FARM FREEZE PROJECT

SOLAR-POWERED COLD STORAGE FOR SMALLHOLDER FARMERS

ENACCESS | ClimaVault AFRICA LTD

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PROJECT OVERVIEW

The Farm Freeze project demonstrates the deployment of an Open Source, solar-powered cooling hub designed to reduce post-harvest losses among smallholder farmers in rural Uganda. Implemented by ClimaVault Africa Ltd in collaboration with EnAccess, the project integrates renewable energy, IoT-based monitoring, and an innovative pay-as-you-store business model to address food spoilage, income instability, and limited access to reliable electricity.

Farm Freeze builds on the Open Solar Cooling Hub concept, combining modular cold storage hardware with Open Source software for monitoring temperature, humidity, and energy usage. The system is designed to be affordable, replicable, and adaptable to off-grid and weak-grid contexts.

500
smallholder farmers and local operatorsdirectly served

Up to 30%
reduction in post-harvest losses

30–40%
average income gains

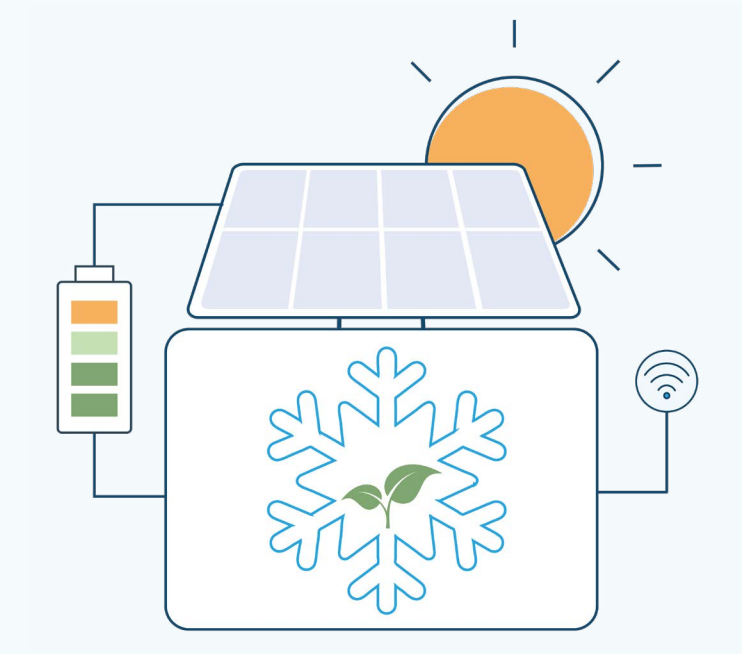
~70%
lower energy costs vs diesel/grid alternatives

THE CHALLENGE

Smallholder farmers in rural Uganda face persistent post-harvest losses driven primarily by the lack of affordable and reliable cold storage. Perishable produce such as fruits, vegetables, and dairy often deteriorates rapidly after harvest, forcing farmers to sell immediately at low prices or incur significant losses. This challenge affects farming communities across rural regions of Uganda, where smallholder producers form the backbone of local food systems and household incomes.

The problem is intensified by a hot tropical climate, limited access to reliable grid electricity, and weak cold-chain infrastructure connecting rural production areas to urban markets. Farmers also operate under tight financial constraints, with limited access to credit or capital investment, making it difficult to adopt conventional cold storage technologies. Poor market access and price volatility further reduce farmers' ability to recover value from their produce.

Existing cold storage solutions are largely unsuitable for these conditions. Grid-connected or diesel-powered cold rooms are expensive to install and operate, energy-intensive, and often unreliable in off-grid or weak-grid areas. Household-scale refrigeration does not meet the storage needs of smallholder producers, while centralized commercial cold storage facilities are rarely accessible to rural farmers. As a result, there remains a critical gap for affordable, scalable, and energy-efficient cold storage solutions tailored to smallholder farming contexts.



SOLUTION

FarmFreeze is an Open Source technology framework that enables deployment of solar-powered, IoT-enabled cooling hubs that provide reliable cold storage without dependence on grid electricity. The installation consists of a modular cold storage hub designed for shared use by smallholder farmers, powered entirely by a solar photovoltaic (PV) system sized for off-grid operation. The system maintains controlled temperature and humidity conditions suitable for preserving perishable produce such as fruits, vegetables, and dairy, supporting extended shelf life and improved produce quality.

The system was implemented by ClimaVault Africa Ltd in collaboration with EnAccess, with support from local technicians and operators. Local sourcing and fabrication were prioritized where possible to ensure contextual suitability, cost control, and ease of maintenance.

FarmFreeze builds on the Open Solar Cooling Hub concept. Open Source hardware designs, software, and documentation were used as a foundation and adapted to local conditions, including climatic factors, crop types, and the availability of components. This approach enabled iterative refinement of the system while maintaining full transparency and replicability. All hardware designs, software code, and financial model templates are publicly available as Open Source resources via the EnAccess repository: https://github.com/EnAccess/OpenSolarCoolingHub.

Additional technologies and integrations include IoT-based monitoring of temperature, humidity, and energy usage, supported by digital dashboards that allow operators to track system performance in

real time. An innovative pay-as-you-store business model was integrated, enabling farmers to access cold storage services without upfront capital investment. The system also explored the use of stored produce as collateral for short-term financing, improving farmers' liquidity and bargaining power while strengthening linkages between cold storage infrastructure and inclusive financial mechanisms.

IMPLEMENTATION AND DEPLOYMENT

The implementation phase aimed to demonstrate the technical feasibility, operational reliability, and user adoption of the FarmFreeze solar-powered IoT cooling hub in a real-world, off-grid agricultural setting. The focus was on validating system performance, documenting design and deployment processes, and assessing the practicality of the pay-as-you-store model for smallholder farmers.

