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A DATA-DRIVEN CIRCULAR ECONOMY ROADMAP FOR GHANA'S INFORMAL CASSAVA VALUE CHAIN

(2025-2028)



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About This Report

This report presents a circular economy roadmap for the cassava value chain, outlining priority interventions, enabling actions, and implementation pathways. The sections move from baseline conditions and challenges to phased actions and governance considerations to support coordinated delivery and impact.



RILLO * RICE * ARROZ * ROZ





EXECUTIVE SUMMARY

Ghana's informal cassava value chain plays a critical role in food security, rural employment, and women's livelihoods. Despite its economic and cultural importance, the sector remains inefficient, resource-intensive, and mostly informally structured. Waste streams such as cassava peels and effluent are underutilised, energy use is inefficient and carbon-intensive, and social capital remains weak due to low cooperative engagement. Recognising this, the Circular Economy (CE) Roadmap for Ghana's Informal Cassava Value Chain (2025-2028) provides a structured and data-driven pathway to facilitate the sector's transition into a more regenerative, inclusive, and resource-efficient system.

The roadmap builds directly on a comprehensive opportunity mapping exercise conducted by KNUST in partnership with UNIDO, covering 765 informal cassava value chain actors across Mampong Municipality, Sekyere Central District, and Techiman Municipality. These included producers, processors, and traders, predominantly women, engaged in gari, agbelima, and cassava flour production. Through Material Flow Analysis (MFA),

Life Cycle Assessment (LCA), and social diagnostics, the study identified critical points of leakage and inefficiency. Although the value chain retains about 92.7% of inputs, approximately 155 tonnes of cassava are lost annually, particularly during field handling, processing, and trading. Around 98 tonnes of peels are generated every year, of which 40% are discarded, and over 235,000 litres of liquid effluent from pressing are completely unutilised.



92.7% of inputs, approximately **155 tonnes** of cassava are lost annually, particularly during field handling, processing, and trading.



Around **98 tonnes** of peels are generated every year, of which **40%** are discarded, and over **235,000** litres of liquid effluent from pressing are completely unutilised.



Each kilogram of gari requires an average of **17.03 MJ of energy**, mostly from **firewood**, which contributes to an estimated **494,081 kg of CO₂-equivalent emissions** annually.



only **15.2%** of actors belong to cooperatives, and just **17% have completed secondary education or higher**, limiting access to training, finance, and scaling opportunities.

Processing operations were found to be the environmental hotspot. Each kilogram of gari requires an average of 17.03 MJ of energy, mostly from firewood, which contributes to an estimated 494,081 kg of CO₂-equivalent emissions annually. Meanwhile, only 15.2% of actors belong to cooperatives, and just 17% have completed secondary education or higher, limiting access to training, finance, and scaling opportunities. Despite these constraints, the report found that many actors are already practising low-level circularity informally; for example, using peels for livestock feed or reducing market waste through informal redistribution.

In response, the roadmap lays out a phased strategy from 2025 to 2028, guided by a vision of zero waste, energy efficiency, resource sovereignty, and inclusive livelihoods. Strategic goals include reducing total value chain waste by 25%, valorising at least 70% of peels and effluent, cutting firewood use in gari processing by 20%, increasing cassava productivity by 20%, and increasing cooperative participation among women and youth by 40%. The roadmap structures its actions into thirteen integrated steps, beginning with baseline analysis and ending in business model scaling.

Three flagship pilot interventions anchor the roadmap's transition strategy. First is the valorisation of cassava effluent into a natural bio-herbicide, building on evidence of phytotoxic properties and aiming to process at least 100,000 litres of

effluent across five pilot hubs. Second is the establishment of two peel valorisation micro-centres to convert peel waste into livestock feed and compost, products in high local demand. Third is the deployment of shared energy-efficient oven services in high-firewood-use communities to lower emissions and improve processing efficiency. The final intervention is a regenerative agriculture model where smallholder farmers integrate organic compost with grain legumes as intercrops under cassava plantations to improve soil health and cassava productivity. These interventions were selected based on feasibility, social demand, and their potential for high circular impact.

Supporting these interventions is a comprehensive programme of capacity development. This includes a modular training curriculum tailored for farmers, processors, and traders, delivered in local languages and through practical demonstration. Thirty extension officers will be trained in circular techniques, while vocational institutes will partner on fabricating and adapting CE tools like compost bins, efficient ovens, and effluent catchment units. At the policy level, the roadmap calls for integration of circular principles into the Medium-Term Agriculture Sector Investment Plan (METASIP) and District Medium-Term Development Plans, allowing for consistent tracking and institutional ownership.

A robust monitoring, reporting, and verification (MRV) system underpins the roadmap, ensuring that impact is measurable and adaptive. Environmental indicators include firewood reduction per kilogram of product and greenhouse gas emissions avoided. Economic indicators cover new revenue streams from circular products and cassava productivity enhancement, cost savings from bio-input substitution, and jobs created in innovation hubs. Social indicators focus on cooperative participation, actor training, and gender inclusion. These are supported by practical data tools such as mobile cooperative logs, quarterly fuel and waste audits, and localised household surveys.

To finance the roadmap's interventions, an estimated \$370,000 is required for pilot-scale infrastructure and support. This includes \$75,000 for energy-efficient oven roll-out, \$120,000 for two peel processing hubs, \$95,000 for the effluent pilot and certification, and \$80,000 for regenerative agriculture pilot and demonstration program integrating organic compost and legumes as intercrops under cassava plantations. Seed funding will be mobilised through UNIDO and DACF allocations, with co-financing encouraged from private innovators and the Ghana Climate Innovation Centre. De-risking mechanisms include SME guarantee funds and innovation prize awards. A CE Investment Prospectus will be published in 2026 to mobilise broader support.

The roadmap culminates in the incubation and scaling of four viable business models: the effluent-to-bio-herbicide social enterprise, the peel-to-feed women-led cooperative, the shared clean oven service model, and the regenerative cassava farming model to improve soil health

and crop productivity. These models will be linked to existing innovation hubs, supported through demo days and investment roundtables, and scaled into other food systems such as fish, mango and pineapple post-2027. A CE Playbook will be developed to document methods, training, and designs for replication.

This roadmap lays out a data-driven plan to transition Ghana's cassava sector from a traditional linear model to a resilient circular economy, maximizing resource efficiency and value retention at every stage. The vision is a sustainable cassava value chain where productivity is improved, losses and waste are minimized, energy and inputs are used efficiently, and all byproducts (like peels and effluent) are valorized for economic gain. Strategic objectives include improvement in cassava productivity, reducing post-harvest and yield losses, valorizing waste streams, improving energy and water efficiency, enhancing rural livelihoods (especially for women and youth), and strengthening cooperatives and market linkages. For example, the study found producers lose ~7% of cassava harvests, and processors lose ~4%, which represent "leakage" that circular interventions can address. Objectives therefore include reducing these losses, increasing peel reuse (currently ~60%), cutting firewood use (2.7 kg/kg of product) and related GHG emissions, and boosting farmer productivity and profits by an estimated 25% through circular innovations. A gender-sensitive approach will be used throughout – for instance, designing efficient gari ovens for women processors – and cooperatives will be strengthened to improve collaboration and access to resources.

Step 1: Vision and Strategic Intent



Vision:

Ghana's cassava value chain stands at a pivotal junction. Historically defined by high labour intensity, firewood dependence, and underutilised by-products, the chain is now being reimagined through a regenerative lens. The long-term vision is to transition from a largely linear and resource-intensive model to a circular system that is environmentally restorative, economically inclusive, and socially resilient.

This circular transition aims to close material loops, eliminate avoidable waste, and ensure that the benefits of value creation are widely shared, particularly among women, youth, and marginalised rural actors who dominate cassava processing and trading. By grounding innovation in local knowledge and embedding environmental responsibility at every stage, the sector can become a demonstrator of what regenerative agri-food systems can look like in Ghana and across West Africa.

This is not only a matter of technical redesign, it is a systemic change, where waste becomes feedstock, emissions are reduced through efficient energy systems, and social capital is rebuilt through stronger cooperative structures. The CE in this context becomes a vehicle for livelihood enhancement, climate mitigation, and national food and income security.



Strategic Goals (2025-2028):

The strategic intent of the circular transition is operationalised through the following measurable and time-bound goals, based on evidence from the baseline assessment:

1. Reduce cassava value chain waste by 25% by 2028.

Justification: The report estimates total annual leakage across the cassava value chain at approximately 155,000 kg, or 7.3% of total production. Cutting this by a quarter (~39,000 kg) through better harvesting, market handling, and byproduct valorisation is both achievable and impactful.

2. Valorise at least 70% of cassava peels and effluent by 2028.

Justification: Around 97,965 kg of peels and 235,116 L of effluent are generated annually. Currently, 60% of peels are reused as animal feed, but 40% (~39,186 kg) remain unutilised. Effluent, which has shown herbicidal potential in field studies, remains entirely uncollected. Scaling circular innovations to capture and valorise these streams will recover value and reduce environmental burden.



Strategic Goals (2025-2028):

3. Replace 20% of firewood use in gari processing with energy-efficient alternatives by 2027.

Justification: The firewood used in processing (~244,185 kg/year) contributes to extremely high energy intensity, 17.03 MJ per kg of final product. Efficient ovens and partial substitution with alternative fuels can reduce both fuel loads and emissions without disrupting livelihoods.

4. Increase women and youth cooperative participation by 40% by 2026 to enhance social capital.

Justification: While 68% of actors are women, cooperative participation remains low at 15%. Organising and empowering informal actors, especially women processors and traders, into formal cooperatives is essential for scaling CE practices, unlocking finance, and promoting knowledge exchange.

5. Increase cassava productivity by 20% by 2028.

Justification: The report estimates average cassava yield at approximately 18,635 kg/ha, which is about 20% below the national average of about 24,000kg/ha. Improving yield by 20% through regenerative agriculture model which integrates organic compost application and grain legumes as intercrop under cassava plantations hold the potential to improve soil health and promote cassava productivity with attendant economic benefits. The compost will improve soil structure, and the grain legumes will fix nitrogen in the soil to improve soil fertility, thereby enhancing crop productivity and nutrient recycling.

Alignment with Policy and Global Frameworks:

This vision is designed to contribute directly to Ghana's broader development, sustainability, and inclusion agendas, ensuring synergy and long-term institutional support:

- **NDPC Medium-Term Development Frameworks (2022-2025):**

The CE roadmap aligns with pillars on sustainable agriculture, local industrialisation, green economy development, and job creation (NDPC, 2021)¹.

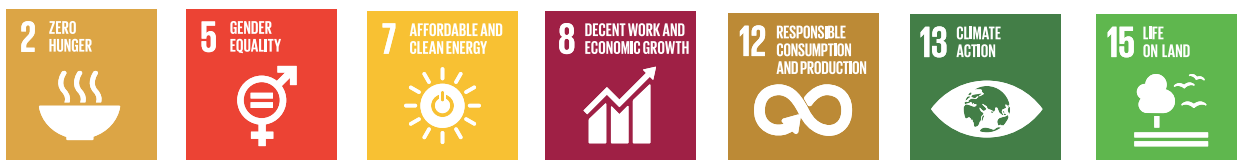
- **Ghana National Plastic Action Plan (2021)²:**

While primarily focused on plastics, its principles (resource recovery, stakeholder collaboration, policy coherence) are applicable to biowaste. The roadmap proposes a similar framework for agricultural waste valorisation.

¹ National Development Planning Commission (2021). Medium-Term National Development Policy Framework (2022–2025): Agenda for Jobs II – Creating Prosperity and Equal Opportunity for All (306 pp.). Accra, Ghana.

² National Plastic Action Partnership. (2021, November 1). A roadmap for radical reduction of plastic pollution in Ghana. Ghana National Plastic Action Partnership

- **Sustainable Development Goals (SDGs):**



- **SDG 2:** End hunger - through enhanced productivity and food system efficiency.
 - **SDG 5:** Women empowerment - through women participation in cooperative activities leading to improved access to resources and opportunities.
 - **SDG 7:** Clean energy - through firewood substitution and oven efficiency.
 - **SDG 8:** Decent work - via new green jobs and cooperative development.
 - **SDG 12:** Responsible consumption and production - through valorisation and waste minimisation.
 - **SDG 13:** Climate action - by reducing GHG emissions in processing (currently 494,081 kg CO₂eq/year).
 - **SDG 15:** Sustainable terrestrial ecosystems - through application of organic compost to improve soil structure and soil health in legume-cassava intercropping systems.
- **Just Transition Principles:**
The gendered approach and prioritisation of women-led processing innovations ensure fairness, equity, and local ownership in the shift to circularity.

