Technical Specifications for a Photovoltaic Renewable Energy System for the Dadaab Sub Office

Site information

Site name of the plant	UNHCR Sub-Office Dadaab
Country of the plant	Kenya
Site coordinates – Latitude	0.047778 N
Site coordinates – Longitude	40.310556 E
Function of the UNHCR compound	Staff Offices and Residential Units

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ATS	Automatic Transfer Switch
BMS	Battery Management System
DG	Diesel Generator
EPC	Engineering, Procurement and Construction
GPS	Global Positioning System
IEC	International Electrotechnical Commission
kW	kilo-watt
kW_p	kilo-watt-peak
kWh	kilo-watt-hour
MCB	Miniature Circuit Breaker
MCCB	Moulded Case Circuit Breaker
MDB	Main Distribution Board
MPPT	Maximum Power Point Tracking
PF	Power Factor: Ratio of Active power (kW) to apparent power (KVA).
PPA	Power Purchase Agreement
PV	Photovoltaic
SLD	Single Line Diagram
SoC	State of Charge (of the battery)
SoW	Scope of Works
SPD	Surge Protective Device
STC	Standard Test Conditions for PV modules: cell temperature of 25°C. irradiance of 1000 W/m^2 with an air mass 1.5 (AM1.5)
TBD	To Be Defined
UV	Ultraviolet radiation

Disclaimer

This document describes the specifications for the design of a power plant to meet the contractual requirements stipulated in this RFP. The specifications referring to the detailed system design must be considered as a technical orientation to develop the bidding documents. The bidder is responsible for carrying out a site visit to verify the site characteristics at their own responsibility before designing the system, as well as for calculating all related costs to install and operate the system. All standards referring to the quality of service, as outlined in this document, must be met in the system performance over the entire term of the contract.

1 Key parameters required for the new photovoltaic renewable energy system

The following key parameters define the minimum requirements that are specific to the Dadaab project. All references in this document relating to "key parameters", this chapter name, or which refer to the parameter name in brackets must use the values defined below.

Key Parameters	unit	Requirement
Continuous AC power rating available any time ($P_{nominal}$)	kW @ 0.8 PF @40ºC	310 kW
Peak power for 15 minutes available any time ($P_{peak.\ 15\ minutes}$)	% of $P_{nominal}$	125 % of $P_{nominal}$
Peak power for 5 seconds available any time ($P_{peak.}$ 5 seconds)	% of $P_{nominal}$	150% of $P_{nominal}$
Nominal voltage ($V_{nominal}$)	V	230/400 V
Rated voltage at the supply terminals (V_{supply})	% ($V_{nominal}$)	+5% ($V_{nominal}$)
Nominal frequency and tolerance ($f_{nominal}$)	Hz (± 2 Hz)	50 Hz
Available Ground space for PV panels installation	m^2	3,700
PV Generator Capacity @STC conditions	kWp	650
PV generator energy yield	MWh/year	1,134[1]
Ratio PV inverter vs PV capacity	kW	1.15[2]
Minimal usable storage capacity ($C_{minimum}$)	kWh	1,400
Mounting of the photovoltaic modules	-	Ground Mount
System type	-	Off-grid Hybrid
Number of existing diesel generators integrated to the system	-	2 x 500kVA and 2 x 450kVA
Responsibility for the distribution of electricity to each building	-	UNHCR
Daily average demand ($E_{daily\ average}$)	kWh	3,8661[3]
Annual Demand	kWh	1,411,242[4]
Time of availability of local service technician	-	Permanent, day and night
Time of availability of high-level remote support	-	Permanent, day and night
Maximum autonomy time to run only on diesel generator(s)	Days per year	14 days
Minimum autonomy time to run at nominal power on the Battery if it was charged to 90 % before and not re-charged thereafter	Hours	TBD by bidder
Minimum annual availability ($A_{annual,\ minimum}$)	%	99.5%
Maximum monthly outage time ($T_{monthly\ outage,\ maximum}$)	%	0.5
Diesel back-up ability to service the annual demand	%	130

[1] This is an indicative figure based on non-curtailed PV system simulation. The bidder to simulate the system based on the actual system setup and performance.

[2] This only applies to PV inverter; hybrid inverter sizing should address the $P_{nominal}$ requirement.

[3] The Daily average demand is an estimated non-binding value for information purposes only

[4] The Annual demand is an estimated non-binding value for information purposes only

The PV generator energy yield refers to the energy that the PV generator would generate during one year, ignoring any effects from the battery, the diesel generators, or possible grid black-outs; this must be demonstrated with a simulation using reputable PV software[5], which does not need to include the batteries nor diesel generators.

The energy consumption of the air-conditioning system of the technical room (see section 8.1), as well as any other auxiliary components, shall be added to the PV generator minimum energy yield.

The following environmental parameters shall be considered for the design:

Table 1: Environmental parameters for design. Source: Weatherspark.

Parameter	Value
Ambient temperature	Min: 22°C Max: 36°C
Relative humidity	Max: 61.5%
Rain	61 mm/year
Average Wind speed	7.9 m/s

2 Area available in the UNHCR compound

The UNHCR Sub-Office Dadaab compound occupies a surface area of 125,048 m^2. The compound is covered with trees with most of the roofs ruled out due to shading and fragmentation. The areas approved for the PV generator[6] include a space of land in the Care Compound ("Care Compound"), and the area south west of the current Generator shed ("Genset Area") for ground mount systems as seen in Figure 1 below.

[5] Such as Homer, PVSyst, Helioscope or similar software

[6] PV generator as per IC 61836: power supply unit using the photovoltaic effect to convert solar irradiation into direct current electricity. The main component of a photovoltaic generator is the photovoltaic array.

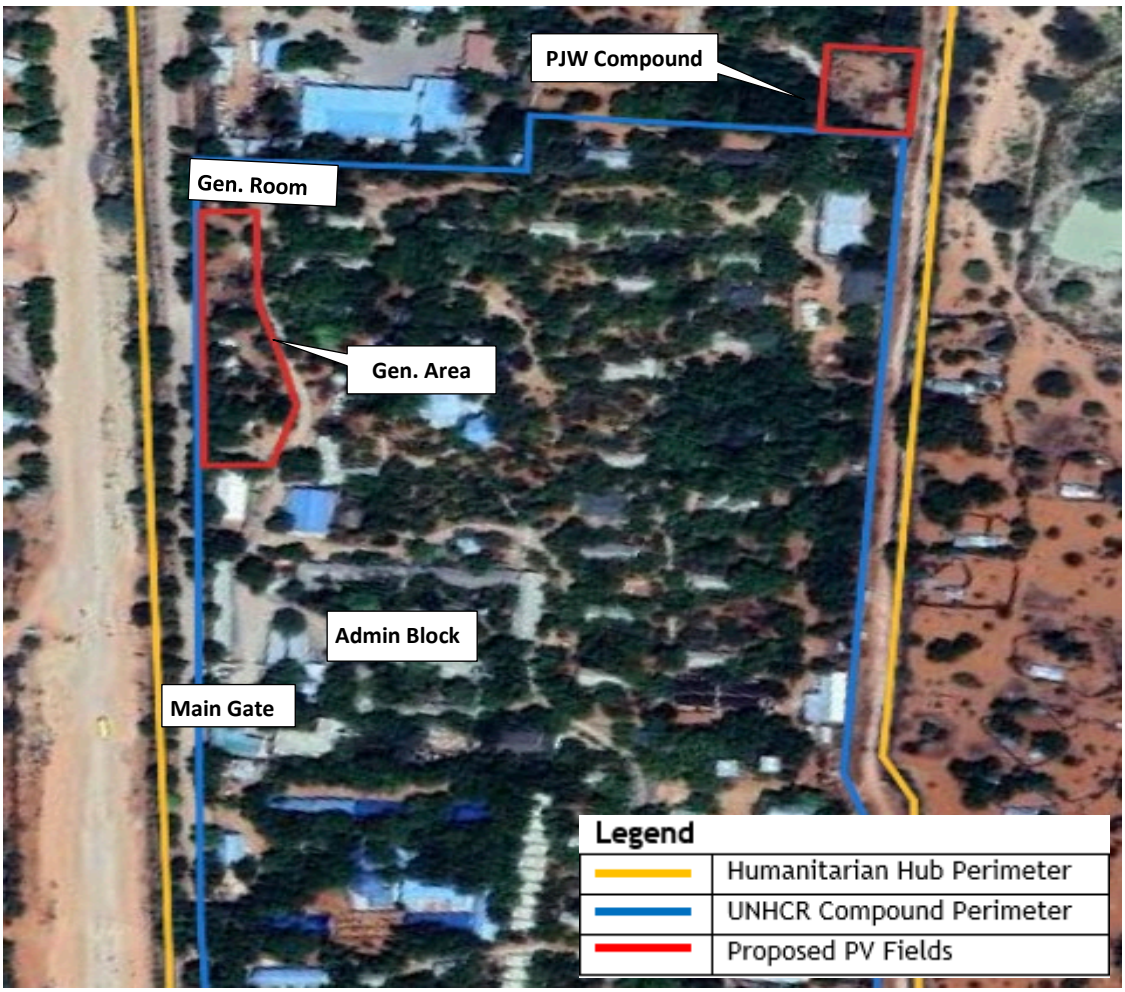

Figure 1: Areas designated for the Photovoltaic Renewable Energy System

Due to the limitation of the land space, the bidder is expected to use the provided areas as listed in Table 4 to undertake the project sizing and simulation for the maximum plant performance.

