# Why Food Loss & Waste Technologies Scale or Fail

## The role of women in building scalable, circular food systems

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# Acknowledgements

Food loss and waste (FLW) reduction is central to building resilient food systems. Around the world, CARE works with farmers, fishers and other livestock keepers, businesses, and local institutions to identify and grow practical solutions that reduce FLW, strengthen livelihoods, and improve food security. This paper brings together evidence from 21 countries and more than 25 projects to understand why effective FLW solutions so often fail to scale — and what it takes to achieve durable, system-level change. It reflects CARE's commitment to contributing to SDG 12.3 and to advancing women-centered, market-aligned FLW strategies that deliver lasting impact.

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# Executive summary

Reducing FLW is one of the most effective ways to strengthen food security, improve nutrition, reach climate and biodiversity goals, and boost local economies simultaneously. Yet even the most promising technologies often fail to scale. The reason is simple: The incentives, design choices, and delivery models behind them don't fit the realities and needs of "first mile"[1] producers, businesses, and consumers.

## The challenge

Sustainable Development Goal 12.3 set a clear target: halve food waste at retail and consumer levels and reduce food losses along supply chains by 2030. A decade of global attention, investment, and innovation has followed. Yet progress remains limited.

The problem is not a lack of good technologies. Tools like solar dryers, hermetic storage bags, small-scale processing equipment, cold chain, and biodigesters work. The problem is that they do not scale. Promising pilots stall. Farmers try a technology once and abandon it. Projects end and practices stop. After a decade of investment, the same solutions keep cycling through the same pilot trap.

At the same time, food systems are absorbing compounding shocks with increasing frequency. Communities on the margins bear the cost every time. Russia's 2022 invasion of Ukraine sent global grain and fertilizer prices soaring to forty-year highs. Conflict in Iran drove urea prices up roughly 50% since February 2026, leaving farmers across Africa and South Asia facing input shortages at the start of planting season. A new El Niño is forecast to develop by mid-2026, leading to conditions that historically reduce maize yields in southern Africa, disrupt monsoons in South Asia, and deepen drought across the Sahel. All of these types of shocks hit the same communities hardest: small-scale food producers and countries with the least buffer.

A food system that wastes a third of what it produces while remaining vulnerable to every price spike and climate disruption is not a resilient one. Scaling FLW solutions grounded in circular economy approaches is one of the most practical ways to change that— particularly when we remove barriers for women, who make up approximately half the farming workforce, to lead and advance these approaches.

# Why and what it takes to break the pattern

This paper draws on CARE's Global Food Loss and Waste survey — spanning 21 countries and more than 25 projects — alongside peer literature and expert interviews. Across all of it, four factors consistently determined whether FLW solutions scaled or stalled. These drivers reflect what kept coming up across every context: labor realities, incentives, market reliability, and social norms. Separately, each shapes adoption. Together, they determine scale.

1. **Women's time and labor burden**
   Solutions scale when they reduce unpaid labor and align with women's daily responsibilities.

2. **Enterprise viability**
   Solutions succeed when users can recover costs or generate income through workable business models.

3. **Market pull**
   Adoption accelerates when aggregation, buyer linkages, and reliable offtake create downstream demand.

4. **Affordability and cost recovery**
   Solutions endure when financing, subsidies, or low-cost models reduce upfront risk for users.

These four factors don't operate in isolation. They interact with delivery platforms, enabling policies, and social norms. But when they are absent — even from technically excellent solutions — technologies fail to scale. When they are present, adoption takes off. Building on these insights, we offer a practical, women-centered approach that delivers real, lasting impact.

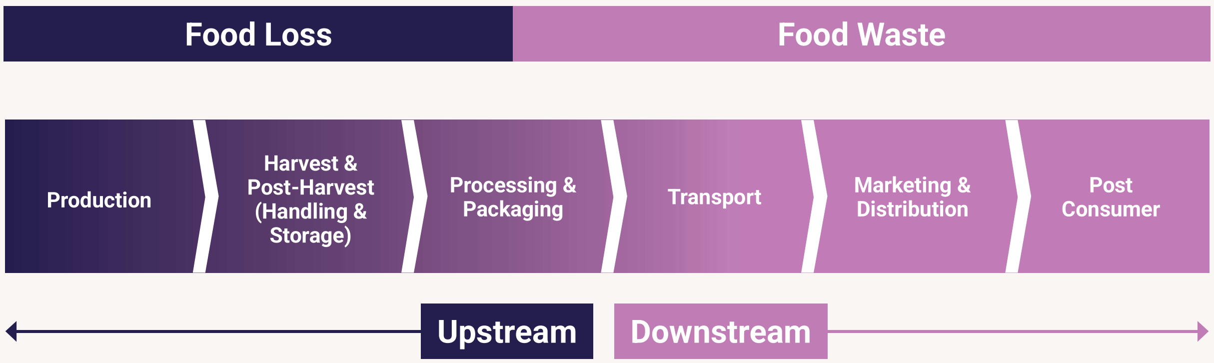
# Key concepts and framing

**Food loss**
*Food loss* occurs when food is reduced in quantity or quality before it reaches its final product stage in the food value chain.

**Food waste**
*Food waste* occurs when food that is still safe and fit for consumption is discarded.

**Upstream**
In the food system, *upstream* refers to the earlier stages of the food value chain, where food is produced, harvested, handled, stored, and initially processed.

**Downstream**
In the food system, *downstream* refers to the later stages of the food value chain, where food is transported, distributed, sold, consumed, and managed after purchase.




**Producers**
Unless otherwise specified, *producers* refer to farmers, fishers, pastoralists, and livestock keepers engaged in primary food production.

**FLW solutions**
In this paper, *FLW solutions* refer to the practices (e.g. planning, management skills, and behaviors) and the technologies (e.g. technical and digital tools) used to reduce food loss and waste across the food value chain.

