

EVIDENCE BRIEF
SERIESDirect-drive solar vaccine refrigerators—
a new choice for vaccine storage

This document is directed toward supply chain managers in low- and middle-income countries and provides information about direct-drive solar refrigerators, which may be a good option for vaccine storage in areas with little or no electricity. It provides background about the technology and some practical guidance about weighing this option for specific situations.

THE NEED FOR OFF-GRID COOLING OPTIONS

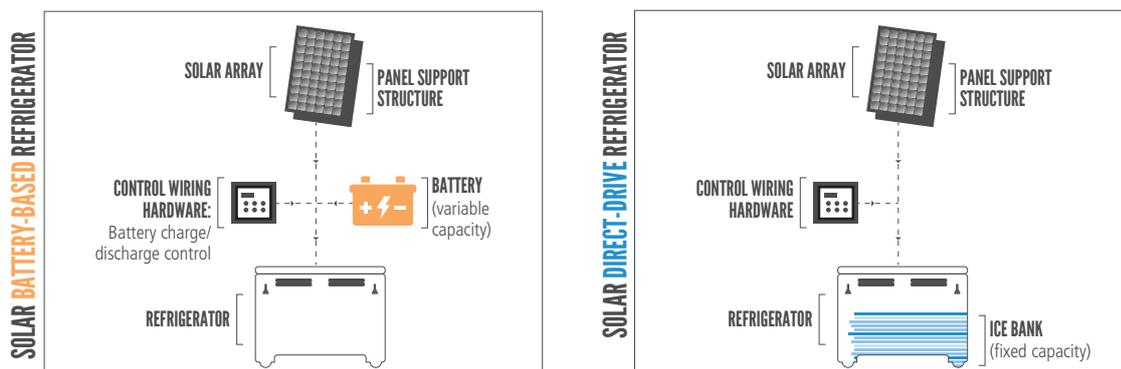
Keeping heat-sensitive vaccines at the right temperature is crucial yet often difficult in areas with limited or no electrical power or frequent or long-duration power outages that make the use of grid-powered cooling impractical for vaccine storage.

For a long time, refrigerators powered by gas or kerosene (called “absorption refrigerators”) were considered the best option in areas where electricity is unreliable. However, there are a number of drawbacks with these devices including:

- The ongoing supply of gas or kerosene is expensive for immunization programs in the long term.
- Absorption cooling is less efficient than the compressor method that is used in electric refrigerators.
- Supply of gas or kerosene is subject to interruption, and once on site it is vulnerable to diversion for other purposes.
- Keeping temperature in the safe range of 2°C to 8°C for vaccines is difficult in absorption refrigerators. There is a high risk of exposing vaccine to freezing temperatures.
- Gas and kerosene refrigerators require frequent maintenance to keep them operating well.
- Operating gas and kerosene refrigerators contributes to global warming.
- There are currently no absorption refrigerators prequalified by the World Health Organization (WHO), and although the United Nations Children’s Fund (UNICEF) will procure them under special request by countries, WHO and UNICEF have both published guidance that solar technology should be the preferred choice over absorption devices.

In the 1980s, solar refrigerators were introduced in areas without electricity as a solution to the problems cited for gas and kerosene refrigerators. However, one of the major drawbacks of solar refrigerator technology has been the large battery systems that were required to store the sun’s energy for use during the night and cloudy periods. These batteries have a relatively short lifetime of 3 to 5 years, and replacements are expensive and sometimes unavailable for local purchase in low-income countries. For these reasons solar refrigerators have often been abandoned when the battery dies—well short of the useful life of the refrigerator itself.

Figure 1. Schematic showing the difference between battery-based and direct-drive solar refrigerators.



NEW SOLAR TECHNOLOGIES OFFER A SOLUTION

In recent years a new approach to solar refrigerator design has emerged that eliminates the expensive (and problematic) energy storage batteries. “Direct-drive” technology uses the sun’s energy to freeze water or other phase change material and then uses the cooling from that “ice bank” to keep the refrigerator cold during the night and cloudy days. These refrigerators are called “direct-drive solar refrigerators” because they are wired directly to the photovoltaic generators (see Figure 1). As of May 2013, there are five companies that have direct-drive solar vaccine refrigerators prequalified by WHO.

