Factor [E]

Solutions to Reduce Post-Harvest Loss for Smallholder Farmers

July 2025

Contents

In partnership with
Shell Foundation | Foreign, Commonwealth & Development Office | ANDMORE Associates, LLC | MSC MicroSave Consulting | ISF

Introduction

The Challenge

Significant post-harvest losses pose a serious threat to the livelihoods and food security of smallholder farmers in emerging and frontier markets. These losses account for up to 40% of global food production, resulting in an annual economic cost of **$1 trillion**. Our research estimates that the cost of post-harvest losses is over $600 million annually in Kenya, $2.2 billion in Nigeria, and $18.5 billion in India.

Beyond the financial impact, these losses reduce annual harvest value of smallholder farmers by 15%, affecting more than 400 million people globally. They also contribute to global food waste, which is responsible for 8–10% of human-generated greenhouse gas emissions.

Current solutions to address this loss often require access to electricity grids, which remain limited in many emerging markets, creating a significant barrier to adoption. Even where grid access is available, energy-intensive technologies can further increase carbon emissions, exacerbating climate challenges rather than mitigating them.

Annual Economic Losses of Post-Harvest Loss in USD

600M	2.2B	18.5B
Kenya	Nigeria	India

Introduction

The ask

The sustainable and climate-smart way to meet the growing demand for energy across the agri-food sector is through efficient renewable energy technologies. Distributed Renewable Energy (DRE) solutions can play a key role in reducing post-harvest losses experienced by farmers.

Despite the growth in the number of available DRE solutions, many of the technologies favour commercial farmers because smallholder farmers cannot afford them. Existing solutions are often too expensive. Thus, to increase the adoption of DRE solutions and reduce the trend of food losses among smallholder farmers, it is important to identify solutions that are low-cost, practical, and scalable.

By virtue of its mandate to raise incomes of smallholder farmers while lowering emissions through the use of clean energy solutions, Shell Foundation wants to explore what type of low-cost, practical, and scalable solutions exist that can address the energy needs of smallholder farmers towards reducing post-harvest loss.

Introduction

Innovation has the potential to shift the paradigm

With funding from Shell Foundation and FCDO, a consortium comprising Factor E, ISF Advisors, ArdMore Associates, and MicroSave Consulting conducted primary research in India, Nigeria, and Kenya. The study identified the value chains most affected by post-harvest losses, particularly those impacting smallholder farmers and women. Subsequently, we conducted an innovation prize to identify the most promising solutions to reduce post-harvest losses in the value chains identified by our research. During that process, we assessed nearly 800 potential solutions to determine which innovations offer the greatest potential for impact at scale. Our approach prioritized low-cost products and renewable energy solutions that can be deployed directly at the farm gate.

Our collective goal is to enable 850,000 farmers to achieve a living income through clean energy solutions while simultaneously avoiding or reducing 5 million metric tons of greenhouse gas emissions over the next five years. This research outlines the pathway to achieving that goal.

The Consortium

Shell Foundation | Foreign, Commonwealth & Development Office | ANDMORE Associates, LLC | MSC MicroSave Consulting | ISF

Section 1:
Market Landscape Key Findings

Summarized findings from primary and secondary research to identify crops and value chain points with the greatest opportunity for impact.

Primary and Secondary Research Methods

For primary research, consortium partners, MicroSave Consulting (MSC) and ISF conducted focus group discussions with farmer organizations and semi-structured interviews with key stakeholders, including traders, logistics providers, retail procurement agents, processing firms, aggregators, government agencies, academics, and industry experts.

Using quantitative data, key informant interviews, and secondary research, we evaluated and ranked crops based on monetary value of loss, percentage of post-harvest loss, and the level of smallholder farmer participation in the value chain.

The output of this work was a list of ten crops and the key points in each of those value chains where smallholder farmers lose the most value. Each of these points in the value chain became a focus for solutions landscaping to generate maximum leverage from innovations in post harvest loss reduction.

Secondary Research

Crop Perishability & Value

India

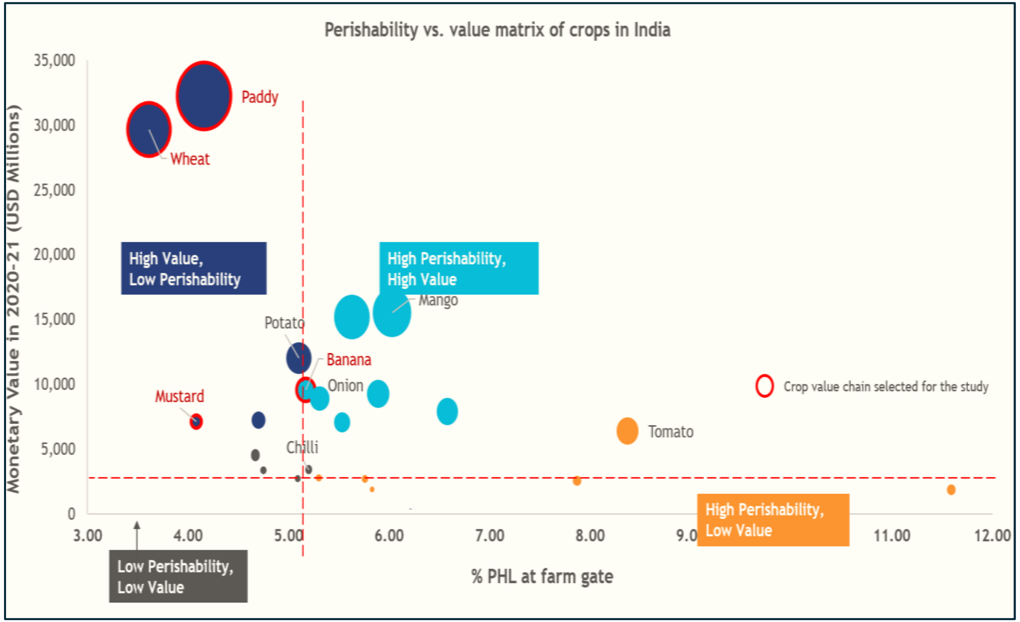
- In India, Paddy and Wheat are the two **most widely cultivated crops by smallholder farmers** and thus solutions targeting them have the greatest potential for widespread adoption and impact

- The onion supply chain **remains underdeveloped and suffers significant losses due to suboptimal storage facilities**. Thus, it presents more opportunities for storage-based PHL reduction solutions.

- A **large percentage of India's smallholder farmers** are involved in banana cultivation. It is also a highly perishable fruit.

- Mustard is the **second most important oilseed** after Soybean and contributes roughly 27% of India's total oilseed production.

Illustrative chart of Perishability vs. Value Matrix used to prioritize value chains in each market using secondary research



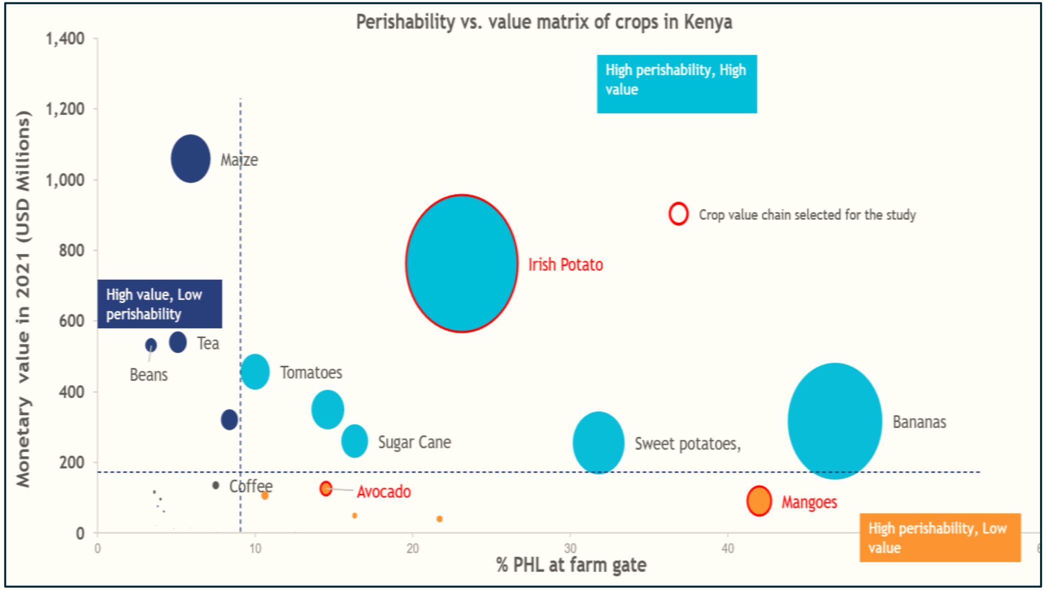
Secondary Research

Crop Perishability & Value

Kenya

- In Kenya, **mangoes**, **avocados** and **Irish potatoes** all face high perishability rates;
- Irish Potatoes are the **second most important food crop** in Kenya after maize and experience the **highest monetary loss**. They also record very high smallholder farmer involvement.
- Mangoes alone have a **perishability rate that can be as high as 45%**.
- Avocado, despite its perishability, remains a **key export crop** for Kenya generating significant monetary value.

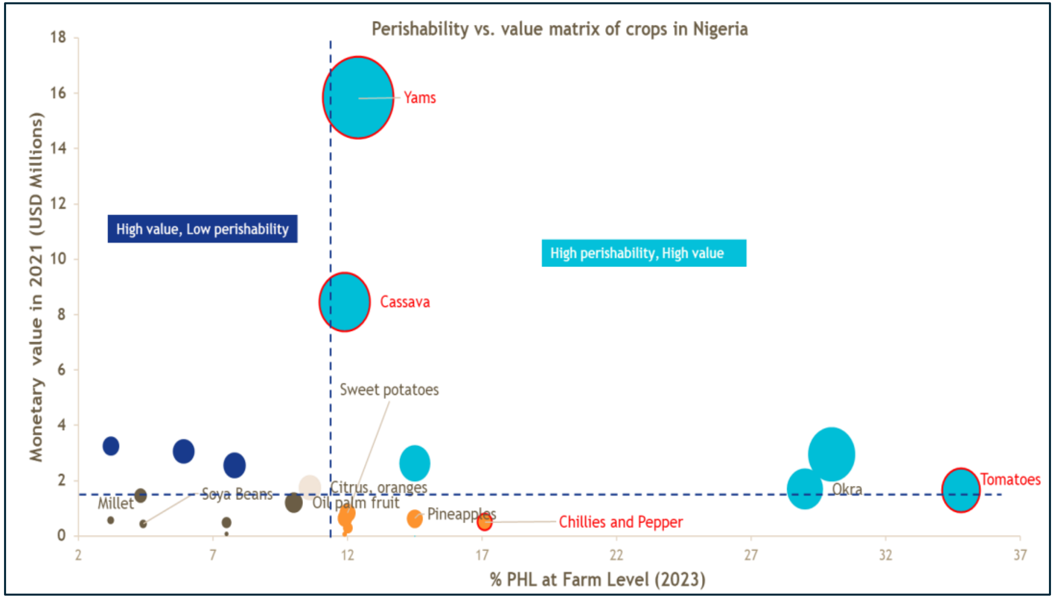
Illustrative chart of Perishability vs. Value Matrix used to prioritize value chains in each market using secondary research



Secondary Research
Crop Perishability & Value

Nigeria
- In Nigeria, the **cassava and yam value chains ranked 1st and 2nd in the PHL Index**. They also record very high smallholder farmer involvement.
- Tomato has the **highest PHL at the farmgate level** in Nigeria due to the moisture content and fragility of the value chain.
- Chillies and peppers are widely consumed in the Nigerian market. The production of chillies and peppers is **prevalent among smallholder farmers**.

