CASA
Commercial Agriculture for Smallholders and Agribusiness

Opportunities and drivers for SME agribusinesses to reduce food loss in Africa and Asia

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Commercial Agriculture for Smallholders and Agribusiness

CASA aims to drive global investment for inclusive climate-resilient agri-food systems that increase smallholder incomes.

The programme makes the case for increased agribusiness investment by demonstrating the commercial and development potential of sourcing models involving empowered smallholder producers and by tackling the information and evidence gaps holding back investment.

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Contents

List of figures

Acronyms and abbreviations

BSFL	Black soldier fly larvae
CASA	Commercial Agriculture for Smallholders and Agribusiness
Capex	Capital expenditure
DFI	Development finance institution
FAO	Food and Agriculture Organization
INR	Indian rupee
IPCC	Intergovernmental Panel on Climate Change
LMIC	Low- or middle-income country
PICS	Purdue Improved Crop Storage
R&D	Research and development
RBF	Results-based finance
SDG	Sustainable Development Goal
SLS	Smart Logistics Solutions
SMEs	Small and medium-sized enterprises
USAID	United States Agency for International Development

Executive summary

Climate change, conflict, and the COVID-19 pandemic and its aftermath have caused a sharp increase in food insecurity globally. **Reducing food loss – a decrease in the quantity and/or quality of food that takes place from production through to processing – in places where food insecurity is most severe has the potential to be a win-win for food security, climate outcomes, and for commercially driven agribusinesses.**

This report reviews the common drivers of food loss in Sub-Saharan Africa and South Asia, which include inadequate storage, lack of cold chain, and poor post-harvest and distribution practices. It then highlights five technologies or approaches which have the potential to address food loss, and which are appropriate for agricultural small and medium-sized enterprises (agri-SMEs) operating in much of Sub-Saharan Africa and South Asia, which face particular challenges (e.g. an unreliable electrical grid and fragmented value chains). Finally, the report highlights the main barriers to adoption and scale for these technologies and approaches, and identifies opportunities for governments, development partners, investors, and technology manufacturers to improve their uptake among agri-SMEs.

The five technologies and approaches covered in this report are as follows:

- **Decentralization of processing using solar dryers:** The decentralization of primary food processing, in which some portion of value addition is undertaken close to the farm gate by farmers or SMEs, can have multiple benefits, including reducing food loss, lowering transport costs, and increasing rural incomes. Solar drying technology can enable this model, particularly in areas where there is a tradition of sun drying fruits and vegetables and there is a viable domestic or regional market for these products. Successful models typically involve an agribusiness off-taker who works with farmers and SME producers, providing technology and services (e.g., guaranteed off-take, training etc.) that ensure the production of high-quality produce.
- **Hermetic storage (e.g. bags and cocoons):** This maturing technology is increasingly available in local markets and represents a potentially easy-to-implement solution which could help to substantially address food loss during storage – where most loss occurs – for key staple grains. Cost and usage remain challenges for smallholders, with greater potential for small- to medium-scale traders and aggregators in rural areas with limited storage infrastructure. By creating a hypoxic environment around the produce, these solutions can achieve 100% insect mortality and reduce the growth of mould and aflatoxins. Bags are more appropriate for agri-SMEs involved in distribution, whereas cocoons (i.e. storage containers consisting of two plastic halves joined together by an airtight zip) are more useful for those storing large volumes for periods of six months or longer.
- **Off-grid cold storage (e.g. solar-powered cold rooms):** Innovative technologies and delivery mechanisms are still being tested in markets in India, Nigeria, and Kenya. Despite the high upfront cost, there are several examples of agri-SMEs and co-operatives achieving payback periods of as little as two years across a range of fruit and vegetable value chains, with returns driven by reductions in food loss and improved pricing due to better quality of the produce. Cooling as a service business models also offer the potential to reach smaller agri-SMEs and micro-entrepreneurs operating in informal rural and peri-urban value chains, but their application is limited to high-value crops that are generally out of the reach of the rural poor.
- **Agri-ecommerce platforms:** Agri-ecommerce platforms are a well-developed technology that aims to reduce food loss by improving the availability of information on market demand for farmers. Technology providers can also engage in logistics, warehousing, and quality control, taking collection of the produce from rural-based hubs, combining it at a central packing house, and delivering to urban retailers. Models of this

kind have scaled more effectively in South Asia than Sub-Saharan Africa, where they are constrained by poor road and logistics infrastructure.

- **Waste-to-value approaches:** Waste-to-value or circular economy approaches have the potential to reduce food loss by utilizing bruised or damaged fruits and vegetables which are unable to be sold as intended as inputs into other food products. Although the application of these approaches to the production of products such as condiments and oils is popular, they are unlikely to have a material impact on food security. However, models such as using black soldier fly larvae (BSFL) to produce animal feed (after consuming the food waste) are more promising, with a range of related technologies and business models operating in markets in both Africa and Asia.

The main barriers to the success and scaling up of these technologies and approaches include a lack of knowledge and awareness of their commercial benefits, a lack of finance for manufacturers and agri-SME customers, a need for further research and development (R&D) and business model innovation (e.g. to bring down cost), and a lack of supportive policies and regulatory frameworks. Policymakers, development partners, investors, and the private sector can all play important roles in addressing these barriers by helping to do the following:

1. Build product awareness and trust

Opportunity 1.1: Manufacturers and distributors of less established food loss technologies (e.g. solar cold rooms and hermetic cocoons) should increase their use of traditional and digital marketing campaigns to drive awareness of the financial benefits of food loss technologies for agri-SMEs. This could include holding product demonstrations (e.g. at larger aggregation points), developing more tailored case studies and testimonials (e.g. for specific crops and geographies) that can be easily shared, and building simple tools such as return on investment calculators to help agri-SMEs make investment decisions.

Opportunity 1.2: Where development partners and development finance institutions (DFIs) have invested in food loss technologies or agribusinesses adopting waste-to-value approaches, they should also fund robust data collection and the development of studies which can clarify the investment case for agri-SMEs. To be effective in driving uptake, awareness, and trust, these studies must capture data on both financial return on investment and impact. Where possible, they should also take a comparative approach (i.e. across multiple products or value chains), and information should be made publicly available. There is an opportunity for the Commercial Agriculture for Smallholders and Agribusiness (CASA) programme to invest in data collection and case study development as it scales up its support to agribusinesses to reduce food loss (e.g. in the vegetables sector or in waste-to-value for animal feed).

2. Increase finance through providing subsidies and engaging in risk sharing

Opportunity 2.1: Development partners and DFIs should provide domestic banks and non-bank financial institutions with subsidies to lend to agri-SMEs investing in food loss technologies or approaches. There are several instruments which could be used to do this, including payments to the lender for originating a loan for a specific purpose (e.g. capex (capital expenditure) investment in food loss technologies), impact-linked payments, and funded first-loss guarantees for making relevant investments. Aceli Africa is an example of a donor-funded vehicle which provides these types of incentives, although it focuses on lending to agri-SMEs more broadly, rather than specifically on food loss reduction.

Opportunity 2.2: Given high customer acquisition costs and customers' price sensitivity, there is an opportunity for development partners to utilize results-based finance (RBF) schemes to introduce service-based models in harder-to-reach areas where traction on technologies has been achieved (e.g. in countries such as Nigeria where RBF is already being utilized for solar home systems). This could be linked to the level of utilization – for example, in the case of cold rooms and storage facilities, which typically have remote monitoring capabilities.

Opportunity 2.3: Development partners should fund research which explores the viability of tapping into finance from voluntary carbon markets to accelerate the manufacturing and roll-out of technologies which reduce food loss. There is a precedent for manufacturers and distributors in comparable sectors (e.g. clean cooking) accessing carbon credits as an additional revenue stream, but given recent concerns over the quality of offsets and the challenges associated with monitoring and verification, care must be taken when encouraging the use of this approach for food loss technologies. A detailed study should be conducted to identify the technologies and scenarios where offsets are credible (e.g. where there are likely to be material reductions in greenhouse gas (GHG) emissions) and where monitoring and verification are likely to be viable.

3. Fund product R&D and business model innovation

Opportunity 3.1: Development partners and governments should continue to support product developers and manufacturers to reduce the cost and improve the reliability of nascent food loss technologies (e.g. solar cold rooms). Competitions such as the Global LEAP Off-Grid Cold Chain Challenge have successfully funded early-stage pilots and are worth replicating, but given the potential impact of lowering product costs there is a case to be made for continuing to provide credible manufacturers with additional matched grant funding to accelerate further R&D. This could be deployed directly into companies by development partners as part of sustainable agriculture programmes (e.g. CASA), or through competitions which are focused on improving the effectiveness of existing products, rather than piloting new innovations.

Opportunity 3.2: Development partners should also provide matched grant funding and technical assistance to credible agri-SMEs with strong management teams to test new business models which reduce food loss. This could include aggregation models leveraging hermetic storage or off-grid cold storage, processing closer to sites of production utilizing solar drying, or various waste-to-value approaches. For example, CASA's market systems development component could work with agribusinesses in the vegetable sector to assess the costs and benefits of installing off-grid cold rooms at key aggregation points and could provide repayable grant funding to support upfront investment if viable. Similar support could also be provided to pilot solar drying of low-grade fruits and vegetables.

4. Develop supportive policies and enforce standards

Opportunity 4.1: Where they exist, governments in Sub-Saharan Africa and South Asia should reduce or eliminate import tariffs and customs duties for food loss technologies and their components (e.g. solar panels). Development partners can support policy change and implementation by helping to make the socioeconomic case for tariff reduction, as well as funding technical assistance to develop streamlined customs procedures, training for relevant customs staff, and strengthening industry associations and lobby groups to hold governments to account.

Opportunity 4.2: Development partners should provide technical support to regulatory bodies and enforcement agencies to improve the enforcement of food safety standards. This could include providing training on best practices as well as technical assistance and financing to improve processes and systems. This will help to create the right incentives for smaller traders and aggregators to invest in appropriate drying and storage technologies that will help to reduce losses while maintaining quality.