Challenges and mitigation:

The project faced challenges such as variable solar availability, limited digital familiarity among users, and logistical constraints in sourcing components. These were addressed through conservative system sizing, simplified user interfaces, hands-on training, and prioritisation of locally available materials.

Community and stakeholder involvement:

Farmers, local operators, and technicians were actively engaged throughout the implementation process, from design to field testing. Their input helped refine system functionality, improve usability, and strengthen local ownership, contributing to the overall success and sustainability of the solution.

IMPACT AND RESULTS

Results from field deployment and monitoring of the Farm Freeze system in a rural agricultural setting in central Uganda indicate measurable improvements across post-harvest management, farmer livelihoods, and energy use. The pilot system directly served 500 smallholder farmers and local operators, with additional indirect beneficiaries including traders and aggregators accessing higher-quality produce.

Main results are:

Reduction in post-harvest losses:

Up to 30% reduction in spoilage for stored fruits and vegetables compared to traditional ambient storage

Increase in farmer income:

Average income gains of 30–40%, driven by reduced losses and improved price realisation through delayed sales.

Better income stability:

access to reliable cold storage enabled producers to delay sales, reduce distress selling, and negotiate better market prices, contributing to improved income stability.

Crop quality retention:

Shelf life for selected perishable crops extended by 3–7 days, depending on crop type and harvest conditions

Energy cost savings and decreased local emissions:

Approximately 70% lower energy costs compared to diesel-powered or grid-dependent cold storage alternatives.

Capacity building: farmers and operators expressed increased confidence in using shared infrastructure and digital tools, supported by hands-on training and simplified monitoring dashboards.

Broader social and economic impact

The deployment contributed to improved household food security by reducing losses and stabilising incomes, allowing farmers to better plan sales and consumption. Collective use of the cooling hub encouraged cooperation among farmers, strengthened trust in shared infrastructure, and supported more coordinated market engagement. The pay-as-you-store model aligned well with seasonal cash flows, improving affordability and inclusivity.

Adoption and replication interest

Following deployment, interest was expressed by neighbouring farmer groups, cooperatives, and development partners seeking similar cold storage solutions. The availability of Open Source technical documentation, software, and financial models has positioned Farm Freeze as a replicable solution suitable for expansion across East and Southern Africa, as well as adaptation for humanitarian and aggregation contexts.

Testimonials from farmers and operators

"Before the cooling hub, we had to sell our produce immediately, even when prices were low. With Farm Freeze, we can store and wait for better prices."
— Smallholder farmer, Central Uganda

"The system is easy to use, and the solar power means we don't worry about fuel or electricity costs."
— Local operator

"We have been integrating the Open Source IoT system into our water and irrigation solutions, and even at this early testing stage, the results are promising. The system's accessibility and flexibility make it easy to adapt to our needs, and it gives us confidence that we can scale and replicate it across different deployment sites as we refine the model."
— Rodgers Mwijukye, CEO, Drought Guard Africa

INNOVATION AND DIFFERENTIATION

FarmFreeze differs from existing cold storage solutions by operating fully on renewable energy, making it suitable for off-grid and weak-grid environments where conventional systems are not viable. It combines Open Source hardware and software, allowing stakeholders to access, adapt, and replicate the technology without starting from scratch, significantly reducing barriers to deployment. The integration of IoT monitoring enhances transparency and enables real-time performance tracking and optimisation, while the flexible pay-as-you-store financial model aligns with smallholder farmers' cash flows and improves affordability.

By embedding anOpen Source approach at its core, FarmFreeze not only delivers a technically robust and cost-effective solution but also creates a shared platform that enables wider adoption, collaboration, fast/targeted testing, and feedback loops, allowing faster scaling across different regions and use cases.

SCALABILITY AND REPLICATION POTENTIAL

The modular design and Open documentation make Farm Freeze highly scalable. The system can be adapted for different crops, storage capacities, and climatic conditions. By publishing designs and code openly, the project enables NGOs, cooperatives, and social enterprises to replicate or localize the solution across Sub-Saharan Africa and other regions facing similar challenges.

KEY TAKEAWAYS

Farm Freeze shows that combining renewable energy, Open Source technology, and inclusive business models can significantly improve post-harvest management for smallholder farmers. The project provides a practical blueprint for sustainable, climate-resilient cold storage infrastructure.

2. LESSONS LEARNT FROM THE FARM FREEZE PROJECT

The Farm Freeze project highlighted the importance of designing cold storage solutions that are not only technically efficient but also socially and economically aligned with smallholder farming realities. One key lesson was that affordability and flexibility matter more than technical sophistication alone. Farmers were more willing to adopt the system when payment was usage-based rather than requiring upfront investment.

From a technical perspective, simplicity and robustness proved critical. Systems deployed in rural environments must tolerate dust, heat, limited technical support, and intermittent connectivity. Over-engineering can increase failure points and maintenance costs. Clear documentation and modular design significantly reduced installation and troubleshooting challenges.

Another important lesson was the value of early and continuous user engagement. Training sessions and feedback loops helped adapt operating procedures to local practices, improving trust and system utilisation. Farmers responded positively when they understood how cold storage directly translated into better prices and reduced losses.

The project also demonstrated that Open Source approaches accelerate learning and collaboration. Publishing designs and code encouraged peer review and reuse while lowering barriers for future adopters. However, it requires additional effort to ensure documentation quality and clarity.

Finally, integrating technology with financial mechanisms, such as produce-as-collateral, showed strong potential but requires close coordination with local financial partners to manage risk and build confidence.

Overall, Farm Freeze confirms that scalable cold storage solutions must balance technology, business models, and community engagement to achieve lasting impact.