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Investing in rural people

SunDanzer
DC-Powered Refrigeration

Lessons Learned From Piloting Solar Refrigeration in the Rwandan Dairy Sector

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Executive Summary

Under the auspices of the IFAD Green Technologies to Facilitate Development of Value Chains for Perishable Crops and Animal Products grant, SunDanzer Refrigeration and its in-country Clean Energy Technologies have been deploying 50 liter and 165 liter solar powered DC fridges into the Dairy section since May of 2020 using a Pay-As-You-Go business model. It is important to note that efforts were significantly impeded by the COVID pandemic. In the roughly year-and-a-half experience, the key Lessons Learned can be summarized as follows:

- Affordability and financing are an essential starting point
- Market characteristics vary significantly by region (market is not homogenous)
- Small rural shops were by far the predominate use case, not “evening milk” (the expected use case from initial research); small farmers, by and large, could not afford the fridge and lacked entrepreneurial initiative
- The price of milk is closely correlated to the ability to buy
- Pricing and financing need to be subsidized to sustain the market
- There are significant logistics and support issues involved in the sales and support of solar powered fridges; remote monitoring of fridges is highly desirable
- There is no major market for Domestic Use, just Productive Use
- Customers want lighting and USB charging as part of the system
- There is a need for solar powered fridges in grid-connected areas
- A “community” orientation (serving a gamut of local needs) revealed itself to be the best approach to the market
- Diversification into a broad set of use cases and “offers” is needed to move toward a sustainable business model

In conclusion, there currently does not exist, in our assessment, a significant nor sustainable market for solar powered refrigeration in the Dairy Sector of Rwanda. As efforts broaden to other sectors such as Fisheries, we will be better able to assess whether a viable market exists at this time.

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1. Background

SunDanzer Refrigeration is the recipient of the multi-year, $2.2M USD IFAD grant entitled Green Technologies to Facilitate Development of Value Chains for Perishable Crops and Animal Products (GreenTech). The GreenTech grant largely focuses on solar powered cooling solutions for dairy farmers and artisanal fishers in East and Central Africa. One major project consists of piloting 300 small-scale, solar powered, and PAYG enabled refrigerators (50-160 liters in volume) in the dairy sector.

This particular project is, to a significant extent, a sequel to the USAID funded Photovoltaics for Sustainable Milk for Africa through Refrigeration Technology (PV-SMART) project conducted in Kenya from 2015 through 2018. While technically successful, this project was a market failure, primarily due to the high cost of the system. A significant portion of the cost was associated with the "direct drive" battery-less design of the system. This required six 83-watt solar modules and an expensive (both equipment and installation, see photo below) pole mount for the PV. About 100 of the targeted 155 systems were deployed. Also, effective financing was not in place. Very few units were purchased at full price.

Photo 1 Elaborate and expensive pole mounting for PV SMART systems

2. Affordability and Financing are Essential

SunDanzer, in order to significantly lower cost, shifted to designs that utilized batteries. The availability and declining price of solar panels, lithium iron phosphate batteries, and Solar Home Systems (SHSs) enabled a much more economical solution. In addition, SunDanzer redesigned its 50 liter fridge to be a lower cost refrigerator by reducing the amount of insulation and utilizing a lower cost compressor, trading off efficiency for cost. The incremental cost of increasing PV wattage and storage was outweighed by the lower fridge cost. In the process of lowering the manufacturing cost, the volume of the same fridge increased to 100 liters.

Cost was also reduced by leveraging the advanced capabilities of the SHS. SunDanzer partnered with Zimpertec to customize their Litio controller with a programmable second DC output that can be dedicated to power the fridge. The fridge, when equipped with "ice" packs or "ice" bags (phase change material), could be programmed to shut off at night and not utilize the battery. The phase change material would be cooled during the day when there is ample power to charge the batteries and run the fridge. This enables a much smaller battery to be used.

SunDanzer also knew it would have to provide affordable and easy financing, similar to what MKOPA Labs reported in their groundbreaking 2019 Lessons Learned Paper: PAYG Solar powered fridge, Developing a "first time" product for low income customers. SunDanzer, through its in-country partner Clean Energy Technologies Ltd. (CET) ended up providing 18 months of 0% interest financing and subsidizing the price to what the market could bear (the specifics of pricing and financing are detailed later in this paper).