HOW TO CHOOSE A SOLAR DIRECT-DRIVE REFRIGERATOR

When comparing solar direct-drive vaccine refrigerators qualified by performance, quality, and safety (PQS), some of the differentiating factors include vaccine capacity; purchase price; lifetime cost; presence of ancillary batteries; climate zone; and autonomy, which is the number of consecutive cloudy days that a solar refrigerator can maintain cooling performance. Below is a summary of information on each of the prequalified solar direct-drive refrigerators, taken from the PQS Devices Catalogue which can be downloaded from WHO. (See “Finding more information” on page 4.)

SUMMARY OF PREQUALIFIED SOLAR DIRECT-DRIVE REFRIGERATORS		Dometic TCW2000 SDD	Dometic TCW3000 SDD	Haier HTC-60	SunDanzer BFRV55	Sure Chill Company Sure Chill® BLF 100 DC	Vestfrost MKS044
	Vaccine capacity:	99-L refrigerator/ 42-L freezer	156 L	21 L	54.5 L	99 L	19.5 L
	Climate zone:	Temperate	Temperate	Temperate	Hot	Hot	Temperate
	Autonomy:	85 hours with 500W array at a solar radiation reference period of 3.5 kWh/m ² /day and ambient temperature of 32°C.	87 hours with 250W array at a solar radiation reference period of 3.5 kWh/m ² /day and ambient temperature of 32°C.	135 hours with 360W array at a solar radiation reference period of 3.5 kWh/m ² /day and ambient temperature of 32°C.	83 hours with 240W array at a solar radiation reference period of 3.5 kWh/m ² /day and ambient temperature of 43°C.	170 hours with 370W array at a solar radiation reference period of 3.5 kWh/m ² /day and ambient temperature of 43°C.	147 hours with 160W array at a solar radiation reference period of 6.0 kWh/m ² /day and ambient temperature of 32°C.
	Notes:			A small, ancillary battery is required to operate a fan. This battery requires periodic replacement.			A small, ancillary battery is required to operate a fan. This battery requires periodic replacement.

HOW TO SUSTAIN STORAGE SYSTEMS USING DIRECT-DRIVE REFRIGERATORS

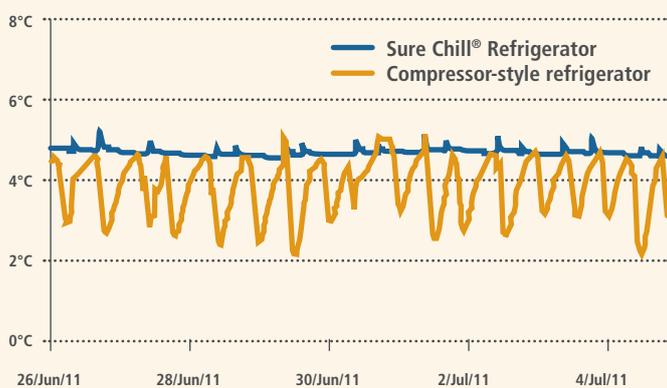
Years of experience have resulted in a number of lessons learned to improve the chances for long-term success of solar refrigerator technologies. These lessons are highly applicable to the use of direct-drive solar refrigerators as well.

- Beyond the initial investment, countries must plan for long-term costs including regular maintenance and repair.
- Design and installation should be done by experienced professionals. For solar direct-drive units, matching the solar power system with a particular refrigerator and specific site is complex and critical, and correct installation is also key to success. WHO maintains a list of qualified suppliers that have experience providing quality integrated solar refrigerator systems.
- Local solar and refrigerator technicians must be identified and trained to repair and maintain the particular technology installed. A well-managed stock of spare parts should be kept available.
- Temperatures inside the refrigerator should be electronically monitored, and managers should act quickly to diagnose problems when a refrigerator fails to keep proper temperature.

EARLY FIELD EXPERIENCE WITH DIRECT-DRIVE REFRIGERATORS

Project Optimize, a collaboration between WHO and PATH, is helping national immunization programs prepare for the future. In Vietnam and Senegal, project Optimize worked with the respective national immunization programs to evaluate solar direct-drive vaccine refrigerators from two different manufacturers—the BLF 100 DC Sure Chill® vaccine refrigerator manufactured by UK-based Sure Chill Company was evaluated in Vietnam and the BFRV55 from US manufacturer SunDanzer was evaluated in Senegal. Both of these refrigerators are prequalified by the PQS program of WHO.

Figure 2.
Temperature fluctuation during normal operation of the Sure Chill® versus a regular compressor-style refrigerator.



Vietnam field test: Sure Chill® BLF 100 DC

In Vietnam, the electric grid is extensive, yet many small communities throughout the country experience frequent power outages. Also, funding for electricity at small health centers is sometimes not available, and as a result, refrigerators are often unplugged between immunization days, which is hard on the refrigerator mechanism.

