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SunDanzer
DC-Powered Refrigeration

Lessons Learned: Preparing for Solar Refrigeration Pilots in the Artisanal Fisheries Sectors of Rwanda, Tanzania and Mozambique

Document Date: September 23, 2021
Document Version: 1.1

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 partners in Rwanda (Clean Energy Technologies), Tanzania (Simusolar) and Mozambique (SolarWorks!) have been preparing to pilot solar powered fridges and freezers in 2022 in the Artisanal Fisheries sector. The goal is to specify and commercialize a solar cooling product that would increase income and improve living standards (i.e., successfully be used for Productive Use). Throughout 2021, informal and formal research was conducted to lay the groundwork for approximately 110 deployments to distribute across all three countries. The key findings of this research are summarized below:

- Artisanal Fisheries is a more promising commercial market for solar powered cooling than Dairy.
- Like the Dairy Sector, affordability and financing are the fundamental starting points; the price that the Artisanal Fisheries Sector can bear is significantly below what an unsubsidized price might be.
- The prime beneficiaries of the sector, fishers and fish traders, are generally adversarial, with fish traders often being able to dictate the quantity they purchase and the price. Conceptually, entrepreneurs could also provide "cooling-as-a-service" to both fishers and fish traders.
- Fish traders with their greater income and business acumen represent the prime target market, but their empowerment would likely further disadvantage fishers.
- Both fishers and fish traders stand to reap similar benefits which include preventing losses, being able to sell more fish at a higher price, using the fridge or freezer for other business (e.g., making and selling ice) or domestic purposes.
- Artisanal fishers and fish traders participate in the informal market and value chain.
- Solar powered cooling is generally a substitute for ice. Hence, the price and availability of ice largely determines the market for fridges and freezers.
- Remote offshore islands represent the best market because the cost of ice is higher and its availability lower than mainland fishing communities.
- Logistically and from a safety perspective, selling fridges/freezers to offshore islands poses challenges.
- Fishing communities provide other potential customers and use cases and customers beyond fishers and fish traders, particularly small shops and bars/restaurants.
- Freezers were greatly preferred in Tanzania and Mozambique while in Rwanda co-ops appeared content with fridges.
- Post-harvest losses could be mitigated by selling the fish for drying, salting or smoking.
- The Tanzanian social enterprise Devergy is a case study in attempting to build a business selling solar powered fridges to rural communities.

In conclusion, Artisanal Fisheries, while a more promising market than Dairy, by itself and without subsidy is not a sustainable market for solar powered cooling. However, it could prove more viable if the fisher and fish trader customer base in fishing communities can be leveraged to reach other buyers and use cases such as small shops and offer other products such as fishing lights or Solar Home Systems.

Table of Contents

Table of Photos and Figures

1. BACKGROUND

SunDanzer Refrigeration is the recipient of the multi-year, 2.2M USD IFAD grant Green Technologies to Facilitate Development of Value Chains for Perishable Crops and Animal Products (GreenTech). The GreenTech grant focuses on solar powered cooling solutions for dairy farmers and artisanal fishers in East and Central Africa. The informal artisanal fisheries sector lies on the fringe of or outside the established, formal value chain of the commercial fish industry. To understand how benefit can be brought to this sector, pilots consisting of 20-50 units of small scale, solar powered, PAYG enabled refrigerators or freezers (160 liters in volume) were initiated in Rwanda, Tanzania and Mozambique.

The GreenTech project is, to some extent, a sequel to the *USAID funded Photovoltaics for Sustainable Milk for Africa through Refrigeration Technology (PV-SMART)* project conducted in Kenya from 2015-2018. While technically successful, this project was a market failure, primarily due to the high cost of the system. A significant part 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 pole mount (both equipment and installation) for the PV. About 100 of the targeted 155 systems were deployed. Also, effective financing was not in place. Very few units were bought at full price.

Photo 1. Installing pole mount solar arrays for PV SMART project in Kenya

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. 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.

