The 11 Commandments of a proper introduction of solar cold chain equipment

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Introduction

The National Expanded Programs on Immunization (NEPI), since its implementation in developing countries and precisely in sub-Saharan Africa, has significantly contributed in reducing both child mortality and morbidity. The NEPIs have achieved this success because of the solidity of their cold chain and logistics systems as the vaccines are thermo-sensitive products which generally need to be stored between +2 and +8°C. The NEPIs, especially for remote areas with erratic or no access to grid electricity, relied mainly on absorption refrigerators (usually fueled with kerosene or bottled gaz) to store the life saving vaccines. The main advantage of these refrigerators is that they can be used at I in remote areas; but the availability of kerosene or bottled gaz in addition to their high running and maintenance costs associated with poor temperature controls (especially with kerosene) and the development of the solar refrigerators render them obsolete and hence their absence from WHO's PQS. Even though solar refrigerators have been remotely used for over 30 years, it is only in the last decade that many countries, precisely in sub-Saharan Africa, are transitioning from absorption to solar refrigerators especially for remote health service delivery centers.

Under the LOGIVAC project, AMP assisted the Benin's Ministry of Health (MOH) to implement the EVM+HERMES and CCEM initiative with the sole objective of optimizing the vaccines supply system. LOGIVAC is a three-year project funded by the Bill & Melinda Gates Foundation that provides technical support to increase the capacity and competence of health logisticians (or supply chain managers) in sub-Saharan Africa. The project is jointly implemented by the Agence de Médecine Préventive (AMP) and the World Health Organization (WHO) in collaboration with regional public and private partners.

To this end, two workshops were organized, in Benin by the MOH and AMP, for EVM+HERMES and CCEM initiative. During the second workshop, Benin, through its Ministry of Health, has made four strategic orientations:

- Professionalization of operations management at the Health Zone level
- Consolidation of the vaccines storage at the 34 Health Zone instead of the 84 communes
- Acquisition of solar cold chain equipment in replacement of the absorption refrigerators
- Search for integration at the Health Zone level.

This document concerns the third strategic orientation which is the implementation of solar cold chain equipment in replacement of the absorption refrigerators in LOGIVAC's demonstration site (Comé Health Zone).

Solar refrigerators and freezers

Solar refrigerators and freezers collect their energy source from sunlight through a process known as photovoltaic (PV), which is the direct conversion of sunlight to electricity. There are two types of solar refrigerators: with battery-driven compressors or with solar direct drive (SDD) compressors without a large battery.

- Solar battery refrigerators (fig.1): the components include the PV modules, the refrigerator/freezer, the regulator and the battery

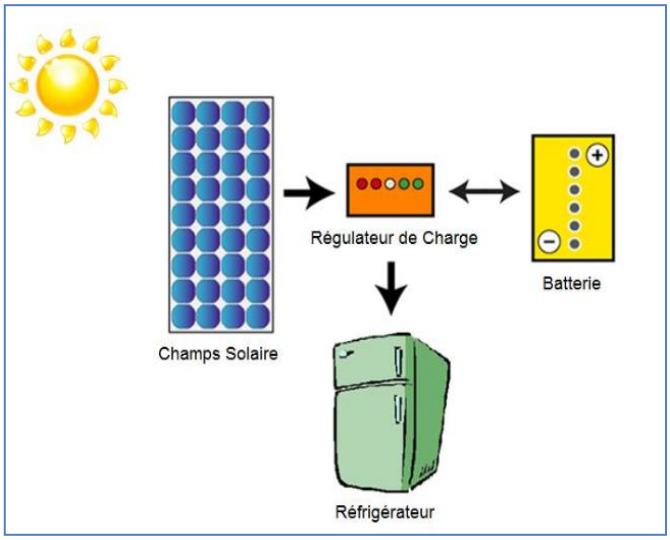


Figure 1: Sketch of solar refrigerator with battery (included in the figure are the solar panels, the regulator, the batteries and the refrigerator)

Source: SELF-AMP (2013). "Technicians training in solar refrigeration – Lesson 2: Solar Refrigerator/Freezer Systems, Components and Operation" SELF-AMP 2013.

- Solar direct drive refrigerators: the components include the PV modules and the refrigerator/freezer.

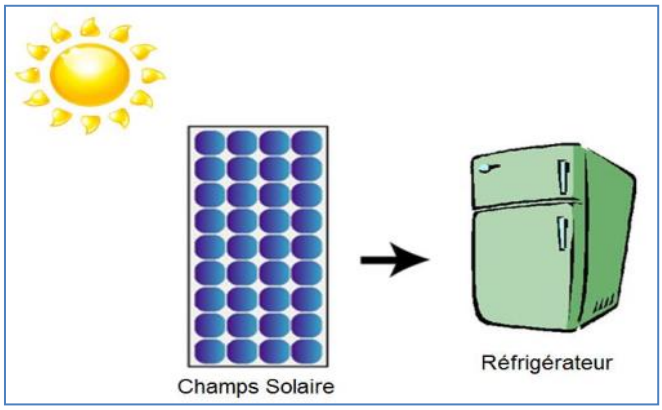


Figure 2: Sketch of a solar direct drive refrigerator (without battery) (included in the figure are the solar panels and the refrigerator)

Source: SELF-AMP (2013). "Technicians training in solar refrigeration – Lesson 2: Solar Refrigerator/Freezer Systems, Components and Operation" SELF-AMP 2013.

The following table provides a comparison of the two types of solar refrigerators.

