a critical agricultural resource. Despite having vast water resources, poor management has led to severe inefficiencies and contamination.

Key water wastage indicators include:

- Average annual rainfall in northern states has decreased by 20% over the past two decades,[12]
- Lake Chad has shrunk by 90% since the 1960s,[13]
- Groundwater levels in key agricultural regions like Kano and Katsina states have dropped by over 15 meters in the past decade,[14]
- 70% of surface water sources in Nigeria are contaminated,[15]
- The World Bank states that poor water sanitation costs Nigeria approximately ₦455 billion each year, equivalent to around $3 billion, which is about 1.3% of national GDP.[16]
- The irrigation infrastructure remains severely underdeveloped, with less than 2% of Nigeria's farmland being irrigated, making the country highly dependent on increasingly unreliable rainfall.

This forces farmers to resort to contaminated water sources, with studies showing that farmers prefer wastewater for irrigation farming because it is cheaper and contains nitrogen, phosphorus, and potassium, despite the health and environmental risks.

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[12] Okafor, G.C., Ogbu, K.N., Agyekum, J. et al (2024):L Rainfall projections under different climate scenarios over the Kaduna River Basin, Nigeria. Discov Environ 2, 89 (2024). https://doi.org/10.1007/s44274-024-00127-0
[13] ibid
[14] ibid
[15] VOA Africa (March 21, 2022): UNICEF Nigeria Warns Millions at Risk of Water Contamination Ailments by Timothy Obiezu https://www.voanews.com/a/unicef-nigeria-warns-millions-at-risk-of-water-contamination-ailments/6494928.html
[16] Vanguard Newspaper (28 January 2025): Poor sanitation costs Nigeria N455bn yearly, says World Bank Group https://www.vanguardngr.com/2025/01/poor-sanitation-costs-nigeria-n455bn-yearly-says-world-bank-group/

2.3 Energy Waste and Fossil Fuel Dependency

Nigeria's agricultural sector demonstrates massive inefficiency in energy utilization, missing opportunities for sustainable energy generation from agricultural waste while maintaining high dependence on fossil fuels.

Energy waste statistics reveal:

Nigeria produces 144 million tonnes of agricultural waste annually,[17] yet most of these biomass potential remains unutilized.

The agricultural sector could generate 6.8 million m^3/day of biogas from animal waste alone.[18]

Crop residues could produce 15.014 billion m^3/year of biogas.[19]

Agricultural waste has the potential to generate over 4,000 MW of electricity.[20]

Despite the enormous potential agricultural waste to energy holds, fossil fuels still comprise 25% of Nigeria's energy mix, and most agricultural waste is simply burned on-site, contributing to greenhouse gas emissions and air pollution while wasting valuable energy resources.

2.4 Wood and Forest Resource Destruction

Nigeria has one of the highest deforestation rates globally, driven primarily by population growth, agriculture, demand for fuelwood, logging, and poor urban planning and development. Nigeria loses roughly 3.7% of its forest cover each year and has lost about 96% of its natural forest cover to agriculture, logging, and development.[21]

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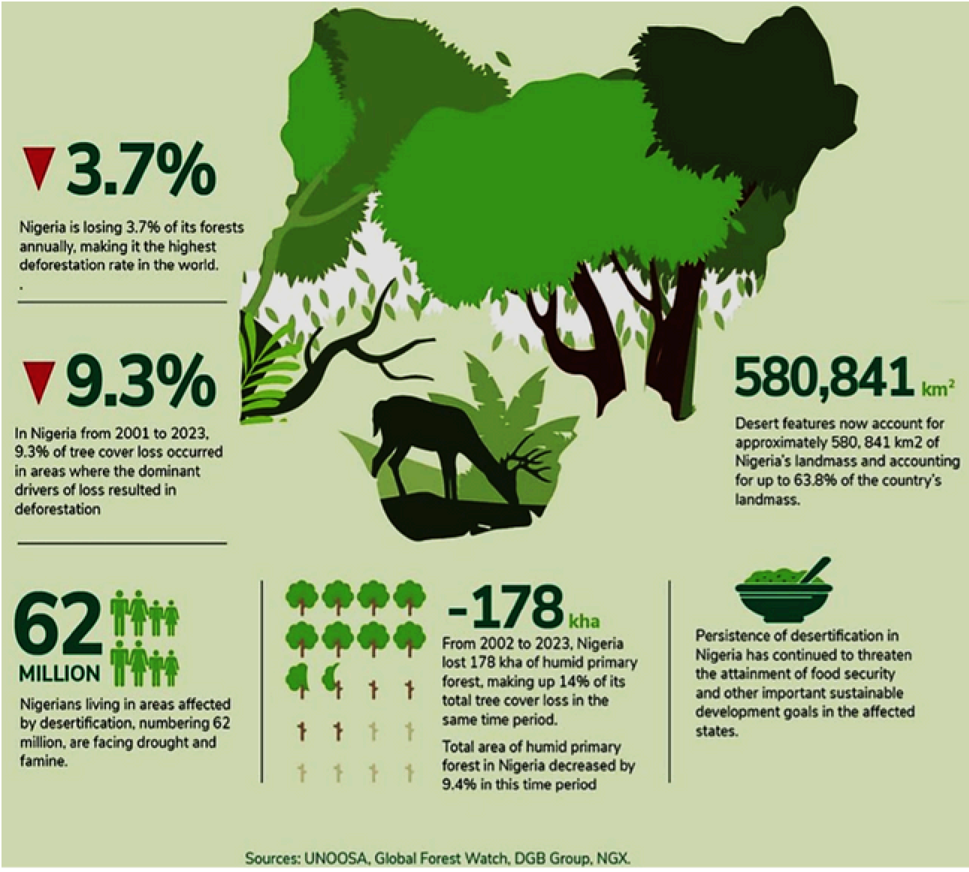
[17] Earth.Org (2023): The Problem with Solid Waste Management in Nigeria's Low-Income Neighbourhoods by Mathias Agbo Jr. Aug 23rd 2023https://earth.org/the-problem-with-solid-waste-management-in-nigerias-low-income-neighbourhoods

[18] Okeke Ugochukwu Godfrey. (2024). Renewable Energy from Agricultural Waste: Biogas Potential for Sustainable Energy Generation in Nigeria's Rural Agricultural Communities. Journal of Engineering Research and Reports, 26(12), 341–367. https://doi.org/10.9734/jerr/2024/v26i121362

[19] ibid

[20] ibid

[21] Nigeria loses an estimated 3.7% of forest each year | DD India https://youtu.be/8xVQhtoQ_-8?si=jZA8H4-K1JuZ3pCv



Deforestation and wood waste represent another critical area of resource wastage in Nigerian agriculture. Nigeria loses 350,000 hectares of land annually to desertification, while agricultural expansion drives significant forest destruction.

Forest and wood waste data shows:

- Nigeria lost 945,000 hectares of tree cover between 2001-2019, equivalent to a 9.4% decrease.
- In 2020, Nigeria had 20 Mha of natural forest, extending over 22% of its land area. In 2024, it lost 250 kha of natural forest, equivalent to 110 Mt of CO_2 emissions.[22]
- Wood processing industries generate 7 million m^3 of forestry wastes annually.
- Major cities like Lagos generate 295,650 tons of wood waste annually, with Abeokuta producing 489,100 tons per year
- Sawmill recovery rates are only 45-55%, meaning 45-55% of processed wood becomes waste

[22] Global Forest Watch – Nigeria (Accessed August 2025): Primary Forest loss in Nigeria. https://www.globalforestwatch.org/dashboards/country/NGA/


The consequences include increased desertification, soil erosion, and flooding, alongside a significant loss of biodiversity, impact on livelihoods, and climate change.

2.5 Labour Inefficiency and Human Resource Waste

Nigeria's agricultural labour force, despite comprising approximately 70% of the national workforce, operates at extremely low efficiency levels due to systemic problems in knowledge transfer and technology adoption.

Labour efficiency issues include:

- Over 80% of farmers are smallholder farmers with limited access to modern techniques[23]
- Agricultural extension service delivery systems are inadequate and ineffective
- Technical efficiency remains low due to suboptimal resource utilization

This labour inefficiency translates to low productivity per capita and limited knowledge transfer, perpetuating cycles of poor agricultural practices and continued resource waste.


[23] Ezekiel, Oiganji. (2018). Mechanization For Smallholder Farming An Indispensable Tool For Economic Diversification. https://www.researchgate.net/publication/326997503_MECHANIZATION_FOR_SMALLHOLDER_FARMING_AN_INDISPENSABLE_TOOL_FOR_ECONOMIC_DIVERSIFICATION

2.6 Soil Degradation through "Dirty" Agricultural Practices

The major causes of soil contamination in Nigeria are linked to several key human activities, including oil spills, industrial waste discharge, mining, and excessive use of agrochemicals such as pesticides and fertilizers. Improper waste disposal, both domestic and industrial, is also a leading contributor to soil pollution, along with flooding and the mismanagement of waste dumpsites.

Table 1: Major Causes and Key Contaminants

Source	Key Contaminants	Affected Regions	Notes
Oil Spills	TPH, PAHs, heavy metals	Niger Delta	Long-term ecosystem
Pesticides & Fertilizers	DDT, Endosulfan,	North & South farming belts	Food chain contamination,
Industrial Effluents	Pb, Cd, Cr, Cu	Kano, Lagos, Aba	From tanneries & factories
Mining Activities	Pb, As, Hg, Zn	Zamfara, Jos, Ebonyi	Unsafe artisanal
Dumpsites & E-waste	Pb, Cd, plastics,	Lagos, Abuja	Open burning & leachate
Mechanic Workshops	TPH, Pb, Zn	Nationwide urban	Engine oil & solvents
Sewage/Waste water	Nitrates, pathogens	Urban areas	Low treatment infrastructure

Agricultural activities degrade the soil through several harmful practices such as excessive tillage, mono-cropping, overuse of chemical fertilizers and pesticides, improper irrigation, deforestation, and overgrazing. Intensified cultivation and deep ploughing break down soil structure, reducing its fertility and increasing susceptibility to erosion and compaction.

Planting the same crop repeatedly depletes specific nutrients, weakening soil health and biodiversity. Frequent, deep tillage disrupts soil aggregation, increases erosion loss, and destroys soil organisms needed for soil fertility. Overuse or misuse of fertilizers and pesticides (especially the Highly Hazardous Pesticides - HHPs) can cause nutrient imbalances, harm beneficial soil organisms, lead to soil acidification, and pollute the environment.

When livestock densities exceed the land's carrying capacity, ground cover is depleted, soil particles compact, and erosion accelerates. Clearing forests for farmland strips soil of its protective vegetative cover, drastically increasing susceptibility to both water and wind erosion.

Inefficient water management, such as excessive watering or poor drainage - causes salinity, waterlogging, and loss of fertile topsoil. Agrochemicals, industrial runoff, and waste introduce toxic pollutants and heavy metals, degrading physical, chemical, and biological soil properties.

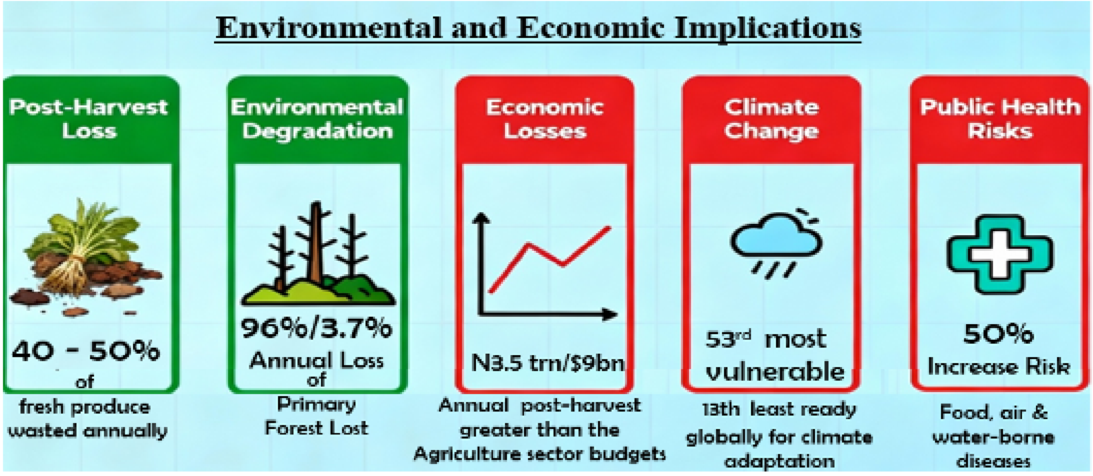
Each of these agricultural activities disrupts soil's natural structure, impairs its fertility, and increases threats such as erosion, compaction, nutrient loss, and pollution. The impacts include:

- Soil organic carbon content declining from 0.9% to 0.42% within four years of continuous cultivation,[24]
- Severe degradation of phosphorus in cassava, maize, sorghum, and yam farmlands
- Annual applications of nitrogen fertilizers seriously reducing exchangeable calcium and magnesium contents of savannah soils

[24] I.A Jaiyeoba (2003): Changes in soil properties due to continuous cultivation in Nigerian semiarid Savannah. Soil and Tillage Research. Volume 70, Issue 1, March 2003, Pages 91-98. https://doi.org/10.1016/S0167-1987(02)00138-1

Table 2: Agricultural Waste and the Volumes – Section Summary

Sector Indicators	Value
% GDP from agriculture	24%
% workforce in agriculture	70%+
Annual food waste	37.9 million tonnes
Economic loss from food waste	$8–9 billion
Agricultural share of GHGs	~30%
Emissions from agriculture	37 $MtCO_2e$
Nigerians facing food insecurity (2025 est.)	26.5 million
Post-harvest loss	30–50%
Waste Type and Losses	**Amount**
Total Agricultural Waste	144 million tonnes
Post-Harvest Losses (Fresh Produce)	50%
Post-Harvest Losses (Grains)	5-20%
Post-Harvest Losses (Tubers/Fruits/Vegetables)	50-60%
Post-Harvest Losses (Fish)	20%
Animal Manure (Daily)	227,500 tonnes
Crop Residues (Annual)	84 million tonnes
Wood Waste (Annual)	5-7 million m^3
Water Resources	70% contamination rate with inadequate irrigation infrastructure
Forest Resources	350,000 hectares lost annually with millions of tonnes of wood waste
Human Resources:	Over 80% of farmers operating with suboptimal efficiency
Energy Resources	Massive untapped potential of 4,000+ MW from agricultural waste

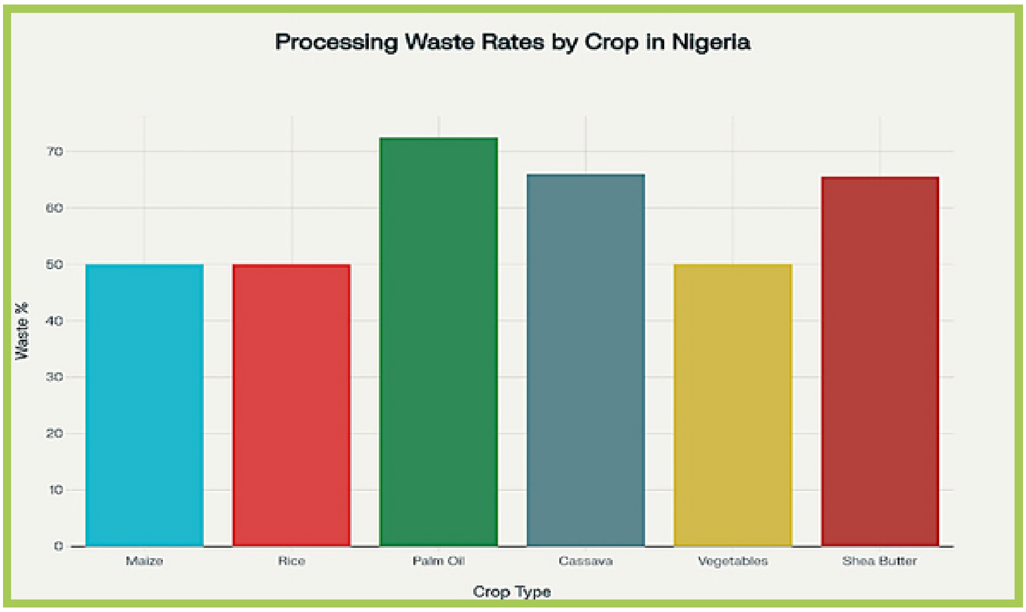

Environmental and Economic Implications
Post-Harvest Loss
40 - 50%
of
fresh produce wasted annually
Environmental Degradation
96%/3.7%
Annual Loss
of
Primary Forest Lost
Economic Losses
N3.5 trn/$9bn
Annual post-harvest greater than the Agriculture sector budgets
Climate Change
53rd most vulnerable
13th least ready globally for climate adaptation
Public Health Risks
50%
Increase Risk
Food, air & water-borne diseases

Chapter Three: Crop-Specific Processing Systems and Waste Streams

3.1 Overview of Crop Specific Losses

The data from the field reveals that all major crops in Nigeria experience processing waste rates up to 40%, with some crops losing over 50% of their potential value through inefficient processing methods.

