

COOLING FROM THE SUN

Innovations for Effective Post-Harvest Cold Storage in Rural Areas

Expanding access to cold storage for rural farmers reduces food waste, supports food security, and increases farmers' income. Innovations that use solar energy and low-cost materials, such as the Farm SunFridge (FSF) model, increase access to refrigerated cold storage for rural farmers who lack reliable electricity. To make certain this innovation reaches rural farmers, farmer producer organizations (FPOs), and farming communities who can benefit from it, officials from government agencies must ensure that grants and loans for solar-powered cold storage using the FSF model are accessible through subsidies and funds that support agricultural development.

Access to Cold Storage Helps Maximize Current Agricultural Outputs

In India, approximately 60% of food loss and waste happens before it reaches the consumer.¹ Of this loss, nearly one-third is directly attributable to a lack of cold storage, which causes produce to spoil before getting to markets.² The financial impact is significant— according to NITI Aayog, post-harvest agricultural losses amount to as much as INR 92,561 crore annually.³ Reducing these post-

harvest losses for current agricultural outputs can increase economic security for farmers and contribute to India's development goals, in particular increasing food security and agricultural sustainability in the near term. These two goals lay the groundwork for the country to transition from relying on food imports to profiting from food exports in the long term.

While refrigerated cold storage extends the shelf life of perishable agricultural products, especially fruits and vegetables, the high costs of construction and a stable power supply are barriers for rural farmers. Combined with minimal options to finance expenses, these factors limit access to cold storage in rural areas.⁴ To overcome these challenges, researchers designed, developed, and tested the FSF, an innovative solar-powered refrigerated and evaporatively cooled (EC) storage facility that is affordable for smallholder farming communities (see Box 1). In tests, FSF storage more than tripled the shelf life of amaranth compared to evaporative cooling alone or no cooling at all.⁵ Farmers using the FSF test storage facilities also report increased shelf life for tomatoes, eggs, and gooseberry juice, giving them greater control over when and how often to bring produce and agricultural products to market (Table 1).

TABLE 1

Farmers Using FSF Test Facilities Report Extended Shelf Life for Perishable Fruits and Vegetables

Perishable Crop	Shelf Life in FSF	Shelf Life at Room Temperature
Eggs	60 days	7 days
Gooseberry juice	30 days	5 days
Tomato puree	20 days	2 days
Tomatoes	10 days	4 days
Coriander	8 days	3 days

When water evaporates, changing form from a liquid to a vapor, it draws heat from the surrounding environment.

Evaporative cooling uses this principle to cool the inside of a structure as water evaporates through the outer wall.

The Farm SunFridge Builds on Traditional Technology for Off-Grid Cold Storage

The majority of small-holder farms in India are in rural areas that may not be connected to a power utility. Where farms have access to electrical grid, the quality of electricity is poor and supply is intermittent. This makes the cold storage facilities powered by electricity impractical for smallholder farmers. For centuries, farmers and others have relied on EC principles. The FSF innovation adds solar-powered refrigeration to EC structures, allowing the facilities to reach cooler temperatures without relying on power from the electric grid—as much as 20 degrees Celsius cooler than EC storage and 35 degrees Celsius cooler than outdoor air temperatures.

In developing the FSF, researchers tested and selected the most effective, low-cost, and locally available materials.⁶ After the facilities are built, there are no annual operating costs aside from maintaining the structures and regularly cleaning the solar panels. The panels can last for 20 years or more, while some materials in the EC walls, such as the outer cloth covering, may need to be replaced after seven years. Battery-free operation reduces up-front costs by INR 2,00,000 and eliminates annual replacement costs of INR 50,000 compared to solar-powered structures that rely on batteries for continuous cooling.

The FSF design both reduces costs and maximizes the efficiency of solar power without the need for supplemental electricity (see Figure 1). FSF cold storage can be constructed on a small scale for approximately INR 5,00,000—one-third the cost of comparable structures that are commercially available in India. This comparatively low cost and off-grid design then allows farmers to store harvested products directly on their fields or in farm



BOX 1

How Does the Solar-Powered Farm SunFridge Work?

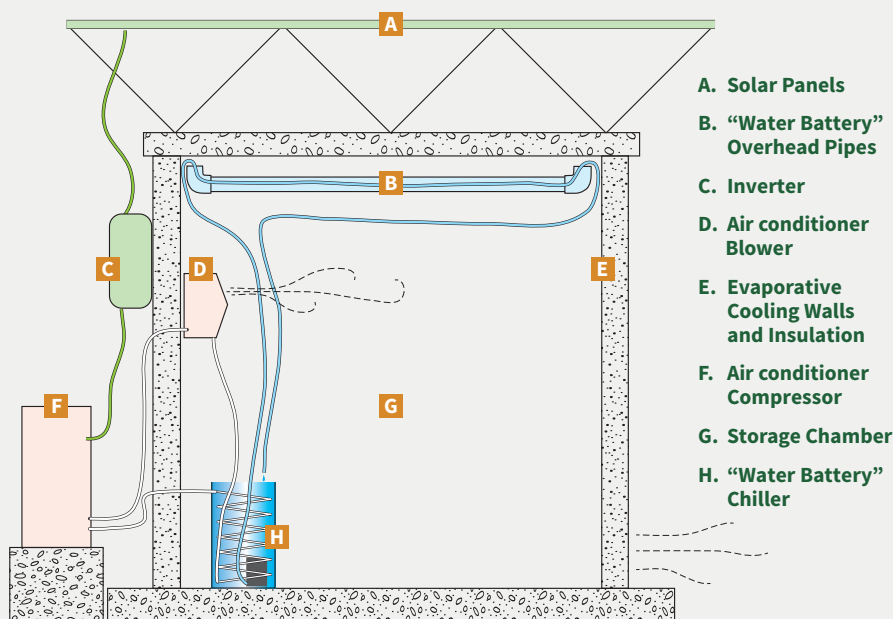
The Farm SunFridge (FSF) enhances a traditional evaporatively cooled (EC) structure with solar-powered refrigeration and innovative building materials. During daylight hours, a sensor moderates the demand for refrigeration in response to the amount of solar energy available. The solar power also cools a “water battery,” which chills water in overhead pipes to maintain cooler temperatures during nighttime hours when solar energy is not available.