**Enabling systems**
*Enabling systems* refer to the institutional, financial, market, and policy conditions that support the adoption and scaling of FLW solutions. This includes delivery platforms (e.g., technology-enabled systems, digital marketplaces, and logistics networks that connect producers to consumers, inputs, or services), extension platforms (e.g., agricultural extension services, Farmer Field and Business Schools [FFBS]), financial mechanisms (e.g., savings groups, blended finance, subsidies, carbon finance), and regulatory or standards frameworks.

**Circular food economy**
A *circular food economy* means redesigning how food is grown, made, moved, and eaten so that as little as possible goes to waste. Instead of a straight line from farm to trash, resources keep circulating. Nutrients go back to soil, byproducts become inputs, and leftover food gets redirected before it spoils. The goal is a system that's better for nature *and* creates more economic value along the way.

**Scaling**
*Scaling* refers to sustainable systems change beyond direct project implementation. It includes scaling out (expanding reach), scaling up (institutional and policy integration), and scaling deep (norms and behavior shifts).

# The case for scaling FLW solutions

In an era of rising hunger, shrinking aid budgets, and accelerating climate shocks, reducing FLW is no longer optional — it is imperative. It stands out as one of the most economically strategic, market-ready, and relevant opportunities to strengthen food security, livelihoods, and resilience at scale. The challenge today is not a lack of innovation, but the persistent gap between proven FLW solutions and sustained uptake by producers, businesses, and policymakers. Scaling FLW solutions requires aligning context-appropriate practices and technologies with market incentives, private sector-engagement, and enabling systems — including targeted subsidies, coherent standards, and climate and carbon finance mechanisms that reward efficiency, resilience, and circularity across food systems.

Food systems are structurally exposed to compounding shocks, the burden of which fall predictably on those least prepared to bear it. Over the past 5 years, wars have sent global fertilizer prices skyrocketing. Increasingly severe El Nino's threaten maize yields in southern Africa, monsoons in South Asia, and harvests across the Sahel. The cost of these shocks is highest for the smallest-scale producers and the women who hold post-harvest systems together with the least support.


Timothy Buckley/CARE

Reducing FLW — and building circular food systems that recover value from agricultural waste, restore soil fertility, and diversify input sources — is one of the most practical forms of structural resilience available. A household or business that produces its own soil amendments through biochar or bioslurry, stores its grain safely, and works with market-linked enterprises is partially insulated from global price spikes.

The overall benefits of reducing food loss and waste are enormous. Despite modest global gains, acute food insecurity and malnutrition have increased for the sixth consecutive year in fragile regions.[2] The FAO's *State of Food Security and Nutrition in the World 2025* estimates that in 2024, between 638 and 720 million people faced hunger, while about 2.8 billion were moderately or severely food insecure.[3] **Yet the food currently lost or wasted could feed roughly 1.26 billion people each year**.[4] In total, **this amounts** to about 2.5 billion tons of uneaten food annually, representing **more than USD $1 trillion in lost economic value**.[5,6]

The climate and environmental costs are equally severe.

- Farming accounts for almost all the world's freshwater use (92%). About a quarter of that water — water already used to grow the food — is wasted when the food gets thrown away. The water itself isn't "lost" in that moment. Instead, it's that we got nothing useful out of it.[7]
- Loss and waste also consume 19% of fertilizer, 18% of cropland, and occupies 21% of landfill volume, releasing methane gas- a dangerous greenhouse gas.[8]
- FLW squanders land, soil, seed, water, energy, and labor while accelerating ecosystem degradation, climate change and biodiversity loss.

## Where does food loss and waste happen?

Some food loss happens early — at the farm or fishery during harvest and handling. It's often driven by gaps in training, market access, climate information, financing, and basic infrastructure. When small-scale producers lack the tools and knowledge to reduce loss, even good solutions can't take hold.

Food waste also happens later, during storage, transport, retail, and even at the consumer level. Inconsistent quality standards, weak cold chains, poor market coordination, and limited systems for redistribution all push food out of the supply chain before it needs to go.

Increasingly, the bigger problem is downstream, not at the farm gate. This is why piecemeal fixes don't work — the system needs to be addressed as a whole.


FatmataJalloh/CARE

## Women and FLW

FLW — and the corresponding losses in time, income and nutrition — impact women in unique ways. Women contribute roughly 40% of the agricultural labor force globally, [9] but their labor and constraints remain largely invisible, including in measurement systems and technology design processes.

**Women do up to 50% of post-harvest processing, but men are consistently more likely to adopt technology to reduce post-harvest loss. That's because the technology is mostly designed for men, nor accounts for women's lack of access to land, lower control over income, and barriers accessing credit.[10]**

This underscores the critical need, as called for in the FAOs *Status of Women in Agrifood Systems*, for disaggregated data between women and men, and rigorous evaluation that link women's time use, access to assets, and decision-making authority to food systems outcomes.[11] Such measures could ensure that FLW and scaling strategies are designed with the women who sustain food systems rather than excluding them.

FLW reduction offers a powerful pathway to address some of the world's most pressing challenges. When designed and scaled effectively through a circular economy approach, FLW solutions improve food availability and affordability (including nutritious foods like vegetables), strengthen local economies, stabilize markets, increase incomes for producers, and generate resilient jobs without expanding production or intensifying pressure on natural resources and ecosystems.

Many FLW solutions contribute to climate mitigation, reducing methane emissions while rehabilitating soil health. Critically, some of the most scalable FLW solutions are driven by women-led micro- and small enterprises embedded in local markets. Unlocking their full potential requires moving beyond pilot projects toward systems that enable adoption at scale.

## The Hidden nutrition and food security crisis inside food loss and waste

FLW is not just an efficiency problem, it is also about diet quality and equality. Nowhere is this more visible than in what gets lost. The foods most commonly lost or wasted are nutrient-dense perishables: vegetables, fruits, eggs, milk, and animal-source foods that women and young children already struggle to access and afford.

Around 40% of the world's food production is lost or wasted between harvest and consumption — a quantity large enough to cover the daily food needs of everyone currently facing food insecurity, with food still left over.

Close to 1/5 of food produced annually never gets eaten, roughly 1 billion meals wasted every single day.

