BUSINESS OPPORTUNITIES TO REDUCE POST-HARVEST LOSS OF NUTRITIOUS FOODS

MODELLING THE RETURN ON INVESTMENT FOR FIELD-READY TECHNOLOGIES IN NIGERIA

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ABOUT GAIN

The Global Alliance for Improved Nutrition (GAIN) is a Swiss-based foundation launched at the UN in 2002 to tackle the human suffering caused by malnutrition. Working with governments, businesses and civil society, we aim to transform food systems so that they deliver more nutritious food for all people, especially the most vulnerable.

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SUMMARY

Reduction of post-harvest loss could have a major positive impact on increasing the affordability and accessibility of nutrient-dense fresh fruits and vegetables, particularly in low- and middle-income countries. While technologies to do so exist, their financial viability for the firms that would need to adopt them has not always been clear. This paper sheds light on this topic by analysing the costs and benefits of three innovations within the context of Nigeria's tomato value chain: reusable plastic crates to transport fresh fruit and vegetables to market, solar-powered cold rooms to store them, and refrigerated trucks to transport them to market. For the crates and cold rooms, we considered both own-use and lease cases. A stylised cost-benefit analysis for each technology and use case was done based on data obtained from five Nigerian companies. To take account of the uncertainty, we developed a baseline scenario for each technology based on the data provided by the companies, and then varied the key assumptions to test the robustness of the results. The results suggested that five of the six technology-business model combinations represent viable economic investments for food system firms, at least under certain circumstances, while the other (a 10 MT cold room rented as a service in a rural setting) would require subsidies to make it viable.

KEY MESSAGES

- Levels of post-harvest loss for fresh fruit and vegetables are high, particularly in low- and middle-income countries, and lead to lower food accessibility and affordability.
- While technologies exist to reduce loss, adopting them must be financially viable for the firms that produce and handle most of these foods.
- We-undertake a cost-benefit analysis of six different business models for using three post-harvest technologies within Nigeria's tomato value chain.
- Five of the six technology-business model combinations represent viable economic investments for food system firms, at least under certain circumstances, while the other would require subsidies to make it viable.
- While several of the technology-business model combinations would be viable investments for firms to adopt using loans, it can be very difficult for agri-food firms to access financing in settings such as Nigeria, indicating an important area for future intervention.

BACKGROUND AND OBJECTIVE

One deep irony of current food systems is that, even amid ongoing hunger and malnutrition, much potentially nutritious food goes uneaten. Loss and wastage occur along the supply chain, from primary production through storage and distribution to sales outlets and consumers' homes. The quantities involved are staggering: just between the supply chain stages of post-harvest through distribution, it is estimated that 14% of all food produced globally is lost (1). For the most nutrient-dense foods, which tend to be highly perishable, the levels are even higher, exceeding 20% for the category of fruits and vegetables (1). Levels may be higher still in sub-Saharan Africa, where there has been little investment in infrastructure and reducing post-harvest loss and much of the needed supporting infrastructure (e.g., electricity, water, and roads) is lacking: meta-analysis has suggested an average quantity loss of 43.5% for vegetables and 55.9% for fruits (2).

The profligacy of letting food go to waste when so many of the Earth's inhabitants are hungry or malnourished has been roundly condemned. Pope Francis has said that, "If we wish to build a future where no one is left behind, we must create a present that radically rejects the squandering of food" (3). The Sustainable Development Goals target 12.3 commits countries to reducing food loss along production and supply chains, and to halving food waste at retail and consumer levels (4).

Although it is hard to prove empirically that food loss and waste contribute significantly to the global burden of hunger and malnutrition: it is estimated that the amount of food losses registered by the FAO in 2017 would be enough to feed 940m people (5). Numerous pathways plausibly link food loss and waste, including loss in terms of both quantity and quality, to malnutrition. Firstly, loss and waste along the supply chain almost certainly increase final prices for consumers, making nutritious foods less affordable to poor consumers. Secondly, degraded foods usually contain reduced levels of essentials nutrients. Thirdly, the inability to extend the shelf-life of nutrient-dense foods may make certain nutrients less available in remote markets at certain times of the year. Furthermore, producing food that is never eaten clearly adds to the (already unsustainable) burden the food system places on planetary resources. Food loss and waste thus represent a clear threat to the present and future food and nutrition security of poor communities around the world. Such loss is not inevitable. Affognon and colleagues [2015] identified a large number of interventions deployed in sub-Saharan Africa and showed that losses of vegetables and fruits could be reduced to 10.7% and 24.8%, respectively, were these to be more widely used (2); for vegetables, this implies a 75% relative reduction in the rate of loss.

Reduction of post-harvest loss of nutritious foods is thus feasible and could have large societal benefits. However, since almost all food is produced and handled by private enterprises, the actual decisions to deploy potentially impactful interventions need to be taken at the level of individual businesses working in nutritious food supply chains. In sub-Saharan Africa, this generally means small and medium-sized enterprises (SMEs), which produce and handle the majority of nutrient-dense foods (6). These SMEs can only be expected to invest in technologies to reduce post-harvest losses if: (i) they can capture for themselves at least part of the economic return, (ii) the financial return to their investment is net positive within a relatively short time horizon and under prevailing lending rates, and (iii) the initial outlay is affordable given limited access to credit.