Table 1: Comparison of the two types of solar refrigerators

Attribute	Solar Battery	Solar Direct Drive
WHO PQS prequalified	Yes = 6 (April 10, 2013)	Yes = 7 (April 10, 2013)
Refrigerator only (net volume)	1 (126.5 liter vaccine storage)	5 (19.5,21, 54.5, 99, and 156 liters)
Combined Refrigerator/Freezer	4(37.5, 37.5, 76, and 86 liters)	1(99 liters)
Either Refrigerator or Freezer	1(109.5 liters)	0
Technology maturity	30+ year cold chain experience	Limited experience, first PQS in 2011
Reliability	Battery replacement every 5 years	No battery, less electric connections
Complexity	Installation more complex	Site assessment more complex
Climate adaptability	PV &/or battery can be increase	Limited PV adjustment, storage fixed
Transport	More volume, battery hazards	Less volume, no battery hazard
Installation	Longer, battery space required, same day acceptance tests	Shorter, low sunlight can prevent same day acceptance tests
Capital Cost (2013)	equal	equal
Life Cost (estimated)	higher	lower

Source: SELF-AMP (2013). "Technicians training in solar refrigeration – Lesson 2: Solar Refrigerator/Freezer Systems, Components and Operation" SELF-AMP 2013.

Objective

The primary objective of this document is to provide a step-by-step approach of a successful acquisition/introduction of solar cold chain equipment for vaccines management based on the experience gained by AMP in Benin.

The steps, which are called "commandments", provide the NEPIs and/or their technical and financial partners (TFP) detailed information regarding the introduction of solar cold chain equipment. It is recommended that the NEPI and/or their TFP follow the commandment in the specified order to increase the chance of successfully implementing solar refrigerators/freezers in replacement of absorption ones in remote areas with poor or no access to grid electricity.

Commandment 1: Site identification and updated cold chain equipment inventory

The first commandment in the "solarization" process is the identification of sites that should receive the new solar cold chain equipment based on pre-established criteria. In Benin, AMP, through the LOGIVAC project, conducted a thorough situation analysis and cold chain equipment inventory of the 37 service delivery points and 4 lowest distribution level stores in its demonstration site (Comé Health Zone, Benin). These two activities have enabled to identify the sites that should receive the new solar cold chain equipment. LOGIVAC has taken into account the 2nd strategic orientation made by Benin's Ministry of Health during the second EVM+HERMES & CCEM[1] workshop that was held in Cotonou (Bénin) on September 20th and 21st 2012,which stated to progressively replace the current absorption refrigerators by the solar ones for the service delivery points.

The two criteria set forth by the LOGIVAC team and the local health authorities were to prioritize service delivery points that lack an active cold chain equipment and the ones that have difficulties paying (due to a lack of frequentation) and accessing kerosene to run their absorption refrigerator.

Based on these criteria, seven service delivery points were identified.

Lessons learned

- **Priority is given to health centers that do not have access to grid electricity**
- **An updated inventory should be available or should be realized**

1 Ministère de la Santé du Bénin, Agence de Médecine Préventive (2012). Rapport du deuxième atelier d'optimisation de la chaîne logistique des vaccins du PEV au Bénin

Commandment 2: Estimating the required volume

The second commandment is to determine the required cold chain volume. In order to determine this volume, one needs the following data:

- Demographic data:
    - Total population and target populations per site,
    - National population growth rate.
- EPI Data:
    - Current EPI
        - Vaccines' presentations and formulations
        - Current EPI schedule
        - Targeted coverage and wastage rates per antigen
    - Planned future vaccine introduction
        - Vaccines' presentations, formulations and years of introduction
        - Future EPI schedule
        - Targeted coverage and wastage rates per antigen.
    - Campaigns
        - Vaccines' presentations and formulations
        - Targeted coverage and wastage rates per antigen

These data will enable to estimate the required vaccine volume per Fully Immunized Child (FIC). LOGIVAC determined the current and future required vaccine volume per FIC using the WHO EPI Logistics Planning Tool even though the Vaccine Volume Calculator Tool could also be used to rapidly estimate the volumes. It is important to note the computation of required cold chain capacities must be done using the data valid for the last year of the planning period, i.e. the fifth year of a five-year plan. One can debate that this 2nd Commandment should take place before choosing technology, but the starting point should be a valid updated cold chain inventory. The following table provides the antigens and their estimated volume per FIC of all vaccines used in Benin for routine EPI and for possible SIAs.

Table 2: Vaccine storage estimates

Characteristis of vaccines selected for use							Vaccine wastage			Target Group
Vaccine	Presentation (dose/vial)	Packed volume national data		Maxi packed volume from data base		Price of vaccine	National vaccine wastage figures	\\\HO/GAVI indicative wastage rates	\\\astage factor	
choose from dropdown list	choose from dropdown list	Vaccines (cm³/dose)	Diluents (cm³/dose)	Vaccines (cm³/dose)	Diluents (cm³/dose)	($US/dose)				Enter as % of total population
BCG	20			1,2	0,7			50	2,00	4,0%
OPV	20			1,0			17	25	1,20	3,9%
DTP-HepB-Hib	10			2,6			15	25	1,18	3,9%
Measles	10			3,5	4,0		45	40	1,82	3,9%
YF	10			2,5	6,0		45	40	1,82	3,9%
PCV-13	1			15,7				5	1,05	3,9%
TT	10			3,0			15	25	1,18	5,0%
bOPV1+3	20			1,1			10	25	1,11	22,0%
mOPV1	20			1,1			10	25	1,11	22,0%
mOPV3	20			1,1			10	25	1,11	22,0%
Men A	10			2,6	4,0		15	40	1,18	70,0%
OPV	20			1,0			10	25	1,11	22,0%