Summary:

Strategic Goal	Current Baseline	2028 Target	Evidence Source
Reduce total cassava waste	7.3% (~155,000 kg/year)	≤5.5%	MFA & Table 10
Valorise peels and effluent	60% of peels reused; effluent entirely wasted	≥70% valorisation	Sections 2.3 and 2.5
Firewood dependency in processing	17.03 MJ/kg (mainly firewood)	-20% use	Table 4
Women/youth in cooperatives	15% total (esp. low male participation)	+40% from baseline	Tables 2a & 2b



The vision and goals outlined above must be grounded in a clear understanding of the current state of the value chain: its resource flows, inefficiencies, social dynamics, and hotspots. We now turn to Step 2: Baseline and Opportunity Mapping, where we use material flow analysis (MFA), life cycle assessment (LCA), and actor-level data to identify the most urgent and viable entry points for circular interventions.



Step 2: Baseline and Opportunity Mapping

Establishing a robust CE roadmap requires a grounded understanding of how resources flow through the cassava value chain, where they are efficiently used, where they leak, and where untapped opportunities lie. This section draws upon field-collected data from 765 informal actors across Ashanti and Bono East regions and incorporates MFA and LCA to pinpoint resource inefficiencies and potential for circular value creation.

2.1 Material Flow and Loss Patterns (MFA Insights)

Material retention across the value chain is relatively high at 92.7%, meaning that most of the cassava harvested is ultimately processed or sold. However, a leakage of 7.3%, equating to over 155 tonnes per year, represents a significant loss of economic and nutritional value.

Key loss points include:

- **Field Losses (~2.1%):** Equivalent to ~44,900 kg/year due to poor harvesting techniques or delayed collection.
- **Processing Residues:** Only 28.3% of raw cassava input becomes finished product; the rest is lost primarily as peels and liquid starch (effluent).
- **Peel Waste (~97,965 kg/year):** 60% is reused as animal feed, but 40% (~39,186 kg/year) remains unutilised, either discarded or burnt.
- **Effluent Loss (~235,116 L/year):** Entirely unmanaged, despite demonstrated herbicidal potential.
- **Production:** Average yield of 7,546 kg/acre (18,635kg/ha) and Median yield of ~6,000 kg/acre, with labour productivity ~75 kg per man-day. Almost all harvests

reach market: about 98% of farm output is sold and only ~2% is lost in the field. Major constraints are erratic rainfall, limited access to improved planting materials and tools, and high labour costs.

- **Processing:** Out of ~783,720 kg of cassava processed, only ~222,062 kg (~28%) becomes final product; the remaining ~72% is byproduct in the form of peels and effluent or loss. On average, processors lose ~4% of input due to spoilage or inefficiency. Processing is energy-intensive (~2.7 kg firewood per kg of output), leading to high GHG emissions (~494,081 kg CO₂eq at processing). Key processing constraints are lack of improved ovens or stoves, knowledge gaps about efficient methods, and costly raw materials (cassava and firewood).
- **Trading/Marketing:** Traders handle roughly 888,000 kg of cassava monthly, selling ~876,993 kg (~98.8% of inputs) and losing only ~1.2%. Yet absolute fuel use is high (~132 L per farm trip) due to poor aggregation and planning. Trader constraints include high transport costs, high raw material (cassava) costs, and low awareness of circular practices.
- **Byproducts and Waste:** Processors generate large quantities of cassava peels (~97,965 kg from the sample). About 60% of peels are reused as animal feed, leaving ~40% unused. Effluent (liquid starch from pressing) is also a major waste stream: high volumes are discarded despite its potential value. These byproducts represent key circular economy opportunities.

2.2 Life Cycle Emissions and Environmental Burdens (LCA Insights)

The LCA component revealed striking contrasts between the different value chain stages:

Stage	GHG Emissions (kg CO ₂ eq/year)	Toxic Emissions (kg/year)	Energy Use (MJ)	Water Use (L)
Production	150,418	1,858	1.66 million	57,663
Processing	494,081	29,565	3.78 million	12,595
Trading	79,234	163	145,505	3,000

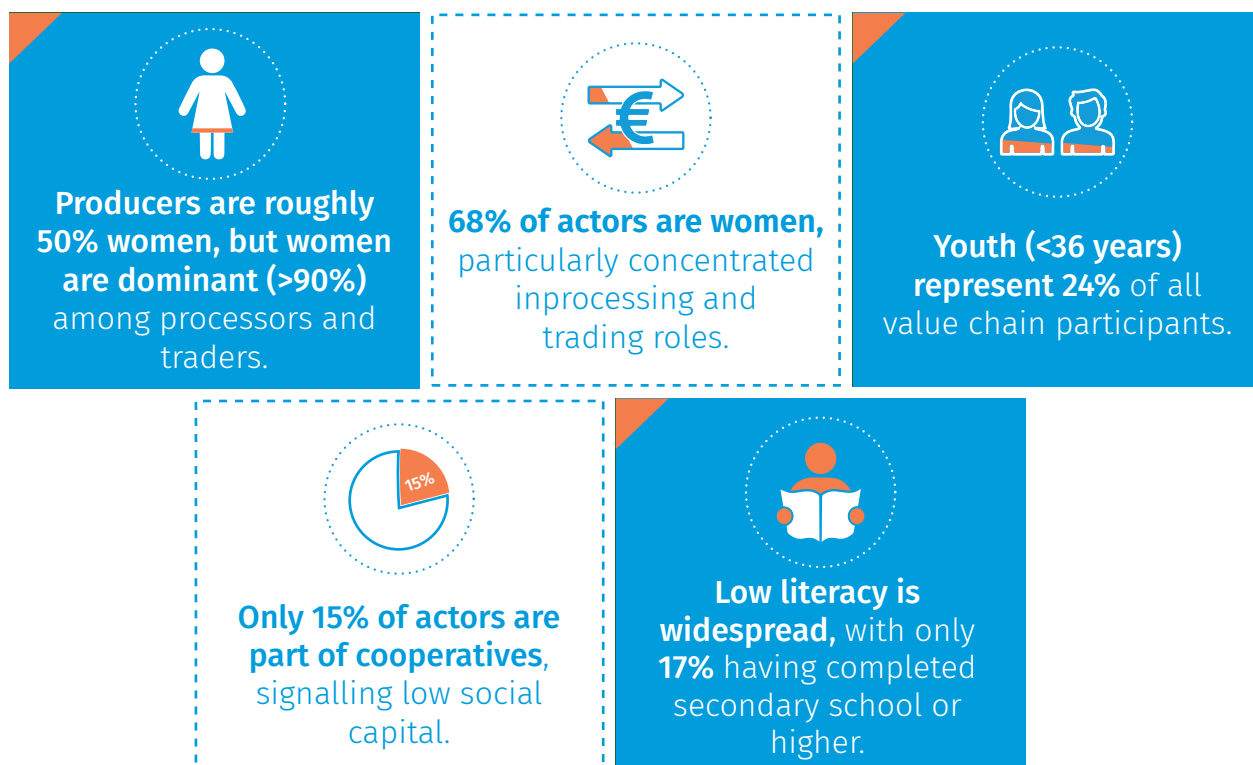


Key Insight: Processing accounts for over 60% of total emissions in the value chain, driven primarily by the combustion of 244 tonnes of firewood annually.

- Energy, Water and Emissions:** The gari chain is heavily firewood-dependent: ~2.7 kg of firewood are used per kg of product. Water use is high on farms (for herbicide application) but modest at processing/trading; however, any savings (e.g. wastewater reuse) would yield circular benefits. Processing generates the most GHG and toxic emissions compared with production and trading nodes of the value chain. Despite low water use at the processing node (0.057 L/kg), the lack of effluent recovery and reuse represents a missed opportunity to reduce herbicide costs, environmental pollution, and synthetic input dependency in smallholder farming systems.

2.3 Social Baseline and Inclusion Gaps

A CE must be socially inclusive to be sustainable. The baseline findings show:



This has significant implications for training delivery, which must be conducted in local languages and adapted for low-literacy audiences.

Furthermore, while women dominate processing (93%) and trading (98%), men control larger landholdings and are more active in farming cooperatives. Circular innovations must therefore be gender-intentional to address structural inequalities and ensure fair participation.

Very few actors belong to cooperatives, indicating low social capital. Engaging more (especially women) in cooperatives can improve access to resources and support services.

There is no formal infrastructure for byproduct valorisation, no pilot initiatives on circular processing innovations, and no local circular innovation hubs serving these regions, despite clear demand and opportunity.

2.4 Current Circular Practices and Systemic Gaps

Practice	Status	Observations
Peel Reuse	Informal (60% reused)	Peels are often fed to livestock but not processed into commercial feed or compost.
Effluent Reuse	Non-existent	Despite evidence of herbicidal properties, no systems exist for collection or utilisation.
Clean Energy for Processing	Lacking	95% of energy comes from firewood; no fuel-efficient ovens in use.
Logistics & Aggregation	Poorly coordinated	Fuel usage for transport (~37,742 L/year) suggests potential for cooperative haulage.
Cooperative Activity	Very low	Only 15% of actors are in groups; men are especially under-represented.

2.5 Circular Hotspots Identified

Hotspot	Description	Opportunity
Energy Use in Processing	~17.03 MJ/kg, mostly firewood	Transition to fuel-efficient ovens; explore biogas or solar drying.
Peel Waste	~97,965 kg/year; 40% unutilised	Process into compost or animal feed; job creation for women/youth.
Effluent Loss	~235,116 L/year	Convert into bio-herbicide; reduce chemical costs for smallholders.

Summary

Indicator	Baseline Value	Implication
Material retention	92.7%	Relatively efficient, but leakage still high (~155 t/year)
Firewood use	244,185 kg/year	Critical energy hotspot; GHGs & deforestation risk
GHG emissions (processing)	494,081 kg CO ₂ eq	~3x more than farming; firewood primary driver
Peel valorisation rate	60%	Significant untapped value (~39,186 kg)
Effluent valorisation rate	0%	Large opportunity for low-cost herbicide replacement
Cooperative membership	15%	Weak social capital; barrier to CE adoption
Female participation	68% of actors	Target group for CE interventions, esp. processors



The baseline clearly identifies where interventions will have the greatest environmental, economic, and social return. Step 3 now takes this insight forward by defining the geographic and value chain focus, and by applying a materiality filter to prioritise circular actions that are both feasible and impactful.



Step 3: Prioritisation and Scope Definition

The informal cassava value chain is widespread across Ghana, but for this roadmap, prioritisation has been driven by the presence of intense value chain activity, clear CE hotspots, and demonstrated community readiness to innovate. By narrowing the geographic and sectoral scope, the roadmap ensures that pilot interventions are not only impactful but also feasible within the three-year implementation window.

Geographic Scope

The geographic focus for this circular transition is anchored in two regions: Ashanti (Mampong and Sekyere Central) and Bono East (Techiman Municipality). These districts were selected through purposive sampling during the opportunity mapping study due to their high concentration of cassava production, processing, and trade. Collectively, these areas accounted for 100% of the total sample and provided a rich representation of smallholder farms, women-led processing hubs, and market-based trading operations in an informal setting.

- **Mampong Municipality** was notable for having both household-scale and cooperative-level processors actively engaged in gari production.
- **Sekyere Central District** offered insights into rural processing clusters and informal waste management practices.
- **Techiman Municipality** emerged as a central trading hub, with dense volumes of cassava flowing through markets and a high density of traders (over 60 traders sampled), making it a strategic point for circular logistics and byproduct

aggregation.

These locations are not only ecologically and socially distinct but are also already embedded in ongoing institutional partnerships through the UNIDO project and KNUST's field activities, ensuring continuity, trust, and ease of follow-up.

