Powering the Future

A Sustainability-Focused Maintenance Guide for Decentralised Solar Energy in Public Institutions

2025

SELCO Foundation

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Contents

Introduction

Deepening healthcare costs has pushed more than 344 million people into poverty.[2]

Affordable and accessible healthcare lies at the centre of universal health coverage. However, **4.5 billion people across the globe cannot access reliable health services, with more than 2 billion facing high out-of-pocket expenditures towards health.[1] Deepening healthcare costs has pushed more than 344 million into poverty, thus widening the inequity in accessing quality healthcare.[2]** With growing climate change that has direct and indirect health impacts, the disease burden across the globe will rise. Environmental, social and public health determinants will exacerbate these burdens, while increasing need for reliable healthcare access. Without access, the inequity in healthcare will be on the rise.

In the context of accessing health services, infrastructure, including access to energy, is vital to provide comfort to the patients and the staff. However, 25,000 health facilities in sub-Saharan Africa have no access to electricity, while about 68,350 facilities have unreliable electricity access.[3]

Additionally, health sector is currently one of the highest carbon emitters. If the health sector were a country, it would be the fifth largest emitter.[4]

To be able to achieve universal health coverage for all, we need to think of ways in which we can re-design health service delivery and optimise for people and planet.

Access to energy enables the provision of a wide range of services and enhances the quality of care that health facilities can provide.

Access to quality energy supports the usage of life-saving medical equipment such as fetal heart monitors and ultrasounds during pregnancy and childbirth. Reliable energy helps in the efficient functioning of refrigerators and vaccine cold storage, which helps maintain the shelf life of the vaccine and limits wastage of vaccines and other medicines. Energy access also improves Information and Communications Technology (ICT) functions, which enables telemedicine, administrative services, and improves access to healthcare services for a wider population. Energy in health facilities allows the staff to receive and provide timely communication and tend to emergencies by aiding in charging mobile devices.[5]. Patient records are maintained mainly on paper due to the unavailability of electricity. However, with an uninterrupted electricity supply, patient records and health statistics can be computerised, allowing efficient transfer of information. It also helps in reducing staff attrition as staff feel motivated to come to work regularly in a comfortable setting that facilitates their objectives. By improving the healthcare delivery services, there is a direct improvement in the health outcomes of the region and the healthcare system.

25,000 health facilities in sub-Saharan Africa have no access to electricity, while about 68,350 facilities have unreliable electricity access.[3]

1 World Health Organization. (2025). Universal health coverage (UHC). Retrieaved from https://www.who.int/news-room/fact-sheets/detail/universal-health-coverage-(uhc)
2 ibid.
3 World Health Organization, World Bank, Sustainable Energy for All, & International Renewable Energy Agency. (2023). Energizing health: Accelerating electricity access in health-care facilities. World Health Organization. https://www.who.int/publications/i/item/9789240066960
4 Health Care Without Harm, & Arup. (2019). Health care's climate footprint: How the health sector contributes to the global climate crisis and opportunities for action. Health Care Without Harm. https://global.noharm.org/resources/health-care-climate-footprint-report
5 Sustainable Energy for All. (2019). Lasting impact: Sustainable off-grid solar delivery models to power health and education. https://www.seforall.org/system/files/2019-04/Powering-Health_042019.pdf

A vital component for ensuring effective service delivery in a manner that allows for achieving global and local climate goals is having decentralised renewable energy (DRE) play the role of a catalyst. However, to maximise the gains from decentralised solar energy, it is essential to focus on operations and maintenance (O&M) as it influences the performance of the system and thus it directly impacts the services and the perception of safety and the well-being of staff and patients at the facility.

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Chapter 1

Understanding Operations and Maintenance (O&M) for DRE in Healthcare Facilities

Need for O&M

In a longitudinal study, it was found that more than 49% of the respondents stopped using an appliance due to breakdown of the appliance[6]. This suggests that lack of maintenance has resulted in discontinuation of usage of the product and thus users fail to gain the benefits of the product. This also applies to energy systems at public institutions.

In the health setting that has a solar energy system, when systems are not maintained, the connected equipment do not receive adequate power and remain unused as there is unreliable energy and thus, restricted services.

Think of a person who walked 8 km to reach a health facility for a diagnosis being told that his blood sample will not be collected that day because the facility cannot store the sample due to lack of electricity.

Not only does he lose that day's income but will have to miss one more day of work or as in most cases, would give up on seeking healthcare.

Building Trust with Local Capacity

When individuals are unable to seek care at facilities that are claimed to be powered by solar, it breaks the trust of the community in solar energy systems as a reliable source of energy. When communities fail to see the benefits that the DRE system brings with it, there remains limited uptake for other DRE-based solutions. This hinders the development of the DRE market within communities. It also affects the aspirations of those who wish to set up their own enterprise with reliable energy. This highlights that O&M is not only important for utilising an equipment to its fullest potential at a public institution but also in developing the local capacity and ecosystem for DRE uptake of different solutions.