Source: Vaccine Volume Calculator

Lessons learned

- **The vaccines storage volume per FIC should be estimated**
- **The target population for each health center should be determined**
- **These two above information should enable to determine the vaccines volumes required per health center**
- **Proceed the same way with SIAs**

Commandment 3: Identification of a technical partner with appropriate expertise

The third and important commandment is the identification of solar technical partner. It is seldom that EPI has this technical expertise internally. The first partner should be the Directorate in charge of Infrastructure, Equipment and Maintenance (DIEM) or its equivalent within the Ministry of Health. In the search of sustainability and health system strengthening, this directorate should be supported to ensure the planning, supervision, technical reception and evaluation of the "solarization" process (from ordering to installation and maintenance). In case the sought capacity is not in-house, it is better to look for specialized private firms that have great expertise not only in solar system, but also in the site assessment, installation and maintenance of WHO pre-qualified solar cold chain equipment. Selected firms must have been agreed upon with solar system Qualified Suppliers in order for their warranty period to remain valid which is generally done by having at least one technician that has received trainings from the Quality Suppliers.

However, if this expertise is not available within the private sector, then the DIEM (or its equivalent) can be tasked to carry out the installation work provided they have engineers and/or technicians who are well versed in solar engineering. Once again, solar system Qualified Suppliers' agreement must be sought to make sure their warranty still remains. Typically, solar system Qualified Suppliers approve DIEM and/or private firms when at least one of their technicians comes to the country to provide them with on-site training on installation and maintenance of solar refrigerators.

AMP, developed the Terms of Reference (ToR) for site assessment, installation of two refrigerators, technicians and end-users 'training and maintenance, and after a thorough analysis in Benin decided to request technical assistance from a solar dedicated NGO. In agreement with the Qualified Suppliers for the safeguard of their warranty, AMP contracted the Solar Electric Light Fund (SELF[2]), a US-based not-for-profit organization, which has more than 23 years' experience in the solar system to assist in this interesting and challenging undertaking. It is noteworthy to state that SELF has been contracted not only because of its impressive technical expertise; but also because of its presence in Benin. Once the partner has been identified and selected, the next step includes the development of a contract. This contract should be based on the already developed ToR.

Lessons learned

- **The MoH, especially EPI should have experience outsourcing with private firms**
- **The EPI should have the expertise necessary to develop ToR, to disseminate them, to develop analysis criteria and to select the appropriate private partner**

[2] SELF'swebsite is www.self.org

Commandment 4: Site assessment

Once the contract signed by the various parties (generally the EPI and the technical partner), in our case by AMP and SELF, the site assessment can be planned. It is very important to inform the local health authorities of this visit and to request the availability of one local agent who may guide to the various sites.

This site assessment is the most critical element in succeeding the introduction of solar cold chain equipment[3].

This assessment will enable to determine the following essential information necessary for equipment and manufacturer selection:

- GPS coordinates
    - These coordinates should be sent to the various Qualified Suppliers for free radiation, precipitation (rainfall) and meteorological analyses, which will enable them to determine which type (battery-driven or direct drive) of solar equipment is appropriate for each location.
- Other important issues
    - Cable lengths and sizes based on the room in which the refrigerator will be installed and the place where the solar panel will be situated
    - Installation type for solar panels
        - On a pole or on roof top again based on the room in which the refrigerator will be installed

    - Anti-theft system
    - Installation materials that need to be purchased locally
        - Poles
        - Sand
        - Concrete
    - Access to the sites (this can be difficult during rainy seasons)

[3]It is noteworthy to inform that while AMP, the local authorities and SELF performed the sites assessments; SELF was developing and customizing the technicians and users 'trainings materials.

These assessment results will enable to select the appropriate equipment and to determine the necessary accessories such as poles, cable lengths and sizes, extra panels, etc. The appropriate tools necessary and used by AMP and SELF during this phase were the following:

Table 3: Site assessment tools

Flashlight Rechargeable (With Charged Batteries)
Ladder
Compass
Solar Sitting Device (Solar Pathfinder With Tripod, Box, Extra Wax Pencil, Extra Sun path Diagrams)
Inclinometer (Measures Roof Angles)
Tape Measures (10 Meter)
Tape Measures (30 Meter)
Camera (Charged with storage)
20 Piece screwdriver Set (Stanley)
First Aid Kit
Pencils And Notebooks
Clamping Ammeter
Multimeter11 Function meter
Batteries 9 Volt For Meters
Batteries AAA For Meters
Shovels

The assessment may take from two to three hours, in each location, depending on the characteristics of the service delivery point.

In addition of the above-mentioned characteristics, the selection of the equipment also depends on the required storage capacity and thus the link to the overall required vaccine volume per FIC. Indeed, the capacity of any active cold chain equipment, in our case of the selected solar cold chain equipment per FIC, according to Mr. Souleymane Koné from his 2012 “Global Vaccine Volume Estimates”, should be superior (>) to the required vaccine volume per FIC[4].

The site assessment should yield a report specifying which equipment and the complementary tools to acquire.

[4]S. Koné (2012). « Global estimates of the cold storage capacity for new vaccine introduction for GAVI supported countries » (OMS/HQ/IVB, 2012).

Lessons learned

- **The radiation, precipitation and meteorological analyses advised for battery driven refrigerators advised for battery driven**
- **The site assessment tools mentioned in table 3 or their equivalent should be available**
- **The health centers should be informed prior to the arrival of the site assessment teams**
- **The appropriate mode of transportation should be made available**

Commandment 5: Equipment acquisition

After validation of the site assessment report, the next phase consists in an efficient acquisition of the selected equipment. The use of updated WHO-PQS data is critical as this provides not only the price of the equipment, but also the accompanying accessories and the contact (email) of the manufacturer. However, a pro-forma can be obtained from UNICEF's country office. This phase is very important as the manufacturer needs to receive details regarding the cable lengths and sizes, the mounting options (poles or roof), etc. The Appendix 1 provides the list of other materials and tools that AMP procured in addition of the solar cold chain equipment kit (provided in the WHO-PQS).