Approximately 14% of food is lost after harvest and before it reaches markets, pointing to persistent gaps in post-harvest management and supply chain systems.

In many low-income countries, as much as 50% of vegetables and fruits are lost before they arrive at markets.

Estimated annual losses and waste by food group include:

- 30% of cereals
- 40–50% of root crops, fruits, and vegetables
- 20% of oilseeds, meat, and dairy
- 35% of fish

Losses and waste are significantly higher in hotter climates, where elevated temperatures strain storage, processing, and transportation systems.

Losses of animal-source foods after harvest drive up prices, placing nutrient-rich foods further out of reach for the lowest-income households and deepening nutrition inequities.

Together, food loss and waste becomes a direct driver of malnutrition—not just hunger. Prioritizing FLW prevention and food safety in nutrient-dense value chains, paired with hygiene promotion, clean water, sanitation and behavior change, can stabilize prices and increase year-round food availability for low-income consumers and the most marginalized households.


# Why scaling is difficult

## Defining scale for FLW

Across the broader development community, scaling is increasingly understood as systems transformation rather than distribution of technologies or replication of pilots.[12]

CARE defines *impact at scale* as achieving resilient, systemic change through pathways beyond CARE and its partners' direct work with communities, delivering impact in the lives of women and girls for the majority of those affected by a targeted problem. This can apply at national, regional, or global levels, and applies in both long-term development and humanitarian crises.[13]

This paper applies a women-centered scaling lens, recognizing that women's labor, time use, and decision-making power directly shape whether FLW solutions take hold and last. For FLW solutions, success ultimately means that CARE's presence is no longer required as communities, markets, and governments embed solutions into their daily practices and systems.

## The scaling problem is a systems problem

Even the most effective post-harvest storage tool or redistribution platform will stall without the right conditions around it, which include farmer training, market linkages, financing, policy support, and community trust.

Transformational scaling means building those conditions deliberately so solutions can take root, generate value, and last.[14] It also means designing solutions with women from the start, not considering their needs as an afterthought. Women make up a significant share of agricultural labor and dominate many food handling and retail roles, yet they are frequently excluded from training, financing, and decision-making. A cold storage cooperative that doesn't account for women's mobility constraints, land tenure, or access to credit won't reach the people who need it most and won't scale.

No single actor can scale FLW solutions alone. Success depends on coordinated progress across primary food producers, markets, households, private sector partners, and public institutions. Adoption only happens when solutions are profitable, reliable, reduce risk, and fit within local labor realities and social norms.[15] In practice, these conditions are rarely all in place at once.

## Six patterns explain why FLW solutions so often stall, and what it takes to make them last

### 1. Value takes time to show up.

Many FLW solutions don't deliver immediate, visible returns. For example, using heavy machinery delivers fast, visible results: less labor, easier harvest. But it can quietly degrade soil over time. Investing in soil health works the other way: more effort and cost upfront, then farmers must wait several seasons before they can see results. When those results come, they tend to be long-lasting: higher yields, greater resilience, and lower losses over time.

In Southern Zambia, CARE's CBA SCALE+ and REFLESE programs integrated biochar as a low-cost soil restoration solution. Farmers reported land restoration and time savings, with benefits persisting across seasons — a clear signal that some solutions are worth the wait.

### 2. Value is often hidden downstream.

The benefits of FLW solutions frequently accrue slowly. They are often spread across multiple actors or depend on what happens further down the supply chain. This makes them all but invisible in systems that reward immediate returns. As a result, FLW solutions are undervalued and incentives to adopt them stay weak.

For example, solar dryer technology works. It reduces spoilage and extends shelf life. But for producers to see the benefits, aggregation systems, market demand for dried products, and support for women's labor burdens all need to be in place.

In Zimbabwe's Takunda program, solar drying reduced post-harvest losses and extended shelf life, but the technology's value only became visible when a processing company expressed interest in product development. The lesson: benefits often emerge downstream, not at the farm gate.

### 3. Incentives are conditional.

Adoption depends on clear, credible returns. In FLW reduction, those returns are rarely guaranteed. Income gains depend on access to subsidies, technical assistance, extension services, and financing. Without these, even profitable technologies struggle to move beyond pilots.

In Vietnam's She Feeds the World program, women initially hesitated to adopt pineapple leaf fiber processing. Adoption accelerated only after purchase contracts guaranteed demand for the fiber. A contract did what years of training couldn't.

### 4. Markets and policy pull in different directions.

Technically sound technologies only scale when markets, delivery platforms, policies, and financing mechanisms support them. Small-scale processing requires aggregation and buyer relationships. For example, cold storage depends on reliable electricity and functioning supply chains.

In Nepal's Poshan program, cold storage reduced spoilage, but scaling stalled when financial institutions deemed investments too risky and subsidies prioritize production inputs over post-harvest technologies. When policy and finance point the wrong way, even effective solutions go nowhere.

Josh Estey/CARE

**5. Social norms and women's time shape outcomes as much as technology does.**
Adoption is driven not only by markets but also by labor allocation, household decision-making, and social norms. Technologies that add to women's workload without offsetting time savings tend to stall. Solutions that don't fit local norms rarely endure.

For example, in Mozambique's CASCADE program, women reported meaningful reductions in time spent on post-harvest drying and processing. Adoption spread beyond formal project participants through community demonstrations and peer-to-peer testimony. Trusted social networks and visible time savings proved more powerful than training alone.

**6. Financial risk stops adoption before it starts.**
Technologies are far more likely to scale when they are low-cost, require minimal maintenance, and can be repaired locally. High upfront costs, dependence on electricity, or unavailable spare parts are adoption killers, particularly without financing options.

For example, evidence from Zambia shows that women's participation in Village Savings and Loan Associations (VSLAs) increased adoption of resilient agricultural practices by 47%. Two-thirds of that impact was driven by improved access to agricultural information and digital tools. When women have financial tools they control, adoption follows.[16]

Structural barriers — including limited technical capacity, environmental volatility, weak infrastructure, and uneven access to markets — compound these challenges and reduce the likelihood that FLW solutions endure. Across these examples, a consistent pattern emerges: technologies scale only when systems align to make their value visible, viable, and accessible.