6 Efficiency for Access (2023). Appliance Impacts Over Time: Longitudinal insights from off-grid TV, refrigerators, & solar water pumps users. Retrieved on December 02, 2024 from https://storage.googleapis.com/e4a-website-assets/Appliance-Impacts-Over-Time.pdf

What is O&M?

Operations and Maintenance (O&M) is an important component that ensure sustainability of the intervention. It can be defined as a set of activities carried out to enhance the energy system's performance and functionality by examining all the components and connections, rectifying issues that may emerge, and effectively coordinating and allocating resources for the same. Often, O&M is equated with the annual maintenance contract (AMC) signed with a vendor for a specific period of time, such as two years or five years. Each component has a warranty period, which means they can be replaced during that period without any hassle. While the AMC and warranty are important components of O&M, sustainability of program O&M has a much broader scope than that.

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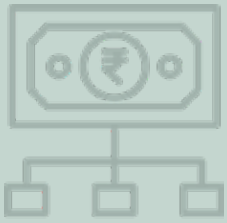
O&M - Enhance the energy system's performance and functionality to ensure intervention sustainability

Regularly examining all the components and connections

Rectifying issues that may emerge



Effectively coordinating and allocating resources for the same

The Analogy of a Car

When you own a car, you clean it on the outside regularly and carry out inspections of coolants, air filters and tire pressure every few weeks.

This is important to ensure that the car remains fully functional, and that you can drive the car without any trouble at any time you please.

After driving for about 10,000 km, the car must undergo maintenance to check all the components and repair and replace components for wear and tear (scheduled maintenance).

This is equivalent to preventive maintenance for the solar energy system

It includes activities for enhancing the performance of the system (preventive maintenance), which require basic knowledge of the system, such as cleaning the panels to prevent dust accumulation and checking all the wires for defects

These are activities covered under maintenance contracts of the asset. The car manufacturers also suggest that if you don't drive 10,000 km, the car must undergo servicing at least once a year, where all components of the vehicle are checked, and the engine oil is changed to ensure the safety of the vehicle and the validity of the warranty of components.

This is equivalent to scheduled maintenance for the solar energy system

For a solar energy system, the scheduled maintenance includes visits by technicians who visually inspect all the components, check the electrical performance of the system and carry out minor repairs if identified. Scheduled maintenance is helpful in addressing any issue before it aggravates and results in disruption of the system.

There may be unanticipated events which disrupt the functioning and require immediate attention

For example, if there is a breakdown in the middle of a highway, the car must require immediate attention, and the affected component may need repair or replacement, which may be due to causes not covered under scheduled maintenance. This is called corrective maintenance. When the components are under warranty, the user/owner is required to pay for transactions, i.e. transportation and labour cost. Therefore, when issues emerge within the warranty period, technicians or engineers address these issues, with the costs covered by the original equipment manufacturer.

However, when an accident is caused by the one driving the car, the entire cost has to be borne by the owner.

Here, the cost of damage is not covered under the warranty as the issue emerged due to human factors.

Maintenance has different implications in these two situations -

Where either components have reached their end of life

Have been affected due to different factors (such as human-made causes, weather-related issues, and others) that may or may not be covered by warranty

This is equivalent to corrective maintenance for the solar energy system

For a solar energy system, this includes issues such as damage to the inverter due to lightning strikes and broken panels due to stone pelting, among others. These are issues that fall beyond the warranty of the component and scheduled maintenance. In short, it can be said that O&M activities include addressing out-of-AMC and out-of-warranty issues as well.

What is a Good O&M Strategy?

A comprehensive O&M strategy requires diligent planning that covers the different types of maintenance of the energy systems. It requires allocation of adequate resources- human, material, financial – to carry out these activities effectively, with clearly outlined flows for information, finances and hardware, and capacity for delivering these roles. Implementation of programs require planning for O&M at the start to prevent hiccups post installation.