AMP, upon SELF's report, decided to acquire seven solar battery driven refrigerators from Dulas (VC-65-2) and one solar direct drive from SunDanzer(BFRV-55). This sole direct drive was installed in a lowest distribution level to determine its performances. This distribution level already has 3 compression refrigerators just in case if anything happens to the solar direct drive. Again this will provide direct hands on experience with the SDD technology in South Benin.

In order to smoothen this phase, AMP lacked the required technical expertise in-house and therefore requested SELF to lead the technical discussions (cable sizes, voltage, type of mounting poles, type of cable protections) with manufacturers.

In the case the country procures cold chain equipment through UNICEF Supply Division, after validating the site assessment report, the EPI team should directly contact UNICEF through their country representation, to acquire the selected equipment and tools. UNICEF and the EPI's technical partner might hold technical discussions with Qualified suppliers as aforementioned it is seldom that the EPI team has the necessary technical know-how in-house.

In the case of countries that procure directly their cold chain equipment from Qualified Suppliers, the technical partner must be able to advise EPI on this matter. These countries must order only WHO-PQS pre-qualified equipment.

Lessons learned

- **An Updated WHO-PQS should be utilized**
- **There are other tools and materials that need to be purchased as expressed in Appendix 1**
- **UNICEF needs to be involved throughout the entire process**
- **A significant technical expertise is required to hold discussions with manufacturers (UNICEF SD could play this role if the countries pass with UNICEF to procure the equipment**

Commandment 6: Equipment reception

Once payment is made, the manufacturer will ship the material via its own forwarder. The EPI team, through UNICEF or the technical partner, should request the following critical transportation documents, which vary based on the modes of transportation utilized. Indeed, a **bill of lading** should be provided if the materials are sent by sea; while an **airway bill** is necessary if they are sent by air. Irrespective of the modes of transportation, the buyer (in our case AMP or the country in general) should also request the Electronic Cargo Tracking Note (BESC), which is mandatory for customs clearings.

Prior to the arrival of its goods, which combine both the sea and air modes of transportation, AMP contacted its transit agent to prepare the arrival of the materials. In addition to contacting a transit agent, LOGIVAC also prepared the locations where the equipment will be stored before their transfer to the various installation sites (health centers).

Lessons learned

- **The store where the equipment and supplies will be held need to be identified prior to the arrival of the materials**
- **All documents should be immediately shared with the transit agent/institution**
- **The store agents need to be debriefed about the storage conditions and the weight of the various wooden crates**

Commandment 7: Technicians' training

It is recommended to schedule the technicians' training only upon reception of the equipment or to plan it with sufficient lead time after the manufacturer confirms the shipment of the acquired equipment. AMP previously planned this training 4 weeks after the shipment of its seven solar battery driven refrigerators; but due to circumstances linked with the forwarder, the refrigerators only arrive in Cotonou after 8 weeks. This delay has had consequences on AMP-SELF technicians' training.

AMP and SELF developed an exhaustive training content for technicians. This training lasted 10 days with the first 5 days being based on theory and the remaining 5 days on the actual installations of two refrigerators: one direct-drive and one battery-driven. The content of the training is provided in the following table.

Table 4: Technicians' training content

Solar Electricity and Health Care - Project Overview
Solar Refrigerator/Freezer Systems, Components and Operation
Safety
Solar Electricity Basics
PV Modules
LAB: PV Module Measurements
PV Array Mounting Structures
PV Array Wiring
Refrigerator/Freezers and Placement
LAB: Pre-installation Site Assessment
Batteries
Battery Charging and Controls
Temperature Monitoring
Planning Installation Logistics
LAB: Battery Wiring
Installation Preparation, Pretest and Commissioning
Maintenance
Troubleshooting and Repair
User Training
On Site Installation

This training was conducted by experienced professional agents from SELF whom have an extended experience in training and in installing solar refrigerators. It is important for the various MoH to select trainees from not only EPI; but also from the Directorate of Infrastructure, Equipment and Maintenance (DIEM). Hence, AMP supported the participation of one agent from EPI and two from the DIEM. Moreover, given that these refrigerators were installed in LOGIVAC's demonstration,

agents from Come Health Zone and from a private firm (Esor Ika), which is contracted to maintain the cold chain equipment present in the health zone. The trained agents from the MoH (DIEM and EPI) will be responsible of assisting EPI in its process of introducing solar refrigerators by providing future training to other technicians. AMP not only supported training, but also acquired tools necessary for the entire installation and maintenance of the various solar refrigerators. The Appendix 2 provides a list of tools necessary for the laboratory exercises, the installation and maintenance of the solar cold chain equipment. AMP made sure to purchase two sets of the above mentioned tools as one will be given to Benin's MoH and one will be kept for future AMP trainings in solar refrigeration.