The technologies and approaches profiled in this report are not the only solutions for addressing food loss and improving food security in Sub-Saharan Africa and South Asia. Indeed, in many cases these are second-best or interim solutions which will ideally no longer be necessary when there is reliable electrical grid access and more structured and well-regulated value chains. However, in the current context and operating environment which some agri-SMEs in parts of these regions face, these technologies and approaches offer the potential to reduce food loss, contribute to improvements in food security, and mitigate climate change. They can also deliver a solid return on investment for agri-SMEs by helping to generate increased revenues from higher volumes of, and better quality of, produce in the right contexts.

1. Background and context

Climate change, the COVID-19 pandemic and its aftermath, and conflict have all caused a sharp increase in food insecurity globally. The Intergovernmental Panel on Climate Change (IPCC) notes that climate change is already affecting food security as increasing temperatures, changes in rainfall, and more extreme weather events reduce crop yields in low-latitude regions[1]. The COVID-19 pandemic pushed 70 million additional people into extreme poverty in 2020, while rising energy prices and disrupted global food supplies because of Russia's war on Ukraine have led to sharp increases in the prices of food and the inputs required for food production[2]. This has been compounded by the devaluation of many currencies in low- and middle-income countries (LMICs) against the US dollar. As a result, the World Food Programme has estimated that the number of people suffering acute food insecurity globally more than doubled between 2019 and 2022, rising from 135 to 345 million people[3].

As well as being affected by rising temperatures and changes in rainfall, agriculture is one of the main drivers of the climate crisis and generates more than one-quarter of the world's GHG emissions[4]. Land-use change for crop production or pasture is a key driver,[5] while other activities along the value chain, such as agricultural production, processing, and distribution, all also contribute. Food loss and waste alone is estimated to contribute between 8 and 10% of total GHG emissions,[6] with food loss – i.e. a decrease in the quantity or quality of food that takes place from production through to processing – being the main issue in large parts of Africa and Asia, rather than food waste (see Chapter 2 for further discussion). Aside from the negative environmental impact, food loss also directly impacts food security and farmers' livelihoods, while eroding agribusinesses' revenue and profitability. Reducing food loss in agribusiness supply chains in places where food insecurity is most severe therefore has the potential to be a win-win for food security and nutrition, climate outcomes, and commercially driven agribusinesses.

Reducing food loss is on the agenda of various development partners, including UN agencies, the World Bank, bilateral donors, and philanthropic foundations. Sustainable Development Goal (SDG) target 12.3 focuses on "halving of per-capita global food waste at the retail and consumer levels and the reduction of food losses along production and supply chains, including post-harvest losses".[7] Bilateral donors are increasingly seeking to fund innovations which reduce food loss to improve food security and nutritional outcomes: for example, the United States Agency for International Development's (USAID's) Feed the Future programme provides matching grants to companies in Bangladesh, Kenya, Nepal, Niger, Nigeria, and Tanzania applying new solutions to combat food loss in nutrient-dense value chains[8]. Development partners have also funded competitions and "challenges" to support the development of new technologies and business which reduce food loss, including the Global LEAP Awards: 'Off-Grid Cold Chain Challenge' funded by the UK Foreign, Commonwealth and Development Organization, alongside IKEA Foundation, DOEN Foundation, and Good Energies Foundation[9]. Yet, despite these initiatives, progress has been slow, with the 2023 SDGs report highlighting that "levels of food loss have hardly changed since 2016 and are falling short of the target of substantially reducing post-harvest food losses by 2030"[10].

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[1] IPCC (2019) *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.*
[2] World Bank (2022) *Poverty and Shared Prosperity 2022: Correcting Course*
[3] https://www.reuters.com/world/people-facing-acute-food-insecurity-reach-340-million-worldwide-wfp-2022-08-24
[4] McKinsey (2020) *Agriculture and climate change.*
[5] Lynch, J. *et al*. (2021) *Agriculture's contribution to climate change and role in mitigation is distinct from predominantly fossil CO2-emitting sectors.*
[6] https://www.wri.org/insights/3-ways-reduce-food-loss-waste-africa
[7] https://sdgs.un.org/goals/goal12
[8] https://www.marketlinks.org/announcements/private-sector-partnership-opportunities-reduce-food-loss-and-waste-request
[9] https://www.clasp.ngo/updates/2022-global-leap-awards-off-grid-cold-chain-challenge-announces-preliminary-finalists/
[10] UN (2023) *The Sustainable Development Goals Report 2023*

Given the scale of the challenge, the aim of this report is to highlight innovative and commercially viable technologies and approaches which agri-SMEs can use to tackle the main drivers of food loss in Sub-Saharan Africa and South Asia, which have the highest levels of food insecurity in the world[11]. We focus on agri-SMEs as they are responsible for producing and processing most food in these regions, including over 80% of animal-sourced foods and fruit and vegetables in Sub-Saharan Africa[12]. The report assesses barriers to uptake and scale for each, as well as drawing on case studies to highlight real world challenges to, and drivers of, uptake, and lessons learned. It then outlines the opportunities for development partners, investors, and policymakers to help take these technologies and approaches to scale, thereby enhancing food security and helping to minimize the climate and environmental impacts of food loss.

[11] FAO (2019) *State of Food and Agriculture (SOFA) report.*
[12] https://climatechampions.unfccc.int/harnessing-the-power-of-african-smes-to-deliver-both-nutrition-and-climate-goals/

2. Drivers of food loss in agribusiness supply chains

Defining food loss

Food loss and waste refers to any food which leaves the supply chain without being consumed. **The United Nations Food and Agriculture Organization (FAO) defines food loss as "the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retailers, food service providers and consumers"[13].** This is clearly differentiated from food waste, which "refers to the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers and consumers"[14]. As shown in Figure 1 below, 60% of total food produced globally is lost before it reaches the retail stage, with most of this occurring at the post-harvest and storage and distribution stages.

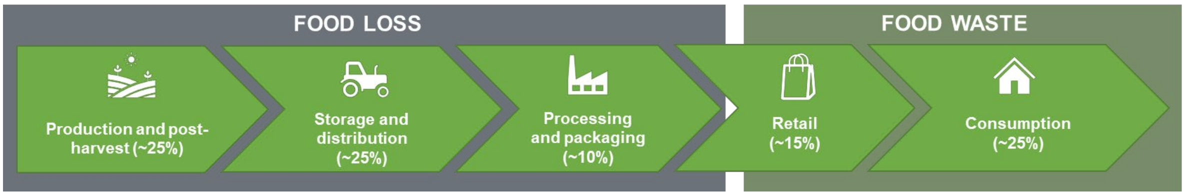

Figure 1: Food loss and waste (% total food produced) along the value chain (Source: adapted from FAO, 2013; 2019)

The proportion of food that is lost as compared to the proportion of food that is wasted varies significantly by region. In higher-income regions, such as North America and Europe, more food is wasted at the retail and consumer level than is lost earlier in the value chain. Conversely, levels of food loss are much higher than levels of food waste in the lowest-income regions, with food loss making up 95% of agricultural production that is not consumed in Sub-Saharan Africa and 87% in South and Southeast Asia in 2015 (see Figure 2). **Given that Sub-Saharan Africa and South Asia are the regions that face the highest levels of food insecurity today, it is logical that this report focuses on the drivers of, and solutions to, the problem of food loss specifically, rather than food waste, in these regions.**

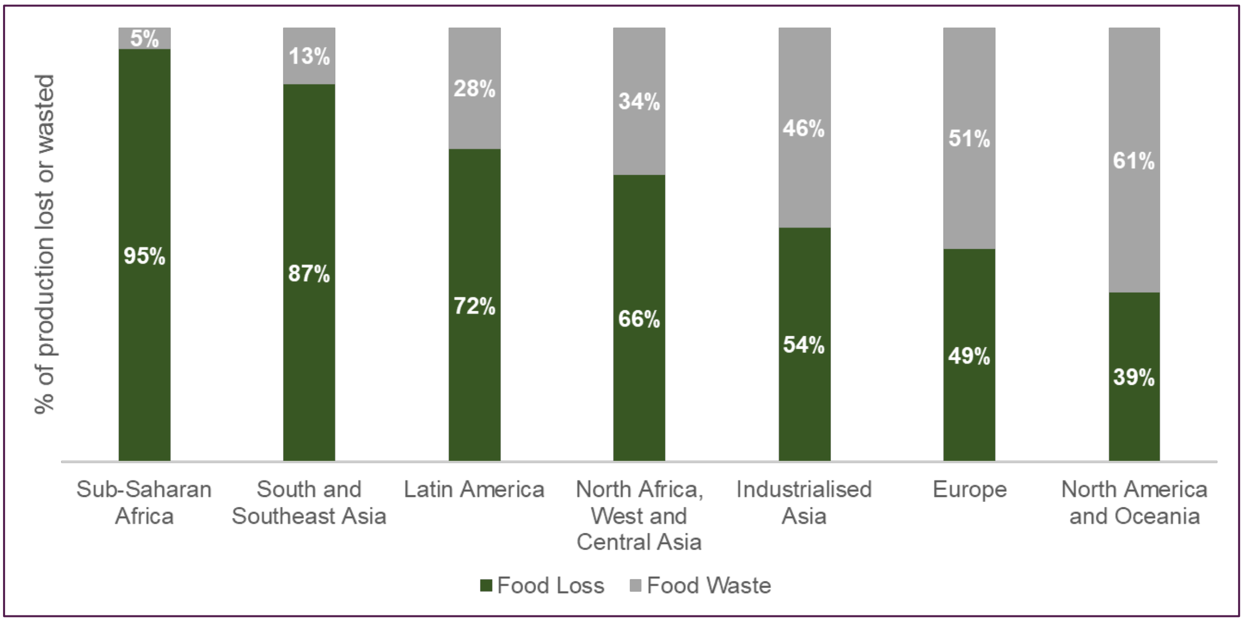

Figure 2: Food loss versus food waste by region (Source: Deloitte, 2015).

[13] FAO (2019) *State of Food and Agriculture (SOFA) report.*
[14] *Ibid.*

Drivers of food loss

Common drivers of food loss in Sub-Saharan Africa and South Asia include inadequate storage, lack of cold chain, and poor post-harvest and distribution practices. Fragmented value chains with weak linkages between producers, traders, and buyers is also a key issue, with the majority of produce aggregated and traded multiple times, leading to longer storage and/or transportation periods and greater risk of damage or spoilage. Primary losses along the value chain (from aggregation and processing to retail (see Figure 3) are due to spillage, biological degradation, and damage[15].