In May of 2019, Winrock International published a study entitled "Mozambique Market Needs, KAP and Technology Assessment Report" in support of GreenTech's goal to specify and commercialize a solar cooling product for artisanal fisheries. Its cursory research provided useful insights into the market and general information. However, this study did not target the geographical regions where SunDanzer in-country partner SolarWorks! had a presence (the Southern coast) and did not have a commercial focus aimed at laying the groundwork for a pilot and a product offering. Consequently, SunDanzer and SolarWorks! collaborated in defining and focusing additional research conducted by Gaia EES Consulting (Maputo) entitled Cold Chain Solutions for Fishing Communities. This research, along with similar research in Tanzania by Nexus Africa (Dar es Salaam) entitled Tanzania Market Needs, KAP and Technology Assessment Report, informs most of the Lessons Learned documented here.

2. Focus and Scope

What is unique about the GreenTech project, distinguishing it from *MKOPA's June 2019 landmark solar refrigeration research in Kenya*, is threefold:

1. GreenTech's objective is to identify Productive Use cases where market-based solar cooling solutions can enable beneficiaries to increase their income and contribute to a virtuous, upward cycle. 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 or freezers.
2. GreenTech targets poor, artisanal fishers and fish traders as one 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 Fisheries Sector and fish preservation. While MKOPA took a horizontal approach to the market, GreenTech takes a vertical one.
3. The intended pilot deployment of 100+ systems in Rwanda, Tanzania and Mozambique surpasses the estimated <50 units deployed in MKOPA's series of three small pilots.

This document captures the initial Lessons Learned from the early stages of the project before pilot implementation; additional post-pilot Lessons Learned will be published at the conclusion of the project.

3. Primary Research

Again, the following are the Lessons Learned from preliminary field research conducted prior to pilot deployment. The research, conducted mainly from April to November of 2021 consisted of:

- Informal field visits to fishing coops and fishing unions in Rwanda
- Informal field visits to fishing villages on islands in Lake Victoria near Mwanza, Tanzania

- Methodical, formal survey research in the Lake Victoria region of Mwanza, Tanzania conducted by Nexus Africa, Dar es Salaam (entitled Tanzania Market Needs, KAP and Technology Assessment Report)
  - 51 interviewees from 14 different off-shore islands
- Methodical, formal survey research on the south coast of Mozambique (Gaza and Imhambane Provinces) by Gaia EES Consulting, Maputo (entitled Cold Chain Solutions for Fishing Communities)
  - 73 interviewees, 35 from 2 offshore islands

These Lessons Learned are general findings across all regions, unless referenced to be region-specific.

4. Lessons Learned

4.1. Market Comparison to the Dairy Sector

In our opinion, the Fisheries Sector is overall a more attractive and viable market for solar powered refrigeration compared with the Dairy Sector. As a food product, a kilo of fish has a much higher monetary value than a liter of milk. In other words, there is much more money to be made in fish. Consequently, the Sector has a greater ability to pay and a greater financial motivation to avoid spoilage.

Like the Dairy Sector, there are formal and informal value chains with the informal value chains and local markets typically providing the best opportunities to get the highest price for fish.

Also, like the Dairy Sector, affordable pricing and financing are the starting point of any cooling solution. From the research, we saw again that cash sales would be the rare exception and there was a point where the cooling solution would be simply too expensive to be considered. This point varies from geography to geography but is significantly below what an unsubsidized market price might be. An initial estimate based on findings is that a 160 Liter fridge or freezer costing $1,600-$1,800 USD financed over 24 months would gain market traction; this is estimated to be about 30 to 40% below the unsubsidized material and operational cost of a Last Mile Distributor (LMD). Pilot deployment will give us actual data as to market pricing and costs.

4.2. Fishers vs. Fish Traders

One of the target beneficiaries of GreenTech in the Fisheries Sector are artisanal fishermen (we did not encounter any women fishers). They are most in need of refrigeration as they typically did not cool their catch. Instead, they kept their catch in the boat, sometimes for many hours, and sold it to fish traders on shore later in the day. In terms of food safety, this first link of a cold chain was more or less missing. Due to the short amount of time before the fish spoiled and became a post-harvest loss, they were often at the mercy of fish traders, who had the power to dictate how much they bought and at what price. Fishermen did have a perceived need for cooling and saw a multiplicity of benefits. The Word Cloud below cites perceived benefits by both fishermen and fish traders, which overlapped greatly.