The scope includes smallholder farmers, agro-processors (gari, chips, flour), traders/marketers, and related support services. Key priority areas identified by the study are:

- **Energy Efficiency in Processing:** Processing is the most energy-intensive node (≈ 17 MJ/kg), driven by firewood-based for roasting/frying gari. Priority interventions include designing and deploying improved stoves/ovens to cut fuel use and GHG emissions.
- **Byproduct Valorisation:** Two major waste streams present high-value opportunities:
 - Cassava Peels: $\sim 40\%$ of peels are currently discarded. Valorising these peels into compost, biogas, or formulated animal feed is a priority.
 - Effluent (Liquid Starch): High volumes of effluent are lost during processing. Research shows effluent can be processed into bio-herbicide for weed control by smallholders, so this is a targeted innovation area.
- **Logistics and Transport:** Farmers incur high fuel use (~ 132 L/farm) due to small loads and poor planning. Aggregating harvests, scheduling transport, and improving route planning are priority actions to cut transport energy use and losses.
- **Knowledge and Capacity:** Actors at all

nodes have limited awareness of circular practices. Training and extension on best practices (e.g. composting, efficient processing) are needed.

- **Gender and Social Inclusion:** Women are central to cassava production but are even more present in processing and trading. Ensuring equal access to inputs, training, and financing (a gendered approach) is a priority. Low cooperative membership indicates a social priority: building value-chain associations to pool resources and share innovations.

Value Chain Focus

Within these districts, the roadmap focuses exclusively on cassava-based product systems, particularly:

- **Gari** (cassava grits), which is the most processed product, primarily by women
- **Cassava flour** (Konkonte), produced from fresh tubers after they are dried into chips
- **Agbelima** (fermented dough), a culturally important and commercially traded product.

These product systems were selected because they dominate the processing activity in the study zones and are associated with the three highest circularity leakage points: high firewood usage in gari production, underutilised peel waste, and effluent loss during pressing and fermentation. The alignment of value chain importance with circular intervention potential makes this product cluster a good pilot site for action.

Prioritised Opportunities

Drawing from the MFA and LCA diagnostics, as well as the constraints and practices reported by actors, four circular

interventions stand out for immediate investment and piloting:

1. Deployment of energy-efficient ovens to reduce firewood dependence in gari production

- Women processors currently rely on open fire roasting, consuming ~2.7 kg of firewood per kg of gari. With 244 tonnes of firewood used annually, this not only drives up GHGs (494,081 kg CO₂eq/year from processing) but also exposes processors to health risks. Field interest in improved ovens was high, particularly among processors seeking to reduce fuel costs.

2. Valorisation of cassava peels into animal feed and compost

- Processors generate nearly 98 tonnes of peels annually, with 40% discarded. Peels are nutritionally valuable and can be converted into feed pellets or compost with minimal technology. The study found that while 60% of peels are fed to animals, no formal processing or packaging is in place, representing a missed enterprise opportunity, especially for women and youth.

3. Effluent collection and conversion into bio-herbicide

- Each tonne of cassava processed generates ~300 L of liquid starch. With 235,116 L/year currently going to waste, the potential to produce a natural herbicide is significant. Preliminary academic evidence and anecdotal processor accounts confirm its phytotoxic properties. If scaled, this innovation could reduce reliance on synthetic herbicides and introduce a new local input into smallholder farming.

4. Regenerative agriculture to improve soil health and productivity

- Average cassava yield in the study area is significantly lower than the national average of about 24Mt/Ha. Low soil fertility and poor agronomic practices could account for this yield gap. There is potential for regenerative agricultural intervention to promote soil fertility and adoption of Good Agricultural Practices (GAPs) to improve cassava yield for enhanced household income and business profitability at the farmer level. Application of organic compost in cassava-legume (cowpea and groundnut) intercropping systems could be piloted on smallholder farms to evaluate impact on soil health and cassava yield in the study locations. If

scaled, this innovation could allow cassava farmers to utilize compost made from cassava peels and other farm residues to improve circularity, improve soil health and enhance crop productivity.

These four interventions were not selected arbitrarily. Each emerged from quantitative resource flow analysis, stakeholder interest, and precedent within the local innovation ecosystem (e.g. KNUST’s experience in product valorisation and pilot-ready communities in Ashanti and Bono East regions).

Feasibility and Impact Assessment

Using a feasibility-impact filter informed by the opportunity mapping data and field interviews, all four interventions rank as both high impact and high feasibility:

Opportunity	Feasibility	Impact	Justification
Energy-efficient ovens	High	High	Low-tech prototypes exist; strong interest from women; immediate fuel and GHG savings
Peel valorisation	High	High	Abundant feedstock; low entry cost; demand from livestock owners
Effluent valorisation	Medium-High	High	Requires more R&D but offers systemic agronomic benefits and circular innovation leadership
Regenerative agricultural intervention	High	High	Local knowledge and capacity with respect to intercropping system using legumes. While organic compost will improve soil structure, the nitrogen fixing property of legume intercrop will benefit the over all soil health in the study location.

These priorities are not only technically viable but are also socially embedded, they respond to real pain points identified by value chain actors and offer economic incentives alongside environmental gains.

Summary

Parameter	Value
Firewood use in processing	~244,185 kg/year
Energy intensity (gari)	17.03 MJ/kg
Peel waste (total)	97,965 kg/year
Unused peels (40%)	~39,186 kg/year
Effluent loss	~235,116 L/year
Processing GHG emissions	494,081 kg CO ₂ eq/year
Processor interest in innovation	Strong (based on constraints and interviews)
Cooperative readiness in Techiman/ Mampong	Emergent; 6 planned for formation; strengthen existing ones (2).



Having defined where and what to act on, the next step is to identify who will be central to this transformation. Step 4 maps the network of institutions, cooperatives, innovators, and informal actors who must be mobilised, trained, and resourced to co-create, implement, and sustain the CE vision on the ground.



Step 4: Stakeholder Mapping and Engagement Design

A circular transition within Ghana's cassava value chain cannot be driven by technical solutions alone, it requires committed collaboration across a diverse network of actors already embedded in the production, processing, and trading of cassava. The opportunity mapping study conducted in Ashanti and Bono East revealed a rich but under-connected landscape of value chain participants, institutions, and facilitators whose coordination will be essential to achieving scale and resilience.

Stakeholder mapping during the baseline exercise focused on actors' roles, levels of engagement, institutional capacity, and social capital, especially cooperative presence and gendered participation. The results underline both the potential and the fragmentation of the current ecosystem. This section presents a grounded design for activating stakeholder roles, responsibilities, and platforms for meaningful engagement.

4.1 Key Stakeholders and Institutional Roles

1. Ministry of Environment, Science, Technology and Innovation (MESTI)

MESTI serves as the national policy lead on Ghana's circular economy transition and will act as the co-chair of the project Steering Committee. As the line ministry responsible for environmental governance and sustainability innovation, MESTI's role includes anchoring this roadmap within the national CE policy framework, ensuring alignment with the Circular

Economy Action Plan, and overseeing cross-sector coordination with trade, agriculture, and local government actors. MESTI will also provide guidance on environmental safeguards, data reporting protocols, and the eventual integration of CE indicators into national M&E frameworks.

2. United Nations Industrial Development Organization (UNIDO)

As the commissioning agency of the opportunity mapping exercise and lead technical partner, UNIDO plays a central coordinating role. It facilitated the Material Flow Analysis (MFA) and Life Cycle Assessment (LCA) processes and will continue to guide roadmap implementation and pilot design. UNIDO will support innovation partnerships, build linkages with global CE platforms, and provide capacity support to national agencies, particularly on integrating CE into industrial upgrading pathways and SME development strategies.

3. Ministry of Trade, Industry and Agribusiness (MoTIA)

Given that circular opportunities such as peel valorisation, bio-herbicide commercialisation, and energy-efficient oven fabrication contribute to Ghana's local industrialisation ambitions and agribusiness development, MoTIA will support the formalisation of circular enterprises and facilitate the scaling of clean technologies. MoTIA's Business Resource Centres (BRCs) and local fabrication ecosystems are critical channels for incubating and sustaining CE business models developed through this roadmap.

4. Ministry of Food and Agriculture (MoFA)

MoFA's participation is essential in integrating circularity into agricultural practices and farmer extension. This includes promoting sustainable input use (e.g., bio-herbicides), supporting compost and feed trials, regenerative agricultural technology trials, and aligning CE interventions with the Medium-Term Agricultural Sector Investment Plan (METASIP). MoFA will also play a key role in validating CE innovations through farmer field trials and supporting their scale-up through the national extension system.

5. Local Government Authorities (District Assemblies in Mampong, Techiman, Sekyere Central)

District Assemblies are critical to local-level CE implementation. Their responsibilities include embedding CE into District Medium-Term Development Plans (DMTDPs), allocating land for processing hubs, facilitating local SME licensing, and coordinating environmental permitting. The roadmap anticipates their role in mobilising local cooperatives, validating pilot activities, and supporting data collection for Monitoring, Reporting, and Verification (MRV).

6. Value Chain Actors: Producers, Processors, Traders

The success of the roadmap ultimately rests with the 765 value chain actors surveyed:

- **Producers (465 sampled, 50.3% women):** Critical for field-level application of compost and the reuse of planting materials. Many operate on low-margin, high-labour models and will benefit from circular inputs and training.

- **Processors (198 sampled, 93.4% women):** Primary interface for cassava transformation and largest generators of waste (peels, effluent). Their engagement is central to energy efficiency upgrades and waste valorisation pilots.

- **Traders (102 sampled):** Though responsible for a smaller share of waste (~1.24% per actor), collectively generate an estimated **11,007 kg/month** in post-harvest and market losses. They are a critical but often under-supported group, with only **10.8%** belonging to cooperatives.

7. Cooperatives and Informal Groups

Social capital across the cassava value chain remains low, with only 15.2% of all actors reporting cooperative membership. The roadmap identifies cooperative formation and strengthening—particularly among women processors and rural traders—as essential mechanisms for accessing shared infrastructure, finance, and training. These groups will be supported as both beneficiaries and implementation partners, especially in the peel valorisation and clean oven pilots.

4.2 Stakeholder Engagement Platforms

Informed by the opportunity mapping findings and the constraints actors face (e.g. limited literacy, weak network structures, high cost of inputs), three key engagement platforms are proposed to build trust, increase coordination, and support bottom-up participation in roadmap implementation:

1. Regional Circular Design Labs (6 over 3 years)

These will be held twice annually, once in Ashanti and once in Bono East, between 2025 and 2027. Each lab will bring together value chain actors, local government, researchers, and SMEs to collaboratively design and refine circular innovations. For example, design labs may focus on fabricating efficient ovens with local artisans or trialling peel composting techniques with processors and farmers.

2. Bi-annual Value Chain Forums

These forums will convene producers, processors, traders, district-level officers, and national stakeholders for knowledge exchange, reporting on pilot progress, and planning next steps.

They will also serve as feedback loops, ensuring innovations remain grounded in community experience and evolving constraints.

3. Community Listening Sessions and Practical Demonstrations

Field data highlighted the low formal education levels among actors (only 17% had secondary education or higher). To ensure accessibility, roadmap consultations and trainings will use oral, pictorial, and demonstration-based formats. Listening sessions will surface barriers and local innovations, while demonstration days will test new approaches in real time, such as using effluent for weed control or constructing low-cost peel dryers powered by solar energy.

Summary

Stakeholder Group	Role	Data Insight
UNIDO	Roadmap coordination, funding, pilot support	Commissioning agency; provided LCA/MFA technical support
MoTI	Industry support, CE policy integration	Responsible for local manufacturing and product certification
MoFA	Input validation, training, farm-level circularity	Engages farmers; central to effluent-based herbicide uptake
District Assemblies	Host pilots, integrate CE into planning	Key in coordinating local actors and facilities
Producers	Field-level waste and transport practices	465 surveyed; only 13.8% in cooperatives
Processors	Generate peels and effluent, manage energy	198 surveyed; 93.4% women; high firewood use and losses
Traders	Manage downstream waste and markets	102 surveyed; waste per actor ~108 kg/month
Cooperatives	Enable scaling, training, finance access	Only 15.2% of actors are members; major scaling gap



With stakeholders identified and practical engagement platforms in place, the roadmap must now be anchored in a clear structure of action. Step 5 lays out the strategic pillars, from sustainable energy and waste valorisation to policy support and education, and identifies the policy instruments and system enablers needed to drive a successful and inclusive circular transition.



Step 5: Pillars, Levers and Enablers

The successful implementation of a CE roadmap depends not only on identifying opportunities and actors but also on structuring the transition around a coherent set of pillars, supported by appropriate policy tools and system enablers. These pillars guide where action should be focused, while levers and enablers help unlock the change needed across technical,

financial, institutional, and behavioural dimensions.

The following strategic pillars, policy instruments, and system enablers have been derived directly from the opportunity mapping study conducted in Ashanti and Bono East regions, and are tailored to the realities of the cassava value chain.