Illustrative chart of Perishability vs. Value Matrix used to prioritize value chains in each market using secondary research



Primary Research

Summary of findings from focus group discussions identifying post-harvest loss by country and crop in Kenya, Nigeria, and India.

Crop Value Chains with the Highest Post-Harvest Losses

Roots and Tubers
Smallholder farmers report the highest post-harvest losses in the roots and tubers value chain, particularly for yams, cassava, and Irish potatoes, with losses ranging from 20% to 50%. Poor moisture management was identified as the primary cause of these losses.

Horticultural Crops
Bananas, tomatoes, and onions also experience losses of up to 50%. Bananas and tomatoes are highly perishable and require proper storage conditions and packaging to maintain their quality. Onions, if not adequately dried, are susceptible to rapid deterioration, especially when exposed to moisture.

Oil Seeds and Cereals
In contrast, mustard and cereals experience relatively lower rates of post-harvest losses, ranging from 4% to 10%. The vast number of farmers cultivating these crops results in significant cumulative losses across the value chain. Key challenges for these crops include spillage during handling, drying, and threshing, as well as pest infestations during storage.

Lowest Loss → **High Loss**

Cereals, Mustard, Mango, Avocado, Red Pepper, Irish Potato, Cassava, Banana, Tomato, Yam

Primary Research

Summary of findings from focus group discussions on the key drivers of post-harvest loss.

Key Drivers of Post-Harvest Loss

Harvesting technique: Manual or outdated harvesting methods can cause physical damage to crops and lead to spoilage. Late or early harvesting timing sometimes driven by labor shortages can degrade the quality and decrease volume of harvest.

Drying technique: Field drying or curing makes crops vulnerable to unpredictable weather conditions, such as extreme heat or sudden rains, while exposure to pests, contaminants, and animals can lead to significant losses and reduced crop quality.

Storage and packaging: Insufficient ventilation, temperature control, and protection from pests and moisture lead to significant losses further along the value chain. Given the high costs of cold storage facilities, few smallholder farmers participate in the storage process. Notably, to avoid high storage and other logistics costs, many farmers sell directly to aggregators, settling for a lower crop value. The lack of adequate storage infrastructure also pushes farmers to sell their produce immediately after harvest, which prevents them from capitalizing on higher market prices later in the season.

Processing: Farmers cannot adopt techniques or solutions unless market prices adequately compensate for such investments. The margins in staple crops don’t allow for costly value addition.

Key challenges in high priority value chains

Kenya	Nigeria	India
Mango • Harvest timing & technique • Drying • Packaging	**Cassava & Yam** • Drying • Low cost storage	**Wheat & Paddy** • Spillage • Pests • Low margins • Limited quality premium
Avocado • Harvest timing & technique • Quality & grading • Packaging • Access to export markets	**Tomato** • Harvest timing & technique • Transportation • Packaging • Market access	**Mustard** • Harvest timing & technique • Drying • Manual threshing
Irish Potato • Harvest technique • Moisture • Low cost storage • Timing of sales	**Red Pepper +Chili** • Drying • Packaging • Low cost storage • Market access	**Onion** • Harvesting timing & technique • Pests & fungus • Moisture • Drying
		Banana • Pre-harvest weather damage • Harvest timing & technique • Drying • Packaging • Market access

Existing solutions to manage Post-Harvest loss in crops

PHL Drivers	Solution Types
Harvesting inefficiencies – Late/early harvesting, manual labour dependence, technical knowledge gaps	• **Mechanized harvesting tools** (combine harvesters, motorized fruit pickers and harvesters) to reduce physical damage. • **Optimized harvesting schedules** through digital advisories and predictive analytics • **Standardized harvesting techniques** using improved handling practices to minimize bruising.
Handling and sorting issues – Poor sorting/grading, pest infestations, moisture retention, inadequate threshing, manual winnowing	• **Improved** drying technologies such as solar dryers and mechanical dryers to regulate moisture content. • **Humidity-controlled storage systems** to prevent mould growth and fungal contamination • **Adoption of post-harvest pest control treatments** (e.g. biopesticides) to reduce infestation risks.
Storage and packaging limitations – Inadequate cold storage, improper packaging	• **Affordable cold storage solutions** (solar-powered, community cooling hubs and evaporative coolers) • **Advanced packaging solutions** like hermetic bags, biopolymer packaging to extend shelf life.
Rough handling during transportation – Poor infrastructure, limited market access, low price realization	• **Small-scale processing mills** can minimize transport distances and enable greater value realization. • **Use of ventilated and cushioned** transport crates to reduce bruising and crushing. • **Development of aggregation hubs** to streamline logistics and minimize multiple handling points

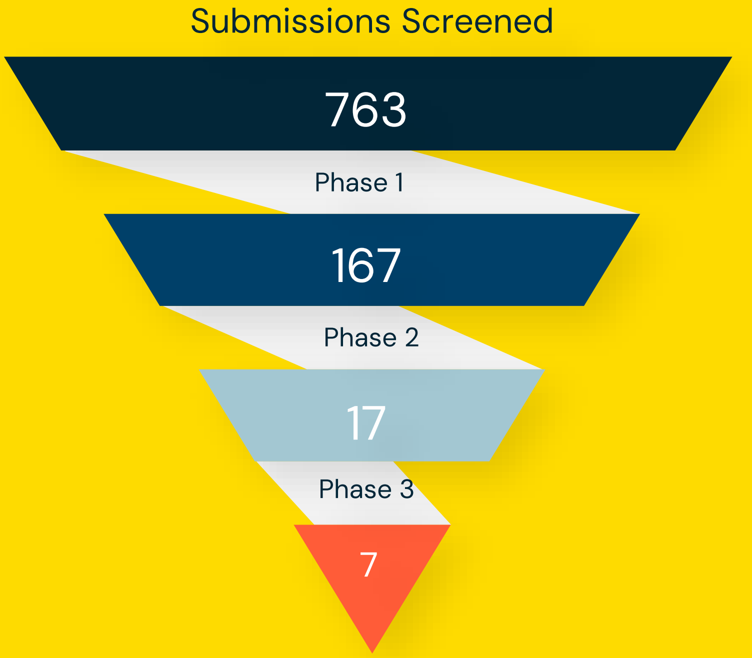
Market Landscape Summary

1. **Fruits, vegetables, and roots and tubers present the greatest opportunity for breakthrough innovation to generate impact at scale for smallholder farmers.**
    a. In India, wheat, paddy, onion, banana, and mustard
    b. In Kenya, mango, avocado, and Irish potato
    c. In Nigeria, red pepper, chili, tomato, yam, and cassava
2. **Innovations for post harvest loss reduction can maximize impact by targeting the following opportunities:**
    a. Moisture reduction during storage and handling especially for yams, cassava and Irish potatoes.
    b. Storage and packaging of bananas, mangoes, avocados, tomatoes and onions that slow spoilage, limit physical damage, and control moisture.
    c. Proper drying of fruits and vegetables.
3. **While mustard and cereals are grown at large scale reaching more smallholder farmers than any other value chain, post harvest losses in these value chains are modest and low margins leave little room for value addition at the farm gate.**
4. **Cost and accessibility of existing storage and processing solutions** remains a significant barrier to smallholder farmer adoption and value addition.

Section 2:
Solutions Landscape Key Findings

Solutions were identified, categorized, and reviewed based on applications to our innovation prize (n = 768) as well as our own research.

Post-Harvest Loss Innovation Prize



Factor E and Shell Foundation sponsored a global search for post-harvest loss reduction innovation, with the following criteria:

Innovation: Must address challenges faced by smallholder farmers in emerging markets with novel technologies, business models, hardware, or software that can become commercially viable.

Solution Validation: Should be successfully tested in a lab or field setting.

Global Relevance: Open to global innovations, but with direct applicability to South Asia and Sub-Saharan Africa, and scalability to other emerging markets.

Gender Impact: Priority for solutions that positively impact female farmers.

Scalability: Clear path to scale, with potential to empower over 1 million farmers and generate significant commercial returns.

Farm-Level Use: Designed for direct use by farmers, with minimal behavioral changes required for adoption.

Financial Traction: Progress towards financial sustainability and evidence of prior fundraising are strong positives.