Figure 1 Common reasons to buy a freezer and increase revenue according to survey respondents (from Gaia MZ research)

Unfortunately, fishermen for the most part were far too poor to afford a fridge or freezer, occupying the Bottom of the Pyramid. It was not uncommon for a fisherman to not own their own boat (renting a boat in exchange for a part of their catch) and be living largely day-to-day. On Benguerra Island in Mozambique, one fisherman wanted to organize other fishers in his village in order to buy several fridges where they could preserve their catch if a trader did not want to buy it all or offer a good price. In effect, he wanted to create an informal co-operative. Other fishermen saw an opportunity to become fish traders as well as also make and sell ice blocks and/or cold drinks.

In both areas researched in Mozambique and Tanzania, fishermen were not organized into co-ops while in Rwanda they were. However, the Rwandese co-ops did not have refrigeration, even when grid electricity was available. In one case, Rwandese fish traders provided ice to co-ops to preserve the catch. In exchange, they dictated the price and the quantity purchased. The Muhazi Fishery Union (collection of co-ops) in Rwanda wanted to purchase up to 10 fridges for its member co-ops to shift the balance of power. The traders would not need to provide ice and the fishermen would get a higher price for their fish. The Union had a line of credit with a bank and wanted to use it to purchase the fridges at a discount.

It is speculated that easy financing helps drive the sale of fridges; many co-ops do not appear to have access to favorable credit. This would explain why co-ops that had access to electricity and lower cost AC fridges have did not possess them. Also in Rwanda, the KPECO co-op in the Mwiri Sector of the Eastern Province, recently purchased a second fridge. They are able to preserve their tilapia right at the lakeshore and aggregate the fish until sold or transported to town for sale. They estimated that they saved 300,000 RWF ($300 USD) in the first four months of owning their first fridge. COPEDEP-KORA co-op on Bugarura Island on Lake Kivu wanted to purchase a fridge to serve as a selling point in the town of Gisenyi, indicative of the trend of co-ops vertically integrating to obtain the highest price for their product.

4.3. Entrepreneurial Cooling-as-Service

Given the inability of fishers to be able to buy fridges or freezers (unless organized into co-ops), it is logical that an opportunity exists for entrepreneurs to buy fridges or freezers and operate a Cooling-as-a-Service business where fishermen can store their catch until bought. (Smaller fish traders would also have need of such a service). The ability to obtain a higher price, preserve unsold fish and prevent post-harvest loss would create demand for such a service. In a village near the shore of Lake Victoria, we found such a

business that was on-grid. In their own investigation, SolarWorks! in Mozambique saw a similar opportunity and spoke to small rural businessmen that expressed interest in exploiting it. From an economic perspective, the service would have to be less expensive than buying ice (provided that ice was available for purchase). Evidence of this use case is very anecdotal and was not investigated in the research.

4.4. Fish Traders

Next on the value chain and income Pyramid are fish traders. Field visits and research revealed a wide range of profiles from the very small trader (most common) with no cooling capability or utilizing ice and handling less than 100 kilos of fish, progressing to large traders with several fridges or freezers handling hundreds of kilos of fish. We also discovered that women comprised a significant percentage of small fish traders.

Small fish traders stand to gain as much as fishermen in terms of the benefit from solar cooling. They take on significant risk in keeping fish fresh and delivering it to market. The value chain they participate in is informal and there is no guarantee they will be able to sell all their fish before it goes bad. If they utilize ice, they incur a monetary and time cost in procuring it.

Photo 2 Fish trader or reseller in Vilanculos, MZ selling fish on a street corner, hopefully before it goes bad

Findings suggest they represent the "sweet spot" in the market. Unlike fishermen, they are businesspeople and can readily ascertain the value, determine payback and more readily take risk. Moreover, they have a greater ability to buy by virtue of their higher income level. *Ironically, empowering small fish traders with fridges or freezers could further shift the balance of power away from fishermen and disadvantage them. It appears to be a situation where capitalizing on the best market opportunity*

may cause harm further down the value chain. On the other hand, it could also enable them to buy more fish from fishermen.

The following general comparisons are quoted from the Gaia study:

- The traders had a more accelerated business mindset compared to the fishermen.
- The traders had better economic and living conditions compared to the fishermen.
- The fishermen are currently at the mercy of the trader with regards to product pricing due to a lack of efficient product conservation.
- The fishermen expressed a sense of uncertainty regarding how much fish/seafood they can catch and sell in a day because sometimes they can go out to sea and catch many fish while on other days, they don't catch anything. They expressed that the freezer would really reduce that uncertainty and allow them to manage their sales better. They also expressed that the freezer would help them immensely during closed season, when only line fishing is permitted.
- The traders expressed a similar sense of uncertainty regarding the conservation of all of the fish/seafood they purchase from the fishermen because sometimes there is a high demand for their products and other times there is low demand.

