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SUPPLY DIVISION

COLD CHAIN

SUPPORT PACKAGE

PROCUREMENT GUIDELINES

BATTERY POWERED SOLAR REFRIGERATORS AND FREEZERS

Procurement Guidelines

Battery Powered Solar Refrigerators and Freezers

Key information for UNICEF staff and partners, ensuring the effective and efficient procurement of Cold Chain equipment.

This module gives guidance to the procurement of solar powered refrigerators and freezers with battery storage.

Always make sure that you have the latest version of this document by checking the CCSP website.

Document Update: October 28, 2014

Suggestions and feedback: sd.coldchain@unicef.org

Contents

Acronyms

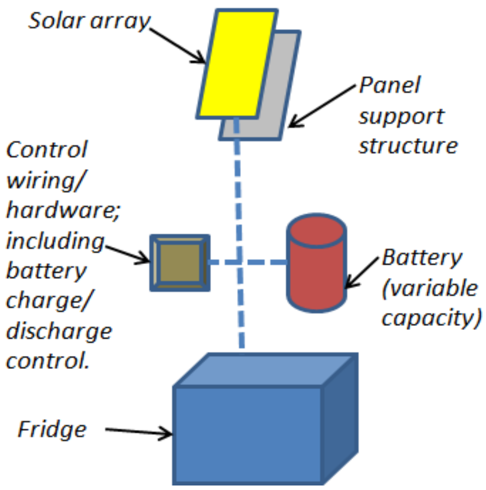
CCSP	Cold Chain Support Package
CO	Country Office
DOA	Direct Order Arrangement
LTA	Long Term Arrangement
PHC	Primary Health Care
PIS	Product Information Sheets
PQS	Performance Quality and Safety
PQT	Prequalification Team
PS	Procurement Services
SD	Supply Division (UNICEF)
SDD	Solar Direct Drive
VVM	Vaccine Vial Monitor
WHO	World Health Organization

1 Needs Identification

1.1 Introduction

Solar-powered refrigeration equipment, or so called off-grid Photo Voltaic (PV) systems, run on direct-current electricity provided by solar energy. Batteries are used to store energy. In off-grid Photo Voltaic (PV) systems batteries are essential to providing power during periods of low or no sunlight.

Fig 1. Conventional solar battery powered refrigeration system



Conventional solar powered systems store the power in a battery and requires charge regulators. The conventional complete solar refrigeration system with battery power storage consists of:

- a solar refrigerator
- a power supply pack (PV solar arrays, batteries)
- charge regulators, cables and accessories

Manufacturers of Solar Arrays generally state that a properly installed system will provide power for the solar refrigerator for over 20 years with no fuel costs and little maintenance. When compared to diesel fuel power generation in particular, PV is a cost-competitive option, especially in the developing world where electricity and diesel prices are often high.

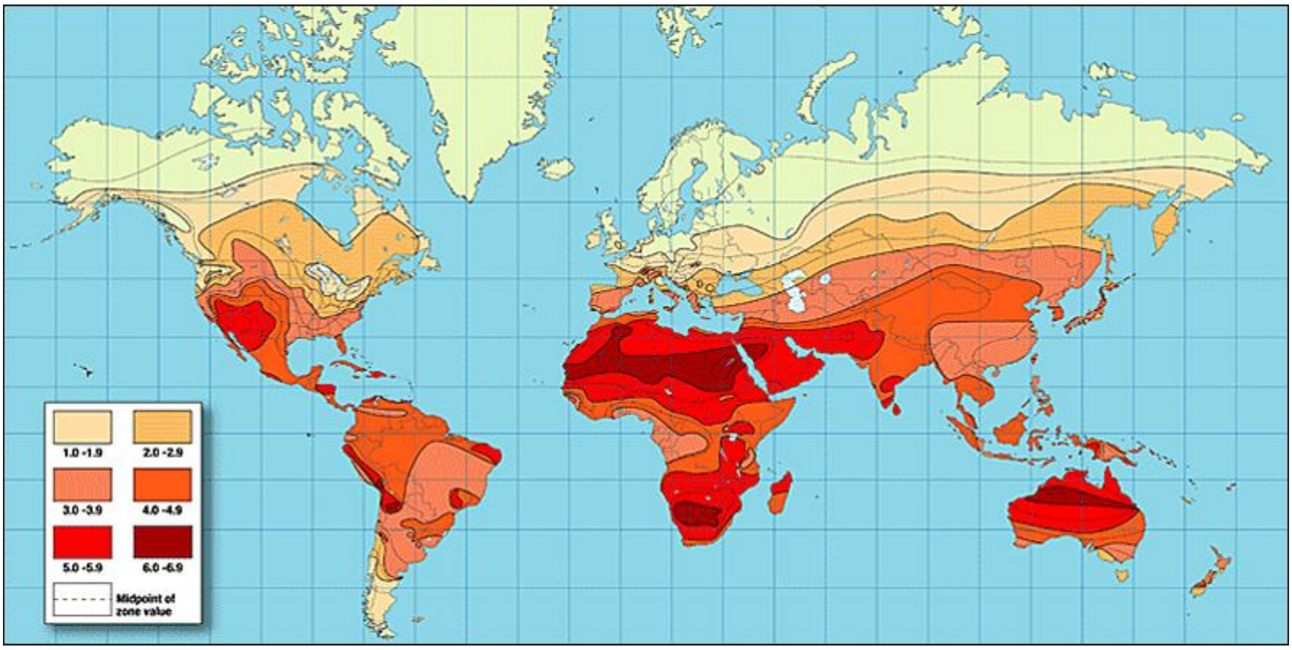
All UNICEF procurement of solar refrigeration systems must be undertaken through Supply Division (SD).