Overview of Processing Waste Rates



Processing waste rates across major crops in Nigeria showing extremely high waste levels

3.2 Maize Processing: Traditional Methods Creating Multiple Waste Streams

Processing Inefficiencies: Nigerian maize processing suffers from 40-60% overall post-harvest losses through multiple inefficient traditional methods.[25] The process involves several wasteful stages:

[25] ibid

Harvesting and Drying Waste: 15-25% losses occur during sun drying due to weather dependency and contamination. Farmers rely entirely on sun drying (100% usage) with no access to mechanical driers.

Storage Problems: 20-30% losses result from traditional sack storage methods that invite pest attacks and moisture damage. 98.9% of farmers use chemicals for storage treatment, contributing to contamination.

Transportation Waste: 10-15% losses occur during transport using head loads and poor road conditions.

Labour and Resource Waste

The traditional maize processing is extremely labour-intensive:

- Hand threshing (mean score 2.79 out of 3.0)
- Hand winnowing (mean score 2.69 out of 3.0)
- Manual grinding using mortar and pestle (mean score 2.03)

No farmers in the study area had access to metal silos, hermetic bags, or mechanical driers, forcing reliance on inefficient traditional methods that waste 15-20 labour hours per tonne processed.

3.3 Rice Processing: Water Pollution and Energy Waste

Parboiling Problems: Over 90% of Nigerian rice is parboiled using highly polluting traditional methods.[26] Traditional parboiling is the most commonly used process in local areas and by small-scale processors, particularly women, who process the vast majority of rice in Nigeria. The parboiling process generates severe environmental problems:

Air Pollution: The use of "3-stone stoves" and direct combustion of firewood or rice husks as the primary energy sources generates substantial smoke and carbon emissions, exposing operators to intense heat and harmful fumes.

Water Contamination: Traditional methods can involve long soaking periods at ambient temperatures, which can lead to fermentation and the generation of off-flavours and significant wastewater with high organic content.

Waste Generation: Rice milling generates 20% husk, 8-12% bran, with only 68-72% milled rice recovered.[27] The massive waste includes:

- Tonnes of rice husks dumped indiscriminately around mills
- Husks occasionally set ablaze, creating air pollution
- During rainy seasons, husk dumps wash into nearby streams as wastewater

Processing waste accounts for 50% overall post-harvest losses, with daily water waste of 200-300 million liters and fuel wood consumption of 5,000-8,000 tonnes daily.[28]

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[27] Biotech Express (15/03/2024). Unlocking Rice Bran's Healing Potential: Functional Food for Nutritional Security. https://biotechexpressmag.com/unlocking-rice-brans-healing-potential-functional-food-for-nutritional-security
[28] Afolabi, Morakinyo & Bamgboye, A.I.. (2016). Performance characterization and optimization of a synchronized medium-scale oil palm fruit processing mill: MORAKINYO and BAMGBOYE. Journal of Food Process Engineering. 40. 10.1111/jfpe.12523.

Major constraints for local processors include a lack of modern parboiling technologies and poor understanding of the process, which leads to lower quality rice compared to imported alternatives and significant post-harvest losses.

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3.4 Palm Oil Processing: Severe Environmental Devastation

Traditional Extraction Waste: Traditional palm oil processing generates 70-75% solid waste from oil palm processing.[29] The process creates multiple pollution streams:

Water Pollution: Traditional methods generate palm oil mill effluent (POME) containing biochemical oxygen demand (BOD) of 75-290 mg/L, indicating significant pollution.

[29] Gbadebo, O.V.,Ogunwale, O.G., Hammed, I.S. and Ajayi, O.O (2021): Environmental Implications of Oil Palm Wastes Disposal Methods in Ikire, Irewole Local Government Area of Osun State, Southwest Nigeria. Journal of Forestry Research and Management. Vol. 18(4).1-8; 2021, ISSN 0189-8418

POME contamination by metals like magnesium, nitrite, chloride, and sodium compromises shallow well water quality.

Processing Method Problems: The traditional village method involves washing pounded fruit mash in warm water and hand/feet squeezing to separate fibre and nuts. This creates:

- Excessive water usage of 500-800 million liters daily
- Extremely low extraction efficiency
- High contamination levels
- Very labour intensive
- Depend on heavy diesel machines

Environmental Impact: 75% of oil palm processors dispose waste brown water on bare land. Continuous disposal at particular locations causes soil structure changes and contamination. The traditional processing creates:

- Very high ecosystem damage from untreated effluent discharge
- High air pollution from waste burning
- Water scarcity from excessive consumption

3.5 Cassava Processing: The Most Wasteful Crop System

Massive Waste Generation: Cassava processing to cassava flour or Garri is extremely wasteful, with only 34% yield, while generating 66% waste.[30] According to the FAO, Nigeria discards more than 10 metric tons of cassava peels from the 59.5 metric tons of annual cassava production without regard to the environment.[31] The majority (91%) of the cassava peels in Nigeria are abandoned close to the processing site, while some are used for landfilling or burning. The open dumping of cassava peels and/or burning emits CO_2, methane, aflatoxins, and offensive odour.

[30] O.R. Karim, O.S. Fasasi and S.A. Oyeyinka, (2009). Gari Yield and Chemical Composition of Cassava Roots Stored Using Traditional Methods. Pakistan Journal of Nutrition, 8: 1830-1833.
[31] Kigho Moses Oghenejoboh, et al. "Value Added Cassava Waste Management and Environmental Sustainability in Nigeria: A Review." Environmental Challenges, vol. 4, 2021, p. 100127, www.sciencedirect.com/science/article/pii/S2667010021001062, https://doi.org/10.1016/j.envc.2021.100127.

The waste breakdown includes:

- 30% solid waste (peels and sieviates)
- 19.8% gaseous emissions
- 16.2% liquid waste (toxic effluents)

With Nigeria producing an average of 45 million tonnes of cassava annually, approximately 30 million tonnes become waste.[32]

Accumulated dumping of cassava peels causes environmental challenges in Nigeria.

Photo credit: CGIAR – scaling up the use of cassava peel as animal feed in Nigeria. https://www.rtb.cgiar.org/news/scaling-up-the-use-of-cassava-peel-as-animal-feed-in-nigeria/

Water-Intensive and Polluting Process: Cassava processing is the most water-intensive agricultural process:

- Daily water waste: 1,000-1,500 million liters
- Cassava waste waters have extremely high COD exceeding 32,000 mg/L and BOD of 16,000 mg/L[33]
- Cassava peels contains an average of 140.90 ppm free cyanide

[32] ibid
[33] Omilani, O., Abass, A. B., & Okoruwa, V. O. (2019). Smallholder Agroprocessors' Willingness to Pay for Value-Added Solid-Waste Management Solutions. Sustainability, 11(6), 1759. https://doi.org/10.3390/su11061759

Traditional Processing Problems

The traditional 7-8 step process includes multiple wasteful stages:
- Manual peeling (most labour and time consuming)
- Open fermentation creating contamination
- Grinding done with diesel powered machines or mortar and pestle
- Wood fire roasting generating smoke pollution – and lots of firewood
- Poor waste management with toxic effluent discharge

Cassava processing by traditional methods is labour-intensive but the application of improved processing technology has reduced processing time and labour and encouraged further production. Industrial utilization of cassava products is increasing but this accounts for less than 5 percent of the total production.[34]

Cassava residues are sometimes used for animal feeds. Other findings show that the peels, when dried, can be used as biofuel for heating and cooking, as the dried peels are significant potential for biogas production.

3.6 Vegetable Processing: Massive Post-Harvest Losses

Vegetable processing in Nigeria includes both traditional and modern methods, such as smoking, milling, and pickling, though the sector faces challenges like high post-harvest losses due to poor handling and transportation. A significant amount of vegetables are lost between harvest and consumption due to issues like poor transportation and storage conditions, which are often exacerbated by high temperatures and humidity.

[34] CASSAVA DEVELOPMENT IN NIGERIA: A Country Case Study towards a Global Strategy for Cassava Development. Prepared by Department of Agriculture Federal Ministry of Agriculture and Natural Resources Nigeria. https://www.fao.org/4/a0154e/a0154e05.htm#:~:text=Cassava%20is%20usually%20consumed%20in,percent%20of%20the%20total%20production.

Scale of postharvest losses: Postharvest losses of fruits and vegetables in Nigeria are alarmingly high, reaching up to 50%, mainly due to poor handling and transportation. Improper harvesting practices also cause significant mechanical damage, accounting for 5.4% to 32.6% of total losses. Additionally, fruits and vegetables make up nearly 39% of household food waste, underscoring the urgent need for greater consumer awareness and improved handling practices to reduce overall losses.[35]

The problems in summary include:

Poor Harvesting Practices and processing limitations: Manual harvesting leads to physical damage and bruising. Timing is often not optimal, resulting in under-ripe or over-ripe produce. Only about 20% of total vegetable output is processed, largely because of insufficient processing infrastructure.[36]

Storage and Transport Problems: Another critical factor is the lack of effective cold chain management, with about 23% of perishables spoiling because of inadequate cooling facilities, especially in developing regions. Vegetables are often spread on flat surfaces overnight before market, shortening shelf life. Direct sunlight exposure at markets causes temperature fluctuations, moisture loss, and quality degradation.

Traditional Preservation Methods: Traditional preservation methods include salting, smoking, sun drying, dewing, and zeer pots, all of which result in 20-35% processing losses. These methods are:

- Weather-dependent and unreliable
- Prone to contamination
- Labour-intensive with poor quality outcomes

[35] Eliminating Postharvest Losses in Fruits and Vegetables Grown in Nigeria: A Review. (2025). Continental Journal of Applied Sciences, 20(1), 1–38. https://doi.org/10.5281/ZENODO.14802528

[36] Ngowi, E. R., & Selejio, O. (2019). Post-harvest loss and adoption of improved post-harvest storage technologies by smallholder maize farmers in Tanzania. African Journal of Economic Review, 7(1), 249-267.

Overall, post-harvest losses reach 40-60% with daily water waste of 100-200 million liters. Farmers face constraints such as limited access to resources and technical knowledge, hindering the adoption of more advanced or eco-friendly practices.

3.7 Shea Butter Processing: Deforestation and Resource Depletion

Shea butter processing in Nigeria involves traditional methods, such as manual crushing and boiling, and modern, mechanized processes that use machines for crushing, roasting, and oil extraction to achieve higher efficiency and yield. Nigeria is the world's largest producer of Shea nuts.

Traditional Processing Problems: Traditional Shea butter processing is laborious, time-consuming, and results in 65.6% waste. The process generates multiple environmental problems:

Deforestation: Traditional methods require large quantities of fuel wood, contributing to forest degradation.

Water Scarcity: Processing requires large volumes of scarce and expensive water. 46% of processors dispose waste brown water on bare land.

Resource Waste

The traditional processing system wastes enormous resources[37]:

- Labour hours: Approximately 15–20 labour hours are required to produce 1 kg of shea butter traditionally, considering the extensive manual steps involved.
- Wood: An estimated 1.5–2 kg of firewood is used for every 1 kg of butter produced, primarily for boiling and roasting.
- Water: The process generally consumes around 20–25 liters of water per 1 kg of shea butter, factoring in the needs for boiling, washing, and rinsing.
- Processing generates waste brown water and black sludge. Processors complain of constant dehydration and respiratory challenges due to indoor smoke pollution.

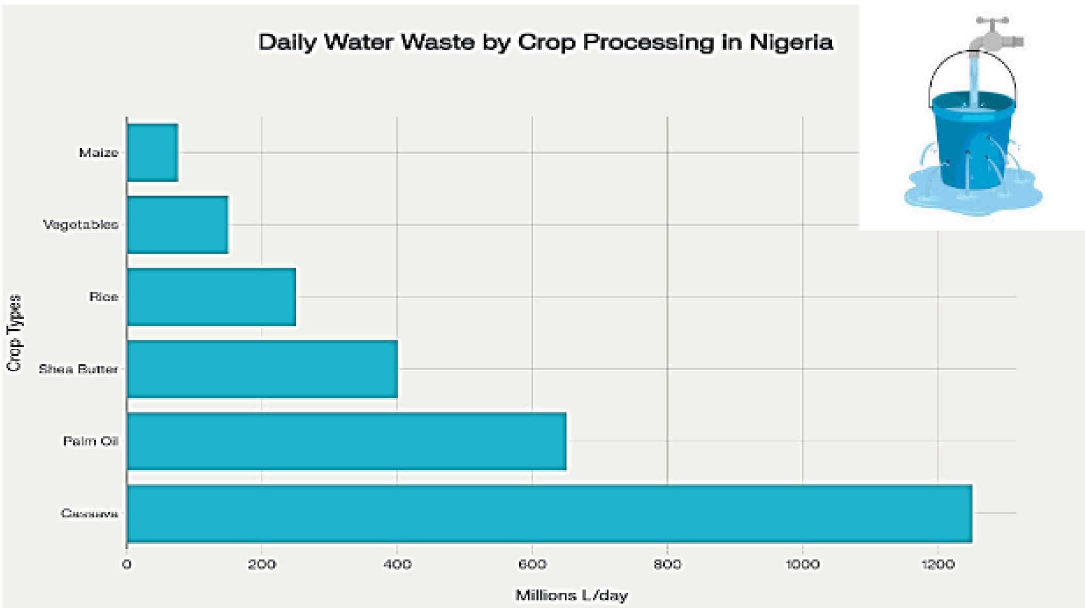
[37] FAO (2022). Reducing post-harvest losses of shea nut (Vitellaria paradoxa) and butter in West and Central Africa: A practical guide for extension workers, processors, and policymakers. Rome: FAO. https://openknowledge.fao.org/server/api/core/bitstreams/d36fd55c-65ac-4025-a64c-c5bbda712945/content

Chapter Four: Quantifying Daily Water and Resource Waste

4.1 Daily Water Waste across Crop Processing

Water waste in agro-processing represents a critical yet often overlooked dimension of resource inefficiency within Nigeria's agricultural sector. As crops move from farms through various stages of processing, vast quantities of water are utilized and frequently squandered during cleaning, milling, extraction, and other value addition activities.