# What the evidence shows

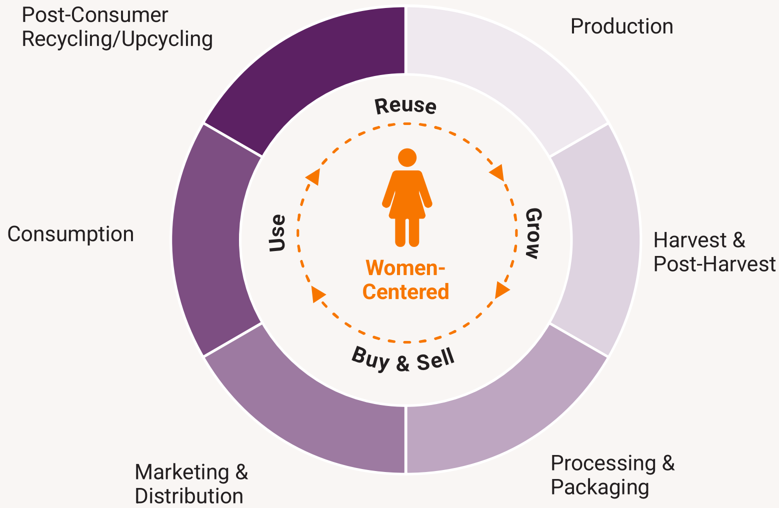
## Scope and methodology

This paper draws on evidence from a CARE survey on FLW conducted between October 2025 and January 2026, alongside a review of project documentation, select Farmer Field and Business School (FFBS) program evaluations, and targeted follow-up interviews with survey respondents. The survey captured insights from CARE country offices, project teams, and implementing partners across 21 countries, representing more than 25 projects.


The survey explored practices and technologies to reduce FLW across the food value chain. It captured information on the use of CARE's Women-Centered Circular Economy Model (WCCEM), as well as from project linkages to environmental and climate outcomes (including nature-based solutions and methane abatement indicators). Information about connections to women and youth, sustainability, scalability, successes, failures, adoption rates, lessons learned, and recommendations are also incorporated. While this dataset does not capture all CARE programs that incorporate FLW solutions, it provided a geographically diverse snapshot of technologies, practices, delivery models, and scaling dynamics currently in use across multiple value chains and stages of the food system.

A deeper examination focused on technologies that recurred across countries. These technologies include solar drying, hermetic storage, small-scale processing, cold storage systems, biochar, and biodigesters. Other high-impact FLW interventions are widely recognized in the sector, but this paper focused specifically on technologies that generated sufficient cross-country evidence of recurring scaling patterns.

## CARE's Women-Centered Circular Food Economy Model to Reduce Food Loss and Waste




### About CARE's model

CARE's Women-Centered Circular Economy Model (WCCEM) applies circular economy principles across the food value chain to design out food loss and waste, circulate resources to build systems health, and protect renewable resources and assets. What distinguishes this model is its focus on who is impacted at each stage, centering women as key actors at every stage.

The model identifies practical solutions, economic incentives, and enterprise opportunities—particularly for women—while aligning technical innovation with local market realities. In practice, it is co-designed with producers, private sector partners, research institutions, and local experts to ensure solutions are locally-led, systems-aligned, and scalable.

## Technical evidence annex

To support transparency and analytical rigor, a detailed **technical evidence annex** was developed as a companion to this paper. This annex includes extended technical case summaries, a structured "driver-to-evidence map," and survey and interview materials. **These companion materials informed the analysis presented here but are not included to preserve the length and accessibility of this paper.**

## Cross-cutting patterns revealed

Across projects, several consistent patterns emerged.

- **Good technology alone was not sufficient for long-term scale.** Many solutions demonstrated clear technical benefits, yet adoption often slowed once project support ended.
- **System alignment determined durability.** The lasting success of technologies were linked to viable income opportunities, reliable markets, accessible financing, and ongoing training. When they weren't, progress stalled even if the technology worked well.
- **Women's time, labor, and decision-making power shaped outcomes.** Adoption was stronger when technologies reduced unpaid labor or translated into predictable income, and when women had authority over purchasing and enterprise decisions. Where labor burdens increased without compensation, scaling was limited.
- **Market reliability and practical access to capital affected whether people kept using new technologies.** Farmers continued to use the technologies when they could recover costs, access trusted buyers, and access financing without excessive risk. High upfront costs, weak supply chains, or uncertain demand made it harder for farmers to keep using the technologies over time.

The central challenge in FLW reduction isn't inventing new tools. Instead, it's creating the conditions for those tools to be used long-term. The evidence points to four interrelated drivers that consistently determine whether FLW solutions expand or stall after project funding ends. These drivers form the foundation for scale.

## High-level findings: drivers of scale

Drawing on cross-country evidence, four key factors consistently determined whether FLW solutions scaled or stalled. These factors reflected patterns observed across diverse contexts and markets.

**Women's time and labor burden** — technologies scale when they reduce unpaid work, align with women's daily responsibilities, and reflect women's preferences.

**Enterprise viability** — solutions take hold when users can recover costs or earn income through workable business models.

**Market pull** — adoption accelerates when aggregation, buyer linkages, and reliable offtake create clear downstream demand.

**Affordability and cost recovery** — solutions last when financing, subsidies, or low-cost models reduce upfront risk.

These four factors do not operate in isolation. They interact with delivery platforms, enabling policies, and social norms. But when they are absent — even from strong technical solutions — technologies fail to grow. When they are present, adoption takes off.

## Technologies that helped, and what made the difference

Each example below highlights what supported adoption and scale, as well as what limited it. Together, these patterns reinforce the four drivers of scale noted above.