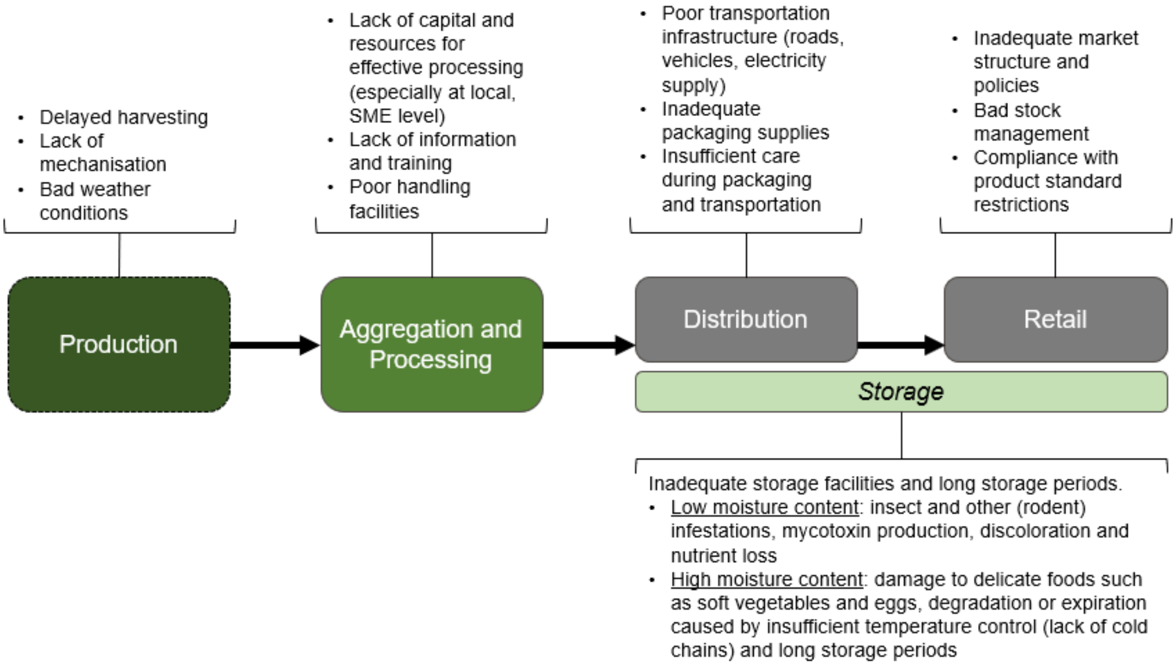

Figure 3: Drivers of food loss across value chain (Source: adapted from International Finance Corporation (2017) and UNECE (2011))

Spillage occurs at the harvesting, transportation, and processing stages due to poor handling of crops and lack of appropriate machinery and storage facilities. It is much more common with staple crops, such as grains, as compared to fruits and vegetables, as the former require more intensive processing, and are often processed into small components (e.g. rice grains) and stored and transported in large quantities.

Biological degradation can occur at all stages in the value chain but is most common during storage operations. Staples with lower moisture content (e.g., roots, tubers, and grains) are less perishable[16], whereas high moisture content foods (e.g. fruit and livestock products) are especially susceptible to biological degradation, particularly in LMICs, where only 20% of perishable food is refrigerated (compared to 60% in high-income countries)[17]. Lack of cold chain infrastructure is a main driver of biological degradation, as limited access to reliable grid power and the high capex associated with cold chain investments are significant constraints to development.

Damage is caused predominantly during storage and transportation. Softer, more perishable goods are prone to damage as they are more delicate, making them more susceptible to subsequent biological degradation and being rejected by off-takers or consumers.

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[15] International Finance Corporation (2017) *From farm to fork: Private enterprise can reduce food loss through climate-smart agriculture.*

[16] Hodges, R.J., Buzby, J.C. and Bennett, B. (2010) *Postharvest losses and waste in developed and less developed countries: Opportunities to improve resource use.*

[17] International Institute of Refrigeration (2020) *The Role of Refrigeration in Worldwide Nutrition.*

Inadequate care when packaging goods, lack of appropriate packaging or distribution materials (e.g. use of baskets rather than plastic crates), and suboptimal road surface conditions contribute to this[18].

Quantifying food loss

The FAO estimates that 13.8% of all food produced is lost annually, amounting to an estimated US$ 400 billion of lost income[19]. However, data on food loss in LMICs is patchy. The task of collecting robust food loss data is made more difficult because food supply chains are complex, vary across regions, and do not adopt universal reporting standards[20]. Despite this, there have been dozens of studies which aim to quantify food loss in specific value chains in Africa and Asia, and which can be used as a basis for extrapolation. These studies demonstrate that although levels of food loss vary greatly between crops (e.g. non-perishable versus perishable) and type of value chain (e.g. traditional versus mechanized), the proportion of food lost at different stages of the value chain on aggregate is very similar across regions facing high levels of food insecurity. As shown in Figure 4 below, the highest levels of post-harvest food loss in Sub-Saharan Africa and South and Southeast Asia occur during the production, handling, and storage stages, although there is significant variation by type of crop[21]. For example, in fruit and vegetable value chains in Sub-Saharan Africa, the greatest proportion of food loss or waste (38%) occurs at the processing stage, whereas for grains and staples this occurs at the handling and storage phase (42%)[22].

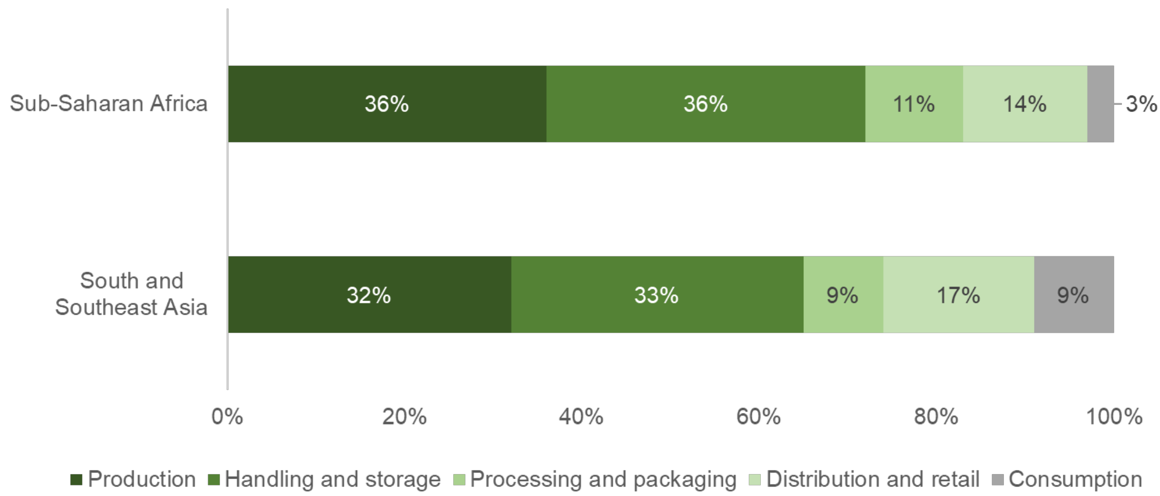

Figure 4: Food loss and waste in Sub-Saharan Africa and South and Southeast Asia by stage of the value chain (Source: BCG, 2018)

Across Sub-Saharan Africa and South Asia, the highest levels of food loss occur in the fruit and vegetable value chains (including roots and tubers). Fruits prone to degradation and damage face very high levels of food loss, with 56% of mangoes and 34% of tomatoes by volume estimated to be lost before they reach the consumer (see Figure 5). Roots and tubers, such as yam and cassava, also exhibit high levels of losses of over 40%. Staple grains, such as wheat and maize, have lower levels of food loss, with approximately a quarter lost before they reach consumers in LMICs in Africa and Asia[23].

[18] Lipinski, B. *et al*. (2013) *Reducing Food Loss and Waste*. Working Paper, Instalment 2 of Creating a Sustainable Food Future. Washington, DC: World Resources Institute.
[19] International Institute of Refrigeration (2020) *The Role of Refrigeration in Worldwide Nutrition.*
[20] Sheahan, M. and Barrett, C.B. (2017) *Review: Food loss and waste in Sub-Saharan Africa.*
[21] BCG (2018) *Tackling the 1.6 billion-Ton Food Loss and Waste Crisis.*
[22] Deloitte (2015) *Reducing Food Loss Along African Agricultural Value Chains.*
[23] Soethoundt *et al*. (2021) *Adoption of food loss and waste-reducing interventions in Low- and Middle-Income Countries.*

However, losses are significantly higher than comparable figures in high-income countries, which underlines the need for interventions targeting food loss across both staple and fruit and vegetable value chains in the region to address the food security challenge.