The Global Alliance for Improved Nutrition (GAIN) worked for four years (2015-2019) to address post-harvest losses of fresh fruits and vegetables (FFV) in Nigeria through a project known as N-PLAN (the Nigeria Postharvest Loss Alliance for Nutrition) (7). In brief, it focused on tomatoes as an archetypal nutrient-dense FFV characterised by high levels of post-harvest loss: in 2018, it is estimated that Nigeria produced 3.5m MT of tomatoes and 0.59m MT (nearly 17%) were lost along the food chain (8). N-PLAN reached 354 businesses overall, including 15 Nigerian SMEs that benefited from one-to-one technical assistance provided by international or national business leaders. It also provided small grants of approximately USD 250,000 per firm, co-investing with SMEs to increase their capacity to use loss-reduction technologies. As part of this, N-PLAN brought to Nigeria three technologies that were not widely used in tomato supply chains previously: reusable plastic crates (RPCs) for distributors to transport fresh FFV to market; refrigerated trucks to transport FFV to market; and cold rooms for FFV producers to keep FFV fresh until it is ready to transport to market. Under N-PLAN, all three interventions entailed capital outlays subsidised by GAIN. While these innovations were successful within that context, the project subsidy left it unclear whether they are commercially viable for continued use within Nigeria—with or without a subsidy. However, as noted above, widespread and sustained adoption at the level truly needed to meaningfully reduce PHL requires both the adoption and the ongoing use of technology to be financially viable.

This working paper addresses this unresolved question by analysing the costs and benefits associated with each of the three innovations for reducing post-harvest losses to determine the conditions under which they represent viable economic investments for archetypal SMEs in Nigeria. The results are then discussed in terms of their implications for sustainably increasing the uptake of PHL-reduction technologies in that country, considering both their benefits and their costs.

METHODOLOGY

To compare the costs and benefits associated with these three innovations, a Microsoft Excel-based financial model was developed. The model presents a cost-benefit analysis (CBA) of each technology to assess whether it represents a viable investment opportunity for a private company under different scenario. The model can also be used to estimate the extent to which a subsidy is required to make the technologies viable from the companies' perspectives.

The model relies on various assumptions about the costs and benefits associated with each technology. Some of these are fixed assumptions that are relevant to all technologies, such as currency conversion rates and loan terms. Others are technology-specific changeable assumptions, such as capital costs; installation, maintenance, and labour costs; rent and energy costs; taxes; quantities of FFV stored; and FFV prices. Once these parameters are set, the model produces an analysis of the costs and benefits of each of the technologies under two scenarios: an up-front purchase scenario and a financing scenario.

The parameters used in the modelling were established based on primary data and business records collected through interviews with business leaders at five firms in Nigeria. The firms were chosen from among N-PLAN members and affiliates to cover a diversity of technologies and models for commercialising them. In the interest of preserving confidentiality and anonymity, the firm names are not included here and are instead replaced with pseudonyms. They included Cold Room Firm A (using cold rooms on-farm), Cold Room Firm B (offering cold rooms as a service, in a rural setting), Cold Room

Firm C (offering cold rooms as a service, not in a rural setting), Truck Firm (refrigerated truck as service), RPC Firm A (RPCs for storing/transporting own produce), and RPC Firm B (an RPC leasing model). Some companies were using more than one business model, but these are referred to as separate 'firms' here for clarity. Examples of the RPC and cold room technologies are shown in Figure 1. As this study was conducted during the COVID-19 pandemic, all data was collected remotely (via email or phone). Following completion of the analysis, debriefing sessions were held with four out of the five companies to double-check the key assumptions and test the validity of the findings.

Figure 1. Examples of RPCs (left) and Cold Rooms (right)

In addition to basic CBA, we undertook sensitivity analyses, showing how the results would change if key assumptions related to capacity or use rates, discount rates, interest rates, and/or post-harvest loss savings were to change. Multiple changes were made to these parameters simultaneously, to test how sensitive the results were to these key assumptions.

For each scenario, we report the following standard financial results:

- **Average annual increase in gross margin**. Gross margin is net sales revenue *minus* the cost of goods sold.
- **Net Present Value**. The sum of all future inflows and outflows of cash associated with the investment, with future cashflows discounted to the present day.
- **Internal Rate of Return**. The discount rate that would make the Net Present Value equal to zero.
- **Pay-back period**. The number years required for the investment to break even.

The judgement of financial viability was based primarily on a positive Net Present Value, a pay-back period of generally less than five years, and the robustness of the results to changes in underlying assumptions.

The modelling analysis is purely illustrative and based on the data provided by the companies that participated in this study; other firms in the same business may have different parameters, depending on their location, management structure, specific technological set-up, staffing choices, and many other factors. To partly account for this substantive uncertainty in the results, we have included some sensitivity analyses to demonstrate how the results vary as the key underlying assumptions change.

FINDINGS

This section sets out the results of the CBA modelling, by firm. For each of the three technologies (cold rooms, refrigerated trucks, and RPCs), the analysis reviews the costs and benefits associated with the companies either purchasing the technologies up-front or using a bank loan to finance the purchase (i.e., spreading the cost of the technology over the term of the loan).

COLD ROOM FIRM A

Cold Room Firm A purchased and installed a 10 MT Solar-Powered Cold Room, which they use on their farm to provide post-harvest storage for the FFV that they produce. The company received a grant through N-PLAN to purchase the cold room, but for the purpose of this analysis we have looked at two scenarios to help judge the financial viability of the technology: one in which an SME uses its own funds to purchase the cold-room up-front, and another in which the SME uses a bank loan. The key assumptions for the modelling are set out in Table 1, below.

For the sensitivity analysis, we focused on assessing the impact of varying the key drivers of the CBA model – the amount of storage capacity used (i.e., how much fruit and vegetables the company puts in the storeroom) and the impact of cold room storage on reducing post-harvest losses. We looked at the following scenarios:

- Baseline: 80% storage capacity utilised,15% reduction in post-harvest losses
- Sensitivity analysis (SA) 1: 80% storage capacity, 5% reduction in post-harvest losses
- SA 2: 60% storage capacity, 15% reduction in post-harvest losses
- SA 3: 60% storage capacity, 5% reduction in post-harvest losses

Table 1. Assumptions underlining CBA for Cold Room Firm A

Assumption		Sources
Capital costs: cost of purchasing and installing cold room	USD 20,308	Company data
Related capital cost – cost of storage materials required to use cold room	USD 333	Company data
Additional operational and maintenance costs related to the cold room	USD 2,333	Assumption based on staff costs and technical support costs provided by Cold Room Firm B
Reduction in post-harvest loss	15%	Assumption from the company
Storage capacity utilisation	80%	Consultant's assumption; varied in the sensitivity analysis to account for this uncertainty
Asset life of technology (yrs.)	10 – 15 years	Estimate from the company; as the technology is relatively new, it is uncertain whether it will remain productive for up to 15 years.
Discount rate	12%	Based on Nigeria's monetary policy rate, which stood at 12.5% at the time of the analysis[1]
Nominal interest rate (for modelling of loan)	24%	Based on interest rates typically offered to the agricultural sector by commercial banks in Nigeria.[2] Rates from the leading commercial banks vary from around 23% to 30%. Note that under the Central Bank of Nigeria's Agricultural Credit Guarantee Scheme rates are much lower, but lending under this scheme is rationed.
Loan term (for modelling of loan)	5 years	Consultant's assumption, based on previous experience of the Nigerian market.