### Solar Drying

Global evidence shows that solar dryers can reduce post-harvest spoilage by 20 to 60% and extend shelf life by several months compared to traditional drying methods.[17] They can also reduce spoilage, quicken drying times, lower operating costs, and improve product quality, with some studies reporting meaningful income gains and cost savings when dryers are used consistently within organized production or processing systems.[18]

However, adoption remains uneven. Limited documentation on economic and social results reduces awareness of benefits and broader adoption, and many solutions are not adapted to local contexts or supported by government policy.[19]

In Mozambique, CARE's *CASCADE* project introduced solar drying through 75 FFBS groups, reaching approximately 265,000 people (nearly 140,000 women). Women reported spending less time on post-harvest drying and related processing tasks, a traditionally time- and labor-intensive activity. This freed time for farming, household tasks, and income-generating activities. Adoption extended beyond formal FFBS participants through demonstration plots and peer-to-peer testimony. 28% of FFBS members purchased seeds using income earned demonstration plots — an early signal of financial autonomy and reinvestment capacity.

CARE Zimbabwe's *Takunda* project supported 95 producers using solar dried ingredients to make enriched porridges, earning average incomes of approximately USD $30 per month. The model extended to over 5,000 associated vegetable producers (75% women). Private sector interest emerged, signaling commercial viability, but scaling stalled when required nutritional testing was not completed before the project ended.

**The pattern:** Solar drying scales when it is part of collective aggregation and processing models, reduces women's time burden, connects to reliable market demand, and generates income. It stalls when women take on extra work without income returns, market pathways are incomplete, or commercialization support ends too soon.

## Hermetic storage

Hermetic storage is one of the most scaled post-harvest technologies in the Global South, with more than 20 million bags sold across Africa and Asia over the past decade.[20] Peer-reviewed studies show that hermetic storage can reduce grain losses to below 1% for 8–12 months, and reduce post-harvest losses by 40–70%, compared to traditional storage losses of 20–30%. Adoption has been driven by relatively low unit costs (USD $2–3 per bag), immediate and observable loss reductions, compatibility with existing storage, and the ability to sell grain later at higher seasonal prices. This can increase income by 10–30% through price arbitrage.[21]

**A $3 bag = A $300 decision**
Hermetic storage bags cost USD $2–3.

For a smallholder farmer earning $1–2 a day, a $3 hermetic bag costs more than a full day's wages. For a median-income worker in Washington, DC, that's the equivalent of spending $300 out of pocket — today, in cash, with no credit.

Despite this cost, hermetic bags pay off: post-harvest grain losses drop from 20–30% with traditional storage to under 1% for up to 12 months, and farmers who hold grain to sell later can increase income by 10–30% through seasonal price arbitrage.

Still, sustained use remains uneven. Research in Malawi shows that while 80% of farmers are aware of hermetically sealed bags, only 11–20% report using them, and just 7% report repeated use.[22] In Nigeria, 95% of merchants were aware of Purdue Improved Crop Storage (PICS) bags (a product that uses hermetic storage technology to prevent post-harvest loss), but 46% had never used them due cost and limited access to. Counterfeit products and inconsistent rural availability further undermine trust and scale.

Between 2024 and 2025, CARE Kenya's Danida Market Development Partnership (DMDP) introduced hermetic bags through 22 FFBS groups, reaching 660 members (435 women). Project staff reported reduced post-harvest losses, improved grain quality, and time savings for women due to less need for sorting, pesticide application, and repeated drying. Sustained adoption was supported by local availability, repairable materials, and access to finance through VSLAs, as well as alignment with government and policy frameworks. However, counterfeit products and limited market links slowed wider growth.

CARE Nepal's Nurture Every Future (Poshan) program promoted hermetic storage bags for rice and wheat storage among farmers and cooperatives at the processing and packaging stage. Women, who typically manage post-harvest storage, reported fewer hours spent on repeated drying and pest control. Unit costs were generally affordable where bags were available, but adoption remained limited in remote areas due to weak distribution and the absence of bulk procurement mechanisms. Women often managed storage but they rarely controlled purchasing decisions, limiting independent scale.

In Zambia, CARE's Resilient Future: Sustainable Livelihoods and Ecosystems through FFBS Expansion (SUFFBS-REFLESE) program reached over 26,700 farmers (~17,100 women), trained 4,400 lead farmers in post-harvest loss management, and linked ~60,400 households to distributors of hermetic bags and related supplies. Cooperative aggregation and market linkages created viable pathways beyond project support. However, conflicting extension advice, uneven agrodealer networks, and limited market access slowed sustained adoption in some areas.

**The pattern:** The use of hermetic storage technology spreads when it is affordable, accessible, trusted, and when women can make purchasing decisions. It stalls when counterfeit supply chains are unreliable, rural availability is inconsistent, counterfeit products reduce confidence, and when women lack authority over purchasing decisions.

## Small-scale processing

Processing equipment (like threshers, mills, oil presses, and fiber extractors) can turn surplus perishable food into marketable, shelf-stable products. This can generate income and reduce physical labor, but it requires enough throughput volumes to be viable, making aggregation and collective use essential.

Research shows that small-scale processing increases women's income and resilience when structured as business activities rather than as unpaid household labor.[23] However, evidence from private sector actors indicates that larger-scale mechanization can displace women's income if control over harvesting and processing shifts to men, underscoring the importance of women-responsive design.

In Vietnam, CARE's She Feeds the World program introduced pineapple fiber processing through women's groups, reaching over 22,000 farmers. Initially met with skepticism, adoption increased after exposure visits to a private fiber producer and guaranteed purchase contracts. Women's groups operated fiber-extraction machines collectively, generating reliable income as Grade-1 fiber sold consistently at 200,000 VND per kilogram. As income became visible and predictable, household dynamics shifted and initially resistant husbands became more supportive. Women expanded participation by inviting other growers, extending benefits beyond direct project participants. Despite strong pilot results, pineapple fiber processing has not scaled beyond the project. High upfront equipment costs and limited market depth constrained expansion, reinforcing that processing technologies require accessible financing and sufficiently deep markets to scale.

