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From Organic Waste to Agrifood Value: Appropriate Technologies for Circular Economy and Job Creation

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Abstract

Africa faces a dual challenge of persistent un and under- and informal employment—especially among youth and women—and environmental degradation exacerbated by poor waste management. Tailored organic waste management can represent a strong solution to promote both decent work and environmental sustainability. This paper explores how appropriate technologies for managing organic waste can contribute to employment creation and a Just Transition in agrifood systems, particularly in rural and urban settings. The research integrates a desk review with key informant interviews. Identified examples lead to the conclusion that waste-to-agrifood technologies exist along a continuum, ranging from farm-enhancing practices that improve soil health and reduce input costs to income-generating activities that create market opportunities and employment. Composting, biochar production, and black soldier fly farming, among others, illustrate how organic waste can be repurposed into fertilisers, animal feed, and bioenergy, addressing environmental and economic challenges. At smaller scales, they provide direct benefits to smallholder farmers and decentralised communities, while at commercial levels, they create job opportunities downstream and upstream the value chains, from waste collection and processing to specialized roles in biotechnology or logistics. To unlock their full potential in strengthening agrifood systems, creating green jobs, and advancing sustainable development in Africa, competencies development, investments in infrastructure, financial access, as well as social dialogue are essential. An appropriate technology approach could make organic waste solutions more accessible and adaptable to local contexts.

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Acronyms

ASH	Africa Sun Holdings
BSF	Black Solider Fly
C40	C40 Cities Climate Leadership Group
CRCs	Carbon Removal Certificates
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
GAMA	Greater Accra Metropolitan Area
GHGs	Greenhouse Gases
ha	Hectare
ICIPE	International Centre of Insect Physiology and Ecology
IFAD	International Fund for Agricultural Development
ILO	International Labour Organization
IRRC	Integrated Resource Recovery Centre
ISWM	Integrated Solid Waste Management
ITDG	Intermediate Technology Development Group (now Practical Action)
KII	Key Informant Interview
MEFT	Ministry of Environment, Forestry and Tourism of Namibia
MSWM	Municipal Solid Waste Management
NEET	Not in Employment, Education, or Training
OECD	Organisation for Economic Co-operation and Development
Tn	Metric Ton
TPY	Tonnes Per Year
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa

UNEP	United Nations Environment Programme

Foreword

This working paper has been prepared by the Investment, Sectoral Strategies and Transitions Team of the EMPINVEST branch of the ILO. It is in line with its mandate of promoting employment creation (Convention 122), with a focus on the transition to formal jobs for informal workers (Recommendation 204) in the context of a Just Transition to a green economy.

Africa faces a dual challenge: persistent unemployment, underemployment, and informality—especially among youth and women—alongside worsening environmental degradation, largely due to inefficient organic waste management. This research explores how the choice of appropriate technologies for managing organic waste can address both challenges by promoting decent employment and environmental sustainability, especially within agrifood systems in rural and urban areas.

Using a combination of desk research and key informant interviews, this paper identifies a continuum of organic waste-to-agrifood technologies, from low-tech solutions that improve soil health and reduce farm input costs, to commercial ventures generating income and employment opportunities. Technologies such as composting, biochar production, and black soldier fly farming convert organic waste into valuable products like fertilizers, animal feed, and bioenergy. These innovations offer direct benefits to smallholder farmers and communities while creating upstream and downstream employment in value chains—from waste collection and processing to logistics and biotechnology.

To scale these solutions and ensure they support a Just Transition in Africa's agrifood systems, key enablers include: Investment in infrastructure and technology, skills development and capacity building, access to finance, social dialogue and inclusive policymaking.

To unlock the full employment and sustainability potential of organic waste management technologies, the following actions are essential: skills and competency development, investment in infrastructure and technology, financial inclusion, social dialogue and policy support. It is key to engage stakeholders—workers' and employers' organizations, government, including local communities, and the private sector—in policy development and promote integrated approaches linking employment, waste, agriculture, and climate goals.

Ensuring a "Just Transition"—by promoting decent jobs and skills development—will be key for aligning circular economy goals (SDG 12 on responsible consumption and production) with decent work (SDG 8). In this regard, the appropriate technology choice could support the creation of decent jobs while ensuring environment sustainability.

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Introduction

Employment, Agrifood Systems and Organic Waste Inefficiencies in Africa

In 2023, 145 million people in Sub-Saharan Africa lived in extreme working poverty, with resilience further strained by climate shocks, conflict, and limited fiscal space (ILO, 2024b). Furthermore, by 2030, Africa's youth population will reach 200 million, and by 2050, the continent is expected to grow by 950 million people (UNECA, 2024), increasing pressure on food systems and the need for decent jobs.

Employment trends across Africa vary between regions. North Africa has low formal employment, especially among women, whose participation is 49 percentage points below men's (ILO, 2024b). Sub-Saharan Africa faces high informality and underemployment, with nearly one in four youth not in employment, education or training (NEET) in 2023 (ILO, 2024a). Young women face greater barriers, and 8.9 million youth lived near conflict zones in 2022.

A key barrier remains, the skills mismatch: in agrifood systems, two-thirds of youth are mismatched—40 per cent underqualified, and 24 per cent overqualified (OECD, 2021). Moreover, in rural areas, informal apprenticeships and poorly trained trainers contribute to a lack of recognised skills (ILO, 2012), limiting youth participation in green agrifood transformation. Addressing this gap is a policy priority and requires interventions that equip rural youth with both technical know-how and skills that enable them to contribute meaningfully to transforming agrifood systems and creating productive and decent employment. Moreover, informal apprenticeships[1] are widely used to learn skills and acquire competencies for employment in the informal economy of many developing countries.

Agriculture is central to Africa's economy, accounting for a significant share of GDP and employing 1.23 billion people globally and sustaining 3.83 billion people living in households that depend on agriculture (Davis, B. et al., 2023), who produce up to 70 per cent of the continent's food (IFAD, n.d.). Yet productivity remains low due to outdated practices, limited access to finance and technologies, and poor infrastructure. Over 257 million Africans already face undernourishment (FAO & ECA, 2018), while post-harvest losses reach 40 per cent for perishables and storage capacity covers less than ten per cent of food production (World Bank, 2025). Thus, weaknesses in agriculture reinforce both food insecurity and waste generation.

Urbanization and population growth are projected to triple Africa's waste by 2050 (World Bank, 2018). Waste collection rates remain low, averaging 44 per cent in Sub-Saharan Africa, but rural areas are particularly underserved. Organic waste dominates in low- and middle-income contexts, accounting for 50–80 percent of municipal streams and 35 per cent of urban emissions (ESCAP, 2017; C40 Cities & Accra Metropolitan Assembly, 2024). Poor systems drive illegal dumping, environmental degradation, and health risks, while their economic costs exceed those of proper treatment (C40, 2019a). In African cities, organic waste is still largely landfilled or incinerated. Both approaches are inefficient and generate very few jobs: only 1.8 jobs/10,000 tons per year—far below composting or other reuse strategies (Ribeiro-Broomhead, J. et al., 2021). Incineration

[1] Informal apprenticeship is a skills transfer from a master craftsperson to a young apprentice who get the skills through imitation, observation, and then repetition while working with the master craftsperson (for more information, see ILO, 2012.

is especially unsuitable for organic waste, which has high moisture content and greater energy costs (M. Brown, 2015; ESCAP, 2017). Recycling plants also require highly skilled staff, often lacking in low-income settings. Despite its modern image, incineration does not qualify as a green solution, as it neither creates sufficient jobs nor aligns with clean energy pathways (Zero Waste Europe, 2023).