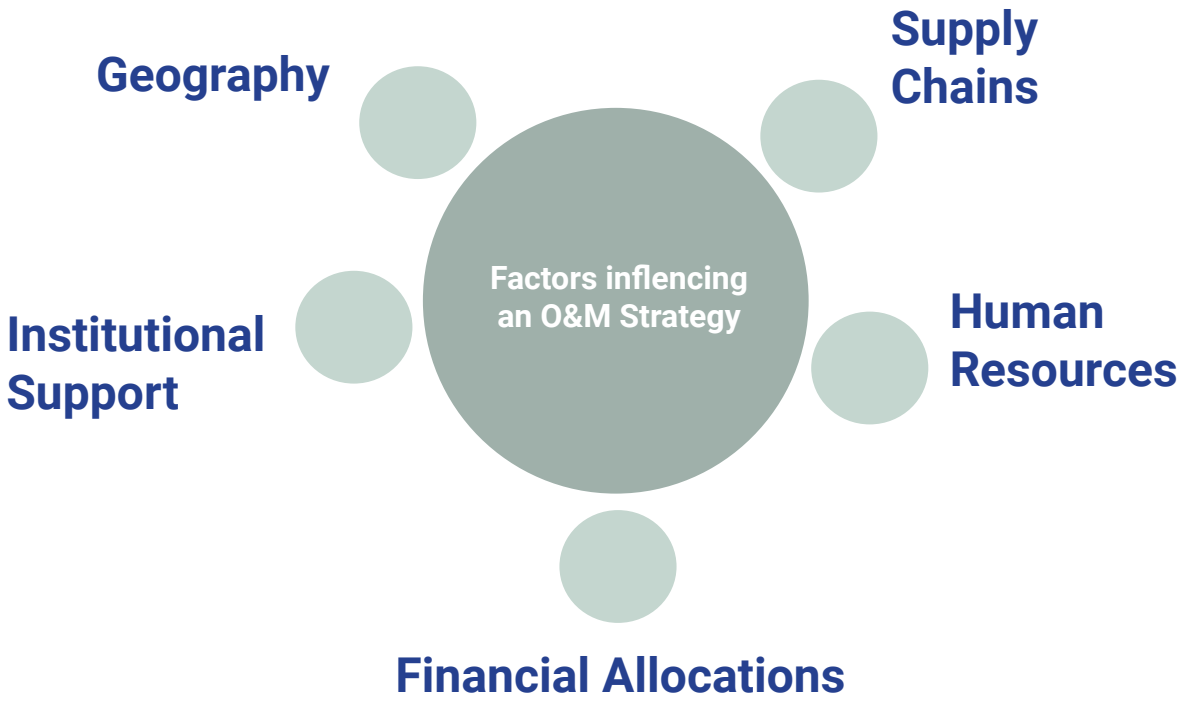
O&M for public assets such as solar energy systems at health facilities require additional processes for defining the ownership of the system at the facility level as well as at the ecosystem level to prevent thefts, encourage the health staff to take care of the system, utilise it to provide better services as well as to ensure adequate funding for maintenance activities. While most implementations of solar energy systems for health focus on having well-defined contracts with vendors, it is equally important to establish ownership and processes within the government setting to manage these contracts and carry out O&M in a timely manner.

Examples from around the world (Uganda, Zimbabwe) have indicated that with the involvement of multiple stakeholders, such as funding agencies, government, international NGOs and vendors, ill-defined roles and responsibilities result in a lack of ownership and hence lack of O&M.[7]

A report by SEforAll (2024) indicates that solar energy is perceived as being free of cost, which results in lack of financial and human resource allocation for O&M, and thus ad-hoc and reactive maintenance activities[8].

This highlights the need for detailing the processes required for establishing a sustainable O&M plan that takes into account geographical factors, supply chain for technologies, human resources, financial allocations, and institutional support in facilitating long term sustainability. As users engage with technologies that support effective service delivery, their trust in the energy system improves as it enables better services. This increases the utilisation of the system and thus the faith in the technology to improve their ability in providing the services which are otherwise restricted.

7 SEforALL (2024). State of the Market Report for Healthcare Facility Electrification. Retrieved from https://www.seforall.org/system/files/2024-02/Report_SOTM_2024.pdf on 31 December 2024.
8 ibid.


Geography
Supply Chains
Factors inflencing an O&M Strategy
Institutional Support
Human Resources
Financial Allocations

Types of Maintenance

O&M for solar energy systems at health facilities require well-defined processes and accountability for allocation of resources, resolution of issues, and monitoring the systems. A plan for O&M is vital for sustainability of health-energy programs. This is to account for effective health service delivery by maximising the performance of the energy system to enable energy-driven health services and to enhance the safety and well-being of healthcare staff and patients seeking care at the health facility.

The degree and frequency of maintenance services depends on the quality of the solar energy components and installation practices, as well as the location of the facility. For example, facilities in regions prone to rain-related disasters have a higher chance of system breakdown if the installation did not account for these challenges.

O&M consists of preventive maintenance, scheduled maintenance and corrective maintenance

Preventive maintenance focuses on activities that enhance the performance of the system

Scheduled maintenance are activities carried out by trained personnel who validate the functionality of all components of the system

Corrective maintenance includes repairs and replacement of components that have failed or resulted in frequent issues

Types of Maintenance	Technical Capacity	Finance	Frequency
Preventive Maintenance	Very Low (Health Staff, Admin Staff, Security Staff)	Not applicable	Weekly
Scheduled Maintenance	Medium (Trained technician from the Vendor)	Built under the Maintenance Contract	Twice in a year
Corrective Maintenance	High (Trained technician from the vendor)	To be allocated	As per requirement

Factors Impacting Operations and Maintenance

Factors impacting O&M lead to multuple approaches to O&M. A certain model could focus on the capacity that lies within the government to plan the O&M and execute it through contracts with vendors. While another model emphasises the private capacity to adhere to contracts with an NGO given its reach across different regions, in conjunction with remote monitoring systems. The factors also determine costs, for example, the geography of the region determines the ease of access to services, frequency of maintenance/repair and the cost of carrying out O&M.