**The pattern:** Small-scale processing works when organized as women-led businesses with guaranteed purchasers, aggregation models, and visible income returns. It stalls when introduced as an added household task without compensation, when financing for equipment is unavailable, or when markets are too shallow.

## Cold storage/Cold chain

Cold storage technologies reduce post-harvest losses by slowing spoilage and extending the shelf life of perishable foods, particularly fruits, vegetables, and dairy. Small cold rooms and modular systems, such as CoolBot-enabled units, lower capital costs by using locally available air-conditioning equipment and insulated rooms. Evidence shows cold storage can help producers avoid seasonal price crashes and stabilize income.[24] However, these systems require reliable electricity, sufficient throughput volumes, aggregation, and market coordination to remain viable.

In Nepal, CARE's Poshan project integrated CoolBot cold storage with complementary FLW solutions and market linkages. This reduced spoilage and labor, with women noting fewer hours spent managing post-harvest losses. Findings emphasized that cold storage performed best when embedded within upstream and downstream value chain interventions rather than introduced as standalone infrastructure. Scaling, however, remained limited by high upfront costs and limited access to credit (particularly for cooperatives and women-led groups). Subsidies often prioritized production inputs over loss reduction or post-harvest investments, and financial institutions viewed cold storage units as high-risk due to uncertain utilization and inconsistent supply volumes. Where aggregation, transport, and demand coordination were weak, cold rooms risked underuse, but in contexts with cooperative ownership, government support, reliable energy, and structured market demand, lower-cost systems offered a pragmatic pathway to expand cold chains in smallholder settings.

Interviews with peer organizations support these findings. In Thailand, university-led adaptation improved technical fit, but high upfront costs limited individual adoption, reinforcing the need for cooperative ownership and aggregation. In Bangladesh, early deployments were largely abandoned and left unused, prompting a shift toward project design and implementation led by local innovators and researchers, highlighting the importance of locally led adaptation and local ownership.

**The pattern:** Cold storage scales when it is part of coordinated aggregation systems, with reliable access to energy and transport, linked to predictable market demand, and financed through accessible credit or public support to mitigate utilization risk. It stalls when introduced as standalone infrastructure without sufficient throughput, energy reliability, cooperative ownership, or aligned financial incentives.

## Biodigesters

Biodigesters are sealed anaerobic systems that convert organic waste into biogas and bioslurry, a nutrient-rich fertilizer. They reduce methane emissions, replace firewood, lower fertilizer costs, and close nutrient loops within farming systems. Evidence shows biodigesters deliver reinforcing benefits across waste reduction, energy access, soil health, and women's time savings when embedded within supportive financing and service systems. However, sustained adoption depends on reliable feedstock supply, technical support, accessible financing, and bioslurry linkages to agronomic practices and input markets.

In Honduras, CARE's Prosper Centro America/ CARE10x/Lions Club program reached over 120 direct participants (60% women) across three departments. Women reported saving 2–3 hours per day previously spent collecting firewood and cooking with smoke. Adoption was driven by a co-responsibility financing model: households covered 50% of installation costs through cooperative-managed revolving loans, creating ownership and regenerating capital for additional households. 100% of participating households continue operating biodigesters more than two years after project support ended. Sustained use was reinforced through promoting equality for women and girls, promoting community engagement around environmental awareness, addressing social norms related to use for local buy-in, and correct use. Additional factors included embedding biodigesters within community managed systems (e.g. rural savings groups, cooperatives, and revolving funds), integrating the innovation withing FFBS platforms for capacity strengthening, peer learning, and diffusion beyond project participants. Additionally, building partnerships between government and the private sector were key for institutionalization at municipal and national levels and for scaling beyond project timelines. The next phase aims to put 1,000 biodigesters in the hands of smallholder farmers.

CARE Niger has promoted biodigesters across two projects: Creation of Green Jobs and Income through the Promotion of Biodigesters in the Zinder Region and the Innovation Program for Resilience in the Sahel. These initiatives reached over 6,200 people (over 4,000 women) through a locally anchored social enterprise model using lease-to-own financing repaid by farmers in bioslurry rather than cash over the course of a year. Each 4m³ biodigester generates approximately USD $1,330 in additional annual income, reduces 45 minutes to 1.5 hours of daily labor for women and children, and prevents up to 7.48 tons of $CO_2$ emissions per year. Critically, the use of biodigester compost has increased farmers yield of millet (286.64%), sorghum (62.96%), peanuts (47.37%), and cowpeas (30.91%).[25] Units installed between 2021 and 2023 remain operational and trained local masons organized in cooperatives continue constructing new systems beyond project support, indicating replication beyond direct subsidy. Scaling was supported by local production, flexible financing, enterprise integration, and private-sector engagement. Key constraints include upfront capital costs, seasonal feedstock variability, and limited subsidy mechanisms.

**The pattern:** Biodigesters scale when they meet multiple household needs simultaneously (energy, soil fertility, income, and time savings), are financed through co-responsibility or flexible repayment models, and are constructed and maintained by local technicians using locally available materials. They stall when introduced without financing, service systems, reliable inputs, or integration into farmer organizations and market structures.

## Biochar

Biochar is a carbon-rich material produced from agricultural residues and applied to soils to improve health and crop yields. It also represents a direct circular economy intervention: converting crop stalks, husks, and other post-harvest waste — material that would otherwise be burned or left to decompose — into a productive soil input. This closes a nutrient loop within the farming system, reducing dependence on external fertilizer inputs while sequestering carbon that open burning would otherwise release. Research shows that biochar can increase soil organic matter, improve water-holding capacity, enhance soil structure, and reduce greenhouse gas emissions.[xxv] These benefits indirectly reduce food loss and waste by stabilizing yields, improving crop quality, and reducing vulnerability to drought and soil nutrient stress. Despite strong technical evidence, agricultural adoption remains uneven due to gaps in awareness, equipment access, extension integration, and linkages to soil health or carbon incentive systems.