Labour Market Opportunities at the Intersection of Agriculture and Waste Management

Informal workers make up 28 per cent of global agricultural employment and often face food insecurity, low incomes, and limited protection.[2] In Africa, smallholders generate most of the food supply but struggle with low productivity and inadequate access to credit, technology, and infrastructure. Large volumes of manure, crop residues, and post-harvest losses are wasted, harming ecosystems but also representing a missed opportunity. Valorization of these waste streams into compost, biofertiliser, biogas, or animal feed can reduce chemical dependence, improve soil health, and create rural jobs.

Urban waste systems also hold potential. An estimated 19–24 million people worldwide work in waste collection and recycling, yet only four million are formally employed (ILO, 2013). In African cities, waste pickers—often women and marginalized groups—are vital to recycling yet remain excluded from formal systems and exposed to unsafe conditions (UNDP, 2023). Recognizing their contribution and creating pathways to dignity and protection is crucial for building inclusive green economies.

Circular economy approaches that valorize organic waste—such as composting, biochar, or insect-based recycling—can generate scalable, labour-intensive opportunities. With appropriate technologies, skills, and policy frameworks, these solutions can shift from farm support to income generation, particularly for smallholders, urban waste systems, and decentralized communities. This study therefore explores how technological choices, policy frameworks, and education systems interact to shape youth-sensitive employment opportunities in organic waste management, while addressing environmental degradation and food system pressures.

Principles of Appropriate Technology

In recent discussions on development economics, the focus has shifted away from the sheer quantity of growth to its qualitative aspects, particularly productive transformation and the dynamics of the growth process. Structural and technological change, along with the development of social capabilities, plays a crucial role in driving technology development and innovation, but also productivity, income growth, job creation, the transition to formality, as well as poverty reduction. Lessons from Asia show that sustained growth emerges from employment-oriented structural change and rapid technological learning (Nübler and Ernst, 2013). *Technology* encompasses more than physical tools; it also includes skills, processes, organizational arrangements, and the goods or services produced (Practical Action, n.d.). Technological change and the evolution of employment is not deterministic, but needs to be shaped (Nübler, 2016) by policies, regulations and institutions, which is a social construct. Market adjustment and a process of societal learning processes are key endogenous factors for the job-creation dynamics Yet, transferring

[2] See Agriculture; plantations; other rural sectors | International Labour Organization, consulted on 14 April 2025.

modern, capital-intensive technologies from industrialized contexts often fails in developing settings when local skills and institutions are not taken into account.

The concept of appropriate technology arose to address these challenges. Popularized by Schumacher's Small is Beautiful (1974) and later promoted by the Intermediate Technology Development Group (Baron, C.G., 1978), it refers to accessible, labour-intensive, energy-efficient, and environmentally sound solutions that communities can manage autonomously (Barrett, H. et al., 2003). However, critics warn against assuming that a single technological pathway is universally "appropriate," as this risks imposing external values and excluding local perspectives (Hollick, M., 1982). For this reason, the ILO has emphasized that technology selection must be embedded in social dialogue among social partners and the government, inclusive decision-making, and broader strategies addressing poverty and inequality.

Historically, technology choices have prioritized efficiency over inclusivity, neglecting opportunities for local capacity development. By contrast, appropriate technologies, especially in labour-intensive, capital-scarce economies, can foster learning, skill-building, and job creation for informal workers, provided they are both viable and context-sensitive (Ernst et al., 2023). The goal is not to rely exclusively on labour-intensive methods but to balance them with capital-intensive ones, optimizing both efficiency and capability development. In agricultural waste management, smallholders in Africa already engage in farm-waste recycling and composting, though often at low efficiency. Supporting regenerative, climate-smart practices adapted to local contexts can strengthen productivity, expand employment, and ensure sustainable adoption without undermining traditional systems.

In agriculture, reusing organic waste (e.g., composting) is common but needs support for regenerative, climate-smart solutions tailored to local practices

- Farm-enhancing technologies: low capital investment, improve soil fertility, reduce input costs, and mitigate environmental degradation (e.g: Composting, biochar application)
- Profit-generating technologies: require more infrastructure, investment, and coordination (e.g: mushrooms, insect-based feed, biogas, organic fertilizers) - Provide income opportunities, reduce landfill use, and create jobs
- Capability-generating technologies: combination of imported (and adjusted) and local, traditional technologies enhancing a learning process of local communities, workers and economic units

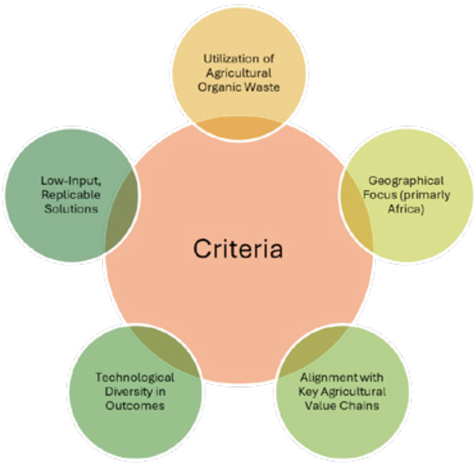
The key factors influencing the transition to the adoption of a new technology are as follows:

- Scale, market access, investment, and policy support
- Skills development for capability development, creating local jobs, higher productivity & income
- Technologies like biochar or compost become profit-generating when value is added through processing, branding, or linking to markets
- Incentives like subsidies, carbon pricing, Technical and Vocational Education and Training support and grants help technologies scale and transition to profitable ventures

1 Research Methodology

A qualitative research methodology was used, integrating a desk review of relevant literature and documented best practices with Key Informant Interviews (KII). The technology examples were identified among peer-reviewed literature, technical reports, case study documentation, and grey literature from international organizations such as ILO, FAO, UNDP, as well as websites and news. The selection was guided by the following criteria (selection framework) to ensure alignment with the research objectives: a) identify technologies that utilise agricultural organic waste to generate value-added products or services; b) identify alternative technological solutions for organic waste transformation; c) select predominantly examples from African countries; d) select examples of technologies that are resource-efficient, low-cost, and have the potential to be scalable or replicable (appropriate technology); e) focus on technologies that are linked to Africa's major agricultural value chains. For the selection of case studies, appropriate technologies linked to the main African agricultural activities and their main sub-categories have been prioritized according to FAO statistics on total production (tn) and total cultivated land (ha) in 2023 (FAO, n.d.) including cereal, legumes/pulses, animal waste, oilseed, root and tuber waste.