This inefficiency is particularly evident in high-volume staples such as cassava, palm oil, and shea butter, where daily processing can lead to millions of liters of water being discarded. Such patterns of water waste not only undermine sustainability efforts but also increase operational costs and place added strain on local water resources, affecting both rural communities and downstream users.



Daily water waste across crop processing operations in Nigeria

Cassava processing in Nigeria consumes the highest amount of water in the agroprocessing sector, with daily use estimated at up to 1,250 million liters,[38] while palm oil processing uses approximately 650 million liters daily.[39] These figures highlight the substantial water demandassociated with traditional methods and underscore the need for efficient resource management and improved wastewater handling.

- For cassava, the high water consumption is attributed to washing, fermentation, and extraction processes across thousands of facilities nationwide.
- Palm oil's significant water use stems from fruit sterilization, oil extraction, clarification, and the generation of large volumes of wastewater.

These trends reflect persistent resource and environmental challenges facing Nigeria's agroprocessing sector, confirming cassava and palm oil as the leading water-consuming processes.

These massive water consumption occurs in a country where more than 70% of surface water sources are already contaminated.[40] Addressing water waste in agro-processing is essential for maximizing resource use, fostering environmental stewardship, and supporting the resilience of Nigeria's food systems.

4.2 Labour Inefficiency and Human Resource Waste

All crop-processing systems rely heavily on manual labour with extremely low efficiency:

- Shea butter: 150-200 hours per tonne
- Cassava: 80-120 hours per tonne
- Palm oil: 40-60 hours per tonne
- Rice: 25-30 hours per tonne

These inefficient traditional methods trap millions of farmers in poverty while destroying the environment through wasteful resource consumption.

[38] Okoye, F. C., Eze, V. C., & Onukwuli, O. D. (2020). Effects of Cassava Wastewater on Opa Stream in Ile-Ife, Nigeria. Open Journals Nigeria, 2(1), 25-32. https://openjournalsnigeria.org.ng
[39] Okomu Nigeria Plc. (2021). Environmental Impact Assessment (EIA) of the Proposed Palm Oil Mill. Okomu Nigeria Plc. https://okomunigeria.com
[40] VOA (21 March 2022): UNICEF Nigeria Warns Millions at Risk of Water Contamination Ailments by Timothy Obiezu https://www.voanews.com/a/unicef-nigeria-warns-millions-at-risk-of-water-contamination-ailments/6494928.html

Table 3:

Crop/Product	Annual Production (Million Tonnes)	Processing Waste (Million Tonnes)	Water Waste (Million Liters/Day)	Fuel Wood Consumption (Tonnes/ Day)	Labour Hours Wasted (Hours/Tonne)	Economic Loss (Billion Naira)
Maize	11	4.4-6.6	50-100	2,000-3,000	15-20	500-800
Rice	4.8	2.4	200-300	5,000-8,000	25-30	400-600
Palm Oil	1.02	0.7-0.8	500-800	3,000-5,000	40-60	200-300
Cassava (Gari)	45	30	1000-1500	8,000-12,000	80-120	1,500-2,000
Vegetables	1.5	0.6-0.9	100-200	1,000-2,000	20-30	300-500
Shea Butter	0.6	0.4	300-500	10,000-15,000	150-200	100-200

Nigeria's agricultural processing sector operates as a massive waste generation system, losing trillions of naira annually while causing severe environmental degradation. The combination of outdated traditional methods, lack of modern equipment, poor infrastructure, and inadequate training creates a perfect storm of inefficiency that undermines food security, environmental sustainability, and economic development.

Chapter Five: Renewable Energy Solutions for Sustainable Agro-Processing

5.1 Overview of Renewable Energy Applications

To reduce agro-processing waste and encourage the adoption of renewable clean technologies, several global programs have been developed to enhance economic empowerment especially at the community level. These initiatives integrate renewable energy solutions into agro-processing systems and domestic energy access, thereby reducing wastages, increasing production efficiency, improving income, and advancing environmental sustainability.

Table 4 outlines various renewable energy options for productive uses in agro-processing, agriculture, and domestic applications. The table identifies potential technologies suitable for different types of businesses and community enterprises.

Table 4: Renewable Energy for Agro-Processing and Lighting

Energy Need	Type of Productive Use	Type of Business	Renewable Energy Technology
Electrification	Information & communication (e.g. mobile charging stations, internet services)	Shops	Solar PV, micro-hydropower, small wind turbines
	Service provision using electrical appliances (television, sewing, solar refrigerator, battery charging)	Shops	Solar PV, micro-hydropower
Food Processing	Drying (improved product quality compared to open-sun drying)	Cooperatives, farm-gate clusters, markets	Solar dryers, biogas-powered dryers, biomass plants
	Smoking (fish and meat products)	Shops, markets, cooperatives	Improved biomass stoves, efficient ovens
	Cooking & baking (enhanced efficiency and value-added food products)	Food vendors, bakeries, restaurants, home-based businesses	Solar ovens, biogas-powered ovens, biomass ovens, clean cookstoves
Agriculture	Irrigation (increased yields, diversification into high-value crops)	Farmers	Solar, wind, biofuel, or micro-hydro-powered water pumps
	Post-harvest processing (higher quality, reduced labour intensity)	Farmers, millers	Solar dryers, micro-hydro, biomass-efficient stoves, electric shredders, small wind turbines
Livestock & Poultry	Enhanced productivity and waste management	Poultry farms, abattoirs, shops	Biogas plants, egg incubators, milk chillers, fodder cutters
Cooling	Preservation and storage of food and medical products	Farmers, fishers, butchers, markets	Biogas-to-electricity systems, solar cold storage
	Reduced cooling costs and provision of cooled products (e.g. beverages)	Shops, small businesses	Solar PV, efficient cooling systems
Lighting	Extended operating hours and new home-based activities	Shops, homes, markets	Solar PV, solar lamps, small wind turbines
	Improved night-time activities (e.g. fishing, food vending)	Fishermen, Suya vendors	Solar PV, solar lamps
Mobility	Cleaner transportation and improved market access	Cooperatives, vehicle owners, businesses	Electric cargo bikes, CNG and e-vehicle conversions

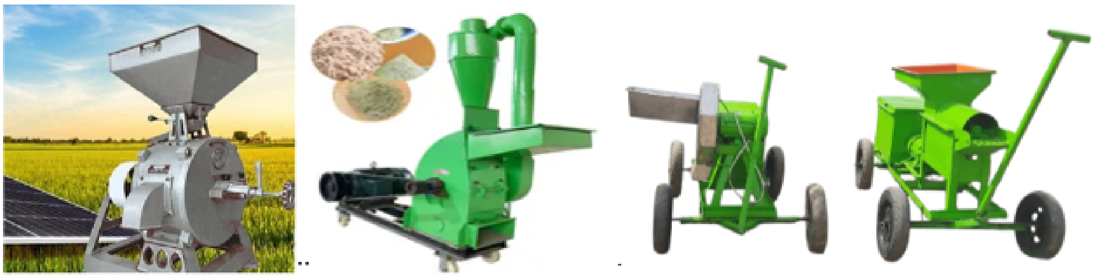
Source: Authors' compilation based on renewable energy technologies available in Nigeria.

5.2 Technology Profiles and Case Examples

1. Solar-Powered Milling Machine

The Technology

The solar-powered milling machine is a clean energy technology designed to process grains such as maize, groundnut, rice, and wheat using electricity generated from solar panels. It provides an alternative to diesel-powered mills and is particularly suitable for regions like northern Nigeria, where solar radiation is abundant and grid electricity is often unreliable.



How It Works

The system operates through a solar panel array that captures sunlight and converts it into electrical energy stored in batteries. This energy powers an electric motor that drives the milling unit. Portable and mini solar-powered milling machines have recently been introduced in Nigeria to support smallholder farmers and women processors. These machines enable local grain milling within farming communities, cutting down transportation time and costs while improving access to milling services.

Case Study Example

A notable pilot initiative implemented by CLASP[41], in partnership with Farm Warehouse, demonstrated the practical benefits of solar-powered mills in rural Nigerian communities.

[41] Efficiency for Access Coalition (January 2020): Solar Milling: Exploring Market Requirements to Close the commercial Viablity Gap. Accessed 30.01.2025. https://efficiencyforaccess.org/wp-content/uploads/2020.01_SolarMilling_MarketRequirements_Report.pdf?utm_source=chatgpt.com

The project introduced solar mills that allowed farmers to process grains immediately after harvest, reducing the delays and costs associated with distant diesel mills. This localized approach not only improved efficiency but also encouraged women's participation in grain processing and small-scale agribusiness.

The solar-powered cassava processing/milling facility represents a groundbreaking application of renewable energy in Nigeria's agro-processing sector. It was pioneered through a collaboration between the United Nations Development Programme (UNDP) and the Energy Commission of Nigeria, resulting in the establishment of Nigeria's first fully solar-powered cassava processing facility in Mbatyou-Mbateva, Buruku Local Government Area of Benue State.[42]

Before the installation, local women relied heavily on firewood and diesel engines, which were costly, labor-intensive, and environmentally damaging. With the introduction of solar technology, these women organized into cooperatives now operate an efficient, clean, and sustainable production line that meets local demand and supports community livelihoods.

The facility is powered by a 15 kVA solar energy system consisting of 60 solar panels rated at 360 W each, along with batteries and inverters that ensure continuous operation. The system supplies electricity to a range of cassava processing equipment including peeling machines, graters, pressers, vibrating sifters, fryers, and cooling bowls. The entire operation from peeling to frying is driven by solar-powered electric engines, allowing the facility to produce up to 10 bags of Garri per day, equivalent to about 1,000 kilograms.

[42] EnviroNews (26 March 2018): UNDP, ECN transform rural Benue with solar-powered agro-processing mills. (Accessed 15.09.2025)https://www.environewsnigeria.com/undp-ecn-transform-rural-benue-with-solar-powered-agro-processing-mills/?utm_source=chatgpt.com

Impact

The adoption of solar milling technology has been shown to reduce postharvest losses previously estimated at around 30%, by enabling timely processing at the community level. It has also increased production capacity and fostered local value addition, particularly among women processors who now operate clean, affordable, and reliable milling systems. Moreover, by replacing diesel with solar power, the machines significantly reduce emissions and operating expenses, contributing to both economic and environmental sustainability. CLASP's broader initiative to promote productive-use appliances such as solar refrigerators, water pumps, and mills illustrates how renewable energy technologies can drive inclusive growth and livelihood transformation in off-grid and weak-grid areas across Nigeria.

The shift to solar energy has eliminated the need for firewood in Garri frying and replaced diesel engines with clean electric motors, leading to lower production costs, minimal maintenance, and improved working conditions. Women processors now produce more than 10 bags of Garri daily with significantly less physical labor and processing time. The facility's success underscores the potential of renewable energy to empower women economically, enhance food processing efficiency, and promote climate-friendly agricultural practices in rural Nigeria.

See more solar powered machines operating in Nigeria in Annex

2. Biogas Digesters

A biogas digester is an airtight system designed to convert organic waste materials such as animal manure, sewage, and food residues into renewable energy through a process known as anaerobic digestion. In this oxygen-free environment, microorganisms break down the organic matter to produce biogas a mixture primarily composed of methane (CH_4) and carbon dioxide (CO_2).

The methane component serves as a clean fuel for cooking, heating, or generating electricity, while the residual material, called digestate, is a nutrient-rich organic fertilizer suitable for agricultural use. This technology offers an environmentally friendly solution for waste management, renewable energy generation, and sustainable farming.




How It Works

Organic waste is collected and fed into a sealed digester tank, where it decomposes under controlled anaerobic conditions. The microorganisms inside the digester break down the waste and release biogas, which is captured and stored in a gas holder. This gas can then be piped to power generators, stoves, or other energy systems within the facility. The remaining digestate is periodically removed, dried, and applied as an organic fertilizer to improve soil fertility. The entire process reduces waste volume, limits greenhouse gas emissions, and provides a consistent source of renewable energy for daily operations.

Case Study Example

At the Ikorodu Mini Abattoir in Lagos State, a fully functional biogas plant demonstrates the practical benefits of this technology.[43] The facility operates with four 5,000-litre digesters that process slaughterhouse waste and concentrated wastewater. The biogas generated is used to power electricity for approximately six hours daily, as well as to pump water within the facility. The system simultaneously produces organic fertilizer as a valuable by-product, ensuring that waste from the abattoir is effectively recycled into useful resources.

[43] Uwaegbulam, Chinedum (09.09.2019). "Lagos abattoir converts cow waste to biogas." The Guardian (Nigeria), 9 September 2019. Accessed 12.10.2025 - https://guardian.ng/property/lagos-abattoir-converts-cow-waste-to-biogas/?utm_source=chatgpt.com

Impact


The adoption of the biogas plant at Ikorodu Mini Abattoir has significantly reduced the facility's waste disposal challenges and eliminated odour problems that previously affected nearby communities. It has lowered dependence on diesel-powered generators, thereby cutting fuel costs and emissions. In addition to promoting environmental cleanliness, the project demonstrates how renewable energy can support both waste-to-value systems and circular economy models within agro-processing. The production of organic fertilizer also opens economic opportunities for women and local entrepreneurs engaged in fertilizer distribution and agricultural services, underscoring the technology's contribution to inclusive and sustainable development.

See Annex for example of companies supplying biogas in Nigeria.

3. Biomass Briquette Machines

The Technology

Biomass briquette machines are renewable energy technologies that convert agricultural residues such as rice husks, sawdust, crop stalks, and grasses into compact solid fuel blocks known as briquettes. These briquettes serve as a cleaner and more sustainable alternative to traditional fuels like firewood and charcoal. The technology promotes local value addition, turning agricultural waste that would otherwise be discarded or burned into useful energy products. In Nigeria, low-cost biomass briquetting machines have been locally designed, fabricated, and tested to suit rural conditions. They align closely with national efforts to promote clean energy solutions for agro-processing, enhance women's economic participation, and strengthen the circular economy by transforming waste into marketable products.

How It Works

The briquetting process begins with the collection and drying of agro-residues such as crop stalks, husks, or sawdust. These materials are then crushed or shredded into fine particles and fed into a manually operated or motorized briquetting machine. Inside the machine, the biomass is compressed under high pressure sometimes with a small amount of binder to form solid briquettes. The compacted briquettes are then dried and ready for use as fuel in households, small enterprises, or processing facilities. The process requires minimal energy input and eliminates the need for destructive firewood harvesting, making it both affordable and environmentally friendly.