3. Focus: Productive Use and Dairy

What is unique about the GreenTech project in Rwanda, distinguishing it from MKOPAs landmark work in Kenya, is threefold:

1. **Focus on Productive Use**. While MKOPA focused on Domestic uses and used a consumer-oriented, front-opening fridge, GreenTech focuses on Productive Use applications and uses commercially oriented, top-opening chest fridges. The project is driven by the question "How can farmers make more money if they owned a fridge?"
2. **Focus on the Dairy Industry**. GreenTech targets smallholder dairy farmers and dairy cooperatives as one of its beneficiaries. We believe the project is unique in the realm of research in off-grid solar refrigeration and Productive Use markets because of its focus on the Dairy Sector and milk cooling. MKOPA took a horizontal approach to the market, while we took a vertical one.
3. **Scale**. The intended pilot deployment of 300 systems in Rwanda far surpasses the estimated <50 units deployed in MKOPA's series of three small pilots.

In short, the Lessons Learned here not only apply to Rwanda but specifically to the Dairy Sector and Productive Use cases. The large number of pilot units also entails a much deeper dive. Note that this document contains the initial Lessons Learned from the early stages of the project; there will be additional Lessons Learned published at the conclusion of the project. The next section overviews the progress to date.

4. Project History in Rwanda (2018 to 2021)

The project began in the summer of 2018 with a Market Assessment and Strategy. The Market Assessment pointed to an opportunity using solar milk coolers to monetize "evening milk" that was not being collected and sold. The Market Strategy was to partner with BBOX, a top tier supplier of SHSs in Rwanda. Initial promising discussions did not result in an agreement and the initiative languished.

In late 2019, Clean Energy Technologies (CET) was approached as a potential in-country partner. In April 2020 a formal distribution agreement was signed. In May and June of 2020 SunDanzer and CET spent four weeks on the ground investigating the market. They discovered the proposed strategy was based on true market conditions and a new, multi-faceted strategy was developed (which is articulated in the section entitled: Breakthrough Concept: Community Ecosystem Approach).

To date (November 2021), 27 systems have been sold with progress impeded by COVID lockdowns and restrictions and CET having to build a PAYG-based Last Mile Distribution operation to be able to sell and support the products.

Photo 2 Jean Claude UWIZEYE of CET conducting a sales training (165 and 50 liter fridges in background)

5. Lessons Learned From the Field

5.1. Limited Evening Milk Market

The very first, eye-opening lesson was learning that the Evening Milk use case was not nearly as pervasive as anticipated. Initial market intelligence recommended focusing on farmers who had no way to monetize their production of evening milk. We quickly discovered that the majority of cooperatives collected evening milk. So, there was no pervasive need for preserving it until morning to add to the morning milk. The understanding of the market we were given was inaccurate and overly simplistic. We had to start over to determine who could benefit from a solar fridge and find use cases that had significant economic benefit. We then spent an entire month on the ground visiting farmers and dairy co-ops.

5.2. Localized Market Characteristics

We found out that the Dairy Sector of Rwanda is not homogeneous; it has significant differences from region to region, district to district and even co-op to co-op. The clear implication was that we could not take a general, "one-size-fits-all" approach. Here is a partial list of variables that influence the marketing and sales of solar refrigeration:

- Micro-climate (e.g. the severity of the dry season)
- Local customs regarding milk drinking (e.g. Eastern Province has a culture of milk drinking and the per capita consumption is high. This increases demand and influences the informal price of milk)
- Constituency of the co-op membership (e.g. whether the farmers were small or large scale)

5.3. Varying Customers and Use Cases

Instead of a general need to cool and store evening milk we found a wide range of customers and use cases, varying greatly in their interest, willingness to buy and strength of their business case. These are listed below in approximate order of demand.

5.3.1 Kiosks/Boutiques

The greatest demand came from owner/operators of small rural shops that sold fresh milk and "ikiviguto" (cultured buttermilk) as core products. The shop owners had the means to purchase the fridges and saw how they would increase their business by increasing traffic (through the novelty of a fridge and attractiveness of cold drinks). They also could purchase more milk from farmers since they could preserve it and sell it in the afternoon, evening and the next day (if they did not sell out). Interestingly, all the shopkeepers queried stated that they would not charge more for cold milk or soda, but would profit from the increased volume.