Table 2: Description of the areas designated for solar system installation

Location	Area (m^2)	Solar PV Mounting	Description	Shape
Care Compound	1,200	Ground-mounted	The area is located at Care Compound next to Pumzika Cafeteria. There are a number of trees near the area acting as a habitat for birds.	Rectangular
Genset Area	2,562	Ground-mounted	The area is mainly covered by trees and other vegetation including the juliflora plant. There are also has 9 concrete huts that are so far not in use. The trees will be cut while the huts will be demolished to provide space for installation of the solar PV system. The area is adjacent to a road used by UNHCR vehicles in access-ing various points of the compound.	Irregular

3 Scope of Works

The Contractor is responsible for the following Scope of Works (SOW):

1. Initial site visit after contract award to collect all necessary information needed for the detailed engineering design.
2. Detailed Renewable Energy System Engineering Design.
3. Supply, construction, and commissioning of the renewable energy system described in Section 3, including any civil works required to make the system operational. The system must integrate four ($) of the existing generators: 2 x 500kVA currently on-site and the 2 x 450kVA units to be used only as backup.
4. Operation and Maintenance (O&M) obligations for a period of 5 years after commissioning (see Section 11).
5. Training to local UNHCR technical staff. This training will play an essential role for the envisioned O&M services and to guarantee that safety and environmental standards provided by the Environmental Management and Occupational Health and Safety Requirements (Annex D) are followed.
6. Supply of spare parts and any tools required for the O&M phase and handling of the waste generated during the O&M phase according to applicable legislation and UNHCR standards.

The list of required works specified in this document is by no means exhaustive. The Contractor is responsible for providing all materials and services necessary to accomplish the SOW mentioned above.

UNHCR reserves the right to modify the planned quantities at the time of the award of the contract and during its validity. The unit prices shown in the bidding offer will be applicable as long as the total quantities have not been reduced by more than 25% of the total quantities originally specified.

The Contractor is requested to coordinate with and involve UNHCR's technical staff as much as possible throughout the installation and commissioning phases (see section 12 for further information). The Contractor is also encouraged to hire as many local personnel as possible. If qualified personnel cannot be found on-site, it is permitted to hire labour outside the work area.

The Contractor is responsible for arranging their own power and water supply during the installation of the infrastructure. If possible, UNHCR may avail the necessary power and water services to the Contractor, and the Contractor will pay a respective fee to UNHCR to cover the costs.

The installations supplied shall be tested, commissioned, and handed over complete and in perfect operating condition in line with the dates agreed at contract signature.

The installations shall be covered under a defect liability (parts and labour) for a minimum period of 24 months from the date of commissioning.

4 System Overview and introduction

This technical specification provides the information for preparing the detailed technical offer. In addition to minimum requirements of the technical bidding documents, this technical specification document includes the operation, maintenance and reporting specifications for after the successful bidder is awarded as contracted service provider. The terms *bidder*, *contractor*, and *service provider* are used simultaneously depending on the stage of project.

The requirement is to install a renewable energy system following Section 1 requirements and composed of:

a) PV modules

b) PV support structure, including all necessary components needed for the installation.

c) Power conversion and modulation equipment, such as PV inverters and battery inverters.

d) Li-ion batteries, including a Battery Management System (BMS).

e) Electric boards, including switchgear and protections.

f) Cabling, conduits, and trenching.

g) Earthing system.

h) Control and monitoring system, including communications network, weather sensors, and energy/power meters.

i) Integrating three of the existing on-site generators; 165kVA and 280kVA currently on-site.

j) And external lightning protection system.

k) All other necessary equipment and materials to ensure the correct and safe operation of the system.

4.1 PV power system layout

The PV power system must make use of multiple MPPT PV string inverters to increase the availability in case of failure of a single inverter or a failure of a PV string / increase: i) the availability in case of failure of a single inverter and, ii) the efficiency due to PV strings orientation mismatch. Each inverter must have at minimum one DC switch and a Surge Protective Device (SPD) per MPPT input. The DC switch and the SPD can be integrated within the PV inverter or installed in a separate string combiner box. String fuses must be installed inside the string combiner box if more than 2 PV strings are connected in parallel. Each inverter must be connected to a centralized on-line monitoring system to identify power output and potential failure of the inverter or individual strings. For details on the surge protection requirements, refer to Section 7.7.4.

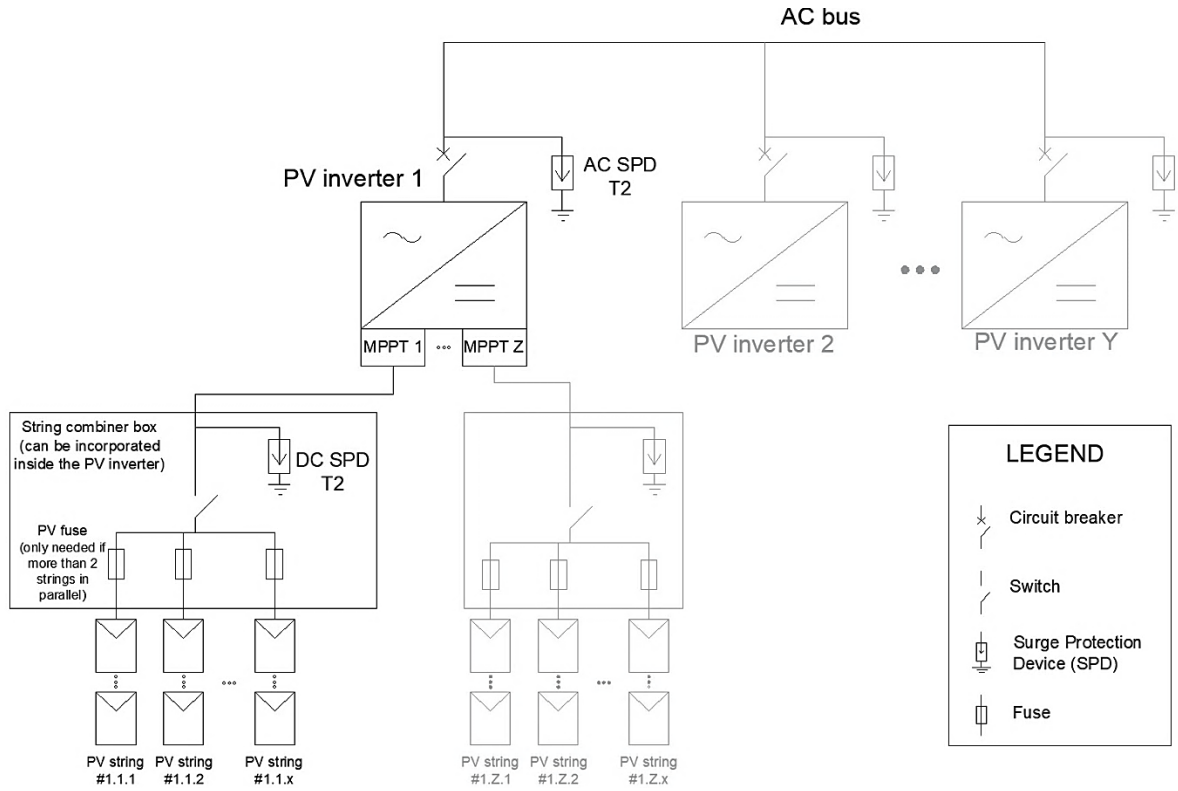

Figure 2: PV system SLD sample

4.2 Design requirements

The following general requirements shall be met:

1. The proposed system to support AC, DC or hybrid coupling options, in accordance with the design report submitted in Annex C.
2. The SOW includes a renewable energy system that needs to be connected to the LV side of the utility transformer and to the generators, besides integrating the PV generator as power sources. The AC output of the renewable energy system shall connect and feed directly to the ATSs by-passing the existing load management system (since the renewable energy system will manage the load itself) up to and including the connection to the LV side of the existing grid transformer. If needed, the supplier is responsible for the supply and installation of a new main distribution board.
3. The loads shall be fed from the PV generator and the grid during normal operation with grid availability. The system shall give priority to the energy from the PV generator, maximizing the PV energy use. Excess PV energy shall be used to charge the battery. If PV energy is not sufficient, the battery shall be charged from the grid. If the battery is full, excess PV energy shall be fed into the grid, according to the Tshwane SSEG regulations.
4. In the event of a grid blackout, the system shall automatically switch to off-grid mode and continue powering the loads while preventing any power from feeding into the grid. The battery inverter or a diesel generator shall automatically switch to grid-forming mode so that the grid-following PV inverters continue powering the loads. The system shall maximise the use of the PV energy and battery energy. The loads shall be powered by the PV inverters and battery inverter if the batteries are sufficiently charged. If the battery SOC is below the minimum threshold recommended by the manufacturer or if the power demand exceeds the available power from the battery inverter and PV inverters, the main diesel generator shall be automatically switched on. The system shall then maximise the PV energy use while ensuring a minimum genset load of 30%. Once the battery is charged from the diesel generator, the diesel generator shall switch off, and the loads shall be powered by the PV inverters and battery inverters.