Case Study Example

A strong example of the technology's transformative potential can be seen through the experience of the Dapaya Women Multi-Purpose Cooperative in Jugwol, Biu Local Government Area of Borno State. Comprising 30 members, the cooperative originally functioned as a village savings and loans association but lacked a viable business venture. Through the Feed the Future Nigeria Rural Resilience Activity (RRA) a USAID-funded initiative implemented by Mercy Corps the group received training and technical support to venture into briquette production.[44] They were further supported by Biu Women Castor & Jatropha Farmers, who provided them with a briquette-making machine and mentorship in 2022. Using a small group loan of NGN 13,000 (approximately USD 29), the women procured raw materials and began production.

[44] Mercy Corps (March 04.2023): Dapaya women empowering members through charcoal briquette production. Accessed 23.10.2025 - https://nigeria.mercycorps.org/blog/dapaya-women-empowering-members?utm_source=chatgpt.com

Within weeks, they produced over 1.8 metric tons of briquettes valued at NGN 140,000 and earned profits from local sales. The venture has helped them transition from a savings group into a productive enterprise, with ambitions to acquire additional machines and expand their market reach.



A second example is the *Community Briquette-Making for Safer Cooking Initiative* in Gwoza, also in Borno State, where women have been trained to transform farm and kitchen waste into affordable, clean fuel.[45] The initiative has improved safety by reducing the need for risky forest trips to gather firewood, created alternative sources of income, and promoted environmental restoration. One beneficiary, Aisha Adamu, earns around NGN 500,000 (USD 400) monthly from briquette sales and has reinvested profits into a poultry business, generating nearly NGN 1.7 million in less than a year. Another participant, Aisha Yusuf, expanded her business into grain trading after purchasing land with her briquette profits. To date, more than 500 women have been trained under this initiative, many of whom now train others, amplifying the impact across communities.



Photo credit: UNDP Nigeria/Amalachukwu Ibeneme

Impact

The adoption of biomass briquette machines in northern Nigeria demonstrates how simple, locally adaptable technologies can deliver significant environmental, economic, and social benefits.

[45] UNDP (May7, 2025): A new Lifeline: How Briquette-Making is Empowering Women in Gwoza Community. Accessed 23.10.2025 - https://www.undp.org/nigeria/stories/new-lifeline-how-briquette-making-empowering-women-gwoza-community?utm_source=chatgpt.com

They reduce deforestation and carbon emissions by replacing firewood and charcoal with sustainable fuel sources, while also minimizing waste through the reuse of agricultural residues. For women in vulnerable, conflict-affected regions, briquette production provides a safer and more dignified livelihood option that strengthens household resilience and promotes community recovery. It has also diversified local economies, enabling cooperatives and small enterprises to generate income and reinvest profits into other ventures.

The initiatives in Biu and Gwoza highlight the potential of women-led clean energy enterprises to drive post-conflict recovery, environmental protection, and inclusive growth. While challenges such as access to consistent raw materials and market expansion remain, continued support from partners like UNDP and Mercy Corps is helping to build scalable, community-driven energy solutions that enable people not only to survive but to thrive.

See Annex for example of major briquette-making companies in Nigeria.

4. Solar Powered Irrigation Pumps

The Technology

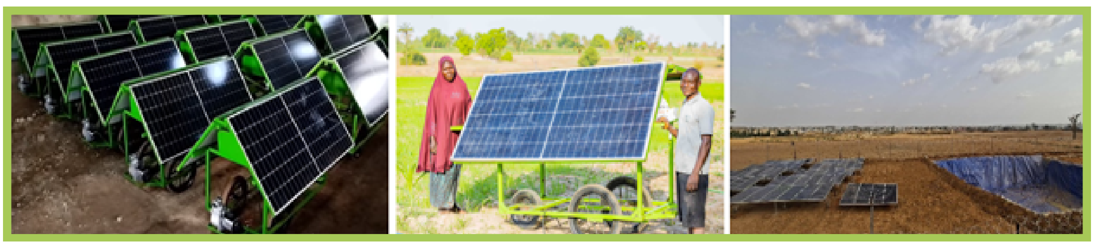
Solar-powered irrigation pumps are renewable energy systems that use electricity generated from photovoltaic (PV) panels to draw water for agricultural use. They provide a sustainable alternative to petrol or diesel pumps, which are expensive to operate and contribute to greenhouse gas emissions. These systems are particularly valuable for smallholder farmers in rural communities where access to grid electricity is limited or unreliable. By replacing fossil-fuel-powered irrigation with solar energy, farmers can irrigate their crops more efficiently, reduce production costs, and maintain productivity during dry seasons. The technology supports climate-smart agriculture by enabling farmers to adapt to erratic rainfall patterns, drought, and rising temperatures—all of which threaten food security across Nigeria.

How It Works

A solar-powered irrigation system typically consists of solar panels, a controller, and a submersible or surface water pump. The panels capture sunlight and convert it into electricity that powers the pump, drawing water from rivers, boreholes, or shallow wells. The water is then distributed to the fields through pipes or drip irrigation systems. The energy harnessed during the day can also be stored in batteries or used directly for continuous irrigation when sunlight is available. Unlike traditional pumps, which require fuel and frequent maintenance, solar-powered pumps operate quietly, have minimal operating costs, and can function off-grid. Their modular design allows for scalability, serving anything from small backyard gardens to medium-sized commercial farms.

Case Study Example

An emerging Nigerian enterprise, Nimsy Agro Solar Concept, has developed and deployed an innovative solar-powered irrigation model designed specifically for smallholder and medium-scale farmers. Its flagship product, the Nimsy Solar Pump 1.2HP, is a portable irrigation solution built on a three-wheel cart for easy mobility and field deployment.[46] The system integrates solar panels, a pump, and mounting accessories, providing a complete off-grid irrigation package that eliminates the need for diesel or petrol. Nimsy Agro Solar Concept works through trusted partnerships with organizations such as Heifer Nigeria and the Alliance for a Green Revolution in Africa (AGRA) to reach farming communities across nine states in Nigeria. Their approach combines technology provision with capacity building, ensuring farmers especially women and youth can operate and maintain the systems effectively. By promoting inclusivity and affordability, the company helps transform small-scale irrigation from a costly and fuel-dependent activity into a clean, efficient, and accessible service.



[46] Nimsy Agro Solar Concept. (n.d.). Powering agriculture with renewable energy. Retrieved from https://nimsyagrosolar.com/

Impact

The introduction of solar-powered irrigation pumps has led to tangible economic, environmental, and social benefits. Farmers using the Nimsy Solar Pump report operational cost savings of up to USD 90 per month from reduced fuel expenditure.[47] The ability to irrigate during the dry season enables all-year farming, increasing crop yields and allowing farmers to harvest multiple times a year rather than depending solely on rainfall. This improves food security and provides farmers with more stable and diversified incomes, while freeing up funds for family needs or reinvestment into their farms. Environmentally, the transition from fuel-based to solar-powered irrigation reduces carbon emissions and local air pollution, contributing to cleaner farming environments. It also enhances resilience to climate variability by making water available during droughts and unpredictable rainfall periods.

5. Solar Cold Rooms

The Technology

Solar cold rooms are off-grid refrigerated storage systems powered entirely by solar energy, designed to preserve perishable foods in areas with limited or unreliable electricity. Each unit typically consists of a well-insulated chamber connected to photovoltaic solar panels, batteries for energy storage, and a refrigeration system that maintains low, stable temperatures. By using clean energy rather than diesel or grid electricity, these cold rooms significantly extend the shelf life of perishable produce from just a few days to as long as three weeks. This makes them particularly valuable in agriculture, fisheries, and food markets, where post-harvest losses are a major challenge. In Nigeria, solar cold room technology has been locally adapted and scaled by innovative enterprises that promote sustainable food systems while empowering smallholder farmers and market traders, especially women.

[47] Ojeleye, O. A., et al. (2025). Creating an enabling environment for solar-powered irrigation: review of technical, economic and systemic barriers [Working paper]. CGIAR. Retrieved from https://cgspace.cgiar.org/bitstreams/c96bae28-1469-4c0c-8379-ceb91524c017/download

How It Works

The system captures solar energy through rooftop photovoltaic panels, converting it into electricity that powers the cold room's refrigeration units. The energy is stored in batteries, ensuring 24-hour cooling even during cloudy weather or at night. Farmers and traders typically bring their produce in clean plastic crates, which are stacked inside the cold room under controlled temperature and humidity conditions. The model often operates on a pay-as-you-store basis, allowing users to rent space at affordable daily rates instead of bearing the cost of ownership or maintenance. This approach lowers the financial barrier for small-scale traders while providing reliable access to cold storage facilities. The clean-energy design also reduces dependence on diesel generators and grid power, contributing to lower emissions and operational costs.

Case Study Example

A leading example is ColdHubs Nigeria, a social enterprise providing modular, walk-in, solar-powered cold storage units for smallholder farmers and food traders.[48] Each ColdHub is a "plug-and-play" off-grid cold room installed in major food production and consumption centers, including markets and farming communities. Farmers and traders store their fresh produce such as vegetables, fruits, and peppers in clean plastic crates stacked inside the cold room. ColdHubs extend the shelf life of perishable produce from about two days to as long as 21 days, reducing post-harvest losses by up to 80%. One such installation, a 3-ton capacity cold room at the Kara section of Bodija Market in Ibadan, Oyo State, holds approximately 150 crates of produce and serves hundreds of traders daily. In 2023, a much larger 100-ton capacity solar cold room was launched at the Dan Magaji Fruit and Vegetable Market in Zaria, Kaduna State, serving farmers across the tomato-production belt of Kano, Katsina, and Kaduna. Smaller units, such as the 3.75-ton facility in Sabongida, Nasarawa State, deployed by Ecotutu, target off-grid fresh-produce value chains in rural communities.

[48] ColdHubs (Accessed 12.10.2025): 2021 in Numbers: ColdHubs Impact Data and foundation for 2022 https://coldhubs.com/2022/02/26/2022-2-26-2021-in-numbers-coldhubs-impact-data-and-foundation-for-2022/?utm_source=chatgpt.com

Another emerging model, Coldbox Store Solutions[49], provides digitally managed, solar-powered commercial cold rooms with integrated supply chain and traceability systems.

Similarly, Koolboks operates across Nigeria with a lease-to-own model for solar-powered freezers and refrigerators, as well as cooling-as-a-service business - featuring thermal storage (ice battery) technology that keeps units cold for several days without sunlight or electricity.[50] This innovation makes refrigeration accessible to small businesses, women traders, and micro-entrepreneurs who face frequent power shortages.

Impact

The deployment of solar cold rooms in Nigeria has had measurable social, economic, and environmental impact. ColdHubs alone has saved more than 13.8 million kilograms of food from spoilage, served over

[49] Habiba Daggash, Ayodeji Ojo, Fola Aminu, Zihe Meng, Scarlett Santana, Suleiman Babamanu, and Andrew Allee (September 2024):, Harvesting Sunshine: How Productive Uses of Minigrid Electricity Make Farmers Richer and Energy Cheaper, RMI, 2024
[50] Emmanuel Nwosu (September 2025): Solar cooling startup Koolboks raises $11 million to expand across Africa. TechCabal. Accessed 12.09.2025 - https://techcabal.com/2025/09/03/koolboks-raises-11-million-for-africa-expansion/

11,000 farmers, retailers, and wholesalers, and helped increase user incomes from an average of USD 60 to USD 120 per month. The initiative has created over 100 new jobs for women and prevented approximately 3.9 million kilograms of CO_2 emissions by eliminating diesel generator use.[51]

See Annex for example of leading companies supplying solar cold storage and cold chain systems in Nigeria.

6. Solar Dryers (Nigeria)

The Technology

Solar dryers are renewable energy systems that use sunlight to remove moisture from agricultural products such as grains, fruits, vegetables, fish, meat, and herbs for preservation and value addition.

By replacing traditional open-sun drying methods, they provide a cleaner, faster, and more reliable drying process that protects products from contamination, pests, and weather-related losses. These dryers are among the most affordable and effective renewable energy technologies for smallholder farmers and processors in tropical regions like Nigeria, where solar radiation is abundant. Their use helps extend the shelf life of perishable produce, reduce post-harvest losses, and create new market opportunities, particularly for women engaged in small-scale agro-processing.

How It Works

Solar dryers work by capturing solar energy and converting it into heat, which is then used to circulate warm air around the agricultural produce in a controlled environment. Most systems feature a transparent or semi-transparent cover often made from acrylic or polyethylene that allows sunlight to enter while trapping heat.

[51] Ibid

The air inside the dryer is heated, and through natural or forced convection, it removes moisture from the products placed on trays or racks. Some designs, such as the hybrid or "bubble" dryers, incorporate small fans powered by solar energy to enhance airflow and ensure uniform drying. Compared to open-sun drying, solar dryers provide better protection against dust, insects, and rainfall, while significantly reducing drying time and improving product quality.

Case Study Example

In Nigeria, several organizations and enterprises have developed and deployed solar drying technologies suited to local needs. The Nigerian Stored Products Research Institute (NSPRI)[52] designed a multipurpose solar dryer made of transparent acrylic and polyethylene materials, with a stacked capacity of about 80 kilograms per batch. This "multi-crop" dryer is effective for processing a range of products including leafy vegetables, beans, plantain, mango chips, pepper, and onions, and has been introduced in various farming communities.

Similarly, the Developmental Association for Renewable Energies (DARE) introduced the Solar Bubble Dryer (SBD) in Kaduna State to dry tomatoes, mangoes, grains, and apples. The SBD is mobile, fully off-grid, and capable of drying up to 500 kilograms of paddy rice in just two to four days, depending on sunlight intensity.[53]

Private sector participation is also growing; for instance, OGV Limited, based in Zaria, operates industrial-scale solar dryers and provides drying services to rural farmers, including those processing vegetables, fruits, and fish.

[52] The Guardian Nigeria. (2018, November 5). NSPRI develops cost-effective multipurpose solar dryer. The Guardian Nigeria. Retrieved from https://guardian.ng/features/nspri-develops-cost-effective-multipurpose-s
[53] Voice of Nigeria (VON). (2021, January 18). NGO introduces first solar-bubble-dryer to Nigerian farmers. Voice of Nigeria (VON). Retrieved from https://von.gov.ng/ngo-introduces-1st-solar-bubble-dryer-to-nigerian-farmers/

Moreover, the Women Environmental Programme (WEP)[54] has championed women-led solar drying enterprises, such as in Adogo village, where 30 women farmers were trained to install and operate solar tent dryers for community-based agro-processing businesses.

Impact

The expansion of solar dryer technology across Nigeria has yielded substantial economic, social, and environmental benefits. By enabling efficient and hygienic preservation of perishables, solar dryers reduce food spoilage, boost product quality, and allow processors particularly women to engage in profitable value-added activities such as producing dried pepper flakes, mango chips, and smoked fish. The controlled drying environment reduces dependence on open-sun drying, which is weather-dependent, labor-intensive, and often results in significant losses. Solar dryers also enhance food safety and market competitiveness by producing higher-quality, uniformly dried products that attract premium prices.
Environmentally, the technology minimizes the need for firewood or fossil fuels in drying, reducing both deforestation and carbon emissions. Beyond their technical function, solar dryers foster local enterprise development through cooperative or pay-per-use business models that support income diversification, resilience to climate variability, and inclusive participation in agro-value chains. However, challenges remain around the initial cost of installation, maintenance, market linkages for dried products, and the need for training and awareness to ensure sustainability and scale-up.

See Annex for example of leading companies supplying solar dryers in Nigeria.