1.2 Choosing Solar Powered Systems

The choice of solar powered equipment for use in a country programme requires careful analysis and evaluation. The products are appropriate for the safe storage of vaccines in various scenarios and settings as below:

- Hard to reach and remote areas
- Areas with no access to the national power grid
- Areas with limited/intermittent power supply, i.e. availability of national power supply for less than 8 hours per day
- Locations with at least 3.5 kWh/m2 of solar irradiation per day

Fig 2. World Map of Direct Normal Irradiation on the Horizontal Plane



Source: www.solarcellcentral.com

The map provides a quick reference for an initial assessment of the feasibility of solar power. It divides the world into five solar performance regions based on yearly averages of daily hours of sunlight and ambient temperature. Each specific site has its own specific weather conditions and seasonal changes that can significantly affect the amount of sunlight available.

1.3 Types of Battery Powered Solar Refrigerators and Freezers

UNICEF SD procures a range of Solar Refrigerators/Freezers of varying sizes via Long Term Arrangements (LTAs). For details refer to Section 3.

1.4 Initial Investment Cost

Battery-based solar systems require a high initial capital investment. However, with proper maintenance, the returns are enormous as the recurrent costs are limited to periodic replacement of batteries only. The specifications for the batteries procured for these systems through UNICEF SD have a minimum life span of five years. The batteries are found to give a service of more than five years in field settings where proper maintenance is practiced. It is, however, very important to keep to a very strict regime of periodic maintenance as prescribed in the documents accompanying the systems upon procurement.

2 Key Considerations for Battery Powered Solar Systems

2.1 WHO PQS Compliance

The solar power components connected to a Direct Current (DC) compression cycle refrigerator system (12 volt) comply with WHO PQS[1] specifications E03/RF04. The power system is purpose-designed to match the power consumption of the connected refrigeration equipment as well as the site-specific climate conditions, taking into consideration ambient temperatures, available solar radiation at the site of installation and autonomy requirements as per WHO guidelines. The climate zone classification as per WHO is as follows:

Table 1. Climate Zone Classification (WHO)

	Cold	Temperate	Hot
Up to	27°C	32°C	43°C

2.2 System-Sizing

Correctly sizing a solar PV system requires careful attention to detail and critical planning. Solar system sizing is a step-by-step process that accounts for facility energy needs and the local solar resource in order to determine the necessary size (in kWp) of the solar array.

Photovoltaic panels, also called PV modules, are the basic building block of a PV system. The array of solar panels are normally sized to ensure that enough power is supplied to the photovoltaic solar refrigeration systems[2]. The power consumption varies by storage capacity and model. Countries experience varying weather conditions and solar radiation levels at different periods of the year depending on where they are located globally[3]. Even within a country, different solar radiations, temperature and altitudes vary. These factors and elements influence the overall exercise of calculating the size of the solar array and the battery bank for optimum operation of the solar powered system.

a. Limiting Factors to System Sizing

Availability of radiation/temperature data is usually limited to main cities and towns already connected to the national power grid. If the national grid power is available for at least 8 hours per 24 hours, it is currently not cost effective/justifiable to use solar powered refrigeration systems in these locations due to the relatively high initial capital investment. However, solar powered systems are used in locations without power grid connection and where the meteorological data is non-existent or very scanty. Reasonable solar data analysis of the regions has to be considered in order to offer appropriately sized systems for the requested areas/locations.

It is also worth noting that circumstances arise in country Expanded Programme on Immunization (EPI) programmes necessitating change of predetermined installation locations. This could alter the

[1] UNICEF SD procures pre-qualified and listed equipment that conform to the WHO guidelines for developing countries and those in transition.
[2] The power output of a solar module is the amount of power it will generate under standard test conditions. This measure is used to describe the size of a PV system (e.g. 10 kWp PV installation).
[3] The amount of solar energy that reaches a given area over a given amount of time is commonly expressed as kWh/m2/day. This indicates the amount of useful solar energy available locally for collection through solar PV.

system appropriateness from the previously intended site location and may lead to non-optimum operation.

The lack of vital radiation/temperature information from any known data bank and the potential for programmes to change installation sites/location after procurement of equipment has called for UNICEF SD to devise a methodology to circumvent the limitations by using a system-sizing based on the worst case scenario at country level.

b. System sizing of solar arrays

Solar array size affects battery autonomy[4]. A larger solar array will reduce the number of batteries required for a system. A system sizing template in tropical locations has been prepared as one method of use. It includes information extracted from various data sources on temperature and radiation which are vital parameters for system sizing of a solar array for refrigerators. The tool for system sizing has been attached in Annex 2.