Project Optimize monitored the Sure Chill® refrigerator for one year starting in May 2011 at two district health centers in Vietnam, one in the north and the other in the south of the country.

The Sure Chill® solar refrigerator maintained extremely stable temperatures. For the refrigerators in both the northern and southern provinces in Vietnam, the temperature recorded in the center of the refrigerator rarely fluctuated outside of the range between 4°C and 5°C over a monitoring period of one year. This stable temperature profile can be seen in Figure 2, which also displays the typical temperature fluctuation of a compressor-style vaccine refrigerator during normal operation as comparison. The Sure Chill® also performed extremely well over a period of more than 10 days with very cloudy weather in northern Vietnam.

Users were happy to have a vaccine refrigerator that was independent of the electric grid—when power was cut, they did not have to worry about the vaccine in the Sure Chill®. Challenges with this refrigerator included managing a large amount of condensation resulting from the high humidity, especially in the north of Vietnam, and electrical problems with the compressor controller. The Sure Chill Company has worked diligently to resolve these issues and has also made a number of other improvements to the Sure Chill® as a result of the demonstration in Vietnam, highlighting the importance of carefully monitored field demonstrations for new technologies.



Figure 3.
Field testing new technologies allows manufacturers to make improvements to their products. Photo: Fatou Kandé

Senegal field test: SunDanzer BFRV55

In Senegal, frequent power cuts at regional and district vaccine stores put vaccines at risk. This is especially true at the district level where generators in good working order are not always available to provide back-up electricity.

Optimize installed 15 SunDanzer refrigerators in health posts in Podor, Pete, and Richard Toll districts in the north of the country. SunDanzer has a unique design for the solar generator installation—rather than the traditional configuration where both solar panels are placed in a single plane tilted toward the direction of the equator, they have formed their two panels in a tent shape, with one facing east and the other west. (See Figure 4) This configuration allows solar energy generation to start earlier and continue later into the day. Although larger individual panels are required for the tent configuration, the price of solar generators has dropped in recent years, making it a viable option compared to the traditional parallel panel design.

The SunDanzer refrigerators have performed reliably for over a year with no serious mechanical or electrical problems. Temperatures have been tracked remotely for 13 of the refrigerators beginning in March 2012 for most of them and continuing through December 2012 for 4 units and until April 2013 for the remaining 9. According to the temperature data, cooling performance is steady, even while refrigerators are in regular use and being opened frequently for vaccine storage and removal. Of the 13 units with detailed temperature data, one tended towards temperatures that were slightly too cold in the last quarter of the one-year monitoring, and one had frequent warm temperature spikes in the first half of the one-year period. When looking at the combined data from the other 11 units, the monitored temperature is in the target range of 2°C to 8°C for nearly 99 percent of the cumulative time.

There were some lessons learned about user interactions with the refrigerators. Early in the study, when reviewing the monitoring data, supervisors and researchers noticed some strange temperature profiles for some of the refrigerators. For example, sometimes the temperature would suddenly rise by 5 or more degrees and take some time to return to the normal range. This is different than what would be seen for a normal door opening, where the temperature might rise a few degrees for one reading but be back in range on the next. On investigation, it was found that this temperature behavior was a result of some health workers placing non-vaccine products in the refrigerator. After discussions with the staff at the health posts, compliant use increased, and a corresponding improvement in temperature performance of the refrigerators can be seen in the data.

Experience in both countries has shown that solar direct-drive refrigerators are a viable solution for areas lacking consistent electricity. The technology brings important advantages and is a good option for countries to consider at a time when WHO and UNICEF are discouraging the purchase of absorption refrigerators. There are currently several different offerings in the market, and solar manufacturers are eager to continue perfecting their technologies.



Figure 4.
East/West-facing solar generators for the SunDanzer refrigerators in Senegal. Photo: PATH

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FINDING MORE INFORMATION

PQS Devices Catalogue. WHO Performance, Quality, and Safety. Updated regularly and available online at http://apps.who.int/immunization_standards/vaccine_quality/pqs_catalogue/

Optimize: Vietnam Report. PATH and WHO; 2013. Available online at www.path.org/publications/detail.php?i=2269

Senegal Report. PATH and WHO; 2013. Available online at <http://www.path.org/publications/detail.php?i=2272>

PATH <http://sites.path.org/vpsse/optimize>

World Health Organization

http://www.who.int/immunization_delivery/optimize/en/index.html