Upfront purchase

In this scenario, it is assumed that a company purchases the cold-room in cash with an up-front payment. In this case, as shown in the table below, the cold room would be a viable economic investment in the base-case and under two of the sensitivity analyses. Thus, even making conservative assumptions about the amount of storage capacity utilised, or the extent to which the cold room reduces post-harvest losses, the cold room still generates a significant profit.

The break-even point for the technology occurs when the level of PHL reduction falls to just 5%. In general, the technology should be able to reduce the level of PHL to around the baseline assumption, unless the company is using the equipment incorrectly or it runs into technical problems and does not

[1] https://www.cbn.gov.ng/rates/GovtSecurities.asp

[2] Available on the Central Bank of Nigeria website.

or cannot seek technical support to fix the cold room.[3] Overall, these initial results suggest that it would made economic and financial sense for a company similar to Cold Room Firm A (i.e., one producing fruits and vegetables at similar volumes) to purchase a cold room. In practice, however most SMEs in Nigeria (or elsewhere in sub-Saharan Africa) would not have access to enough cash to fund such a purchase on their own. (A graphical depiction of the return on investment over time is included in the appendix).

Table 2. Results of the Cold Room Firm A modelling – up-front cash purchase

Scenario	Baseline	SA 1	SA 2	SA 3
Average annual increase in gross margin (US$)	$18,190	$6,063	$13,643	$4,547
NPV (US$)	$64,614	-$9,133	$36,958	-$18,351
Internal Rate of Return (IRR)	50%	-10%	30%	N/A
Pay-back period	Year 2	N/A	Year 3	N/A
Viable economic investment	**Yes**	**No**	**Yes**	**No**

Loan to purchase

In this scenario it is assumed that a company purchases the cold-room by getting a loan. The loan is assumed to be have a 5-year tenor and attract an interest rate of 24% per annum. The company is required to pay 40% of the costs of the cold-room upfront as part of the loan. The assumptions on the parameters of the loan are based on the consultant's prior experience of working with the Nigerian financial sector, we understand that the nominal interest rates on loans to the private sector/ particularly agriculture typically vary from around 22% to 28% (and higher).

In this case, as shown in the table below, the cold room would be a viable economic investment in the base case and under one of the sensitivities. The viability of the investment is heavily influenced by the effectiveness of the cold-room in reducing post-harvest losses as shown in sensitivity 1.

Table 3. Results of the Cold Room Firm A modelling – loan to purchase

Scenario	Baseline	SA 1	SA 2	SA 3
Increase in gross margin (US$)	$16,752	$4,625	$12,204	$3,109
NPV (US$)	$75,793	$2,046	$48,138	-$7,172
Internal Rate of Return (IRR)	99%	2%	53%	-5%
Pay-back period	Year 1	Year 14	Year 2	N/A
Viable economic investment	**Yes**	**No**	**Yes**	**No**

[3] These are both real constraints within Nigeria, particularly if the technology is imported or the staff has not been properly trained.

Overall, these initial results suggest that it would make economic and financial sense for a company similar to Cold Room Firm A (i.e., producing fruits and vegetables at similar volumes) to purchase a cold- room using a loan to do so – however, it is riskier than the option of purchasing the cold-room up- front. This suggests that there could be scope for interventions to support financing options that reduces the risks for financial institutions (which could then improve the financial terms on which a loan might be offered e.g., some form of first-loss guarantee product to reduce the interest rate for the loan or extend the repayment period) and also reduces the risk for the company (potentially part-subsidy).

COLD ROOM FIRM B

Cold Room Firm B also used an N-PLAN grant to purchase a 10-ton Solar Powered Cold Room. In contrast to Cold Room Firm A, however, they use the cold room on their farm to provide post-harvest storage for the fresh fruits and vegetables that are produced by local farmers, which can be stored in the cold room for a fee. In addition, the cold room is used by the company to store some of its own produce before it is sent to market: the company purchases 'fresh cuts' (i.e., fruits and vegetables that are still in a fresh state but have undergone very basic processing, such as washing, peeling, or cutting) of FFV such as pineapples, bananas, plantain, eggplants, and cucumbers. Table 4 summarises the key underlying assumptions for the modelling, and for the sensitivity analysis.

Table 4. Key assumptions for Cold Room Firm B modelling

Assumption		Source
Capital costs – cost of purchasing and installing cold room	$20,000	Company data
Battery cost	$2,500	Company data
Battery asset life	7 – 12 years	Company/ engineer
Related capital cost – cost of storage materials required to use cold room	$333	Company data
Operational and maintenance costs related to the cold room (per annum)	$5,000	Company data
Cost of storing 12 kg of tomatoes per day	Approx. 200 Naira	Company data
Cost of storing 12 kg of tomatoes per week	Approx. 500 Naira	Company data
Storage capacity utilisation from customers	35%	Company data
Revenue from storing company's own produce in storage room	2,000 Naira per day	Company data
Discount rate	12%	Standard assumption across technologies
Nominal interest rate (for modelling of loan)	24%	Standard assumption across technologies
Loan term (for modelling of loan)	5 years	Standard assumption across technologies
Asset life of technology (yrs.)	10 – 15 years	Based on assumption used for Cold Room Firm A

For this company's CBA, we examined only a baseline case, without sensitivity analyses. Under the baseline, 35% of storage capacity was sold to customers (with an equal split between selling daily and weekly storage slots), with the company using around 15% of the storage space per day.