Workers lift a solar panel onto the roof of the Gbandiwlo Health Centre in Kailahun District, Sierra Leone. The panel will power a UNICEF-provided refrigerator.

c. Default System Size Categories

Three value categories of 3.5, 4.5 and 5.5 KWh/m2/day have been identified as fitting the typical locations where these systems find application. A default minimum ambient temperature of 32°C is used as basic parameter to facilitate calculations, amongst others.

As indicated above, a small solar array could suffice in one location and perform intermittently in another with the consequence of short battery life. Based on this rationale, and the constraints summarised above, the worst case scenario for insolation (radiation) and temperature data collated for countries is used as an average default value for system sizing as displayed in the Solar Insolation Table.

d. Solar Array structure

Solar Array structures are installed either on the ground, the roof or are pole mounted. The Array is therefore exposed to varying conditions including gales and strong winds. The structure must therefore be designed to withstand wind loads of +200 kg per square metre. It is a standard condition to supply all the fittings for either ground or roof mounting as a basic requirement for installation. Theft deterrent fasteners and protection against the effect of lightning are provided with the necessary accessories, earth cable, spikes/rods and fixtures to ensure sound and effective earth on site.

[4] Autonomy is the number of days that a solar refrigerator, or combined refrigerator and freezer, can maintain the vaccine load within the acceptable temperature range under low solar radiation conditions (e.g. rain)

e. Batteries

(i) Battery types:

Power packs for battery powered PV refrigeration systems are equipped either with dry charged (=flooded) or Sealed Gel batteries with proof of conformity to IEC 61427 /IEC 60 896-21, 22. UNICEF SD recommends the Sealed Gel batteries, which are maintenance free and do not need topping up with distilled water. Flooded batteries are filled with electrolyte supplied in separate hermetic containers when the batteries are delivered. It is important to ensure that the electrolyte level mark on the transparent containers is achieved. Please take note that once the initial level of electrolyte/acid is reached, any consequent topping up is with distilled water only and never again with electrolyte/acid for the rest of the battery's life.

WHO PQS allows for high quality sealed batteries to be used in solar vaccine refrigeration. Sealed batteries eliminate a maintenance burden, which is the need for electrolyte replenishment. It is believed that this will increase battery life. Some lead acid (flooded) batteries carry a 10 year warranty (at 25°C).

For both types of batteries, it is a requirement that they be capable of withstanding a minimum of 1000 cycles to 50% Depth of Discharge (DOD). Sealed Gel batteries should meet the same specification as flooded batteries.

(ii) Battery sizing:

Systems supplied by UNICEF SD already have a correctly sized battery included. The battery bank is sized according to the load it is meant to support. Another important factor that effects the size of both the PV array and battery bank is autonomy. Energy stored in the battery bank will be used for periods of inadequate sunlight, so greater autonomy requires a larger battery bank. Determining how much autonomy is needed depends on the local climate, specifically, the maximum number of days with cloudy weather. The availability of other power sources may also influence the amount of autonomy needed for the PV system, for example, a diesel generator can be used during periods of low sunlight in order to offset the need for a large battery bank.

As a rule, the batteries are sized to permit a minimum of 5 days of continuous operation of the refrigerator when:

- The fridge is fully loaded and including icepack freezing as prescribed on PQS category capacity requirement at an ambient temperature of 32/43°C.
- Battery power pack fully charged (=5 days autonomy).

The autonomy days ensure that with the photovoltaic array exposed to limited irradiance, cloudy or rainy days, the refrigerator runs efficiently for these 5 days. This provides for safe storage of vaccines during cloudy days in the months of the year when insolation/radiation is low.

(iii) Battery quality:
In remote settings in developing countries, high quality batteries are difficult to replace and are expensive. Lack of local availability, importation documentation, long lead times, transportation and logistics all further complicate battery replacement[5].

WHO PQS allows for high quality sealed batteries to be used in solar vaccine refrigeration. Sealed batteries eliminate a maintenance burden, which is the need for electrolyte replenishment. It is believed that this will increase battery life. Some lead acid (flooded) batteries carry a 10 year warranty (at 25°C).

(iv) Battery Electrolyte :
With limited exceptions, it is not advisable to procure electrolyte (mixed acid and water at the correct ratio) locally since this requires chemical analysis of the electrolyte for breakdown in terms of sulphuric technical grade given in level of iron, lead, arsenic, chloride, mercury, and cadmium content in ppm (parts per million). This is to ensure the purity level of the electrolyte. Poor grade of electrolyte severely shortens the useful life of batteries.

(v) Battery maintenance:
For flooded batteries, once the initial top-up of the electrolyte has been done during installation, no further electrolyte should ever be added for the rest of the life of the battery. Distilled (de-ionized) water should be topped up whenever the level gets low. Terminals should be cleaned, tightened from time to time and greased to prevent oxidation.

f. Accessories for Battery Powered Systems

Annex 3 gives a list of recommended accessories for battery powered systems.

2.3 Charge Regulator

The charge regulators procured for solar powered PV refrigeration systems are designed with an indicator for high/low voltage status. This is important for indicating the state of charge of the battery power pack especially when freezing ice packs. For gel batteries, the charge regulators are specifically configured and calibrated. Care should be taken whenever batteries are changed to ensure the type/model replaced is the same. When replacement is done without recalibration for the type of batteries, the system will not operate optimally.