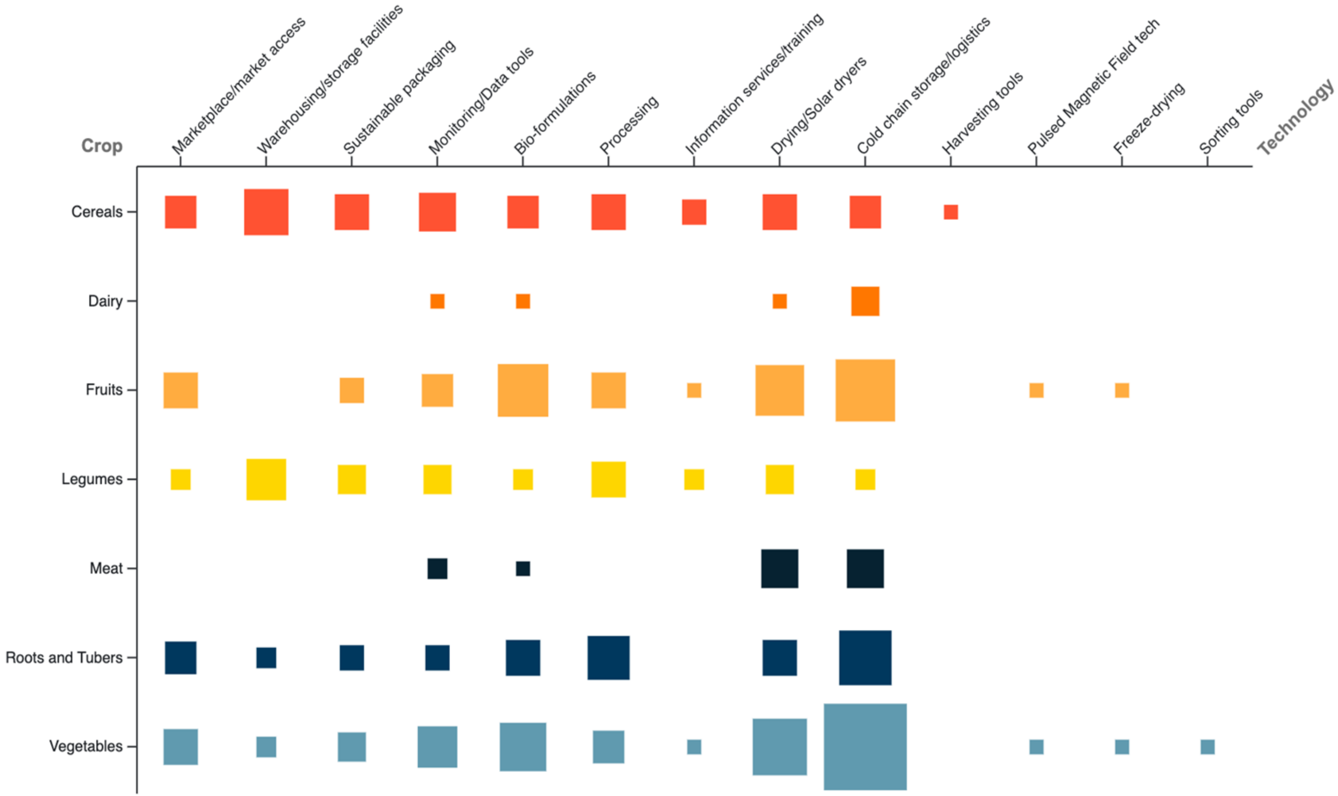
Technology Readiness: Preferably at or beyond validation stage, ideally with paying customers.

Founding Team: Strong, diverse leadership with a visionary CEO is essential.

Mapping Innovation to Crop Type

A matrix was created based on request for proposals (RFP) responses to correlate which innovation categories were most commonly applied to which crops. Applicants were allowed to choose multiple crop types.

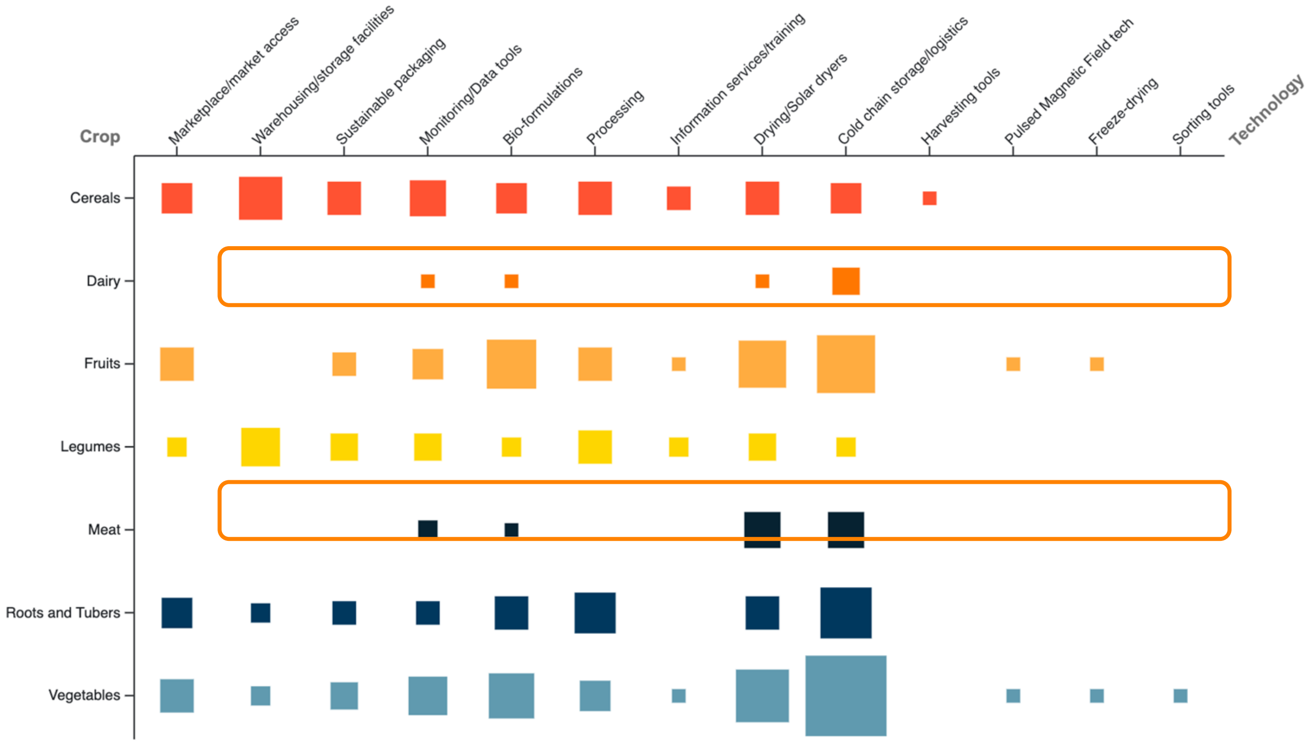
Correlation between innovation category and crop type



Mapping Innovation to Crop Type

Meat and dairy, both high value crops, received the least attention from our respondents.

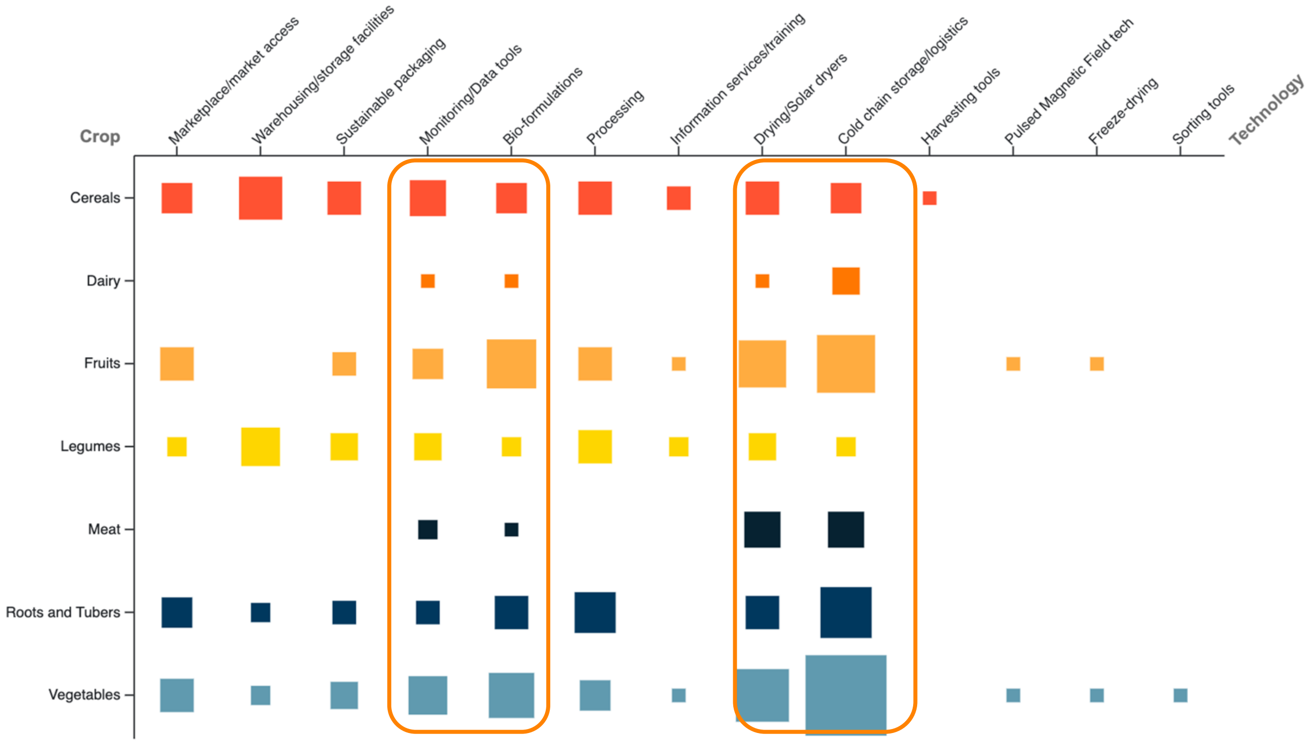
Correlation between innovation category and crop type



Mapping Innovation to Crop Type

Four innovation categories were broadly applied across our crop categories: **monitoring and data tools, bio-formulations, drying, and cold chain.**

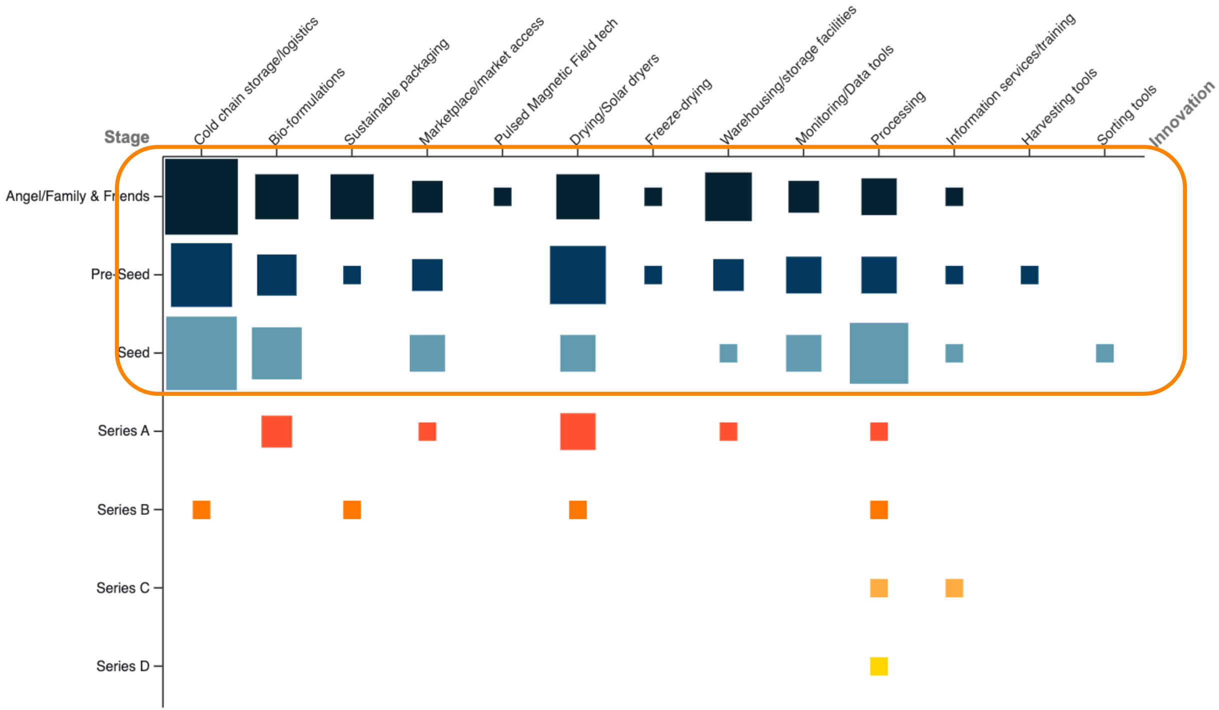
Correlation between innovation category and crop type



Innovation Maturity

Most of the innovations identified are at the **seed stage** or earlier, indicating that the market is **still nascent**.