Upfront purchase

In this scenario it is assumed that Cold Room Firm B purchases the cold room in cash with an up-front payment. In this case, as shown in the table below, the cold room would not be a viable economic investment in the baseline scenario. Having consulted with the company, we understand that this is because the level of demand for the cold room in the rural setting is currently insufficient. The company does not have enough farmer clients (or other customers that might have the need for a cold room) who are willing to pay to use the service. This is partly because there is another cold room, operated by a competitor, in the area. Including the use of the cold room for Cold Room Firm B's own produce, the company utilises around 50% of the cold room's space. For the investment to break even, the firm would need to increase this to 70% of space utilised. It would require a significant portion of the costs to be subsidised (around 50% of the up-front capital costs) for it to make sense for a company with a similar business model to purchase the cold room and use it to offer a service.

In comparison to the results for Cold Room Firm A, this demonstrates that the economic value generated by purchasing the cold room comes from the reduction in post-harvest losses, which creates additional agricultural products, which can be sold. A company using the cold room to provide a service is only able to obtain a portion of the increase in economic value, whereas a farm such as Cold Room Firm A is able to keep all of the value created by the cold room itself.

Table 5. Results of Cold Room Firm B modelling – up-front cash purchase

Scenario	Baseline
Average annual increase in gross margin (US$)	$2,442
NPV (US$)	- $4,940
Internal Rate of Return (IRR)	- 5%
Pay-back period	N/A
Viable economic investment	**No**

In general, if a technology is not a viable investment when purchased outright, it will be even less viable when purchased using a loan. Analysis assuming that Cold Room Firm B purchases the cold room by getting a loan confirms this: the technology would also not be a viable economic investment under a loan scenario, with an IRR of -10%.

COLD ROOM FIRM C – COLD-ROOM AS SERVICE

Cold Room Firm C used an NPLAN grant to purchase a three-ton solar-powered cold room, which they use on their farm to provide post-harvest storage for the fresh fruits and vegetables that are produced by local farmers and stored in the cold room for a fee. They thus have a similar business model to Cold Room Firm B, but with a smaller cold room and without storing their own produce, as well.

The key assumptions for the modelling are set out in Table 6, below. For the sensitivity analysis, we assessed the impact of varying the amount of storage capacity used (i.e., how much storage space the company can sell, on average, over the year). We looked at the following situations:

- Baseline: Average number of crates per day set at level provided by company (150 crates per day)
- SA 1: 120 crates per day stored on average
- SA 2: 100 crates per day stored on average

Table 6. Key assumptions for Cold Room Firm C modelling

Assumption		Source
Capital costs – cost of purchasing and installing cold room	$30,555	Company data
Related capital cost – cost of storage materials required to use cold room	$333	Company data
Battery (five to seven-year asset life)	$6,800	Company data
Operational and maintenance costs related to the cold room (per year)	$5,283	Company data
Price charged for leasing space for 20 kg of produce per day	$0.27	Company data
Average number of crates in storage per day	150	Company data
Discount rate	12%	Standard assumption across technologies
Nominal interest rate (for modelling of loan)	24%	Standard assumption across technologies
Loan term (for modelling of loan)	5 years	Standard assumption across technologies
Asset life of technology (yrs.)	20 years	Company data

Upfront purchase

In this scenario, it is assumed that Cold Room Firm C purchases the cold room in cash with an up-front payment. In this case, as shown in the table below, the cold room would be considered a viable investment in the baseline scenario; however, this result is not particularly robust to the sensitivity analysis. If Cold Room Firm C suffered from a 20% decline in demand for its services, the investment would become more marginal. The break-even point for the investment is 110 crates stored per day, compared to the baseline assumption of 150 crates per day. Storage volume can thus decrease only fairly slightly before the firm's investment becomes unviable. We validated these findings with representatives of Cold Room Firm C, who confirmed that the results are similar to their own financial modelling.

Table 7. Results of the Cold Room Firm C modelling – up-front cash purchase

Scenario	Baseline	SA 1	SA 2
Average annual increase in gross margin (US$)	$9,300	$6,383	$4,439
NPV (US$)	$29,533	$10,081	- $2,885
Internal Rate of Return (IRR)	28%	18%	10%
Pay-back period	Year 5	Year 10	N/A
Viable economic investment	**Yes**	**Borderline/ No**	**No**

Loan to purchase

In this scenario, it is assumed that a company purchases the cold room by getting a loan. The loan is assumed to have the same tenor and interest rate as the other technologies. In this case, as shown in the table below, the cold room would be only a borderline viable investment in the baseline case and would not be a viable economic investment under the sensitivity analyses. The viability of the investment is heavily influenced by the price that the company is able to charge to farmers who want to store fruit and vegetables (and other perishable products) in the cold room – and the amount of storage space that the company is able to sell. Again, these initial results suggest that it would not make economic and financial sense for a company similar to Cold Room Firm C to obtain a loan to purchase the cold room and then use it to provide services to farmers. The company would require a subsidy to be able to purchase the cold room if it had to access finance on the terms assumed here. (A graphical depiction of the return on investment over time is included in the appendix).

Table 8. Results of the Cold Room Firm C modelling – loan to purchase

Scenario	Baseline	SA 1	SA 2
Increase in gross margin (US$)	$7,586	$4,669	$2,724
NPV (US$)	$24,270	$4,818	- $8,150
Internal Rate of Return (IRR)	30%	15%	7%
Pay-back period	Year 7	Year 14	N/A
Viable economic investment	**Borderline**	**No**	**No**

RPC FIRM A - PURCHASE OF RPCs

This entity is not a private company but rather a tomato producers' association. They used the grant from the N-PLAN programme to purchase 8,000 RPCs. The RPCs are used to move tomatoes to processing facilities with an off-taker that has an agreement with the cooperative and to transport tomatoes to markets for sale. The analysis again considers two scenarios: whether it is economically viable for them to purchase the crates up-front and whether it is possible for them to use a bank loan to fund the purchase of the crates. The key assumptions for the modelling are set out below.