5.1 Strategic Pillars

1. Clean Energy Transition

The cassava processing node, dominated by women, was found to be extremely energy-intensive, consuming over 244,000 kg of firewood annually, which translates to an average of 17.03 MJ per kg of gari produced. This is a major environmental and social hotspot, contributing to deforestation, high greenhouse gas emissions (494,081 kg CO₂eq/year), and significant health risks for

women exposed to prolonged woodsmoke during roasting.

This pillar calls for a shift from firewood dependency to more efficient and cleaner thermal energy systems, such as locally fabricated energy-efficient ovens (e.g. Smoke-free ovens) or bio-based fuel alternatives. Circular energy systems could drastically reduce fuel costs, improve air quality, and enhance productivity, especially among small-scale women processors.



The cassava processing node, dominated by women, was found to be extremely energy-intensive, consuming over **244,000kg of firewood annually**



2. Waste Valorisation

Across the processing and trading stages, the study identified substantial volumes of unutilised byproducts:

- **Cassava peels:** 97,965 kg/year generated; 40% (~39,186 kg) discarded or underused.
- **Effluent:** 235,116 L/year lost during pressing, despite evidence of herbicidal properties.
- **Market waste:** ~11,007 kg/month from

traders.

This pillar aims to capture and re-integrate these waste streams into productive use. Valorisation pathways include composting, livestock feed production, and local development of effluent-based bio-herbicides. The roadmap envisions decentralised peel processing micro-units, effluent capture systems, and coordinated waste aggregation at markets.

3. Social Capital Strengthening

The mapping revealed very low cooperative membership (15.2% overall) and a marked gender imbalance in land access and decision-making. While 68% of cassava actors are women, their involvement in cooperatives, especially those led by men, is limited. Most actors operate in isolation, limiting their ability to access finance, training, or scale innovation.

This pillar focuses on building social capital through the formation and strengthening of cooperatives and associations, particularly for women and youth. Cooperatives can serve as the delivery channels for CE training, aggregation of waste/byproducts, and shared access to processing equipment or transport. Empowered social groups also offer a foundation for sustained behavioural change and peer-to-peer knowledge diffusion.

4. Inclusive Innovation

The roadmap's design labs, listening sessions, and hackathons aim to mobilise actors at all levels to co-develop, test, and scale appropriate circular innovations. The opportunity mapping revealed a rich pool of tacit knowledge and informal practices (e.g., using peels for livestock feed) that can be formalised and improved.

This pillar emphasises bottom-up innovation processes, local fabrication of equipment, and the embedding of user-led design in every stage of the circular transition. It also calls for integration of CE topics into farmer field schools, extension training, and community demonstrations.

5.2 Policy Instruments

To support these pillars, three policy levers have been identified as appropriate and realistic within the context of the value chain:

1. Incentives for Circular Tech Adoption

Targeted subsidies or grants can support the procurement and local fabrication of energy-efficient ovens, peel shredders, and effluent collection kits. Such incentives will reduce the upfront cost burden for women processors and SMEs and help accelerate adoption of circular technologies.

2. Certification Schemes for Circular Products

Although still emerging, products like effluent-based bio-herbicides and peel-based compost require quality assurance to gain trust and scale. The roadmap proposes the development of basic local certification protocols, led by MoFA's Plant Protection and Regulatory Services Directorate (PPRSD) and local assemblies, to ensure safety, agronomic efficacy, and regulatory compliance.

3. Circular Innovation Challenge Fund

To stimulate grassroots innovation, a regional challenge fund could be launched to reward circular solutions with proven local relevance and scalability. Priority would be given to innovations led by cooperatives, women's groups, and youth associations, especially those that reduce waste, improve energy use, or generate new income streams.

5.3 System Enablers

In order to implement these pillars and instruments effectively, the roadmap includes the following system enablers, grounded in observations from the field:

1. CE Toolkits for Local Government Institutions

District Assemblies require practical tools to integrate CE into spatial planning, enterprise permitting, and local budgeting. Toolkits may include templates for valorisation hub licensing, monitoring circular KPIs in DMTDPs, and guidelines for safe effluent use in agriculture.

2. Modular CE Training in Local Languages

With only 17% of cassava actors having attained secondary education or higher, all training must be designed for accessibility.

Modules should use visual aids, participatory demonstrations, and oral delivery in local languages (Twi, Bono, etc.). Topics include waste segregation, cooperative management, oven maintenance, and safe handling of bio-herbicides, as well as food safety and hygienic handling of cassava-based food products.

3. Mobile Data Tracking Tools for Cooperatives

Simple mobile-based logs or paper-to-digital systems can help newly formed cooperatives track waste volumes, product outputs, energy consumption, and market returns. These tools also serve as evidence for future funding, monitoring CE uptake, and supporting transparency in group operations.

Summary

Element	Insight from Report
Firewood use	244,185 kg/year (\approx 17.03 MJ/kg product)
GHG emissions (processing)	494,081 kg CO ₂ eq/year
Peel waste	97,965 kg/year; 40% unutilised
Effluent lost	235,116 L/year; no formal reuse
Cooperative membership	Only 15.2% across all actor categories
Female processor share	93.4% of processors; but low in formal groups
Education level	Only 17% had secondary school or higher
Tech readiness	Processors already reusing 60% of peels informally
Cassava yield at farmer level	Average cassava yield of about 18,635kg/ha compared to national average of about 24,000kg/ha.



With the foundational pillars and enabling structures now in place, the next section shifts from planning to action. Step 6 details how these priorities will be tested through concrete pilot projects, designed with clear objectives, targeted stakeholders, measurable KPIs, and scalable business models. These pilots will not only validate circular solutions but serve as living laboratories for Ghana's agro-based CE.

Step 6: Pilot Design and Execution

Based on the baseline data and direct field consultations, three pilot interventions have been identified as immediate circular economy opportunities within Ghana's cassava value chain. Each one addresses a different point of inefficiency in the value chain, waste, energy, or underutilised resources, and reflects the current structure of the sector, where most processing is done informally and over 9 in 10 processors are women. These pilots are structured to be practical, affordable, and adaptable, using tools that can be fabricated locally and operated with limited technical training. They are designed to generate evidence for scale while directly supporting communities that already participate in the value chain.

Pilot 1: Valorisation of Cassava Effluent into Bio-Herbicide

Context and Rationale



An estimated **235,116 litres of cassava processing effluent**, starch water, are generated annually by surveyed processors.

An estimated 235,116 litres of cassava processing effluent, starch water, are generated annually by surveyed processors. That's roughly the amount needed to fill 100 standard water tanks, yet none of it is currently reused. The waste is typically discharged into the environment, where it creates odour and suppresses nearby vegetation.

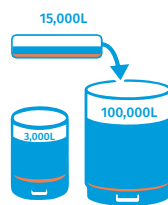
Field observations and the literature suggest that cassava effluent may have herbicidal properties due to its acidity and chemical composition. This pilot aims to test whether it can be processed and applied as a low-cost bio-herbicide, particularly for smallholder farmers who struggle to afford synthetic agro-inputs.

Pilot 1: Valorisation of Cassava Effluent into Bio-Herbicide

Pilot Summary



The intervention will be carried out across five processing hubs (**three in Techiman and two in Mampong**), each processing approximately **10 tonnes of cassava**



per month and producing **3,000 litres** of effluent. With a combined yield of around **15,000 litres** per month, the pilot is expected to recover **≥ 100,000 litres** within **seven months**.

The intervention will be carried out across five processing hubs (three in Techiman and two in Mampong), each processing approximately 10 tonnes of cassava per month and producing 3,000 litres of effluent. With a combined yield of around 15,000 litres per month, the pilot is expected to recover ≥100,000 litres within seven months. The full pilot will last 18 months, including design, fabrication, field testing, and monitoring.

Key Activities

- Construct low-cost effluent catchment and settling tanks using locally available materials.
- Filter and dilute effluent for safe field application.
- Train ≥100 smallholder farmers on safe handling and application methods.
- Compare crop performance and weed control outcomes with conventional herbicides.

Success Criteria

Indicator	Target Value	Explanation
Effluent reused	≥100,000 L	About four full tanker trucks of liquid waste repurposed.
Farmers adopting	≥100	Equivalent to one fully booked training group of trial participants.
Reduction in synthetic herbicide	≥30%	For every 10 litres used before, 3 litres are replaced with bio-herbicide.
Yield impact	No significant drop	No reduction in cassava or maize yield compared to control plots.
Equipment uptime	≥90%	Functional collection systems in use at least 27 days per month.
Safety incidents	0	No injuries or reported health impacts during pilot.
Satisfaction rate	≥80%	4 in 5 users report positive experience with the new solution.

Stakeholders and Roles

- **KNUST:** Research design, field trials, training delivery.
- **Processors:** Supply effluent and manage site operations.
- **Fabricators:** Construct collection and treatment infrastructure.
- **Farmers:** Apply product and provide field trial feedback.
- **MoFA Extension:** Deliver farmer training and monitor safety.
- **District Assemblies:** Facilitate permits and coordination.

Pilot 2: Peel Valorisation into Livestock Feed and Compost

Context and Rationale

Each year, surveyed processors generate approximately 98 tonnes of cassava peels. Around 60% of this is already reused informally, mostly as animal feed, but about 39 tonnes remain unused. That's the same weight as 15 small pickup trucks filled with waste, often left to rot or attract vermin.

This pilot will formalise the process of peel reuse by establishing two processing hubs, one in each target region, to convert peels into livestock feed and compost. The approach focuses on women-led groups, who already handle peel collection and processing in informal settings.

Pilot Summary



The initiative will run for **12 months in 2026**, supporting the creation of two **local micro-processing** hubs for drying, grinding, and composting.



It aims to divert at least **28,000 kg of unused peels**, with practical demonstration plots and informal market engagement.

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Key Activities

- Engage existing women's groups to organise collection and management.
- Build drying racks and choppers from locally sourced materials.
- Conduct compost trials on cassava farms to test soil and yield impacts.
- Test livestock feed with local buyers and smallholder farmers.

Success Criteria

Indicator	Target Value	Explanation
Peel reused	≥28,000 kg	Roughly the weight of 4 mature dairy cows of peel redirected into productive use.
Compost batches piloted	≥20	Enough to fertilise 20 smallholder cassava farms.
Feed batches produced	≥50	Provides a feed trial base for at least 50 small livestock owners.
Women's groups involved	≥4	One group per district engaged in operations.
Market sale of output	≥60% of volume	More than half the product finds willing buyers or users.
Satisfaction rate	≥80%	8 out of 10 participants express confidence in the new practice.

Stakeholders and Roles

- **Women's Cooperatives:** Lead collection and operations.
- **Local Fabricators:** Build and supply equipment.
- **KNUST:** Provide composting protocols and safety guidance.
- **Farmers and Traders:** Use or distribute finished products.

Pilot 3: Clean Energy Transition for Gari Processing

Context and Rationale

Processing gari requires heat-intensive roasting, which in the mapped regions currently consumes more than 244,000 kilograms of firewood annually. This is equivalent to burning the weight of ten full-grown giraffes every year just to roast cassava. The work environment is also risky, processors face exposure to open flames, high temperatures, and smoke.

This pilot introduces ten energy-efficient gari ovens, custom-designed with local fabricators and vocational institutes. The aim is to reduce fuel consumption and improve user safety, while testing shared access models for informal groups.

Pilot Summary

The ovens will be deployed across selected sites in Techiman and Mampong. The pilot will run for 12 months and will provide training for at least 50 processors in energy-saving and maintenance techniques.

Key Activities

- Co-design the ovens with end users and technical partners.
- Install ovens in shared or cooperative locations.
- Train processors in fuel stacking, airflow control, and safe use.
- Monitor firewood consumption and production rates.

Success Criteria

Indicator	Target Value	Explanation
Energy-efficient ovens deployed	10 units	Covering two processing clusters with shared usage models.
Firewood reduction	≥20%	Saving one in every five logs previously consumed.
Processors trained	≥50	A group large enough to represent one medium-sized association of processors.
Productivity increase	≥15%	For every 10 bags of gari previously produced, 11.5 bags expected after upgrade.
Safety incidents	0	No recorded injuries or burns due to improved design.
Equipment uptime	≥90%	More than 11 months out of 12 in active operation.
Satisfaction rate	≥80%	Majority of users report improved experience with equipment.