Geography

Terrain

Assess if the region is plains, valleys, or mountains, and the presence of forests or islands, which impact the cost and turnaround time for O&M.

Disaster Vulnerability

Identify regions prone to thunderstorms, sandstorms, or flooding, as these require higher monitoring and maintenance to ensure system functionality.

Connectivity

It is important to evaluate the access to internet and road infrastructure for transportation services to determine ease of contact and turnaround time for O&M. Improved connectivity can facilitate better monitoring and timely support

Human Resources

Awareness

Assess the awareness of solar technology of the target end user as it influences their trust and engagement with the technology, which in turn influences the ownership of the system. Awareness of maintenance modalities, actions for continued utilization of technologies have all shown evidence of increased trust, and thereby ownership.

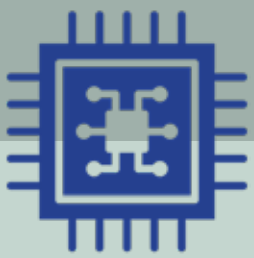
Skill Availability

Determine the availability of trained human resources for executing maintenance activities – be it medical equipment maintenance, streetlights, or water pumps. This determines the response time required for issue redressal.

Supply Chains

Enterprise Maturity

The market maturity for clean energy is reflected by the supply chain for solar technologies as well as the spread of enterprises across the region. This influences the cost of O&M and the turnaround time.



Components Availability and Quality

Assess the availability of technologies and spares, and ease of providing services, considering the cost of local availability versus importing. It is also essential to evaluate the quality of components that are available in the region as it impacts the plan for O&M.

Institutions

Existing Structures

Identify public health departments and energy departments that can integrate O&M of energy systems into their existing maintenance plans or allocate resources required for O&M.

Governance System

Analyze decision-makers' roles, involvement levels, and collaboration, impacting model choices. Analyse the processes to allocate roles and responsibilities of all the stakeholders involved.

Private Institutions and Capacity

Evaluate the capacity of NGOs and CEEs to manage and execute O&M, considering possible shared responsibilities and collaborations.

Finance

Funding Needs

Determine availability of funding for three levels- funds for maintenance contracts which may be included along with the CAPEX, funds for small corrective measures which may be available at the facility level, and funds for battery and other component replacement at the end-of-life.

Funding Sources

It is necessary to ascertain if funds are available through government, philanthropy or any other sources, as the frequency of funding and the size of funds required varies for different levels of maintenance activities.

Chapter 2

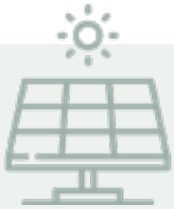
Establishing Standards: Guidelines for Comprehensive Operations and Maintenance

The chapter presents guidelines that focus on the specific activities and processes involved in carrying out preventive, scheduled and corrective maintenance. Each section also highlights roles of people who must take up the tasks.

Preventative Maintenance

The chapter presents guidelines that focus on the specific activities and processes involved in carrying out preventive, scheduled and corrective maintenance. Each of the section also highlights roles of people who must take up the tasks.

Scheduled maintenance is a planned set of activities that ensure the system works at its utmost efficiency, which must be carried out by an entity that has trained technicians and engineers to address any problems that may be identified during the visit to the site, including tampering, overloading and wear and tear of components. It is necessary to ensure that the technicians must carry out the activities in a manner that does not tamper with the warranty of the components.



SOLAR PANEL MAINTENANCE

Purpose

To maintain panel efficiency by removing dirt, debris and bird droppings that could block sunlight, reducing power generation.

Frequency

Bi-weekly

Activities

- Clean the panels using normal water and soft sponges or cloth only.
- Do not use detergents, chemicals, or abrasive materials that could damage the panel surface.
- Inspection for Wear and Loose Wire Connections: Regular check for any damages or loose connections that could affect the performance of the solar system.
- Panel Damage: Look for cracks, chips, or any physical damages on the panels that could affect performance or lead to further issues.
- Inspect panels for corrosion, especially in areas with high humidity or salt exposure, particularly near panel edges or connections.
- Trim trees and weeds near the panels to prevent shaded areas, which can reduce energy production.

Bad Practices

- Staff should not stand, step, walk, sit or run on the panels to avoid physical damage and ensure the panels' integrity.
- Do not use hard brushes or abrasive cloths that may scratch or damage the panels.
- Do not disconnect any wires or components of the solar system unless specifically instructed by the contractor.
- Avoid spilling water on the back of the panels or in the gaps where components are housed. Water can damage the internal wiring and other components.
- Do not remove or tamper with labels or components on the panels or other equipment.
- Avoid using paints, adhesives, or any chemicals on panels as these can degrade the material or create a barrier to sunlight.

BATTERY MAINTENANCE

For Lead Acid Batteries

- Check the battery water level at least once a month and inform the contractor to refill it with distilled water if low water levels or a fully dry battery are observed.
- Ensure the battery room is well-ventilated to avoid the accumulation of dangerous gases and to maintain optimal battery temperature.
- Regularly check for any loose connections or unusual burning smells from the battery or any solar system components, as these could indicate overheating or electrical faults.
- Prevent corrosion at the terminals by providing a thin layer of petroleum-based jelly around the nut-bolt and terminal interfaces.
- Ensure that the batteries are be kept in a location that prevents exposure to sunlight.