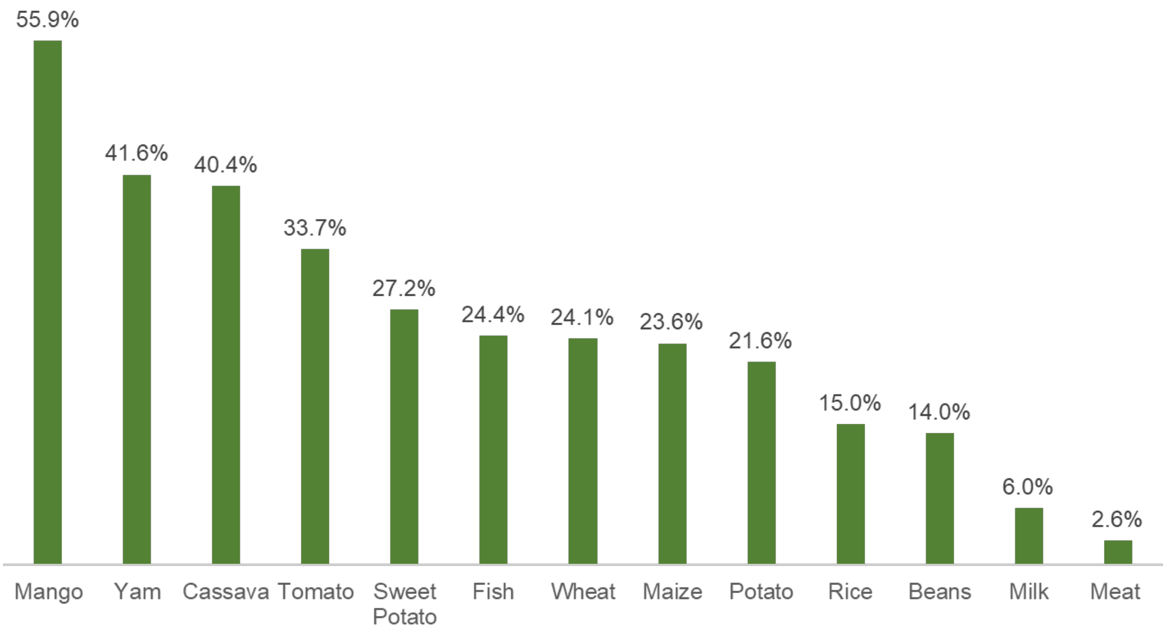

Figure 5: Food loss for selected crops in Africa and Asian LMICs (Source: adapted from Soethoundt *et al*. (2021))

3. Technologies and approaches that can be used to reduce food loss for agribusiness SMEs

The previous chapter highlighted that food loss in agricultural value chains across Sub-Saharan Africa and South Asia is driven by gaps in storage, distribution, and cold chain infrastructure. However, there are cross-cutting barriers which make the required investment in technology and infrastructure challenging. Most critically, these include a lack of – or unstable – access to electricity, highly fragmented and informal value chains, and limited access to finance that would enable agri-SMEs to invest in new technologies.

In 2020, 733 million people globally did not have access to electricity, with 80% of these people living in rural areas. Although over three-quarters of those without access to electricity are in Sub-Saharan Africa, many rural people and businesses in South Asia still face regular power cuts because of weak or unstable grid access[24]. This is a clear barrier to agri-SMEs in these areas investing in the same types of grid-powered cold chain technology, and in some cases processing and storage infrastructure, as are used in countries with reliable grid access.

Many of the foods that are most frequently consumed in low-income countries in Sub-Saharan Africa and South Asia – ranging from staples to fruit and vegetables – pass through highly fragmented and informal value chains. Some of these are dominated by small-scale traders and middlemen who are focused on turning over high volumes as quickly as possible due to a lack of working capital, limited price premiums for quality, and weak knowledge around food safety practices[25]. Other barriers include weak enforcement of food safety regulations (e.g. around aflatoxin levels in maize, rice, and groundnuts)[26] and low levels of reputational risk faced by agribusinesses arising from food quality issues (e.g. due to limited consumption of branded products). These factors all reduce incentives for investment in the infrastructure which can reduce food loss and ensure food quality across the value chain.

Access to finance for agri-SMEs is also limited, particularly in Sub-Saharan Africa. In 2018 alone, there was an estimated annual US$ 65 billion financing gap for agri-SMEs in Sub-Saharan Africa (with funding needs ranging from US$ 25,000 to US$ 1.5 million for such businesses), compared with actual investment of US$ 60 billion in the same year. This is driven by the higher risk profile and lower returns associated with agricultural loans when compared to most other sectors, which act as a disincentive for banks to lend[27]. This is clearly a barrier to investment in many types of storage, cold chain, and distribution infrastructure for agri-SMEs.

The rest of this chapter sets out five technologies and approaches which agri-SMEs can leverage to reduce food loss in their supply chains:

1. decentralization of processing using solar dryers
2. hermetic storage
3. off-grid cold storage
4. agri-ecommerce platforms
5. waste-to-value models

These technologies and approaches were selected because they target the drivers of food loss at different stages in the value chain, and there is evidence that they have the potential to be commercially viable within certain African and Asian contexts. We demonstrate this through case studies that draw on real-life impact data from agribusinesses which have adopted them.

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[24] Lighting Global (2022) *Off-Grid Solar Market Trends Report 2022.*
[25] International Finance Corporation (2017) *From farm to fork: Private enterprise can reduce food loss through climate-smart agriculture.*
[26] Oloo, B. *et al*. (2018) *Food Safety Legislation in Some Developing Countries.* In: Food Safety: Some Global Trends.
[27] Dalberg and KFW (2018) *Africa Agricultural Finance Market Landscape.*

Some of these technologies and approaches are "high-tech" solutions (e.g. solar cold rooms and aggregation via digital platforms), but others are "lower-tech" solutions (e.g. hermetic cocoons and bags and basic solar dryers) which nevertheless have the potential to be transformative.

1. Decentralization of processing using solar dryers

The decentralization of primary food processing, in which some portion of value addition is undertaken close to the farm gate by farmers or SMEs, can have the dual benefit of reducing food loss and increasing rural incomes. This is achieved by reducing the time from harvest to primary processing, which minimizes food losses due to damage in transit and degradation during storage. Meanwhile, undertaking initial processing close to the point of production gives rural people a value-added product to sell.

Solar drying technology is one technology which can enable this model, particularly in areas where there is a tradition of sun drying fruits and vegetables and there is a viable domestic or regional market for these products. For example, this is the case with mangoes and bananas in Southeast Asia and onions, carrots, and spices in India[28]. Removing moisture from perishable foods increases their shelf life by up to six months, but traditional sun drying, which consists of simply laying produce on mats or plastic sheeting under the sun, is a low-cost preservation method that results in high losses and contamination from dust and rain. Solar systems, whether passive (natural convection) or active (air circulation via fans) can be relatively simple in design and are able to protect the produce from contamination, preserve nutrients and colour, and reduce spoilage. Drying enables farmers and SMEs to utilize low-grade produce[29] that would ordinarily be discarded, reducing food loss. The increased shelf life allows aggregation and collective marketing, reducing price variability and increasing revenue streams, while off-takers also achieve cost savings due to transporting less bulky final products.

Successful models of decentralized processing using solar dryers involve an agribusiness off-taker who works with farmers and SME producers, providing technology and services (e.g. guaranteed off-take, training etc.) that ensure high-quality produce. For example, S4S Technologies in Maharashtra, India, provides basic solar dryers to micro-entrepreneurs who aggregate vegetables (e.g. ginger and onions) for drying, then buys back the dried produce for use in spices and sale to institutional kitchens. In a study carried out with 800 micro-entrepreneurs over a six-week period, the company found that its decentralized drying model reduced food loss by approximately 38 MT (approximately 2% of total production) when compared with its centralized processing facilities, while savings from reduced losses and transportation costs increased company margins by 15%. Meanwhile, micro-entrepreneurs earned approximately Indian rupees (INR) 6,500 (~US$ 80) per month from their processing activities – a clear win-win.

While vegetables and fruit are commonly preserved from spoilage by sun drying in India, preserving food this way is less common in other areas and will be more challenging to implement. Finance for upfront investment in dryers can be a barrier for smaller SMEs: even the most basic dryers can cost around US$ 200 and larger dryers with solar-powered circulation fans can cost between US$ 1,400 and 2,600[30]. A larger agri-SME or corporate agribusiness that plays a role in providing financing and developing the end market and products for sale, as well as providing services to their suppliers to ensure a smooth supply chain, is therefore key.

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[28] Udomkun, P. *et al*. (2020) *Review of solar dryers for agricultural products in Asia and Africa: An innovation landscape approach.*

[29] Warrier, R. and Lade, (no date) *Value addition through solar drying*. M. LEIS India. https://leisaindia.org/value-addition-through-solar-drying/.

[30] GrainPro interview.

2. Hermetic storage

Staple food value chains across Sub-Saharan Africa and South Asia, which are critical for food security, are typically highly fragmented and, in some cases, have volatile enabling environments, including public procurement for reserves, poor enforcement of quality standards and cross-border trade regulations, and elites with a vested interest in "gaming the system". An example of this is the maize sector in Kenya, which is dominated by thousands of small and medium-sized aggregators, traders, and wholesalers[31]. When compounded by a lack of regulation and incentives for ensuring quality (e.g. ensuring there are low levels of moisture and aflatoxin), this fragmentation makes the structured trade (and, consequently, access to finance) which would enable investments in improved silos and drying facilities challenging for all but the largest off-takers.

In this context, hermetic storage technology represents a potential quick win which could help to substantially address food loss during storage – where most loss occurs – for key staples (e.g. maize, rice, wheat etc.), if used by small- to medium-scale traders and aggregators in rural areas with limited storage infrastructure. Given their applicability to key staple food value chains, they also have a high potential to improve food security in Africa and Asia. Two examples of hermetic storage technology which have been proven to be effective in reducing food loss and which are commercially viable are hermetic bags and hermetic cocoons. Both work by creating an airtight environment around the produce, which limits the reproduction of insect pests and reduces damage to the grain or other produce stored within[32,33].

Hermetic bags have been widely promoted by the development sector for use by smallholder farmers since the development and commercialization of Purdue Improved Crop Storage (PICS) bags in 2007[34]. Today, there are several companies which produce hermetic bags across a range of sizes (typically between 25 and 100 kg) and specifications (e.g. single-, double-, and triple-layered), including GrainPro, A to Z, and several others which have a licence to manufacture PICS bags[35]. There is now a strong body of evidence which demonstrates that hermetic bags can achieve 100% insect mortality (as effective or better than insecticides), reduce mould and aflatoxin growth, and reduce food loss to below 1% after several months of storing cereals (e.g. maize and rice) and legumes (e.g. beans, nuts, and pigeon peas)[36]. The bags are relatively cheap (US$ 1–3 per bag, depending on the quantity purchased) and have demonstrated returns of investment ranging from 13 to 80%, depending on the crop stored[37]. Although development programmes and companies manufacturing hermetic bags have primarily targeted smallholder farmers, there is a clear use case for hermetic bags among agri-SME aggregators and traders that are regularly engaged in the distribution of staple crops (see case study).

