

PROCUREMENT GUIDELINES

**SOLAR DIRECT DRIVE
REFRIGERATORS AND
FREEZERS**

Procurement Guidelines

Solar Direct Drive Refrigerators and Freezers

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

This module gives guidance to the procurement of solar direct drive refrigerators and freezers without battery power storage.

Always make sure that you have the latest version of this document by checking the [CCSP website](#).

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Suggestions and feedback: sd.coldchain@unicef.org

Contents

1	NEEDS IDENTIFICATION	5
1.1	INTRODUCTION	5
1.2	INITIAL INVESTMENT COST	5
1.3	TYPES OF SOLAR DIRECT DRIVE COMPRESSION TYPE REFRIGERATION EQUIPMENT	6
1.4	SOLAR DIRECT DRIVE (SDD) REFRIGERATORS, FREEZERS AND COMBINED REFRIGERATOR/FREEZERS	6
1.4.1	<i>Climatic condition and autonomy</i>	6
1.4.2	<i>Temperature Stability</i>	6
1.4.3	<i>WHO-PQS listed SDDs and freeze protection</i>	7
2	KEY CONSIDERATIONS FOR SOLAR DIRECT DRIVE SYSTEMS	7
2.1	CHOOSING SOLAR DIRECT DRIVE SYSTEMS	7
3	SYSTEMS SUPPLIED BY UNICEF SD	8
3.1	UNICEF SD LTA LIST OF SDDs	8
4	BUDGETING	9
5	ORDERING	9
5.1	STARTING THE PROCESS	9
5.2	DELIVERY LEAD TIMES	9
6	SITE PREPARATION	9
7	TRANSPORT HANDLING	10
8	INSTALLATION	10
8.1	CONSIDERATIONS FOR COs AND PS PARTNERS	10
8.2	TIMING OF THE INSTALLATION	11
8.3	IN-COUNTRY LOGISTICS AND INSTALLATION	11
8.3.1	<i>Installation without UNICEF SD Support</i>	11
8.3.2	<i>Installation with UNICEF SD Support</i>	11
8.4	SELECTING THE INSTALLATION SITE	11
8.5	OPTIMIZATION OF THE PV SOLAR ARRAYS INSTALLATION	12
8.5.1	<i>Selecting a Suitable Site</i>	12
8.5.2	<i>Positioning of PV Solar Arrays</i>	12
8.6	FINALISING INSTALLATION	12
9	COMMISSIONING	12
10	USER TRAINING	13
11	TECHNICIAN TRAINING	13
12	MAINTENANCE	13
12.1	COMMON CAUSES FOR SYSTEM FAILURE	13
12.2	ROUTINE MAINTENANCE	14
13	COMPLAINTS HANDLING	14
14	WARRANTY	14
15	DECOMMISSIONING	15
16	ANNEXES	15
	ANNEX 1: SOLAR DIRECT DRIVE SYSTEMS - INSTALLATION COMPLETION CHECKLIST	15
	ANNEX 3: RECOMMENDED ACCESSORIES FOR SOLAR DIRECT DRIVE SYSTEMS	15
	ANNEX 4: ADDITIONAL RESOURCES	15
	ANNEX 5: RECORD OF REVISIONS	17

Acronyms

CCSP	Cold Chain Support Package
CO	Country Office
DOA	Direct Order Arrangement
LTA	Long Term Arrangement
PHC	Primary Health Care
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

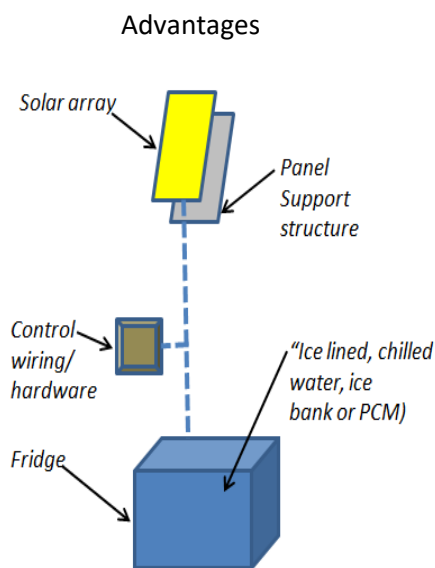
1 Needs Identification

1.1 Introduction

Solar-powered refrigeration equipment runs on electricity provided by solar energy. They are able to keep vaccines at their appropriate temperature, without the need for electricity from a national grid.