Stakeholders and Roles

- **Processors:** Main users and testers of equipment.
- **Vocational Institutes:** Fabrication support and training.
- **KNUST:** Support monitoring and user feedback.
- **MoTI & MoFA:** Assist with policy linkage and coordination.
- **District Assemblies:** Support rollout and community facilitation.

Pilot 4: Regenerative agriculture for improved soil health and productivity

Context and Rationale

Average yield for smallholder cassava farmers was found to be about 20% lower than the national average. Low soil fertility and poor agronomic practices partly account for this state of affairs. This pilot is aimed at integrating the use of organic composts and legume intercrops (cowpea and groundnuts) on selected cassava farms/sites for improved soil structure, fertility and enhanced crop yield. If scaled, this innovation could allow cassava farmers to utilize compost from cassava peels and other farm residues to improve circularity, improve soil health and enhance crop productivity. Field trials will be established, and yield data will be analyzed after one full production cycle.

Pilot 4: Regenerative agriculture for improved soil health and productivity

Pilot Summary

The initiative will run for 12-15 months in 2026/27 crop year depending on the cassava variety planted. Six pilot sites (2 per district) will be established to test various treatments under different input combination and intercropping patterns. It aims to improve cassava yield by at least 20% through the use of demonstration plots and farms to enhance knowledge transfer.

Key Activities

- Engage existing farmers to identify pilot project sites.
- Set up demonstration plots and experimental farms at strategic locations.
- Conduct compost trials, legume intercropping trials and assess impact on soil health and crop yield.
- Evaluate the impact of technology on farm income and business profitability.

Success Criteria

Indicator	Target Value	Explanation
Field trials established	≥6	At least six trial/demo sites established across three districts (2 sites per district). Demo plots for different combinations of technologies including composting and legume intercropping patterns established.
Compost produced for field trials	≥20	Enough to fertilise at least 6 demo sites.
Women's groups involved	≥6	Two groups per district engaged in trials.
Fertility of soil improved	≥25% of volume	Structure and fertility of soil for cassava production improved through compost application and intercropping with legumes.
Yield improved	≥20%	Cassava yield expected to increase by at least 20% following the interventions.
Farm income improved	≥30%	Income from cassava and intercropped legumes likely to increase farm income by at least 30% and profitability by at least 20%.

Stakeholders and Roles

- **Farmer Cooperatives:** Provide land and actively participate in field trials and demonstrations.
- **Agro-input Dealers:** Supply of certified seeds of grain legumes (cowpea and groundnut).
- **KNUST:** Provide composting protocols and technical expertise to guide intercropping as well as GAPs on selected farms or Demo sites.
- **Farmers:** Undertake field activities and marketing of harvested produce.

Cross-Cutting Pilot Features

All pilots are designed with local capacity in mind. Women, who represent most processors (9 in 10), are central to all four. Young people will be engaged in fabrication and operations. Each pilot uses low-cost materials, designed for ease of use in areas with low literacy levels, noting that about 4 in 5 of surveyed actors had not completed secondary school, so training will be delivered in local languages, combining visual instruction with demonstrations. All pilots will be integrated into the Monitoring, Reporting, and Verification (MRV) system in Step 8, ensuring clear performance tracking across environmental, economic, and social metrics.



About **4 in 5** of surveyed actors had not completed **secondary school**, so training will be delivered in local languages, combining visual instruction with demonstrations..



Step 7: Action Plan and Implementation Pathways

The transition to a circular cassava economy in Ghana requires an actionable, phased plan that is both technically feasible and socially inclusive. This action plan spans from 2025 to 2028, aligning with Ghana's medium-term planning cycles. It responds directly to field data collected from Ashanti and Bono East Regions, where over 97,000 kg of peels, more than 235,000 litres of effluent, and roughly 244,000 kg of firewood are used or wasted annually across the surveyed cassava processors.

The roadmap breaks down implementation into three core phases: (1) early prototyping and capacity building, (2) demonstration and network strengthening, and (3) national integration and replication. Each phase builds on validated interventions, starting with targeted pilots and ending with institutional embedding and cross-district scale-up.

Short-Term Actions (2025–2026): Foundation and Prototyping

The short-term focus is on operational readiness: co-developing pilot models, validating their design with stakeholders, and deploying foundational tools and trainings.

Key Activities:

- Stakeholder Validation Workshops will be held in Mampong and Techiman. These sessions will involve processors, traders, local officials, and cooperative representatives. This ensures that pilot activities reflect the needs of real actors, especially women, who make up 93.4% of surveyed processors, but only 15.2% belong to cooperatives.
- Finalisation of the Bio-Herbicide Pilot, including site selection, farmer enrolment, formulation testing, and risk protocols. With 235,116 litres of cassava effluent produced annually and 100% discarded, the pilot targets recovery of at least 100,000 litres over 18 months.
- Establishing the regenerative agriculture pilot that integrates organic compost and legume intercropping system in cassava production across the three study districts (2 communities per district).
- Initial training for Women Processors, focusing on safe energy use, waste handling, and benefits of cooperation as well as food safety standards. This responds to a critical gap: only 17% of surveyed actors had completed secondary school.
- Fabrication and Installation of 10 Energy-Efficient Ovens, prioritising clusters with high firewood consumption (currently averaging 17.03 MJ/kg of gari). These ovens will be co-designed with users and fabricated by local metalworkers and vocational institutes.

Medium-Term Actions (2026–2027): Demonstration and Organisational Strengthening

This phase is focused on validating circular outputs, deepening cooperative structures, and broadening participation.

Key Activities:

- Establish Two Peel Valorisation Micro-Centres, one in each region. These centres will process unused peel waste, currently ~39,000 kg/year, into compost and livestock feed. Drying and chopping tools will be fabricated locally, with training on safety and hygiene.
- Complete the Effluent-to-Herbicide Pilot, with MoFA-supported field trials. Results will inform potential safety regulations and further scale.
- Complete the Regenerative Agriculture Pilot, with MoFA-supported field trials and Demos. Results will inform further scale.
- Form Six New Cooperatives, three per region, aimed at engaging processors, traders, and equipment fabricators. This responds to the low baseline: only 10.8% of traders and 13.8% of producers are currently organised into any formal group.
- Host Two Regional Value Chain Forums to assess pilot outcomes, refine designs, and begin planning for broader replication. These forums will also serve as platforms for showcasing early entrepreneurial innovations.

Long-Term Actions (2027–2028): Scaling and Policy Integration

The long-term phase focuses on moving beyond pilots and integrating circular approaches into mainstream policies, markets, and agricultural planning tools.

Key Activities:

- Scale Peel and Compost Operations to Four Districts, extending beyond the original pilot sites. New districts will be selected based on cassava production volume and the presence of active processor groups.
- Scale the Regenerative Agriculture project to Four Districts, extending beyond the original pilot districts. New districts will be selected based on cassava production volume, farmer interest and the potential for the use of legumes as intercrop.
- Certify Effluent-Derived Bio-Herbicide in partnership with the Environmental Protection Agency (EPA) and MoFA-PPRSD, enabling formal distribution and market uptake as a low-cost input.
- Integrate Circular Economy Indicators into national and district agricultural reporting systems. These include metrics such as:
 - % of firewood reduction per kg of gari produced
 - Volume of waste valorised
 - % increase in cooperative participation
- Publish a CE Casebook and Investment Prospectus, to attract funding and document models. This will include technical schematics, business models, and cost-benefit data from pilots.

Phased Summary Table

Phase	Timeline	Key Outputs
Short-Term	2025–2026	2 validation workshops, 10 ovens installed, effluent pilot launched, 100+ trained
Medium-Term	2026–2027	2 micro-centres built, herbicide trial completed, 6 coops formed, 2 forums held. Six sites for regenerative agriculture trials completed, trial results determined and communicated to stakeholders.
Long-Term	2027–2028	Compost/feed scaled to 4 districts, bio-herbicide certified, CE KPIs adopted

Summary Table

Metric	Baseline	Target by 2028
Firewood use (kg/year)	~244,185 kg	≥20% reduction in pilot hubs
Peel waste (kg/year)	~97,965 kg	≥70% valorised through feed/compost
Effluent discarded (L/year)	~235,116 L	≥100,000 L valorised in pilot
Cooperative participation	15.2% (processors)	+40% via 6 new cooperatives
Certified circular products	0	At least 1 (bio-herbicide)
CE indicators in national systems	None	Adopted into MoFA and DMTDPs by 2028

This action plan builds directly on the pilots described in Step 6, translating interventions into time-bound, geographically targeted, and institutionally supported pathways. Activities are sequenced to ensure that early testing feeds directly into policy dialogues and business model replication.



Step 8: Monitoring, Reporting, and Verification (MRV)

Robust Monitoring, Reporting, and Verification (MRV) is critical to ensure that the transition towards a circular cassava economy delivers measurable impact. MRV not only helps track progress against environmental, economic, and social goals but also builds credibility, supports adaptive learning, and generates the evidence needed to attract policy and investment support.

The MRV framework proposed here is grounded in the quantitative and qualitative baselines established by the cassava opportunity mapping report. It translates the roadmap's strategic goals into KPIs across three dimensions, environmental, economic, and social, while leveraging appropriate data collection tools suited to the low-digital and low-literacy realities observed in the surveyed regions.

8.1 Environmental KPIs

Environmental indicators focus on resource efficiency, emissions reductions, and waste recovery, directly aligned with the LCA and MFA diagnostics in the report:

Indicator	Baseline	2028 Target	Source/Method
% Reduction in Firewood Use per kg Product	17.03 MJ/kg	-20%	Oven monitoring logs, processor self-reports
% of Peels Valorised	60% informal reuse	≥70% formal use	Volume tracking at valorisation hubs
% of Effluent Valorised	0% currently reused	≥42.5% (100,000 L)	Collection unit logs, cooperative records
GHG Avoided (kg CO₂e/year)	494,081 (processing)	≥100,000 kg reduction	Based on energy and waste reductions from pilots

The report highlights firewood use and effluent disposal as two of the biggest environmental hotspots. These KPIs directly measure improvements in these areas.

8.2 Economic KPIs

Economic indicators aim to assess whether circular innovations are creating value, improving livelihoods, and lowering operational costs:

Indicator	Baseline	2028 Target	Source/Method
Revenue from Circular Products (GHS)	0	Disaggregated by product (bio-herbicide, compost, feed)	Processor and trader sales logs
Cost Savings from Herbicide Substitution	~GHS 20-40/acre	≥30% savings among adopters	Farmer surveys and field cost comparisons
Jobs Created in CE Innovation Hubs	0	≥50 (processors, fabricators, waste handlers)	Cooperative employment records, hub staffing logs

The report notes the economic burden of agrochemical inputs on farmers and identifies local equipment fabrication and waste processing as high-potential job creators.

8.3 Social KPIs


Social indicators reflect the roadmap’s goal to strengthen social capital, promote gender inclusion, and expand cooperative membership, areas where the baseline showed clear gaps:

Indicator	Baseline	2028 Target	Source/Method
% Women and Youth in Cooperatives	15.2% overall (low male participation)	≥40% increase	Cooperative registers, gender/youth disaggregation
Number of Actors Trained in CE Practices	0	≥500 (processors, farmers, fabricators)	Training logs and attendance registers
Inclusion Score (Cooperative Index)	No index yet	New index combining gender, youth, and regional balance	To be developed through participatory scoring with local groups

These indicators are designed to ensure that CE practices are not only technically adopted but **socially anchored** in inclusive, well-supported structures.

8.4 Data Collection Tools

Given the constraints identified in the report, especially low literacy (only 17% of actors had senior secondary or higher education) and limited digital infrastructure, MRV tools must be practical, community-led, and low-cost.



Only **17%** of actors had **senior secondary or higher education** and limited digital infrastructure, MRV tools must be practical, community-led, and low-cost.

Tool	Description
Mobile Cooperative Logs	Low-bandwidth apps or SMS forms for recording byproduct volumes, training attendance, and revenue. Optional paper-to-digital sync via field agents.
Periodic Fuel and Waste Audits	Quarterly visits by extension officers or trained youth to measure fuel use, effluent collection, and peel recovery at pilot sites.
Household and Farm Surveys	Seasonal surveys to assess farmer cost savings, product uptake, and satisfaction with CE products (e.g. herbicide efficacy). Conducted in local languages by trusted enumerators.

The roadmap proposes that MRV be embedded in the routine activities of processors' groups, extension systems, and district officers, not introduced as a parallel system.