[5] In response to this problem, Research & Development by industry and partners have led to the development of direct drive (i.e. battery-free) solar vaccine refrigerators. In addition, research is on-going in long-life batteries, including the Lithium ion and Nickel Metal Hydride types.

3 Products Supplied by UNICEF SD

As a general rule, UNICEF only supplies solar powered refrigeration systems that meet the quality and performance requirements set by the World Health Organization (WHO) in the WHO PQS Catalogue.[6] UNICEF SD can provide a range of Battery Powered Systems available on Long Term Arrangement (LTA[7]), classified by vaccine storage capacity.

The following battery powered refrigerators are supplied by UNICEF SD (LTA, 2014), available from various manufacturers:

Table 2. Battery powered refrigerators available on LTA

Net Volume	Available Value Categories
< 30 litres	3.5, 4.5 and 5.5 KWh/m2/day
30-50 litres	3.5, 4.5 and 5.5 KWh/m2/day
> 50 litres	3.5, 4.5 and 5.5 KWh/m2/day

The UNICEF SD Technical Unit reviews the country program requests or Procurement Service request to determine the solar system size suitable for the specific country in which the systems are to be installed. This will ensure that the system is sized to the optimum power required to run the system.

4 Budgeting

For information about budgeting for procurement, refer to the General Procurement Guidelines.

5 Ordering

5.1 Starting the Process

Refer to the General Procurement Guideline and the UNICEF SD Procurement Services website for general guidance on how to order Cold Chain products and services. In the event that the General Procurement Guideline does not provide sufficient information, please contact the Supply Division Procurement Services for specific queries.

The option of ordering installation services through UNICEF SD is covered elsewhere in this document.

5.2 Delivery Lead Times

Refer to the section 'When to Order' in the document 'General Procurement Guidelines'.

[6] UNICEF SD procures pre-qualified and listed equipment that conform to WHO standards. These standards are documented in the WHO PQS (Performance, Quality and Safety) manual, which is accessible online.
[7] UNICEF SD establishes Long Term Arrangements (LTAs) with product suppliers, usually for a period of 24 months. Refer to the document General Procurement Guideline for further details on LTAs.

6 Site Preparation

The following instructions give the main guideline of what is defined as 'Site Readiness'. This is required in order for the contracted technician to start working immediately upon arriving at the installation site:

a) Ensure that the goods will be on the actual installation site within carrying distance from the final location before the arrival of the engineer.
b) Store the complete solar refrigeration systems together in a secured area and cover it against adverse weather conditions.
c) Ensure that the intended installation site is cleared (for ground mounting) or a strong stable roof is in place (for roof mounting) to allow for immediate installation to begin[8].
d) Provide installation space/room for the solar refrigerator cabinet with adequate ventilation or windows for good air circulation and - where security is a concern – with wall(s) with netting/burglar proof grills.
e) The delivery crates are to be opened by engineers from the service supplier to verify that all accessories of equipment have arrived as packed by the supplier.
f) Ensure that there is local unskilled labour available for positioning the materials and carrying out manual installation works, such as mounting of charge controller, positioning batteries, inter-connecting batteries and filling of electrolyte under the supervision of the supplier engineer.
g) For solar installations, it is recommended to have a local electrician/technician present to assist in the installation and to learn from the supplier engineer as a capacity building process.
h) During installation it is recommended that all technical personnel who will be responsible for the future daily operation, maintenance and service of the solar refrigeration systems will be present and participate in the installation work, thereby acquiring basic skills and understanding of the equipment.

7 Transport Handling

Transport handling for refrigerators and freezers requires caution. In the unlikely event of oil circulation in the refrigeration circuit of a refrigerator and freezer system, the equipment will be rendered inoperative. Refrigerators and freezers should always be transported in the upright position to avoid the oil in the compressor getting into the system cycle. After transportation of these products, a minimum of three hours should be allowed for the stabilisation of the oil before starting the unit.

The necessary local resources for transportation, manpower and time should be included in the planning process. For further information on transport issues refer to the document 'General Procurement Guidelines'.

[8] Roof mounting structures come in a variety of forms and play several important roles in an overall PV system's design. The most common and least expensive type of mounting structure is a stationary structure, where panels are given a fixed orientation optimized for exposure to the sun.

8 Installation

8.1 Considerations for COs and PS Partners

It is generally recommended to look at training to be added as a component to installation projects for solar refrigeration systems. This will enable local staff to conduct the installation of further systems on their own which also is a considerable cost saving factor.

In order to ensure timely installation of solar systems, the following aspects are to be considered:

a) Lead time until arrival of the solar refrigeration systems: The regular supplier lead time from placement of the PO until delivery to port of shipment (FCA) can vary from 1 to 15 weeks. In addition to lead time, sufficient time needs to be added to allow for the transit time by sea to the destination port.
b) Are local staff with suitable base level qualifications available for training if required? If so, what would is the estimated number of training participants?
c) Is there outstanding repair work or maintenance that could be linked to the project?
d) Is there a need to distribute the equipment to one or more destinations other than the place of delivery defined in the PO? Please inform SD whether the Systems are already available on site or what the estimated timeline is for in-country distribution.
e) Are the installation sites ready for installation?
f) If the PV solar arrays will be roof mounted, provide information on whether the roof is corrugated iron sheets (GSI), flat cement or another construction.
g) A travel preparation time of approximately 4-6 weeks from declaration of site readiness until arrival of the technician has to be considered. It should be noted that this general timeline very much depends on the actual circumstances in each case, such as visa requirements, medical requirements, travel conditions with flight availability, etc. For best possible planning, the customer should provide all relevant information to SD.
h) Who in the CO can be contacted for queries (please provide contact details)? The contact(s) should be available for clarification on procurement related aspects of the projects and for technical enquiries (e.g. site preparation, energy sources, logistics, etc.).