5. The PV inverters shall be controlled (via frequency shifting, digital control, or similar) to prevent overcharging the battery and/or feeding power to the diesel generators.
6. The battery inverters shall act as charge controllers in the presence of an external AC source. They shall be able to work in dual mode (grid following + grid forming).
7. The bidder must submit a design with a high degree of automated control and redundancy. There must be a fallback with manual control and black-start capability of the system.
8. The system shall feature a manual bypass mode to bypass the renewable energy system itself and connect to the existing non-integrated back-up generators.

If required for compliance with these specifications, the Contractor is responsible for upgrading the existing transfer switches. The contractor must ensure safe local storage of the required most common spare parts, tools, and diesel to meet the requirements of the system operations.

5 Quality assurance

The Contractor shall have a Quality Assurance system at their disposal complying with ISO 9001 or higher standards. The Contractor shall ensure that all equipment proposed has already been proven to work reliably.

All systems and equipment must use a previously demonstrated technology deployed on a commercial scale. All equipment shall be new and in perfect condition, and it shall be installed according to the manufacturers' specifications, complying with the manufacturer's warranties.

All containers and packaging of separately shipped components shall be suitable for land or sea transport and offer suitable protection of the equipment inside against damage from weather, vibration, or shock from transportation.

6 Reference standards

The engineering, construction, and commissioning shall follow all relevant international and national regulations and standards. Particular attention shall be paid to the following standards or their national adaptations:

- Wiring and electrical regulations and codes adopted by the Republic Kenya
- **Decree No 6997 dated 29 /9/2020**, which establishes a compliance specifications sheet for PV panels, Solar collectors, batteries, and power converters
- **Circular No. 006/2021 issued on 19/10/2021** issued by the Lebanese Industrial Center, which sets the obligatory national measurement requirements regarding Solar energy and photovoltaic systems
- UNHCR Health and Safety Requirements for Contractors
- IEC 60364, specifically IEC 60364-7-712: Low voltage electrical installations - Part 7-712: Requirements for special installations or locations - Solar photovoltaic (PV) power supply systems
- IEC TS 62257: Recommendations for renewable energy and hybrid systems for rural electrification
- IEC 62548: Photovoltaic (PV) arrays - Design requirements
- IEC 62305 - Protection against lightning
- IEC 62619 - Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries for use in industrial applications.

- EN 45554 - General methods for the assessment of the ability to repair, reuse and upgrade energy-related products.

The latest editions of the standards shall apply.

7 Power quality

This chapter describes the minimum requirements of the power quality the bidder and service provider must guarantee. The supply terminals at the main distribution board are the point of reference for the power quality.

7.1 Voltage

Standard of reference is IEC 60038 “IEC standard voltages” with nominal value of voltage and frequency defined under “key parameters”.

Rated voltage at the supply terminals must be the nominal voltage. The tolerance specified in Table 3 from the rated value is acceptable under nominal load conditions.

Voltage lower than the one specified in Table 3 in any phase for a period longer than the time specified in Table 3 is considered as unavailability of the system.

Table 3. Voltage requirements

Parameter	Requirement
Voltage tolerance at the supply terminals (deviation from nominal voltage) under nominal load conditions.	+-5%
Minimum voltage, under which is considered as unavailability of the system.	-10% of the nominal value at the supply terminals in any phase
Maximum time for undervoltage, above which is considered as unavailability of the system.	1 second

7.2 Frequency

Under nominal load, the frequency must remain within the range specified in Table 4. Deviation for more than the time specified in Table 4 outside the range is considered as unavailability of the system.

Table 4. Frequency requirements

Parameter	Requirement
Frequency tolerance range under nominal load	+-2 Hz of the nominal frequency
Maximum time of frequency allowed to be out of tolerance, above which is considered as unavailability of the system.	10 seconds

8 Equipment component specification

The bidder must follow the minimum requirements for the system components offered and installed. Changes from the specification offered to the specification implemented require prior written approval by UNHCR. UNCHR will not accept a specification implemented with a lower performance and/or quality than the specification offered in the bid.

8.1 Switchgear

All electrical boards shall comply with IEC 61439 or equivalent.

Protection by extra-low voltage systems (SELV and PELV as defined by the IEC) shall be Class III or better. For all other systems, Class II protection or better is required.

Electrical boards installed outdoors shall have minimum IP protection of IP65 as per IEC 60529 and be UV resistant.

Switchgear in the DC side shall be rated for DC use and shall interrupt all poles. Positive and negative terminals shall be marked with their corresponding signs.

A circuit breaker shall protect each PV inverter AC output.

Electric boards that combine the AC output of the PV inverters can be installed either outdoors with minimum IP protection of IP65 or indoors with minimum IP protection of IP44. They shall have insulation Class II or equivalent and shall be flame-retardant.

The main distribution board that combines the diesel generator, the battery inverter, and the PV inverters shall be located indoors, shall have insulation Class II or equivalent and IP protection of at least IP44, and shall be flame retardant. All AC inputs (diesel generator, battery inverters, PV inverters) and output feeders shall be protected via circuit breakers. The board shall include an SPD Type I+II as per IEC 61643-12.

All switchgear shall be installed in a shaded place at all times of the day.

8.2 PV modules

Each module must be tested in the factory at STC conditions with individual serial numbers on the nameplate and factory test report. The factory test report must be attached to the commissioning report. Power tolerance must be positive only and within 0 … +5W.

The PV module manufacturer must have valid and internationally recognized ISO certification for the factory the PV modules are produced. Relevant minimum standards are ISO 9001 and ISO 14001. Certificates must be attached to the bid.

The modules must be certified by an internationally reputable organization according to the minimum scope of IEC 61215, IEC TS 62804, IEC 61730, IEC 61701 and IEC 62716 family of standards. Certificates must be valid for the time of production of the modules.

Modules must be of “Tier 1” quality.

Modules, connection boxes, and connectors must have an IP67 rating following IEC 60529. Third-party test reports must be provided stating compliance for the type of module offered.

Modules must have factory installed connecting cables of 4 mm^2 cross-section with pre-installed connectors. All connectors used must be fully compatible and from the same manufacturer.

Table 5. PV modules requirements

Parameter	Requirement
Type	Mono-crystalline silicon
Min. number of bypass diodes per module	>= 3
Design wind loads	>= 2400 Pa
Linear decrease of the power output after 25 years	>= 80% of the nominal value
Warranty	Minimum 10 years product warranty
System voltage	Minimum 1000 V
Efficiency under STC conditions	>= 20%

8.3 PV support structure

The PV support can be either ground mounted or using elevated structures such as a solar car park. Alternatives to a car park such as similar larger shading structures without relevant existing built structures below can be acceptable, like for storage, rest areas, etc. Support structures must be fixed in angle and without a tracking system. Smallest installed PV module capacity per structure is 5kW for smaller systems to be cost efficient.

The contractor is fully responsible to undertake all required foreseeable action to ensure that the stability and endurance of the support fulfils local requirements, weather conditions, and local and national regulations. All possible risks of injuries must be insured by the contractor.

Failure of the support structure resulting in reduced PV production capacity is under responsibility of the contractor and subject to reduced payments proportional to time and percentage of the unavailable generation capacity.

8.3.1 Ground Mounted

The PV support structure must be made either of hot-dip galvanized steel (minimum 80 µm zinc coating) or aluminium. Screws must be stainless steel only.

The bidder is required to conduct any assessment deemed necessary to be comfortable with the ground risk. Detailed geotechnical assessments, if deemed necessary, should be conducted post award to allow for findings to be included in the final design. If the supporting base is designed with a concrete foundation, the relevant structural calculations following the local national standards or optionally international standards considering the local soil conditions and wind loads must be provided to be attached to the commissioning report. Foundations without concrete can be acceptable if clearly demonstrated by product or manufacturer certificates that the requirements of the project lifetime will be met and structural calculations that meet the local and international standards are provided.