In Côte d'Ivoire, CARE's Cocoa Upcycling Pilot supported 200 women across seven VSLAs (248 direct participants; 1,612 indirect beneficiaries) to convert cocoa pod waste into biochar and biochar-based products. 60 women entrepreneurs produced approximately 1,400 kg of biochar, generating USD $700 in income over a four-month period. The initiative linked women's groups to cooperatives and private-sector actors for commercialization. However, scaling was limited by the short project duration, seasonal availability of raw materials, and the need for storage and supply coordination to ensure continuous production.

In Southern Zambia, biochar has been integrated into CARE's FFBS platforms across four districts, expanding from 45 pilot groups to 224 FFBS groups and reaching approximately 6,654 farmers. An estimated 3,500 farmers (around 53%) have adopted the practice. Adoption was driven by low production costs, use of locally available materials, strong peer-to-peer training, and integration into existing farmer platforms rather than stand-alone delivery. Farmers reported reduced dependence on external inputs, improved yields (from approximately 750 kg to 900 kg per quarter-hectare), and lower production costs. However, staff noted that continued scaling depends on institutional partnerships, extension support, and sustained integration in FFBS platforms, and within ministry systems.

**The pattern:** Biochar scales when it is low-cost, locally produced, embedded within existing farmer organizations, and linked to visible yield and income gains within one or two seasons. It stalls when introduced as a short-term pilot without secure raw material supply, storage coordination, extension integration, or clear market or soil health incentive pathways.

Vanessa Mwingira/CARE

# What's missing: The measurement gap

Recurring patterns are clear: women's time, enterprise design, financing mechanisms, market pull, and delivery platforms shape whether technologies sustain beyond pilots. Yet many of these drivers are inferred rather than systematically measured. Without stronger, more intentional metrics, it remains difficult to rigorously compare interventions, identify predictors of scale, or credibly link FLW reduction to climate, nutrition, and investment outcomes.

**Key measurement gaps limiting scale and investment include:**

**Women's time-use and labor data linked to adoption and sustained use**
Across technologies, women's time savings and labor burdens repeatedly emerged as drivers of sustained use, yet time-use and labor were rarely quantitatively measured. Without structured tracking, the sector cannot accurately reflect whether technologies reduce labor burdens, redistribute unpaid work, or add uncompensated tasks. Better evidence could also help private sector actors, especially technology developers, recognize and market these benefits more effectively, which could strengthen adoption and scale.

**Social and behavioral drivers of adoption**
Programs rarely track *why* people choose to adopt or continue using FLW solutions, such as whether they feel able, motivated, or supported by opportunities to use them consistently. These everyday factors are often inferred, not measured, yet they strongly influence whether solutions take hold over time.[26]

**Cost, cost-recovery, and reinvestment tracking**
Revolving funds, lease-to-own models, and enterprise structures appear central to sustained adoption, yet systematic cost-recovery and reinvestment data are rarely collected. Without this, financing gaps remain.

**Sustained use and post-project durability**
Installation and training numbers are commonly reported, but continued functionality post-project is not. Where durability was measured (e.g., 100% continued biodigester operation in Honduras after project end), it became one of the strongest signals of genuine scale.

**Methane abatement**
Many FLW solutions contribute to methane reduction, yet only two of 25 country offices surveyed reported measuring methane impacts. This limits access to climate finance and leaves uncounted agriculture's mitigation potential.

**Soil, water, and ecological impacts**
Contributions to soil health, water, biodiversity, and nature-based solutions are rarely measured in ways that are accessible for small enterprises. The absence of standardized environmental indicators limits alignment with environmental commitments and finance.

**Quantitative loss and waste reduction by technology and context**
Percentages for FLW reduction at baseline and endline are not consistently measured. This limits cross-technology comparison and obscures which interventions deliver the greatest reductions under which conditions.

**Nutrient-dense food loss rates**
Cost and affordability of a healthy diet and food safety standards for recovered foods are rarely tracked, obscuring the nutritional dimensions of FLW.

**Formal recognition of circular economy**
Circularity is widespread across contexts but are rarely framed, measured, or financed as circular economy interventions. The absence of standardized circular metrics limits visibility, comparability, competitiveness, and access to green or climate-linked financing.

Strengthening measurement does not require complex systems. It requires intentional design from the outset, treating measurement as a scaling investment rather than an administrative burden.

# CARE's commitments

## The case for a Women-Centered Circular Economy Model (WCCEM)

The evidence presented in this paper points to a clear pathway: to expand FLW solutions, we need to focus on women as key players in circular food systems. A circular food economy is not just about managing waste and loss; it's a broader systems approach that retains value by reducing avoidable losses, regenerating soil nutrients, converting unavoidable waste into productive inputs, supporting local businesses, and improving food security all while aligning financial and behavioral incentives.

Across contexts, FLW solutions lasted when they aligned with women's time realities, generated predictable income, and were embedded in market-linked enterprise models. Circular practices are already present in many communities, but they are often informal, undercounted, and disconnected from finance and markets. Scaling requires formalizing these nutrient and value loops, linking environmental regeneration with women-led enterprise and market participation. CARE's WCCEM positions FLW reduction as a pathway to link women's economic empowerment, climate resilience, and food system regeneration at scale.

## Areas of contribution and commitment

Building on existing programming and the insights presented here, CARE's contribution will focus on several priority areas.

**1.Training 500k farmers, predominately women small-scale producers, on FLW solutions using CARE's WCCEM**
CARE's FFBS programming in Guatemala, Nepal, Peru, Thailand, Uganda and Zimbabwe is ready to scale the WCCEM, linking farmers to the green economy and accelerating local innovation. CARE commits to training half a million predominantly women small-scale farmers on FLW reduction practices.

**2. Refine measurement and learning**
Update and tailor key performance indicators within CARE's FLW and circular economy programming to better capture loss reduction, women's time use, enterprise viability, social and behavioral drivers of adoption, environmental and climate outcomes, all without overburdening implementation teams or small enterprises.

**3. Develop and pilot improved metrics and learning**
Test light-touch, time-use measures that accurately capture women's time, and cost-recovery indicators in a limited number of country contexts (e.g., 3–5 pilots) to strengthen understanding of scaling predictors.