Lessons learned

- **An excellent training material should be utilized or developed for the training**
- **The training needs to be facilitated by experienced facilitators**
- **The necessary tools, presented in Appendix 2 or their equivalent, need to be available**
- **The training should be scheduled at least 8 weeks starting from the period the manufacturer confirms reception of the funding or after UNICEF confirms payment**
- **The training needs to be theoretical and practical with installation of at least one solar cold chain equipment**
- **The training participants need to be selected according to their roles and responsibilities (engineers, technicians, logisticians)**

Commandment 8: Equipment Installation

Equipment installation should take place immediately after the 10-day training in order to capitalize the lessons learned. AMP contracted the trained agents from DIEM and Come health zone to proceed with the installation of the 6 remaining refrigerators. It is important to provide at least two and a half days per health facility. The two days for the installation of the refrigerator and the remaining half a day for user training. This user training was included as part of the technicians' training. Moreover, regarding battery-driven refrigerators, installers will have to get back to the facility two days later to launch the refrigerator by setting the fuse in its required place. Indeed, it takes two full days for the batteries to be fully charged[5]. Hence, the importance of developing an appropriate installation circuit, which will enable the installers to eventually go back to the facilities for the launching of the solar battery-driven refrigerators. This process might not be necessary for some models of solar direct-drive refrigerators; other models, however, requires several days (up to one week) of running in order to fully freeze the water for the ice-lining (for instance the SureChill model formerly called TrueEnergy).

Depending on the type of installation, roof top or poles, the following additional tools and accessories were locally acquired by AMP for the installation of the remaining 6 refrigerators.

[5] However there is another way that professionals from SELF tend to use. They pre-charge the battery before going to the site, then install it with a full charge, commission the fridge and this therefore avoids a return trip.

Table 5: Locally acquired materials and tools

Tools
4” Nominal Galvanised Steel Pole, 6 Meter
3” Nominal Galvanised Steel Pole, 6 Meter
4" Aluminium Cap
3" Aluminium Cap
Cement
Sand
Gravel
Water
Cordes 20m
Tip # 8
Form Wooden Boards
Poles (Teck) Or Other
Galvanized Wire
Polyurethane Expensive Foam
Corrosion Paint
Rubber

Nominal Galvanized Steel Pole and Aluminum Cap

Poles were used for 4 out of the 8 installations that were made. The utilization of poles required addition cable lengths and larger cable diameters (**Commandment 4**).

Once installation is completed, it is imperative for the EPI team to visit the facilities in order to verify the functionality of the equipment and to determine if the health agents have received efficient user training.

A team composed of AMP and Come health zone agents have spent two days to verify the work done by the installers. This monitoring and evaluation has enabled the team to debrief health agents on the arrangement of vaccines in the new solar refrigerators and also on the importance of preventive maintenance.

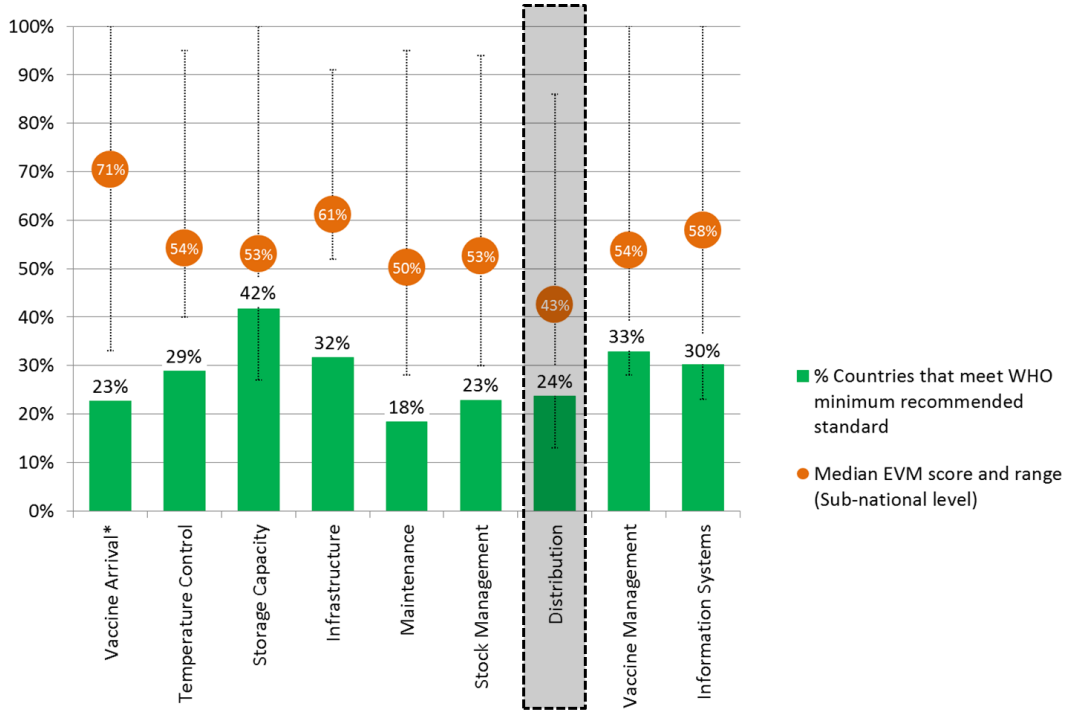
Lessons learned

- **The equipment installation should immediately take place after training**
- **The cold chain equipment and all necessary tools and materials need to be transported to the various installation sites**
- **An installation circuit needs to be developed in order to maximize the start-ups of the refrigerators**
- **The resources need to be made available for immediate supervisions at the end of each installation and for monitoring**
- **The presence of masons and at some lesser point of carpenters is a necessity (especially for poles top installations)**

Commandment 9: Maintenance

Maintenance is critical to safeguard the longevity of any equipment including solar cold chain equipment. However, maintenance and distribution are the two major bottlenecks as expressed in the following Figure.

Figure 3: Overall EVM scores by criteria and by level in 57 GAVI countries



Source: Patrick Lydon "GAVI Alliance Immunization Supply Chain Strategy – System Design and Optimization Priority Working Group" WHO analysis (2013).