The previous findings pertain to Tanzania and Mozambique; we have not had any exposure to small fish traders in Rwanda.

Photo 3 Woman fish trader on island of Gana in Lake Victoria (in the background is a non-functioning chest fridge filled with fish and ice)

4.5. Formal and Informal Value Chains

As in the Dairy Sector, both formal and informal value chains exist. Generally speaking, the formal value chain (serving urban and international markets) incorporates a cold chain, while a cold chain is largely

absent in the informal value chain (serving mainly local markets). Hence, the opportunity for solar refrigeration and freezing lies with the fishers and fish traders working within the informal value chain. For example, on Lake Victoria the Nile perch commercial fishery provided "free" ice to fishermen to both secure and ensure the quality of their catch. It was found that a largely informal value chain existed around tilapia and served nearby local markets. Here, small fish traders had to buy ice, typically from the boats that provided ice for "free" to the Nile perch fishermen.

4.6. Price and Availability of Ice

Many small fish traders used bought ice combined with some sort of cooler (e.g., broken chest freezer or insulated box). They often would accumulate fish for several days and then transport them to market. Essentially, solar powered refrigerators and/or freezers are a substitute for ice and the value proposition is largely economic and dependent on how much the trader pays for ice and how far they have to travel to get it. Other value proposition factors include: the volatility of the price of ice, whether there is a surplus that is available for sale (fishermen have priority over the supply) and how often it is completely unavailable (e.g., due to grid or mechanical failure stopping ice production).

4.7. Island vs. Mainland

The price of ice and its availability correlates to the location of the fishing village; the more remote the location, the higher the price of ice and chance it will be unavailable. Contributing factors are ice melts during transportation, transport cost is high because of the distance, and when ice is scarce, it is consumed by closer islands first without reaching the farthest islands. Research in both Tanzania and Mozambique showed that the most favorable economics for solar fridges and/or freezers was on off-shore islands. The further offshore the island (with less frequent boat service and longer travel times), the greater the interest due to the potential savings and benefits. Just like a Solar Home System can be paid for by not having to purchase kerosene, fridges or freezers can be paid for by not having to buy expensive ice. The implication for geographical segmentation is obvious: targeting islands and remote off-grid mainland villages.

Photo 4 Small fish trader's truck and cooler at a remote mainland fishing village near Vilanculos

4.8. Island Logistical Challenges

Supplying fridges or freezers to remote island communities introduces logistical issues in installation and service. The boats going to these islands are typically small and there are no docks for landing, making the loading and unloading of a large appliance somewhat challenging. We think four men are needed to be able to safely and efficiently move a 160L fridge on and off a boat. Once on an island, transport of the fridge to the installation site is another hurdle and one not to be taken for granted as three-wheeled cargo motorcycles are often absent from the smaller islands. Large appliances can get moved onto these remote islands, however special considerations and careful planning are required. If a technician is required to service a fridge, it is a long journey, in many cases requiring an overnight stay. Finally, travel on Lake Victoria and the Indian Ocean can be hazardous, especially on the "public" boats that often are filled beyond safe capacity.

Photo 5 Typical small boat heading for the rocky shore of remote and rocky Kunene Island on Lake Victoria; loading and unloading fridges would be somewhat precarious

4.9. Additional Use Cases in Fishing Communities

While the scope of the GreenTech pilots is limited to artisanal fishers and fish traders, the market for solar powered fridges and freezers in remote fishing communities is broader. It includes fridges for cold drinks that would be purchased by small shops, restaurants and bars. In these remote off-grid communities we found existing DC fridges, AC fridges run by generators and coolers filled with ice, as well as a voiced strong interest in purchasing. This finding is consistent with a similar finding in the Lessons Learned from the Dairy Sector of Rwanda as well as what is commonly known to be the core use case and viable market for solar refrigeration in developing countries across the world.