For Lithion Ion Batteries

- Keep the premises cool and dry.
- Keep away from direct sources of heat and open flames.
- Keep the room and the terminals free from dust.
- Ensure the connection of terminals and connecting plates/cables are intact.
- Ensure all cables are intact without damages.
- Ensure the battery management system parameters are set as per the OEM recommendations

Protection During Extreme Weather

- Swich off the system as per the discussion with the contractor during extreme weather conditions. For example, switching off the inverter/isolator during heavy lightning or thunderstorms to prevent damage from electrical surges. Wait until the weather stabilizes before reactivating the system.
- Maintain adequate ventilation around the inverters and batteries to prevent overheating especially for the geographies with extreme hot weather.

Troubleshooting and Communication

- If a system shuts down, the concerned staff shall register the complaints within 72 hours through the identified mechanism (digital app, phone call to the contractor) and the contractor must assist in troubleshooting the issue remotely through phone or video calls, wherever applicable.
- If the issue is not resolved remotely, the staff shall lodge a formal complaint, as applicable, for further action. This ensures a quick response to any ongoing issues and returns the solar system to full functionality.

Scheduled Maintenance

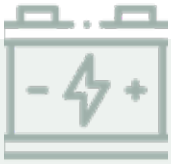
These processes are carried out at least twice a year, at intervals of six months, to validate the functionality status of all the components. Annexure A has details of checklists which must be filled out by the technician visiting the health facility.

SOLAR PANELS

- Cleaning of solar panels and keeping it free from dust and grime (droppings, leaves, lichens).
- Check the physical condition of the panels (At the front and rear sides), for any possible external interferences (Human, Animal, Nature).
- Check the stability of the panels with MMS & roof (Clamping torque check, tightening of nut-bolts, if needed. MMS-roof gripping strength, Civil work, MMS stability and damages, replacement of nut bolts, if required).
- Ensure there are no objects in the vicinity that could cast shadows on the panels. If such objects are present, they must be removed, or the panels must be relocated accordingly.
- Check and analyze the panel output power with respect to its designed capacity.
- Check if the panel's cable connectivity is maximum and the cables are protected from external damage.
- Check the solar cables for any possible electrical damage.
- Prevent corrosion on the metal structures/components like MMS by providing a thin layer using zinc spray, whenever required.

INVERTER

- Check appearance/cleanliness of the cabinet, ventilation system and insulated surfaces.
- Check if inverter displays all parameters
- Check inverter has no faults displayed
- Check inverter configurations are set as per the instructions
- Check inverter inputs lines are connected
- Perform temperature checks on all breakers, connections and associated controls.
- Check all fuses for signs of heating.
- Check inverter input power lines show normal values and are free from faults.
- Check inverter isolators box (MCB, Fuses, cable, enclosure condition and connectivity).
- Check the state of AC/DC surge arrestors, cable connections and circuit breakers.
- Check inverter has no physical damages and is kept dust free
- Check inverter room has active ventilation
- Check inverter room has no flammable materials stored.
- Check that vermin have not infested the inverter. Typical signs of this include spider webs on ventilation grills.



BATTERY BANK

- Check the battery health (string/ individual) (Load testing, Voltages)
- Check battery physical condition (Body damages, terminal damages)
- Check for cable connectivity and for any damages
- Check electrolyte parameters (Distilled water levels to be filled till the optimum level, SG values) for lead-acid batteries
- Check terminal protection (Corrosion, tightness, Caps & petroleum jelly coating)

LOAD SIDE

- Check only the specified loads are connected to the system
- Check the discipline in power consumption at the center.
- Check no new lines are tapped
- Check all critical loads receive solar-battery-grid-generator power
- Check all critical loads are functional

ORIENTATION TO HEALTH FACILITY STAFF

- Provide a quick orientation to staff on basic maintenance & operations practice
- Share updated contact details with health staff.

OTHER COMPONENTS

Changeover Switches

- Check the functionality
- Check the input & output lines
- Check the solar positioning of the switches

AC and DC Cables

- Check cable connectivity
- Check DC cabling, strings and terminations and end termination contacts
- Check cable damages and protections
- Inspection of cable for insulation damage
- Check AC distribution boards for any loose connections
- Tightening of termination including replacement of MC4 connectors, if needed
- If some cables/wires need to be replaced, make sure it is of proper rating and type.

GIPB/AJB/DCCB/ACDB/Isolator Box

- Check if any loose connections exist
- Check for any cable burnt marks
- Check for any damages to the box
- Check SPD, MCB & fuse condition, functionality & positions
- Check the setup box for stability

Earthing Protection

- Check connectivity status with equipment and earth pits
- Check physical condition of the pits
- Check the resistance of the pits

Lightning Arrestor

- Check the physical stability of the set up
- Check the connectivity status with earth pit
- Check if any damages exist

Corrective Maintenance

Corrective or unscheduled maintenance is the repair or replacement of equipment after a fault or failure has occurred. Corrective maintenance is the unplanned, on call service visits that must be carried out in a timely manner based on the agreed timelines. Such maintenance is reactive and involves identifying, troubleshooting, and fixing the issue to restore the equipment to full operational capacity.