Hermetic cocoons are storage containers, consisting of two ultraviolet-resistant plastic halves joined together by an airtight zip, which can be used to store agricultural commodities and seeds without the need for chemicals. They are manufactured exclusively by GrainPro and range in size from 5 MT to 300 MT, with the cost of a 20 MT cocoon ranging from US$ 2000 to US$ 3000, depending on the location and import tariffs[38].

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[31] USAID (2015) *Kenya Agricultural Value Chain Enterprises Maize Value Chain Analysis.*

[32] Baributsa *et al*. (2020) *Developments in the use of hermetic bags for grain storage*.

[33] This method is not suitable for all types of food, due to the risk of botulism. Some foods, especially those with low acidity, can create conditions conducive to the growth of Clostridium botulinum bacteria, which can produce a deadly toxin in the absence of oxygen. This risk is primarily associated with vacuum-sealed low-acid foods.

[34] https://picsnetwork.org/who-we-are/

[35] Baributsa *et al*. (2020) *Developments in the use of hermetic bags for grain storage.*

[36] *Ibid*.

[37] Baributsa, D. and Njoroge, A.W. (2020) *The use and profitability of hermetic technologies for grain storage among smallholder farmers in eastern Kenya.*

[38] Wellspring interview with GrainPro.

Studies conducted across Africa and Asia have shown that cocoons effectively reduce the insect population to as low as one insect per kilogram of grain, without the use of insecticide, extend the germination life of seeds, and ensure the moisture content of grains remains stable[39,40]. Cocoons have also outperformed conventional fumigation practices in reducing insect populations and minimizing weight loss when storing grain for periods longer than eight months[41]. The return on investment on hermetic cocoons for agri-SMEs is highly sensitive to the value of the crop, the level of food loss reduction, and import tariffs in place, but payback periods as low as one year have been demonstrated[42].

A key barrier to uptake of both hermetic bags and cocoons among agri-SMEs is knowledge and awareness of the financial benefits of using these technologies for storage and distribution. Although over 23 million PICS bags alone have been sold to date, much of this has been subsidized by development partners as part of agriculture programmes targeting smallholder farmers rather than SMEs. Finally, appropriate use of hermetic bags and cocoons still requires grain to be dried to the appropriate level of moisture content prior to storage, and appropriate drying and testing facilities may be unavailable in many areas. However, there are innovative aggregation models being piloted which can help overcome this barrier, including the use of mobile aggregation centres which leverage mobile drying units and hermetic bags (see the GrainPro case study, below).

Case study 1: Mobile aggregation models using hermetic bags

The most basic use case for agri-SMEs adopting hermetic bags or cocoons is using them to store staples which they have produced or aggregated, to improve their margins by reducing levels of food loss. However, there are also examples of products enabling innovative business models which also reduce food loss and increase incomes experienced by the suppliers of agri-SMEs, typically smallholder farmers.

Smart Logistics Solutions' (SLS's) mobile aggregation centre model in Kenya is an example of this. SLS agents use motorbikes, a weighing scale, moisture meters, mobile dryers, and a GrainPro hermetic bag to aggregate beans from contracted farmer groups at their farms. For SLS, this flexible model has enabled them to increase sourcing volumes by 60%, while halving sourcing costs, due to reduced facility rental and logistics costs. Meanwhile, smallholders reported that the levels of food loss faced fell from 30% to 10% due to the mobile drying and hermetic storage solutions, increasing their revenues[43]. This has resulted in further commercial benefit for SLS, as farmers' loyalty to the company has improved and side selling has been reduced.

3. Off-grid cold storage

Establishing cold chain infrastructure which is as widespread and reliable as that in industrialized regions has the potential to increase food supply in LMICs by 15%[44]. However, as highlighted previously, limited grid power is a key barrier to doing this. There are a range of cold chain technologies that are appropriate for agribusinesses operating in areas with unreliable grid power, or which are entirely off-grid. Some of these – including absorption refrigerators and refrigerated vehicles powered by diesel or petrol – have been available for decades but are expensive to power and therefore are typically only used by agribusinesses

[39] http://www.knowledgebank.irri.org/step-by-step-production/postharvest/storage/grain-storage-systems/hermetic-storage-systems/cocoon
[40] Alam *et al*. (2022) *Hermetic Storage Technology to Reduce Postharvest Loss of Paddy: Farmers to Commercial Scale.*
[41] Chigoverah, A. (2018) *Are GrainPro Cocoons™ an effective alternative to conventional phosphine fumigation in large-scale control of stored-maize insect pests?*
[42] Alam *et al*. (2022) *Hermetic Storage Technology to Reduce Postharvest Loss of Paddy: Farmers to Commercial Scale.*
[43] IDH Farmfit (2023) *Mobile Aggregation Center (MAC): An Aggregation and Service Solution in Smallholder Agriculture.*
[44] Efficiency for Access (2021) *Solar Appliance Technology Brief: Walk-in Cold Rooms.*

selling high-margin crops (e.g. export-oriented cash crops) or those focused on high-end domestic customer segments. However, over the past decade a range of solar-powered cold chain technologies that are appropriate for off-grid areas have emerged, including solar-powered cold rooms and milk chillers.

Solar-powered cold rooms are an emerging technology which has the potential to reduce food loss across a range of perishable food value chains. Most solar-powered cold rooms feature a walk-in insulated space; a solar array, battery, or thermal storage; a cooling unit; and remote monitoring[45]. Although operating costs are much lower than powering cold storage via diesel generators, upfront capital costs can be high. Depending on the manufacturer and cold room specifications, three to 10 MT cold rooms have an upfront capital cost of between US$20,000–40,000 – a significant investment for most agri-SMEs[46,47,48]. Even at this cost, there are several examples of agri-SMEs and co-operatives in India and Nigeria achieving payback periods of as little as two years across a range of fruit and vegetable value chains (e.g. bananas and tomatoes), driven by reductions in food loss and improved pricing due to better-quality produce[49,50].

In many of the examples referred to above, agri-SMEs have financed cold rooms upfront through their own capital, or have had concessional finance (e.g. repayable grants or low interest rate loans) from development partners to cover the capex costs. Once commercial bank interest rates (which are often as high as 20% per annum in many Sub-Saharan African countries) are factored in, payback periods will lengthen significantly. Where this is the case, investments in cold rooms will only be viable at high utilization rates (e.g. 80%+) or where levels of food loss reduction are substantial[51]. However, ongoing innovation around the use of solar direct drive technology and phase change materials (e.g. where solar power is used to freeze water or other liquids) has the potential to materially reduce the cost of solar-powered cold rooms by eliminating expensive batteries, thereby making them a commercially viable investment for larger agri-SMEs in Africa and Asia, even when factoring in financing costs.

Meanwhile, cooling as a service business models offer the greatest potential to extend the benefits of solar cold room technology to smaller agri-SMEs and micro-entrepreneurs, and into informal rural and peri-urban value chains in places where consumers are more likely to face food insecurity. Several companies – including ColdHubs in Nigeria (see Case study 2), Baridi in Kenya, and Koel Fresh in India – have successfully implemented this model, which shifts upfront investment in solar-powered cold rooms to the service provider, with users paying a daily fee to store their produce. Daily payments vary by geography and type of produce stored but can be as low as US$ 0.01– US$ 0.02 per kg per day for fruit and vegetable storage, and approximately double that for meat and fish, which need to be stored at lower temperatures[52]. Given the relatively small daily payments and clear return on investment (e.g. reducing food loss rates by as much as 50% for ColdHubs' customers[53] and increasing price premiums for quality by up to 20%[54]), the rationale for small-scale farmers and traders using cooling as a service appears clear. Yet many operators report that the main barrier to uptake remains making the case to potential customers who have no

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[45] *Ibid*.
[46] Inficold (2021) *How can increased access to solar cold storage improve efficiency and smallholder income in the banana value chain?*
[47] Obanubi *et al*. (2021) *Business opportunities to reduce post-harvest loss of nutritious foods: modelling the return on investment for field-ready technologies in Nigeria.*
[48] Takeshima *et al*. (2023) *Solar-powered cold-storage and agrifood market modernization in Nigeria.*
[49] Inficold (2021) *How can increased access to solar cold storage improve efficiency and smallholder income in the banana value chain?*
[50] Obanubi *et al*. (2021) *Business opportunities to reduce post-harvest loss of nutritious foods: modelling the return on investment for field-ready technologies in Nigeria.*
[51] *Ibid*.
[52] Wellspring interview with Cold Hubs.
[53] https://www.coldhubs.com/coldhubnews/2021/1/30/coldhubss-2020-in-numbers
[54] Takeshima *et al*. (2023) *Solar-powered cold-storage and agrifood market modernization in Nigeria.*

previous experience of using refrigeration regarding the potential financial benefits their services can offer.

Solar-powered milk chillers are another off-grid technology with the potential to reduce food loss and improve food security and nutritional outcomes. These technologies range from 200-litre systems that are appropriate for individual farmers or at small collection points, to 10,000-litre systems used by large dairy companies[55]. As the world's largest milk producer, with 24% of global production in 2022[56], India is a particularly large potential market, but solar-powered milk chillers have also been tested and found to be viable in various Sub-Saharan African markets. Inficold – a leading manufacturer of these products (see Case study 2) – found that payback periods for dairy SMEs and co-operatives can be as low as two years, driven by a reduction in spoilage (e.g. because of quicker cooling of milk at aggregation points) and cost savings that can be as high as 50% versus diesel-powered chillers[57]. As with solar-powered cold rooms, these products require high levels of utilization to deliver a good return on investment, and financing for agri-SMEs remains a key barrier to uptake.

Case study 2: ColdHubs

Company overview

ColdHubs is a Nigerian company that designs, manufactures, and operates solar-powered cold rooms, providing cooling as a service to smallholder farmers and traders. The company currently operates over 70 hubs across Nigeria at markets and aggregation centres and has also recently expanded into Benin and Kenya. While most of their cold rooms are used by customers to keep vegetables (e.g. tomatoes and leafy greens) fresh, ColdHubs also operates cold rooms which reach temperatures that are cold enough for storing fresh fish.

How does the technology reduce food loss?