Summary

MRV Domain	KPI Example	Target
Environmental	GHGs avoided	≥100,000 kg CO ₂ eq/year
Economic	Jobs created	≥50 in CE-linked roles
Social	% women/youth in coops	+40% over baseline
Tools	Effluent logs, fuel audits, farmer surveys	Quarterly and annual cycles



Step 9: Financing Strategy and Investment Mobilisation

Transforming Ghana’s cassava value chain into a circular and regenerative system will require a strategic approach to financing, one that blends public, donor, and private capital, while reducing risk for early-stage innovators and community-based enterprises. The opportunity mapping report recognises the cost barriers faced by processors and traders (especially

women-led operations) and underscores the need for accessible, de-risked finance mechanisms to support circular transition.

This section outlines the estimated costs of key interventions, identifies likely financing sources, proposes de-risking approaches, and highlights the instruments required to attract sustained investment.

9.1 Cost Estimates for Priority Interventions

Based on scale, materials, and the technologies proposed throughout the roadmap, the following indicative cost ranges are grounded in comparable Ghanaian CE and SME development projects referenced within the cassava report’s methodology and institutional context.

Intervention	Estimated Cost (USD)	Notes
Energy-Efficient Oven Prototype Scale-Up	\$75,000	Includes fabrication of 10-15 units, technical training, and local deployment in Ashanti and Bono East
Peel Composting & Feed Processing Hubs	\$120,000	Two micro-centres with shredders, compost bays, drying racks, basic safety gear
Effluent-to-Herbicide Pilot and Certification	\$95,000	Equipment, field trials, MoFA and EPA engagement for regulatory clearance
Regenerative Agriculture for improved soil health and productivity	\$80,000	Inputs sourcing, search for and establishing Demo sites, Experimentation/trial, data capturing, analysis and reporting.

These costs reflect not just equipment, but the technical assistance, cooperative training, and field-level support needed to embed circular practices among actors with limited baseline resources.

9.2 Funding Sources

The opportunity mapping report highlighted weak formalisation and limited financial access across the cassava value chain, only 15.2% of actors belong to cooperatives, and informal processors dominate the landscape. To overcome this, the financing strategy proposes a blended model, drawing from multiple sources to spread risk and support inclusive participation.



Only **15.2%** of actors belong to **cooperatives**, and **informal processors** dominate the landscape.

1. UNIDO Seed Funding

As the commissioning agency and technical lead, UNIDO will provide initial pilot financing and technical support. This includes funding for research-validation, oven design, and the initial rounds of CE training.

2. District Assemblies Common Fund (DACF)

Assemblies in Mampong, Techiman, and Sekyere Central are encouraged to earmark portions of their DACF or IGF (Internally Generated Funds) to support infrastructure for CE pilots, especially those that reduce open dumping, enhance livelihoods, or integrate into local development plans.

3. Private Co-Investors and Ghana Climate Innovation Centre (GCIC)

The roadmap encourages partnerships with innovation centres and socially-aligned investment funds like GCIC, which has supported green SME solutions in Ghana. Local SMEs involved in compost packaging, input distribution, or CE equipment fabrication can co-finance with equity or performance-linked grants.

9.3 De-Risking Mechanisms

Given the relatively low financial capacity of many processors and the experimental nature of some CE interventions, de-risking is essential.

Mechanism	Description
Guarantee Funds for Circular SMEs	Small risk-sharing guarantees (e.g. 20-30%) to enable processors or fabricators to access loans for CE equipment
Circular Innovation Prize Awards	Competitive funding to reward community-led solutions with potential for scale. Could be disbursed annually through design labs or hackathons

These mechanisms aim to reduce the perceived risk for first-movers, incentivise innovation, and crowd in local entrepreneurial solutions.

9.4 Investment Instruments

To mobilise wider support and ensure transparency, two key instruments will be developed:

1. CE Investment Prospectus (mid-2026)

This document will consolidate costed pilot outcomes, highlight success stories (e.g. effluent reuse, feed production), and present clear investable opportunities to donors, banks, and climate funds. It will be curated in collaboration with MoTIA and development finance institutions.

2. Circular Innovation Challenge Fund

This pooled fund will provide grants (USD 2,000-10,000) to processors, cooperatives, or innovators proposing feasible circular solutions. Focus areas include: clean energy ovens, cassava peel upcycling, and bio-herbicide application tools.



This pooled **fund** will provide **grants (USD 2,000-10,000)**

Summary

Element	Value / Detail
Total estimated funding need	~\$370,000 across four interventions
% actors with coop access	15.2% (major barrier to formal financing)
Priority funding sources	UNIDO, DACF, GCIC, SME co-financing
Key risk areas	Technology affordability, low collateral, dealing with multiple regulators
De-risking tools	Guarantee funds, innovation prizes, phased rollout
Investment visibility tool	CE Investment Prospectus (planned mid-2026)



Step 10: Capacity Development and Institutional Strengthening

The cassava opportunity mapping study revealed that while technical potential for circularity exists across the value chain, significant human and institutional capacity gaps limit innovation, replication, and scale. Many processors and traders operate informally with limited training; few actors are members of cooperatives; and formal extension systems do not yet integrate circular principles. For CE interventions to be sustained, these structural weaknesses must be addressed through targeted capacity development and institutional alignment.

This step focuses on strengthening the human capital of processors, farmers, traders, and public officers, while enhancing the institutional environment to embed circularity into Ghana's agricultural governance.

10.1 Modular CE Training Curriculum

The study highlighted that only 17% of value chain actors had secondary education or higher, and many lacked formal training in waste valorisation, energy use, or cooperative management. To bridge this gap, the roadmap proposes a modular training curriculum with differentiated content for farmers, processors, and traders.

Curriculum Components:

- **For Farmers:** Compost use, field application of effluent-based

herbicides, intercropping cassava with legumes, harvesting and postharvest handling.

- **For Processors:** Oven maintenance, peel handling for feed and compost, basic bookkeeping
- **For Traders:** Waste segregation, packaging of value-added cassava products, cooperative marketing.

Modules will be delivered through oral methods, community demonstrations, and visual aids, in local languages (e.g. Twi and Bono), making them accessible to low-literacy actors.

10.2 Extension Officer Upskilling

District-level extension officers are often the first point of contact for farmers and processors but are not yet trained in CE principles. The roadmap proposes the training of 30 extension officers across Ashanti and Bono East in:

- Circular diagnostics and opportunity mapping
- Compost and bio-herbicide demonstration protocols
- Different intercropping patterns using legumes as cassava intercrops.
- Cooperative mobilisation techniques
- Circular product quality assurance basics

These officers will be equipped to support MRV activities (Step 8), supervise pilot rollouts (Step 6), and help embed CE practice into routine fieldwork.

10.3 Partnerships with Technical and Vocational Training Institutes

Local vocational training institutions and technical schools will be engaged to support **co-development and fabrication of circular tools**, such as:

- Improved energy-efficient ovens
- Peel chippers, compost bins, and solar dryers
- Low-cost effluent collection tanks and filtration kits

These partnerships will build local fabrication capacity, generate jobs, and increase tool availability beyond the pilot areas. They also help bridge the gap between informal ingenuity and institutional knowledge.

10.4 Institutional Integration: METASIP and District Plans

The Medium-Term Agriculture Sector Investment Plan (METASIP), Ghana’s national agricultural development framework, provides an ideal vehicle for institutionalising CE. The roadmap calls for CE principles and training modules to be:

- **Integrated into METASIP extension guidelines**, so that circularity becomes part of national outreach and training.
- **Reflected in District Medium-Term Development Plans (DMTDPs)**, with circular KPIs and targets included in budgeting and reporting cycles, as already proposed under Step 7.

Such integration will ensure that circular practices are not isolated pilot activities but part of Ghana’s mainstream agricultural system.

Summary

Capacity Element	Current Baseline	2028 Target
Education (secondary+) among actors	17%	Not directly targeted but mitigated through low-literacy content
Extension officers trained in CE	0	30 officers across 3 districts
Modular CE curricula developed	None	3 actor-specific modules (processors, farmers, traders)
CE tools fabricated locally	Ad hoc	Embedded in vocational school partnerships
CE in extension framework (METASIP)	Not yet	Integrated by 2027
CE in District Plans	Absent	Reflected in ≥3 district DMTDPs by 2028

Step 11: Governance and Integration Framework

Effective CE implementation in the cassava value chain depends on governance structures that are decentralised, inclusive, and aligned with Ghana's national planning systems. The opportunity mapping report makes it clear that while technical opportunities are evident, there is limited formal coordination across institutions, low cooperative membership (15.2% overall), and poor integration of circular principles in agricultural and district planning frameworks.



Low cooperative membership (15.2% overall)

This step proposes a layered governance framework spanning national, regional, and district levels, supported by existing institutions and development mechanisms.

11.1 Multi-Level Governance Structure

National Level

- **Lead Institutions:**
 - **UNIDO:** Acts as the coordinating technical partner supporting roadmap implementation and knowledge exchange.
 - **Ministry of Food and Agriculture (MoFA):** Integrates CE indicators into national agricultural policy and METASIP.
 - **Ministry of Trade, Industry and Agribusiness (MoTIA):** Supports SME formalisation, circular product standards, and access to markets.
- **National Oversight Committee on Agro-Based CE (proposed):**

A multi-stakeholder body to oversee CE roadmap alignment with national policy, reporting annually to NDPC and relevant ministries.

Regional Level (Ashanti, Bono East)

- **Regional CE Task Teams:**

Coordinated by regional MoFA

directorates and district assemblies, these teams will track progress on pilot rollouts, cooperative strengthening, and training delivery. Membership includes District Planning Units, District Directors of Agriculture, and selected cooperative representatives.

- **Mandate:**

Support policy alignment, data collection for MRV (Step 8), and coordination of regional value chain forums (Step 4).

District Level (Mampong, Sekyere Central, Techiman)

- **District Assemblies:**

Integrate CE objectives into District Medium-Term Development Plans (DMTDPs). The report recommends this as a scalable channel for embedding CE KPIs into local budgeting and monitoring frameworks.
- **Cooperative Councils:**

As new cooperatives form, each district will establish local advisory groups to represent grassroots actors in decision-making and ensure participatory feedback loops.

11.2 Integration into National Planning and Policy Systems

To ensure continuity beyond pilot phases, the roadmap identifies three primary integration points:

- 1. METASIP (Medium-Term Agriculture Sector Investment Plan)**
CE themes, particularly waste valorisation and low-cost innovation, will be included in extension modules and investment priorities under METASIP from 2026 onwards.
- 2. District Development Planning**
CE indicators (e.g. volume of waste valorised, number of circular enterprises, women in cooperatives) will be reported as part of annual DMTDP reviews. This creates an institutional link between pilot outcomes and district performance tracking.
- 3. Public Investment Planning**
Ministries and districts will be encouraged to include CE infrastructure in their Public Investment Plans,

qualifying them for DACF allocations and development partner co-financing (Step 9).

11.3 Institutionalisation and Oversight

To move from project-based activity to system-wide transformation, the roadmap proposes:

- **Formalising CE Secretariat Functions** within MoFA's Planning Directorate or a national body like the Council for Scientific and Industrial Research (CSIR), with dedicated staff to support agro-based circularity nationwide.
- **Embedding CE Focal Points** in District Planning Units, trained to coordinate pilot scale-up, data reporting, and institutional learning at the local level.
- **Annual CE Reviews** (starting 2026), jointly led by MoFA, MoTIA, and district representatives to track progress, revise KPIs, and capture innovations from the field.

Summary

Governance Layer	Lead Institutions	Role
National	UNIDO, MoFA, MoTIA	Coordination, policy alignment, investment mobilisation
Regional	Regional MoFA, DAs	Pilot monitoring, training oversight, data collection
District	Mampong, Sekyere Central, Techiman Assemblies	Local integration into DMTDPs, MRV, cooperative strengthening
Policy Integration Area	Baseline	Target by 2028
CE in METASIP	Not integrated	Integrated from 2026
CE indicators in DMTDPs	Absent	Present in ≥3 district plans
Circular product certification (e.g. bio-herbicide)	No formal pathway	EPA/MoFA pilot certification completed

Step 12: Communications, Behavioural Change and Cultural Shifts

While technical pilots, governance reforms, and financing structures lay the foundation for circular transformation, the real test lies in shifting the daily behaviours, norms, and values of those who power Ghana's cassava economy. The opportunity mapping study made it clear: the majority of actors are women (especially processors and traders), often operating in informal settings with limited access to formal training, literacy, or policy guidance. If circular practices are to take root, they must be embedded not just in programmes, but in culture, stories, and community identity.

