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SUPPLY DIVISION

# COLD CHAIN

SUPPORT PACKAGE

# 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.

Document Update: October 05, 2016

Suggestions and feedback: sd.coldchain@unicef.org

# Contents

# Acronyms

| | |
|---|---|
| BPS | Battery Powered System |
| 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 |

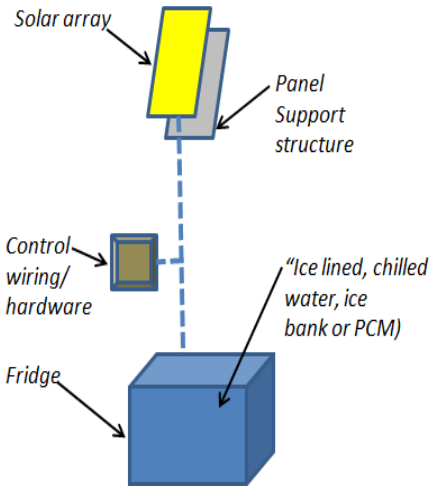
# 1 Needs Identification

## 1.1 Introduction

Solar-powered refrigeration equipment 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. The first SDD, based on an ice bank technology, has been supplied since 2007 and there is fair amount of data available for that category. The other three technologies started to be supplied in 2011-2014 and consequently limited performance data exist from a field setting,

Fig 1. Solar Direct Drive refrigeration systems




Advantages

- 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

Disadvantage

- Relatively new innovation lacking data on performance for the long term analysis

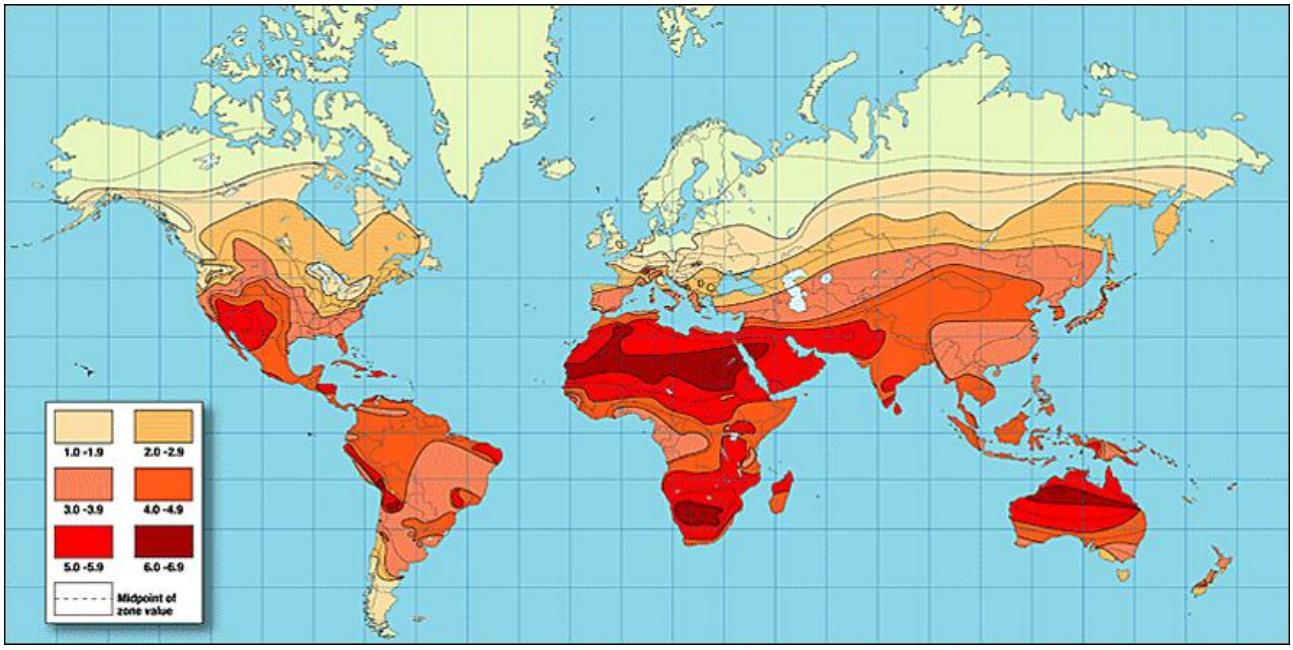
## 1.2 Choosing Solar Powered Direct Drive Systems

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. Programmes relying on batteries must plan for, and fund, the inevitable repair and recurrent replacement costs of batteries. As a result of the lessons learned with battery-based systems, industry and partners have developed battery-less systems, named Solar Direct Drive Systems.

The choice of solar equipment for use in country programmes, whether battery-based or direct drive, 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

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 Solar Direct Drive Refrigerators

UNICEF SD procures a range of Solar Refrigerators/Freezers of varying sizes via Long Term Arrangements (LTAs). For details refer to Section 3. All UNICEF procurement of solar refrigeration systems must be undertaken through Supply Division (SD).