Minimum clearance below the PV modules above ground is 1 m and 10° inclination for the rainwater to drain and to clean the modules.

The support structure must have no shading on the PV modules at any time of the year. Limited shading from trees and other build structures in the morning and evening hours must be avoided and limited to 10% reduced PV production maximum per day.

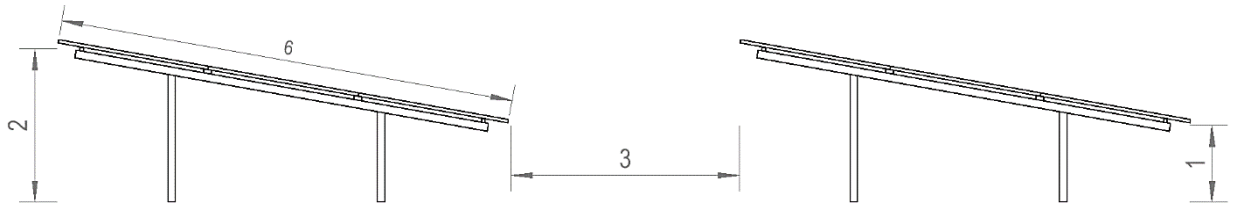

Figure 3: Simplified illustration of a ground mounted structure with 10° inclination allowing water to drain and to wash away the dust.

Indicative dimensions are metric in above illustration. Cross-bracings and foundations are not illustrated. Distance in between the rows is under responsibility of the contractor. The bidder is free to propose an equivalent sub-structure and must demonstrate in a detailed analysis of the shading an optimal system design. Distance in between the rows must prevent shading and allow the required service access.

8.3.2 Car port

Free-standing PV support structure providing a shaded place for parking, storage or rest areas are accepted if not installed above existing buildings.

The PV support structure must be made either of hot-dip galvanized steel (minimum 80 µm zinc coating) or aluminium. Screws must be stainless steel only. The supporting base must have concrete foundation with relevant structural calculations following international and national standards considering the local soil conditions and wind loads attached to the commissioning report.

Minimum clearance below the PV modules above ground depends on the requirement of the usage. The inclination must be 10° for the rainwater to drain and to clean the modules. The size of the structure must meet the requirement of the intended use and to fulfil the purpose of shading at least from 10 am till 3 pm.

The support structure must have no shading on other PV modules any time of the year. Limited shading from trees and other build structures in the morning and evening hours must be avoided and limited to 20% reduced PV production maximum per day.

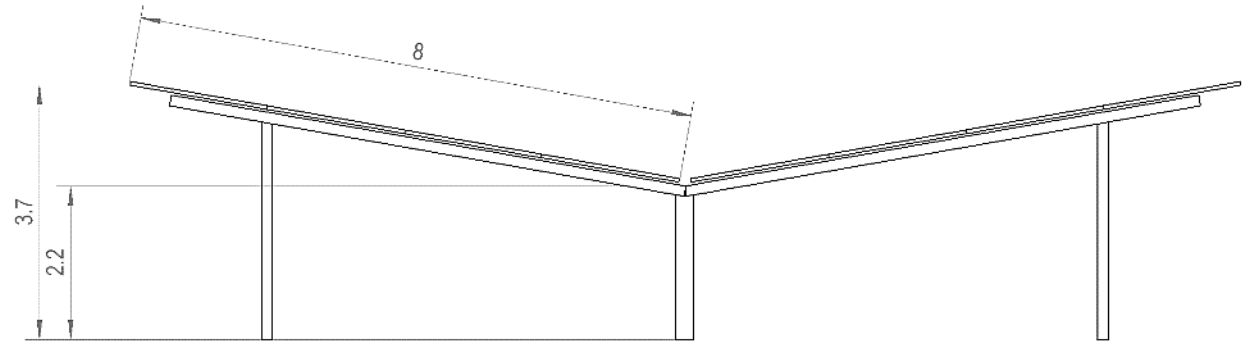

Figure 4: Illustration of a side view of a double PV car park without cross-bracings and foundations. Other designs are acceptable.

The bidder must attach at least the basic structural calculations with required drawings as proof that the offered concept meets the requirements.

In addition, there must be a concept for service and maintenance access and drainage of water.

More details of the recommended size and more specific details like modified height clearance are found in Annex A in case this mounting will be used.

8.3.3 Roof mounted

In case required by the special conditions of the site, the bidder is responsible to carry out a detailed survey of the stability and quality of the roof structures and to compare with the requirements from local and national standards for buildings. The bidder is required to use own and qualified structural calculations to prove the structural integrity of each roof to support the additional loads from the PV modules and additional support structure. The bidder has the full responsibility of any damage or injuries from installation works and during the complete time of the contract. General maintenance works of the roofs remains the responsibility of UNHCR but the roof mounted PV modules must not restrict the maintenance works to be carried out. If maintenance works of the roofs by UNHCR are required, UNHCR takes over the cost to temporarily remove the PV modules in close cooperation with the contractor. If needed, all cost for strengthening or repair of the existing roofs to allow the installation of PV modules must be included in the bid. UNHCR will not pay for any unscheduled cost increase. After installation of the PV modules, there must be no leakage or other damage of the roofs.

8.4 PV inverter

The PV inverter must have multiple MPPT devices to optimise the output from possible shading in the morning and evening hours caused by the fencing, buildings, surrounding trees, vegetation, etc. A shadow analysis highlighting the different string connections must be provided by the Bidders to confirm that this aspect has been considered.

Table 6. Requirement

Parameter	Requirement
Number of PV strings per MPPT	<=3

PV strings with different orientations and/or tilt cannot be connected to the same MPPT.

The following standards are required with the certificates of compliance:

- IEC 62109-1: Safety of power converters for use in photovoltaic power systems - Part 1: General requirements
- IEC 62109-2: Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters
- IEC 6100-6-4: Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments
- IEC 6100-6-3: Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for equipment in residential environments
- IEC 62116:2014 Utility-interconnected photovoltaic inverters-Test procedure of islanding prevention measures

The PV inverters used shall be from the same manufacturer and model.

Table 7. Requirements for PV inverters

Parameter	Requirement
Type	three-phase string inverters
Max. power per inverter	25 kW
Min. number of inverters	8
Warranty	Minimum 5-year product warranty
Euro-efficiency	>=95%
Power factor	shall be adjustable at least between 0.85 and 1, leading and lagging
IP protection	at least IP20 for indoor and IP65 for outdoor installations
Surge Protection	a Type II Surge Protection Device (SPD) shall be included on the DC side, as per EN 50539-11. This can be internal or external to the PV inverter.
The ratio between the kWp of all PV modules connected to an inverter and the nominal AC output power of the inverter	1.15
Power limiting	The inverters shall provide means of controlling or limiting its power output if required by the power management system, either by measuring the line frequency or by an equivalent technique.
Location	The PV inverters can be installed outdoors, right on the rooftop next to the PV field, or indoors, inside a technical room

8.5 Battery inverters

The battery inverters shall comply with the latest versions of the following standards:

- IEC 62109-1: Safety of power converters for use in photovoltaic power systems - Part 1: General requirements
- IEC 62109-2: Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters

The battery inverters used shall be from the same manufacturer and model.

Table 8. Battery inverter requirements

Parameter	Requirement
Type	single-phase or three-phase, as long as the ensemble of all the battery inverters forms a three-phase AC grid with a nominal frequency and voltage as specified in Section 2, and the same nominal power is assigned to each phase.
Battery compatibility	battery inverters shall be compatible with the Li-ion battery and its BMS, and their compatibility shall be certified by both the BMS and the inverter manufacturer. The inverter shall control the battery according to the battery manufacturer specifications.
Warranty	Minimum 5-year product warranty
Efficiency	>=95 %. The manufacturer shall specify the efficiency at several power points, including at least 5%, 20%, 50%, and 100% of the nominal continuous power output at 25˚C.
Max. Total Harmonic Distortion (THD)	<= 4%.
Battery protection	the battery inverters shall provide means of protecting the battery.
Location	the battery inverters shall be installed indoors
IP protection	at least IP20 as per IEC 60529

8.6 Wiring standard

Wiring must follow the IEC 60364 family of standards or its national adaptation, especially IEC 60364-5-52.

All conductors must be copper and be able to connect to all equipment according to their characteristics.

All cables exposed to outdoor conditions shall be UV resistant or be protected from UV light by appropriate protection or be installed in a UV-resistant conduit or trunking.

All cables shall be flame retardant, as defined in IEC 60332-1-2 or equivalent.

Only PV connectors from the same manufacturer and model can be interconnected. PV connectors shall comply with IEC 62852 or equivalent. Under no circumstances is it allowed to cut the PV module cables and install other than the original connectors.