Corrective maintenance can happen either as a response to complete breakdowns or when equipment performance significantly degrades but hasn't fully failed. Corrective maintenance includes services that are chargeable and non-chargeable in nature:

SERVICE WITHIN WARRANTY (NON-CHARGEABLE)

SOLAR PANELS

- Any damage caused, excluding damage caused by animal, human interference, natural calamity or theft
- Repair or replacement of nut bolts in case of corrosion, cables if damaged without proper casing, tightening MMS, fuses (except burnt and theft cases)

BATTERY

- (Lead Acid) Low water level/fully dry/ deep discharge, if the previous AMC was skipped or not conducted
- Application of petroleum jelly at the terminals if the previous AMC was skipped or not conducted
- Bulging of Battery during the warranty duration
- (Lead Acid) Acid Leakage
- Over-usage of the battery due to system malfunction or factors beyond the user's control.
- Loose cables/Disconnected Cables (excluding theft cables, third party interference)

INVERTER

- Repair/replacement of LED Screen excluding physical damages
- Shut down due to any technical issues other than lightning, overload, grid issues, short-circuit, chewing/disconnection of wires/ cables, water droplets, floods or 3rd party interference.
- Repair or replacement of MCB (except burnt and theft cases)
- Repair or replacement of Fan (except burnt and theft cases)
- Repair in terms of continuous buzzing or warning sound
- Repair or replacement of burnt components (except when occurred due to heavy lightning, overload, water droplets)

OTHER COMPONENTS

- (AJB/GIPB/DCCB) MCB Tripping/ Off– repair or replacement
- (Lightning Arrestor) Any damage caused, excluding damage caused by animal, human interference, natural calamity or theft
- (Earthing Connections) Any damage caused, excluding damage caused by animal, human interference, natural calamity or theft

SERVICE OUTSIDE WARRANTY (CHARGEABLE)

SOLAR PANELS

- Replacement of panels owing to cracks (due to stone pelting, hailstones, falling of tree branches, civil works), hotspots, scratches, thick dust, adopting wrong practices while cleaning the panels.
- Blowing away or dislocation of panels from the MMS due to strong winds
- Breakage or displacement of MMS caused by strong winds
- Corrosion on MMS and needs replacement outside warranty period
- Dismantling of panel from MMS owing to civil works by the end user or any 3rd party
- Replacement of theft panels of similar capacity and the additional required consumables for installations

BATTERY

- Breakage or damage of caps, storage racks
- (Lithium-ion) Replacement of blown fuses
- Any physical damage due to insect/ rodent attacks or human interference, disturbing the cable connections, water droplets, flood
- (Lead-acid) Additional distilled water, if needed
- Deep discharge caused due to inactivity/idleness by the end-user
- Burnt Cables, replacement of battery caps or faulty indicators
- Replacement of theft Batteries of similar capacity and the additional required consumables for installations
- Over-usage of the battery beyond its recommended capacity
- Replacement of batteries after 5 years span (Lead-acid), whenever required

INVERTER

- Resolution of issues on account of shut down due to grid issues, voltage fluctuations, heavy lightning/thunderstorms, overloading/heavy loads, short-circuit, burnt cables/MCBs/ SPDs, insect/rodent attacks or disturbing the cables connections, water droplets, flood and so on.
- Replacement of theft Inverters of similar capacity and the additional required consumables for installations

OTHER COMPONENTS

- (LA and Earthing) Burnt or damaged cables due to lightning or short-circuit
- (LA and Earthing) Broken or disconnected LA/earthing connections/earthing pits
- (LA) Blowing away of LA due to heavy wind
- (LA and Earthing) Theft of LA/ earthing cables
- (AJB/GIPB/DCCB) Replacement of burnt Cables/SPD/MCB to lightning or surge strike
- (Cables) Any damages caused due to end-user induced cable set-up disturbance or tapping to connect any additional loads
- (Theft) Replacement of theft items that includes any solar panels, batteries, inverters, earthing electrode, lightning arrestor, cables, luminaries, battery storage racks, consumables and so on
- (Tapping Additional Lines) Any damage caused by tapping additional lines from the solar system
- Replacement of any spares that are not covered under warranty.

SERVICE WITHIN WARRANTY

In case the equipment is under warranty, the manufacturer/contracted supplier bears the corrective maintenance costs for failures either caused by manufacturing defects or early part failures. They must fix any equipment faults, component failures, or defects in workmanship that arise within the warranty period at no additional costs. The list of such non-chargeable services is elaborated further. All service activities performed under warranty must be documented for creating a record of repairs, parts replaced, and troubleshooting completed as per the "On-call service" template shown in Annexure B and must be signed by the end-user. The contracted party- either the government or enterprise must have access to spares which are covered by warranty.