Table 9. Key assumptions for RPC Firm A

Assumption		Source
Capital costs – cost of the RPCs	$22,222	Company data
Costs of handling the crates	100 Naira per crate	Company data
Reduction in post-harvest loss	35%	Based on company data
Discount rate	12%	Standard assumption across technologies
Nominal interest rate (for modelling of loan)	24%	Standard assumption across technologies
Loan term (for modelling of loan)	5 years	Standard assumption across technologies
Breakage rate of the crates (per annum)	25%	Conservative assumption based on company data

For the sensitivity analysis, we focused on assessing the impact of varying the key drivers of the CBA model for this firm: the crate breakage rate and the impact of crate use on reducing post-harvest losses. We looked at the following sensitivities:

- Baseline: 25% Breakage rate per annum, 35% reduction in post-harvest losses.
- SA 1: 35% Breakage rate per annum, 35% reduction in post-harvest losses.
- SA 2: 25% Breakage rate per annum, 15% reduction in post-harvest losses.
- SA 3: 35% Breakage rate per annum, 10% reduction in post-harvest losses.

Upfront purchase

In this scenario, it is assumed that a company purchases the RPCs in cash with an up-front payment. As shown in Table 10, the RPCs would be a viable economic investment for each of the cases examined in the sensitivity analysis. The economic return on the investment is very high and, similar to the case of Cold Room Firm A, is driven by the fact that the purchase of the RPCs leads to a significant increase in the amount of product that the cooperative has available to sell, according to their own data.

Table 10. Results of the RPC Firm A modelling – up-front cash purchase

Scenario	Baseline	SA 1	SA 2	SA 3
Average annual increase in gross margin (US$)	$15,351	$11,096	$6,245	$2,869
NPV (US$)	$120,614	$90,969	$37,297	$8,804
Internal Rate of Return (IRR)	237.6%	227.6%	81.8%	32.9%
Pay-back period	Year 1	Year 1	Year 2	Year 3
Viable economic investment	**Yes**	**Yes**	**Yes**	**Yes**

Thus, even making conservative assumptions about the extent to which the use of RPCs reduces post-harvest losses and the annual breakage rate for the RPCs, it would still make economic and financial sense for a company or cooperative similar to the one examined here (i.e., producing fruits and vegetables at similar volumes) to purchase RPCs for their own use. In practice, however, most companies and few cooperatives would have access to enough cash to fund the purchase on their own – making it is useful to also examine the bank loan scenario. (A graphical depiction of the return on investment over time is included in the appendix).

Loan to purchase

In this scenario, it is assumed that a company purchases the RPCs by getting a loan. The loan is assumed to have the same tenor and interest rate as for the other technologies. In this case, as shown in the table below, the purchase of the RPCs would be a viable economic investment in the base case and under each of the sensitivity analyses examined. The viability of the investment is heavily influenced by the effectiveness of the RPCs in reducing post-harvest losses, as shown in sensitivity analysis 1, and the assumption that the additional tomatoes can be sold either through the firm's agreement with an off-taker or in the open market.

Table 11. Initial results of the RPC Firm A modelling – loan to purchase

Scenario	Baseline	SA 1	SA 2	SA 3
Increase in gross margin (US$)	$13,732	$9,478	$4,626	$1,249
NPV (US$)	$116,888	$87,243	$33,571	$5,077
Internal Rate of Return (IRR)	574.4%	563.4%	180.2%	55.4%
Pay-back period	Year 1	Year 1	Year 1	Year 1
Viable economic investment	**Yes**	**Yes**	**Yes**	**Yes**

Overall, these initial results suggest that it would make economic and financial sense for a company similar to this cooperative to purchase RPCs using a loan to do so. Similar to the Cold Room Firm A case, this suggests that there could be scope for interventions to support financing options that reduce the risks for financial institutions (which could then improve the financial terms on which a loan might be offered--e.g., some form of first-loss guarantee product to reduce the interest rate on the loan or extend the repayment period) and also reduce the risk for the company (potentially part-subsidy).

RPC FIRM B– LEASE OF RPCs

Using the same data provided by RPC Firm A, we considered the costs and benefits of an alternative business model in which they lease out the RPCs to other agri-producers; this could also be analysed as a mixed business model, in which some of the crates are retained for their own usage and some are leased to other agri-producers, but our base case assumes they lease them all.

The analysis again considers two scenarios for the firm: is it economically viable for it to purchase the crates up-front and then use them for leasing; and whether it is possible for it to use a bank loan to fund the purchase of the crates for leasing.

We use the same assumptions as set out in Table 7 for RPC Firm A, however the following assumptions are included, both of which were sourced from RPC Firm A:

- Cost of leasing out an individual crate: 250 Naira to 300 Naira.
- The number of times each crate can be leased per month: varies from one to four, depending on the turnaround time (i.e., the time from leasing the crate to getting it back, which varies from 7 to 21 days, according to RPC Firm A).

For the sensitivity analysis, we focused on assessing the impact of varying the key drivers of the CBA model – the number of times that the crates can be leased out and the breakage rate for the RPCs. We looked at the following sensitivities:

- Baseline: each crate leased twice per month, and the breakage rate set at 25%.
- SA 1: each crate leased once per month, and the breakage rate set at 25%.