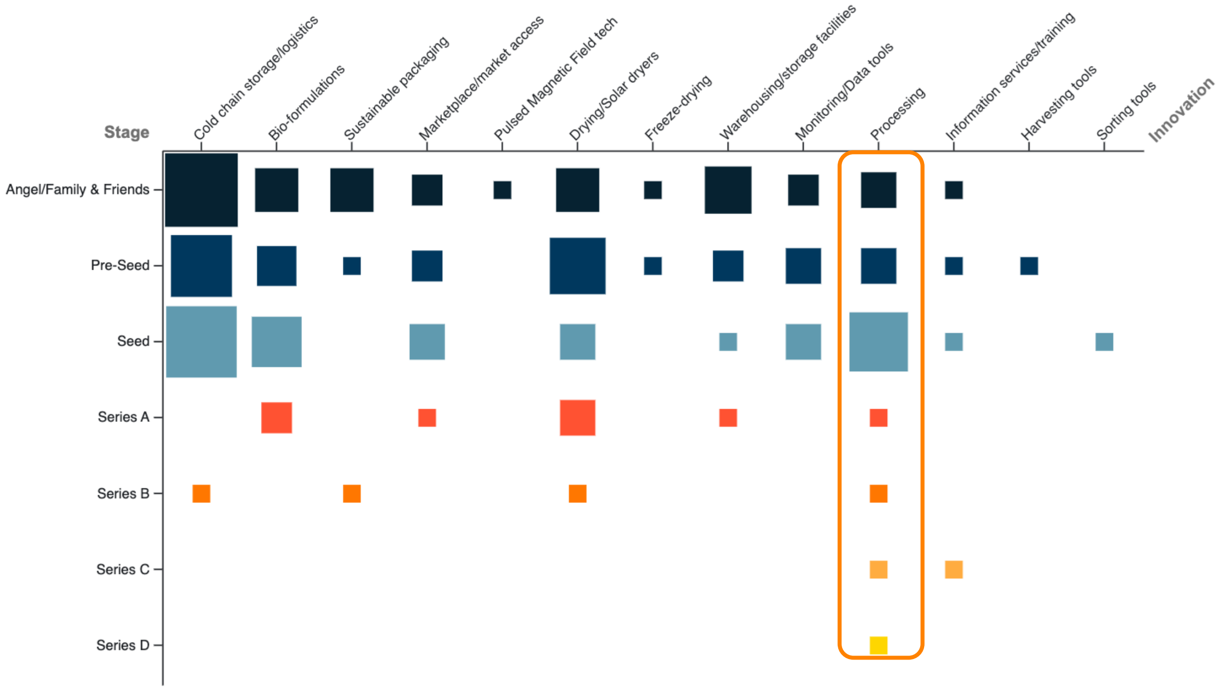
Correlation between innovation category and funding stage



Innovation Maturity

Only **processing technologies** are found at every stage in the venture funding cycle.

Correlation between innovation category and funding stage



Comparison with Scientific Literature

Findings:
Cereal & legume storage is heavily studied.

Packaging & storage of roots & tubers, fruits, and vegetables has also been heavily studied.

Processing, despite being the most mature sector in our dataset, has not been well studied—perhaps because it is generally considered a proven (and possibly low-tech) approach to post-harvest loss reduction. Furthermore, very few processing solutions are designed
and distributed with smallholder farmers as their target customers.

A scoping review of interventions for crop postharvest loss reduction in sub-Saharan Africa and South Asia

Intervention type (tier 1) and intervention stage (tier 2)	Cereals				Legumes					Roots and tubers				Fruits				Vegetables					
	Maize (corn)	Rice	Sorghum	Wheat	Bean	Cowpea	Chickpea	Pigeon pea	Groundnut	Cassava	Potato	Sweet potato	Yam	Banana	Mango	Papaya	Citrus	Cabbage	Onion	Tomato	Leafy vegetable	Intervention total	Intervention (%)
Technology/tool/equipment use	362	101	51	88	15	57	9	2	12	12	141	36	70	46	91	16	131	4	85	59	5	1,393	89.0
Ripening/senescence														2						3		5	0.3
Harvesting		13								2					21		8					44	2.8
Pre-cooling														9	13							22	1.4
Packaging (perishables)					2					3	14	12		15	14		40	2	9	27	2	140	8.9
Storage protectant (perishables)										6	51	7	44	5	30	6	66		27			242	15.5
Storage structure or container (perishables)										1	76	9	26	15	13	10	17	2	44	26	3	242	15.5
Drying	14											8							5	3		30	1.9
Threshing or shelling or de-husking	5	22																				27	1.7
Storage method (durables)	343	55	51	88	13	57	9	2	12													630	40.3
Processing		11																				11	0.7
Handling practice change	40	28		6	4				5	8	10	17	15		15		2	3	12			165	10.5
Handling before and/or after harvest	26	20		6	4				5	4	2	6	3						12			88	5.6
Harvest	14	8								4	8	11	12		11		2	3				73	4.7
Harvest and handling															4							4	0.3
Training/extension	2								3													5	0.3
Expert advice	2																					2	0.1
Training									3													3	0.2
Infrastructure											2											2	0.1
Road transport											2											2	0.1
Crop total	404	129	51	94	19	57	9	2	20	20	153	53	85	46	106	16	133	7	97	59	5	1,565	100
Crop group total	678				107					311				301				168				1,565	

Based on a dataset of 334 studies, each cell represents the number of interventions examined for a specific crop and intervention stage combination. The darkest orange cells indicate the areas with the most data. Blank cells signify no recorded interventions. The blue cells at the bottom summarize the total number of interventions studied for each crop and crop group, while the two rightmost columns show totals by intervention type and stage.

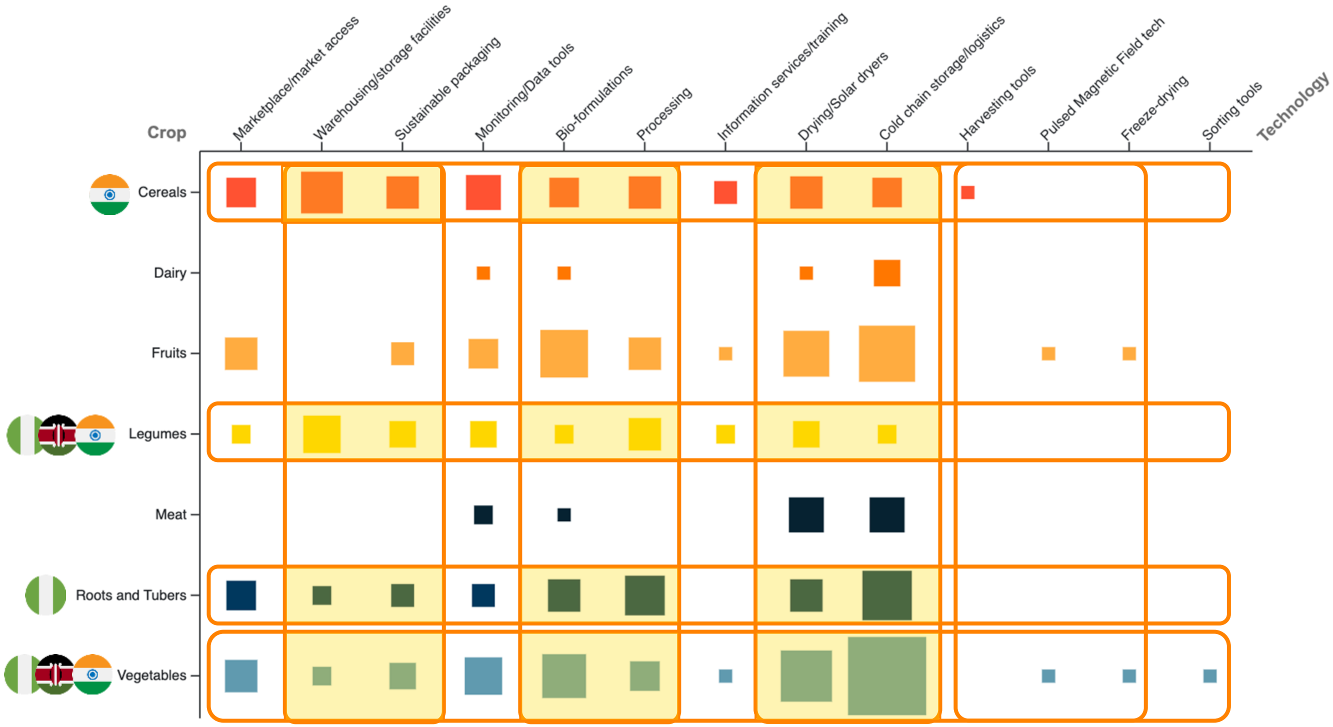
Mapping Innovation to Priority Solutions

The highlighted solutions sets are where our research has indicated the largest opportunity for reducing post harvest losses and providing income uplift for smallholder farmers.

Legumes and vegetables were identified as a priority crop in all three of our target markets.