SERVICE OUTSIDE WARRANTY

Certain services fall outside the original warranty, which require repairs, replacements, and troubleshooting of the issues. In these cases, the government must allocate the costs associated with these services to the contracted party in accordance with the agreed upon costs and terms and ensure functioning of the system. The list of such chargeable services is mentioned in this section. The warranties exclude issues resulting from misuse, animal and human interferences, environmental damage, unauthorized modifications or normal wear and tear and services for such issues will be chargeable. All service activities performed outside warranty must be documented for creating a record of repairs, parts replaced, and troubleshooting completed, which must be signed by the end-user, which is the health staff.

SERVICES ON DEMAND

The end-user may demand certain services that are out-of-warranty based on need. This includes:

- Request by the end-user/ government for alterations/modification/shifting/dismantling or disassembling of the solar system components.
- Additional requirement of distilled water post re-filling as a part of AMC.
- Request for upgradation, additional connections or extension of loads to existing solar system being installed by the end-user / government.
- Request for conducting additional AMC apart from the two applicable AMC services per year.
- Request for unscheduled service visits/service on-call for corrective maintenance/repair/ replacement.
- Re-installation of solar-related products due to theft, involves replacing and reinstalling components that have been stolen from the health facilities.

For such services, an additional cost with respect to transportation charges, labour charges, loading and unloading charges may be quoted and submitted for release of payment to the contracted party. It is also necessary to agree upon timelines within which the services must be carried out.

OTHER CONSIDERATIONS

The government must also consider additional security enhancements to prevent future theft, such as anti-theft mounting, alarm systems, or surveillance, as part of the re-installation process.

Given the range of activities that are required to be carried out, the contracted entity must maintain spares for carrying out these activities seamlessly. It is essential to consider how the finances are allocated for spares right at the beginning of the program and establish a clear process for allocation of resources as and when the need emerges.

The list of spare components is elaborated in Annexure C. The list is indicative and may be different depending on the model and type of components chosen for installation.

O&M is a continuous process to keep the system in robust conditions and meet the energy needs of the facilities. It requires collaboration among various entities such as government departments which allocate financial resources and may also assign dedicated human resources to carry out the activities, enterprises that may be contracted by the government, health facility staff who operate the system on a day-to-day basis and community members or groups that ensure accountability for working condition of systems at the facilities.

Chapter 3

Lessons for Successful O&M Models

O&M for public assets require defined processes with roles and responsibilities identified for all stakeholders for effective governance of specific activities and turnaround times. Unlike personal assets, public assets require an additional layer of streamlined processes for defining who owns the system and how the stakeholders are interconnected in the ecosystem. This requires planning for issue resolution, adequate training for all stakeholders involved directly and indirectly with O&M, and integration of monitoring systems; all of which builds trust in the system.

Some of the best practices for effective O&M delivery are highlighted below. These include defining a prioritisation matrix, defining ownership at the public institution, training and capacity building at various levels, spare parts management, integration of remote monitoring systems into the design, customer relations management portal, and a digital incidence management platform for effective scaling.

Priority Matrix

For an effective operation and maintenance plan, it is essential to create a prioritisation matrix that takes into consideration the modality of issue resolution, time period required to resolve an issue and an escalation process.

The **modality of issue resolution** can be **remote or through in-person visits** depending on the issue at hand. For remote resolution, it is mandatory that the staff at the facility be trained in carrying out basic troubleshooting activities. This will allow the vendor to guide the staff into carrying out certain activities for resolving the issue.

The **time period for resolution** determined for different issues **depends on the criticality of the issue and to what degree is service provision affected by it.** Certain issues which shut down the energy system discontinuing energy supply to essential equipment at the entire health facility must be addressed within 24 hours and must be followed up every 24 hours.

The **escalation process** must be defined such that the **roles and responsibilities of different stakeholders for maintaining the energy system are demarcated**. This process improves the accountability of all the stakeholders in ensuring that the issues that emerge are addressed as soon as possible.

Defining Ownership

In different programs, defining ownership involves clearly identifying the roles and responsibilities of various stakeholders, particularly in terms of management. In many cases, the government department responsible for health would be considered as the owner of the program, as they would be responsible for funding and regulatory framework for integrating energy into the service delivery model for healthcare. If there are NGO partners involved to carry out certain roles, it is important to map out how the NGOs and the government interact, delineating responsibilities for taking the lead, being informed or consulted for different activities such as raising request for out-of-warranty maintenance.

Training and Capacity Building at Various Levels

When a technology is newly introduced, the users must be trained in not only operating it but also be made aware of the benefits they gain from the technology. Along with the vendor training on operations and maintenance, it is also essential to carry out trainings for health facility staff and program managers – e.g. the government department, for building perception on maintenance practices and sustainability that supports effective service delivery. It will also help users overcome fear of using the system and equip them to carry out basic troubleshooting actions. In addition, it is also necessary to conduct annual refresher trainings on maintenance to account for change of staff and to prevent skill decay, which will ensure that maintenance activities are performed with motivation.