## 1.4 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.

# 2 Key Considerations for Solar Direct Drive Systems

## 2.1 Choosing Solar Power as Energy Source

The Procurement Guideline "Battery Powered Systems" provides a detailed justification for choosing solar powered systems under certain circumstances and conditions. In short, 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.

## 2.2 When to Choose Solar Direct Drive Systems

Once the decision has been taken to opt for a solar powered system, there remains the choice to be made between battery-powered and direct-drive (battery-less) systems. The initial cost of Solar Direct Drive Systems is generally higher than Battery Powered Systems, when comparing the same vaccine storage volume. However, a distinct advantage of SDD over BPS is the absence of the battery bank. In view of the fact that batteries are often the main cause for system failure, the extra cost may be justified.

# 3 Systems Supplied by UNICEF SD

## 3.1 SolarChill Based Technology

On March 18, 2010, the World Health Organization prequalified its first solar direct drive vaccine refrigerator (Vestfrost model MKSO44). Ten years in the making, the SolarChill based technology vaccine refrigerator operates with a compressor powered directly from sunlight. Direct-drive" technology uses the sun's energy to freeze water or other material and then uses the cooling from that "ice bank" to keep the refrigerator cold during the night and cloudy days to maintain the vaccine temperatures between the recommended temperature of +2 to +8°C. In low-sun insolation situations or with power completely disrupted, the insulated ice bank of SolarChill maintains acceptable temperatures for up to five days. The convectional circulation of the cold air recharged by the solar power.

As per September 2016 there are thirty six (36) PQS qualified solar refrigerators either SDD or BPS 31 of which are SDDs. These refrigerators are prequalified for minimum ambient operating temperature of +5 °C , +10 °C , 15 oC, +20 °C and 25 oC. and are further prequalified under three temperature zones temperate, Hot, and Multi zone.

The following SDD systems are supplied by UNICEF SD, from various manufacturers:

Table 1. SDD refrigerators and freezers available under PQS (As of September 2016)

| | Refrigerator | Combi ref/freezer | Two-mode ref or freezer | Freezer |
|---|---|---|---|---|
| # <30 Litre | 8 | 1 | 0 | 1 |
| # 30 - 60 Litre | 5 | 2 | 0 | |
| # 60 - 90 Litre | 2 | 1 | 0 | |
| # 90 - 120Litre | 4 | 3 | 0 | |
| # >120 Litre | 4 | 0 | 0 | |

There are varying emerging technologies for use with the direct current compressor:

(1) Ice bank design
(2) Ice lined design
(3) Water lined, and
(4) Use of Phase Change Materials (PCMs).

Lead acid batteries are expensive, short-lived (especially in hot climates), toxic to produce and difficult to dispose of properly in remote regions. They represent a major obstacle to the uptake of solar technology in developing countries.

To learn more about the SolarChill based technology refrigerator and the partnership that made it happen, visit www.solarchill.org.

## 3.2 WHO-PQS Listing

To prequalify the technology for product listing in the PQS[1], WHO established two new categories for refrigerators in its Performance, Quality, and Safety (PQS) standards, and developed both the WHO PQS E03 RF5 for battery-free solar direct refrigerators or combined refrigerator/icepack freezers and the WHO PQS E03 RF06 for solar direct drive refrigerators or combined refrigerator/icepack freezers that require a small ancillary rechargeable battery for control purposes. The MKS 044 l (19.5 litre capacity) was the first to fit the latter category.

Gaining WHO prequalification marked a significant milestone in the effort to produce an environmentally-friendly and battery-free solar refrigerator. Prior to the establishment of the new PQS categories, all prequalified WHO refrigerators using compressors included hydro-fluorocarbons (HFCs) as refrigerants. HFCs are pollutants that contribute to ozone depletion and climate change. Concerns about atmospheric concentrations of powerful greenhouse gas HFCs and their significant impact on climate change have made them less-than-ideal technologies for health systems. Instead of using fluorocarbons, all but one of the PQS listed Solar Direct Drives uses hydrocarbon gas as the refrigerant. This is a technology developed by Greenpeace in 1993 for insulation foam blowing, which makes them safe for the ozone layer and the climate.

[1] UNICEF SD procures pre-qualified and listed equipment that conform to the WHO guidelines for developing countries and those in transition.

# 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:

© UNICEF/NYHQ2011-0744/Asselin

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.

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[2].
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.

[2] 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.

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.
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 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 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 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 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.[3]

## 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 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 , 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.

# 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 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



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

[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.

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 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 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 |
| 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 |

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.



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, 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.

# 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 2: 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 3: 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 |
| SolarChill Resources | SolarChill website |
| Handbook for Vaccine and Cold Chain Handlers | UNICEF Website (India) |
| WHO-UNICEF guidelines on solar refrigerators 2-1 (expected to be posted on the web in 2014) | (to follow) |
| | |

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

## Annex 4: 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 |
| October 5, 2016 | Minor corrections | ANM |