If technical in-country expertise for the installation of solar systems is limited or unavailable, it is recommended that UNICEF SD be alerted as early as possible. This will help minimise the risk of potential bottlenecks, in particular relating to the availability of external technicians, practical preparation of travel and organizing additional training if required.

8.2 Timing of the Installation

A preparation period of 4-6 weeks from declaration of site readiness until arrival of the technicians has to be considered. This depends on prevailing circumstances in each case, such as whether an entry visa is required, period for acquisition, medical requirements, travel conditions with flight availability, etc.

Please contact the UNICEF SD Cold Chain Unit for any related queries.

8.3 In-Country Installation

8.3.1 Installation without UNICEF SD Support

In cases where in-country capacity is available, either internally from the national Cold Chain services or from locally contracted firms, the country may decide to take responsibility for the installation of solar systems themselves. In this case, it is recommended that a proper assessment is carried out to determine whether the in-house or contracted technicians are sufficiently trained and have the professional experience to undertake this type of work. Outsourcing the installation of solar systems provides an opportunity for training in-house technicians.

A technician installs the control box of a UNICEF-sponsored solar refrigerator at the Gbandiwlo health center in Kailahun district, Sierra Leone.

8.3.2 Installation with UNICEF SD Support

If a country does not have sufficient capacity to conduct the installation of ordered Solar Powered Refrigeration Systems, procurement of installation and/or training services through SD is an option.

Should UNICEF SD be chosen to support the installation, early communication will help minimize the risk of potential bottlenecks, in particular with regard to the availability of external technicians, practical preparation of travel and organizing additional training materials and UNICEF SD verification of their content where necessary.

In order to build local capacity in installation, use and maintenance of solar systems, it is recommended to include a training session for local technicians while the contracted installer is present on site. Further information on this type of training can be obtained from the UNICEF SD Cold Chain Unit.

To request SD assistance with installation, the following information needs to be communicated to SD, in a timely manner:

a) When will the solar refrigeration systems be delivered (or when have they been delivered) and under which PO reference?
b) What are the models to be installed? Do other models exist in the country?
c) By which date do the systems need to be in place (timeline for installation)? This will enable UNICEF SD to alert the country programme/customer through the CO in case the envisaged timeline for taking the system into operation is considered unrealistic.
d) What are the requested Terms of Reference (TOR)? UNICEF SD has experience with some countries having specific requirements that go beyond the mere installation of solar powered systems. If the project goes beyond just installation, SD can explore favourable options with the service provider to optimize the project outcomes or when faced with constraints.
e) What is the exact address of the installation site(s)? If different locations are involved, information about distances and travel times between the sites, the number of rooms per site etc. should be provided to SD.
f) Who on the customer side can be contacted for queries (contact details)?

8.4 Selecting the Installation Site

The choice of the site/position for a solar powered refrigeration system and the choice between ground or roof mounting has a crucial bearing on its performance and efficiency. The following should be observed:

- Trees and branches should be cleared to avoid casting shadows on the solar array.
- Orientation of the array should face south for countries north of the equator and face north for those in the south.
- Solar refrigerators should be located away from direct sunshine.
- The solar refrigerator cabinet should be placed at a minimum of 300 mm away from any walls to allow for free air circulation.

8.5 Optimization of the PV Solar Array Installation

8.5.1 Selecting a Suitable Site

Site selection appropriateness, orientation, solar system sizing, component specification as well as historical meteorological weather data are pivotal in the successful performance of the solar powered systems. Poor performance of equipment will always result when designers/engineers fail to accurately assess shading patterns at proposed geographical installation sites. In the absence of virtual data and extremely skilled technical capacity, inappropriately installed systems will not perform optimally.

8.5.2 Positioning of PV Solar Arrays

Devices are available to optimize the angle of the PV solar arrays and so maximise their power output. By combining the capacity to replicate the site-specific annual shading pattern, these devices allow for an accurate solar site analysis to be made. The instant annual insolation data, on an hourly and monthly basis, can then be applied to determine the appropriateness of the selected site intended for the installation, and in retrospect, the anticipated performance of the equipment.

Installation check of a PV solar array in Haiti, using a smart phone App to optimise the angle of the array.

Devices such as these are typically low-cost and non-electronic instrument. They are simple and straight-forward in design and require no special skills or technical know-how. One simple tracing does the job and becomes the permanent record for the solar data.[9]

8.6 Finalising Installation

UNICEF requests that countries complete an Installation Completion Check (Annex 1). This document is to be duly signed by a CO/PS partner representative. Customer concerns, claims or any other issues related to the delivery of the service must be raised before signing the completion report. A signed report serves as

[9] An example of such a device is the 'Solar Pathfinder' which uses a highly polished, transparent, convex plastic dome to give a panoramic view of the entire site. Trees, buildings or other obstacles to the sun are plainly visible as reflections on the surface of the dome with the sun path diagram being seen through the transparent dome at the same time.

confirmation that service delivery was satisfactory, and triggers the release of financial settlement of related invoices.