▶ **Figure 1: criteria for the selection of the examples**



To analyze and categorize case studies of organic waste transformation technologies, a set of guiding criteria was adopted and complemented with KIIs. Table 1 was used as a guiding instrument to identify key aspects related to each technology across various dimensions, including material availability, economic feasibility, environmental suitability, social and cultural acceptance, and technological readiness. This research establishes a categorization of technologies about their contextual relevance and does not intend to evaluate whether case studies represent examples of appropriate technology. Case studies and examples were further developed and complemented with KIIs. Out of 23 contacted, a total of nine Key Informants from UN Agencies, Private Sector, and Academia were interviewed.

▶ **Table 1: categories utilized for case study evaluation**

Type	Category	Details
Inputs/Outputs	Category of final product	Animal feed, compost, bioenergy, etc.
	Types and availability of organic waste utilised	List specific types (e.g., crop residues, food waste) and assess local availability
	Scale of the production	Smallholder scale, small/medium commercial scale, or industrial scale
	Transport and storage requirements	Infrastructure needed (e.g., cold chains, fermentation plots, biodigesters)
Technological	Type of technology	Specific tools, machines, or systems required, including water and electricity
	Maintenance and spare parts	Availability and accessibility of spare parts and technical support at local and country level
Economic	Market demand	Presence of a market for the technology's outputs (e.g., biofertilizers, bioenergy)
	Cost-effectiveness	Affordability and observed return on investment
Human Resources	Skillset needs	Required skills to operate the technology (e.g., university education, vocational training)
	Skills transfer potential	Opportunities for skills transfers to local workforce
	Skillset availability	Availability of skilled labour in the area/ country
	Employment creation	# of workers required relative to the scale of the system
Climatic/Environmental	Climatic suitability	Optimal climatic conditions for the technology (e.g., temperature, humidity, rainfall)
	Ecological impact	Effects on local ecology, including biodiversity, carbon footprint, and potential introduction of non-native species
Social/Cultural	Community acceptance	Alignment with local culture, habits, and willingness to adopt the technology
	Compatibility with existing waste transformation practices	Extent of alignment or conflict with existing waste transformation practices
	Social inclusion	Opportunities to involve marginalized groups, youth, and women in the technology's operations

Type	Category	Details
Knowledge/Information	Educational resources	Availability of training programmes, materials, and knowledge-sharing platforms
Policy/Regulatory	Regulatory compliance	Adherence to regulations including occupational safety, health, and environmental standards

2 Examples of Appropriate Technologies for Organic Waste Management

The Urban Waste Challenge: An Untapped Resource

Municipal Solid Waste Management (MSWM) solutions must be tailored to local contexts. Urban organic waste is commonly processed through composting or anaerobic digestion—individually or combined—both offering opportunities for green job creation, urban greening, emissions reduction, and profit, as the global food waste management market is projected to reach USD 121.8 billion by 2033 (Future Market Insights, 2023; C40 Cities Climate Leadership Group, n.d.).

Composting, being simpler and more affordable, is often preferred at small scales, while anaerobic digestion is more viable for large-scale operations. In Alappuzha, India, a 2014 initiative provided households with subsidized composting bins and biogas systems, alongside community awareness campaigns. Though job creation was not assessed, the project fostered long-term adoption and skills development. It now includes 3,000 biogas plants and 2,800 compost bins, with 33 communal units serving others (The Print, 2017). Another model is the Integrated Resource Recovery Centre (IRRC) approach by the United Nations Economic and Social Comission for Asia and the Pacific (UN ESCAP), launched in 2009. IRRCs are decentralized facilities using low-cost technologies to process both segregated and non-segregated waste. They produce compost or biogas, filter wastewater, and sort recyclables. Designed to match local waste volumes, resources, and technical capacities, IRRCs involve communities, governments, and vulnerable workers through social dialogue to assess benefits, risks, and employment impacts. From 2009–2018, ten IRRCs were implemented across six countries in Asia.

While processing waste is vital, reducing food loss upstream is equally important. FAO estimates 13 per cent of global food is lost post-harvest and 19 per cent is wasted across households, services, and retail (FAO, n.d.; UNEP, 2025; United Nations, n.d.). Aesthetic standards often cause edible produce to be discarded, resulting in environmental and economic inefficiencies. International bodies now promote tools for food waste assessment to support targeted policy and solutions. In La Garay, Argentina, approximately 100 tonnes of carrots were discarded daily due to market standards—equal to the waste of a 100,000-person city (IDB, 2019). In response, the local company Val Mar partnered with CONICET and other institutions to turn discarded carrots into valuable products. Since 2018, a plant has been producing bioethanol, dietary fibers, and carotenoids—used in pharmaceuticals, fuels, and food products. This initiative not only reduced waste but created a new industry in a neglected region.

However, valorization alone cannot fix structural inefficiencies. Campaigns like the supermarket Carrefour's "Tous Anti Gaspi" highlight the importance of shifting consumer behavior and market norms. Mitigation strategies must complement adaptation to enable lasting transformation. Baseline waste assessments are essential to guide interventions and understand waste streams, disposal practices, and the roles of informal actors (ESCAP, 2017). Cities can empower informal workers through capacity-building, helping them self-organize, engage in policy processes, and co-design services. For instance, C40 conducted participatory assessments in Accra, Ghana, between 2021 and 2022, involving waste pickers to improve working conditions and system design (C40 Cities, 2022; C40 Cities & Accra Metropolitan Assembly, 2021).

▶ **Box 1. Tackling food loss: upstream organic waste management and valorization**

Globally, about 13 per cent of food is lost between harvest and retail, while 19 per cent is wasted at the consumption stage (United Nations, n.d.; FAO, n.d.; UNEP, 2025). Much of this waste stems from strict market standards and ends up in landfills, driving both environmental and economic costs. Prevention and reduction strategies must therefore accompany improvements in waste collection and treatment.

One example comes from La Garay, Argentina, where nearly 40 per cent of the carrot harvest was discarded due to size and shape requirements. In response, local stakeholders partnered with research institutions to transform discarded carrots into bioethanol, dietary fibres, and carotenoids, creating new industries and jobs while reducing waste (IDB, 2019).

Such initiatives show the potential of valorisation to convert food loss into economic opportunities. Yet, long-term solutions require tackling consumer biases and market standards that generate waste in the first place. Prevention is key, with valorization serving as a complementary strategy for a more sustainable agrifood system.

Example: Supporting migrant waste pickers' livelihoods in Accra, Ghana

Accra, Ghana, a rapidly growing city of over two million inhabitants, generates approximately 2,200 tons of solid waste per day, a figure projected to double to over 4,400 by 2030 due to urban expansion and population growth (C40 Cities, 2023). Managing this increasing waste volume is a significant challenge, requiring a coordinated approach that integrates formal and informal waste management systems. The current solid waste management system is hybrid, with formal waste management companies providing structured waste collection, while informal workers playing a crucial role in waste sorting, treatment, and recycling. Recent studies show that the informal sector collects approximately 40 per cent of the waste in the Greater Accra Metropolitan Area (GAMA), particularly in areas where private companies do not operate (C40 Cities, 2023).