AMP made sure that each health agent received training on how to effectively operate the solar cold chain equipment (readings of the regulator for battery driven refrigerators, loadings of ice packs etc.). In addition to that, the health agents received training on the various preventive maintenance tasks as part of a global EPI Logistics training that was facilitated by AMP. Moreover, AMP acquired a material which enables to perform the most critical task of solar cold chain preventive maintenance that is the cleaning of the solar panels. This material is called "Mr. Long Arms". AMP, in 2013, implemented a moving warehouse system which delivers vaccines and consumables to each of the 37 health centers. AMP stressed that the logistician in charge of the moving warehouse performs the cleaning of the solar panels[6].

[6] This logistician has received a one year Bachelor's degree training in Health Logistics Management. He was sponsored by AMP and WHO joint LOGIVAC Project. He is in charge of the both vaccines and other pharmaceuticals' warehouse at Comé health zone.

The curative maintenance of the entire cold chain equipment present in Comé Health Zone, including the eight (8) solar cold chain equipment acquired by AMP, is outsourced to a private firm called Esor Ika. Two agents from this private firm participated in AMP-SELF 10 days training. They were sponsored by AMP. These two agents, in addition to the zonal technician and the agents from DIEM who have all received AMP-SELF training will proceed with the curative maintenance in case of a failure. This private firm quarterly visits each health center and it is also immediately available for repairs.

Lessons learned

- **The training content should include a module on preventive maintenance and proper utilization of the solar cold chain equipment**
- **Agents need to be aware of the various preventive maintenance tasks they should perform daily, weekly and monthly**
- **The appropriate tools such as Mr. Long Arms and a ladder should be procured for cleaning the solar panels**
- **Qualified technicians, who have received proper trainings, need to be identified and available**
- **A SOP regarding preventive maintenance need to be developed for health agents**
- **Resources and expertise need to be available in order to facilitate monitoring and evaluation of the maintenance function (when it is outsourced)**

Commandment 10: Monitoring the performance of the newly installed equipment

The utilization of the 30 days continuous temperature monitoring devices is critical to monitor the performance of the newly installed solar equipment. Benin's EPI implemented the recommendation from the EVM improvement plan as it acquired, through UNICEF, and distributed LogTag for every single refrigerator. AMP procured one Fridge-Tag2 for the sole direct-drive refrigerator as this one was installed in a health center that did not have any other LogTag.

After 3 months, the monitoring data confirm that the 08 solar refrigerators installed by AMP in its demonstration site have been performing very well as they have not been any temperature excursions outside of the +2°C and +8°C range. One can therefore consider these installations to be successful as after the cool down period the equipment have been working in the correct temperature ranges for the last 2 and half months.

In addition to the utilization of the 30DT monitoring devices, AMP (LOGIVAC) also implemented the WHO "District Data Vaccine Management Tool (DVD-MT)" at the zonal warehouse. This tool will enable to prevent vaccine stock outs through an efficient stock management. Indeed, a comprehensive implementation and continuous monitoring of the DVD-MT will enable (a) to manage and control the temperature of the cold chain equipment and (b) to correlate coverage and vaccine management data.

Lessons learned

- **Each newly installed refrigerator should be equipped with a 30 Days continuous temperature monitoring devices**
- **A monitoring tool such as the DVDMT or its equivalent should be installed and used in order to monitor the performance of both the logistics and the overall EPI system**
- **Resources need to be available for direct supervision and monitoring activities**

Commandment 11: Budget

One of the most important lessons learned by AMP, through its joint LOGIVAC Project with WHO, is that there are other costs beyond the ones described in the WHO-PQS. Indeed the following table 6 provides the costs for the Dulas VC 65-2 and the SunDanzer BFRV55.

Table 6: Equipment costs

Equipment	Costs	Accessories included in the price
Dulas VC 65-2	2 800 Euros (3 700 USD)	Solar panels, locking door, external temperature indicator, storage baskets, manual
SunDanzer BFRV 55	2 300 USD	2 baskets, lock and manual

The capital cost per each of the 8 refrigerators procured by AMP for LOGIVAC's demonstration was roughly 8 863 USD. This capital cost includes the acquisition, the transport & customs clearance, the technicians' training and the end users training. This cost is 2.40 and 3.85 times the costs, in USD, described in the WHO-PQS for respectively the Dulas VC 65-2 and the SunDanzer BFRV55. This, therefore, implies that to successfully implement solar cold chain equipment, countries should mobilize more financial resources than the ones presented in the WHO-PQS.

The Appendix 3 presents the detailed cost estimates realized by AMP. These costs, however, are only indicatives and do not include the Human Resources from AMP.

Lessons learned

- **The effective installation of both types of solar cold chain equipment requires more financial resources than the ones related presented in the WHO-PQS**
- **The capital cost for one solar cold chain refrigerator, as estimated by AMP, is 8 863 USD**
- **This cost is 2.40 times the one for the Dulas VC 65-2 and is 3.85 times the one of SunDanzer BFRV 55**
- **The WHO-PQS only provides the Ex-works costs estimates**

Conclusion

The above-listed 11 commandments are drawn from two sources:

a) The theoretical content and practical lessons learned from the Technician Training Package prepared and ran with the support of SELF;

b) The field experience gained by AMP through the installation and early monitoring of 08 solar refrigerators in the Come Health Zone, which serve also as demonstration sites for the training of students enrolled in the Bachelor' Degree in Health Logistics Training course ran at the Regional Public Health Institute (IRSP).

By following them, EPI programs will make sure to proceed with proper ordering, reception and installation of solar refrigerators. Additional information can be obtained from WHO website[7].

