SOARING

Solar Cooling

Fact Sheet

Introduction

Solar cooling systems are important renewable-energy-based technologies for reducing post-harvest losses and increasing the incomes of smallholder farmers. Solar cooling systems are primarily used by cooperatives or groups of farmers for horticultural and milk products. Cooling reduces food spoilage and increases shelf life, enabling users to reduce their overall losses, improve their product quality and have more time to secure market access.

This fact sheet gives an overview of releva nt solar cooling technologies for smallholder farmers. Using a case study example, this fact sheet also includes information for determining the profitability of an investment. The case study is about a solar-powered cold room supplied by the Nigerian company, ColdHubs.[1]

Key Facts of the Application Environment

In most countries in sub-Saharan Africa, one-third of the milk produced on small farms cannot be sold regularly due to a mismatch in production and collection schedules.[2] Cows produce milk in the morning and evening, but dairy cooperatives and processors generally collect milk only in the morning. Therefore, without cooling technology, the evening milk must be sold to hawkers, who are not a reliable market, or be traditionally processed, which requires a lot of time and effort. There are also added costs, such as transportation costs, which are incurred when transporting the milk. In the horticultural sector, many perishable products (e.g. tomatoes) have to be sold at "throw-away" prices—before they spoil and need to be thrown away.

Solar cooling systems may help solve some of these problems because they can be used in rural areas, which are often not yet electrified due to a low rural electrification rate (e.g. 28.7% in sub-Saharan Africa in 2020).[3] The market potential for cold rooms includes two customer segments: the markets/traders and farmer cooperatives/farmer groups. For instance, in Nigeria, there are approximately 5,000 farmer groups along the tomato value chain country-wide and around 500 markets, which are not grid-connected.[1]

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Application in a Nutshell

Technology	Solar cooling systems for smallholder farmers.
Application	Solar cooling systems for cooling milk (e.g. evening milk), which often does not reliably generate much income, or to cool solar cold rooms for storing perishable products (e.g. tomatoes).
Technology Overview	The storage systems of solar cooling technologies differ, using either batteries or thermal storage (e.g. ice storage). Solar milk cooling systems can store between 80 L (small-scale units) to 2,500 L (large-scale units). Solar cold rooms can store daily load volumes between 200 kg–1000 kg per day.
Economic and Financial feasibility	Costs range between USD 16,000 and USD 30,000 for cold rooms and between USD 3,200 and USD 25,000 for milk cooling systems. Solar cooling systems have high initial capital expenditures (CAPEX) and low operational costs (OPEX). Financial feasibility is closely linked to the system utilisation rate.
Case Study (Cold-Hubs in Nigeria)	A 5.5-kWp battery storage cold room at a marketplace in Nigeria reached a 94% utilisation rate and increased customer profits by 69%. The project IRR is 36%, and a loan, with which 70% of the total investment is financed (with an annual interest rate of 20%), can be paid back within three years.[1]
Benefits and Outcomes	Cooling for storage and transport reduces post-harvest losses and increases farmer income. Increasing shelf life enables farmers to reduce spoilage and have more opportunities to access markets.
Constraints and Risks	There is a risk of underutilisation, which can occur if the cooling demand has not been carefully assessed and a system has been oversized. Overutilisation is also a potential risk, leading to higher temperatures and reduced cooling of products.
Future Perspectives	Systems are in the nascent market development stage; i.e. public sector intervention is needed to unlock and facilitate private sector engagement. Interventions can include: project development funds; building the capacities of potential system suppliers; and awareness raising of potential investors, such as cooperatives, processors and exporters.

Technical Information

Solar cooling technologies mainly differ in how they store energy. There are two main types of storage systems used in solar PV generators:

- Battery storage systems, which recharge batteries during the day to power the solar cooling technologies at night.
- Thermal storage systems, which produce ice during the day to keep storage temperatures low overnight.

Solar cooling technologies used for milk preservation usually employ thermal storage systems, whereas solar cold rooms used for horticultural product preservation typically use battery storage systems. Recently, however, suppliers of cold rooms have begun to adopt thermal storage systems to reduce the investment and replacement costs of batteries.