To improve waste management, GAMA and private actors are investing in waste recovery infrastructure. A key example is the Accra Composting and Recycling Plant, a large-scale facility capable of processing 2,400 tonnes of municipal solid waste daily, producing 240 tonnes of compost (C40 Cities, 2023). This initiative contributes to reducing landfill dependency by converting organic waste into compost for agricultural use. Additionally, Accra has established transfer stations where waste is sorted before being sent to composting plants or aggregators for recycling.

The informal waste sector operates at all stages of the waste management value chain, from collection to treatment and recycling. Waste collection follows two primary pathways: formally collected waste is transported to composting and recycling plants, landfills, or transfer stations, where informal waste workers recover valuable recyclables. In contrast, waste collected by informal workers is sorted directly at the source, with high-value recyclables sold to aggregators who process them before resale to recycling industries.

Through a process of social dialogue with employers', workers' organizations and the government, AMA has launched initiatives to integrate them into the formal economy (Mayors Migration Council, 2022; Sackey et al., 2024). The Creating Livelihood and Environmentalism in Accra Now (CLEAN) project, funded by the Global Cities Fund for Migrants and Refugees, has brought over

400 informal waste workers—many of whom are migrants—into the formal waste sector by enrolling them in cooperatives overseen by the city government. Participants have been registered into Ghana's national health insurance scheme, and skills training programs have resulted in a 15 per cent increase in job security among waste pickers. To further support these workers, a childcare centre was established in a key waste collection hub, providing a safe environment for children away from hazardous work sites. Moving forward, Accra aims to expand financial support for health services, cooperative registration, and childcare facilities while also establishing a Migrant Desk to facilitate access to social services (Mayors Migration Council, 2022).

Composting for Environmental and Social Sustainability

Composting is a controlled microbiological process that transforms organic waste into a stable soil amendment. Beyond natural decomposition, organized composting provides a hygienic and efficient way to manage large volumes of organic waste (FAO, 2007). For agriculture, it enhances soil fertility by improving structure, nutrient availability, and moisture retention—critical in Africa, where soil fertility is declining due to continuous cropping, leaching, and erosion (FAO, 2007). By recycling organic matter, composting reduces fertiliser dependence, mitigates environmental risks from poor waste disposal, and improves food security through higher yields. At the urban level, separate collection and treatment of organics prevent contamination of recyclables and reduce methane emissions from landfills (Ribeiro-Broomhead, J. et al., 2021).

Composting can range from small-scale backyard to industrial-scale waste systems to process the organic fraction of MSW. The advantage of on-farm composting lies in the availability of necessary resources—feedstock, water, space, and labour—without the need for significant external inputs and farmers benefit from composting in multiple ways. They can reduce input costs by substituting compost for commercial fertilisers and soil conditioners, and in some cases, high-quality compost can be marketed, generating additional income streams. On the other hand, large-scale composting operations at the private sector level, either individually or through farmer cooperatives, can capitalize on economies of scale, making compost sales a viable business model. Communal composting facilities also present an efficient means of managing waste and generating economic returns for communities. By pooling organic waste from multiple sources, communities can establish centralized composting hubs, reducing individual investment burdens while ensuring a steady supply of compost for agricultural use or sale.

The feasibility of composting as a revenue-generating activity depends on the scale of production, the quality of the final product, and the existence of a market for compost-based soil amendments. Organic waste producers, such as farmers, abattoirs, and local markets, can benefit from the circular waste economy by charging tipping fees for organic waste collection. Also, municipalities financially benefit from the implementation of composting, which is a cost-effective waste management solution (Ribeiro-Broomhead, J. et al., 2021). The composting operation in La Pintana, Chile, for instance, which processes 20.5 per cent of the locally generated organic waste, requires only 2.4 per cent of the solid waste budget while generating the equivalent of 3-7 jobs/10,000 TPY (Ribeiro-Broomhead et al., 2021).

Small-scale composting as an activity integrated in a wider on-farm cycle is not likely to create additional jobs apart from those already in-farm. However, large-scale composting, such as urban-scale composting management of organic waste, does. Available literature mostly refers to direct work in producing compost at a facility, without considering recollection, transport, and distribution of the finalised compost, with an average of 6.6 jobs/10,000 TPY. Including jobs for waste collection, compost sales, and other products, in addition to standard compost processing, sums up to a higher job figure of 14 jobs/10,000 TPY, based on a case study in Bali, Indonesia. In the analysis, the authors also suggest that more mechanization leads to fewer jobs, based on the results from a case study analysis in Lahore, Pakistan, that utilises highly mechanized windrow composting to dispose of organic waste, which has a lower job figure compared to the other site analysed of 2.7 jobs/10,000 TPY.

▶ Box 2. Online training and resources on composting

There are several online training resources on composting which can equip farmers, entrepreneurs, and waste management practitioners with practical skills to transform organic waste into valuable agricultural inputs. Videos such as *How I make Vermicompost* provide hands-on guidance on setting up vermicomposting systems, making the process accessible to a wide audience.[3] Platforms like *accessagriculture.org* offer practical demonstrations on constructing composting and vermicomposting beds using locally available materials, emphasising low-cost and scalable methods.[4] The Organic Farm Knowledge platform further supports users with technical insights into composting processes, reinforcing sustainable agricultural practices.[5]

Example: From Backyard Composting to Urban Integral Solid Waste Management

Integrated Solid Waste Management (ISWM) for zero waste is a holistic approach that prioritizes waste reduction and material recovery. It includes policies to redesign products, improve delivery systems, and increase access to reuse, repair, recycling, and composting (2021). ISWM systems tend to create more jobs compared to those that focus on burning or landfilling waste, positioning sustainable waste management as a key component of resilient local and global economies (Ribeiro-Broomhead et al., 2021). Zero waste systems also offer better wages and working conditions than traditional waste management sectors and provide opportunities for skill development.

For cities to succeed in ISWM, investments in training and employment are essential to support workers transitioning to sustainable waste practices. This may involve integrating informal workers into the formal waste management system, especially in organic waste collection and recycling, and creating inclusive jobs in the renewable energy sector. Composting can evolve into a revenue-generating activity when integrated into broader business models. This transition is crucial for industries looking to replace conventional inputs with organic alternatives, while fostering decent jobs in the process. When waste management systems are designed with a focus on employment and sustainability, they can provide income opportunities and increase resilience in agricultural supply chains. However, their success requires coordination among various stakeholders, including municipal authorities, private enterprises, waste workers, and local communities. Efforts to include informal workers, often without social protection or stable incomes, are particularly important in these contexts. The following examples demonstrate how composting can scale up into income-generating activities.

[3] Available at: https://www.youtube.com/watch?v=xfWJbeMMAZw
[4] Available at: https://www.accessagriculture.org/making-vermicompost-bed
[5] Available at: https://organic-farmknowledge.org/tool/43058

Example: Integrated Solid Waste Management in Tunis, Tunisia[6]

The ILO-led waste valorization project in the intercommunal area of Sfax Nord aims to establish sustainable waste treatment systems that prioritize waste minimization, soil revitalization, and employment creation. The initiative focuses on valorizing the organic fraction of municipal waste from households and businesses, reducing reliance on landfill disposal. Key components of the project include source-separated waste collection, mechanical sorting, recycling, and compost production, with the composting process supported by treated wastewater from a local plant. Green waste from gardens, agricultural residues, and household organic waste will be collected, shredded, and processed into compost at designated sites. This compost will be used to restore soil health on depleted lands.

