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EFFICIENCY FOR ACCESS RESEARCH AND DEVELOPMENT FUND: INNOVATOR SERIES

Empowering affordable off-grid cooling through smart solar fridge control

Access to cooling is often overlooked by those used to electricity and modern appliances across the world. Yet cooling solutions play a vital role, from preserving vaccines to enhancing food security and boosting incomes for micro-enterprises. Despite its importance, access to cooling in rural areas throughout the Global South, where power supply is unreliable and costs are high, remains a challenge.

Sun King, previously called Greenlight Planet, a world-leading off-grid solar company, initiated a pilot study to investigate and develop potential solutions to this challenge. Drawing on its experience with solar solutions for underserved consumers in Sub-Saharan Africa and South Asia, Sun King set about developing cooling solutions for off- and weak-grid communities. With support from the Efficiency for Access Research and Development Fund, Sun King embarked on a project to transform access to cooling.

DID YOU KNOW?

Over 1 billion people globally lack access to cooling, affecting food security, vaccine storage and health under extreme heat.

Sun King provides solar energy solutions for the 1.8 billion people lacking reliable electrical grid access. Established in 2008, it has served over 107 million users across Africa and Asia, becoming Africa's leading off-grid solar company. Its range includes solar lamps, solar home systems, and inverters, all aimed at surpassing fossil fuel alternatives. Through innovative Pay-As-You-Go (PAYG) technology, Sun King aims to overcome financial barriers to solar energy adoption.

Sun King

The Efficiency for Access Research and Development Fund supported Sun King in the development of a Smart Cooling System integrated with Pay-As-You-Go technology. The objective was to develop and pilot a high-quality, affordable cooling solution which could satisfy off- and weak-grid customers' needs. This was the first time Sun King worked with cooling technologies, and Efficiency for Access' guidance and support were key to delivering this project.

Martin Sun, Vice President, Research and Procurement, Sun King

An overview of the solution

Across Africa, affordable DC-powered fridges compatible with solar energy are available, yet their steep pricing limits access for low-income families and businesses. Sun King recognised this market gap, and initiated a project to adapt more affordable AC refrigerators across the continent for off-grid and low-income communities. The goal was to make these AC refrigerators technically and financially viable using solar power, reducing ownership costs and ensuring sustainable after-sales services, such as maintenance and repairs.

The project integrated an inverter and PAYG technology into a new control system. It enables availability in areas without reliable electricity and allows customers to pay gradually using mobile money. This dual technological integration aimed to make modern refrigeration solutions more attainable for all.

Assessing the landscape

Sun King began by researching the existing landscape of AC refrigerators available in African markets to thoroughly understand the problem first. This was critical in establishing the key characteristics necessary for these refrigerators to integrate effectively with Sun King's technology. Sun King's R&D team wanted to avoid developing a solar fridge and instead focus on developing an innovation that prioritised enhancing the cooling solutions by adapting locally available, high-efficiency AC refrigerators for solar power.

Sun King's hybrid inverter solar system draws electricity from the grid when available, and also solar power. A control box and battery management system control the flow of electricity to the refrigerator. The smart control box acts like an emergency power system or Uninterrupted Power Supply that sends electricity directly from the grid to the refrigerator when power is available. If the power cuts out, it switches to use energy from a battery instead. This system is smart enough to manage the energy on its own, turning on and off when the power goes out automatically.

The smart control system optimises cooling efficiency by adjusting the refrigerator's energy use based on the available solar power. It can handle sudden increases in current at start-up, also known as 'in-rush', which is typical for AC refrigerators and represents a major technical challenge and breakthrough.

Optimising the smart control unit was crucial for ensuring a steady power supply when it was most needed. This involved careful testing and modifications to standardise the unit's performance, considering night-time operation and additional openings of refrigerator doors during the day.

Additionally, the unit enhances energy efficiency during periods of high demand, through its automated control mechanism, smartly balancing cooling needs with energy conservation and control.

Market research revealed that AC refrigerators' energy consumption increased significantly with storage capacity. The newly developed power system by Sun King is engineered to efficiently operate refrigerators ranging from 50 to 150 litres, sufficient for a typical family's daily needs of 12.5 kilograms of food.

Sun King developed a Minimum Viable Product (MVP) for the smart control system, integrating features like;

- PAYG functionality
- A battery management system
- Multiple DC outputs, including USB ports
- A 600 W inverter

The initial smart control prototype was intensively tested with various refrigerator models to ensure interoperability — the ability of different systems to work together effectively, without special effort from the user — and validate the functionality of the MVP. Testing showed that a high-efficiency AC refrigerator could have a peak power rate of more than 1000 W, requiring the inverter to be compatible. The system, designed with PAYG functionality, allows seamless "plug-and-play" functionality emphasising versatility and ease of use.