Photo 3. Typical contents of fridge in small shop selling "cold drinks"

5.3.2 Medium Scale Farmers

It was quickly discovered that small scale farmers (e.g. less than 6 cows) lacked the funds, business orientation and milk volume to be a viable end customer of a milk cooler. What we did find is that medium sized farmers with more than 6 cows and small commercial growing operations (e.g. bananas, beans) were a reasonable fit. Farming is a business to them and they had funds at their disposal (although they are not typically as prosperous as shopkeepers). They view milk coolers as means to:

- Monetize evening milk (if they are in an area with no evening collection or are located too far away to take advantage of an evening collection)
- Monetize milk by opening a local Selling Point as well as utilizing the fridge and lights for domestic purposes (50L fridge comes with 4 LED lights and phone charging)
- Save transportation costs (by only having to transport once a day instead of twice) and prevent losses (e.g. if rains make roads impassable)

Larger scale dairy farmers also have interest and means regarding milk cooling, but they require significantly larger volumes of milk to cool (e.g. 100-500 liters), far beyond the capacity of our 165 liter milk cooler. In addition, they were often relatively wealthy city dwellers who had farms for status and hobby purposes (not the intended beneficiaries of the GreenTech grant). These well-off farmers were interested in the smaller fridges for their off-grid residences, mainly for domestic purposes.

Photo 4. Farmer Agnes MUKANGIRUWONSANGA uses her fridge to save transport costs and for domestic purposes

5.3.3 Dairy Co-ops

Formally organized cooperatives are also potential customers and channel partners.

The principal use case for co-ops is using the milk coolers at remote Milk Collection Points (MCPs). These points are typically too far away from the main Milk Collection Center (MCC) for an evening collection or the co-op may not have an evening collection. Either way, the cooler can be used to aggregate small amounts of evening milk for morning collection. In the one instance of this application, we found the farmers put over a hundred liters of milk in rectangular plastic containers. This far exceeds the capacity of the fridge to cool the milk quickly and prevent the growth of bacteria. In any case, we found that even when a priority for a co-op, lack of funds prevented implementation. Figure 1 below shows a model cold chain proposed to CEPTL Co-op in Northern Province; a 5 unit pilot has been on hold while the co-op awaits funds.

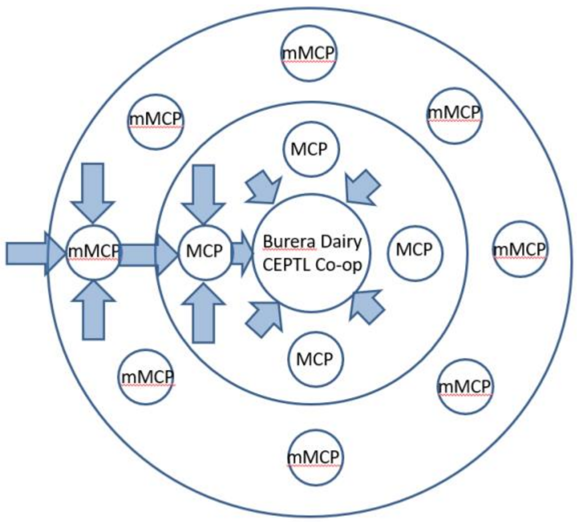

Figure 1. Proposed Network of Milk Coolers for microMCPs and MCPs in Complete Cold Chain

Another use case associated with co-ops is in their retailing initiatives. Co-ops have learned they can make more money selling wholesale locally (250 RWF as opposed to the 220 RWF government minimum paid by processors). They also learned they can make even more money, adding value to and retailing their own products through selling points such as "milk zones". Some of the larger, more successful co-ops like IAKIB are opening shops in off-grid locations which would require solar powered fridges. However, every instance we encountered of such initiatives was in the conceptual or planning stages or had no imminent off-grid plans.

Photo 5. IAKIB milk zone in Gicumbi District

5.3.4 Transporters

Transporters of raw milk or “abucunda” were also targeted as potential buyers. They could set up their own MCP at a remote location, collecting evening milk from local farmers and then selling to the co-op in the morning. They could then purchase products such as yogurt and ikiviguto from the co-op and retail it at their remote location. In both cases, this would augment their transportation business. Our finding was that, while transporters were often entrepreneurial-minded, as relatively low income businesses typically utilizing bicycles, they could not afford the cost of a milk cooler.