DC cables must follow “PV1-F” standard, and DC cables must be kept as short as possible, be single-core, and have a nominal temperature of 90ºC. Cables from the PV strings to the string combiner box must be permanently protected against damage by attaching to the support structure using UV-resistant cable ties at no more than 0.5 m distance or being installed in UV-protected cable pipes. The loop area of the positive and negative cables of each PV string must

be as small as possible to minimise induction loops. Cables from the string combiner box to the PV inverter must be as short as possible.

AC cables shall have XLPE insulation, a nominal voltage of 0.6/1 kV, and a nominal temperature of 90°C.

The cabling installation must be corrosion-resistant and physically strong to withstand impact and strain. All cabling should be carefully installed and secured with suitable fixings arranged at regular intervals. Cables shall not bear any mechanical load on their terminations. If plastic ties are used, they shall be UV resistant.

The cable installation shall minimise the area of induction loops.

All buried cables shall be contained within a PVC conduit of suitable diameter and buried at least 0.3m depth for protection against wildlife and physical damage. DC cables of positive polarity shall run in separate, underground conduits than those of negative polarity. PVC conduits or closed electrical trays shall protect any cable within reach of wildlife.

All load cable terminations shall be tagged and labelled correctly, specifying at least the load power and electrical voltage (DC or AC). Tags and labels shall be easily recognisable. Positive and negative terminals for DC power cables and busbars shall be clearly labelled with red colour for positive and black colour for negative.

The cables cross-sections shall ensure the following maximum voltage drops:

Table 9. Maximum voltage drop requirements

Parameter	Requirement
From PV modules to the main distribution board	5%
From the battery to the main distribution board	3%

The calculations shall consider the output of the PV modules at STC conditions and the maximum continuous power output of the battery inverter and PV inverter. The copper resistivity at a temperature of 90 °C must be taken into account. The bidder must justify these maximum voltage drops in their technical offer.

The supplier is responsible for all trenching works required to interconnect all components.

8.7 Earthing, Equipotential Bonding, and Lightning Protection

8.7.1 System type

The earthing system shall comply with IEC 60364-7-712. Conductor colours to follow IEC with brown, black, grey, blue, green/yellow.

All the system shall be interconnected by a single equipotential bonding and connected to the existing earthing installation.

The earthing conductors shall always be as close as possible to the active conductors to minimise the induced loop areas.

8.7.2 Earthing

The earthing must be a combination of a band strip with no more than 20 m mesh size and earth rods following all parts of IEC 60364 and country's wiring regulations.

All the system (PV structure, PV module frames, metal cable trays, inverters, switchboard, etc) shall be interconnected by an equipotential bonding and connected to the existing earthing installation. The supplier shall ensure that the resistance of the whole earthing installation does

not exceed the value specified in the table below, improving the existing earthing installation if necessary.

Table 10. Earthing resistance requirements

Parameter	Requirement
Max. resistance of the whole earthing installation	10 Ohm

The earthing conductor of the ground-mounted PV arrays (if any) shall be buried if it is longer than 50 m. In such a case, the conductor shall be made of bare copper with a minimum cross-section of 25 mm2 to minimise corrosion.

The earthing conductors shall always be as close as possible to the active conductors to minimise the induced loop areas.

8.7.3 External lightning protection

An external lightning protection system must protect the complete system following the IEC 62305 and IEC 60364-7-712 family of standards. Mesh size must be no more than preferably 15 m x 15 m or maximum 20 m x 20 m and 45 m radius for the sphere to validate the design. The external lightning protection must have its own earth termination system fully integrated into the earthing and equipotential bonding of the remaining system.

8.7.4 Surge protection

The DC and AC sections for the system must be fully protected against overvoltage with type I, type II, type III, and type I+II surge protective devices following IEC standards to ensure high availability of the system.

At a minimum, the following SPDs shall be installed:

- Type II DC SPD at each MPPT input of the PV inverter, to be installed as close as possible to the inverter. It can be incorporated within the inverter itself.
- Type II AC SPD at the AC side of the PV inverter, to be installed next to the circuit breaker, as close as possible to the inverter.
- Type II AC SPD at the AC side of the battery inverter, to be installed as close as possible to the inverter. Only required if the distance between the battery inverter and the main distribution board is higher than 10 m.
- Type I+II AC SPD at the main distribution board (which combines the output of the PV inverters, battery inverters, and diesel generator(s)).

8.8 Weather Station

The Contractor must install a meteorological station to measure the temperature-corrected global horizontal irradiation, PV module temperature, and ambient temperature and log the data in 10 minute or 15-minute intervals.

The meteo station shall follow the ISO 9060:2018 standard.

The recorded information should be easily accessible both on-site (via screens or laptop connection) and remotely (online).

8.9 Battery Storage System

Table 11. Battery Storage System requirements

Parameter	Requirement
Technology	Lithium-ion
Uniformity	All batteries shall be from the same manufacturer and model.
Standards to comply with	Batteries shall comply with relevant standards, including IEC 61427-1 and IEC 61427-2 and other applicable IEC standards, UL, and transport standards such as UN38.3
operating temperature range	At least between 0°C and 45°C
Number of cycles	At a Depth of Discharge (DoD) of 80%, the number of cycles shall be equal or higher than 4500 at a temperature of 35°C.
BMS minimum functionalities	• Control and balance of each individual battery cell • Management of charge / discharge profile according to the type of battery • Protections: over-charging, under-charging, over-temperature, over-load, and a potential explosion • Setting of critical threshold levels • Alarm management system
The integration of the BMS into the renewable energy system's control and monitoring system shall include at least the following parameters	• SOC • Battery voltage • Battery temperatures • Over or Under voltage (min, max, nominal) • Over or Under temperature (min, max, nominal)
DC overcurrent protection device	If applicable, each battery polarity shall be protected by an overcurrent protection device (DC circuit breaker or DC fuse) for paralleling the batteries on the common Main DC bus.
Product warranty	At least 5 years
Location	The batteries shall be installed inside the technical room power house, following the manufacturer's installation requirements.

The manufacturer of the system must have a minimum of 2 years of experience with the technology of the storage system offered and must be 10 years in business with similar storage solutions.

Before connecting the batteries, it shall be ensured that no overheating or uncontrolled ambient temperature is present. The batteries shall be isolated before working on them, ensuring that no current is flowing through the circuit. The installation shall prevent the risk of a potential short-circuit between the opposite polarities caused by a metallic object.

8.10 Control and monitoring system

The control devices shall allow the renewable energy system to operate correctly according to the Design Requirements described in Section 3.2, by managing the operation of the main components (PV inverters, battery inverters, battery, diesel generator, etc). They allow inter-communication

between the various components to ensure optimal operation. They are used to measure and send information to monitoring devices.

Since the generator(s) will be from the existing ones, the supplier needs to consider a registering and communication device to be installed in the generator(s) in order to make possible the monitoring capacity as required below. As well, to make possible the generator(s) automatic switch-on and off based in Design Requirements in Section 3.2.

Each power system shall integrate a data acquisition and monitoring system performing the following functions:

Table 12. Minimum Technical requirements of the data acquisition and monitoring system

Parameter	Requirement
Data acquisition	Measure all the operating parameters of the system with a minimum interval time of 5 minutes. The reporting rate shall be 15 min.
Data storage	Minimum capacity of 180 days.
Data processing	Data processing and editing for the maintenance staff.
Reporting	Generation and submission of daily operational reports to the system operators
Notification	Notification of any recorded system alarm to system operators
Interface	The recorded operational information should be easily accessible both on-site (via screens or laptop connection) and remotely (online).
Internet connection	All necessary materials for the connection to the internet to allow for remote monitoring shall be included.
Internet bursting	Data collected through the monitoring platform should be stored securely in a central database. An Application Programming Interface (API) should be built which supports retrieval of this data by other servers/platforms.
External communication	Configurable FTP push or HTTP put communication method to upload energy and alarming data on an external server.

All necessary components for the measurement, recording, and analysis of at least the following data shall be included:

Table 13. Minimum requirements for data measurement, recording and analysis

Parameter	Requirement
Battery inverters	Charge / discharge power, battery voltage, battery SOC and battery temperature. The battery voltage measurement shall be taken as close as possible to the battery to have an error measurement less than 0.5%.
PV inverters	Power, voltage, and current, both at the DC and AC sides. Maximum power during the day.
Diesel generators	Status, power, cumulated energy, voltage, current, frequency, cumulated working hours and fuel consumption.

Parameter	Requirement
Grid supply	Status, power, energy, voltage, current, frequency.
Irradiation and temperature	Global Horizontal Irradiance, ambient temperature, temperature in the battery room, and PV module's temperature. Appropriate sensors such as pyranometers and temperature probes shall be used.
Alarms	Operational alarms and faults from all different components.
Performance ratio	Performance ratio of the PV generator

Information shall be provided in the form of tables, synoptics, and graphs by the monitoring platform. All information shall be retrievable in .csv format or equivalent (table).