**4. Strengthen climate and environmental linkages**
Explore practical proxies for methane reduction and ecosystem benefits associated with FLW interventions, with the aim of improving access to both adaptation and mitigation climate finance, including piloting carbon methodologies for FLW that benefit small-scale food producers.

**5. Prioritize nutrient-dense value chains in FLW programming**
Focusing on value chains including vegetables, fruits, eggs, dairy, and animal-source foods where losses are highest, women's roles are greatest, and the nutritional payoff of reduction is most direct for women and children. This includes integrating food safety standards and hygienic handling into all post-harvest programming, alongside nutrition behavior change where relevant.

**6. Deepen circular economy practice**
Elevate circular food economy approaches within on-farm and off-farm FLW efforts and expand support for women-led enterprises operating along these pathways.

Taken together, these contributions are intended as part of a broader effort to align FLW reduction with women-centered economic development, circular food systems, and climate resilience. By focusing on where evidence is thinnest and where scaling challenges are most acute, we hope to move the sector toward more actionable, comparable, and equal solutions. These commitments reflect an intention to contribute constructively to the global FLW agenda while continuing to learn alongside partners, governments, and communities.


Fatmata Jalloh/CARE

## What donors, governments, and the private sector can — and should — do

The compounding shocks discussed previously — wars, rising fertilizer costs, climate impacts on crop yields — are not isolated events. They are the new normal. The ask to donors, governments, and the private sector that follows is urgent not because the evidence is new, but because the window to act before the next shock arrives is shrinking.

The tools to reduce FLW already exist. What's missing is the policy environment, market infrastructure, and financing that allow them to scale. But scaling *to whom* matters as much as scaling at all.

Women make up about 40% of the global agricultural labor force. In many low- and middle-income countries, they do most of the work after harvest — processing, drying, storing, and selling food. Yet they are often excluded from the training, financing, and decision-making that determine whether FLW solutions succeed.

Behind that statistic are an estimated 600 million small-scale food producers worldwide, many of them women, along with an untold number of women-led micro- and small businesses embedded in local food markets. Their work sustains food systems, but their needs are rarely considered in how solutions are designed. That must change.

The recommendations below are not aspirational. They reflect what evidence shows is required for FLW solutions to grow — with women at the center, not as an afterthought.

## Donors should fund the conditions that make solutions work, not just the technology

Pilots are not the problem. The gap between pilot and scale is. Multi-year funding must support market linkages, extension, financing mechanisms, training, and behavioral support — not just equipment.

Donors should also require data that tracks how women and men spend their time. This means making labor data by women and men a standard requirement and funding the tools to collect it.

Climate finance must be unlocked for FLW. Reducing methane and improving soil health are real, measurable benefits of FLW solutions — but climate finance rarely flows to the projects delivering them. This means investing in carbon methodologies that work for small-scale FLW contexts and ensuring that women-led enterprises benefit directly.

Above all, donors should support financing for women-led businesses, not just equipment. VSLAs, revolving funds, and lease-to-own models have demonstrated durability and should be supported as scaling vehicles in their own right.

## Governments must align extension services with post-harvest priorities

Agricultural extension often focuses on production. Governments should require and fund training on reducing post-harvest loss (including through FFBS) as a core function.

Subsidies also need to shift. Many current structures support production inputs, while losses often happen after harvest — which is also where women's businesses are most active. Governments should invest more in storage, processing, and tools that reduce loss.

Governments should also enforce quality standards, prevent the proliferation of counterfeit products that undermining trust in technologies like hermetic bags, and integrate FLW reduction explicitly into national climate commitments and NDCs to unlock climate finance at scale.

Finally, national statistics systems should disaggregate post-harvest labor by sex. Making women's contributions visible is essential for policies that actually support them.

## The private sector must design for women

Technology developers should work directly with women when designing products and solutions. This includes understanding how they spend their time and accounting for mobility, labor burden, maintenance capacity, and decision-making authority.

> **A solution that works for women will work for everyone, but the reverse is not true.**

Financial institutions and technology companies should offer flexible financing, including lease-to-own, pay-as-you-go, and cooperative purchasing, built specifically for smallholder post-harvest investment.

Buyers and processors should commit to offtake agreements. The evidence previously reported from Vietnam shows that a guaranteed buyers drive adoption where years of training did not.

Corporate buyers should also set and publicly share clear targets for reducing FLW in their supply chains. This will create accountability and incentivize upstream investment.

Rather than bypassing VSLAs and cooperatives, companies should recognize them as the aggregation and trust networks they already are — and build commercial relationships accordingly.

**The ask is simple:** invest not just in technologies, but in the systems that help those technologies reach the women who need them most. The tools are already in women's hands. Build the conditions that help them grow.

# Conclusion

Reducing food loss and waste is one of the most powerful — and underutilized — ways to improve food security, climate action, strengthen women's economic opportunities, and help the approximately 600 million small-scale producers who grow much of the world's food.

This paper shows that FLW is not a technology problem. The tools already exist. What's missing is a systems approach that treats women's time as a core design variable, connects technology to markets, and invests in the support needed to turn small pilots into lasting change.

For six consecutive years, acute food insecurity has increased in the world's most fragile regions even as the food needed to feed hungry people is lost in fields, storage, and supply chains. The gap between what we know and what we do is unacceptable.

Funders, governments, private sector partners, and civil society organizations all have a role to play. The call is clear: invest in the conditions that allow FLW solutions to grow. Prioritize women's time. Build markets before distributing hardware. Finance businesses, not just equipment. Measure what matters, including nutrition.

The tools to reduce food loss and waste are already in women's hands. Now, we must build the systems that help those tools reach their full potential.

# Endnotes


1 CARE uses the term “first mile” to refer to primary producers and the initial stages of value chains where production begins. We use this term to emphasize that smallholder farmers and primary producers are the origin of value creation in food systems, as opposed to the term ‘last mile’ producers.

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