9 Commissioning

In the case of Cold Chain equipment other than Cold Rooms and Freezer Rooms, there is no formal commissioning procedure. The Forwarding Agent delivers the goods to the destination, after which the beneficiary takes care of in-country distribution and installation.

10 User Training

In order for Cold Chain equipment to perform optimally, staff using the equipment need to be trained in using the equipment correctly and confidently. The training will include routine and preventive maintenance actions, such as temperature monitoring, cleaning of the equipment and fault reporting. The User Manual supplied by the manufacturer is an important source of information.

11 Technician Training

Training on battery-based solar powered refrigeration systems for technicians is vital. Upon request, this training can be provided through UNICEF SD and included in the procurement contract. Training for technicians includes modules on theory and practice in installation covering:

a) Formal practical training course content: This is split into modules with a tailored Solar System Training course content to be covered.
b) Field demonstration: One battery based solar powered system is installed in a field setting by the participants, with the tutors taking an advisory role. In most cases it is anticipated and recommended for the participants to have some basic knowledge of refrigeration.

12 Maintenance

12.1 Common Causes for System Failure

The Table below gives some of the main causes which result in failure of solar battery powered systems:

Table 3. Common Causes for Battery Powered System Failure

Cause for System Failure	Corrective Action
Tapping power for other accessories such as radios and lights from the power pack	Do not use the battery power for any purpose other than powering the refrigerator
Electrolyte in batteries drops below the minimum level	Top battery up with distilled water when electrolyte goes below minimum level (Never again add acid after the initial filling during installation!)
Misuse of refrigerator	Do not use the refrigerator for storage of products other than vaccines
Frequent opening of refrigerator door	Do not open the refrigerator more than strictly necessary
Failure to defrost the refrigerator	Defrost the refrigerator when the ice accumulation thickness gets to approximately 5 to 10 mm

Additional possible causes for system failure can be found in the suppliers user manual.

12.2 Routine Maintenance

Maintenance serves the purpose of keeping Cold Chain equipment in good working order throughout its lifetime. A distinction is made between corrective and preventive maintenance. Countries need to develop in-house capacity for the maintenance of the entire fleet of Cold Chain equipment. A suitably qualified technician needs to be available on location, to carry out first-line maintenance when due. This person will be qualified to carry out basic maintenance actions and be able to determine when outside professional expertise needs to be called in. The technician will be suitably trained and have experience with the maintenance and repair of Cold Chain equipment.

The most frequent maintenance need of solar panels will be the cleaning of the panel faces.

PV solar arrays are low-maintenance devices, but a regular and organized maintenance program is still absolutely essential to system longevity. The panels themselves typically have a very long lifetime, 20-25 years.

Table 4. Routine Maintenance on Battery Powered Systems

Maintenance Action	Description
Cleaning of the panel faces	The most frequent maintenance need of solar panels will be the cleaning of the panel faces. Dirt or other debris on the panel faces will block sunlight and reduce the energy output of the system.
Maintenance of battery bank	Regular maintenance of the battery banks is essential; they should be checked every week, with the electrolyte level replenished as needed, and if properly maintained, should last many years before needing replacement.
Periodic maintenance check	A professional technician should perform a semi-annual maintenance check, examining wiring connections, mounting bolts, and inverter operation and be on call to take corrective action if the system does not work properly.

Maintenance funds should be established upfront and be dedicated only to solar system repair. Mixing maintenance funds with general operating budgets has proven to be an ineffective model. The proportion of equipment serviced externally (outsourcing, contracting) will depend on in-house technical capacity and the availability of financial resources.

A comprehensive computerised database of Cold Chain equipment facilitates the proper management and maintenance of equipment. Countries are advised to develop and maintain such a system.

13 Complaints Handling

For Complaints Handling procedures refer to the General Procurement Guideline.

14 Warranty

For Warranty issues refer to the General Procurement Guideline.

15 Decommissioning

Decommissioning refers to the process of writing-off and physically disposing of equipment that is no longer cost-effective. Countries are advised to adhere to national public sector procedures for the correct disposal of health sector physical assets.

Annex 1: Battery Powered Solar Systems - Installation Completion Checklist

Refer to the WHO Solar Refrigerator Checklist in the publication: WHO_PQS_E03_PV01-VP2.1.doc (Annex 2, pages 7-9).