7. Solar Mini-Grid Processing for Electrifying Agricultural Operations

The Technology

A solar mini-grid is a decentralized electricity generation and distribution system that uses solar photovoltaic (PV) panels combined with battery energy storage and sometimes a backup generator to supply reliable power to a defined area such as a village, farm cluster, or market.

[54] Women Environmental Programme (WEP). (n.d.). Building an efficient solar drying technology for women farmers' economic empowerment. Women & Gender Climate Solutions. Retrieved from https://womengenderclimate.org/gjc_solutions/building-an-efficient-solar-drying-technology-for-women-farmers-economic-empowerment/

Unlike the national grid, which is often unavailable or unreliable in rural parts of Nigeria, mini-grids offer localized, independent power systems tailored to community needs. They are increasingly recognized as the least-cost and most sustainable solution for electrifying off-grid and underserved areas.[55] Supported by government and development partners such as the Rural Electrification Agency (REA) and the Rocky Mountain Institute (RMI), solar mini-grids are helping transform rural economies by enabling "productive use" of energy supporting agricultural operations, small-scale industries, and local enterprises that depend on stable electricity to thrive.[56]

How It Works

Solar mini-grids generate electricity from sunlight using solar PV panels installed on rooftops or ground-mounted structures. The energy captured is stored in batteries for use during the night or cloudy periods, ensuring round-the-clock power supply. The system distributes electricity to multiple end-users through a localized mini-distribution network. Customers, including farmers and small businesses, pay for electricity through prepaid meters or digital pay-as-you-go systems. The mini-grids can power irrigation pumps, grain mills, processing machines, cold storage facilities, and small agro-enterprises activities that would otherwise rely on costly and polluting diesel generators. By replacing fossil fuels with clean solar energy, mini-grids enhance productivity, reduce operational costs, and improve rural livelihoods while promoting environmental sustainability.

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[55] Creeeds Energy & Micro Energy International (June, 2023): Market Study to Support the Nigeria Electrification Project. Component 2: Results – Based Finance Programme for Productive Use Appliances and Equipment for Off-Grid Communities. REA-NEP/AfDB/QCBS/07/2021. https://nep.rea.gov.ng/assets/documents/resource-hub/Market-Study-to-Support-the-Nigeria-Electrification-Project.pdf
[56] Ibid

Case Study Example

A leading national initiative demonstrating the potential of mini-grids in agriculture is the Energizing Agriculture Programme (EAP), implemented by the Rural Electrification Agency (REA) in partnership with the Rocky Mountain Institute (RMI).[57] The EAP is the most ambitious energy-agriculture integration effort in Nigeria, bringing together nearly 30 organizations across eight teams to design, test, and scale business models that link mini-grid power with agricultural productive use. Operating at nearly 20 pilot sites across the country, the program tests 11 business models ranging from solar-powered cassava grating, rice and maize milling, and irrigation pumping to electric mobility solutions for rural logistics. By 2030, the EAP aims to reach approximately 10,000 mini-grid sites, reducing greenhouse gas emissions by an estimated 1.4 million tons of CO_2, creating or improving 150,000 jobs, and positively impacting the livelihoods of nearly 4 million Nigerians.[58]

Complementing this public-sector effort, private-sector investments are also advancing solar-powered agricultural mini-grids. In Nasarawa State, Olam Agri, one of Nigeria's leading rice producers, has partnered with Husk Power Systems to establish a 1.3 MWp solar photovoltaic system integrated with an 860 kWh battery energy storage system at its rice milling facility in Rukubi. The project operates under a 10-year power purchase agreement, reducing the company's diesel consumption by 60% while providing a steady, clean power supply for large-scale rice processing.[59] Similarly, in Kano State, UMZA International Farms Limited, a major rice cultivation and processing enterprise, has partnered with Empower New Energy to deploy a hybrid solar PV and battery plant with an annual projected solar energy output of approximately 1,800 MWh and a 2 MWh battery storage system. The hybrid system, comprising both rooftop and ground-mounted installations, demonstrates the growing potential of commercial and industrial mini-grids to power Nigeria's agricultural value chains sustainably.[60]

See more example of Clean Renewable Energy Solutions for Agricultural Processing in Nigeria in Annex 3

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[57] Andrew Allee, James Sherwood, Ayodeji Ojo, Falaq Tidjani (January 6, 2021): Electrifying Nigerian Agriculture with Clean Minigrids to Improve Livelihoods. RMI (Accessed 11.09.2025) - https://rmi.org/electrifying-nigerian-agriculture-with-clean-minigrids-to-improve-livelihoods/
[58] EAP – energizing Agriculture Program (Accessed 13.10.2025) – Results Energizing Agriculture Programme Project Sites. https://energizingagricultureprogramme.org/results/
[59] Business Day Newspaper (April 14, 2025): Olam Agri, Husk Power launch 1.3 MWp solar system in Nasarawa rice farm by David Olujinmi. Accessed 11.09.2025 - https://businessday.ng/companies/article/olam-agri-husk-power-launch-1-3-mwp-solar-system-in-nasarawa-rice-farm/
[60] Empower New Energy (Nov 11, 2024): Kano Rice Processing Mill Secures Solar Energy Agreement. Accessed 11.09.2025. https://www.empowernewenergy.com/post/press-release

The deployment of mini-grid for agricultural value chain stimulation in Nigeria have been slow and constrained with various challenges, some of these challenges include -

Constraints and Challenges of Using Solar Mini-Grids in Agricultural Operations

1. Demand-side gap: Many mini-grid projects struggle because there is insufficient demand for electricity (i.e., users only use lighting) and not enough “productive use” loads (processing, mills, cold rooms). Without those, financial sustainability is hard.

2. Access to capital & financing: Farmers/processors often lack capital to invest in equipment (mills, cooling units) that would consume electricity and justify mini-grid business models. Financing is a major barrier.

3. Equipment and maintenance: Ensuring the solar, battery and load equipment are well maintained is a challenge in rural areas. Technical skills and localisation of maintenance matter.

4. Tariff & affordability issues: Setting tariffs that both cover costs and are affordable for farmers/agri-processors is tricky. Some users may not be able to pay for high-capacity equipment usage.

5. Integration with value chains: Power access alone is not enough; linking electricity supply with actual agro-value chain actors (farmers, cooperatives, processors, and markets) is critical. Without that integration, the value remains unmet.

6. Infrastructure & site selection risk: Finding the right site (with agro producers, market demand, connectivity, and transport) is key. Also, theft/vandalism, grid-connect risk (if grid extension comes) are concerns.

7. Policy / regulation: Need for enabling policies, tariffs, licensing, standards, and support for productive use of energy in agriculture.

5.3 Economic Models and Financing Mechanisms

Renewable energy (RE) economic models and financing mechanisms are increasingly transforming agroprocessing to minimize agricultural waste globally, continentally, and in Nigeria. Worldwide, business models such as pay-as-you-go solar, mini-grid-powered agroprocessing centers, and public-private partnerships have enabled scalable solutions for example, solar irrigation cooperatives in India[61] and community-powered cold storage in Bangladesh have significantly reduced post-harvest losses by improving energy access and lowering emissions.[62]

Across Africa, blended finance structures, concessional loans, and dedicated RE financing windows like the International Fund for Agricultural Development's ASAP (Adaptation for Smallholder Agriculture Programme) have been successfully used to mainstream renewable technologies into rural agroprocessing, with documented cost savings and environmental benefits in countries like Rwanda, Zambia, and Kenya.[63]

In Nigeria, models piloted through programs such as the Energizing Agriculture Programme (EAP) which leverages innovation accelerators, mini-grids, and microfinance for solar-powered milling and cold storage are already demonstrating dramatic reductions in food spoilage and operational costs, providing evidence of the commercial viability and socio-economic benefits of renewably powered agroprocessing at scale.
Various economic models and financing mechanisms underpin the successful deployment of renewable energy (RE) in agroprocessing, each tailored to diverse business contexts and financial realities at global, regional, and national levels. Below are prominent examples:

Economic and Business Models

- Self-Consumption Model: Farms or cooperatives install RE systems (such as solar PV or biomass) for their own agroprocessing needs. Excess power can be sold to the grid or neighboring businesses, creating additional revenue streams and supporting circular economy practices.

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[61] Shah, T., & Das, B. (2021). Solar-Powered Irrigation in India: Insights on Subsidy, Cooperative Models, and Adoption. International Water Management Institute (IWMI) Working Paper, 189. https://www.iwmi.cgiar.org/Publications/working-papers/iwmi.html
[62] Grameen Shakti & Energy for Impact. (2022). Renewable Energy Solutions for Agricultural Value Chains in Bangladesh. Energy for Impact Reports. https://www.energy4impact.org/news/sustainable-cold-storage-bangladesh
[63] Energy4Impact. (2021). Unlocking Climate Finance for Productive Use of Renewable Energy in Africa: Lessons from Kenya, Rwanda, and Zambia. Energy4Impact Report. https://www.energy4impact.org/news/climate-finance-productivity-africa

- Pay-As-You-Go (PAYG)/Leasing Model: Agroprocessing enterprises acquire RE systems via lease or pay-per-use schemes, allowing them to avoid high upfront costs and match payments to seasonal cash flows. Third-party providers handle installation, ownership, and maintenance, reducing operational and financial risks for the farmer or processor. For instance, Koolboks delivers solar cold storage across Nigeria, letting agro-smes and wholesalers subscribe for as little as $10/month, with no upfront cost. The PAYG model matches income cycles and is also deployed by Eja-Ice via leasing and flexible payments, ensuring wide rural and urban reach.

- Mini-Grid and Microgrid Models: Decentralized, community- or privately-run clean energy microgrids (often hybrid solar-biomass-wind) supply power directly to clusters of agroprocessing facilities, reducing post-harvest losses and operating costs while boosting rural development and job creation. The Energizing Agriculture Programme (REA-RMI) and Olam Agri–Husk Power Partnership are good examples of these.

- Feed-in Tariff (FiT) & Power Purchase Agreements (PPA): Producers sign long-term contracts to sell electricity from renewable installations to the grid at guaranteed rates or directly to commercial buyers. This ensures the predictability of revenues and encourages investment. The Olam Agri and Empower New Energy's 10-year agreement to supply UMZA Rice Mill in Kano with renewable electricity exemplifies a project-level PPA, delivering stable, long-term renewable supply and cost savings is a perfect example.

- Energy-as-a-Service (EaaS): Energy solution providers retain system ownership and farmers/processors pay a recurring fee for access to power and integrated maintenance, lowering technical and financial barriers for users. ColdHubs also provides cold storage as a fee-for-service. Customers pay only for what they use, and the company handles all system ownership and operations, lowering entry barriers for small vendors.

- Shared Community-owned Model: In a shared community model, members of the community form a group or association and purchase an equipment or appliance for shared use.

The mini-grid developer works with the community, providing technical support such as recommendations on equipment compatibility based on energy needs. For instance, the community can own the cold storage system in this model but requires funding through grants, loans, and community contributions/savings to make the initial purchase.

Financing Mechanisms

- Blended Finance: Combines grants, concessional loans, and private capital to de-risk projects and anchor commercial investment. Frequently used by multilateral banks and partnerships to bring rural or high-impact projects to scale.[64]

- Green Loans & Credit Lines: Local banks or microfinance institutions receive dedicated low-interest financing from development finance institutions, which is on-lent to agroprocessors for RE investments under favorable terms.[65]

- Results-Based Financing/Performance Grants: Companies receive payments based on the delivery or verified impact of renewable energy solutions (e.g., reduced emissions, lower food losses), incentivizing entrepreneurship and innovation.[66]

- Equipment Leasing & Asset-Backed Lending: Agroprocessing businesses or cooperatives access RE technology through structured leases or use equipment as collateral, reducing capital constraint risks.[67]

- Green Bonds & Securitization: Governments, major agribusinesses, financial institutions, and development banks can take action by designing and issuing green bonds to pool renewable energy-agroprocessing projects. These bonds enable large-scale capital mobilization from institutional investors and support climate-linked investments in sustainable agriculture, water, and energy systems.

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[64] Anderson N, Xixi C. & Benson I (2024): Unlocking local private capital to finance the productive use of renewable energy (PURE) sector. WOR LD R E SOU R C E S INSTIT U T E WORKING PAPER | Version 1.0 | September 2024 | 1
[65] Ibid
[66] Sustainable Energy for All (SEforALL)(11.11.2024): Universal Energy Facility Launches Financing Mechanism to Expand Energy Access in Zambia.Accessed 20.10.2025. https://www.seforall.org/news/universal-energy-facility-launches-financing-mechanism-to-expand-energy-access-in-zambia
[67] Agrivoltaics (2022): Economic Viability & Business Models. Accessed 20.10.2025 - https://agri-pv.org/en/market-ramp-up/economic-viability-and-business-models/

For example, Nigeria have issued two sovereign green bonds in 2017 and 2019 to finance renewable projects – and preparing to float a third green bond in 2025/2026,[68] while the African Development Bank and private-sector actors continue to innovate with green finance to mainstream renewable energy in agroprocessing, forestry, and infrastructure.[69]

These models/approach enables tailored energy access while supporting resilient and efficient agroient agroprocessing.

[68] DMO (June 2025): Debt management Office - Green Bond III Investor Presentation. https://dmo.gov.ng/fgn-bonds/green-bond/5338-fgn-series-iii-green-bond-investor-presentation/file#:~:text=Climate%20Change%20Financing,up%20mitigation%20and%20adaptation%20efforts.
[69] AFDB (13-Aug-2025): African Development Bank Group Commits $40 Million to Catalyze the Alliance for Green Infrastructure- Project Development Fund. Accessed 25.10.2025 - https://www.afdb.org/en/news-and-events/press-releases/african-development-bank-group-commits-40-million-catalyze-alliance-green-infrastructure-project-development-fund-86032

Chapter Six: Policy Recommendations and Strategic Actions

Nigeria's agricultural sector holds vast potential for transformation through the deployment of clean and renewable energy solutions capable of addressing the deep-seated issues of waste, inefficiency, and environmental degradation identified earlier. Several successful pilot projects across the country have already demonstrated the viability and positive impact of these technologies on productivity, value addition, and rural livelihoods. However, the affordability and accessibility of clean energy solutions remain major constraints for most smallholder farmers —particularly women—who form the backbone of Nigeria's agricultural workforce. Achieving large-scale transformation therefore requires coordinated action across financing innovation, policy reform, capacity development, and gender-inclusive programming to ensure equitable access to these technologies.

Despite their promise, Nigeria continues to grapple with policy, institutional, and market barriers that limit the widespread adoption of clean technologies in agriculture. Overcoming these challenges demands collaboration among public, private, and civil society actors, guided by robust, evidence-based investment strategies and coherent policy direction. A sustainable path forward must rest on an integrated policy and investment framework that promotes regulatory clarity through harmonized institutional mandates and enforceable quality standards; drives financial innovation via concessional credit and result-based incentives; strengthens institutional capacity by mainstreaming clean energy promotion within agricultural extension systems; and advances social inclusion by ensuring that women and youth are central to technology adoption, enterprise development, and decision-making across the agricultural value chain..