Sun King's R&D team testing their smart control system

Sun King incorporated these learnings into the product design for it to be field tested in Kenya and Nigeria. Three smart control systems were tested with female customers and one male customer in a month-long field study, during which the performance of the units was carefully monitored. The collective feedback was exceedingly positive, highlighting that the units led to an increase in cooling service availability and higher incomes.

Sun King's prototype smart control system

Navigating Challenges During the COVID-19 Pandemic

The outbreak of COVID-19 and subsequent lockdown caused global logistics to falter, and prototype samples couldn't be shipped out.

The pandemic highlighted the vulnerability of supply chains during crises, with widespread shortages of products and components significantly impacting the project. This was the team's first venture into developing such a cooling solution, so procuring certain components posed a challenge. Extensive testing was necessary to understanding the performance of control units before making larger purchases.

Effective R&D Collaboration

Sun King harnessed the strengths of their large, multi-disciplinary team, eliminating the need for external talent, which was key during the COVID-19 crisis. With diverse expertise spanning various fields, the team facilitated the easy sharing and application of cross-functional knowledge. The R&D team transitioned to remote working, continuing the design process and collaborating online.

On-field testing proved invaluable in gathering authentic customer feedback, ensuring that the product met real-world needs and expectations. Real-world performance can differ from initial lab results and such extensive field testing can provide vital insights for project success.

Positive Impacts on Inclusivity and Functionality

The research project reflected Sun King's gender diversity, with two women engineers actively contributing, and a woman lead engineer guiding the development. Testing in predominantly women-led households provided valuable feedback to ensure the product meets diverse needs.

Women's ability to access safe and nutritious food, crucial for their own and their family's food security, is influenced by their household status and control over resources. This directly impacts nutrition and health, with variations observed across different regions.

Access to energy-efficient cooling appliances like refrigerators can boost women's labour productivity and free up time for activities outside the home.

The PAYG Business Model

As of January 2024, Sun King has provided over 838.5 million USD in solar loans to consumers in Africa and Asia. In this R&D project, Sun King used its PAYG business model to improve access to cooling in off- and weak-grid markets. During the 2021 pilot, Sun King offered AC solar refrigerators priced from 650 USD, with a flexible payment plan over 24 months including monthly instalments as low as 26.83 USD or daily instalments as low as 0.89 USD.

A customer using Sun King's refrigerator

Key Takeaways

Recent market developments make DC refrigerators more cost competitive with AC solarised counter-parts, however AC refrigerators remain cost-effective. By 2024, Sun King's market research indicated that retail prices for DC refrigerators dropped to between 700 USD and 1,400 USD. In 2019, the Sun King solar-powered AC fridge system was priced at 600 USD, but by 2024, global economic changes likely increased the production and retail costs. While AC cooling systems remain affordable, decreasing DC refrigerator prices provides consumers with greater options. Incorporating PAYG into refrigerators remains crucial, especially for consumers in off-grid areas.

In trials conducted across various off- and weak-grid settings, Sun King's AC refrigerator system showed significant versatility and value, catering well to the diverse needs of both residential and commercial consumers. Despite variations in usage patterns and performance due to location differences, feedback suggests that the product effectively meets customer needs.

Notably, commercial users in weak-grid environments reported substantial benefits, with one business experiencing increased earnings of 46 USD per month. Meanwhile, residential consumers enjoyed cost savings averaging 33 USD monthly, thanks to the system's ability to adapt to unpredictable energy demands, particularly during peak usage times when solar power is limited.

Future Plans

Sun King, traditionally focused on home energy solutions for lighting and small appliances, expanded its scope with this project. It ventured into a new technical area, beyond radios and televisions. The initiative allowed the company to delve into "productive-use" scenarios within the off-grid solar technology sector, an emerging field. The project revealed that such scenarios can deliver substantial value to customers, a key insight for Sun King's strategic development. Along with broadening its existing range of solar home systems and products, Sun King is exploring expansion into various productive-use solar technologies.

This project led Sun King into a more in-depth exploration of technical research and product development in the solar inverter segment. The research highlighted the significant potential of PAYG solar inverters to improve a wide array of existing and upcoming product lines. This includes its Home 8000 inverter, advancing Sun King's mission to expand access to solar energy solutions. By 2024, Sun King has established a robust presence in the African solar inverter market, selling a diverse range of solar inverters for powering refrigerators and a variety of other products. The company is expanding its solar inverter portfolio to power not just residential users but also small businesses, schools, and other settings.

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Sun King's engineers installing solar panels