[7] http://apps.who.int/immunization_standards/vaccine_quality/pqs_catalogue/categorypage.aspx?id_cat=17

Appendix 1: Bills of Materials

Duals Pole Conduit Bill of Materials

PVC CONDUIT SYSTEM – EXTERIOR
CONDUIT ENTRY BOX - PASS THROUGH - MC CABLE TO CONDUIT
INSULATED CONNECTOR BLOCK 3 POLE 4-14AWG
CONDUIT, PVC, 1X10FT SCH 40 PVC CONDUIT
FITTING, PVC, 1 PVC BOX ADAPTER
ELBOW, PVC, STANDARD RADIUS, 1 SCH 40 PVC 90D COND EL
ELBOW, PVC, STANDARD RADIUS, 1 SCH 40 PVC 45D COND EL
FITTING, PVC, 1 PVC COND COUPLING
BOXES AND COVERS, 6 X 6 X 4 PVC JCT BOX & CVR
STRAP/CLAMP, PVC, 1-IN-PVC-2-HOLE-COND-CLAMP
LOCKNUT, 1"
WIRE/CABLE, 4-1C THHN 600V CU-19STR PVC 90D NYL-RED 500RL WIRE
WIRE/CABLE, 4-1C THHN 600V CU-19STR PVC 90D NYL-WHT 500RL WIRE
WIRE/CABLE, 6 BARE SD SOL CU 500R WIRE
LAY-IN LUG AND SS SCREW BAG OF 10 - UL
GROUND RODS AND CLAMPS, 1/2X10FT CU GROUND ROD, ERICO INC., 611300
GROUND RODS AND CLAMPS, 1/2 GRND ROD CLAMP, BLACKBURN, G4
MIDNITE SURGE PROTECTOR DEVICE 115VDC MN
LOCKNUT, 1/2"
CABLE CLIP, SS, 10-12 AWG RHW/USE-2
OPTIONAL INTERIOR CONDUIT
CONDUIT, PVC, 1X10FT SCH 40 PVC CONDUIT
FITTING, PVC, 1 PVC BOX ADAPTER
ELBOW, PVC, STANDARD RADIUS, 1 SCH 40 PVC 90D COND EL
FITTING, PVC, 1 PVC COND COUPLING
CONDUIT BODY & COVER, PVC, 1 LB PVC COND FITTING
CONDUIT BODY & COVER, PVC, 1 LL PVC COND FITTING
CONDUIT BODY & COVER, PVC, 1IN LR PVC COND FITTING
STRAP/CLAMP, PVC, 1-IN-PVC-2-HOLE-COND-CLAMP
STRAIN RELIEF 1/2" 2-HOLE 0.2"
TOOLS AND MISCELLANEOUS
PVC 700 CLEAR AND P-68 PURPLE PRIMER CEMENT/PRIMER COMBO-PACK
TAPCON 1/4X1-1/4 HEX HEAD, 75 PK.
TAPCON 1/4X2-1/4 HEX HEAD, 75 PK.
TAPCON 3/16 in. x 4-1/2 in. Carbide Drill Bit
TAPCON Condrive 500 Installation Tool
CABLE TIES, 11-IN 75LB UVB CBL TIE, GARDNER BENDER GB, 46-310UVB
BAND-IT, 3/8" STAINLESS STEEL BAND
BAND-IT, 3/8" STAINLESS STEEL CLIPS
BAND-IT, 3/16" TO 3/8" BANDING TOOL, USED WITH 6YPY7 BANDS

Duals Roof Conduit Bill of Materials

PVC CONDUIT SYSTEM - EXTERIOR
CONDUIT ENTRY BOX - PASS THROUGH - MC CABLE TO CONDUIT
INSULATED CONNECTOR BLOCK 3 POLE 4-14AWG
CONDUIT, PVC, 1X10FT SCH 40 PVC CONDUIT
FITTING, PVC, 1 PVC BOX ADAPTER
ELBOW, PVC, STANDARD RADIUS, 1 SCH 40 PVC 90D COND EL
ELBOW, PVC, STANDARD RADIUS, 1 SCH 40 PVC 45D COND EL
FITTING, PVC, 1 PVC COND COUPLING
BOXES AND COVERS, 6 X 6 X 4 PVC JCT BOX & CVR
STRAP/CLAMP, PVC, 1-IN-PVC-2-HOLE-COND-CLAMP
LOCKNUT, 1"
WIRE/CABLE, 6-1C THHN 600V CU-19STR PVC 90D NYL-RED 500RL WIRE
WIRE/CABLE, 6-1C THHN 600V CU-19STR PVC 90D NYL-WHT 500RL WIRE
WIRE/CABLE, 6 BARE SD SOL CU 500R WIRE
LAY-IN LUG AND SS SCREW BAG OF 10 - UL
GROUND RODS AND CLAMPS, 1/2X10FT CU GROUND ROD, ERICO INC., 611300
GROUND RODS AND CLAMPS, 1/2 GRND ROD CLAMP, BLACKBURN, G4
MIDNITE SURGE PROTECTOR DEVICE 115VDC MN
LOCKNUT, 1/2"
CABLE CLIP, SS, 10-12 AWG RHW/USE-2
OPTIONAL INTERIOR CONDUIT
CONDUIT, PVC, 1X10FT SCH 40 PVC CONDUIT
FITTING, PVC, 1 PVC BOX ADAPTER
ELBOW, PVC, STANDARD RADIUS, 1 SCH 40 PVC 90D COND EL
FITTING, PVC, 1 PVC COND COUPLING
CONDUIT BODY & COVER, PVC, 1 LB PVC COND FITTING
CONDUIT BODY & COVER, PVC, 1 LL PVC COND FITTING
CONDUIT BODY & COVER, PVC, 1IN LR PVC COND FITTING
STRAP/CLAMP, PVC, 1-IN-PVC-2-HOLE-COND-CLAMP
STRAIN RELIEF 1/2" 2-HOLE 0.2"
TOOLS AND MISCELLANEOUS
PVC 700 CLEAR AND P-68 PURPLE PRIMER CEMENT/PRIMER COMBO-PACK
TAPCON 1/4X1-1/4 HEX HEAD, 75 PK.