While harvesting tools, pulsed magnetic field tech, and freeze drying would address key farmer needs, there was only one solution put forward in each.

Correlation between innovation category and crop type



Prize Downselect: Phase 2

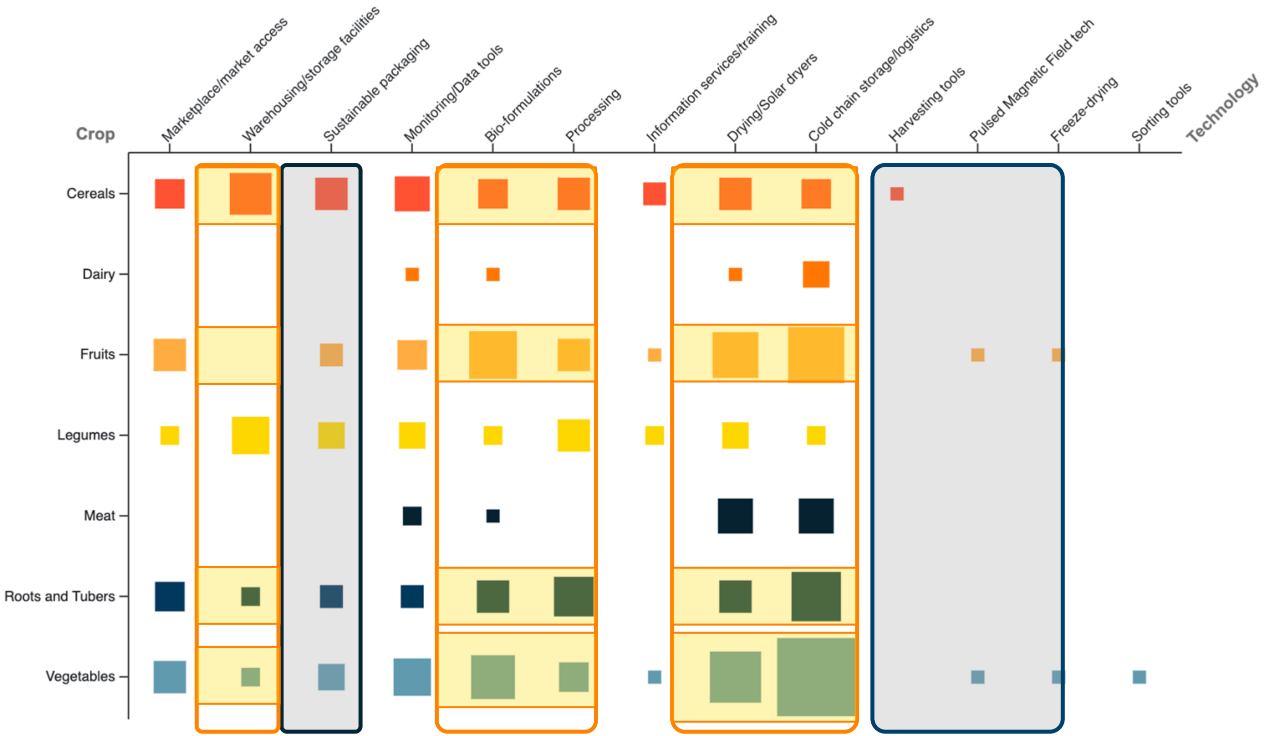
Seven technologies were shortlisted as finalists from the original dataset of **763** applicants. Each of these were scored on aforementioned criteria (see slide 15).

Of the nine priority solution verticals only five had innovations that met our downselecting criteria to advance to the third round screening.

The solution types highlighted in grey present opportunities for future innovation.

The number of remaining innovations after the first and second screening phases are shown at the bottom of the table.

Correlation between innovation category and crop type



Phase 1	11	12	8	11	22	23	2	25	46	1	1	2	1
Phase 2	2	2	1		7	1		1	3				

Prize Solutions: Phase 2

Relevant post-harvest loss reduction solution types and existing solution providers in Kenya, Nigeria and India based on Factor E analysis, their advantages and potential barriers to market adoption.

Measure of Investability

- High
- Medium
- Low

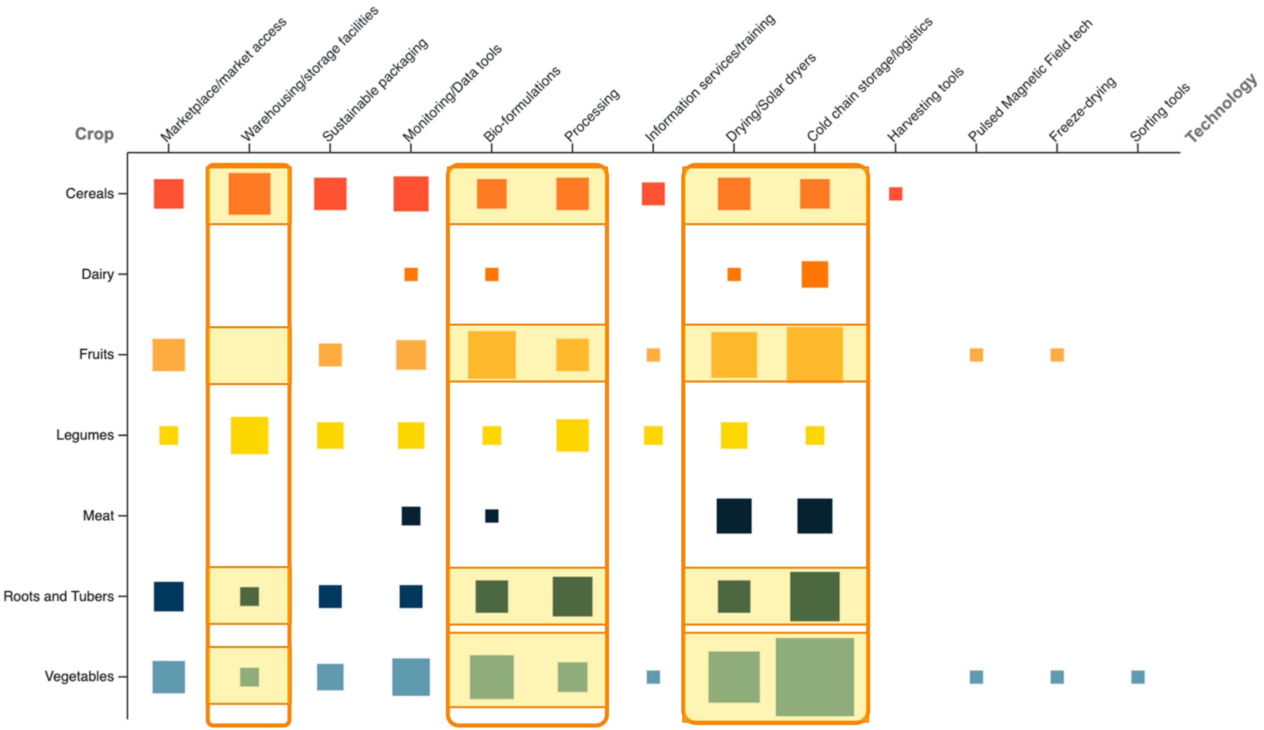
Solution type	Advantages	Barriers to scale	Existing Ventures
Biopolymers (edible coatings, biodegradable packaging, active packaging)	- High impact to farmers - Scalable - Minimal behavioural change needed - Significant differentiation	- Technologies are still nascent in emerging markets (testing for different crops in different markets) - Long and difficult approval process in different countries - Limited awareness by farmers	GreenPod Labs, AgroSustain, Peelon, Ecoresin Biopolymers, Freza, Karpolax, Bio-Pel, Farmer Sphere, HarvestR
Solar-powered/hybrid dryers with a service model/farm-level agro-processing	- Scalable - High impact to farmers (increases income) - Limited behavioural change needed	- High initial cost/capex - Low differentiation (most machines are imported) - Device training & maintenance required	BioAfriq, Iviani Farms, ANATSOR, Jua Technologies
Portable CO_2 cooling	- Climate impact (uses CO_2 to operate) - Scalable - Tech differentiation	- Expensive	NOF - Natural Offset Farming
Micro-warehousing/ warehousing platforms/market linkages	- Scalable - High impact potential	- Low willingness to pay for storage - Significant behavioural change needed - Primarily relevant for low margin crops e.g. grains	Zebra Cropbank, Silo Africa, Radava, Farm to Feed
Electricity-free cooling boxes	- Scalable - High Impact - Low opex	- High initial cost/capex - Low differentiation - Limited accessibility at farm gate	Evaptainers, Rukart

Prize Downselect: Phase 3

For the third round, the project team, with input from the Factor E Investment Committee reduced the pool of prize innovations to seven technologies, which were more rigorously evaluated.

These seven finalists presented solutions in the highlighted categories and crops: **warehousing facilities, bio-formulations, processing, drying, and cold chain storage**.

Correlation between innovation category and crop type



	Marketplace/market access	Warehousing/storage facilities	Sustainable packaging	Monitoring/Data tools	Bio-formulations	Processing	Information services/training	Drying/Solar dryers	Cold chain storage/logistics	Harvesting tools	Pulsed Magnetic Field tech	Freeze-drying	Sorting tools
Phase 1	11	12	8	11	22	23	2	25	46	1	1	2	1
Phase 2	2	2	1		7	1		1	3				

Prize Solutions: Phase 3

These seven ventures represent innovation in five distinct solution types; bio-formulations, cold chain, drying, processing, and warehousing, each of which is relevant for our target crops and target points in the value chain. Subsequently, we completed TEA on bio-formulations, CO_2 cooling, and solar processing which is summarized in Section 4.

Based on TEA and a panel review by experts, including the Factor E Investment Committee and members of Shell Foundation, we selected **Greenpod Labs as the Innovation Prize winner.**

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Greenpod Labs: Leverages ambient active packaging extends shelf life of fruits and vegetables at ambient temperatures

Zebra CropBank: A micro-warehousing platform for farmers to store, manage and monetize their produce.

Ecoresin: A plant-based powder coating to extend the shelf-life of produce.

AgroSustain: An edible coating to extend shelf life and reduce waste

Bio Pel: Uses essential oils slow-release technology to develop powder coatings that extend the shelf-life of produce at ambient temperature..

Natural Offset Farming: An in-field cooling system that utilizes CO_2 in its liquid state to produce cooling energy to extend the shelf life of fresh produce with a "cooling-as-a-service" model.

Anatsor: A mobile, solar-powered cassava and yam processing machine.

Iviani Farms: Builds and operates solar drying facilities at the farm gate to bridges the gap between smallholder farmers and premium markets for dried fruits and vegetables.