Upfront purchase

In this scenario, it is assumed that a company purchases the RPCs in cash with an up-front payment. As shown in Table 12, the RPCs would be a viable economic investment in the baseline case but not if the number of times that the crates are leased per month falls to one. This analysis suggests that the model of leasing RPCs may be viable if the company has certainty about its ability to lease out the RPCs multiple times per year. Based on the information provided by RPC Firm A, they have sufficient demand to lease out their RPCs. However, they seem to encounter challenges when it comes to recovering the RPCs quickly enough: they charge a flat rate for each RPC leased out, but for their model to be more financially viable, they should be charging more to those agri-producers that hold on to the RPCs for longer (i.e., leasing the RPCs for a daily or weekly rate, not a flat rate).

Table 12. Results of the RPC Firm B modelling – up-front cash purchase for leasing model

Scenario	Baseline	SA 1
Average annual increase in gross margin (US$)	$2,923	$1,169
NPV (US$)	$6,906	- $9,142
Internal Rate of Return (IRR)	25%	- 5.6%
Pay-back period	Year 4	n/a
Viable economic investment	**Yes**	**No**

Loan to purchase

We also modelled a scenario under which RPC Firm B uses a bank loan to purchase the RPCs. This produces similar results to the up-front purchase model: the analysis suggests that it would be a viable business model if the company has some ability to ensure that it is leasing out its stock at least two times a month.

Table 13. Results of the RPC Firm B modelling – loan to purchase for leasing model

Scenario	Baseline	Sensitivity 1
Average annual increase in gross margin (US$)	$1,304	- $450
NPV (US$)	$3,179	- $12,869
Internal Rate of Return (IRR)	26.6%	- 21.2%
Pay-back period	Year 4	n/a
Viable economic investment	**Yes**	**No**

REFRIGERATED TRUCK FIRM

Refrigerated Truck Firm purchased and installed a refrigerated truck, which they use to provide a logistics service primarily for fruit and vegetable farmers. They transport their customers' goods to market; their main routes are from Kaduna to Lagos and from Abuja to Lagos. The company received a grant through the N-PLAN programme to purchase the truck room, but for the purpose of this analysis we consider two alternative approaches: an up-front cash purchase and taking a loan, to assess the size of the subsidy (if any) that would be needed to support other companies to purchase similar equipment in lieu of a full grant. The key modelling assumptions are set out below.

Table 14. Key assumptions for Refrigerated Truck Firm modelling

Assumption		Source
Capital costs – cost of purchasing and installing cold room	$25,000	Invoice for the truck
Annual operating and maintenance costs (driver, fuel, maintenance, taxes)	$30,544	Company data
Asset life of truck (yrs.)	6 years	Estimate by firm
Truck re-sale value after six years of usage	$4,167	Estimate by firm
Average revenue per month from hiring truck to transport primarily FFV from Abuja/ Kaduna to Lagos; the company gets its revenue from hiring out the trucks at a flat rate of around $1,100 per journey	$5,555 to $8,333	Company data
Discount rate	12%	Standard assumption across technologies
Nominal interest rate (for modelling of loan)	24%	
Loan term (for modelling of loan)	5 years	

For the sensitivity analysis, we focused on assessing the impact of varying the key drivers of the CBA model. In the case of Refrigerated Truck Firm, this relates to the number of times that the truck is hired out to transport fruit and vegetables each year. Based on data provided by Refrigerated Truck Firm, the company hires out the truck 60 to 90 times each year. Therefore, the baseline and sensitivity analyses consider what happens when the number of times the truck is hired out changes, as follows:

- Baseline assumption, 60 hires per annum
- SA 1, 45 hires per annum
- SA 2, 30 hires per annum

Upfront purchase

In this scenario it is assumed that a company purchases the truck in cash with an up-front payment. In this case, as shown in the table below, the truck would be a viable economic investment in the base-case and under the parameters of first sensitivity analysis (i.e., 45 hires per year). However, if the number of times Refrigerated Truck Firm hires out its truck each year were to fall to below 33, the truck would no longer represent a viable economic investment.

Overall, however, these results suggest that it would made economic and financial sense for a company similar to Refrigerated Truck Firm to purchase a refrigerated truck and hires it out for fresh fruit and vegetable transport.

Table 15. Refrigerated Truck Firm modelling outputs: up-front cash purchase

Scenario	Baseline	SA 1	SA 2
Average annual increase in gross margin (US$)	$45,003	$30,717	$16,431
NPV (US$)	$108,826	$47,644	- $13,538
Internal Rate of Return (IRR)	144%	75%	- 26%
Pay-back period	Year 1	Year 2	N/A
Viable economic investment	**Yes**	**Yes**	**No**

(A graphical depiction of the return on investment over time is included in the appendix).

Loan to purchase

In this scenario it is assumed that a company purchases the refrigerated truck by getting a loan. The loan is assumed to have the same tenor and interest rate as for the other technologies. In this case, as shown in the table below, the truck would be a viable economic investment in the base case and the first sensitivity analysis shown.

Overall, these initial results show that it would make economic and financial sense for a company similar to Refrigerated Truck Firm to purchase a refrigerated truck using a loan. Similar to the other technologies considered, there could be scope for interventions to support financing that reduces the risks for financial institutions. They could then improve the financial terms on which a loan might be offered. This support could come in the form of a first-loss guarantee product to reduce the interest rate for the loan or extend the repayment period. Such an approach would also reduce the risk for the company (potentially as a part-subsidy).

Table 16. Refrigerated Truck Firm modelling outputs – loan to purchase

Scenario	Baseline	SA 1	SA 2
Average annual increase in gross margin (US$)	$21,730	$7,444	- $6,841
NPV (US$)	$121,587	$60,405	- $776
Internal Rate of Return (IRR)	307%	142%	11%
Pay-back period	Year 1	Year 1	N/A
Viable economic investment	**Yes**	**Yes**	**No**

BREAK-EVEN POINTS AND OVERALL VIABILITY

This analysis has aimed to assess in general whether the technologies examined here represent viable investments, and if so, under what conditions. The sensitivity analyses can be used to make a judgement about how risky the technologies are for the companies; if a small change in the key assumptions means that the company would lose money, then the technologies might not represent a good investment. For example, in a case where a cold room is expected to reduce PHL by 15%, it might seem to be a good investment; however, if the sensitivity analysis shows that just a 1% decline in the level of PHL averted (i.e., the PHL reduction is 14% instead of 15%) significantly reduces the net present value or internal rate of return on the investment, this would imply that the technology would not be a good investment because the results are not robust to small changes in the assumptions—which, in the real world are likely to occur.