SunDanzer Conduit Bill of Materials

ELECTRICAL METALLIC TUBING (EMT) SYSTEM
1.5" X 10' EMT CONDUIT TUBING
1.5" SERVICE ENTRANCE
1.5" RAINTIGHT COUPLERS
1.5" ELBOWS - LARGE DIAMETER
1.5" TWO HOLE EMT CLAMP
FASTENERS
1.5" RAINTIGHT MPT THREADED ADAPTER
1.5" CONDULET LB BOX, GASKET, AND COVER
4" X 4" X 4" NEMA 3R JUNCTION BOX
1" CHASE NIPPLE AND LOCK RING
SEALANT
CONCRETE BLOCKS OR EQUAL
CONCRETE MIX
WORK GLOVES
OPTIONAL INTERIOR CONDUIT
1.5" FPT THREAED ADPATOR
1.5" x 10' PVC CONDUIT TUBING
1.5" PVC COUPLERS
1.5" PVC EL
1.5" TWO HOLE EMT CLAMP
FASTENERS
PVC PRIMER
PVC GLUE

Appendix 2: Tools

Demonstration laboratory tools

Pico Light And 3 W Module For Lab Example And Also For User Training (Strongly Recommended)
30 W Solar Module (Approximately 18 Volts, 1.67 Amps)
12 Vdc Submersible Bilge Pump 1.9 Amps
Multi Meter (Sears Multi meter Reading Up To 20 Amp DC With Temperature Ability – Use For Lab And As Back Ups In The Field)
Daystar Solar Meter

Installation tools

Dial Thermometer
Super Glue
Adjustable Wrench 6”
Tool Apron
Safety Glasses
Chalk Line (Filled With Red Or Blue Colored Chalk)
Wire Brush
10cm ”C” Clamp
Claw Hammer
182 Piece Sears Mechanic Tool Set
Wire Stripper/Crimper Tool
Wire Stripper
Adjustable Wrench 12”
Masterforce7 Piece Electricians Plier Kit
3 M 12 Vdc Extension Cord
6 M 12 Vdc Extension Cord With Triple Female Receptacle
12 Vdc Soldering Irons
12 Vdc Battery Charger W/4-AA, 2-C 1-9V Batteries
Unibit#9 (Step Bit)
60 Cm Level
Caulk Gun
Bit Extender
Speed Wood Boring Bits (13 Pieces)
Masonry Bits (14 Piece) As An Alternate You Could Wait Until You Know Which Masonry Fasteners Are Supplied For The Installation And Buy Just The Bits You Will Need
246 Piece Drill And Driver Bit Set (This Is Medium To Lower Quality Set But Contains A Number Of Useful Pieces For A Very Low Sale Price)
Cordless Battery Operated Drill/Hammer Drill, Reciprocating Saw Kit With Battery Charger, Extra Batteries, Light And Carrying Case – You Can Find Many Of These And Some Have A Light Also-Get A Good Quality Like Bosch, Milwaukee, and Makita.
Utility knife With 50 Spare Blades
Shaper W/Spare Blades And Sand Unit
File Kits 4 Piece
Wood Saw

Metal “Hack” Saw W/Spare Blades
Tool Box 66 Cm
120 Cm Level
60 Cm Pry Bar
Angle Finder
12 Vdc Trouble Light With Spare Bulbs
Ball Peen Hammer
Aviation Sheet Metal Shear
40 Cm Pry Bar And Heavy Hammer
Safety Glasses
Combination Square
Framing Square
Sledge Hammer
Fish Tape 50’ (For Pulling Wire Through Conduit)
Torpedo Level
Knockout Punch Kit
EMT Bender With Handle (For Bending Metal Conduit)
Cold Chisel And Starting Chisel Set, Masonry
Head Lamp With Rechargeable Battery
600W 12V To 120V Or 230V Inverter Plus Sealed Battery or Generator (If You Plan To Use Any 230 VAC Tools In Areas With No Power)

Maintenance tools

Soft Cloth Rags
Mild Soap Detergent
Water Bucket
Selection Of Abrasives (Emery And Sander)
Hydrometer
Battery Water Fill Bottle
Baking Soda
Safety Goggles See www.graingers.com part 88200ww
Rubber Gloves
Rubber Apron
Long Handle Brush And Squeegee Kit (Suggest You Get One And Then Source Similar Items For The Actual Sites)

Appendix 3: Budget

The following table provides the costs allocated to the acquisition of cold chain equipment and additional tools; transport & customs clearance; technicians & end-users' training and installation of the 08 solar cold chain equipment acquired by LOGIVAC for Comé's health zone (Bénin)[8]:

Variables	Situation analysis and training	Equipment	Custom fees
Site assessment	1 079		
Training of technicians	7 607		
Solar cold chain equipment		36 019	
Additional Tools and materials		5 964	
Equipment installation		4 382	
Transfer from supplier to Cotonou		5 822	
Transit from the port of Cotonou to Comé		1 705	
Customs fees			8 325
Sub total	**8 686**	**53 892**	**8 325**
Total in USD	**70 903**		
Number of solar refrigerators	**8**		
Cost per unit in USD	**8 863**		

[8] Costs do not include human resources from AMP