The company's solar-powered, walk-in cold rooms are designed to operate in areas which are entirely off-grid. Energy from the solar panels is used to create ice, which cools the insulated walls and keeps the room at approximately 5 degrees Celsius, as well as being stored in batteries, which ensures the cold room can operate 24 hours a day. Each cold room typically has 3–5 MT of capacity and is furnished with shelves where customers store their produce in 20 kg plastic crates. Depending on the type of produce being stored, utilizing ColdHubs' technology can extend the shelf life of fruits and vegetables for two to three weeks, on average. The cold rooms are also fitted with remote sensors, which allow operators to track data on temperature, solar irradiation, and door opening. ColdHubs has also recently designed and started to operate cold rooms which can store produce below 0 degrees Celsius and which are appropriate for fish and meat.

What are the drivers for adoption of ColdHubs' technology?

ColdHubs' customers are typically farmers, traders, and market vendors who are running micro or small enterprises, and therefore do not have sufficient capital to invest in refrigeration technology. The flexibility offered by ColdHubs' pay-as-you-store model is critical to adoption, with customers paying a flat daily fee of 200 Nigerian Naira (~US$ 0.25) per crate per day, and typically storing produce for up to a week. Customers storing tomatoes and leafy greens have reported up to a 50% reduction in food loss due to using ColdHubs' cold rooms. Considering the market price of 20 kg of tomatoes is approximately 5,000 Naira (~US$ 6.50), there is a clear commercial motivation for customers to adopt ColdHubs' technology.

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[55] Lighting Global (2022) *Off-Grid Solar Market Trends Report 2022.*
[56] https://www.fao.org/faostat/en/
[57] Inficold (2022) *How can increased access to solar milk chillers improve efficiency and smallholder incomes in the dairy value chain?*

Project impact

In addition to the monetary benefits for smallholders and traders, ColdHubs' cooling as a service model has resulted in a clear environmental impact. In 2022 alone, the company estimates that it has been able to store 150,000 MT of food which would otherwise have gone to waste. The company also assembles its cold rooms in Nigeria and sources 60% of components locally, contributing to job creation in the country.

Challenges and lessons learned

According to ColdHubs' management, the greatest barrier to uptake has been shifting customers' perceptions around the use of refrigeration. Apart from those selling fish or meat, most customers have not historically used any refrigeration and the company has invested significant resources in education and behaviour change (e.g. via group trainings of farmers and traders, and marketing campaigns). Another key barrier has been acquiring appropriate space within markets to construct cold rooms. Most Nigerian markets have developed organically and have not been designed with a cold chain in mind, but finding appropriate central locations for the cold rooms is key to customer uptake. Finally, the company's target market and customers mean that blended finance (i.e. concessional debt) will be required for scale-up for the foreseeable future.

Case study 3: Inficold

Company overview

Inficold is an Indian refrigeration and cold chain company that designs and manufactures cold rooms, milk chillers, and other cold chain technologies. Its diesel-free systems can either be grid- or solar-powered, making them adaptable for regions where grid coverage is limited or unreliable. The company has over 300 installations across India and Sub-Saharan Africa, including in Burundi, Sudan, and Uganda, and plans to continue its expansion through distribution partnerships across different geographies.

How does the technology reduce food loss?

Inficold's innovative thermal energy storage technology utilizes phase change materials (e.g. turning water into ice) to provide 24 to 48 hours of cooling, eliminating the need for batteries or diesel as a backup. For example, its milk chillers can cater to the cooling requirement of a dairy aggregation point or processing plant with as little as eight hours per day of grid or solar energy availability. This has the potential to significantly reduce food loss or spoilage in areas where cold chain is lacking or unreliable due to either lack of a grid or an unreliable grid, and/or where agri-SMEs cannot afford high diesel costs.

What are the drivers for agribusinesses adopting Inficold's technology?

Increased revenues from reduced food loss and improved quality of produce are key drivers of uptake of Inficold's technology. For example, a co-operative in Uttarakhand which installed a 35 MT solar-powered Inficold dehumidifying cold room saw a decrease in losses of pulses (e.g. from 15% to 2%) and improvements in quality, helping to increase annual sales by 24%[58]. With this financial return, the co-operative was able to achieve a payback period of three years. Similarly, a dairy SME in Pondicherry which invested in a 200-litre milk cooler was able to eliminate milk spoilage (previously ~9%) due to faster cooling times versus using a traditional refrigerator[59].

Cost savings driven by thermal energy storage and solar technology have also promoted adoption. A dairy co-operative in Assam which replaced its existing milk chilling system with a

[58] Inficold (2022) *How can increased access to solar-powered cold storage with in-built dehumidifier, improve efficiency and smallholder income in the pulses value chain?*

[59] Inficold (2021) *How can increased access to diesel-free milk coolers improve efficiency and smallholder incomes in the dairy value chain?*

3,000 litre Inficold solar milk chiller was able to decrease its milk chilling costs by almost half from 0.62 INR/L to 0.3 INR/L by reducing electricity and diesel costs. This resulted in increased incomes for co-operative members and a payback period of less than two years. As a result of using an alternative energy source, carbon emissions were reduced by 10.1 tonnes over a period of 10 months, or 30% versus business as usual[60].

What are some of the key barriers to uptake and lessons learned?

Many agri-SMEs and co-operatives which are potential Inficold customers struggle to access credit which would enable them to afford the upfront cost of the systems. Another key constraint is the awareness of the financial benefits of investing in cold chain technology among potential customers: this has been more of a barrier to adoption for cold storage (where many potential customers are not currently using refrigeration) versus milk chilling (where Inficold's products are typically replacing existing diesel-powered systems). Finally, lack of effective government regulation around the adulteration of perishables with harmful and banned chemicals also poses a barrier to uptake.

Case study 4: Viphya Chambo

Overview

CASA partnered with Viphya Chambo – an aquaculture SME in Mzuzu city, Malawi, with 2.5 hectares of fishponds – to increase fresh fish volumes by establishing an outgrower scheme incorporating smallholder fish farmers. Under this arrangement, Viphya Chambo purchased fish produced by smallholder farmers in Ntchenachena, an area located approximately 100 km north of Mzuzu city, to supplement its supply and to sell at higher-value markets in Mzuzu city. Viphya Chambo also provided fingerlings and extension services to the smallholder farmers to ensure optimal productivity, high volumes, and good quality of the produce. CASA engaged a technical aquaculture expert to design and execute a capacity building programme for both Viphya Chambo and the smallholder fish farmers.

How did the agribusiness supported by CASA promote technologies or approaches that can reduce food loss?

With technical support from CASA, Viphya Chambo expanded its fresh fish handling capacity by off-taking fish from smallholder fish farmers built into the company's supply chain through an outgrower scheme. Viphya Chambo leveraged cold chain facilities – which included a 1 MT refrigerated van (petrol-powered), storage cold rooms (using ice), and refrigerated tricycle van for door-to-door delivery – to aggregate fresh fish grown by smallholder farmers and to transport the fish to more profitable markets. As a result, Viphya Chambo was able to scale its supply of fish and the smallholder farmers saw increased incomes through selling to high-value markets by using Viphya's cold chain facilities, which they would not have been able to acquire on their own. Moreover, this arrangement helped to prevent loss of fish during transportation and sale.

What were the drivers (both at the company and smallholder level) for adopting these technologies and approaches?

The outgrower scheme model was adopted by both Viphya Chambo and the 72 smallholder farmers mainly due to the mutual commercial benefits the arrangement offered to both parties. Through the scheme, smallholder fish farmers were able to increase their incomes after selling their produce to higher-value markets and avoiding financial loss due to post-harvest losses of fresh fish during transportation to distant markets without specialized cold chain facilities. Meanwhile, Viphya Chambo was able to aggregate larger volumes of fish, which it resold at higher prices to its customers in and around Mzuzu city, resulting in increased overall profits.

[60] Inficold (2022) *How can increased access to solar milk chillers improve efficiency and smallholder incomes in the dairy value chain?*

Project impact

The fish off-taking arrangement between Viphya Chambo and the smallholder fish farmers allowed for transportation of 5,162 kg of fish from the production sites to the targeted market, 100 km away, over a six-month period. As a result of this: a total of 5,162 kg of fish was aggregated from the fish farmers, transported, and marketed to better markets, preventing potential loss of about 1,549 kg of the fish at the current rate of 30% fish loss due to lack of cold chain facilities.

Lessons learned

The outgrower model, as implemented by Viphya Chambo, with technical support from CASA, has demonstrated the viability of achieving high volumes of production by smallholder aquaculture farmers while at the same time minimizing post-harvest losses through well-managed aggregation and use of cold chain. Petrol-powered cold chain technology was viable in this case given the target market was high-end customers, but use of solar technology could improve cost savings further for the agribusiness. The scope for mitigating food losses is significant and would proportionately increase if the model was scaled up.

4. Agri-ecommerce platforms

Agri-ecommerce platforms aim to reduce food loss from farm to market by connecting farmers to retailers directly with the help of digital mobile platforms that bypass intermediaries and make supply chains more efficient. Losses in the value chains of perishable produce happen at the aggregation, processing, distribution, and retail levels. An informal and fragmented supply chain contributes to excessive handling of produce, long transport and storage times, and, consequently, high levels of food loss. Producers normally only have access to local markets or brokers and traders, both of which return thin margins, with high price volatility. At the other end of the supply chain, urban retailers struggle to procure consistently high-quality produce.

Mobile phone and mobile money penetration is increasing rapidly across Sub-Saharan Africa and South Asia, with 46% of Sub-Saharan Africans and 59% of Asians using mobile phones in 2021[61,62]. This has enabled the emergence in recent years of dozens of agri-ecommerce companies that utilize digital platforms that match supply and demand of produce (both business to business and business to consumer) and that manage transactions and payments. Typically, these agri-ecommerce companies also engage in logistics, warehousing, and quality control, collecting the produce from rural-based hubs, combining it at a central packing house, and delivering to urban retailers. This enables them to manage quality across the entire supply chain and ensure that food loss is minimized[63]. Twiga Foods, an agri-ecommerce company which sources from smallholder farmers and which has supplied over 140,000 small-scale retailers in Kenya over the past eight years, reports reducing food loss from 30% to 4% for produce (e.g. bananas, onions, potatoes, and tomatoes) sold through its platform[64].