Photo 6. Most transporters utilize bicycles

5.4. Price Per Liter of Milk

The greatest factor restraining demand for solar powered milk coolers in the Rwandan market is the low price per liter of milk, set by the government's MiniAgri and paid by processors. At 220 RWF or $.22 USD per liter, a relatively high volume of milk is needed to cover the cost of the monthly payment and the 100,000 RWF ($100 USD) deposit is beyond the reach of most. Compare Rwanda with Tanzania or Kenya, where farmers get up to 50% more at the "farmgate" for their milk. The entire dairy sector in Rwanda is constrained because there is relatively little money to be made producing milk. Consequently, the sector relies on major subsidies like those from the Rwandan Dairy Development Project (RDDP) for all capital improvements. A fundamental question to answer in assessing whether there is a sustainable, commercial market for small scale milk coolers is "How much money can a farmer make selling a liter of milk?" Once known, the economics are straightforward regarding how much extra milk they have to sell in order to pay for the fridge. In Rwanda, dairy farmers and co-ops are relatively poor because, to a significant extent, the farmgate price of milk is relatively low. The low price of milk paid by formal processors is driving the sale of milk to the informal market (where 250 RWF is the typical wholesale price per liter) and motivating co-ops to do their own processing and selling both wholesale and retail to the local market (where a liter of ikiviguto often retails for 400 RWF).

5.5. Logistics

We quickly learned that centrally warehousing fridges in Kigali and transporting them one at a time to customers throughout the country was costly and inefficient. The solution implemented was to transport fridges in bulk to regional, satellite warehouses where inexpensive, local transport (like a motorized cargo trike) could be hired to move the fridge to the customer site. Also, we discovered that both the 50 liter and 100 liter fridges could be transported using a custom fabricated rack on a motorcycle. Rather than purchasing a motorcycle, CET elected to hire a motorcycle and driver on a long term contract basis.

Photo 7. Trial loading and transporting a complete fridge system by motorcycle

5.6. Last Mile Distribution Model

What we also quickly learned was that a Pay-As-You-Go (PAYG) business model using Last Mile Distributors (LMD) is the only viable way to sell fridges to rural communities. Following are some the principal reasons why:

- LMDs already have a presence in communities by virtue of selling solar home systems
- LMDs have sales and marketing agents as well as technicians and customer support personnel already in place to sell, install and service fridges
- LMDs may already have regional shops where they can store inventory
- LMDs are financing entities and have expertise at assessing credit risk and underwriting
- Fridges can be fairly easily integrated with a LMD's SHSs and PAYG back-end software
- LMDs' PAYG software is essential to administer mobile money payments and issue "tokens" to keep the fridge operating as well as provide a Customer Relationship Management (CRM) platform

While the above may be obvious to many, CET was a project-based renewable energy company; it learned the hard way that it needed to create a LMD operation within the company. This effort was largely driven by the licensing and implementation of the PaygOps software-as-a-service from Solaris.

5.7. Pricing and Financing

We did not set the pricing of milk coolers using a "cost-plus" model. The "commercial" price would then be well above what the market could bear, particularly the target beneficiaries in the Dairy Sector. Based on anecdotal evidence from the field, we settled on the highest pricing we thought the market could bear (see table below). The fridges thus were partially subsidized. Initially, these prices came with "one-year-same-as-cash" financing, which we soon found to be insufficient. We then extended the terms to 18 months, which the market deemed acceptable. However, the financing cost was not reflected in the price; it was in effect fully subsidized. ***Our general conclusion is that solar powered refrigeration for milk cooling is not a sustainable business in Rwanda. And that productive use solar refrigeration is affordable only to the most prosperous, rural shops. The latter being a low volume niche market (albeit the most common use case across developing countries based on SunDanzer's experience).***

Note: The table below contains complete system pricing including: fridge, SHS (controller and battery), accessories, installation and a two-year warranty. The Appendix contains a sample sales brochure.