The project envisions the creation of an 'Ecological Village' by integrating civil society organizations, municipal authorities, and local enterprises into the waste management system. Environmental associations will play a key role in raising awareness and mobilizing residents for waste sorting and source separation. Partnerships with municipalities and the private sector will streamline waste collection, offer necessary training, and provide incentives for households and businesses to participate in selective waste sorting. The project is expected to create around 210 permanent jobs across various sectors, including waste collection, sorting, co-composting operations, and recyclable material transformation. It will also address informal waste collection by integrating existing waste pickers into the formal system. Special attention will be given to gender inclusion, with 69 of the 210 jobs expected to be filled by women, particularly in waste sorting and administrative roles. Workers will receive technical training in waste handling, machine operations, and quality control. Specialized training for composting technicians, agronomists, and laboratory staff will support organic amendment production, promoting sustainable agriculture in the region. Additionally, the project encourages entrepreneurship by fostering small enterprises focused on recycling and compost sales.

The project will integrate several waste management facilities, including mechanical and manual sorting units with a capacity of 20 tonnes per hour, a secondary transformation center for non-organic recyclables, and two co-composting units at state-owned agricultural sites, with a combined capacity of 70,600 tonnes of compost per year. The total estimated budget for the Ecological Village project is €20 million, covering all phases of implementation, with 70 per cent of the funding dedicated to developing waste management infrastructure.

Example: the private sector towards a Just Transition in Zimbabwe[7]

Between 2022 and 2024, in Zimbabwe, FAO collaborated with Sable Chemicals, one of the country's largest chemical fertilizer producers, to pilot a vermicomposting Employment Programme to provide alternative organic fertilizers while creating employment opportunities for rural youth. The pilot project, implemented in Kwekwe district under the Sable's Green Trust, has trained youth in vermicomposting—a process that uses earthworms to transform organic waste into nutrient-rich compost. This transition-oriented initiative has allowed Sable Chemicals to explore organic fertilizer production while supporting local youths with stable employment and knowledge-sharing opportunities.

6 Source: Key Informant Interviews
7 Source: Key Informant Interviews

Sable Chemicals has utilized biodegradable waste from local sources, establishing linkages with the local City Council, city markets, and the local abattoir to obtain organic matter. These inputs were processed into three key products: vermicompost as a basal fertilizer, earthworm poop tea for seed coating, and vermifoliar as a nitrogen-rich foliar spray. The initiative has emphasised employment creation and skill development, with youth engaged in various production roles. Training under the FAO Green Jobs for Rural Youth Employment (GJ4RYE) program has enabled participants to acquire hands-on experience in composting, waste management, and organic farming.

Sable Chemicals is aiming at institutionalizing the initiative by building alliances with local partners and registering it as a stand-alone business. EFG is intended to scale up vermicompost production and distribution, gradually absorbing youth workers from the Wage Employment Program into more permanent roles. Expansion plans include securing additional biodegradable waste sources, mechanizing production to increase efficiency, and conducting large-scale demonstration trials with different farming groups.

Example: Peanut Shells Valorization in Argentina

Over the past decades, Argentina has developed a robust bioeconomy sector, characterized by strong institutional frameworks and active participation from both public and private stakeholders. The country's experience demonstrates how multi-stakeholder collaboration—between private enterprises, local and national public institutions, and the academia—can identify bottlenecks and develop innovative solutions to transform agricultural waste into valuable resources to be re-introduced within the agrifood system. Another example of this is the peanut agro-industrial cluster, which integrates farmers, SMEs, and processing industries into an export-driven value chain, supporting approximately 12,000 direct and indirect jobs. However, the expansion of peanut production has resulted in significant waste, particularly from peanut shell residues. To address this challenge, waste valorization strategies have been implemented, turning these by-products into useful inputs. Peanut shells are processed into biofertilizers, reducing dependence on synthetic alternatives, while thermal power stations convert them into electricity, circularly supplying energy to processing facilities, while ashes from bioenergy production are further repurposed into ecological bricks.[8] The cluster generates employment in various fields, including agrochemical production, farming, industrial equipment, quality control, transportation, and R&D. The demand for specialized skills in biotechnology, environmental management, and sustainable agriculture has also stimulated the education sector, fostering collaborations between universities, technical schools, and industry to enhance workforce capabilities. While replicating this model requires substantial financial and human capital, the core principle—enhancing multi-stakeholder engagement and cooperation to identify locally suitable solutions for reutilizing agricultural waste—is adaptable across different contexts, value chains, and regions.

Scaling Biochar: A Profitable Agriwaste Solution for Rural Jobs and the Private Sector

Biochar, a carbon-rich material produced from organic waste via pyrolysis, enhances soil fertility and supports climate mitigation. It improves soil health by reducing nutrient loss, increasing bioavailability, and minimizing leaching (Scholz et al., 2014). Its high water-holding capacity makes

[8] Furthermore, peanut shells are also being used to produce activated carbon, reducing imports in food processing, pharmaceuticals, and water sanitation as well as to create absorbent blankets for oil spill clean-ups.

drought-prone soils more resilient, while its stable carbon sequestration helps in long-term climate change mitigation (Obia et al., 2013). Biochar can be made from agricultural residues, rice husks, and urban organic waste, with production conditions affecting its properties. It is crucial to prioritize using "true wastes" like biomass that would otherwise be discarded or burned. Biochar production should not involve deforesting land or growing dedicated crops, as this would counteract its environmental benefits. Instead, biochar provides a solution for managing agricultural residues, such as coconut shells, cassava stalks, and cereal straw (Scholz et al., 2014).

Production systems range from small household cookstoves to large industrial pyrolysis plants. Smallholder farmers often use cookstoves to produce biochar, which not only boosts soil fertility but also provides an alternative to firewood. This alleviates deforestation and reduces labor for fuel gathering, which often falls on women. It also mitigates risks associated with firewood collection, such as physical and sexual violence (FAO, n.d.). Biochar production integrates bioenergy, soil enhancement, and economic benefits. Many biochar systems remain flexible, enabling use of various feedstocks, and research is ongoing to develop affordable, farm-level kilns for smallholder farmers (Pasumarthi et al., 2024). Biochar-producing cookstoves enhance fuel efficiency, reduce smoke emissions, and lower indoor air pollution, benefiting rural women and children. These systems help conserve the environment and provide economic opportunities by reducing the time spent collecting fuel. Despite these benefits, biochar production requires training and protective equipment to avoid potential health risks (Mia, S. et al., 2024). Proper implementation can foster both environmental and economic benefits in rural communities.