Section 3:
Solutions Overview

In-depth review of the seven finalists selected for the Post-Harvest Loss Innovation Prize.

Prize Solutions: Zebra Crop

Nigeria- A micro-warehousing platform for farmers to store, manage and monetise their produce.

Challenge
Small-scale Nigerian farmers face major hurdles due to inadequate storage and limited market access. This leads to substantial post-harvest losses, low produce prices, and restricted market opportunities. Building traditional storage is expensive, and navigating complex logistics presents further challenges to sustainable farming practices.

Solution
Zebra Cropbank tackles post-harvest losses by building and leasing small warehouses at the farm gate. This "crop banking" system minimizes transportation costs and simplifies logistics, enabling farmers to safely store their produce. By connecting farmers directly with buyers and aggregating demand, Zebra empowers farmers to sell their produce at higher prices, significantly improving their incomes.

Geographic Market
Nigeria

Crop Value Chain
Cereals

Innovation Category
Warehousing & Storage

Our Assessment
Compelling commercial traction and a huge potential for impact – They have built five ‘crop banks’ which have performed well: $25k of monthly revenue, serving over 2k farmers across Nigeria and an offtaking partnership with one state government. Zebra has reported a 90% increase in produce prices to farmers because they sell directly to processors and exporters and don’t incur logistics costs. A strong second time founder with experience working with farmers.

Decision Rational
Unclear strategy on the shared economy model – It might be difficult and expensive for Zebra Cropbank to manage the quality of the ‘crop banks’ at scale. Also, the company focuses on low value crops such as maize where we don’t see sufficient income uplift potential.

Prize Solutions: Ecoresin

Nigeria- A plant-based powder coating to extend the shelf-life of produce.

Challenge
The fresh produce industry faces significant post-harvest losses due to spoilage, decay, and ripening during transport and storage. These losses harm farmers' incomes, increase food waste, and drive up consumer prices. Traditional cooling solutions, often reliant on energy-intensive cold storage, are expensive and environmentally unsustainable, especially in areas with limited electricity access.

Solution
Ecoresin's biodegradable powder coating, made from cassava starch, provides a sustainable, cost-effective way to extend the shelf life of fruits, vegetables, roots, and tubers for up to 60 days without refrigeration. The solution is affordable and easily accessible to farmers in the region, helping them reduce post-harvest losses and decrease dependence on energy-intensive storage methods.

Geographic Market
Nigeria

Crop Value Chain
Fruits, Vegetables, Roots, & Tubers

Innovation Category
Bio-Formulation

Our Assessment
Accessible solution that eliminates cooling and pre-cooling - A unique solution that preserves high-value fresh produce for up to two months without the need for cooling or pre-cooling. The company has successfully piloted the technology in Nigeria, benefiting over 4,000 farmers, demonstrating strong demand. The team is well-balanced with relevant experience in agriculture and technology.

Decision Rational
Market adoption is uncertain - This product is still in early stages of development and our adoption readiness framework. Additionally, as a food coating, regulatory approvals in Nigeria could cause delays in uptake.

Prize Solutions: AgroSustain

Switzerland- An edible coating to extend shelf life of fruits, vegetables, roots and tubers and reduce waste.

Challenge
A large portion of harvested fruits and vegetables is lost to fungal pathogens and mold during post-harvest handling and storage. Poor storage, inadequate handling, and high humidity create ideal conditions for fungal growth, resulting in significant economic losses and increased food insecurity.

Solution
AgroSustain's edible coating extends the shelf life of fruits, vegetables, and flowers from farm to consumer while reducing reliance on synthetic pesticides. Its two-in-one solution combines the protective benefits of waxes for transportation with coatings that prolong freshness at retail. Proven to extend shelf life by up to four weeks, AgroSustain's innovation helps reduce food waste and improve supply chain efficiency.

Geographic Markets
15 Countries, including Kenya

Crop Value Chain
Fruits, Vegetables & Flowers

Innovation Category
Bio-Formulation

Our Assessment
Globally deployed, patented technology – A patent-protected technology extending shelf life by up to 50% across the entire fruits, vegetables, and flowers supply chain. This innovative solution is already authorized in over 15 countries, supported by a strong team with expertise in agriculture, research, and technology

Decision Rational
Limited farmer impact – The team has been unresponsive to inquiries about their operational model and product costs. Additionally, their focus on B2B clients may limit direct impact at the farm level.

Prize Solutions: Bio-Pel

Israel- Utilizes essential oils slow-release technology to create powder coatings that preserve produce at ambient temperature.

Challenge

Tubers, fruits, and vegetables often spoil due to premature sprouting, fungal attacks, and decay, both at the farm gate and during transportation. Traditional preservation methods rely on synthetic chemicals, which can be expensive and pose health and environmental risks.

Solution

Bio-pel's slow-release essential oils technology provides an edible powder coating to preserve fruits, vegetables, and tubers at ambient temperatures without cooling infrastructure. The coating extends shelf life during storage and transport, offering antifungal, antibacterial, and anti-mold protection.

Geographic Market
Israel & France

Crop Value Chain
Fruits, Vegetables & Tubers

Innovation Category
Bio-Formulation

Our Assessment

Ready for expansion into emerging markets – This unique product has successfully undergone testing and pilots and is already commercialized in Israel and France. The team has strong agricultural expertise, positioning them well for expansion. With a clear strategy, the company is set to enter Ghana and other Sub-Saharan African markets.

Decision Rational

Limited farmer impact, and potentially high cost – Bio-Pel focuses on B2B customers, which may limit its direct impact on farmers. Additionally, the cost for farmers at current pricing is high, decreasing accessibility, adoption, and potential for income uplift.

Prize Solutions: Natural Offset Farming

India & Mexico- An in-field cooling system that utilizes CO_2 in its liquid state to produce cooling energy to extend the shelf life of fruits and vegetables.

Challenge
Post-harvest losses, stemming from spoilage, decay, and ripening during transportation and storage, significantly impact farmers' incomes and contribute to food waste. These losses also drive up consumer prices. While cold storage is a common solution, it can be costly and energy-intensive, particularly in regions with limited electricity access.

Solution
NOF offers a sustainable and cost-effective cooling solution for farmers using liquid CO_2. Their "cooling-as-a-service" model, with low operational and capital costs, reduces on-farm crop losses by up to 30%. Farmers pay a $2-3 daily fee to cool 500 kg of produce. The modular system is adaptable to different market conditions, making it suitable for diverse agricultural settings.

Geographic Market
India & Mexico

Crop Value Chain
Fruits, Vegetables, Flowers, Milk & Seafood

Innovation Category
Cold Chain

Our Assessment
A novel product – Leverages readily available CO_2 for energy-efficient and affordable cooling, demonstrating impressive commercial traction with successful pilots in India and Mexico. The team boasts a strong track record, including seasoned entrepreneurs with expertise in agriculture, technology, and business development

Decision Rational
Difficult for emerging markets – The solution requires CO_2 in liquid state which could be difficult and expensive to acquire in most emerging markets.

Prize Solutions: Anatsor

Nigeria- A modular, mobile, solar-powered cassava and yam processing machine.

Challenge
Cassava has the potential to reduce food insecurity and poverty in Africa, serving as food, animal feed, and an industrial raw material. However, its high perishability causes major losses within days of harvest. This, along with spoilage and inefficient processing, leads to significant post-harvest losses for crops like cassava and yam in West Africa, limiting their economic and food security benefits.

Solution
Anatsor has developed a modular, mobile, solar-powered cassava and yam processing machine that reduces post-harvest losses by up to 80%. Locally designed and fabricated, it is more affordable than imported alternatives. By using solar power, it offers a sustainable solution that lowers costs and reduces reliance on fossil fuels, providing farmers with a more efficient way to process their crops.

Geographic Market
Nigeria

Crop Value Chain
Cassava & Yam

Innovation Category
Processing

Our Assessment
An affordable, locally produced option – A modular, solar-powered solution that is six times more affordable for cassava and yam farmers than existing options. It has the potential to reduce post-harvest losses by up to 80%. Led by a skilled team with expertise in agriculture and technology.

Decision Rational
The product's high cost – At its current cost of $750 per unit—is unaffordable for the majority of smallholder farmers.

Prize Solutions: Iviani Farms

Kenya- Builds and operates solar drying facilities at the farm gate to bridges the gap between smallholder farmers and premium markets for dried fruits and vegetables.

Challenge
Many smallholder farmers depend on rain-fed agriculture, leading to seasonal availability of fresh produce. Without direct market access, they must sell through middlemen at below market prices—often below production costs—resulting in financial losses and increased post-harvest waste.

Solution
Iviani Farm buys fresh fruits and leafy vegetables from local farmers and processes them into dried crisps, extending shelf life from 4–7 days to over 24 months. This provides a stable market for 1,000+ smallholder farmers in Kenya, offers premium prices for their produce, and creates quality jobs for the local community.

Geographic Market
Kenya

Crop Value Chain
Fruits & Leafy Vegetables

Innovation Category
Solar Drying

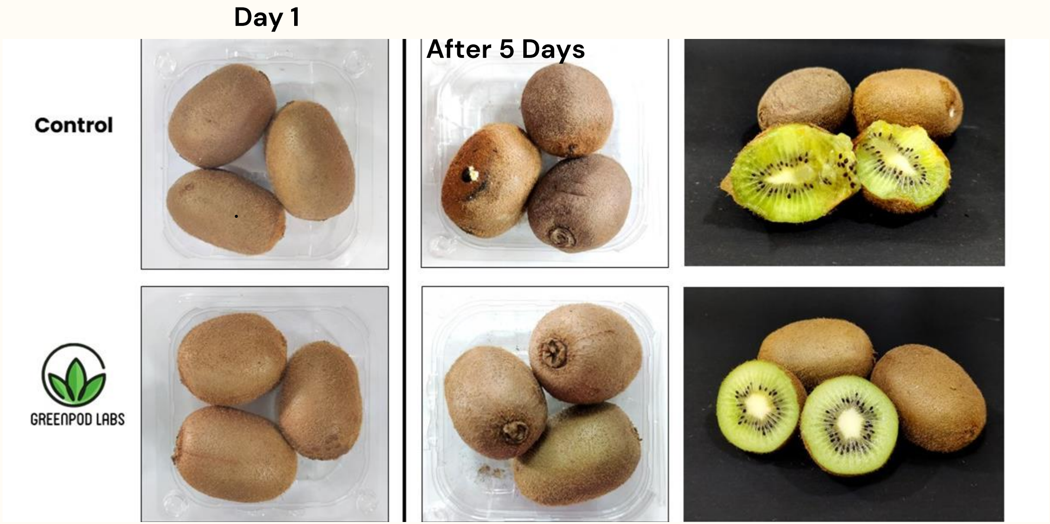
Our Assessment
Eliminating middlemen and boosting farmer profits – An impactful approach to reducing post-harvest losses by providing farmers with fair prices and direct market access, bypassing brokers. The team has strong expertise in agriculture and business development. Since launch, the company has gained solid commercial traction, serving over 1,000 farmers and generating more than $100,000 in annual revenue.