This step outlines a culturally grounded communications strategy that goes beyond awareness-raising, and instead promotes peer-led storytelling, social proof, and participatory design to spark widespread engagement and adoption.

12.1 Community Storytelling and Recognition

Video Spotlights: "Women Turning Waste into Wealth"

Building on the finding that 93.4% of processors are women, short video documentaries will profile female innovators who are piloting peel valorisation, clean ovens, or bio-herbicide trials. These will be shot in local languages (Twi, Bono) and shown at community centres, value chain forums, and shared via WhatsApp groups.

The aim is to reposition circularity as an empowering, homegrown solution, rather

than an external concept. Women will be cast as climate leaders and business pioneers, helping shift social norms and legitimise circular techniques.

Annual "Cassava Circularity Awards"

Held at the end of each implementation year (starting 2026), these awards will publicly recognise outstanding actors in innovation, sustainability, and community cooperation. Categories may include:

- Best Clean Oven Usage
- Most Productive Peel Composting Hub
- Young Circular Champion (under 35)

Recognition, rather than monetary incentive, is a key motivator in informal economies. The awards will generate local pride, stimulate healthy competition, and attract media attention.

12.2 Low-Literacy and Local-Language Messaging

Radio Jingles and Talk Shows

Given the low formal education rates (only 17% of actors had secondary school or above), radio remains the most trusted and accessible medium. Local FM stations in Techiman and Mampong will broadcast jingles on:

- Safe use of effluent herbicide ("Aba so... no more weeds, no more harm!")
- How to reuse cassava peels for livestock feed and soil health
- Cooperative benefits and training dates

Radio dramas and call-in shows will also allow listeners to share experiences and ask questions in real time.

12.3 Visual Public Messaging

Circular Mural Art in Market Hubs

Working with local artists and youth cooperatives, public murals will be painted at key trading hubs and processing sites, especially where market waste volumes are high (11,007 kg/month according to the report) Themes will include:

- Waste-to-wealth (peel, effluent)
- Women leading change
- Farming for the future (compost, bio-inputs)

Murals provide daily reinforcement of circular values in a way that transcends literacy and generates local ownership.

12.4 Community-Led Messaging Channels

All messaging efforts will be designed with and for community actors. Where possible, informal leaders, traders' unions, and religious groups will help co-create content and verify messages before dissemination. This ensures credibility and uptake.

Platforms from previous roadmap steps, design labs, listening sessions, value chain forums, will be used not just for feedback but to generate creative content and field-test messages.

Summary

Communication Tool	Target Group	Justification (from report)
Storytelling videos	Processors (93.4% women)	Highlights real peer leaders
Radio jingles	Farmers, traders, low-literacy actors	Only 17% have secondary education
Mural art in hubs	Traders (waste hotspot)	11,007 kg/month waste in market zones
Awards & recognition	All value chain actors	Builds pride and healthy competition; supports informal incentive culture



Step 13: Circular Business Model Incubation and Scaling

Having piloted three practical circular interventions grounded in field realities, this final roadmap step focuses on translating those interventions into robust, investment-ready business models. These models respond directly to the inefficiencies mapped in Ghana's cassava value chain, ranging from uncontrolled waste and energy loss to limited economic participation among informal actors.

The approach is not to 'introduce' circularity from outside, but to elevate existing practices into structured, cooperative-led businesses. Each model leverages accessible technologies, responds to identifiable demand, and offers measurable returns, financial, social, and environmental. Their development is designed to be iterative, low-barrier, and well-integrated into existing value chain behaviours.

13.1 Circular Business Models Identified

Three circular models have been extracted directly from the pilot interventions and developed for incubation. Each addresses a persistent problem highlighted in the opportunity mapping, matched with a viable circular economy typology:

1. Effluent-to-Bio-Herbicide Social Enterprise

This model responds to the complete loss of cassava effluent, over **235,000 litres per year**, which is dumped without treatment. By converting it into a bio-herbicide, the model provides both an environmental solution and

an affordable agro-input. It fits the "resource recovery" archetype and can lower weed control costs for low-income farmers by up to **30%**.

2. Peel-to-Feed and Compost Women-led Cooperatives

With roughly **97,965 kg of peels** generated annually, and **40%** of this unutilised, there is a clear opportunity to create value from this biomass. This model, under the "cascade valorisation" typology, formalises existing informal reuse (animal feed, compost) into community-run micro-enterprises. Led by women processors and traders, it improves waste management and creates new income streams.

3. Shared Clean Oven Service Model

Many processors rely on inefficient, open-fire gari roasters, consuming nearly **244,000 kg of firewood annually**. This model introduces cleaner, fuel-saving ovens under a cooperative or shared-rental arrangement, aligned with the "product-as-a-service" model. It reduces emissions, improves product consistency, and lowers processing risks, particularly for women.

4. Regenerative Agriculture to improve soil health and productivity

Smallholder cassava farmers in the study sites have sub-optimal output per unit land area. This intervention integrates organic compost application and intercropping of cassava fields using grain legumes. This is likely to improve soil structure, soil fertility and enhance cassava productivity.

13.2 Projected Returns by Model

Each business model is expected to generate multidimensional value. These projected returns are built from the pilot phase results and data on energy use, waste volumes, market interest, and cooperative engagement.

Model	Economic Return	Environmental Return	Social Return
Effluent-to-Bio-Herbicide	Farmers reduce herbicide spending by up to 30%; processors earn from waste	100,000 L effluent diverted; reduces chemical input use	100+ smallholders supported; stronger processor–farmer linkages
Peel-to-Food & Compost Cooperatives	Sale of feed and compost supports 4 cooperatives; up to 60% of output monetised	28,000 kg of waste recovered in first year	Women cooperatives strengthened; new livelihoods in feed/soil input value chains
Shared Clean Oven Service Model	Reduced fuel cost per kg of gari; higher product consistency	≥20% firewood savings per processor; lower air pollutants	Improved health for women processors; community-managed asset ownership
Regenerative agriculture for improved soil health and productivity	Sale of additional cassava tubers and grain legumes supports 4 farmer cooperatives; up to 25% increase in farm income.	More than 28,000 kg of waste recovered in first year. Reduced usage of farm inputs by using grain legumes as intercrop on cassava fields.	Farmer cooperatives strengthened; new livelihoods in composting and grain legume value chains.

These outcomes are not just targets, they reflect feasible gains already observed during pilot preparation and validated through field-level consultations.

13.3 Readiness Pillars and Support Needs

Transitioning these models from concept to operational enterprise requires a blend of infrastructure, policy, and financial enablers. Each model’s success hinges on addressing four pillars of readiness:

Pillar	Support Needs
Technical Readiness	Local fabrication of ovens, fermenters, chippers; design validation with users; basic QA labs
Financial Viability	Seed grants or matching funds; SME de-risking mechanisms; access to revolving cooperative funds
Policy Fit	Support for EPA and MoFA (PPRSD) certification of bio-herbicide; MoTI co-operative recognition and licensure
Market Development	MoFA/NGO input procurement partnerships; linkages with livestock traders and agro-dealer networks

Each need has already been scoped with local partners, including vocational institutes, District Assemblies, and CE innovation networks.

13.4 Incubation Support Mechanisms

To prepare these models for scale, the following ecosystem support instruments will be deployed from 2025 through 2028:

- **Demo Days**
Held once per year, these regional showcases will allow early-stage entrepreneurs to present prototypes to public and private investors, exchange feedback, and receive recognition for circular achievements.
- **Innovation Roundtables**
Structured dialogues between

policymakers (e.g. MoFA, EPA), innovators, and cooperatives to address regulatory hurdles, create pathways to certification, and share lessons from pilot implementation.

- **Pre-Incubation Training**
Delivered by KNUST’s Circular Economy Hub and supported by MoTI’s Business Resource Centres. Focus areas include business planning, production safety, cooperative management, and CE literacy.
- **Access to Makerspaces and Shared Tooling**
Equipment like shredders, peel dryers, and oven parts will be fabricated and stored at municipal-level fabrication hubs. These centres also offer hands-on repair training and prototyping support to local fabricators.

13.5 Scaling Path

The scaling process is divided into three phases to ensure models are tested, refined, and replicated systematically:

Phase	Timeline	Key Outputs
Proof-of-Concept	2025–2026	Three circular business models tested, field data collected, initial sales made
Institutional Links	2026–2027	Bio-herbicide approved by EPA & MoFA PPRSD; MoFA adopts compost into soil health frameworks
Regional Replication	2027–2028	Business models replicated in 4 new districts; toolkit distributed to cooperatives

During replication, models will also be adapted for other bio-based value chains such as plantain, yam, or pineapple, using the CE Playbook as a guide.

Summary: Circular Business Model Scaling Framework

Model	Typology	Lead Actor	Target Region	Primary Outcome
Effluent-to-Bio-Herbicide Enterprise	Resource Recovery	Processors + Farmers	Ashanti and Bono East	Reduce synthetic input use; enable waste income
Peel-to-Feed & Compost Cooperative	Biowaste Valorisation	Women Processor Groups	Ashanti and Bono East	New cooperative income stream; compost market entry
Shared Clean Oven Service Model	Product-as-a-Service	Metalworkers + Cooperatives	Ashanti and Bono East	Safer, cleaner gari processing; fuel savings
Regenerative agriculture model	Soil regeneration and organic input recycling.	Farmer cooperatives	Ashanti and Bono East	New cooperative income stream; nutrient recycling, productivity enhancement and increased farm income.



Alignment to the Project M&E Strategy

The cassava circular economy roadmap aligns closely with the overarching objectives of the project's Monitoring and Evaluation (M&E) framework, even in the absence of finalised activity-level entries in the shared Excel workbook. Drawing from field data, intervention logic, and known UNIDO-aligned outcomes, this final chapter shows how each component of the roadmap is measurable, accountable, and relevant across environmental, economic, and social dimensions.

Each pilot, activity phase, and stakeholder mechanism described throughout the roadmap is purposefully crafted to generate quantifiable impacts that lend themselves to effective tracking and adaptive management.

1. Environmental Impact Tracking

Circular economy transitions are inherently environmental, and the cassava roadmap responds to pressing resource inefficiencies and pollution points documented in the baseline study. At least three key areas of environmental concern have corresponding indicators that align with standard M&E frameworks:

- **Biowaste Valorisation**

Each year, processors discard ~235,116 litres of cassava effluent and 39,186 kg of peel. Through the roadmap's pilot interventions:

- At least 100,000 L of effluent will be processed by end of 2026.

- 28,000 kg of peels will be converted into feed or compost in 2026, with expansion to four districts by 2028.
- These indicators will track reductions in unmanaged waste volumes and downstream impacts on soil and air quality.

- **Energy Efficiency and Emissions Reduction**

Firewood use across surveyed processors is estimated at ~244,185 kg/year. The pilot rollout of 10 energy-efficient ovens aims to:

- Cut energy use per unit of gari by 20% or more.
- Lower indirect emissions and reduce exposure to harmful smoke, especially for women operating roasting platforms.

- **Substitution of Synthetic Agro-Inputs**

By converting effluent into a bio-herbicide, the roadmap provides a low-cost, locally available alternative to chemical herbicides. This supports M&E targets related to:

- Chemical input reduction (target: 30% reduction in synthetic herbicide use across trial plots).
- Agronomic sustainability, with field trials measuring yield impacts and weed suppression efficacy.

2. Economic Impact and Livelihood Metrics

A strong emphasis is placed on making circular innovations economically viable for informal actors. Across the pilots and wider roadmap, the following key economic metrics support impact tracking:

- **Jobs and Enterprise Formation**

Each circular pilot is designed to be community-run or cooperative-led:

- At least 6 new cooperatives will be formalised by 2027 (3 per region).
- Each cooperative will link processors, fabricators, and traders, supporting upskilling and income diversification.
- By 2028, up to 25% profitability increase is projected among CE adopters due to resource savings and added revenue.

- **Revenue and Cost Savings Tracking**

The bio-herbicide pilot introduces a product that could cut herbicide expenditure for 100+ farmers.

- As 1 litre of synthetic herbicide can cost 3–5% of a farmer's weekly income, even modest uptake translates into measurable financial relief.
- The regenerative agriculture model is likely to increase cassava yield, thereby generating additional financial returns from cassava and the grain legumes harvested as intercrops.