Example. Private Sector Engagement in Biochar Production in Namibia[9]

Various civil society organizations, private sector actors, and international development agencies are promoting biochar for climate change mitigation, soil enhancement, and rural development.[10] While biochar improves soil fertility and supports productivity in Integrated Farming Systems, it cannot sustainably provide full-time employment or significant income at small or medium scales. Therefore, biochar production is increasingly integrated with carbon markets through Carbon Removal Certificates (CRCs).[11]

These projects offer farmers biochar production units tailored to local conditions, train them in their use, and facilitate carbon certification through accredited partners. Certified agents audit the carbon sequestration achieved, enabling farmers to generate tradable CRCs. The sale of these credits, rather than biochar itself, becomes the primary income stream for farmers, who continue benefiting from biochar's positive effects. An example is the project implemented in the Ovitoto Conservancy, Namibia, by Africa Sun Holdings (ASH) International, a British company. The project is a biomass-to-biochar initiative under a Public-Private Partnership model. ASH International develops integrated biomass businesses across Africa, producing biochar for agriculture and soil rehabilitation. The initiative focuses on converting encroacher bush into biochar for agricultural use and generating CRCs, which are sold on the carbon market—ASH's primary revenue source.

9 Source: Key Informant Interviews
10 Multinational corporations are investing in biochar-related carbon markets. For instance, Google has partnered with Indian supplier Varaha to purchase carbon credits from an initiative that converts agricultural waste into biochar, sequestering carbon while enhancing soil productivity. Google plans to acquire 100,000 tons of carbon credits by 2030, supporting farmers in turning crop residues into biochar, which can also serve as an alternative to chemical fertilisers (Economic Times, 2024).
11 For instance: the Business Partnership Platform in Vietnam

ASH has established ASH Namibia (Pty) Ltd, holding 80 per cent of the project, while the Ovitoto Conservancy holds a 20 per cent share. The project follows Namibian environmental and labor regulations, using pyrolysis kilns (Kon-Tiki kilns) to transform encroacher bush into biochar, contributing to rangeland restoration, biodiversity conservation, groundwater preservation, and CO_2 sequestration. The initiative has created jobs for local workers, including 30 women, in biomass harvesting, biochar production, and administration. Employment contracts comply with national labor laws, ensuring wages, social security, and workplace injury coverage, with no child or forced labor. A pilot phase evaluated feasibility, management, and operational protocols. Key social impacts include stable income for rural workers, particularly in remote areas with limited employment opportunities. The project also encourages local farmers to use biochar in their practices, improving small-scale crop yields and strengthening subsistence farming. ASH also commits ten per cent of profits to education initiatives, promoting long-term community resilience.

Box 3. Online training and resources on biochar production

Educational material on Biochar production is widely available online. Accessagriculture offers based on examples of Biochar in India.[12] Ripple Africa, also offers a video on how to make Biochar in Africa from crop waste.[13]

Turning Waste into Income through the Insect Economy: Black Soldier Flies

The rising demand for animal protein and the push for sustainability have driven the growth of insect-based protein for animal and fish feed, projected to increase by 80 per cent by 2030 (Feed Mill of the Future, 2024). Edible insects like the Black Soldier Fly (BSF, *Hermetia illucens*) offer a sustainable solution, especially suitable for smallholder farmers due to low production costs and ease of management. BSFs are not disease vectors, may deter pests, and have antimicrobial properties. They thrive in warm, moderately humid environments without needing standing water. FAO estimates that replacing ten per cent of fishmeal in aquaculture with insect meal could save over 15 trillion litres of water annually (FAO, 2013). BSF larvae (BSFL) consume a wide range of organic waste—including manure, municipal and food waste, crop straw, and fruit bunches—and can increase their weight up to 5,000 times in weeks (Kotch, 2024), converting waste into nutrient-rich biomass while reducing landfill use and water demands. BSF-fed animals, such as poultry, demonstrate improved feed efficiency and water use (Veldkamp et al., 2023). BSF farming thus supports a circular economy: organic waste feeds the larvae, which in turn become protein for livestock, fish, or pet food.

In East Africa, BSF production is growing rapidly and could have the potential to lift 4.53 million people above the poverty line and generate between 1,252 to 563,302 new jobs per annum (Abro, Z. et al., 2022). In Kenya and Uganda, there are around 1,200 and 500 producers, respectively (F&S, 2023). Two main systems dominate: smallholder-integrated farms aiming to reduce feed and fertilizer costs, and commercial producers supplying larger buyers. These systems are dynamic, with movement between scales over time. However, the sector faces regulatory gaps, inconsistent production, and limited processing capacity. In Kenya, for instance, regulations are fragmented and focused mainly on feed safety. Future efforts should strengthen regulation,

12 Available at: https://www.accessagriculture.org/biochar-improve-soil-health
13 Available at: https://www.youtube.com/watch?v=ljDeB3bzhgc

training, and public awareness—particularly among women and youth—and promote market strategies (F&S, 2023).

Social acceptance of insect-based feed is critical. ICIPE found that 90 per cent of Kenyan farmers and 85 per cent of feed producers were ready to adopt BSF technology, with demand projected to exceed current capacity by over 2,000 times (Rockefeller Foundation, 2020). This led to widespread training initiatives across Kenya. Given differing regulations globally, feasibility assessments must consider the legal framework and development agencies may need to support regulatory enhancements.

BSF can consume a variety of organic waste streams and require essential infrastructure for breeding, growing, and processing. Key components include waste preparation tools, environmental controls, and post-processing equipment such as dryers or oil pressers. Farms are typically organized into distinct zones aligned with the insect's life cycle. BSF farming is adaptable across scales. Smallholders can use recycled household items and integrate BSF with poultry or aquaculture for greater self-reliance. In regions like Southern and Central Africa and Southeast Asia, where insects are already part of the diet, BSF production is particularly accessible to small enterprises.

BSF farming can generate jobs. A small site producing 2,000 kg/month typically employs two full-time workers*, while medium-sized farms engage about five people plus additional waste aggregators* (FAO, 2021). While advanced education is not required, vocational training is essential—covering BSF biology, breeding, biosecurity, and processing. Biosecurity measures like hygiene and regular cleaning are vital. Breeders must manage egg output and genetic diversity, while rearing and processing require skills in growth optimization and product quality. Legal compliance also remains key to sustainable operations. A major challenge is adapting BSF technology to diverse climates. While BSFs thrive in warmth, colder areas require greenhouses. Additionally, variable waste types call for adaptive, geography-specific methodologies to ensure consistent production

Example: Black Soldier Fly-Based Feed for Sustainable Tilapia Farming in Zimbabwe[14]

Zimbabwe's aquaculture sector has strong growth potential but remains constrained by high production costs, particularly due to expensive imported feed. The Intra-ACP Blue Growth program (FISH4ACP), implemented by FAO and partners, is working to improve sustainability and productivity across the Zimbabwean tilapia value chain. To address feed cost barriers, the project promotes Black Soldier Fly (BSF) larvae as an alternative feed ingredient for small-scale tilapia farmers.