In case of a failure of the remote monitoring platform or the data connection, a simple O&M process shall be ensured by showing at least the following parameters through simple on-site screens and displays in the Technical Room:

- Battery voltage or SOC.
- Total daily energy delivered by the batteries.
- Instantaneous power imported from the grid/diesel generator(s) (if applicable)
- Total daily energy imported from the grid/diesel generator(s) (if applicable)
- Maximum daily power delivered by the PV generator
- Total daily energy delivered by the PV generator

Wired communication bus between all components shall be included. Wireless communication networks are not allowed. Communication cables shall be properly protected against interferences.

8.11 Metering System

The meters shown in Annex C shall be provided and installed.

All meters must be 0.5 % accuracy or better. Current transformers must be also 0.5 % accuracy or better. Energy meters for the generation are supply meters (1 way); for the energy storage, the meter must have separate supply and purchase (2 way) metering. Accurate clock must be provided from GPS or comparable time reference.

Meters must come with valid calibration certificate.

All metering shall be electronic.

9 Civil works and security

The Contractor shall follow the UNHCR “Health and Safety Requirements for Contractors”.

The Contractor is responsible for all required civil, structural and mechanical works such as site preparation, trenching, drainages, cable routes, security fence around PV field and all required waste management during construction and upon works completion.

9.1 Technical room

The technical room will be placed on an isolated space agreed with UNHCR Dadaab Sub Office next to the generator room area, since all the existing generator and power rooms have no extra

space. Depending on the design combinations proposed by the bidder, an appropriate containerized arrangement solution should house at least the batteries, the inverters, and any necessary switchboards. The bidder to give a proposed arrangement and placement of all components, through the schedule of drawings as part of technical returnable. The containerization of the main control and switching devices shall include the PV and battery inverters and the batteries. The bidder will propose an insulated, racked and weather-proofing container with all equipment pre-installed and wired.

Depending on the physical size of the energy equipment (inverters, main switches, etc), the Supplier will devise and propose an appropriate standard shipping container: 10-foot, 20-foot or 40-foot. The container shall be designed and furnished with the following or as needed, so as to ensure that the energy equipment housed within the container is maintained within the ambient parameter ranges (temperature, humidity, etc) of the manufacturer(s), and any internal cabling is done tidily:

1. Arrangement prescriptions
2. One or multiple standard 10', 20' or 40' ISO sea container (depending on the system capacity) must contain all main components in pre-assembled, pre-cabled configuration, with the only exception of PV panels and their supporting structures.
3. The container shall be painted white with a two meters long UNHCR logo painted in the middle of the two longest sides of the container. The logo template shall be provided by UNHCR.
4. The components inside the container(s) must be firmly secured (e.g. using metal rails to place the equipment on the container walls) in order to ensure proper and safe shipment of the systems. The resulting modified container(s) must be certified for regular shipping and no recertification must be needed for any redeployment of the systems.
5. The equipment inside the container(s) must be accessible through the standard double door on one of the short container sides. The internal arrangement must allow ease of commissioning, operation, maintenance and decommissioning for re-shipment.
6. The container(s) must have internal walls and ceiling covered with insulating sandwich panels, or similar asbestos-free insulation means. The thermal transmittance of the insulation must be maximum 0.78 W/m2K.
7. Climatization
8. One inverter split-type air conditioner capable to heat/cool must be installed in the container in order to keep the internal texmperature and humidity at the internal equipment's standard test conditions. The minimum requirement is for 1x12,000 Btu/h for the 20' container and 1x18,000 Btu/hr or 2x12,000 Btu/hr unit(s) for the 40' container.
9. The air conditioner must be rated to meet the minimum European SEER of 8.50 (Class A+++) for cooling and minimum European SCOP of 4.00 (Class A+) for heating as per EU Eco-design Regulation 206/2012 and Energy Labelling Regulation 626/2011. The Bidders may adopt equipment compliant with other efficiency standards equivalent to the above indicated standards (e.g. AHRI 210/240). Bidders must prove the overall compliance with the above minimum values by means of technical calculation to be submitted with the technical offer.
10. The air conditioner must use a refrigerant with zero ozone depleting potential (ODP = 0), a global warming potential of maximum 750 (GWP ≤ 750), low-toxicity class A and maximum flammability class 2L as per ISO 817. As an example R32 refrigerant complies with the

previous requirements, but the bidders are free to propose equivalent or better performing refrigerants.

11. The internal unit(s) must be installed on the wall of the container. The external unit(s) must be pre-installed and secured in a recessed compartment of the container, to be closed by metal plate fixed by nuts and bolts during transportation. Removable plates must also close the pre-cut openings in the container walls e.g. for the necessary refrigerant pipes, cables and vents during transportation.
12. The cooling/heating of the container shall be designed to be as energy-efficient as possible; favouring passive ventilation before active ventilation where possible. Any opening vents of the container will be protected against the intrusion of rodents inside the container.
13. A suitable fan system must be installed in the container(s) for active ventilation. The system must be able to cool the internal equipment by fan whenever possible, and switch the air conditioner on only when the external temperature does not allow free cooling.
14. A High Temperature monitoring of the container including outdoor/external visual and audible alarms shall be included.
15. Electrical system
16. The containers must be equipped with an internal LED lighting system capable to provide min. 400-lux, 3000K, the necessary wall switch and at least two (2) 1-phase, 16A rated electrical sockets, CEE 7 Type F ("Schuko") for the 50Hz and NEMA 5-15 Type B for the 60Hz version. The entire internal electrical system must have a minimum protection rate of IP44. The internal cabling must run in proper ducting systems and cable trays in compliance with current safety installation standards and best practices.
17. Each container must be equipped with a red, 'mushroom' type switch button for quick disconnection of power supply in case of fire or emergency. The button must be recessed in a convenient and always accessible position on an external wall of the container. One (1) CO2 type extinguisher with a minimum capacity of 5 Kg must be included with each modified container, properly fixed to the internal walls near the exit.
18. The manual override transfer switch should be installed inside the container.
19. All the electric boxes, with its breakers, switches, fuses and all the electric distribution boards (AC and DC), and all the system componets should be clearly identified and labeled.
20. Built-in cable entry boxes with waterproof gland plates and terminal blocks, near bottom corners of the container shall be included: it may contain but are not limited to the following
    1. Generator input connections (3-Ø + N + G)
    2. Generator stop/start control (1NO contact)
    3. Grid input connections (3-Ø + N + G)
    4. Load output connection (3-Ø + N + G)
    5. Main grounding connection input
    6. Data connection input
    7. Spare cable entrance inputs/outputs

The Bidders must include a layout of the designed internal arrangement of the containers with their proposals. The Bidders must allow a warranty on manufacturing defects on the assembly of the resulting containerized systems of **at least two (2) years** from the date of delivery.

10 Commissioning

After completion of the installation works, the commissioning phase will take place.

The supplier shall be responsible for preparing and submitting the commissioning procedures and their related checklists for UNHCR approval.

The commissioning phase shall include all the necessary tests to demonstrate that the system operates in accordance with the required technical and performance specifications, manufacturers' specifications, and quality standards. The supplier shall fix any malfunction identified during the tests and repeat the tests until they are passed satisfactorily.

The main aspects to be tested are:

- Inspection of all components and structural elements, including the roof retrofit, if needed.
- PV generator – testing of performance and compliance with standards. The commissioning shall follow IEC 62446. Detailed report following all requirements of IEC 62446-1 must be submitted.
- PV inverters – testing of all functionalities in all modes and power configuration settings.
- Battery and battery inverters – testing of all functionalities in all modes and power configuration settings.
- Functional tests of the whole renewable energy system, considering the interconnection between PV inverter, battery inverters, diesel generators, and grid.
- Safety tests and electrical measurement protocol for compliance according to the requirements in section 7 for the whole technical installation.

After successful commissioning and testing, a 7-day trial period will start. The supplier must demonstrate 168 hours of uninterrupted supply. In case of interruptions of the electric energy supply, the 168-hour period restarts. Commissioning is completed after 168 hours of uninterrupted electric power supply. After a successful 7-day trial period or 168 hours of uninterrupted supply, an acceptance certificate will be issued to the Contractor by UNHCR.

A representative appointed by UNHCR will supervise the complete testing and commissioning. The Contractor has to ensure the representative has access to all relevant documents and works.

11 Spare parts and O&M materials

The following spare parts shall be provided.

Table 14: Spare parts

Parameter	Requirement
PV modules	at least 5% of the total number of modules.
PV connectors	at least 5% of the total number of connectors.
PV inverters	at least one or 10% of the total number of inverters.
Cables and conductors	at least 5 % of each different cable installed per site.

The bidder is free to propose all recommended stock spare parts in the offer's technical description to ensure 5 years of operation.