As well as reducing food loss, agri-ecommerce platforms create efficiencies that reduce wholesale costs and increase profit margins for SME retailers in urban and peri-urban areas, while having the potential to widen the market and increase incomes for thousands of dispersed smallholders. Some companies also offer additional services to smallholders, such as loans and agronomic advice, via their digital platforms, with the aim of supporting them to increase yields and profitability.

To date, agri-ecommerce models have been far more successful in South Asia than in Sub-Saharan Africa; this is primarily due to the better logistics infrastructure in the former region,

[61] GSMA (2022) *The Mobile Economy Sub-Saharan Africa.*
[62] GSMA (2022) *The Mobile Economy Asia Pacific.*
[63] GSMA (2020) *Digital Agriculture Maps – 2020 State of the Sector in Low and Middle-Income Countries.*
[64] https://www.howwemadeitinafrica.com/how-twiga-foods-reduces-the-price-of-food-in-nairobi-using-technology/68379/

including roads, address systems, and distribution networks[65]. For example, in the World Bank's 2023 Logistics Performance Index, middle-income countries in Sub-Saharan Africa, such as Ghana and Nigeria, only scored 2.5 and 2.6 out of 5, respectively, compared to 3.5 for India[66]. This has enabled companies such as Ninjacart – a business to business agri-ecommerce platform headquartered in Bangalore, India – to scale to the extent that it now delivers over 1,400 MT of fruit and vegetables daily[67]. Meanwhile, many agri-ecommerce companies in Sub-Saharan Africa have either failed or have been unable to reach significant scale[68].

Besides logistics infrastructure, maintaining volumes and quality is a key barrier to these models succeeding. Although Twiga Foods' digitally enabled smallholder sourcing model has worked in the banana value chain, inconsistent volumes and quality in other value chains, such as tomatoes, forced it to source more from larger farms and eventually set up its own farms[69]. Clearly, this vertically integrated model does not address the food loss problem in the same way, as smallholder and SME producers (who typically face high levels of post-harvest loss) are excluded entirely.

5. Waste-to-value approaches

Waste-to-value or circular economy approaches have the potential to reduce food loss by utilizing bruised or damaged fruits and vegetables that cannot be sold as intended as inputs for producing other food products. Some examples include utilizing bruised tomatoes for tomato sauces and ketchup, or separating low-grade avocadoes from export-grade fruits and producing avocado oil, or dehydrating fruit which is overripe to produce dried fruit products. While these examples make use of substandard produce, and therefore avoid food loss, they are unlikely to yield significant improvements in food security and are more appropriate for high-end market consumers.

In cases where the food cannot be salvaged for sale or direct human consumption, it becomes food waste and is destined for landfills. However, in many places food waste has a value: for example, it can be fed to livestock or converted to organic composts. Perhaps the simplest form of waste-to-value conversion is to feed the waste directly to chickens and pigs. This takes place informally all along the supply chain, including in urban areas. The next most simple conversion approach is to grind, blend, and compost the waste for home use or sale, an idea that has been piloted in Gambia, where waste is also converted into biomass briquettes[70].

The emergence of BSFL farms[71] worldwide has led to many startups hoping to turn discarded food and other organic waste-to-value as animal feed. Food waste (scraps from restaurants, unsold produce from markets, and even garbage) can be collected and fed to BSFL, which grow rapidly and are rich in protein and fat. Drying the larvae allows them to be preserved and sold for animal feed, and expressing the oil from the larvae allows the protein and lipids to be sold separately as feed inputs. What remains after the larvae have fed on the food waste is a nutrient-rich frass[72] that can be converted to compost and soil additives. BSFL farms are relatively easy to establish as small-scale enterprises, but they are challenging to scale as food waste is limited and there is competition for it from other uses. Commercial BSFL farms recognize the challenge of scale and broaden their sources of waste input by contracting to dispose of waste from large produce aggregators, fruit juice plants, and food processing plants.

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[65] GSMA (2020) *Digital Agriculture Maps – 2020 State of the Sector in Low and Middle-Income Countries.*
[66] https://lpi.worldbank.org/international/global
[67] https://startuptalky.com/ninjacart-success-story/
[68] GSMA (2020) *Digital Agriculture Maps – 2020 State of the Sector in Low and Middle-Income Countries.*
[69] https://www.howwemadeitinafrica.com/kenya-why-b2b-e-commerce-platform-twiga-ventured-into-farming/144341/
[70] https://www.afrik21.africa/en/gambia-kanifing-to-convert-organic-waste-into-fertiliser-and-biomass/
[71] There are several types of insect that can convert food waste into a valuable product, but BSFL is the most prominent.
[72] The excrement of insect larvae.

Case study 5: Regen Organics (previously Sanergy)

Company overview

Regen Organics is a waste-to-value business that focuses on converting sanitation waste, market waste, and pre-consumer food loss to compost and protein using BSFL. Damaged fruits and vegetables are collected from companies and aggregators, and residues are collected from fruit processing firms. The compost is sold through a network of 1,500 agrovets to smallholders and direct to large and medium-sized farms. Regen's centralized model is viable in large urban areas where waste is concentrated, and Regen plans to expand beyond Kenya in the medium term. In the short term, the company plans to explore decentralized models in which black soldier fly eggs are delivered to SMEs in rural areas to be fed on agricultural and market waste there, recognizing that most food waste is found in rural and mid-sized urban areas.

How does the agribusiness reduce food loss?

Rather than minimizing food loss, BSFL farming converts unusable fruit and vegetables into valuable inputs for the food chain (i.e. compost). BSFL farming deals with urban food loss that is at the very end of the supply chain: the food has already arrived at the market or to urban collection centres, where opportunities for it to be productively used (such as to feed livestock) are limited. The inclusion of the food waste in Regen's business model provides the critical scale to profitably dispose of the human waste collected in its urban sanitation programme. As a circular economy approach, BSFL farming is particularly interesting from a food security perspective as the outputs are proteins and fats (which are critical components in animal feed) and compost (which contributes to improved soil health and helps reduce fertilizer use).

Project impact

Including food waste in Regen's input stream has been the key to unlocking the scale needed for the company to pursue its primary goal of human waste disposal. Regen and Fresh Life (the company's sanitation arm) has over 600 employees and serves over 250,000 residents with their urban latrines. In 2022 they disposed of over 43,000 MT of waste with their system, and this was converted into over 6,000 MT of organic fertilizer. A network of 1,500 agrovets sell Regen's farming input products to smallholder farms in 40 counties across Kenya.

Lessons learned

In Sub-Saharan Africa, there are many competing uses for food waste. Less organic waste is available than is needed, so companies like Regen must source from as many available sources as possible. Almost all organic waste has value, so BSFL production is in competition with other uses (e.g. feeding livestock, direct composting).

BSFL production requires scale for profitability. BSFL protein and compost are both low-margin, high-volume commodities. For systems like Regen's, it is essential to source waste from very large cities, and finding alternative sources of revenue may be essential for continued success (e.g. selling black soldier fly eggs and developing models for expanding to rural communities).

Early funding is key. Finding funding for initial startup is critical but is difficult to secure. However, once a certain level of scale is achieved, securing debt or equity is much easier.

Scaling to make use of rural and small-city waste requires new business models. Plans are in place to expand to markets that are too small for the existing Regen model. Support for setting up these supply chain systems will be critical, in order to test ideas and implement pilots.

4. Challenges and opportunities

This chapter draws together some of the common challenges to, and opportunities for, increasing uptake of food loss technologies and approaches among agri-SMEs in Sub-Saharan Africa and South Asia. These include the need to build awareness of the potential return on investment of these technologies, increasing financing for both technology companies developing and manufacturing solutions and their agri-SME customers, continuing to fund product R&D and business model innovations, and developing a more supportive policy and regulatory environment.

1 Build product awareness and trust

- Increase traditional and digital marketing campaigns to drive awareness of the financial benefits of food loss technologies for agri-SMEs
- Ensure investments and programmes to drive uptake of food loss technologies all have robust data collection components which help clarify the investment case for agri-SMEs

2 Increase finance through subsidy and risk sharing

- Incentivise local banks and NBFIs to lend to agri-SMEs investing in food loss technologies through origination/impact payments and guarantees
- Utilise Results Based Finance schemes to introduce service-based models in harder to reach areas
- Conduct research into opportunities to tap into finance from voluntary carbon markets

3 Fund product R&D and business model innovation

- Continue to support product developers and manufacturers to reduce the cost and improve reliability of food loss technologies
- Provide funding and TA to agri-SMEs to test new business models which reduce food loss

4 Develop supportive policies and enforce standards

- Reduce or eliminate import tariffs and customs duties for food loss technologies
- Provide support to regulatory bodies and enforcement agencies to improve enforcement of food safety standards

Figure 6: Summary of opportunities

1. Build product awareness and trust

Several companies – particularly those manufacturing and selling solar cold rooms, hermetic storage solutions, and solar drying technologies – highlighted that building knowledge and awareness of the benefits of their products was the main barrier to uptake. This is particularly the case where food loss technologies require significant changes in behaviour or operating models. Agri-SMEs are ultimately financially motivated, and therefore product marketing needs to be clearly structured around cost savings, additional revenue generated, and payback periods. In the case of some of these products (e.g. hermetic bags and cocoons), there is a robust body of evidence which can be used to demonstrate this. However, in the case of emerging technologies (e.g. solar-powered cold rooms, milk chillers, and dryers) there is not yet sufficient or robust enough data to prove return on investment across different crops or market environments.

Opportunity 1.1: Manufacturers and distributors of less established food loss technologies (e.g. solar cold rooms and hermetic cocoons) should increase their use of traditional and digital marketing campaigns to drive awareness of the financial benefits of food loss technologies for agri-SMEs. This could include holding product demonstrations (e.g. at larger aggregation points), developing more tailored case studies and testimonials (e.g. for specific crops and geographies) that can be easily shared, and building simple tools such as return on investment calculators to help agri-SMEs make investment decisions. In addition to this being driven by manufacturers and distributors, there is an opportunity for development partners to support this by funding and implementing broader (i.e. not linked to a specific product) awareness campaigns – this approach has been effective in the off-grid solar sector (e.g. Lighting Global's "Non-Stop Life" campaign in India)[73].