6.1 Key policy, institutional, and market barriers (Nigeria)

a. Policy and Regulatory Barriers

- **Fragmented Institutional Mandates:** The overlapping responsibilities among key government agencies including the Federal Ministry of Agriculture and Food Security (FMAFS), the Rural Electrification Agency (REA), the Energy Commission of Nigeria (ECN), the National Agency for Science and Engineering Infrastructure (NASENI), and the Standards Organisation of Nigeria (SON) — create coordination gaps and bureaucratic delays. This fragmentation slows project approvals and weakens clarity on ownership and accountability for "productive use" energy initiatives in agriculture.

- **Tariff and Fiscal Disincentives:** Import duties and value-added tax (VAT) on renewable energy components increase the cost of deploying clean technologies. Furthermore, the absence of consistent fiscal incentives or subsidies for renewable energy applications in agriculture discourages private-sector investment and limits affordability for smallholder farmers.

- **Weak Standards and Quality Assurance:** Nigeria lacks robust and enforceable standards for solar dryers, irrigation pumps, cold rooms, and other renewable-powered agro-equipment. This results in the importation of substandard technologies, leading to frequent system failures, low consumer confidence, and poor long-term performance across installations.

- **Diesel-Dependent Public Procurement:** Government procurement frameworks remain biased toward fossil fuel-based systems, such as diesel generators, due to outdated cost evaluation methods that ignore lifecycle savings of clean technologies. The absence of a clear "green procurement" policy reduces market visibility for renewable alternatives in the agricultural sector.

b. Institutional and Capacity Barriers

- **Weak Extension and Technical Support Systems:** Agricultural Development Programmes (ADPs) and extension services remain underfunded and ill equipped to promote or manage renewable energy technologies.

The limited presence of trained technicians outside major cities hinders the maintenance and repair of clean energy systems in rural farming communities.

- **Poor After-Sales and Maintenance Ecosystem:** Many renewable energy vendors focus on installation without establishing strong after-sales or operations and maintenance (O&M) services. The scarcity of spare parts, local workshops, and trained service personnel results in frequent equipment downtime and user frustration.

- **Insufficient Data and Market Intelligence:** Reliable data on post-harvest losses, agricultural energy demand profiles, and farmers' willingness-to-pay for clean technologies remain limited. This information gap deters financial institutions and investors from designing viable business models and de-risks financing mechanisms for the sector.

- **Limited Coordination and Partnerships:** There is a lack of structured platforms that link renewable energy developers, cooperatives, and agricultural value-chain actors. This disconnect hampers joint investments, knowledge sharing, and the creation of aggregated demand hubs that could improve economies of scale and sustainability.

- **Preference for Familiar (Conventional) Practices:** Many rural farming communities have relied on manual labour, diesel-powered machines, or traditional drying and irrigation methods for generations. This long-standing familiarity often leads to skepticism toward new technologies, especially solar or biogas systems, which are perceived as experimental or foreign.

- **Gender Norms and Social Roles:** In many communities, men control land and productive assets, while women, who perform much of the post-harvest and processing, work, have limited decision-making power or financial access to adopt RE equipment (e.g., solar dryers, pumps). These gendered norms reinforce unequal access to clean technologies.

c. Market and Financial Barriers

- **High Capital Costs and Inadequate Financing:** Clean agricultural technologies, particularly solar-powered systems, require significant upfront investment. The limited availability of long-tenor, naira-denominated credit, coupled with exposure to foreign exchange volatility on imported components, makes such systems unaffordable for most farmers and SMEs.

- **Fragmented Demand and Weak Aggregation:** smallholder farmers operating in dispersed rural settings, resulting in fragmented and small-scale energy demand, dominate Nigeria's agricultural sector. The absence of cooperative aggregation mechanisms and the seasonal nature of agricultural income flows further constrain developers' ability to design profitable business cases.

- **Low Consumer Confidence and Perceived Risk:** Experiences with substandard or failed solar systems, coupled with limited consumer education, have created skepticism among end-users. This perception of high risk reduces adoption rates and complicates financing, as lenders perceive the technologies as unreliable.

- **Gender-Specific Barriers to Access:** Women farmers and agro-processors often face additional constraints such as lack of collateral, time poverty, and mobility restrictions, which limit their ability to acquire or manage clean energy assets. Safety concerns and social norms further reduce their participation in technical training and enterprise development related to clean technologies.

6.2 Roles of Public and Private Actors in Scaling Clean Energy for Agriculture

Scaling clean energy in Nigeria's agricultural sector requires joint ownership across actors. Government sets direction and incentives; regulators ensure standards and quality; financial institutions unlock capital; the private sector innovates and delivers; CSOs and cooperatives mobilize and educate communities; while development partners fill data, finance, and capacity gaps. When these actors work in synergy, clean energy transitions in agriculture become technically viable, financially sustainable, and socially inclusive.

Federal and State Governments (FMAFS, REA, NASENI, State Ministries of Agriculture)

The public sector plays a strategic coordination, investing, and enabling role in driving clean energy adoption across agricultural value chains.

- **Policy Integration and Target Setting:** The government can develop a unified Agri-Energy for Productive Use Policy that aligns renewable energy expansion with agricultural modernization. This should include measurable targets such as installed megawatts (MW) of off-grid energy and the number of solar dryers, cold rooms, and irrigation systems deployed by 2030.

- **Fiscal Incentives and Subsidies:** Introduce tax waivers, duty exemptions, and result-based subsidies for verified installations of renewable-powered agricultural equipment. Such fiscal tools lower costs for investors and make clean technologies more affordable for farmers, village groups and cooperatives.

- **Capacity Development and Technical Education:** Integrate clean technology modules into Agricultural Development Programme (ADP) curricula and agricultural extension services. Establish technician academies in partnership with state polytechnics and vocational institutes to build a pipeline of local expertise for installation, maintenance, and repair.

- **Public Procurement Reform:** Enact policies mandating lifecycle cost evaluation in government procurement. All new diesel-powered agricultural and rural energy assets should include a "diesel-to-clean replacement" clause, ensuring the gradual phase-out of fossil-dependent systems in MDAs and state projects.

Regulators and Standards Bodies (NERC, SON, NASENI)

Regulatory institutions ensure quality assurance, market confidence, and operational safety.

- **Streamlined Licensing and Approvals:** The Nigerian Electricity Regulatory Commission (NERC) should fast-track mini-grid and isolated network approvals for agro-processing clusters, reducing bureaucratic delays that currently discourage investors.

- **Product Standards and Certification:** The Standards Organisation of Nigeria (SON) should publish and enforce standards for solar dryers, irrigation pumps, cold storage systems, and mini-grid components. Introducing an approved vendor registry and product certification label will prevent substandard imports and increase consumer trust.

- **Innovation Support:** NASENI can promote local R&D and assembly of clean agricultural technologies, reducing reliance on imports and creating local jobs.

Financial Institutions (CBN-linked DFIs, Bank of Industry, Commercial Banks, MFIs)

Financial institutions are critical for mobilizing capital and reducing risk in the clean energy–for–agriculture ecosystem.

- **Concessional Lending Facilities:** Establish naira-denominated credit lines with 5–10-year tenors for renewable-powered agricultural equipment. These facilities should target SMEs, cooperatives, and women-led enterprises.

- **Risk Mitigation Instruments:** Create first-loss and guarantee windows, alongside foreign exchange (FX) hedging, to attract commercial lenders and offset currency risks tied to imported components.

- **Innovative Financing Models:** Promote asset-backed lending, leasing, and Pay-As-You-Go (PAYGo) receivables financing, enabling farmers and vendors to spread payments over time and increase adoption among low-income users.

Private Sector (OEMs, EPCs, Mini-Grid Developers, Agro Off-Takers)

The private sector drives innovation, delivery, and service efficiency.

- **Flexible Business Models:** Companies should develop service-based models—such as *pay-as-you-store*, *pay-as-you-dry*, or *lease-to-own* that lower entry barriers for farmers and small processors.

- **Bundled Solutions:** Firms should offer integrated packages that combine equipment supply, operations and maintenance (O&M), capacity building, and access to markets. Publishing performance warranties, service-level agreements (SLAs), and uptime guarantees will build client confidence and protect investments.

- **Market Aggregation:** Developers can collaborate with cooperatives, market associations, and anchor off-takers (e.g., supermarkets, processors) to aggregate demand, ensuring stable revenue streams and scalability.

Civil Society Organizations (CSOs), Villages, Cooperatives, and Producer Associations

CSOs, villages and cooperatives are vital intermediaries for community mobilization, capacity building, and accountability.

- **Demand Aggregation and Asset Management:** Cooperatives can pool resources to jointly acquire clean technologies, manage shared facilities, and oversee fair access to services.

- **User Education and Inclusion:** CSOs should conduct awareness campaigns, training sessions, and demonstrations on the safe and productive use of renewable technologies. They can also champion gender equity, ensuring that women and youth have equal access to assets and training opportunities.

- **Monitoring and Social Safeguards:** Local organizations can act as verification partners under Results-Based Financing (RBF) schemes tracking installations, verifying usage, and ensuring that environmental and social safeguards are respected.

Development Partners and Donor Agencies

International partners play a catalytic role in de-risking investment, promoting innovation, and building evidence.

- **Results-Based and Blended Financing:** Donors can fund RBF programs and viability gap support that pay developers or cooperatives based on verified results such as kilowatt-hours supplied, produce dried, or post-harvest losses reduced.

- **Technical Assistance and Data Systems:** Support the creation of Monitoring, Reporting, and Verification (MRV) frameworks, impact evaluation studies, and open-access databases on clean agricultural technologies to guide policy and investment decisions.

- **Knowledge Exchange and Open Toolkits:** Facilitate regional learning platforms, policy dialogues, and toolkits that enable Nigerian stakeholders to learn from successful clean energy–for–agriculture models across Africa and beyond.

6.3 Targeted Recommendations and Assigned Responsibilities

1. Establish a Stable and Inclusive Clean Technology Policy

Lead Actors: Federal and State Ministries of Agriculture and Food Security (FMARD), National Assembly -

The Nigerian government should enact a comprehensive Clean AgTech Policy/Act that guarantees predictable subsidies, provides long-term investment incentives, and mandates active state participation in implementation. The Act should also institutionalize state-level Clean AgTech Task Groups to ensure coordination and policy continuity across regions. Such a framework will promote predictability and inclusiveness, thereby encouraging stronger private sector participation and farmer investment in clean technologies.

2. Upgrade Agricultural Extension and Research Systems

Lead Actors: State Ministries of Agriculture, National Agricultural Research Institutes

Strengthening agricultural extension systems is essential to drive field-level adoption of clean energy technologies. Extension agents should receive specialized training on solar irrigation, cold-chain management, and e-farming solutions, supported by gender- and youth-focused outreach programs. Governments and research institutes should jointly fund demonstration plots with farmer cooperatives to promote practical learning. This will enhance institutional capacity and foster widespread adoption, especially among women and young farmers.

3. Structure Dedicated Clean Technology Financing Mechanisms

Lead Actors: Central Bank of Nigeria (CBN), Nigerian Agricultural Insurance Corporation (NAIC), Commercial Banks, Development Finance Institutions (DFIs)

To reduce financial barriers, Nigeria should establish risk-sharing facilities to support loans for smallholders and cooperatives. Blended finance models combining public, private, and donor funds should be piloted for large-scale clean energy projects. Financial institutions should also promote digital micro-lending platforms to improve reach and transparency. These measures will lower borrowing costs and expand farmers' access to renewable energy equipment and services.

Establish a Clean Agriculture Finance Integration Framework (CAFIF): Instead of creating a new fund, align and re-purpose existing agricultural, climate, and renewable-energy financing mechanisms such as the CBN's Anchor Borrowers' Programme, BOI's Solar Energy Fund, REA's Performance-Based Grant, and the NCCC's Climate Fund to finance clean agricultural technologies.

CAFIF will coordinate these institutions under one umbrella, set clear renewable-agriculture investment quotas (e.g., 10–15% of annual disbursements), and create a joint eligibility and monitoring framework for solar dryers, cold rooms, irrigation systems, and biogas units.

4. Mandate Rural Infrastructure Investments

Lead Actors: Federal Ministry of Works, Rural Electrification Agency (REA), Private Logistics Providers

Clean technology adoption depends heavily on supporting infrastructure. Government and private sector partners should prioritize investments in rural feeder roads, solar mini-grids, and agro-processing hubs within national and state development plans. Incentives such as tax credits and concessional loans should be provided to private cold-chain operators to strengthen logistics. This approach will reduce transport and energy costs while making clean technologies more commercially viable in rural markets.

5. Foster Private Sector and Tech Start-Up Incentives

Lead Actors: Nigerian Investment Promotion Commission (NIPC), Small and Medium Enterprises Development Agency of Nigeria (SMEDAN), Renewable Energy Investors, Tech Hubs, Venture Funds

To stimulate innovation and local manufacturing, government agencies should offer tax reliefs, seed grants, and franchise support schemes to clean-tech start-ups and investors. Partnerships with venture capital firms and technology hubs can accelerate the deployment of scalable agri-tech solutions. These actions will foster innovation, entrepreneurship, and localized adaptation of renewable energy systems suitable for Nigeria's diverse agro-ecological zones.

6. Boost Cooperatives, Village and Farmer-Led Business Models

Lead Actors: State Departments of Cooperatives, Civil Society Organizations (CSOs), Farmer Unions, Village groups and cooperatives

Strengthening farmer cooperatives is key to market aggregation and inclusive financing. States should reform cooperative policies to support scale-up, offer group loan guarantees, and train cooperative managers in business and governance. CSOs can complement this by delivering participatory training and advocacy. Empowered cooperatives will enable collective purchasing, shared infrastructure management, and peer learning across farming communities.

7. Mandate Gender and Social Inclusion Metrics

Lead Actors: All Line Ministries, National Planning Commission, Donors, Lead CSOs

Gender and youth inclusion must be embedded in all clean energy for agriculture initiatives. Government and partners should track participation rates by gender and age, require inclusive targeting in public programs, and enforce a minimum of 30% representation of women and youth on federal and state agricultural boards. These measures will promote equity, enhance diversity in leadership, and accelerate technology diffusion through inclusive participation.

8. Expand Digital Information and Data Systems

Lead Actors: Nigerian Meteorological Agency (NiMet), Agricultural Research Institutes, Private Data and ICT Firms

Investment in digital platforms is crucial to improve information access for farmers. Agencies and private partners should develop mobile-based climate advisories and platforms linking farmers to input suppliers, buyers, and service providers. Open-access databases on weather, soil, and technology performance should also be established to support evidence-based decisions. This will enhance knowledge diffusion, resilience planning, and real-time access to market and technical information.

6.4 Program-Level Recommendations

These recommendations translate the study's findings into actionable program strategies that government agencies, development partners, and civil society coalitions can implement in the short-to-medium term (1–5 years). They are structured around five strategic pillars.

1. National Agri-Energy Acceleration Program (NAEAP)

Goal: Scale clean energy adoption in agriculture through coordinated multi-stakeholder programming.

Key Actions:

- Launch a time-bound national program targeting deployment of 5,000 solar irrigation systems, 1,500 certified dryers, and 300 solar cold storage hubs across Nigeria's agro-ecological zones by 2030.
- Integrate the initiative under FMARD and REA's joint leadership, with NASENI and SON providing technology standardization and quality assurance.
- Create state-level coordination desks to link local farmers, co-ops, and technology providers.
- Embed clean-tech demonstration clusters into Agricultural Development Programmes (ADPs) and anchor them to mini-grid communities.

2. Productive Use of Energy (PUE) for Agriculture Grants

Goal: Stimulate demand for renewable energy in productive agricultural uses.