The supplier has an obligation to notify UNHCR six months prior to product obsolescence, product production halt, or end of service.

When replacing a part, the supplier is obligated to safely manage the end-of-life of the part that is swapped out. This has to be done to maximise recycling and in accordance with all applicable laws and regulations. The supplier is required to both arrange logistics and take financial responsibility for all end-of-life operations. This requirement applies for the duration of the O&M contract.

12 O&M

12.1 General description

After the renewable energy power system testing and commissioning, the supplier will enter an O&M contract. During the O&M contract, the supplier will have to carry out a series of preventive and corrective maintenance tasks and activities as indicated in this section, along with remote monitoring. Additionally, the supplier will be responsible for ensuring the minimum service standards established in this section.

The O&M contract obligations are for the proposed photovoltaic renewable energy system but do not encompass the operational costs (fuel, oil, etc) and maintenance obligations and costs of the existing generator(s) to be incorporated, however, the supplier is responsible to ensure that the automatic control starts and synchronises the generator(s) when required.

Three major types of failures are categorised depending on the impact they will cause to UNHCR power infrastructure supply:

Table 15. Failure types

Failure types	Description
Type A – Major failure	A.1) Power system blackout. A.2) Failures that pose a safety risk at the battery storage system, such as a failure of the air-conditioning unit, of the fire prevention and protection systems, of the BMS, or any other component of the storage system. A.3) Any failure that puts UNHCR personnel's health and safety at risk. A.4) Any other failures/malfunctions not mentioned here and considered to be of high priority by UNHCR.
Type B – Medium failure	B.1) Failures that lead to a decrease in the PV power system energy output of more than 20%. B.2) Any other failures/malfunctions considered to be of medium priority by UNHCR.
Type C – Minor failure	C.1) Any other minor failures. C.2) Any other failures/malfunctions considered to be of minor priority by UNHCR.

For corrective maintenance, if any part of the generation power system fails or malfunctions for any reason within the responsibility of the service provider, two levels of intervention are defined:

Level 1 - remote assistance and troubleshooting through local UNHCR staff. The O&M service provider will establish communication with UNHCR staff as soon as a failure or energy output problem on the PV renewable energy system is identified. Through IT communications, the O&M service provider will work together with the UNHCR staff in understanding, troubleshooting, and restoring the correct operation of the power system. The service provider will have a maximum time to resolve the issue that is defined in Table 17. Restoration times . If, after the prescribed time, this first level of corrective remote O&M has not resulted in the issue being solved, the O&M service provider will be required to trigger level 2.

Level 2 - on-site assistance and troubleshooting through the service provider's own staff. The O&M service provider will be required to deploy to site the necessary skilled labour to further investigate the issue, fix it and restore the service. The service provider will have a maximum time to resolve the issue that is defined in Table 17.

The time responses for three failure types shall be less than the values indicated in the table below.

Table 16. Restoration[7] times per O&M level and failure type

	Level 1 Restoration time	Level 2 Restoration time
Type A	24 hours	24 hours
Type B	2 days	4 days
Type C	4 days	5 days

The following flowchart summarises the process and levels of corrective O&M:

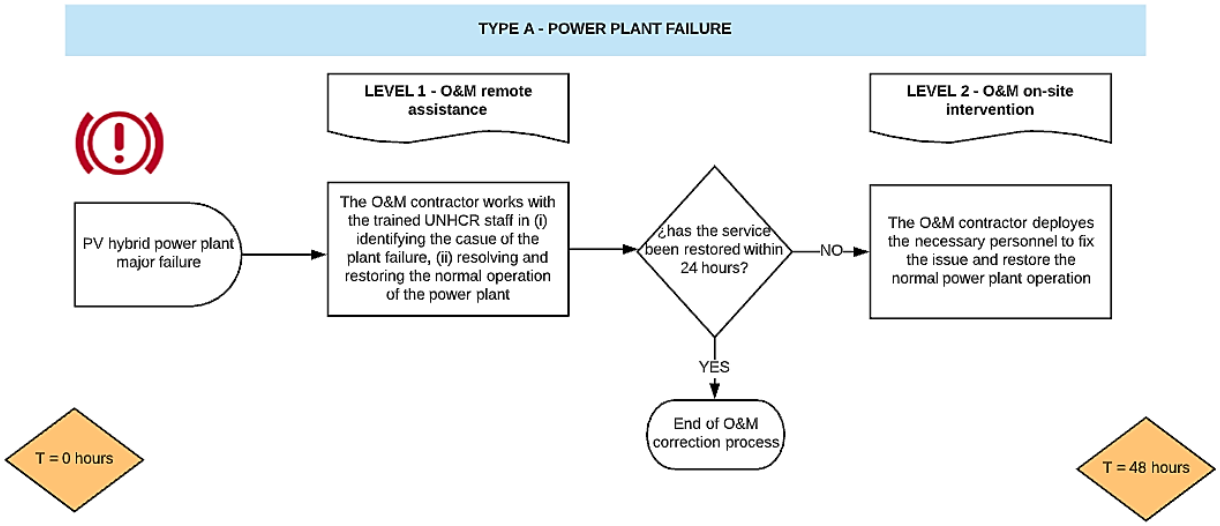

Figure 5: Processes and restoration times for Type A failure

[7] IEC: time interval, from the instant of failure, until restoration

If the O&M contract is not renewed after the O&M contract duration, UNHCR plans to take over the operation of this infrastructure; therefore, handover forms and all relevant documentation will have to be submitted and agreed between the Contractor and UNHCR.

12.2 Allowed interruptions

As allowed interruption is understood when the renewable energy system is not performing, therefore the back -up generators (the ones that are not integrated into the renewable energy system) will have to work since facility total blackout is not allowed. The manual bypass switch will be used to allow existing non-integrated generators to operate in an emergency back-up mode.

Table 17: interruptions

Parameter	Value
Unscheduled interruptions in the PV renewable energy system	
Maximum backup generator start-ups[8]	2 per month
Maximum back-up generator run-time[9]	2.2%
Scheduled interruptions in the PV renewable energy system	
Scheduled maintenance works	Maximum twice a year for a maximum of 4 hours each Time and date to be agreed at least 14-days in advanced

12.3 Liabilities and responsibilities

The O&M service provider will be responsible and liable for the following within the O&M contract period:

- Perform all the O&M tasks as specified in this section
- Do at least two site visits per year
- Replace any equipment that breaks down or malfunctions within the warranty period at its own cost.
- Replace any equipment that breaks down as a direct result of the improper/inadequate operation by the supplier during the O&M period, even if that equipment is out of the warranty period.
- Provide at its own cost collection, reverse logistics, storage, and recycling of the non-working parts encountered during the provision of O&M services, in accordance to all applicable laws and regulations.
- Provide O&M reports to UNHCR as specified in this section
- Handover the O&M operations to the appointed UNHCR staff after the O&M period, including end-of-life management procedures.

[8] From that point on it is understood that back-up generators are the ones not integrated in the renewable energy system. Therefore, if the back-up generators (= non system integrated) are working, this means that the hybrid system is not working

[9] If fuel is supplied by UNCHR and available on site

- Full compliance with the health and safety requirements as per the UNHCR Health and Safety Requirements for Contractors.
- The Contractor has an obligation to notify UNHCR Employer when upgradable software and hardware will be available.

The O&M Contractor will not be responsible and liable to fix or restore the service (unless agreed with UNHCR on a separate agreement) in the following cases:

- UNHCR existing generators, including the one(s) that will be connected to the renewable energy system.
- UNHCR is not capable of delivering fuel to the site.
- UNHCR staff or third parties damage or destroy part of the renewable energy system generation assets.
- UNHCR staff or a third party damages or destroys part of the distribution network assets that affects the correct energy delivery of the power system.