Cold rooms can be customised, but are often the size of regular shipping containers (e.g. 20 feet or 40 feet). Partitions may be used within cold rooms to divide the space and accommodate products with different cooling requirements.

The daily storage capacity refers to the volume of new products that can be brought into the cold room throughout the day or at one time. This differs from the total storage capacity, which is limited by room size. The energy requirements of a cold room depend on: the size of the room; the desired temperature of the products; the volume of new products, as well as the frequency with which new products are loaded into the room.

Spacious cold rooms that handle large volumes of products at low temperatures are more expensive due to the increased need for solar panels and storage system capacity.

Small-scale cold rooms with a daily load of 200 kg–1,000 kg typically have a solar generator capacity of around 3 kWp–15 kWp and a battery capacity of 15 kWh– 45 kWh. The required battery capacity depends on the battery technology and its depth of discharge (DOD), which is the extent (in %) to which the battery can be discharged without affecting its lifetime.

Milk cooling systems vary in size depending on where along the value chain they are used. Smaller systems, like 80 L milk chillers, are used to collect milk at dairy cooperatives' small satellite sites. Larger systems, like 1,000 L or 2,500 L tanks, are used primarily at dairy cooperatives' main milk collection centres (MCC).

Economic and Financial Feasibility

For both solar cold rooms and solar milk cooling, there are high fixed costs and minimal variable costs. The financial viability of a system is thus closely linked to its utilisation. Therefore, it is important to carefully assess the demand for cooling and dimension the technology appropriately. The range of CAPEX for cold rooms and milk chilling systems is large: depending on the unit size, cold rooms may cost between USD 16,000 to USD 32,000 and milk chilling systems range from USD 3,200 to USD 25,000. For solar cold rooms, the standard business model is to charge users (e.g. farmers and traders) a cooling fee (per box and per day). For solar milk cooling systems, the cashflow of the investment is generated by collecting additional milk, e.g. the evening milk. In some cases, also a cooling service fee is charged.

Solar cold rooms have been installed in many countries, including Nigeria (ColdHubs), Senegal (Raach Solar), and Kenya (Ecofrost). Examples of solar milk cooling systems can be found in Kenya (Solar Cooling Engineering/ Phaseun) and in Rwanda.

In general, for both solar cold rooms and solar milk cooling, it is critical to size the system based on the results of a rigorous field survey that carefully assessed the local demand for cooling. Oversizing may lead to underutilisation, which greatly reduces the profitability of the investment.

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Case Study: ColdHubs Cold Room in Nigeria

This case study focuses on a cold room in a market in the Imo State area of Nigeria, where small traders sell fresh vegetables and fruits.[1] The market is not grid-connected and previously had no available cold storage. "ColdHubs, a cold room supplier based in Nigeria, installed a cold room in the market operates it for vendors, who store their products there."

The solar-powered cold room (3 m x 3 m x 2.2 m) supplied by ColdHubs has a standardised design; an installed solar PV capacity of 5.5 kWp and uses batteries for storage. The overall storage capacity is approximately 2 tons. The cold room is designed to cool down 200 kg of product once per day and operates at a utilisation rate of 94% over a single year. The CAPEX for the cold room was USD 27,000 and the batteries for it need to be replaced at least every six years. Operational costs are USD 835 per year, which includes the salary of the hub operator and the rental fee for the site.

Users of the cold room pay USD 0.23 (100 nairas) per crate of produce stored each day. Research has shown that a trader's profit using a cold room increases between 76 USD and 129 USD per week (32,600 nairas and 55,000 nairas), resulting in an overall increase in income of 69% for these users. Per month, around 44 traders use the cold storage and benefit from it.

Under these conditions, investment in the solar cold rooms is profitable, with a project IRR of 36% and an annual operating cashflow of USD 10,650. A loan of 70% of investment costs, at a 20 % per annum interest rate, can be repaid within three years. With a loan tenor of three years, the DSCR (Debt-Service-Coverage-Ratio)[4] is 1.18. The payback period based on the operational cashflow is nearly three years.