Decision Rational
High costs – High setup costs for farm-based factories and an unclear growth strategy.

Prize Solutions: Greenpod Labs

India- A biodegradable active packaging solution to extend the shelf life of fruits, vegetables, roots and tubers

Our Assessment
Cold-free preservation with strong team and market traction - A patented, ambient- temperature solution that extends the shelf life of fruits and vegetables without the need for cold storage. Led by a strong team with over 10 years of experience in agriculture, post-harvest loss, and business development. The company has gained strong commercial traction, serving 200+ farmers and generating ~$10K in monthly revenue, with significant expansion potential across diverse produce types.



Challenge
Key challenges in fruit and vegetable farming include rapid ripening, microbial contamination, and lack of cold storage, causing major losses across the supply chain. Traditional preservation methods, like refrigeration and chemical treatments, are costly, often unavailable, or pose health and environmental risks.

Solution
GreenPod Lab's ambient active packaging technology extends the shelf life of fruits and vegetables without the need for costly cold storage, making it a game-changer for resource-limited settings. This innovative solution works by activating the produce's natural immune system, slowing spoilage and reducing post-harvest losses.

Solutions Landscape & Overview Key Findings

1. **Most innovations were relevant for multiple crop categories**, including all of the crop categories that were identified in our market research as high priority.

2. **The vast majority of the ventures identified during the Post-Harvest Loss Innovation Prize are at seed stage or earlier**, only processing technologies existed at later stages of venture development. There were also many applications that were SMEs (not raising scaling capital).

3. **Four innovation areas stood out as we downselected the applicants for the program priorities; bio-formulations, cold chain, drying, and processing.** Micro-warehousing is also noted as a compelling solution, but is a business model and only technology innovations were selected for techno-economic analysis.

4. In addition to the learnings generated from the Innovation Prize, our desktop research revealed the following insights:

    a. **There's notable early success in biopolymers** (active packaging, edible coatings & films, stickers and biodegradable packaging bags). Biopolymers are increasingly being used for food preservation as they offer biodegradable and non-toxic alternatives to traditional synthetic materials. Investor interest is also rising in this space with startups such as Apeel and Hazel in the US raising ~$900M in funding combined. In emerging markets, biopolymers are still in their early stages of development but show some promising results because of their affordability to smallholder farmers. The global biopolymers market was valued at $8B in 2023 and is expected to hit $22B by 2030, signaling a huge adoption rate across markets.

    b. **Plasma treatments offer a promising solution to reduce fungal contamination and aflatoxin formation in agricultural products.** By generating reactive species such as ions, radicals, and UV photons, plasma disrupts fungal cell membranes, inhibits spore germination, and degrades aflatoxins. This non-thermal, chemical-free approach preserves the quality of grains, nuts, and other foodstuffs while being environmentally friendly. Studies have demonstrated plasma's efficacy against a wide range of fungal pathogens, including Aspergillus flavus and Aspergillus parasiticus, the primary producers of aflatoxins. With scalable technology and minimal residue concerns, plasma treatments are emerging as a valuable tool in post-harvest management.

Section 4: Techno-Economic Analysis of Top Three Solutions

Technical economic analysis for a subset of the seven finalists selected for the Post-Harvest Loss Innovation Prize.

Natural Offset Farming (NOF)

NOF cooling is a patented cooling system that utilizes CO2 in its liquid state to produce cooling energy, providing a unique and energy-efficient way to cool any medium in precision agriculture.

TRL: 8
Technology is tested and already deployed to the market in India and Israel

ARL: 6
Early adoption has proven market need

Innovation Category
Cold Chain

Geographic Focus
India & Mexico

How it works

When pressurized CO_2 is released, it expands quickly into the air, cooling down as it loses energy—a process called adiabatic expansion. The faster it expands, the colder it gets.

A CO_2-rich environment also helps preserve fruits and vegetables by slowing ripening, reducing spoilage, and preventing moisture loss. It inhibits bacteria, mold, and ethylene (a ripening hormone), keeping produce fresh for longer.

The company envisions selling compressed CO2 "pods" which are used with their hardware (they use Nespresso as an analogy) in a cooling as a service model.

Stated Techno-Economics

[+] The unit economics currently show a cost of production of ~$165 and sale price of $100-$140 in India, with an expected reduction to $60-75 at scale.

[+] CO2 pricing is variable and dependent on regulations, with current prices in India ranging from $48-$270 per ton.

[+] NOF's rule of thumb for OPEX is that the cost of treatment should be less than 5% of the value of treated fruits, and the company is currently operating at 0.5-1.2%.

[+] The ROI for traders and farmers using NOF's system is 1-20 days, with additional benefits including reduced rejection rates and increased income.

Natural Offset Farming

Our technical economic analysis

Assumptions

- NOF reports 4.5 kg of CO_2 are used to cool ~50 kg of strawberries
- NOF reports 74 bars (62 bar minimum required pressure to be liquid at room temperature) 4.5kg CO_2 = 102 mol.
- CO_2 cost is **$1-$2 per kg**
- NOF estimates **4.5kg** cylinders for small farmers in India
- 50 kg of strawberries has retail value in India of 5.84USD/kg x 50 kg = **$292**
- Assume farmer price is half retail = **$146 for 50kg**

Calculations

Using calculations for an adiabatic process, and assuming gas expansion to 1 bar (ambient pressure), CO_2 drops from room temperature (300K) to ~111K. Internal energy change is -540kJ. Assume the (now cold) CO_2 absorbs thermal energy from 50 kg of strawberries in a perfectly insulated container (strawberries are 92% water, so we assume 46 kg of water instead), $\Delta T = Q/mC_p$, energy change (540kJ) / mass of water (46kg) × specific heat of water (4.18 kJ/kgK) = **3 degree C**

If treatment cost is $6.75, PHL reduction requirement is 4.6% to break even. At scale, NOF estimates cost of CO_2 at $1 per kg and the treatment cost will be $4.5 for 50kg of produce. At unit cost, the **PHL requirement to break even also lowers to 3.1%.**

Conclusions

Can a 3 degree C temperature change reduce PHL by 5% or more? **Perhaps, our TEA suggests that there is some sizing risk and there must be a benefit from the atmosphere modification**. Note that the temperature change is not the temperature of the ambient air, but what the crop would drop to in absolute terms. Also, from the NOF response, they are cooling the surrounding air (not the produce per se) and there is also benefit (potentially significant) from the CO_2 atmosphere - not just from the temperature reduction. The TEA does suggest caution and further validation before investment.

Cost Reduction:

The company expects to reduce system costs from $165 today to $60-75 at scale, a greater than 50% reduction in cost. Cost reduction analysis by component:

- **Cooling Core** → $40; As a hardware component that is pressure rated, there is little opportunity for significant cost reduction other than volume procurement. Similar manufacturing requirements to vacuum walled containers. ✗
- **Control System** → $25; At high volumes this is the most likely component to see cost savings above 50%, could be replaced with COTS control board. ✓
- **Thermal Box** → $60; Switching to expanded styrofoam (like disposable coolers) should allow this component to drop well below 50%. ✓
- **Two CO_2 Cylinders** → $40 This is a fairly commodity item and is unlikely to change dramatically. ✗
- **Refilling** → $1-$2/kg; The actual cost of CO_2 is unlikely to change. ✗

BioAfriq Energy

BioAfriq offers hybrid solar/biomass-powered dehydration technology with an automated temperature controller and gasifier to reduce moisture levels in fruits and vegetables to about 10% through a drying -as-a-service (DaaS) model.

TRL: 8
Product is already deployed in the Kenyan market

ARL: 6
Early high adoption has proven market need as farmers don't incur the high capex

Innovation Category
Processing

Geographic Focus
Kenya

How it works

This dryer uses solar energy and biomass energy to efficiently dry fruits and vegetables. The hybrid approach ensures consistent drying performance regardless of weather conditions, making it reliable and sustainable.

Fruits and vegetables contain a moisture level of 60%-90% which is favorable for microorganisms such as molds, yeast and bacteria, accelerating spoilage. BioAfriq's dryer can lower this moisture content to a shelf-stable level of less than 10% with a drying efficiency of 20%. The dryer has a capacity of 15,000 kgs per month.

BioAfriq offers drying services to farmers at the farm gate as well as connecting farmers with buyers.

Stated Techno-Economics

[+] BioAfriq's total cost of production and operating the system for a year is $50,000. The company provides drying services to farmers at $0.16/kg.

[+] With a drying capacity of 15,000 kg per month, BioAfriq makes $28,800/year assuming full capacity. Therefore, the system's payback period is ~20 months.

[+] Farmers then sell the dried fruits and vegetables at $1.5/kg, 10x what they currently get from selling fresh fruits to brokers.

BioAfriq Energy

Our technical economic analysis

Assumptions

- BioAfriq reports a 20% drying efficiency i.e. for every 1 kg of produce dried, it yields 0.2kg
- BioAfriq provides drying services at $0.16/kg to farmers at the farm gate
- A kg of dried fruits has a retail value $1.5, 10x that of fresh fruits
- With an annual drying capacity of 180 tons, the system can enable 50 farmers dry up to 1.2 tons of fruits per season.

Calculations

1.2 tons of fresh fruits results in 240 kg of dried produce. Selling this at $1.5/kg, each farmer could earn an additional $360 per season ($720 per year), boosting their income by 24%. If BioAfriq improves the system's drying efficiency to 25%, the farmer's annual net income would increase to $516.

Conclusions

Although the initial cost of BioAfriq's hybrid system is high, providing a DaaS model at the farm gate makes the solution more accessible and affordable to smallholder farmers. The solution is impactful, with a reduction of PHL by 5% and increasing farmers' income by about 24% per season. With a payback period of just 20 months, the solution can be scaled while building resilience in rural farmer communities.