[73] Lighting Global (2022) *Off-Grid Solar Market Trends Report 2022*

Opportunity 1.2: Where development partners and DFIs have invested in food loss technologies or agribusinesses adopting waste-to-value approaches, they should also fund robust data collection and the development of studies which can clarify the investment case for agri-SMEs. To be effective in helping to drive uptake and awareness of, and trust in, food loss technologies, these studies should capture data on the financial return on investment for agri-SMEs utilizing these products, as well as impact data (e.g. on social and environmental benefits), which development partners require. Where possible, they should also take a comparative approach (i.e. across multiple products or value chains), and information should be made publicly available. There is an opportunity for the CASA programme to invest in data collection and case study development as it scales up its support to agribusinesses to reduce food loss (e.g. in the vegetables sector or in waste-to-value for animal feed): this could be alongside providing grants or technical assistance to pilot new technologies and approaches (see Opportunity 3.2), or where CASA is providing tangential support but the agri-SME has already adopted a specific food loss technology or approach.

2. Increase finance through providing subsidies and engaging in risk sharing

Many of the case studies in this report highlight that a lack of capital to make upfront investments in food loss technologies is a key barrier to scale. As highlighted in Chapter 3, agri-SMEs in Sub-Saharan Africa and South Asia are often viewed by commercial banks as high-risk clients. When banks are willing to lend, their financial products are typically not tailored to the needs of agribusinesses (e.g. seasonality, limited collateral). In addition to increasing the availability of finance for agri-SMEs, manufacturers and distributors of technologies which reduce food loss also require patient capital to enable them to innovate, scale up manufacturing operations, and develop rural distribution networks and partnerships.

Opportunity 2.1: **Development partners and DFIs should provide domestic banks and non-bank financial institutions with subsidies for lending to agri-SMEs investing in food loss technologies or approaches.** There are several instruments which could be used to do this, including payments to the lender for originating a loan for a specific purpose (e.g. capex investment in food loss technologies), impact-linked payments, and funded first-loss guarantees for making relevant investments. Aceli Africa is an example of a donor-funded vehicle which provides these types of incentives, although it focuses on agri-SME lending more broadly, rather than specifically food loss reduction.

Opportunity 2.2: Given high customer acquisition costs and customers' price sensitivity, there is an opportunity for development partners to utilize RBF schemes to introduce service-based models in harder-to-reach areas where traction on technologies has been achieved. For example, cooling as a service model offers huge potential to reduce food loss and improve food security and nutrition in areas which need it the most, as they typically target micro-entrepreneurs and agri-SMEs operating in and around informal food markets. There is an opportunity for development partners and DFIs to utilize RBF schemes to introduce cooling as a service model in harder-to-reach areas (e.g. in countries such as Nigeria, where RBF is already being utilized for solar home systems). This could be linked to the level of utilization, as cold rooms or storage as a service facilities typically have remote monitoring capabilities.

Opportunity 2.3: Development partners should fund research which explores the viability of tapping into finance from voluntary carbon markets to accelerate the manufacturing and roll-out of technologies which reduce food loss. There is a precedent for manufacturers and distributors in comparable sectors (e.g. clean cooking) accessing carbon credits as an additional revenue stream, but given recent concerns over the quality of offsets and the challenges associated with monitoring and verification, care must be taken when encouraging the use of this approach for food loss technologies. A detailed study should be conducted to identify the technologies and scenarios where the use of offsets would be credible (e.g. where there is likely to be material GHG emissions reductions) and where monitoring and verification are likely to be viable.

3. Fund product R&D and business model innovation

Several of the emerging technologies and business models profiled in this report – including solar-powered cold chain, solar dryers, and a range of waste-to-value models – are at a relatively early stage in their development and have the potential to be refined or made more affordable through further R&D and innovation. Further product R&D (e.g. around the use of solar direct drives and phase change materials in solar cold rooms) has the potential to significantly reduce technology costs, reducing payback periods for, and increasing the likelihood of uptake by, agri-SMEs. The use of local parts and local assembly is another area which some manufacturers are exploring with a view to reducing costs, and which may be of interest to development partners due to the potential for creating good-quality domestic jobs.

This report has also demonstrated that technologies alone will be insufficient to address the food loss problem, and that integrating these technologies into commercially viable and sustainable business models will be key. There will be no "one size fits all" model that works for each technology or food loss reduction approach: to succeed, these will need to be tailored to fit the operating context (e.g. customer preferences, types of produce, enabling environment).

Opportunity 3.1: Development partners and governments should continue to support product developers and manufacturers to reduce the cost and improve the reliability of nascent food loss technologies (e.g. solar cold rooms). Competitions such as the Global LEAP Off-Grid Cold Chain Challenge have been successful in identifying and supporting early-stage piloting of solar cold chain technologies and are worth replicating (see the box below). However, given the potential impact of developing lower-cost technologies, there is a case to be made (i.e. from an additionality perspective) for continuing to provide credible product designers and manufacturers with additional grant funding to accelerate further R&D. This could be deployed directly into companies by development partners as part of sustainable agriculture programmes (e.g. CASA), or through competitions which focus on improving the effectiveness of existing products, rather than piloting new innovations.

Global LEAP Awards Off-Grid Cold Chain Challenge

Launched in 2018, the Off-Grid Cold Chain Challenge is a competition which aims to identify and support sustainable and affordable cold chain technologies for the fruit, vegetable, and dairy value chains in Sub-Saharan Africa and India. The competition is run by CLASP and Energy 4 Impact and is supported by the Efficiency for Access Coalition (IKEA Foundation, DOEN Foundation, and Good Energies Foundation, together with the UK Foreign, Commonwealth and Development Office). It is run in two phases: the first phase evaluates existing products or prototypes to identify the most promising solutions, while the second phase assesses the technical performance of shortlisted products under field conditions[74]. Finalists and winners receive grant funding of up to £75,000 to support their innovations, including advance payments to finance deployment costs.

The challenge has been successful in helping to identify and pilot new off-grid cold chain technologies: for example, Cold Hubs (Case Study 2) was the winner of the 2018 competition and Inficold (Case Study 3) was a finalist in the 2022 competition. However, manufacturers have highlighted that there is a gap between funding for early-stage innovation and commercial finance, with more grant funding required to help improve solutions and pilot scalable business models. Competitors have also emphasized the need for support to undertake assessments of new product target markets and to build consumer awareness[75].

[74] https://www.clasp.ngo/updates/press-release-global-leap-awards-announces-winners-and-finalists-of-the-2022-off-grid-cold-chain-challenge/;
[75] https://energy4impact.org/news/insights-global-leap-awards-grid-cold-chain-challenge

Opportunity 3.2: Development partners should also provide matched grant funding and technical assistance to credible agri-SMEs with strong management teams to test new business models which reduce food loss. This could include aggregation models leveraging hermetic storage or off-grid cold storage, processing closer to sites of production utilizing solar drying, or various waste-to-value approaches. For example, CASA's market systems development component could work with agribusinesses in the vegetable sector to assess the costs and benefits of installing off-grid cold rooms at key aggregation points and could provide repayable grant funding to support upfront investment if viable. Similar support could also be provided to pilot solar drying of low-grade fruits and vegetables.

4. Develop supportive policies and enforce standards

A supportive policy and regulatory environment will be of fundamental importance in providing the incentives required to accelerate the uptake of food loss reduction technologies that can address food security. In some cases, policy currently creates disincentives for investment (e.g. high import tariffs and customs duties for machinery which can extend payback periods by several years), while in other cases (e.g. cold chain) creative and targeted support and coordination from the government will be critical, given the complexity of the problem. Poor enforcement of food safety standards is another important barrier which, if not addressed, will continue to create a disincentive for many agri-SMEs to invest in the right technology, as poor-quality produce is allowed to be sold in end markets.

Opportunity 4.1: Where they exist, governments in Sub-Saharan Africa and South Asia should reduce or eliminate import tariffs and customs duties for food loss technologies and their components (e.g. solar panels). It is also important for governments to ensure that implementation of tariff exemptions is consistent, in order to reduce uncertainty and risk for companies and investors: for example, several countries in Sub-Saharan Africa reintroduced value-added tax on solar products between 2020 and 2022 at very short notice[76]. Development partners can support policy change and implementation by helping to make the socioeconomic case for tariff reduction, as well as funding technical assistance to develop streamlined customs procedures, training for relevant customs staff, and strengthening industry associations and lobby groups to hold governments to account.

Opportunity 4.2: Development partners should provide technical support to regulatory bodies and enforcement agencies to help them to improve the enforcement of food safety standards. This could include providing training on best practices as well as technical assistance and financing to improve processes and systems. This will help to create the right incentives for smaller traders and aggregators to invest in appropriate drying and storage technologies, which will help to reduce losses while maintaining quality.

[76] Lighting Global (2022) *Off-Grid Solar Market Trends Report 2022.*

5. Conclusion

The technologies and approaches profiled in this report are by no means the only solutions that can be used to address food loss and improve food security in Sub-Saharan Africa and South Asia. Indeed, in many cases these are second-best or interim solutions which will ideally no longer be necessary when there is reliable electrical grid access and more structured and well-regulated value chains. However, in the current context and operating environment which some agri-SMEs in parts of these regions face, they hold the potential to reduce food loss, contribute to improvements in food security, and mitigate against climate change. They can also deliver a solid return on investment for agri-SMEs by helping to generate increased revenues from higher volumes of, and better quality, produce in the right contexts.

However, several barriers to scale remain, including a lack of widespread knowledge and awareness around their commercial benefits, a lack of finance for manufacturers and agri-SME customers, a need for further R&D and business model innovation, and the lack of a supportive policy and regulatory framework. It will take a concerted and co-ordinated effort from policymakers, development partners, and investors and the private sector across Sub-Saharan Africa and South Asia to address these barriers, but this is a challenge which cannot be ignored as we move into a world which may become 2–3 degrees Celsius warmer than pre-industrial times, with 9–10 billion inhabitants to feed.

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