Farmers can build the FSF in two stages with locally available materials. They can first construct the EC chamber, which offers some cooling from the outdoor temperature. In the second stage, they add a solar-powered refrigeration unit to increase cooling. In areas that are connected to the electric grid, the FSF can be programmed to draw first from solar power and then revert to electricity when solar power is unavailable. This design opens the possibility for the solar panels to feed power into the electric grid when the solar energy supply exceeds demand from the FSF.

FIGURE 1

The Farm SunFridge leverages solar-powered refrigeration to enhance traditional evaporative cooling.

The Farm SunFridge allows evaporation through the outer building walls, providing some natural cooling to the interior. Solar panels power a low-cost, commercially available split air conditioner unit, modified to cool both the air and the chiller for a “water battery,” further cooling the structure.



communities. Such storage eliminates time-consuming and costly transport to centralized cold storage warehouses while extending the country’s cold-chain infrastructure right to the point of production.

Research on the FSF test facility in Rajasthan demonstrates that the FSF effectively cools to between 5 degrees Celsius and 15 degrees Celsius in surrounding temperatures reaching 45 degrees Celsius. These results make the FSF a research-proven approach for effective cold storage. The FSF is not explicitly covered in the current Mission for Integrated Horticulture Development (MIDH) Operational Guidelines for post-harvest management and cold chain infrastructure, though the FSF specifications align with MIDH standards for cold storage assistance (Table 2).

Investing in Cold Storage Facilities Benefits All

Currently, the lack of on-farm cold storage facilities and limited transportation options to move perishable produce to regional facilities is a barrier for small-holder farmers. Without effective cold storage, farmers cannot control when they bring their products to market. The inherent risk of spoilage leaves them at the mercy of unstable markets and often reduces the price they receive for their products.

The comparatively low cost, local availability of materials, and short construction time for FSF storage facilities means that cold storage can be constructed rapidly and at a hyper-local scale—individual farmers can build them on their land and FPOs can build them centrally in rural communities. With access to reliable, onsite cold storage for post-harvest products, farmers can reduce waste and the associated economic loss from their harvests. In

TABLE 2

Farm SunFridge Specifications and Capacity

Size	3 x 3 x 3 meters (scalable)
Storage Capacity	2,000 kg produce
Construction Area	35 m ²
Refrigeration Capacity	18,000 BTU/hr
Internal Daytime Temperature	5° C – 8° C
Internal Nighttime Temperature	12° C – 14° C

addition, they gain greater control over when they bring their commodities to market. This control opens the potential for higher profits, increased purchasing power, and in turn, greater household affluence.

Local cold storage will keep produce fresh longer, allowing more of it to reach markets. This longer period of freshness will increase and stabilize the supply of food available, contributing to food security and more reliable prices for both consumers and producers (as illustrated in Box 2).

BOX 2

Experiences During the COVID-19 Pandemic Suggest Access to Solar-Powered Cold Storage May Help Farmers Withstand Economic Shocks

The three FSF pilot facilities, in Rajasthan, Haryana, and Delhi, launched in 2020 and 2021. As the COVID-19 pandemic unfolded, the FSFs proved a valuable resource for farmers to moderate their sales in markets that were fluctuating and unpredictable. One farmer was able to store 20,000 eggs from March 2020, when the markets collapsed due to the pandemic, until May 2020, when he was able to sell them for a profit. This experience suggests that, in addition to stabilizing food supplies and helping farmers to maximize their profits, access to cold storage facilities may help small-scale farmers to withstand economic shocks due to natural disasters or market instability.



Farm SunFridge in operation in Picholiya, Rajasthan.

Financing and Policy Changes Can Expand Access to FSF Cold Storage

The low-cost, innovative FSF design meets the requirements set forth in the MIDH Operational Guidelines for expanding cold chain infrastructure. Increasing FSF cold storage facilities can help extend the national cold chain to the point of production—right to farmers’ fields—while benefiting farmers, consumers, and communities.

MIDH in the Ministry of Agriculture and Farmers Welfare, the National Bank for Agriculture and Rural Development (NABARD), and the National Centre for Cold Chain Development may take steps to ensure farmers and FPOs can access the information, funding, and approvals needed to build FSF structures.

RECOMMENDATIONS

MIDH

MIDH may update the Operational Guidelines for Post-Harvest Management to include FSF technology. The updated guidelines need to:

- Define FSF facilities as solar, evaporative, low-energy cooling chambers.
- Specify FSF in the cost norms and pattern of assistance for cold storage subsidies.

NABARD

NABARD may prioritize and approve grants and micro-loans to FPOs through the newly launched Agriculture Infrastructure Fund for rural farmers to build FSF facilities.

NATIONAL CENTRE FOR COLD CHAIN DEVELOPMENT

The National Centre for Cold Chain Development can build support for solar-powered and battery-less cold storage facilities by including information about FSF innovations and government funding programs in outreach to FPOs and farmers in rural areas.

Meeting the national goals to reduce post-harvest losses of produce and agricultural commodities requires innovative solutions. The FSF is just that—a proven design for cold storage that can make an immediate difference in small-holder farmers’ ability to increase their profits and purchasing power, leading to greater economic stability and growth for their families and communities.



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