Annex 2: Tool for System Sizing of Solar Arrays for Solar Refrigeration Systems

A. AFRICA

Country	Insolation NSOL	Stations NSOL	Insolation Meteonorm (worst case in country)	Meteonorm stations	Ave. annual temp. in Meteonorm stations in C	Ave. monthly low temp. Meteonorm in C	Ave. monthly high temp. in Meteonorm stations in C	Lowest Insolation in country
AFRICA								
Algeria			4.2	Oran	17.9	12.4	25.5	3.5
Angola	3.4-6.8	5	4.5	Luanda	25.8	22.1	28.6	4.5
Benin			4.2	Kandi	27.7	24.8	32.1	4.5
Botswana			5.6	Tsabong	22.8	14.1	28.7	4.5
Burkina Faso			5.9	Ouahigouya	28.7	24.1	33	4.5
Burundi			5	Bujumbura	23.1	22.4	23.9	4.5
Cameroon			4.5	Ngaoundere	22	20.4	24.1	3.5
Cape Verde			4.5	Sal Island	23.5	21.1	26.6	4.5
CAR			4.5	Bria	24.9	23.4	26.9	4.5
Chad			5.6	Bilma	26.8	17	33.3	4.5
Comoros			5.6	Moroni	25.4	23.2	27	4.5
Congo Brazzaville			<4.2	Gamboma	25.6	25.2	26.3	3.5
Djibouti	x	x	5.9	Djibouti	29.9	25.1	36.4	4.5
Equatorial Guinea			4.2	Bitam	24.4	23.2	25.2	3.5
Eritrea	x	x	5.6	Asmara	29	24.3	34.3	4.5
Ethiopia	3.8-6.2	1	5	Addia Abeba	16.7	15.5	18.2	4.5
Gabon			<4.2	Makokou	24.1	22.2	25.3	3.5
Gambia	x	x	4.8	Kaolack	28	24.8	29.9	4.5
Ghana	4.0-6.0	3	4.2	Tamale	27.9	25.4	30.9	4.5
Guinea Conakry			4.2	Labe	21.7	18.8	26.1	4.5
Guinea-Bissau	x	x	4.2	Bissau	26.4	24.5	27.6	4.5
Ivory Coast			4.2	Korhogo	26.7	24.6	29.1	4.5
Kenya	3.3-7.3	8	5.3	Garissa	29.3	27.4	31.4	4.5
Lesotho			5.6	Ibhayi	17.7	11.1	23.6	4.5
Liberia			4.2	Roberts intl.	25.9	24.4	27	4.5
Libya			4.5	Sebha	22.6	11.6	31.2	4.5
Madagasgar			4.2	Antananarivo	17.9	14.1	20.7	4.5
Malawi	x	x	4.8	Lilongwe	20.2	15.7	23.6	4.5
Mali	x	x	5.3	Hombori	30.3	24.8	35.5	5.5
Mauritania			5.3	Atar	28.1	20.7	34.5	4.5
Mauritius			4.5	Saint Denis	20.1	16.8	23	4.5
Morocco			4.8	Midelt	14.3	6.5	24.5	3.5
Mozambique			5.3	Gurue	24.3	20.8	26.9	4.5
Namibia			5.6	Windhoek	20.5	13.9	25.6	4.5
Niger			5	Bilma	26.8	17	33.3	5.5
Nigeria	3.5-4.8	1	4.5	Magaria	27.2	21.1	32.4	4.5
Rep. Dem. Congo	3.9-5.4	1	4.5	Kindu	25.5	24.3	26.2	3.5
Rwanda			4.8	Kigali	21.1	20.6	21.6	4.5
Sao Tome and Principe			<4.2	Sao Tome	25.3	23.8	26.3	3.5
Senegal			5.9	Linguere	28.1	24.3	31.4	4.5
Sierra Leone	x	x	4.8	Freetown	27	25.9	28.5	4.5
Somalia	x	x	5	Mogadiscio	29.3	28.1	31.1	4.5
Sudan	5.5-7.3	1	5	Omdurman	29.4	22.6	34	5.5
Swaziland			4.8	Maputo	23.7	16.4	24.2	4.5
Tanzania			4.5	Dodoma	22.7	19.7	25	4.5
Togo			4.2	Atakpame	26	23.9	28.1	4.5
Uganda	4.3-5.9	3	4.8	Gulu	23.3	21.8	25.1	4.5
Zambia			5	Kabwe	20.2	15.9	24.1	4.5
Zimbabwe			5.9	Harare Bel	19.5	15	22.2	4.5

Source: Data derived from www.weatherbase.com

*Note that Solar Refrigeration Systems may be WHO pre-qualified for temperatures of max. 32 degrees Celsius ('Temperate Climate')

Annex 2: Tool for System Sizing of Solar Arrays (Cont'd)