In partnership with Chinhoyi University of Technology, FISH4ACP launched BSF feed trials in Manicaland province to assess both technical and economic feasibility. Pilot sites were established where extension officers, feed suppliers, and farmers were trained in BSF-based feed production. A cost–benefit analysis comparing BSF-based and conventional fish feed confirmed that incorporating BSF larvae can significantly lower production costs, making it a viable option for widespread use among smallholder farmers. To strengthen production capacity, the project established a breeding facility with 20 cages and machinery for feed processing, with plans to

[14] Sources: a) Food and Agriculture Organization of the United Nations (FAO). (2024). *Boosting Tilapia Farming with Black Soldier Fly-Based Fish Feed: A Case Study from Zimbabwe*. FISH4ACP. Retrieved from https://www.fao.org/in-action/fish-4-acp/where-we-work/africa/zimbabwe/en/; b) Key Informant Interviews.

build a second facility. Each site will produce several tons of dried BSF larvae monthly, valued at USD 500/ton, and is managed by five youth, mostly women—engaging ten people directly in BSF production. These facilities are projected to increase fish output in Manicaland by 60 tons per month, contributing an additional 1,800 tons annually. Youth participants also collect organic waste, with efforts underway to partner with institutions like prisons and boarding schools that generate large waste volumes.

Despite growing momentum, BSF-based feed production in Zimbabwe faces key challenges. The sector lacks a regulatory framework, and farmers require training in BSF rearing, feed formulation, and fish feeding practices tailored to local conditions. In colder regions, BSF production may require greenhouses to maintain optimal breeding temperatures. Expertise in BSF farming remains limited in Zimbabwe, and a formal supply chain has yet to emerge. However, with continued technical assistance and investment, BSF-based feed could transform Zimbabwe's tilapia sector, making aquaculture more affordable and accessible to smallholder producers.

Oyster Mushrooms for Climate-Resilient Smallholder Businesses

Mushrooms are edible fungi that have been consumed by generations of people. There are different types of mushrooms, one of which is the Pleurotus Ostreatus, commonly known as *oyster mushroom* for its resemblance to oysters' shells. In their natural habitat, oyster mushrooms feed on straw and wood and play a crucial role as organic matter decomposers (saprotrophic fungi). But instead of collecting them from the wild, they can be easily grown indoors at a low cost and in a relatively short time by using agricultural waste materials (FAO, 2017). Oyster mushrooms mature within 30 days and are rich in proteins, vitamins, fibre, and minerals and enrich people's diets when meat sources are limited. Oyster mushrooms are highly tolerant of variations in temperature, humidity, light conditions, and carbon dioxide levels. They can be produced easily by all classes of farmers, including young and old men and women, as they require little land, effort, and investment, as well as skills compared to the production of other varieties of crops and mushrooms. Furthermore, oyster mushrooms have a great potential to enhance the circularity of smallholder farms as besides growing upon agricultural by-products, they generate a virtually inexhaustible supply of a co-product called *spent mushroom substrate,* which the mushroom industry is exploring in terms of its potential for production of value-added products (Phan et al., 2012).

Oyster mushroom farming is a practice that can be adopted by small-scale farmers to diversify their income during the dry season, when lack of water may challenge the cultivation of other crops and reduce their vulnerability to adverse weather including floods and extreme droughts. Several case studies presenting different applications of oyster mushroom farming are available to consult online,[15]including interesting in-city-based activities that are enhancing local circularities such as the Champignon de Bruxelles case[16].

Labourwise, oyster mushroom production is a labour-intensive activity as many tasks—such as substrate preparation, bagging, inoculation, environmental monitoring, harvesting, and cleaning—require manual intervention, particularly at smallholder scales. Nevertheless, while oyster mushroom production is labour-intensive, it is not necessarily time-intensive throughout the entire production cycle. During the fructification period—when the mushrooms are growing—workers

15 Such as Practical Actions or (Phan et al., 2012).
16 Available at: https://www.visit.brussels/en/visitors/venue-details.Le-Champignon-de-Bruxelles.269708

typically do not need to engage in constant activities. Instead, their role is focused on monitoring and maintaining the growing environment, such as controlling humidity, temperature, and ventilation. These tasks are less demanding and can often be performed intermittently. This means that during the fruiting phase, workers have the flexibility to dedicate time to other tasks or activities, whether within the mushroom operation (e.g., planning the next production cycle, cleaning equipment, or processing harvested mushrooms) or in other areas. A rural family can easily manage a small-scale oyster mushroom business while carrying on additional income-generating activities. In a cost-benefit analysis conducted by FAO in Uganda in 2017, mushroom cultivation was compared to the opportunity cost of labour in farms affected by a dry spell between 2016-2026, and it was observed that the net benefit of mushroom growing over 11 years is more than seven times higher than the opportunity cost of labour (FAO, 2017). At the same time, in non-hazard conditions, the net benefits from mushroom growing were more than nine times higher than the opportunity cost of labour, bringing USD 5.3 per one US dollar invested. The main capital investment included a growing room and a solar dryer to commercialize dried mushrooms.

Establishing and managing an oyster mushroom business does not require advanced training. In a benefit/cost analysis conducted on general mushroom production in developing countries for income diversification, Celik and Peker identified that managers who were graduates of elementary and high schools (30.8 per cent elementary school, 30.8 per cent high schools) formed the majority (61.6 per cent) of the businesses (Celik et al., 2009). Mushroom production can be managed by people with lower-level education in rural areas although vocational training opportunities shall be provided to develop strengthened human resources.

▶ Box 4. Online training and resources on oyster mushrooms

Several platforms offer effective step-by-step training courses and materials which are freely accessible online. *Accessagriculture.org* offers an effective 12-minute video on oyster mushroom cultivation, showcasing its potential to improve livelihoods, particularly for women and small-scale farmers.[17] The video explains the benefits of mushrooms as a nutritious, protein-rich food and a source of income, requiring minimal land, effort, and cost. It provides step-by-step instructions on preparing the substrate, planting mushroom seed, maintaining proper hygiene, and harvesting. Additionally, it highlights innovative practices like substrate sterilization, effective pest control, and recycling used substrate as compost. Other platforms offer step-by-step written guides for oyster mushroom farming, such as *MushroomClasses.com*.[18]

Example: Young Mushroom Agripreneurs under Grant-based Schemes[19]

Green Quality Produce was founded by Charles Muswati and three fellow agricultural graduates in response to limited employment opportunities in Marondera District, Zimbabwe. Supported by a GJ4RYE project grant, the team built a sustainable oyster mushroom business using affordable and readily available agricultural residues such as cotton hulls, wheat straw, maize husks, banana leaves, sawdust as substrates, purchased at $30/ton from local farms and cotton processors. Although the GJ4RYE project did not include dedicated mushroom training, the group

17 Retrieved from https://www.accessagriculture.org/growing-oyster-mushrooms
18 Retrieved from https://mushroomclasses.com/grow-oyster-mushrooms-on-straw/
19 Sources: Key Informant Interviews.

leveraged their academic background in agriculture to manage technical aspects such as inoculation, agar preparation, sterilization, and incubation. Each member received a USD 2,500 grant over two years, as well as soft skills training and ongoing mentorship in business development and technical agriculture.