A sensitivity analysis conducted as part of this case study indicated that profitability is highly sensitive to the utilisation rate: a 70% rate (instead of the observed 94%) results in a project IRR of only 25% and the required loan tenor is at least five years.

Benefits and Outcomes

In sub-Saharan Africa, up to 40% of food loss occurs post-harvest. Cold storage reduces these losses by increasing the shelf life of products. For produce, such as tomatoes, the shelf life can be increased from two days to three weeks.[5]

Cold storage primarily improves users' incomes by increasing the volume of products they can sell, allowing them more time to find buyers and secure better prices. This increase in income is generally more than enough to offset the cooling fees, provided that the user successfully secures a buyer. For dairy farmers, cooling often reduces the need to traditionally process dairy products into butter or cheese or sell their products at unregulated hawker markets. Farmers earn more income, have fewer expenses (e.g. by avoiding transportation costs for selling the processed products in the town), and use less time and labour selling raw milk than they do selling processed dairy products. Cooling also often benefits women, who are frequently involved in horticultural and dairy production.

Constraints and Risks

Most risks are associated with solar cooling systems that are underutilised or overutilised. Underutilisation occurs if the cooling demand for the entire year has not been properly assessed and there are fewer perishable products for the system to cool than expected. In some cases, a solar cold room will always be underutilised due to the seasonality of local products, i.e. if the harvesting of some major perishable products happens, e.g. over the course of just one to two months. Therefore, there are no products to be stored for the rest of the year. In this case, the excess power should be used for other income-generating purposes, as much as possible, to optimise the utilisation rate.

Overutilisation occurs due to technical issues arising from system usage patterns that differ from the usage patterns used to design the system. For example, if the number of door openings or the daily load volume is significantly higher than expected, the required cooling temperature may not be reached, resulting in spoiled products and dissatisfied clients. User demand for solar cold rooms can be negatively affected if the products are not cooled effectively due to such technical issues. There are also constraints that need to be considered, including: a lack of awareness of the potential benefits of cooling and limited user demand due to a lack of market linkages. For example, if a user does not have buyer connections or their products cannot be transported from a cold hub site without spoiling, then the user has little incentive to continue using the cold storage.

The development of a single solar cooling project has high transaction costs, including the time and resources needed to arrive at a comprehensive understanding of socioeconomic capacities and the agricultural context. These high transaction costs are key barriers to the successful deployment of systems, even if they have the potential to be profitable.

Future Perspectives

- Generally, the solar cooling sector is still at a nascent stage. Therefore, it is essential that the public sector encourages private-sector engagement.
- A project development fund can alleviate the burden of high transaction costs for the development of projects from the shoulders of the system suppliers.
- Developing the capacities of potential system suppliers is crucial. System suppliers should be able to correctly size systems and develop feasible business models. One model is that the supplier invests in and provides cooling services. Alternatively, the supplier can apply a lease-to-own model or a supplier credit, allowing customers with limited ability-to-pay (such as rural cooperatives) to pay off the system over a longer period, out of the realised benefits (cooling fee revenues). However, in such payment modes, the supplier faces the risk of non-payment, and must therefore integrate support services into the business model, such as: advice on creating market linkages; system management support; and information campaigns for farmers/ potential users of the cooling system. In these ways, suppliers can better ensure that the system is well utilised and that the cooperative generates enough cooling-fee revenues to pay off the system costs.
- Awareness about the benefits and profitability of solar cooling systems has to be raised across various stakeholder groups including farmers' associations, rural cooperatives, and larger value chain actors (e.g. processors and exporters). These larger stakeholders have a strong interest in securing a regular supply of high-quality products. Therefore, they could be potential investors or partners in solar cooling systems near their clients. They could be encouraged to apply contract farming and/or to close off-taking contracts in advance, so that the risk of market linkage for the cooled products is mitigated.

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