Solar Direct Drive refrigeration systems are the new generation of solar powered refrigeration systems bypassing the use of a battery and charge controller. Instead the power is stored using different non battery based technologies. There are currently four technologies existing: PCM (phase change material), Ice-lined (ILR), water-lined and ice bank.

Fig 1. Solar Direct Drive refrigeration systems



- Do not require a battery to store energy
- Do not require electricity and can be used in rural areas where sunshine is abundant
- Do not require solar charge regulators
- Easy installation
- Easy maintenance
- Cheaper in comparison to the battery powered systems

Surveys conducted on Battery Powered Systems have found that a large proportion of equipment failures are related to the batteries. It is not a question of *if* a battery will fail, but rather *when* it will fail. Batteries can fail due to improper design, misuse, poor installation, over use of the refrigerator, overload of the refrigerator resulting in prolonged running cycles and lack of

maintenance and delayed repairs. As a result of the lessons learned with battery-based systems, Solar Direct Drive Systems are the best options and recommended by WHO-PQS.

Solar powered vaccine refrigeration systems are now widely used. They are sometimes the only available solution in areas where no reliable conventional energy supply is available. WHO, PATH and others have conducted several in depth reviews of solar vaccine refrigeration programmes launched in Africa, the Americas and in South-East Asia.

1.2 Initial Investment Cost

Solar powered systems require a high initial capital investment. However, with proper maintenance, the returns are enormous. A comparison of the life time cost of different types of refrigeration systems is given in the PATH publication: [Solar Direct Drive – The Better Option](#).

1.3 Types of Solar Direct Drive Compression Type Refrigeration Equipment

There are three different types:

a. Solar Direct Drive Refrigerator (without freezer compartment)

The entire unit is used only for keeping vaccines cool at a temperature of +2 °C to +8 °C.

b. Solar Direct Drive Combined Refrigerator/Freezer

The unit has two compartments, one for keeping vaccines cool at a temperature of +2 °C to +8 °C and the other for waterpacks freezing at -20 °C

c. Solar Direct Drive Freezer

Waterpacks freezer: Designed for the purpose of water pack freezing at -20 °C

1.4 Solar Direct Drive (SDD) Refrigerators, Freezers and Combined refrigerator/freezers

1.4.1 Climatic condition and autonomy

Vaccine storage refrigerators and Combined refrigerator/freezers are designed to operate in different climatic conditions and exhibit special characteristics. Majority of the Solar direct drive refrigerators and combined refrigerator/freezers listed in current PQS are high performing, which means these devices are able to perform at max ambient temperature of +43 °C and at min ambient of +10 °C or less. All PQS prequalified SDD equipment have an autonomy of minimum 3 days.

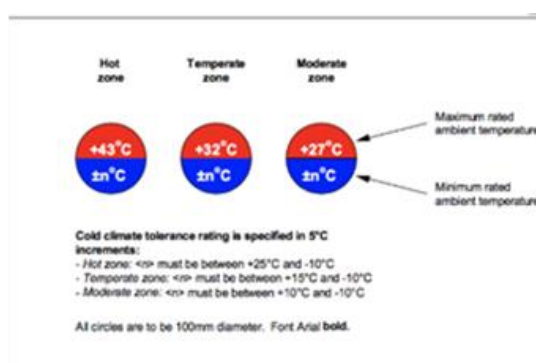
Autonomy (solar refrigerators): is the maximum number of days during which the refrigerator can continue to maintain a full vaccine load at a temperature between +2°C and +8°C when the photovoltaic panels are not generating electricity.

1.4.2 Temperature Stability

An appliance is said to be high performing if it is designed for operation with in an extended ambient temperature range i.e. $\leq +10^{\circ}\text{C}$ min and $+43^{\circ}\text{C}$ max rated ambient temperature.

High performing SDD refrigerators, freezers and combined refrigerator/freezers listed in current PQS are tested for temperature stability at ambient temperatures of + 43°C in WHO accredited laboratories to ensure that the equipment will perform optimally. They are referred as hot zone appliances.

PQS prequalified SDD refrigerators and combined refrigerator/freezers have excellent temperature recovery qualities. Temperature recovery is the fridge's ability to return to its set operating temperature after being exposed to an elevated temperature. The frequency and duration of door openings will raise the internal temperature of the refrigerator and, depending on the temperature recovery properties this may cause unsafe vaccine storage temperatures.



Temperature zone symbol

1.4.3 WHO-PQS¹ listed SDDs and freeze protection

WHO-PQS listed SDD refrigerators and combined refrigerator/freezers are classified as Grade A, B or C based on the number of user interventions required to ensure freeze protection. This is not applicable for freezers.