Key Actions:

- Establish a Results-Based Financing (RBF) mechanism to subsidize verified productive-use equipment (e.g., dryers, pumps, cold rooms).
- Offer performance-based incentives to technology providers per verified outcome (e.g., ₦/kg dried or ₦/m^3 water pumped).
- Prioritize women- and youth-led enterprises through additional grant weighting.
- Implement through REA, CBN, and BOI under an "Energizing Agriculture Programme" window.

3. Green Agribusiness Facility (GAF)

Goal: Build access to affordable finance for smallholder farmers and agri-SMEs adopting clean technologies.

Key Actions:

- Create a naira-based concessional credit line (7–10 years tenor, ≤10% interest) to finance solar-powered processing, irrigation, and storage systems.
- Blend funds from CBN's Anchor Borrowers' Programme, BOI, commercial banks, and climate finance facilities.
- Establish a Guarantee Fund (20–30% first-loss coverage) to derisk lending to farmers and agri-SMEs.
- Collaborate with fintech and microfinance institutions to deliver asset-financing and lease-to-own models to small producers.

4. Gender-Responsive Rural Enterprise Support (GRES)

Goal: Ensure that women and youth benefit equitably from clean technology transitions.

Key Actions:

- Fund women-led processing hubs equipped with solar dryers, mini cold rooms, and small-scale biogas units.

- Incorporate gender equity requirements (minimum 40% of assets to women/youth groups).
- Provide targeted business development and technical training on maintenance, management, and marketing.
- Integrate gender impact indicators (income, labour hours saved, and participation in decision-making) into monitoring systems.

5. Agri-Energy Innovation and Data Hub

Goal: Strengthen evidence, data sharing, and innovation for scaling clean agricultural technologies.

Key Actions:

- Establish a national database and GIS mapping of clean-tech installations (solar dryers, irrigation, cold storage, biogas digesters).
- Collaborate with research institutions (NSPRI, NASENI, universities) to collect performance data and conduct lifecycle cost analyses.
- Launch annual AgriTech Innovation Challenges to incubate youth-driven solutions in clean energy for agriculture.
- Develop an open-source Monitoring, Reporting, and Verification (MRV) dashboard to track progress and support transparent investment decisions.

6. State-Level "Agro-Energy Hubs" Pilot Program

Goal: Demonstrate integrated, replicable clean-technology clusters.

Key Actions:

- Pilot regional hubs across the states - combining solar-powered irrigation, cold storage, drying, and processing units.
- Co-manage hubs with cooperatives, women associations, and private developers.
- Introduce state matching grants (20%) for cooperatives investing in certified equipment.
- Use the pilots as learning laboratories to refine national scale-up models.

8. Capacity Building and Standards Program

Goal: Build a strong local ecosystem of technicians, fabricators, and maintenance service providers.

Key Actions:

- Collaborate with NASENI, SON, and polytechnics to develop national curricula for solar drying, cold-chain, and irrigation systems.
- Train and certify 1,000 local technicians across states to ensure after-sales maintenance.
- Enforce equipment standards and certification labels to curb substandard imports.
- Support local assembly and fabrication to reduce costs and build domestic manufacturing capability.

Tabulated Summary of Recommendations for Lead Actors, Expected Actions andPossible Outcomes

Recommendation	Lead Actor(s)	Concrete Actions	Outcome
Establish a Stable, Inclusive Clean Tech Policy	Federal Ministry of Agriculture, National Assembly	Enact a “Clean AgTech Act” guaranteeing predictable subsidies, long-term incentives, and requiring state input. Form state-level Clean AgTech Task Groups	Predictability and inclusion spur private and farmer investment
Upgrade Agricultural Extension & Research	State Ministries of Agriculture, National Research Institutes	Train extension agents on solar irrigation, cold-chain, and e-farming; develop gender/youth-focused outreach; fund demonstration plots in collaboration with farmer groups	Improved capacity and increased field-level adoption, esp. among women/youth
Structure Dedicated Clean Tech Finance	Central Bank/NAIC, Commercial Banks, Development Finance Institutions	Create risk-sharing facilities for smallholder/coop loans; pilot blended finance (public/private) for large-scale projects; promote digital micro-lending	Lower cost and wider access to equipment and services

Recommendation	Lead Actor(s)	Concrete Actions	Outcome
Mandate Infrastructure Investments	Ministry of Works, Rural Electrification Agency, Private Logistics Providers	Prioritize rural feeder roads, solar mini-grids, and agro-processing hubs in rural infrastructure plans; offer incentives to private cold chain operators	Lowered logistics cost, expanded off-grid energy, market viability for clean tech
Foster Private Sector and Tech Start-up Incentives	NIPC, SMEDAN, Tech Hubs, Venture Funds	Offer tax breaks, seed grants, franchise schemes for tech deployment, support local manufacturing of agri-tech	Innovation and local adaptation of clean solutions
Boost Cooperatives and Farmer-Led Models	State Depts. of Cooperatives, CSOs, Farmer Unions	Reform co-op policies for scale up, offer group loan guarantees, train managers; support CSOs to deliver participatory training and advocacy	Market aggregation, lower transaction costs, peer learning

Recommendation	Lead Actor(s)	Concrete Actions	Outcome
Mandate Gender and Social Inclusion Metrics	All line ministries, National Planning Commission, Donors, Lead CSOs	Track participation by gender/youth; require inclusive targeting in public programs, ensure at least 30% women/youth representation in state and federal agri boards	Equity and faster diffusion of innovation
Expand Digital Information Systems	Nigerian Meteorological Agency, Research Institutes, Private Data Companies	Disseminate mobile-based climate/tech advisories; build digital platforms linking farmers to input/output markets and service providers	Knowledge diffusion, access to up-to-date weather and tech support

Annex – Data Summary

Annex 1: Summary of the Economic Impact of Agro Processing Waste for Selected Crops

Crop	Processing Stage	Traditional Method Issues	Resource Waste Type	Environmental Impact	Health Risk
Maize	Harvesting & Drying	Sun drying - weather depend nt, contamination	Labour, Time, Quality	Low	Medium -contamination
	Storage	Sacks storage - pest attack, moisture	Storage materials, Produce	Medium	High - mycotoxins
	Transportation	Head loads, poor roads	Fuel, Time, Quality	Medium	Low
	Milling/Grinding	Hand grinding - inefficient	Labour, Energy	Low	Low
	Overall Post-Harvest	Multiple inefficient steps	Multiple resources	High	High

Crop	Processing Stage	Traditional Method Issues	Resource Waste Type	Environmental Impact	Health Risk
Rice	Parboiling	Coal/husk burning - pollution	Fuel, Fire wood, Water, Air quality	High - air pollution	High - smoke, chemicals
	Milling	Manual dehusking, poor cleaning	Water, Labour, Quality	Medium	Medium - impurities
	Storage	Open storage - pest damage	Storage space, Produce	Low	High - aflatoxins
	Transportation	Poor packaging, road damage	Fuel, Packaging	Medium	Low
	Overall Post-Harvest	Water contamination, impurities	Water, Energy, Quality	High	High

Crop	Processing Stage	Traditional Method Issues	Resource Waste Type	Environmental Impact	Health Risk
Palm Oil	Fruit Processing	Manual fruit boiling	Water, Energy	High - water pollution	High - contaminated water
	Traditional Extraction	Hand/feet squeezing - low extraction	Labour, Yield potential, fire wood loss	Medium	Medium
	Waste Generation	Open burning of waste	Biomass potential	Very High	High - air pollution
	Water Usage	Excessive water use	Water resources	High - water scarcity	High - waterborne diseases
	Environmental Pollution	River/soil contamination	Soil, Water quality	Very High - ecosystem damage	Very High

Crop	Processing Stage	Traditional Method Issues	Resource Waste Type	Environmental Impact	Health Risk
Cassava	Peeling	Manual peeling - waste	Labour, Raw material	Medium	Medium
	Fermentation	Open fermentation - contamination	Water, Time	High - water contamination	High - cyanide, bacteria
	Gari Production	Wood fire roasting - smoke	Fuel wood, Labour	High - air pollution	High - smoke inhalation
	Waste Generation	Waste dumping	Organic matter potential	High - soil contamination	High - toxic waste
	Overall Processing	Multiple water-intensive steps	Water, Labour, Fuel	Very High	Very High

Crop	Processing Stage	Traditional Method Issues	Resource Waste Type	Environmental Impact	Health Risk
Vegetables	Harvesting	Manual harvesting - damage	Labour, Quality	Medium	Medium - pesticide residues
	Storage & Transport	No cold storage	Energy, Produce	Low	Medium - spoilage
	Market Display	Sun exposure - wilting	Quality, Market value	Low	Low
	Processing	No value addition	Value addition potential	Low	Low
	Overall Post-Harvest	Lack of processing facilities	Multiple resources	Medium	Medium

Crop	Processing Stage	Traditional Method Issues	Resource Waste Type	Environmental Impact	Health Risk
Shea Butter	Nut Drying	Sun drying - inconsistent	Energy, Quality	Medium	Medium
	Traditional Processing	Manual grinding - laborious	Labour, Time, Water	Medium	Medium
	Water Usage	Scarce water sources	Water, Distance	High - water stress	High - waterborne diseases
	Fuel Wood Consumption	Deforestation from fuel needs	Forest resources	Very High - deforestation	High - respiratory issues
	Waste Generation	Poor waste management	Organic matter, Water	High	High

Annex 2: Matrix of Agricultural & Food Processes in Nigeria

Crop/Product	Process Stage	Dirty / Inefficient Practices	Resources Wasted	Health Issues / Food Safety Risks
Maize	Harvesting, Drying, Storage, Milling	Manual harvesting → delays; sun-drying on bare ground; poor storage in woven bags → mould; rudimentary hammer mills	Grain losses, labour, fuel (diesel), water (wet milling)	Aflatoxin contamination; smoke residues from parboiling
Rice	Harvesting, Parboiling, Milling, Storage	Unthreshed bundles left in field → shattering; parboiling with firewood in drums; poor mills → high broken grains; storage in jute bags	Water, firewood, labour, low milling recovery	Smoke inhalation; poor grain hygiene; mycotoxins
Cassava	Harvest, Peeling, Processing (Garri, fufu), Storage	Late harvesting → rot; manual peeling with knives → waste; open-air fermentation; roasting with firewood	Roots, labour, firewood, water	Cyanide residues if poorly processed; smoke exposure

Crop/Product	Process Stage	Dirty / Inefficient Practices	Resources Wasted	Health Issues / Food Safety Risks
Yam	Harvest, Storage, Processing (pounded yam, yam flour)	Bruising during harvest; poor yam barns → pests/rot; sun drying on bare ground	Roots, labour, storage materials	Spoilage → mycotoxins; food poisoning from rotten yam
Palm Oil	Harvesting, Processing (pounding, boiling, clarification)	Manual harvesting with climbing hooks; crude digester (mortar); boiling with firewood; poor clarification → dirty oil	Water, wood, oil losses, labour	High FFA (low quality oil); smoke inhalation
Vegetables	Harvest, Transport, Storage	Harvested with bare hands → bruising; packed in raffia baskets; no cold chain	Vegetables, water, labour	Contamination with pathogens; pesticide residues
Tomato & Pepper	Harvest, Transport, Processing (pepper paste)	Harvested in bulk → crushing; packed in woven baskets → spoilage; crude open-pan boiling with firewood	Vegetables, firewood, water, labour	Mycotoxins in rotted tomato; smoke exposure

Crop/Product	Process Stage	Dirty / Inefficient Practices	Resources Wasted	Health Issues / Food Safety Risks
Beans (Cowpea)	Harvest, Storage, Milling	Poor threshing → losses; storage in bags → weevil damage; milling in dusty environment	Grains, labour, fuel	Pesticide misuse for storage → poisoning; aflatoxin
Shea Butter	Collection, Processing	Women roast nuts with firewood; pounding in mortars; manual oil extraction	Nuts, firewood, water, labour	Smoke inhalation; unhygienic butter → contamination
Fish (Livestock)	Harvest, Smoking, Storage	Overfishing of small fish; smoking with firewood in chorkor kilns; poor storage in raffia baskets	Fish, firewood, labour	Smoke inhalation; PAH (carcinogens in smoked fish)
Beef (Livestock)	Slaughter, Butchering, Transport	Slaughter on bare floors; open-air meat cutting; transport in open trucks without refrigeration	Water, labour, animal losses	Contamination with pathogens, zoonoses

Crop/Product	Process Stage	Dirty / Inefficient Practices	Resources Wasted	Health Issues / Food Safety Risks
Bread (Baking)	Mixing, Baking, Packaging	Use of low-quality flour; wood-fired or diesel ovens; unhygienic bakeries; poor packaging	Wood, fuel, water, labour	Inhalation of smoke; contamination from dirty environments
Groundnut Oil	Harvest, Shelling, Oil Extraction	Manual shelling; open-pan roasting with firewood; oil extraction with crude presses	Nuts, firewood, labour, oil loss	Aflatoxin from contaminated nuts; smoke inhalation
Soybean	Harvest, Processing (soy flour, soy milk)	Delayed harvest → shattering; sun drying on bare ground; crude milling and boiling	Grain, water, labour, fuel	Bacterial contamination of soy milk; mycotoxin risks
Milk (Dairy)	Milking, Transport, Processing	Milking by hand without sanitation; transported in open containers; no refrigeration	Milk, labour	Contamination with pathogens (Brucella, TB)
Poultry	Rearing, Processing	Overcrowded housing; poor hygiene; open-air slaughter; defeathering with boiling water/firewood	Feed, water, labour, fuel	Zoonotic risks (Salmonella, Avian flu); contamination

Annex 3: Clean Renewable Energy Solutions for Agricultural Processing in Nigeria

Crop / Process	Current "Dirty" Practice	Renewable Energy Solution	How it Works	Example (Nigeria / West Africa)
Rice (parboiling, milling)	Firewood parboiling in drums; diesel milling machines	mproved rice parboilers with biomass briquettes or LPG; solar dryers; solar/diesel hybrid mills	Energy-efficient parboilers reduce firewood use by >60%. Solar dryers cut drying time, avoid contamination. Hybrid mills use solar PV for day milling.	FAO's GEM rice parboiling project in Ebonyi trained women cooperatives on energy-efficient parboilers; NCAT, Katsina solar rice dryers piloted for farmer groups.
Cassava (Garri, fufu)	Firewood frying of Garri; diesel graters	Biogas cookers; solar-powered graters and dryers; efficient fryers	Biogas digesters turn cassava peel waste into fuel; solar drying tents protect against dirt; efficient Garri fryers save 30–40% wood.	IITA/Presco "Waste to Wealth" cassava biogas project in Edo powered Garri processing from cassava peels. FIIRO Lagos developed energy-efficient Garri fryers.
Palm Oil	Firewood boiling/sterilizati on; open pits	Biogas boilers; small-scale hydro/solar for milling; improved oil presses	Palm oil mill effluent (POME) is fed into digesters to produce gas for sterilization; solar powers presses.	NIFOR, Benin City tested palm oil mill effluent biogas digesters to replace firewood.