Table 1. Solar Powered Milk Cooler System Pricing

Price (USD)	Size of Fridge (Liters)	Financing (Months)	Accessories
$1,200	165	18	None
$1,000	100	18	4 LED lights, USB charging
$800	50	18	4 LED lights, USB charging

5.8. Productive vs. Domestic Use

In our view there are three broad use cases for solar powered refrigeration in Africa: (1) Domestic (2) Medical (3) Productive Use. The Medical market is for storing vaccines and medicines and is dominated by World Health Organization PQS certified direct drive (batteryless) fridges and large tenders administered by UNICEF. Some SHS manufacturers are attempting to enter this market (e.g. private clinics) with lower cost non-certified systems, but with what appears to be marginal results. Other SHS manufacturers have introduced front-opening fridges for domestic use. It is our strong opinion that households still cannot afford a fridge at market prices and heavily prioritize TVs. Productive Use, in our opinion, is the only viable application for solar refrigeration; business people have the financial resource to buy a fridge and the business acumen to know how they can make money with one. ***As evidenced in Rwanda in this pilot, in Uganda in KKopa's pilot, and in developing countries across the world (again based on SunDanzer's experience), the "sweet spot" for solar refrigeration has been and remains small rural shops that see opportunity, primarily for selling "cold drinks".***

5.9. Demand in Grid-Connected Areas

Counterintuitively, demand was encountered in areas where grid electricity was available, effectively expanding the market for solar powered DC refrigeration. The demand is driven by three factors:

1. **Availability of Financing**. Obtaining credit from a Last Mile Distributor seems to be both easier and more readily available than a loan from a bank, micro-lender or Savings And Credit Cooperative organization (SACCO).
2. **High Cost of Electricity.** The electrical rates in Rwanda are relatively high ($.257USDkWh) and is a major "pain point" of storeowners and co-ops, which are seeking to lower their energy costs.
3. **Intermittent Grid.** While the grid in Rwanda is relatively stable, in the more remote areas, it is more likely to go down and take longer to come back up. In other countries, like Nigeria and Zimbabwe, where the grid is characteristically more intermittent, this factor would constitute a greater driver of demand.

5.10. Demand for Lighting and USB Phone Charging (Programmable Dual Outputs)

The 165 liter fridges were sold with only USB charging capability. However, there was interest from storekeepers and farmers to also have lights, even if they already had a SHS. Logically, this would also be a requirement for domestic use cases. Anticipating this necessity, SunDanzer and Zimpertec collaborated to develop a Dual Programmable Output capability in the SHS. This enabled one output to be dedicated to the fridge and have priority in respect to battery capacity. (It also enables the fridge to be shut off at night if equipped with ice packs/phase change material.) The second output powering the lights and USB ports can be programmed to automatically shut off to preserve power for the fridge at a predetermined level of charge. The SHS controlling the 50 liter fridges came with Dual Programmable Outputs and in one case, a storekeeper opted for this smaller fridge because it came with lights as well as USB charging. In general, lights are an important feature in a solar fridge system, leveraging the investment in panels, battery and controller.

5.11. Significant Support Requirements, Need for Real-Time Monitoring

CET experienced significant support demands in deploying the first solar powered fridges. LMDs need to be prepared for a wide range of new technical and non-technical issues. Some of the issues CET encountered were:

- Store customers playing with the controller keypad and disabling it (solution: mount the controller higher where it could not be reached)
- Faulty firmware in the SHS (solution: manually upload new firmware to each controller)

- Users claiming the fridge was not working (the thermostat was put in the OFF position)
- Users claiming the fridge was not working because the compressor could not be heard (not aware the compressor cycles in accordance to thermostat settings)

To minimize support requirements and increase customer satisfaction, some needs became clear:

- Pre-installation testing and preparation
- Installation guidelines
- User training requirements
- Phone support and troubleshooting

Perhaps the most difficult issue concerned technical troubleshooting. This involved coordinating a phone call with owner at the fridge, which was not always easy. Also, having a non-technical person help diagnose the problem was an issue. This sometimes resulted in dispatching a technician because the problem could not be isolated and/or resolved. For this reason, having the ability to remotely monitor the fridge and controller using Internet of Things (IOT) technology and the mobile network is seen as highly desirable if not essential.

SunDanzer was approached by the Collaborative Labeling and Appliance Standards Program (CLASP) to participate in a project collecting data on solar powered fridge usage. As a result, working with CET, CLASP retrofitted 25 fridges with remote IOT monitoring, measuring energy consumption, inside and outside temperatures, fridge openings, voltage as well as conducted user interviews. This will provide a wealth of information and provide CET with a valuable means to obtain technical performance data to help troubleshoot problems quickly and accurately.