Grade A

Majority of the PQS listed SDD refrigerators and combined refrigerator/freezers are Grade A, with user-independent freeze protection (UIFP) feature, which means when the appliance is used within its nominated temperature range (upper hot zone temperature +43°C and minimum rated ambient temperature) there is no intervention required by the user to ensure that the vaccines will not be exposed to freezing temperatures outside of the acceptable temperature range, whatever the position of the vaccines in the vaccine storage compartment.

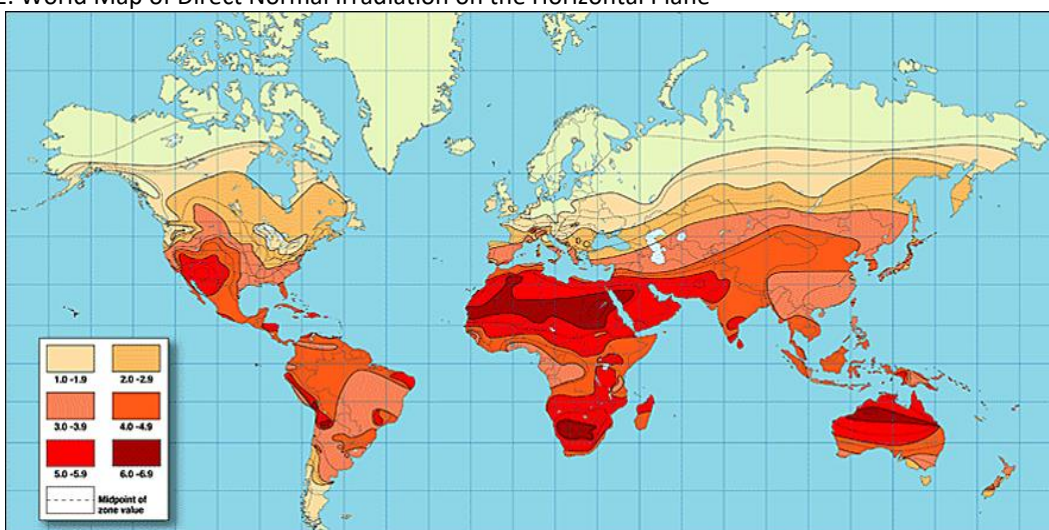
2 Key Considerations for Solar Direct Drive Systems

2.1 Choosing Solar Direct Drive Systems

The choice of solar direct drive equipment for use in country programmes, requires careful analysis and evaluation. The products are appropriate for the safe storage of vaccines in various scenarios and settings as below: For choosing solar powered systems, one would opt for solar powered systems in the following scenarios:

- 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

¹ WHO PQS is the WHO product quality system. PQS stands for Performance, Quality and Safety.

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.

It is essential to ensure that a qualified servicing network is in place to make an on/site assessment, install the systems and provide long-term system maintenance. Replacement of parts such as compressors, thermostats and compressor controllers etc.

3 Systems Supplied by UNICEF SD

3.1 UNICEF SD LTA list of SDDs

UNICEF SD procures a range of Solar Refrigerators/Freezers of varying sizes via Long Term Arrangements (LTAs). As of December 2020 There are 43 PQS pre-qualified solar direct drive refrigerators and freezers. These appliances are prequalified for minimum ambient operating temperature of +5 °C or +10 °C. They are further prequalified under different temperature zones, Hot zone (+43°C) and Temperate zone (+32°C). Appliances (SDD refrigerators and combined refrigerator/freezers) prequalified for minimum ambient operating temperature of +5 °C or +10 °C and maximum ambient operating temperature +43°C are said to be high performing. An SDD freezer prequalified for maximum ambient operating temperature +43°C is also high performing.

Table 1. PQS prequalified SDD refrigerators and freezers available in SD’s LTA (As of December 2020)

SDD systems	Ambient operating temperature		Freeze protection	Volume category	# of equipment	Remarks
	Max	Min				
Combined refrigerator/freezers	+43°C	+10°C or +5°C	Grade A	<30	2	All are high performing except those with +32°C ambient operating temperature
				≥30 <60	5	
				≥60 <90	1	
				≥90 <120	2	
	+32°C			≥90 <120	1	
Refrigerators	+43°C	+10°C or +5°C	Grade A	<30	8	
				≥30 <60	7	
				≥60 <90	3	
				≥90 <120	5	
	+32°C			≥120	1	
Waterpacks freezers	+43°C	Not applicable	Not applicable	≥30 <60	2	
				≥60 <90	1	
Grand Total					43	

Note:

SDD refrigerators and combined refrigerator/freezers are supplied with PQS prequalified 30-day electronic temperature logger

Majority of SDDs listed in PQS are using hydrocarbon refrigerants mainly R600a (Zero Ozone Depletion Potential and low Global Warming Potential)

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 Guidelines](#) 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 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 pole or ground mounting) or a strong stable roof is in place (for roof mounting) to allow for immediate installation to begin².
- 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) 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 array frame, cabling inter-connecting PV solar arrays and connecting the cabinet to the array power under the supervision of the supplier engineer.