Cost Reduction:

BioAfriq expects to lower the cost of production from $24,000 to ~$ 10,000 as well as lower OPEX by 20% to $20,800, a ~40% reduction in total cost of production and OPEX. Cost reduction analysis by component:

- **Three Heating System & Digital Temperature Controllers** → $5,670; As a hardware component, there is little opportunity for significant cost reduction other than volume procurement. ✗
- **Nine 200W Solar Panels** → $0.4/W; Cost of solar panels is dropping year on year. With high volumes this is the most likely component to see cost savings above 50%. ✓
- **200AH (48V) Batteries** → $200/kwh; Similar to solar panels, the cost of lithium batteries has been coming down year on year. Local manufacturing is also increasing. This can reduce the cost significantly. ✓
- **Moisture Meter** → $480 This is a fairly commodity item and is unlikely to change dramatically. ✗
- **Concrete Floor Slab for Dryers** → **$9.6/m2;** Can be replaced with a cheaper alternative like stabilized soil, wooden floor or precast concrete slabs. ✓
- **Stainless Steel Washing Troughs and Tables** → $3,840; Can be replaced with coated or concrete and reduce the cost by more than 50%. ✓
- **Biomass** → $2,121; By subsidizing the cost of drying if farmers provide their farm waste to BioAfriq, this cost can be reduced by more than 50%. ✓
- **Labour costs** → $8,160; Optimizing the processing process to require minimal human labour can reduce the cost by 40%. ✓

GreenPod Labs

GreenPod Labs has developed active packaging solutions from plant extracts that preserve fresh produce at ambient temperatures.

TRL: 8
Solution is at the early stages of deployment in India and Kenya

ARL: 7
Early high adoption has proven market need

Innovation Category
Coatings

Geographic Focus
India & Kenya

How it works

The solution uses "Plant Defence Mechanism" by which the product activates the plant's built-in immune system that actively inhibit the growth of bacteria and fungi on fruits surfaces and therefore, extend their shelf life and maintain their quality and freshness.

GreenPod Labs packages its products in 1.25g sachets. To use the product, a farmer simply places the sachet in storage crates or boxes with the produce. No additional equipment or energy input is required.

Stated Techno-Economics

[+] The company sells the product at $6 for 100 sachets ($0.006/sachet). The cost of production is ~$1.95 per 100 sachets.

[+] Biopolymers are generally expensive, with current prices ranging from $4,000-$15,000 per ton.

[+] GreenPod's product costs $48,000/ton which is significantly higher the market range. However, packing the product in 1.25g sachets and one sachet preserving up to 10 tons of produce, makes it more affordable and accessible to farmers.

GreenPod Labs

Our technical economic analysis

Assumptions

- GreenPod reports that 1 1.25g sachet can be used to preserve 10 tons of produce
- GreenPod sells the product at $6/100 sachets (each sachet costs $0.06) or $48k per ton
- Cost of treatment is $0.006 per kg of produce
- Product cost of production is $1.95/100 sachets
- Average selling price of mangoes at the farm gate is $0.15/kg

Calculations

For a mango farmer in Kenya, who harvests 60,000 kg of mangoes per season, only 60% (36,000 kg) finds a ready market (brokers, food processors, exporters) after harvest and 30% (18,000 kg) of the harvest is lost at the farm gate due to over-ripening and microbial attacks, while the remaining 10% (6,000 kg) is either consumed by the farmer's family or is wasted due to improper harvesting and handling practices:

- Total cost of sachets to preserve 18,000kg: 18,000 x $0.006 = $108
- With the average selling price of $0.15/kg, farmers would save about $2,700 every season with GreenPod Labs or $2,592 of additional income. This is a 38% increase in income to farmers.

Conclusions

Utilizing natural plant extracts can extend the shelf life of fruits and vegetables by up to 60 days, enough time for farmers to find markets for their produce, and potentially boost their incomes by up to 38%. This preservation approach ensures produce maintains its quality and freshness at ambient temperatures. Additionally, by packaging the solution in smaller sachets (1.25g), GreenPod Labs ensures that it remains accessible to smallholder farmers and logistics providers at a fraction of the cost. This strategic packaging not only lowers the entry cost but also allows for flexible usage, making it an ideal solution for emerging markets.

Cost Reduction:

GreenPod Labs expects to reduce solution cost from $48k per ton today to $20k per ton at scale, a greater than 50% reduction in cost. To maintain its 68% gross margin, GreenPod should reduce its cost of production by ~50%. Cost reduction by component per sachet:

- **Plant Polymer & Active Ingredients** → $0.0033; At high volume and contracting local suppliers, this component has the potential to see cost savings of about 50%. ✓
- **Manufacturing cost** → $0.0032; Optimizing the manufacturing process through automation can have significant cost reduction by more than 50%. Automation will improve efficiency and reduce labour costs. ✓
- **Sachet Material & Sealing Cost** → $0.0085; This is a commodity item and has little opportunity for significant cost reduction other than volume procurement. ✗
- **Transportation** → $0.002; By optimizing delivery routes and consolidating shipments, cost can significantly reduce. ✓

Technical Economic Analysis Summary

1. **All three technologies evaluated address affordability through an "as a service" (XaaS) business model, providing products or functionalities on a subscription or usage-based basis rather than as a one-time purchase.** This model benefits farmers with lower upfront costs, scalability, continuous updates/improvements, and reduced maintenance burdens but comes with drawbacks such as recurring fees and long-term cost accumulation (vs asset appreciation). It also presents a more complicated business model.

2. **Biopolymers** benefit from both a large potential for cost reductions as scale occurs as well as a low cost to the end user with minimal behaviour change.

3. **CO2 cooling** is a novel recombination of de-risked technologies; however, some components of the solution are already commoditized and unlikely to see significant cost reductions. Additionally, there is a perception challenge regarding the use and potential release of CO_2 in the process. Depending on the specific use case, this could either increase costs (if sourced from a net-zero supply) or contribute emissions. While these emissions may still be lower than those mitigated by cooling, a detailed life-cycle analysis would be required to quantify the net impact.

4. Simple TEA of **biomass assisted drying** looks promising, but in Factor E’s experience, asset utilization and financing costs can dramatically alter the total cost of a system when a more detailed business model analysis is performed.

Section 5:
Key Takeaways

Synthesized insights from this project spanning market landscape, solution landscape, and techno-economic analysis.

[!]

Key Takeaways

1. **Technology Applicability:** While the project initially aimed to match high-opportunity post-harvest loss challenges (specific to geography and crop type) with innovative technologies, the most promising solutions are broadly applicable across multiple geographies and high-value crops. This flexibility offers entrepreneurs with multiple paths to market.

2. **Business Model Innovation:** The sector remains nascent, and business model innovation is critical to success. All finalists in our innovation prize utilized an "XaaS" model to enhance affordability for smallholder farmers, either through consumable products (e.g., coatings) or service-based offerings. However, these models are still unproven in the market.

3. **Market Challenges:** Aligning XaaS offerings with harvest seasonality will be crucial for success. Additionally, despite primary research identifying handling and harvesting as high-potential areas, little innovation is occurring in these categories, likely due to the commoditized nature of such solutions, which limits profitability (e.g., low margins in tools like mango pickers).

4. **Market-Based vs. Aid-Based Solutions:** Many RFP applicants proposed non-market-based solutions, underscoring the historical reliance of post-harvest loss interventions—and agriculture more broadly—on subsidies and aid-driven approaches rather than commercially viable models.

5. **Investment Potential:** Despite challenges, there are exciting and investable innovations in the sector. GreenPod Labs stands out as a high-tech yet cost-effective solution with venture-backable potential. Additionally, global startups like Apeel demonstrate scalable investment opportunities in post-harvest innovation.

Appendix

Key post-harvest loss drivers across the selected crop value chains and the existing solutions and solution providers

Existing low-cost post-harvest loss reduction solutions for the selected crop value chains in India, Kenya and Nigeria.

	Crop value chain	Existing low-cost and accessible solutions that are applicable at the farm gate	Existing solution providers landscaped
India	Tomatoes/ onions	Electricity-free cooling solutions, Biopolymers (biodegradable sachets), Drying solutions e.g. tarpaulin, solar dryers, air dryers etc, CO2 cooling, Digital marketplaces, Training/access to information on proper handling techniques, Low-cost harvesters	GreenPod Labs, Peelon, NOF-Natural Offset Farming, Machphy Solutions, Agrograde, Navork Innovations, Raheja Solar Food Processing, S4S Technologies, FarMart, Crofarm
	Bananas	Electricity-free cooling solutions, Biopolymers (biodegradable sachets, Drying solutions e.g. solar dryers, air dryers etc, CO2 cooling, Digital marketplaces, Training/access to information on proper handling techniques	I Support Farming, Machphy Solutions, Natural Offset Farming, GreenPod Labs, Agrograde, Navork Innovations, Raheja Solar Food Processing, Crofarm
	Mustard	Drying solutions e.g. tarpaulin, solar dryers, air dryers etc, Digital marketplaces, Training/access to information on proper handling techniques, Low-cost harvesters, Farm-level processing/ pre-processing solutions e.g. threshers, warehousing/micro-warehousing	FarMart, S4S Technologies
	Wheat/paddy	Drying solutions e.g. tarpaulin, solar dryers, air dryers etc, Digital marketplaces, Training/access to information on proper handling techniques, Low-cost harvesters, Farm-level portable processing/ pre-processing solutions e.g. threshers, warehousing/micro-warehousing	FarMart, S4S Technologies, Ergos
Kenya	Mangoes	Electricity-free cooling solutions, Biopolymers (biodegradable sachets, Drying solutions e.g. solar dryers, air dryers etc, CO2 cooling, Digital marketplaces, Training/access to information on proper handling techniques	BioAfriq, GreenPod Labs, Farm to Feed, VunaTec, AgroSustain, Iviani Farms
	Avocadoes	Electricity-free cooling solutions, Biopolymers (biodegradable sachets, CO2 cooling, Digital marketplaces, Training/access to information on proper handling techniques	GreenPod Labs, VunaTec, AgroSustain
	Irish potatoes	Digital marketplaces and market linkages, Training/access to information on proper handling techniques, farm-level pre-processing solutions, low-cost harvesters	Farm to Feed, VunaTec, AgroSustain
Nigeria	Tomatoes	Electricity-free cooling, Biopolymers, CO2 cooling, Digital marketplaces, Training/access to information on proper handling techniques	Ecoresein Biopolymers
	Yam/cassava	Biopolymers, Drying solutions, Training/access to information on proper handling techniques, Farm-level portable processing/pre-processing solutions e.g solar-powered processing machines	Ecoresin BioPolymers, ANATSOR, Solar-bubble-dryers, Solarisque
	Red pepper/chilli	Electricity-free cooling, Drying solutions, Biopolymer (biodegradable airtight packaging bags), Digital marketplaces and market linkages	Solarisque

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