6. Breakthrough Concept: Community Ecosystem Approach

The most significant insight was realizing that fridge sales were driven geographically and not only by use case. That is, not only did other store owners see the fridges in neighboring stores and desire to purchase one, but the entire community saw possibilities. CET witnessed an organic "clustering" that transpired. For example, in Kageyo Sector after a couple of sales to shops:

- A purchasing fishing co-op saw the fridge as a means to reduce post-harvest losses and gain some leverage with fish traders
- A local co-op expressed interest in 500 liter solar powered bulk milk coolers for milk collection and the MCC for the dry season when the low volume collected did not justify running their diesel generator and 2500 liter bulk milk cooler
- Prosperous local farmers (more than 25 cows) purchased 50 liter milk coolers for both evening milk and domestic purposes
- An entrepreneur purchased a milk cooler as a central feature of a shop/restaurant he started
- A veterinarian expressed interest in a 50 liter fridge for storing animal vaccines and medicines on-site (instead of a grid-powered fridge kilometers away)

This phenomenon is, of course, conducive to a sustainable business in that it concentrates sales, installation and support activities to a specific region... increasing efficiency, maximizing revenue potential and reducing the cost of sales. This "community eco-system" approach is, in our opinion, the optimal way to go-to-market. Rather than "rolling out" refrigeration across an organization and across a country as a new offering, it makes more sense, in our opinion to pilot the offering in a carefully selected, promising region. The experience can then be used to make a "go or no go" decision whether to roll out and tune operations for further expansion (if the pilot is deemed

successful). While the previous revelations can be depicted as common sense, we came about this conclusion by observing the natural unfolding of our efforts and visits to the field.

7. Pivoting into Other Models and Use Cases

When it became obvious that the Dairy Sector of Rwanda was not capable of supporting a sustainable business selling and supporting small scale refrigeration, three potential business directions became clear.

7.1. Broadening the "offer" to include a full suite of solar powered cooling solutions for the dairy cold chain

After visiting more than a dozen co-ops and MCCs it became apparent that their expressed "pain point" was not improving the quality or quantity of milk collected and implementing a cold chain. It was the high cost of cooling milk at the MCC. While the Rwandan government (Rwanda Energy Group) has done a remarkable job in electrifying the country with grid electricity, the cost of that electricity is high. At $.257 USD/Kwh, many co-ops cannot afford the cost of running their power-hungry bulk milk coolers. Across the board, co-op leaders were interested in solar power to reduce their energy costs at the MCC level, often inquiring if their existing equipment could be powered by solar. In addition, one co-op visited had an existing solar array, but needed support to upgrade it to be grid-interactive as opposed to having to switch manually from solar to grid (which underutilized the solar electric system and increased energy costs. It became clear there was a need for a renewable energy company to provide a full suite of solutions tailored to the dairy industry. For example, solar powered cold chain solutions at the farm, MCP and MCC levels. However, it was not clear whether this is a viable business as co-ops were often running at a loss and entirely dependent on subsidies for capital expenditures for upgrades.

7.2. Diversifying into artisanal fisheries

The GreenTech grant calls for providing productive use solutions to artisanal fishers. There are many lakes in Rwanda and they support a robust artisanal fishery and many formal co-ops. As mentioned, there was a natural synergy between dairy farming and fishing on a local level. Hence, the scope of the work in Rwanda was expanded to include the Fisheries Sector. Initial results indicated a higher level of perceived need and ability to pay.

7.3. Diversifying into Youth business opportunities

CET, knowing the target number of 300 systems and experiencing the limitations of the Dairy Sector, sought out additional opportunities. With the help of a business development consultant, they looked at the Youth Sector and developed the concept of offering entrepreneurial "franchises" to Youth centered around a 100 liter solar powered fridge integrated onto a pedal tricycle. The cart would serve as a "selling point" for local dairy products and could be moved from location to location to optimize sales. Since youth unemployment is high, it is an area that is receiving attention and funding from both government and NGOs. This would create an opportunity for Youth to not only earn income, but also acquire a valuable asset and build a business that has value and could be sold. The potential pivot into this arena has been well received by IFAD. This initiative is currently in the proposal development phase.

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