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Residents carry a solar panel that will power a UNICEF-provided refrigerator at the Health Centre in the village of Gbandiwlo, in Kailahun District in Sierra Leone.

² Roof or pole 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.

- 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 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 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 UNICEF SD.

- h) Who on the customer side 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, 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 should be allowed for. 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 logistics and 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.

8.3.2 Installation with UNICEF SD Support

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

Should UNICEF SD be chosen to support the service bundle, early communication will help minimize the risk of potential bottlenecks, in particular with regard to the availability of local service provider, practical preparation of storage, delivery of equipment, organizing installation teams and additional training materials. Operational employment plan is a key document to issue tender for the service bundle.

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.

8.4 Selecting the Installation Site

The choice of the site/position for a solar powered PV 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 Arrays 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.

Devices such as these are typically low-cost and non-electronic instrument. They are simple and straightforward 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.³

8.6 Finalising Installation

UNICEF requests that countries complete an Installation Completion Check which is being used for CCEOP. 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 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.

For installation of solar refrigerators/freezers, the installation completion checklist should contain a section that outlines whether the product is installed as per supplier requirement and whether it is working properly, this should serve as confirmation of not only installation but also commissioning.

³ 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.

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, cleaning of solar panel and fault reporting. The User Manual supplied by the manufacturer is an important source of information.

11 Technician Training

Training on solar powered PV 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 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.



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A trained electrician in Bangladesh works on a circuit board for solar charging at the MAWTS training institute in Mirpur, Dhaka.

12 Maintenance

12.1 Common Causes for System Failure

The following are some of the main causes which result in failure of solar powered systems:

Table 2. Common Causes for Solar Direct Drive System Failure

Cause for System Failure	Corrective Action
Tapping power from the SDD system	Do not power other accessories such as radios and lights
Misuse of refrigerator	Do not use the refrigerator for storage of products other than vaccines
Frequent opening of refrigerator	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

More causes for system failure can be found from 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.



© UNICEF/NYHQ2012-0040/Asselin

A worker cleans solar panels on a UNICEF-sponsored solar-powered system near N'Djamena, the capital of Chad.

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

Table 3. Routine Maintenance on SDD Systems

Maintenance Action	Description
Cleaning of the panel faces	The most frequent maintenance need of PV solar arrays 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.
Periodic maintenance check	A professional technician should perform a semi-annual maintenance check, examining wiring connections, mounting bolts, etc 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.

16 Annexes

Annex 1: Solar Direct Drive 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 3: Recommended Accessories for Solar Direct Drive Systems

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

- 1 Compass to assist in the process of site orientation
- 1 Set, assorted no. of Cable lugs suitable for the various cable terminations

Annex 4: Additional Resources

Links to additional resources specifically on Solar Direct Drive Systems.

Description	Source
Direct-drive solar vaccine refrigerators, a new choice for vaccine storage.	PATH, May 2013
Solar Direct Drive – The Better Option	PATH/WHO
Harnessing solar energy for health needs	PATH, July 2012
WHO-UNICEF INTRODUCING SOLAR-POWERED VACCINE REFRIGERATOR AND FREEZER SYSTEMS	https://apps.who.int/iris/bitstream/handle/10665/195778/9789241509862_eng.pdf;jsessionid=0143F7C9D10742FC267F73A7A116CCD6?sequence=1
The Vaccine management handbook	https://apps.who.int/iris/bitstream/handle/10665/255749/WHO-IVB-17.06-eng.pdf?sequence=1
PQS catalogue	https://apps.who.int/immunization_standards/vaccine_quality/pqs_catalogue/PdfCatalogue.aspx?cat_type=device
The UNICEF supply catalogue	https://supply.unicef.org/all-materials/cold-chain-equipment.html

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 9, 2014	Update, minor corrections	BR
September 1, 2014	Update, minor corrections	BR
October 28, 2014	Minor corrections	BR
September , 29,2016	Minor corrections	DH
December 21, 2020	Updated by	TY