B. Asia & Middle East

Country	Insolation NSOL	Stations NSOL	Insolation Meteonorm (worst case in country)	Meteonorm stations	Ave. annual temp. in Meteonorm stations in C	Ave. monthly low temp. Meteonorm in C	Ave. monthly high temp. in Meteonorm stations in C	Lowest Insolation in country
ASIA & MIDDLE EAST								
Afghanistan			3.7	Tirin Kot	16.4	3.3	29.7	3.5
Armenia			3.1	Yerevan Zvar	12.1	-3.5	26	2**
Azerbaijan			3.1	Gabala	10.9	-0.5	22.3	2**
Bangladesh	x	x	5	Tangail	25.9	19.2	28.9	4.5
Bhutan			5	Pagri	0.7	-8.4	8.3	3.5
Cambodia			4.2	Stung Treng	27.1	25.1	30.1	4.5
Fiji	3.6-5.9	1	4.5	Suva	25	23	26.9	4.5
Georgia			3.1	Kutaisi	13.2	1.9	24.6	1.5**
India			4.2	Gondiya	27.1	20.5	35	3.5
Indonesia	x	x	3.9	Surabaja	26.7	26.2	27.4	3.5
Iraq	x	x	4.2	Mamoon	20.2	7.5	32.7	3.5
Kazakhstan			<3.1	Zaryk	4.5	-12.7	20.6	0.9**
Kiribati	x	x	5	Christmas Isl.	27.3	26.8	27.6	4.5
Kyrgyzstan			3.1	Bishkek	8	-3.3	20	1.5**
Laos			3.9	Luangphabang	24.4	18.6	27.7	4.5
Lebanon			5.3	Rayack	14.3	5.3	22.6	3.5
Maldives			5.5	x	x	x	x	5.5
Marshall Islands			x	x	x	x	x	4.5
Micronesia			x	Pohnpei	27.2	26.9	27.4	4.5
Mongolia			3.1	Kjujirt	-1.8	-18.5	14.5	1.5**
Myanmar (Burma)	4.1-7.1	1	4.2	Mandalay	27.1	20.9	29.7	3.5
Nauru			x	x	x	x	x	4.5
Nepal			3.1	Kathmandu	18	9.8	23.7	3.5
Pakistan	4.2-6.6	1	3.4	Jacobabad	27.1	15.1	36.9	3.5
Palau			x	x	x	x	x	4.5
Pap. New Guinea	x	x	3.9	Madang	26.7	26.4	26.9	4.5
Philippines			4.2	Cabanatuan	26.9	24.9	28.7	3.5
Samoa			3.4	Apia	26.5	25.9	26.9	4.5
Solomon Islands			4.2	Honiara	26.5	26	26.9	4.5
Sri Lanka			4.5	Kurunegala	27.3	25.7	28.6	4.5
Syria			4.2	Palmyra	18.6	6.7	29.4	3.5
Tajikistan			3.4	Dushanbe	14.7	2.1	27.1	3.5
Tonga			x	x	x	x	x	4.5
Turkmenistan			3.9	Bayramaly	16.8	2.4	30.7	3.5
Tuvalu			x	x	x	x	x	4.5
Uzbekistan			3.7	Bukhara	15.4	0.7	29.6	2**
Vanuatu			4.2	Vila	24.8	23.1	26.5	4.5
Vietnam			3.9	Cantho	28.2	26.7	29.8	3.5
Yemen	x	x	5.3	Tais	27.9	24.1	31.7	4.5

C. South America

Country	Insolation NSOL	Stations NSOL	Insolation Meteonorm (worst case in country)	Meteonorm stations	Ave. annual temp. in Meteonorm stations in C	Ave. monthly low temp. Meteonorm in C	Ave. monthly high temp. in Meteonorm stations in C	Lowest Insolation in country
SOUTH AMERICA								
Argentina			<2.8	Ceres Airport	19.1	12.4	25.7	0.9**
Barbados	4.4-6.3	5	5	Husbands	27.1	25.6	27.8	4.5
Bolivia			3.9	Santa Ana	27.3	25.1	28.8	4.5
Brazil			3.9	Vera	24	21.9	25	3.5
Chile			2.8	Arica	19	16.4	22.3	
Colombia			3.9	Villavicencio	25.3	23.9	27	4.5
Equador			3.4	Puto	20.8	19.8	21.3	4.5
French Guiana			3.9	Maripasoula	26.2	25.6	27	4.5
Guyana	3.7-6.1	16	3.9	Boa Vista	28.5	26.7	29.5	4.5
Haiti	4.3-6.3	2	5	Port au Prince	27.3	25.5	28.8	4.5
Nicaragua	3.4-6.3	7	5	Managua	27.3	26.4	29	5.5
Paraguay			3.7	Mariscal	24.6	18.9	28.7	3.5
Peru	2.5-7.7	60	3.9	Yurimaguas	26.6	26	27.1	4.5
Suriname			3.9	Paramaribo	26.8	26.2	27.5	4.5
Uruguay			3.7	Paysandu	18	11.8	25.3	2.6**
Venezuela	3.6-6.7	79	4.5	San Fernando	26.9	25.7	28.7	4.5

Annex 3: Recommended Accessories for Battery Powered Solar Systems

As a minimum, the list of accessories includes the following per complete system:

1 Thermometer suitable for measuring the electrolyte temperature
1 Hydrometer
1 Compass to assist in the process of site orientation
1 Plastic funnel
1 Plastic jug
1 Acid pump
1 Set, assorted no. of Cable lugs suitable for the various cable terminations
1 Safety acid apron
1 Safety glasses
1 Anti acid gloves

Annex 4: Additional Resources

Links to additional resources specifically on Solar Battery Drive systems.

Description	Source
Harnessing solar energy for health needs	PATH, July 2012
Handbook for Vaccine and Cold Chain Handlers	UNICEF Website (India)

Note: Users of this manual are invited to suggest additional resource materials, to add to this list.

Annex 5: Record of Revisions

Date	Description	By
April 1, 2012	First draft of this manual, by UNICEF SD\HTC\Cold Chain Unit	GK,DH,AS
June 26, 2014	Second draft of this manual	BR
August 20, 2014	Updated, minor corrections	BR
October 28, 2014	Minor corrections	BR