Crop / Process	Current "Dirty" Practice	Renewable Energy Solution	How it Works	Example (Nigeria / West Africa)
Shea Butter	Open firewood roasting of nuts	Solar dryers; improved biomass stoves; mechanized presses on solar mini-grids	Solar dryers dry nuts hygienically; clean cookstoves reduce wood use by >50%; solar-powered presses improve extraction.	USAID/Mercy Corps Shea Project in Kwara & Niger States introduced solar drying domes for women cooperatives.
Vegetables (tomato, pepper, leafy greens)	Sun-drying on roadsides; spoilage in transit	Solar cold rooms; solar dryers; clean-pack houses	Solar-powered cold storage extends shelf-life 2–3×; solar dryers preserve hygienically.	ColdHubs Nigeria operates >50 solar-powered cold rooms across Imo, Kano, Plateau. Farmers reduced post-harvest losses by 60–80%.
Maize & Beans	Ground drying → mould; diesel mills	Solar dryers; solar milling systems	Solar bubble dryers dry grain faster and hygienically; solar mills reduce diesel dependence.	German GIZ-SEDIN programme in Niger State piloted solar dryers for maize/soybeans; Solar Milling Project in Katsina powered community grain milling.

Crop / Process	Current "Dirty" Practice	Renewable Energy Solution	How it Works	Example (Nigeria / West Africa)
Fish (smoking, storage)	Traditional mud/firewood kilns; no cold chain	Improved fish smoking kilns (FAO Thiaroye Technique – FTT); solar-powered cold rooms	FTT kilns cut firewood use by 50%, reduce PAH (cancer-causing smoke residues). Solar cold storage reduces spoilage.	FTT-Thiaroye fish smoking kilns deployed in Lagos, Delta & Ondo with FAO support; ColdHubs solar cold rooms also store fish in coastal areas.
Beef & Dairy	Open-air slaughter; spoilage in transport	Solar-powered abattoirs, biogas digesters, cold chain trucks	Biogas from abattoir waste powers operations; solar chillers extend meat/milk shelf life.	Jos Abattoir biogas pilot (UNIDO 2019) used abattoir waste to produce electricity and clean water.

Annex 4: List of Companies Proving Solar Powered Processing Machines in Nigeria and their Business Models

Below is a table of notable companies active in the manufacturing or supply of clean (solar or renewable energy-powered) milling machines for agriculture in Nigeria, including business model, spread, contact details, and website:

Name/Org	Spread/Region	Business Model	Website / Contact	Example Milling Supported
Farm Warehouse	National, smallholders, rural farms	Distributor, direct sales, PU financing	farmwarehouse.com.ng	Grain, maize, sorghum, rice, flour
PowerGen Nigeria	Niger, pilot in rural communities	Lease-to-own, appliance financing with minigrids utility	powergenrenewable.com	Rice, grains, flour
Energy Excell Systems & Solutions (EESL)	Niger, minigrids sites	Retailer, utility partnership, instalment finance	energyexcell.com	Rice, grains
Saf-Aga Renewable Energy	Abuja, North Central Nigeria	Supplier, project installer, service hub	safagaenergy.com	Water pumps, rice mills, grain mills

Name/Org	Spread/Region	Business Model	Website / Contact	Example Milling Supported
UMZA International Farms Ltd (with Paras Energy, Empower New Energy)	Kano	Commercial rice/oil milling, solar installation	umzagroup.comempowernew energy.com	Rice, oilseed
Fullmark Urja Ltd	National, agro processing clusters	Manufacturer,sales/tec hnical support	fullmarkurja.com	Rice, flour, grain
Agsol (Global/Nigeria pilots)	Off-grid, pilot deployments	Pay-as-you-go solar mill, local partners, IoT enabled	agsol.com	Cassava, maize, flour, rice
Koolmill/Nayo Tropical Tech	Pilot, micro rice mills	Innovation project, downsized ultra-low power mills	koolmill.co.uknayotropical.com	Rice, grains

Annex 5: List of Companies Proving Biogas Digesters in Nigeria and their Business Models

Below is a table of key companies involved in the manufacturing and supply of biogas digesters in Nigeria, including their business models, coverage, contact details, and website:

Website / Contact	Website / Contact	Website / Contact	Website / Contact	Website / Contact
blonergy.com.ng	blonergy.com.ng	blonergy.com.ng	blonergy.com.ng	blonergy.com.ng
avenamlinks.com	avenamlinks.com	avenamlinks.com	avenamlinks.com	avenamlinks.com
facebook.com/Nigeria biogas chamraqbiogas@gmail.com	facebook.com/Nigeria biogas chamraqbiogas@gmail.com	facebook.com/Nigeria biogas chamraqbiogas@gmail.com	facebook.com/Nigeria biogas chamraqbiogas@gmail.com	facebook.com/Nigeria biogas chamraqbiogas@gmail.com
Water pumps, rice mills, grain mills	Water pumps, rice mills, grain mills	Water pumps, rice mills, grain mills	Water pumps, rice mills, grain mills	Water pumps, rice mills, grain mills
Fikky-Fissy Optimum Services	South-South, Akwa Ibom	Installations, supply, consulting	Large farm/industrial units	Facebook: Nigeria Biogas Practitioners Uyo, Akwa Ibom State

Website / Contact	Website / Contact	Website / Contact	Website / Contact	Website / Contact
Clarke Energy	National, commercial sector	Design, engineering, large-scale supply	Industrial/agro/CHP digesters	clarke-energy.com/Nigeria
Ground Zero Africa	Lagos, installs nationwide	Biomass & biogas consulting, supply	Farm, commercial, multi-feedstock	groundzeroafrica.com
Chiwis Biogas Engineering	SW, NW Nigeria	Installation, training, consulting	Training and custom digester build	Facebook: Chiwis biogas engineer
Bioflex Nigeria	SW, Oyo region	Installation, supply, technology demo	Onsite install/documentation	YouTube: Bioflex biogas system Ibadan Phone: 08163938313
Polite Bio-digester Installation	National	Installation,maintenance	Sanitation, institutional units	Facebook: Bio-digester toilet systems and biogas solutions
Quintas Renewable Energy Solutions Ltd	Ondo (HQ), National	Manufacture,pilot/demo, direct sales, consulting and hybrid solar-biomass clean heat solutions	Institutional, farm, gasifiers, awarded for innovation	quintasenergies.com

Annex 6: List of Companies Making Briquette in Nigeria and their Business Models

Below is a list of major briquette-making companies in Nigeria,

Website / Contact	Website / Contact	Website / Contact	Website / Contact	Website / Contact
Murtash Nigeria Limited	National, rural	Manufacture, supply, youth/farmer engagement	Carbonized ag. waste briquettes	cleancooking.org/Murtash-Nigeria-limited
Lapariah Briquettes harcoal	Ilorin, SW	Sawdust/rice husk briquette production, supply	Household, small business supply	facebook.com/lapariahenergy
Gavi Global	National, export	Briquette charcoal supply/export, bulk sales	Hardwood briquettes, global shipping	gaviglobal.com/briquette-charcoal-suppliers
Brycoal	Kano, NW	Manufacture, bulk supply, retail, innovation	Charcoal, crop waste briquettes	brycoal.com f6s.com/company/brycoal

Website / Contact	Website / Contact	Website / Contact	Website / Contact	Website / Contact
Daganda Briquette	North, retail/export	Briquette charcoal, retail/wholesale, export	Rice husk & crop residue, retail/export	ibnashirglobal.com/daganda-briquette-charcoal-25kg
Happy Fresh Natural Flame	Multi-state	Exporters, direct sales, franchise models	Clean cooking, bulk supply	nigeria.tradekey.com/briquette.htm
Roshan Renewable Technologies Ltd	Abuja HQ, national/7+ states	Manufacture/supply Happy Fuel Efficient Stoves, Happy Charcoal Briquettes; women entrepreneurship model	Palm shell, bamboo, agri-waste briquettes, clean stoves	roshanrenewables.com facebook.com/roshanrenewables

Website / Contact	Website / Contact	Website / Contact	Website / Contact	Website / Contact
Golden Seed (Maxiburn)	National	Bulk, industrial, commercial supply	Palm kernel biomass briquettes	Facebook: Kernel Briquettes, Golden Seed
ARMADA International Ltd	National, industrial	Pellet/briquette factory, direct/wholesale	Biomass pellets, clean cookstoves,15–20t/day	armadanigeria.com/pellet-factory
Chamraq Biogas Nigeria	National, Minna HQ	Biogas digesters, eco-friendly briquettes, training, and clean cooking stoves	Odourless briquettes, magic/incense, portable digesters	facebook.com/nigeriabiogas chamraqbiogas@gmail.com chamraqbiogas.com
Zulwood Energies	Lagos/Nigeria/ Africa	Sawdust/wood waste briquettes, clean cook stoves	Wood/sawdust briquettes, retail/wholesale	f6s.com/company/zulwood-energies

Annex 7: List of Companies Providing Solar Irrigation System in Nigeria and their Business Models

The table below gives a list of leading companies supplying and/or manufacturing solar irrigation systems in Nigeria, including business model, spread, and contact/web details:

Name/Org	Spread/Region	Business Model	Website / Contact	Example Milling Supported
Nimsy Agro Solar Concept	Rural solar hubs: Kaduna, Kano, Plateau; expanding nationally	Rental (pay-per-use), lease-to-own, direct sales, rural solar hubs; install, sales, support, clean energy agri-solutions	Mobile solar irrigation pumps (1HP, 2HP), solar reservoir, thresher, dryer, mill; women farmers & youth rural employment	nimsyagrosolar.com info@nimsyagrosolar.com 08127600682, 09034878051
Spunvertek Ltd	National, SME focus	Direct sales, project install, training	Solar-powered irrigation, farm clusters	spunvertek.com.ng
NASENI	National, R&D, public	Manufacture, supply via programs and gov't agencies	Solar irrigation pumps for small & large farms	naseni.gov.ng

Name/Org	Spread/Region	Business Model	Website / Contact	Example Milling Supported
IrriTech Nigeria Ltd	Lagos, nationwide	Product sales, kit installation, advisory	Drip, micro, & portable solar irrigation	irritechng.com
Rubitec Solar	Lagos, SW, national	Sales/install, commercial projects, custom design	Solar pumps, commercial/industrial systems	rubitecsolar.com
Lihon Energy	National	Product sales, financing, B2B support	Solar pumps, irrigation for smallholders	lihonenergy.com
SunCulture	ECOWAS/West Africa, Nigeria pilots	PAYG lease, B2B, partnershipdevelopment	Solar drip, pump sets for small farms, drylands	sunculture.com
Irri-Go (CESEL)	National (as-a-service)	"Irrigation-as-a-Service", infrastructure clusters	Solar irrigation for youth, vulnerable, clusters	irri-go.ng
Ecofarms & Agroservices	South/Southwest, national	Direct supply, install, training	Drip and sprinkler solar irrigation	ecofarmsandagroservices.com

Name/Org	Spread/Region	Business Model	Website / Contact	Example Milling Supported
Ecofarms & Agroservices	South/Southwest, national	Direct supply, install, training	Drip and sprinkler solar irrigation	ecofarmsandagroservices .com
Havenhill Synergy	National, pilots	Infrastructure-as-Service for farmer groups	Cluster-based solar irrigation pilot	havenhillsynergy.com
Gennex Technologies	National, installer	Design, install, after-sales, larger projects	Solar pumps, rural and commercial solutions	gennextechnologies.com
Caps Clean Energy	National, SME/coop	Design, supply, field support	Solar irrigation, solar pump systems	abgcapsenergy.com
Irri-Go (CESEL)	National (as-a-service)	"Irrigation-as-a-Service", infrastructure clusters	Solar irrigation for youth, vulnerable, clusters	irri-go.ng

Annex 8: List of Companies Providing Solar Cold Storage Systems in Nigeria and their Business Models

Below is a table of notable solar cold storage and cold chain companies operating in Nigeria, offering solutions for agricultural produce, frozen goods, and pharmaceuticals:

#	Name	Spread in Nigeria	What They Do	Business Model	Contact (Web • Email • Phone)
1	**ColdHubs Ltd.**	Operates ~58 solar cold rooms across 28 states	100% solar-powered walk-in cold rooms and "IcePoints" for fresh produce	**Pay-as-you-store** per crate/day model	www.coldhubs.com
2	**Ecotutu Ltd.**	HQ Lagos • Deployments in south-west & north-central Nigeria	Solar-powered cold storage hubs for food & health chains	**Pay-as-you-chill / service rental model**	www.ecotutu.com
3	**Solaristique Nigeria Ltd.**	Installs cold rooms nationwide on client sites	Mini solar cold rooms and community cooling centres	**Equipment supply + installation model** with training & maintenance	www.solaristique.com
4	**Akpo Oyegwa Refrigeration Co.**	Provides cold room projects nationwide (contractor model)	Solar-powered cold rooms and blast freezers	**Custom design-build projects** for agribusiness & hospitality	www.nigeriacontractor.com
5	**Aldelano Solar Solutions**	Supplies ColdBox™ units nationwide via dealers & partners	Off-grid solar ColdBox™ and ColdCart™ units for food and health	**Manufacturer & distributor model** – sold through local partners	www.aldelanosolarsolutions.com
6	**Coldbox Store**	Expanding hubs in southeast and north-central Nigeria	Solar-powered cold rooms & aggregation centres with digital traceability (SCOS)	**Service / leasing model** – rent space for produce storage and aggregation	www.coldboxstore.com
7	**Koolboks Ltd.**	Nationwide distributor network; active in > 25 states across Nigeria	Solar-powered freezers & fridges with ice-battery storage for off-grid users	**Pay-as-you-go / lease-to-own model** for micro-enterprises, market women & traders	www.koolboks.com

Annex 9: List of Companies Providing Solar Dryers in Nigeria and their Business Models

Below is a table summarizing key solar dryer companies and organizations in Nigeria, including their spread, business model, contact details, and examples of fruits they can dry:

Name/Org	Address/Region	Spread in Nigeria	Business Model & Contact	Fruits It Can Dry
Osomobegbe Global Ventures (OGV)	Benin City, Edo, National	Solar drying centers in Benin, rural outreach	Direct sales, installation, service hub ogvlimitedsolutions.com.ng	Mango, tomato, pepper, pineapple
Kaspharyn Solutions	Lagos, Nigeria	Fabrication & install across Nigeria	Custom construction, direct purchase kspharynsolutions.com	Tomato, pepper, banana, pineapple
Sosai Renewable Energies	Kaduna & Northern Nigeria	Over 20 rural communities (solar kiosks, mini-grids)	Lease-to-own, community center kiosk, women entrepreneur franchise sosairen.org	Tomato, pepper, banana, leafy veg
NSPRI (Parabolic Solar Dryer)	National, research-driven	17 pilot locations, partnering research sites	Grant/donor, coop/hub install, R&D nspri.gov.ng	Mango, tomato, okra, pepper, apple
Clamore Solar	(International distributor, reach in Nigeria/West Africa)	Commercial/agro partnerships, market installation	Direct sale, contract install sales@clamorepower.com	Pineapple, guava, pawpaw, tomato
DEHYTRAY (JUA Technologies)	Purdue US, Nigeria distributor	National reach via B2B, cooperatives, NGOs	Retail online, NGO/corp bulk, subsidy jua-technologies.com	Mango, orange, tomato, leafy veg
DARE (Solar Bubble Dryer)	Kaduna region	Mobile drying units, rural pilot deployments	Community pilot, NGO donor, direct purchase darenigeria.com	Maize, rice, tomato, pineapple