- **Local Innovation Ecosystem**

Circular technology fabrication (e.g., ovens, fermenters, chippers) will stimulate local fabrication industries:

- Vocational institutions and

informal artisans will jointly produce at least 10 tools and infrastructure elements under the pilots.

3. Social Inclusion and Gender Participation

Inclusion is not an add-on but embedded into every aspect of the roadmap:

- **Women's Leadership**

With 93.4% of processors being women, all three pilot models (bio-herbicide, peel valorisation, oven sharing) are intentionally routed through female-led or majority-female clusters.

- Training modules will be developed in accessible formats and languages to address the 17% secondary education attainment rate among actors.

- **Cooperative Participation**

The baseline recorded just 15.2% cooperative membership among processors.

- The roadmap targets a +40% increase, using structured mobilisation, training, and shared asset ownership.
- This contributes to social capital KPIs within M&E themes, often linked to resilience and sustainability in informal economies.

- **Youth Engagement**

Youth participation (24%) will be tracked across two areas:

- Fabrication and deployment of CE tools.
- Entrepreneurship through demo days and innovation challenges planned during scale-up.

4. Behavioural Change and Institutional Uptake

The roadmap explicitly outlines measures to embed behavioural change and institutional transformation:

- **Behavioural Indicators**

- Use of CE tools (e.g., clean ovens, peel dryers) will be tracked by equipment uptime logs and adoption surveys.
- Participation in CE campaigns (e.g., radio broadcasts, mural

art) will be tracked to assess shifts in awareness.

- **Policy and Governance Integration**

- At least one CE product (bio-herbicide) will be certified with EPA and MoFA.
- CE KPIs, such as % of by-products valorised, % of processors in cooperatives, will be embedded in District Medium-Term Development Plans (DMTDPs) by 2028.

Closing Summary Table: Roadmap-M&E Alignment

Impact Area	Roadmap Output	M&E Indicator
Waste Recovery	100,000 L effluent valorised	Volume of waste diverted from open disposal
Energy Efficiency	10 ovens deployed, 20% firewood reduction	Fuel use per unit of gari processed
Product Innovation	Bio-herbicide trials completed	Farmers using CE inputs; chemical substitution rate
	Regenerative agriculture trails completed	Farmers integrating organic compost with grain legumes; % increase in cassava productivity.
Cooperative Growth	6 new coops; 40% increase in membership	% of actors in organised structures
Job Creation	Fabricator engagement, new cooperative jobs	Number of new jobs from CE interventions
Inclusion	Women/youth leading pilots and training	Participation by gender and age
Policy Integration	CE indicators in MoFA reports and DMTDPs	CE policy embedded in institutional documents



Conclusion

This roadmap sets out a realistic, data-driven pathway for transitioning Ghana's cassava value chain towards a circular, inclusive, and regenerative system. Built on thorough opportunity mapping in the Ashanti and Bono East regions, it identifies the key material inefficiencies, wasteful disposal of cassava peels and effluent, unsustainable firewood use, and weak cooperative structures, and responds with targeted, grounded interventions. These include four circular innovation pilots (bio-herbicide from effluent, peel-to-feed and compost, energy-efficient gari ovens and regenerative agriculture through integration of organic compost and grain legumes as intercrops on cassava fields), supported by phased implementation, inclusive training, and infrastructure mobilisation.

The roadmap does not propose an idealised vision detached from field realities. Instead,

it centres on what is already visible and possible within the informal and women-dominated cassava ecosystem: low-cost tools, peer-led learning, cooperative strengthening, and decentralised processing. It aligns with national priorities on waste recovery, green industrialisation, and gender-responsive development, while proposing metrics and governance models that enable measurement and scale.

Through its phased action plan, the roadmap prepares the groundwork for sustainable replication beyond cassava, offering a template for fish, mango, pineapple, and other agro-waste-rich systems. It ensures that innovation is not just piloted but absorbed, that actors are not just consulted but empowered, and that circularity is not just an environmental ideal but a lived economic alternative.



Appendix: Roadmap KPI Matrix

The table below presents all identifiable KPIs categorised as either vertical (function-specific) or horizontal (cross-cutting). Each entry includes:

- **Baseline metric:** Value or condition at roadmap start.
- **KPI:** The measurable target or output to be achieved.
- **Action required:** The intervention/activity that drives change.
- **Broader CE indicator:** Overarching theme the KPI contributes to.
- **KPI Category:** Vertical or horizontal.
- **TBL Score:** Triple Bottom Line impact (Economy, Environment, and Social), each rated out of 5.

Baseline Metric	KPI	Action Required	Broader CE Indicator	Category	TBL Score (Econ.Env. Soc)
244,185 kg firewood/year	≥20% reduction in firewood per unit gari	Deploy 10 energy-efficient ovens	Energy efficiency	Vertical	3.5.4
17.03 MJ/kg energy use	MJ/kg reduced to <13.6	Oven upgrades, user training	Emissions reduction	Vertical	4.5.4
97,965 kg peels/year (60% reused)	≥70% valorised formally	Launch peel-to-feed/compost pilots	Waste recovery	Horizontal	3.5.5
235,116 L effluent/year (0% reused)	≥100,000 L valorised	Effluent-to-bio-herbicide processing	Pollution prevention	Horizontal	4.5.4
494,081 kg CO ₂ eq/year (processing)	≥100,000 kg CO ₂ eq avoided	Improved stoves, byproduct reuse	GHG reduction	Horizontal	4.5.3
0 certified products	Bio-herbicide EPA certified	Run bio-herbicide trials, regulatory filing	Green product development	Vertical	3.4.4
GHS 20–40/acre herbicide cost	≥30% cost savings	Farmer trials with effluent-based alternatives	Input substitution	Vertical	4.3.3
0 revenue from CE products	Disaggregated CE revenue streams tracked	Compost, herbicide, feed production	Value creation	Horizontal	5.2.4
0 CE jobs	≥50 jobs created	CE hub staffing, tool fabrication	Inclusive green jobs	Horizontal	3.3.5

Baseline Metric	KPI	Action Required	Broader CE Indicator	Category	TBL Score (Econ.Env. Soc)
15.2% cooperative membership	+40% increase	Form 6 cooperatives, mobilise processors	Organisational strengthening	Horizontal	2.2.5
93.4% of processors are women	Women lead all 3 pilots	Design with gender lens, use women's clusters	Gender equity	Vertical	2.1.5
17% have secondary education	≥500 trained in CE	Deliver CE modules, hands-on demos	CE skills development	Vertical	3.1.4
0 CE modules	3 modular curricula developed	Content for processors, farmers, traders	Circular literacy	Vertical	3.1.4
0 local tools embedded	10 tools fabricated & used	Link artisans, processors, vocational centres	Technology transfer	Vertical	4.2.4
0 extension officers CE-trained	30 officers trained	Integrate CE into METASIP, conduct workshops	Institutional capacity	Horizontal	2.3.3
0 CE indicators in DMTDPs	≥3 DMTDPs include CE KPIs	Engage planners, align with NDPC guidance	Policy integration	Horizontal	2.3.4
7.3% total cassava loss	≤5.5% by 2028	Reduce peel/effluent loss via pilots	Resource efficiency	Horizontal	3.4.3
0 innovation showcases	Annual Demo Days held	Engage innovators, publicise solutions	Innovation ecosystem	Horizontal	4.2.4
0 inclusion index	Composite inclusion index developed	Gender, youth, regional balance scoring	Social cohesion	Horizontal	2.2.5
0 awareness campaigns	Participation rates in CE outreach tracked	Radio, murals, forums on CE themes	Behavioural change	Horizontal	3.1.5
0 CE extension protocols	Integrated in METASIP by 2027	Develop national extension packages	Sector-wide transformation	Horizontal	2.3.4
1L synthetic herbicide = 3–5% weekly income	Herbicide affordability improved	Roll out bio-herbicide to 100+ farmers	Financial inclusion	Vertical	3.2.4

Baseline Metric	KPI	Action Required	Broader CE Indicator	Category	TBL Score (Econ.Env. Soc)
244,185 kg firewood/year	≥20% firewood reduction	Deploy 10 energy-efficient ovens, train processors	Energy efficiency	Vertical (processing)	3.5.5
17.03 MJ/kg gari	Energy intensity per unit reduced	Oven airflow redesign and thermal insulation	Emissions reduction	Vertical (processing)	3.5.4
235,116 L effluent/year (0% reused)	≥100,000 L effluent reused	Install catchment tanks, fabricate dilution systems	Biowaste recovery	Horizontal	2.5.5
97,965 kg peels/year (40% unutilised)	≥70% peel valorisation	Set up feed/compost hubs, engage women's groups	Organic waste valorisation	Horizontal	3.4.5
494,081 kg CO₂eq/year from processing	≥100,000 kg CO ₂ e avoided	Firewood substitution, reduce smoke exposure	GHG mitigation	Horizontal	2.5.4
GHS 20-40/acre spent on herbicides	≥30% cost savings on herbicides	Replace synthetic inputs with bio-herbicide	Input cost reduction	Vertical (farming)	4.2.3
0 jobs in CE innovation hubs	≥50 jobs created	Hire fabricators, waste handlers, trainers	Green job creation	Horizontal	5.2.4
15.2% cooperative membership	+40% participation	Formalise 6 cooperatives, shared asset models	Institutional inclusion	Horizontal	2.1.5
93.4% processors are women	≥500 women/youth trained	Design inclusive CE training in local languages	Gender-responsive CE uptake	Horizontal	2.1.5
0 CE-certified products	≥1 product certified (bio-herbicide)	Guide through EPA/MoFA certification	CE product legitimacy	Vertical (products)	3.4.3
0 DMTDPs include CE	≥3 DMTDPs with CE indicators	Embed KPIs into district plans	Policy mainstreaming	Horizontal	2.2.4
0 mobile logs in use	Mobile data tracking tools piloted	Train coops on data entry, field support agents	Digital MRV capacity	Vertical (monitoring)	2.1.4

Baseline Metric	KPI	Action Required	Broader CE Indicator	Category	TBL Score (Econ.Env. Soc)
0 youth fabrication involvement	Youth-led tool production in 2 districts	Partner with vocational schools	Local innovation	Vertical (skills)	3.1.4
0 CE modules in METASIP	CE modules in national extension	Co-design with MoFA, integrate into METASIP	Policy coherence	Horizontal	2.3.3
0 market outlets for compost/feed	≥60% market sale of outputs	Connect to agro-dealers/livestock networks	CE enterprise viability	Horizontal	5.2.4
No CE Inclusion Index	New inclusion index piloted	Develop participatory scoring with cooperatives	Equity in CE participation	Horizontal	2.1.5
0 training coverage	≥500 actors trained	Conduct modular CE training sessions	Capacity development	Vertical (training)	3.1.5
0 Gari oven service sharing	10 shared ovens deployed	Formalise shared access models	CE as a service	Horizontal	3.3.4
No campaign participation records	Uptake of CE campaign tools	Use mural art, radio, SMS	Behavioural change	Horizontal	1.1.3
0 prototype showcases	Annual demo days held	Link innovators with cooperatives	Incubation pathways	Horizontal	4.2.3

Notes:

- TBL Scoring uses a 5-point scale per dimension, highlighting relative strength across Economic (E), Environmental (Env), and Social (Soc) contributions.
- Vertical KPIs are specific to functions like farming, processing, or cooperative operations.
- Horizontal KPIs cut across multiple actors or systems, influencing the ecosystem more broadly.
- Many KPIs overlap across steps in the roadmap, especially those associated with pilots and implementation phases.
- Data Sources include processor logs, field surveys, cooperative records, and institutional reports.





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Republic of Ghana

About Ghana Circular Economy Centre

The Ghana Circular Economy Centre (GCEC) project supports Ghana's transition to a resource-efficient and inclusive circular economy by promoting innovation, strengthening policy and institutional frameworks, and building capacity across key value chains, including plastics, agriculture and agro-processing (cassava, mango, pineapple and tilapia), and textiles.

The project is implemented by the United Nations Industrial Development Organization (UNIDO) in partnership with the Ministry of Environment, Science and Technology (MEST), with funding support from Global Affairs Canada.

The GCEC serves as a national hub for knowledge generation, stakeholder engagement, and the piloting of circular solutions to advance sustainable industrial development, improve resource efficiency, and create decent jobs.

Host Institution



Value Chain Leads



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