The table below summarises the break-even point for each technology set-up and how that point compares to the baseline assumptions. For each technology, the CBA models suggest that it represents a good economic investment in the baseline scenarios. However, in the case where the 10 MT cold room is used in a rural setting, the analysis suggests that the technology would not currently be a viable investment because the data provided by the company suggests that there is currently insufficient demand for the services. The company would need to achieve around 70% usage rates for its cold room to break even, but it currently only achieves up to 50%, and that figures includes using the space for some of its own produce.

For the other technology-business model combinations, a comparison between the baseline assumptions and the break-even points suggests that most of the technologies are a viable investment from a business point of view (see Table 17).

Table 17. Refrigerated Truck Firm modelling outputs – loan to purchase

Technology	Key baseline assumptions	Break-even point	Viable investment
10 MT cold room on-farm	15% reduction in PHL	5% reduction in PHL	**Yes**
10 MT cold room as service (rural setting)	50% of storage space sold	At least 70% of storage sold	**No**
3 MT cold room as a service	150 crates stored per day (on average)	110 crates stored per day	**Yes**
Refrigerated truck as service	Truck hired 60 – 90 times each year at a flat rate	Truck hired less than 33 times each year	**Yes**
RPCs for own produce	35% reduction in PHL	15% reduction in PHL	**Yes**
RPCs, leasing model	Each crate leased twice per month	Each crate leased only once per month	**Yes/ marginal**

DISCUSSION

Based on the data obtained from the companies, each of the three technologies analysed has substantial potential to reduce the incidence of PHL for FFVs or other perishable crops. As a result of this, the technologies have the potential to create economic value, because reduced PHL equates to a larger quantity and/or higher quality FFVs to sell. The analysis also suggests that the technologies are of more value to agri-producers (i.e., farmers), rather than SMEs with a business model that involves using the technologies to provide a service. Intuitively this makes sense. An agri-producer will retain all the increase in economic value created by the technologies, whereas a service provider can only obtain a portion of the increased economic value – otherwise there is no incentive for an agri-producer to purchase the service. Moreover, an agri-producer also has the flexibility to provide the technology as a service alongside using it for its own produce, if it has spare capacity—as seen in the case of Cold Room Firm B.

The SMEs consulted all reported that they would consider purchasing additional units of the technology. However, they also reported that they cannot do so because they lack access to sufficient funds. The modelling here shows that some of the technologies examined here would also be viable investments for agri-producers if they took out bank loans—this would be particularly true if interest rates were lower than those assumed here, which may be the case in many cases. Lack of access to financing is a common problem for SMEs in low- and middle-income countries, particularly for those in the agri-food sector and for women-owned firms (9,10). Such SMEs are seen as less desirable for financial service providers due to modest funding needs, unreliable financial accounts, limited collateral, short credit histories, and/or uncertain growth prospects—all of which increase the risk and lower the potential returns for investors (11,12). For the SMEs examined here, the lack of access to the capital required to meet banks' collateral requirements was a particularly important barrier. According to business owners, this was exacerbated by the fact that most of the bank representatives lacked knowledge of the technologies in question, making them unable to properly value them for use as collateral. There is thus the potential for development partners to consider providing guarantees or other interventions to help SMEs access finance, enabling them to purchase such technologies in the future.

There are, of course, certain limitations to this analysis. It draws on information from only a small number of firms, using specific business models in specific settings. The results are thus of unknown generalisability. The findings are subject to uncertainty and should be interpreted as such, particularly because they rely on long-term assumptions and trends that will vary over time. Finally, the analysis does not calculate the exact financial return associated with the technologies but rather provides an indicative picture of financial viability. Perhaps most importantly, this analysis only considered the economic cost of the PHL avoided – not the potential societal benefits of reduced loss in the form of lower environmental impacts of food production (4) and potentially improved diets (13). Were this analysis to be repeated using full-cost accounting that included these costs and benefits, the benefits to technology adoption might be considerably higher.

CONCLUSION

The reduction of post-harvest loss is central to any strategy to improve access to nutritious foods in poor communities and is also expected to reduce the pressure the food system places on scarce planetary resources. Many technologies have been shown to reduce post-harvest losses. This paper set out to assess whether three specific technologies to reduce post-harvest loss of fresh fruits and vegetables are likely to be commercially viable for continued use within Nigeria.

The findings suggest ways for development partners and donors to better support the adoption of technologies designed to reduce post-harvest loss—in ways that represent financially viable investments, as needed for long-term sustainability. In particular, while the analysis shows that most of these technologies represent financially viable investments, and while the firm representatives interviewed were eager to scale up their use, access to financing represented a serious barrier. There is thus an important role for interventions that can improve access to finance, such as the provision of loan guarantees. Most of the technologies' viabilities would also improve still further if their impact on PHL reduction were greater and/or if the demand for their services was stronger. This suggests a need to continue to innovate and develop new, better and accessible technologies for reducing PHL and to raise awareness of the benefit of using such technologies among farmers and other actors within the fresh fruit and vegetables value chain.

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APPENDIX: GRAPHICAL DEPICTIONS OF RETURNS FROM INVESTMENT IN TECHNOLOGY

Cold Room Firm A

The chart below shows how the Cold Room Firm A's financial returns from the technology change over time in the baseline scenario. It shows that the company starts to achieve a positive return from the technology after 2 years.