Photo 6 Shopkeeper displaying cold drinks in her solar powered fridge on Bwiru Island in Lake Victoria

4.10. Fridge vs. Freezer

In both Tanzania and Mozambique there was a clear preference for freezers, by both fishermen and traders, while in Rwanda co-ops seemed content with fridges. Freezers have the advantage of being able to make ice, which can be taken on boats or sold, as well as freeze fish. However, many users of freezers and potential users would not freeze fish (many buyers want fresh and not frozen fish) and would turn off the freezer before the fish started freezing. They generally like the added cooling capability to cool a large volume of fish more quickly.

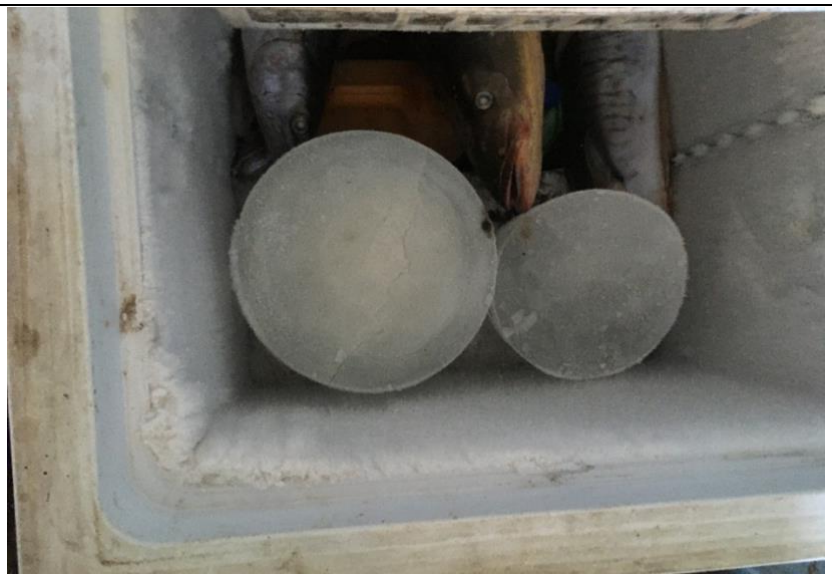

Photo 7 Fish and ice blocks in AC freezer run by the diesel minigrid on Barazuto Island

4.11. Fresh vs. Dried, Salted or Smoked Fish

Fish that is not sold fresh does not necessarily become a post-harvest loss for fishermen. Instead, it can be sold for significantly less (40-60%) to individuals who will dry, salt or smoke it and then sell it. The implication is that solar powered cooling would enable a greater percentage of fish to be sold fresh, providing greater income for both fishermen and trader. However, there would likely be an adverse impact on the stakeholders in the preserved fish value chain.

4.12. The Trailblazing Tale of Devergy

We know of only one case where a company made a concerted effort to build an entire business providing Productive Use solar refrigeration to rural communities: Devergy Ltd, a former Tanzanian social enterprise. They went out of business because their flow of grant funds stopped, supporting our assertion that a standalone, sustainable business is presently not possible. Here is their story in short:

Devergy started operations in 2012 as a provider of distributed DC micro-grids. In 2018, they concluded that the micro-grid business was not sustainable and pivoted their business into providing solar powered fridges for Productive Use. We safely assume they did so in pursuit of an existing market need that they determined could support a business. They sold, financed and deployed approximately 60 freezers in Southwest Tanzania, but could not scale to the point of the PAYG cash flow sustaining operations.

They initially piloted DC freezers from Phocos (a German solar power electronics company) which could run for 12 hours and satisfied the needs of customers. However, they found DC fridges to be expensive in low volume and needed to lower the cost of the system. They chose then to provide Boss 200L AC freezers running off an inverter and lead acid batteries (that they had in inventory from the DC micro grid systems). They could purchase the Boss freezers locally when they needed them for about $350 USD. The total system price to the customer was about $2,345 USD financed for two years or $1,825 cash. All the sales, to fish traders and restaurant owners, were financed. However, the AC system only ran for 8 hours, which was not enough to keep goods frozen and resulted in dissatisfaction. Of course, additional batteries and solar panels could be added, but the market would not bear the cost.

One interesting use case was a fish trader who would put the frozen fish on buses to nearby towns. The fish would thaw and stay preserved by the time resellers (we presume) picked them up when the bus arrived.

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