12.4 O&M tasks

Table 18: O&M tasks

Preventive Maintenance Service Description		
PV Arrays		
Item	**Activity**	**Frequency**
1	PV module cleaning according to manufacturer recommendations	Biweekly[10]
2	PV module visual inspection and infrared inspection.	Annual
3	General cleaning and vegetation removal. Determine if any new objects, such as vegetation growth, are causing shading of the array and move them if possible; remove any debris from behind collectors and from gutters.	Annual
4	Measure the I-V curve characteristics of each PV strings (Voc, Isc, Vmp, Imp, and Pmp).	Annual
5	Calibrate weather sensors and meters	As per manufacturer
6	Test earthing resistance.	Annual
7	Inspect DC cabling and MC4 connectors for signs of defects. Replace damaged MC4 connectors.	Annual
8	Inspect the PV combiner boxes (if any) - fuse check and replacement, electrical connection tightness and retorquing, water intrusion, corrosion damage, intrusion by pests.	Annual
9	Check all hardware for signs of corrosion and remove rust and re-paint if necessary.	Annual
10	Inspect ballasted mounting system (if any) for abnormal movement	Annual
11	Torque inspection of PV structure and PV modules.	Every 2 years
12	In roof-mounted generators, inspect the roof penetrations to ensure the proper waterproofness.	Annual
Inverters		
Item	**Activity**	**Frequency**
1	Perform a remote performance test on the PV generator, considering the measurements of the PV inverter output power, irradiance, as well as ambient and PV module temperature.	Monthly

[10] Water provided by UNHCR

2	Remotely collect and inspect inverter logs (alarms and faults logs)	Monthly
3	Remotely check inverter's well behaviour with safe fallback setting	Monthly
4	Inspect housing and/or shelter for physical damage.	Annual
5	Clean dust from heat rejection fins.	Annual
6	Turn off and on logging and communications to ensure they are communicating and ensure battery backups are working.	Annual
7	Check output AC cable connection tightness.	Annual
8	Clean and replace air filters.	As needed
9	Install any recent software upgrades.	As upgrades become available.
10	Replace surge protection devices.	As per manufacturer
Li-ion batteries and BMS		
Item	**Activity**	**Frequency**
1	This might include charging up to a certain SOC level on a monthly basis.	As per manufacturer
2	Visual inspection of the batteries to check for defects, cracks, leaks, the integrity of the enclosure, and support structure.	Every 6 months
3	Inspect electrical protections and cables.	Every 6 months
4	Visual inspection of the communication cables.	Every 6 months
5	Check all terminals for corrosion and proper torque.	Every 6 months
6	Inspect Air Conditioning system. Replace air filters as needed.	Every 6 months
7	Inspect Fire Detection and Suppression system.	Every 6 months
8	Check the registered minimum voltage of the battery modules.	Every 6 months
9	Check the battery SOH and assess its lifetime.	Every 6 months
10	Check the battery number of cycles completed on the BMS.	Every 6 months
11	Check the electrical resistance of each battery module.	Every 6 months
12	Inspection of the communication system - all battery modules shall be communicating with the BMS.	Every 6 months
13	Collect data for events and alarms, analyse them, and correct if necessary.	Every 6 months
14	Thermographic measurement of the battery for potential hotspot detection.	Every 6 months
15	Check with UNHCR if any new loads have been added and report. This will affect the system's autonomy.	Every 6 months
Wiring Systems		
Item	**Activity**	**Frequency**
1	Inspect all switchboards: tightness of the electrical connections, corrosion, intrusion of water or insects, sealing.	Annual
2	Check proper position of DC disconnect switches and fuses and replace failed fuses.	Annual
3	Check proper position of AC disconnect switches and breakers.	Annual
4	Inspect cabling for signs of cracks, defects, pulling out of connections, overheating, short or open circuits, and ground faults.	Annual
5	Test the disconnect switches to ensure they are not jammed.	Annual
6	Test system grounding.	Annual
7	Insulation resistance RiSO (resistance in ohms of wires, cables to guard against electric shocks and avoid equipment damage from accidental discharges).	Annual

8	Check the SPDs, replace when needed.	Every 6 months or after a lightning storm event.
9	Thermographic measurements on the electrical connections.	Every 6 months
10	Check grounding hardware	Annual
Monitoring System, and Data logging		
Item	**Activity**	**Frequency**
1	Test monitoring system hardware and its communication.	Annual
2	Ensure all documentation is in place.	Every 6 months
3	Document the preventive maintenance that has been carried out: observations, work performed, replacements, meter readings, and system testing results. Include non-conformance reports to identify potential short-term and long-term power production issues	Every 6 months
4	Update as-built drawings if necessary	As needed

Apart from these O&M tasks, the Contractor shall conduct any other necessary task to comply with the warranty of the manufacturers.

12.5 O&M reporting

The Contractor shall perform remote monitoring during the O&M period. A quarterly O&M report shall be prepared, including at least:

- Average, maximum, and minimum voltage at the supply terminals recorded over the last 3 months.
- Average, maximum, and minimum frequency at the supply terminals recorded over the last 3 months.
- Monthly energy demand.
- Monthly energy provided by the PV generator, the diesel generators, and the utility grid (if any).
- Monthly fuel consumption
- Temperature-corrected Performance Ratio of the PV generator.
- Number of grid outages and their duration.
- Unscheduled down-times and their duration.
- List of faults and alarms.
- List of O&M tasks undertaken.

Together with the quarterly O&M report, hourly values of the following parameters shall be provided in a separate file (Excel, CSV, or similar):

- Power of the loads, the PV inverters, the battery inverters, the diesel generators (if any), and the grid (if any) in kW.
- SOC (in %), voltage (in V), and temperature (in ºC) of the battery.
- Global Horizontal Irradiance as measured by a pyranometer (in W/m2).

Each visit shall end with a Monitoring and O&M Report, which summarises all the measurements taken to demonstrate that the system is working up to the specifications laid out in this document. The report shall also include all the O&M tasks undertaken.

During each of these visits, the supplier shall provide a 6-hour training to the UNHCR personnel. The trainings shall revisit the O&M requirements of the system. Any necessary documentation shall be provided along the trainings.

Apart from these two visits, the Contractor shall conduct any necessary site visits for corrective O&M during the defects liability period in case of system failure.

13 Training

Bidders shall describe a training plan for UNHCR personnel to be conducted upon completion of construction works. The training shall last a total of 32h and shall be offered to 2 staff to be appointed by UNHCR. Bidders are also encouraged to involve the appointed UNHCR staff during the project installation, in particular during the testing and commissioning.

The objective of the training will be to (i) provide the appointed UNHCR staff with a basic understanding of the Solar PV hybrid power system and (ii) empower the appointed UNHCR staff with the necessary information SO that they can read the power system signals (through the PV and battery inverters displays) and identify what part of the power system is malfunctioning or failing at any time, (iii) act as focal points between UNHCR and the O&M Contractor during Level 1 of the corrective O&M as described above, and (iv) empower the appointed staff to ensure the proper use of the system and end-of-use of its specific parts, in order to enable the continuity of operation and longevity of the system and minimise its negative environmental impacts.

Training shall cover design fundamentals of the hybrid system installed, technical characteristics including functionalities, operations & maintenance, safety, controlling, monitoring, proper use and care (cleaning), end of life management, and reporting.

The Contractor shall provide an O&M plan following IEC 62446-2 for UNHCR approval, including preventing and corrective maintenance, tasks, responsible people, and a list of materials and tools needed for each task.

Training is to be provided at the site.

All associated costs shall be borne by the Contractor, including at least transport to site, accommodation, meals, and training materials.

14 Health and Safety Requirements

The Contractor shall follow all applicable health and safety codes as per national regulations and the UNHCR Health and Safety Requirements for Contractors.

The Contractor shall at all times take all reasonable precautions to maintain the health and safety of the Contractor’s personnel, and that suitable arrangements are made for all necessary welfare and hygiene requirements.

The Contractor shall appoint an accident prevention officer at the Site, responsible for maintaining safety and protection against accidents. This person shall be qualified for this responsibility and shall have the authority to issue instructions and take protective measures to prevent accidents. Throughout the performance of the contract, the Contractor shall provide whatever is required by this person to exercise this responsibility and authority.

The Contractor shall notify the details of any accident as soon as practicable after its occurrence. The Contractor shall maintain records and make reports concerning health, safety, and welfare of persons, and damage to property, as the Employer may reasonably require.

Only certified electricians are allowed to do electrical works at voltage levels above the Extra Low Voltage as defined by IEC 60364. If the nominal voltage of the battery is higher than 120 Vdc and the positive and negative poles can be inadvertently touched at the same time, (1) insulating rubber gloves and an insulating mat shall be used, and (2) workers shall be accompanied by a third person.

Only personnel trained and certified to work at heights are allowed to do SO.

The installation team must include at least one person trained in First Aid.

15 Documentation

After the initial site visit, the Contractor shall provide a complete Engineering Design Report, including at least the following set of drawings:

- Layout drawings specifying the physical location and positioning of all components.
- Civil engineering drawings, including at least:
    - PV support structure (different views)
- Functional drawings and Single Line Diagrams.
- Installation drawings
    - Details of the installation of all equipment inside the technical room, including at least the power conversion equipment, battery, switchboards, cable trays, and internal electrical distribution.
- Detailed electrical drawings, including at least:
    - General Single Line Diagram
    - Earthing diagrams
    - Communication and control diagram
    - Physical diagram of the PV strings
    - Detailed diagrams of the connections between all main components

After commissioning, the supplier shall provide a new “as-built” Engineering Design, updating those items that could have been modified during the previous installation and commissioning phases. In addition, the Contractor shall also provide:

- O&M manuals to be used by the local technical team for the proper handling of the facilities.
- Detailed O&M plan shall clearly indicate and describe the tasks to be carried out (daily, weekly, monthly, quarterly, yearly) and the personnel involved.