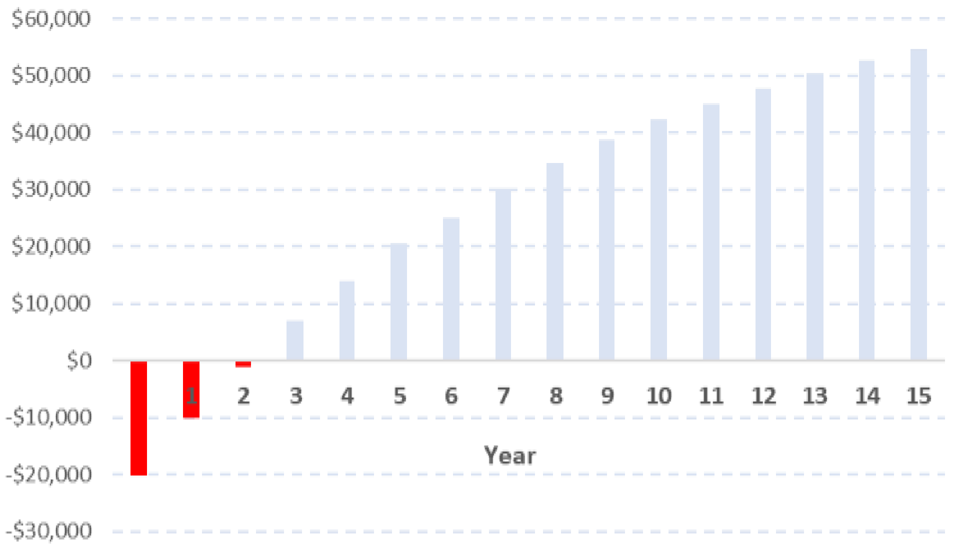


Figure A1: Annual discounted cash-flow for Cold Room Firm A, up-front purchase

The chart below shows how the Cold Room Firm C's financial returns from the technology change over time in the baseline scenario, when a loan is used to fund the purchase of the cold room. The company starts to achieve a positive return from the technology after year 5.

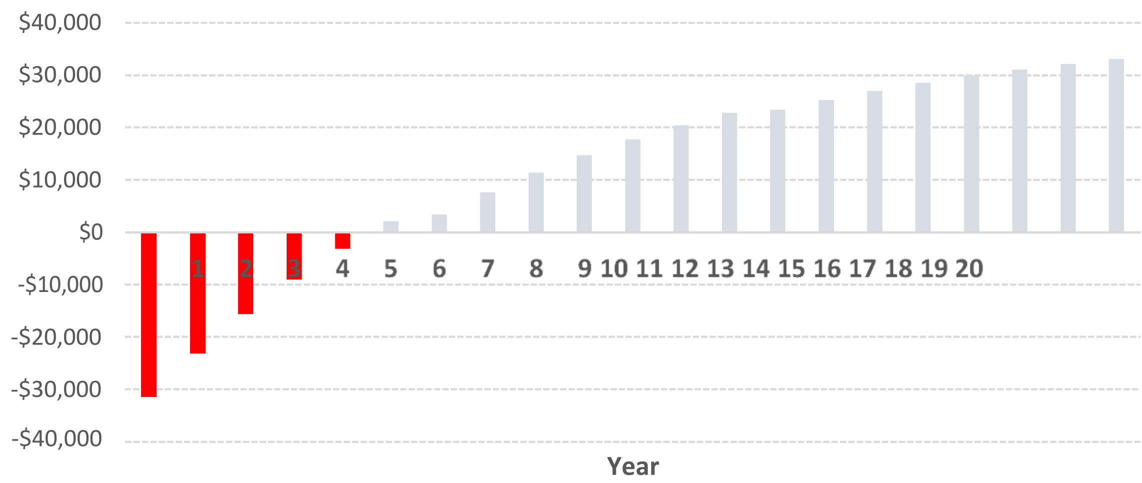
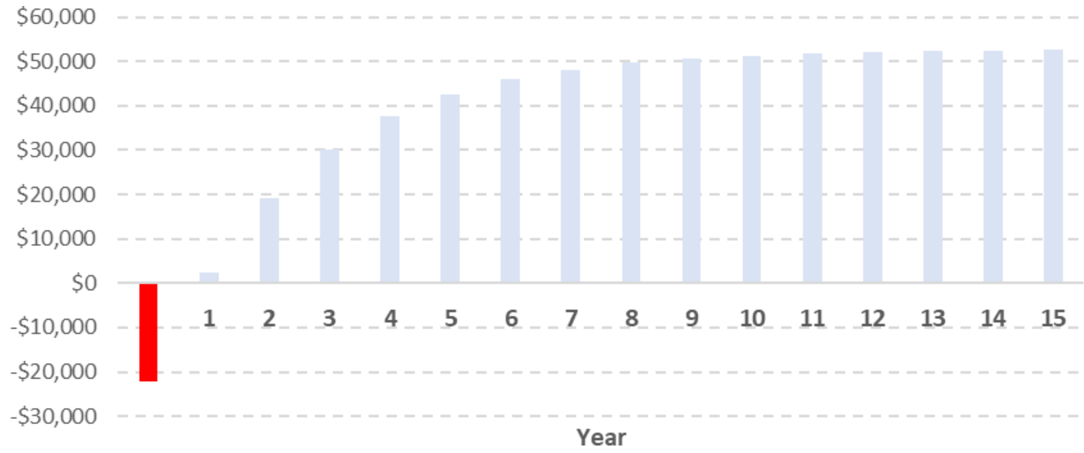


Figure A2. Annual discounted cash-flow Cold Room Firm C, loan purchase

Figure A3, below, shows how RPC Firm A's financial returns on the technology would change over time in the baseline scenario, when a loan is used to fund the purchase of the RPCs. The company starts to achieve a positive return on the technology after just one year.

Figure A3. Annual discounted cash-flow – RPC Firm A, up-front purchase



The chart below shows how Refrigerated Truck Firm's financial returns from the technology change over time in the baseline scenario, when a loan is used to fund the purchase of the refrigerated truck. It shows that the company starts to achieve a positive return from the technology after just 1 year.

Figure A4. Annual discounted cash-flow Refrigerated Truck Firm up-front purchase