Since its inception, Green Quality Produce has tripled its production capacity and expanded its team from 4 to 8 full-time staff. Currently, it produces between 2,000 and 3,000 mushroom kits per month—translating to 4,000–6,000 kg of mushrooms. The business has also become a hub for practical training, regularly hosting students, recent graduates, and local farmers to share knowledge on organic production and sustainable enterprise management. One challenge faced by the business is competition for raw materials. Many households and farmers in the region traditionally compost agricultural waste or use it for animal bedding and mulching. To address this, the team built strong market linkages with farms and cotton processors to secure a reliable supply of substrate materials.

The success of Green Quality Produce has attracted regional interest. Charles has been invited to present the business model in Zambia and Namibia, and the team has gained valuable experience in financial planning, market analysis, and supply chain management. These skills have been key to scaling operations and strengthening the enterprise's resilience. Looking ahead, the team plans to diversify by introducing button mushrooms and exploring export opportunities. They also aim to establish a dedicated training centre to build local capacity in sustainable agribusiness and youth entrepreneurship.

3 Dichotomy and Continuum Between Farm-Enhancing and Profit-Generating Organic Waste Management Technologies

Organic waste, either from agricultural or urban sources, can be repurposed through various technologies that offer different benefits depending on scale, market conditions, and policy incentives. Some of these technologies can be considered 'appropriate' in the sense that they enable farmers and cities to manage and valorize organic waste into economically useful activities. Others may serve more as enhancements to existing farming systems—improving productivity, supporting capabilities development, and strengthening sustainability—without necessarily evolving into independent business models. Still, these uses are not separated by a fixed boundary. Rather, they exist along a continuum, where technologies can shift between farm-enhancing and income-generating roles depending on contextual factors such as organization, investment, demand, and policy support.

Technologies that enhance farms directly tend to require low capital investment and deliver clear operational benefits: reducing input costs, improving soil fertility, enhancing nutrient cycles, and mitigating environmental degradation. Many of these practices—like composting or biochar application—have been used for centuries and remain vital tools in sustainable agriculture. Their strength lies in their accessibility and ease of integration into diversified farming systems, particularly for smallholders with limited external inputs. These traditional methods reduce reliance on synthetic fertilisers and support long-term soil health, often without needing to interact with formal markets or become part of a business venture.

Yet, the same organic waste can be transformed into marketable products—such as mushrooms, insect-based feed, biogas, or organic fertilizers—or used to provide services like waste collection and bioenergy generation. These applications require more infrastructure and coordination, but they can create income-generating opportunities for rural entrepreneurs, cooperatives, and local governments. They also offer environmental and social benefits: reducing landfill use, curbing greenhouse gas emissions, and providing jobs, especially for youth and marginalized groups. For instance, as documented in the Kenya and Uganda report by Fair & Sustainable Consulting (2023), BSF farming at small scale can be used to reduce poultry feed costs—staying within the farm-enhancing sphere—but when scaled up and linked to external buyers, it becomes a commercially viable enterprise.

Where a given technology falls on this continuum depends on a variety of factors. Scale, investment, market access, workforce capacity, and the broader enabling environment all play a role. A farmer using waste to make compost for personal use remains on the farm-enhancing side of the spectrum. But with cooperative structures, supportive policy, and targeted technical assistance, that same practice can evolve into a business activity with marketable outputs. Biogas digesters used to fuel household cooking systems are typically farm-level tools—yet if surplus gas is sold or used to run services for others, they enter the realm of commercial ventures. Biochar, often used to improve soil directly, becomes an income source when connected to carbon credit systems or processed into high-value amendments. Recognizing this fluidity helps ensure that technological interventions are not only technically appropriate but also human-centered and aligned with economic resilience and livelihood goals.

Market dynamics are particularly decisive in determining whether a technology remains farm-enhancing or shifts toward profit-making. Some solutions only become financially viable when there is demand beyond the farm gate. Biochar, for example, does not constitute a business model unless buyers exist—whether for its soil amendment properties or its role in carbon sequestration. Similarly, compost remains a practice of on-farm resource cycling unless it is processed, packaged, branded, and sold through established distribution channels. Value addition becomes a critical factor in moving along the continuum: transforming practical sustainability tools into drivers of rural enterprise.

Labour intensity and skill requirements also change as technologies scale. At small scale, composting is a low-effort activity that fits easily into farm routines. At larger scales, it becomes more labour-intensive, requiring equipment, logistics management, and marketing capabilities. The same applies to BSF farming: managing a few colonies on a farm is feasible for one household, but larger operations demand trained staff, environmental controls, and regular monitoring—generating jobs and stimulating local economies.

Policy incentives can shift technologies along this spectrum as well. A government subsidy for biochar production, motivated by its climate benefits, may turn a farm input into a commercial opportunity. Anaerobic digestion systems can be adopted for household energy use, but when policy frameworks support their broader use—through feed-in tariffs, infrastructure grants, or carbon pricing—they become scalable solutions for energy and waste sectors. Without such support, many technologies risk remaining underutilized, as the costs and complexity of scaling up are not matched by clear economic returns. Understanding the continuum between farm-enhancing and income-generating functions allows development programmes and policymakers to adopt a more nuanced and flexible approach. It opens space for technologies to evolve organically according to local needs and capacities, while ensuring that interventions remain economically viable, socially inclusive, and environmentally sound.

▶ Conclusion

Waste-to-agrifood technologies operate along a continuum—from farm-enhancing solutions that strengthen soil health and productivity to income-generating activities that create jobs and economic value until capability-generating technologies stimulating a structural transformation. Recognizing this spectrum is essential to ensure waste-to-resource innovations remain relevant, viable, and aligned with sustainability goals. Movement along it depends on market conditions, policy incentives, financial investments, and scale of operation as well as on the societal construct. Composting, biochar production, and black soldier fly farming demonstrate how organic waste can be repurposed into fertilisers, animal feed, or bioenergy depending on local contexts. Technology choices are an important instrument to steer the evolution into a desired direction, e.g. creating a structural transformation towards a more sustainable and inclusive development.

Recent debates in development economics stress the qualitative aspects of inclusive growth—technological change, skills development, and the transition to formality—as drivers of productivity, incomes, structural transformation and thus poverty reduction. Within this, an appropriate technology approach can play a pivotal role: identifying solutions that are adapted to local resource availability, simple to operate, and supportive of workforce skill-building. At the farm scale, such technologies require minimal inputs, lower costs, enhance productivity, and foster learning for smallholders and community-based users. At larger, commercial scales, they generate diverse employment opportunities along the waste management chain.

In Africa, where youth unemployment and informality remain pressing challenges, these innovations offer concrete opportunities for rural and peri-urban job creation. However, scalability requires not only supportive policy frameworks and financial access, but also attention to job quality, underpinned by social dialogue and collaboration between governments, the private sector, trade unions, and research institutions. Practical cases illustrate this: in Ghana and Argentina, social dialogue has facilitated community adoption of context-specific solutions, while a private-sector biochar initiative in Namibia highlights how such approaches can also integrate with modern mechanisms like carbon markets.

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