Spare Part Management

In health facilities, especially in remote or rural areas, the reliability of the solar energy system is critical to maintaining essential services. Having the right spares available ensures that repairs can be conducted immediately, minimizing downtime. Often, resources required for repair need to be procured from the manufacturer, who may not be locally present. This would result in high cost of repair, with importation of parts and hiring technicians externally. Spare part management involves maintaining detailed records of components in stock and their condition. Warehousing for spares also forms an important component of O&M, along with identifying transport facilities for the movement of spares from the hub to the facilities. Management of spares also relies on who is defined as the owner of the system and the program as they would be responsible to manage contracts with vendors for maintaining spares or maintain the spares locally at a hub that can service multiple facilities. Public procurement processes for spares must also be clearly defined to ensure that maintenance activities are lucrative for enterprises and the government can manage its budgets efficiently.

Integration of Remote Monitoring Systems in System Design

Remote monitoring systems (RMS) are essential for real-time tracking and data analysis, which allows the stakeholders to monitor the health and performance of the systems. This is important to address issues as soon as they arise and as efficiently as possible. RMS is particularly important for facilities located in hard-to-reach areas, as geographical distance may inhibit contracted vendors from visiting these facilities due to high costs. RMS allows for early issue identification, before it affects the performance of the system, which allows for carrying out minor repairs instead of corrective measures that require component replacements. Remote monitoring also builds in accountability for projects at scale as it provides concrete data on functionality of a large number of systems. This can also be used for fund disbursement in certain financial settings with contracted vendors.

Establishing Customer Relationship Management (CRM) Platform

A CRM platform becomes essential for settings where the practice of maintenance has been absent and thus the faith in issue resolution system is low. In situations where trust is low, it is less likely that the health facility staff/user of the technology would report issues – as they do not trust that there would be a resolution. With active calls from executives to monitor issues and address them, the trust of the health facility staff is built to use the technology. It also empowers the staff to take ownership of the systems and maintain them, with the assurance that the CRM team would be available if they face any challenge.

Scaling O&M Through a Digital Incidence Management Portal

At any given point in time, there are at least three stakeholders involved in O&M – health facility staff, vendor, and the health system decision makers, such as the Department of Health. When issues emerge, there are multiple rounds of interaction for resolution of these issues. To ease this process for all the stakeholders, a digital incidence management portal plays a pivotal role for programs at scale. An incidence management platform allows for streamlined data on maintenance issues. It allows various stakeholders to interact and take action with clear allocation of responsibilities for different levels of issues.

This platform can be introduced for all programs when the end-users have trust in the technology and issue resolution process. This allows for regular monitoring of issues that emerge, faster follow-ups and turnaround time for issue resolution. The digital management will bring forth the gaps in processes and provide insights for better management systems for O&M.

Conclusion

Operations and maintenance are integral to successful and sustainable health-energy programs. It is critical to plan for O&M from the inception of programs as it shapes the implementation approach and quality of the program, overall. If planned comprehensively and in a timely manner with all relevant stakeholders, O&M can inform technical specifications, installation, training, ownership and the scope of financing the life cycle of a sustainable health-energy program at scale.

Expanding the scope of O&M beyond contracts with vendors and scheduled maintenance is a key ambit of the overall program sustainability plan. O&M must include preventive, scheduled and corrective maintenance, carried out at different frequencies by different stakeholders. Delineating activities, processes and roles and responsibilities of stakeholders for carrying out comprehensive O&M ensures there are mechanisms in place to be able to cater to the expanded scope of O&M.

Operations and maintenance for public assets not only aims at extending the life of the system but also develops a local ecosystem for solar energy adoption by improving employment opportunities for skilled human resource, trust in the solar energy systems for enhancing healthcare, and closer collaboration amongst stakeholders. Each of aspects are imperative to ensure that programs do not stop at implementation; instead a local enabling support ecosystem is built to ensure program outcomes and goals are achieved.

ANNEXURE A

Template for Scheduled Maintenance (AMC)
Report of DRE Systems in Healthcare Facilities

BASIC DETAILS

Health centre name _____

Health centre Point of Contact (PoC) name with designation _____

_____

Health centre Point of Contact (PoC) contact number _____

Health Centre Address (mention state, district and block name) _____

_____

Service Person Name _____

Last Scheduled Maintenance Date

_____ / _____ / _____
DD MM YYYY

Date of current Scheduled Maintenance

_____ / _____ / _____
DD MM YYYY

System is within warranty period

YES / NO

SCHEDULED MAINTENANCE CHECKLIST

NO.	CHECKLIST	RESPONSE	REMARKS (ISSUE & ACTION TAKEN)
	GENERAL		
1	Is the solar system functional?	YES NO	
2	Is there any tapping observed in solar load wiring?	YES / NO	
3	Are there any heavy or extra loads running on solar?	YES / NO	
	SOLAR PANEL		
4	Is there any physical damage on the solar panels?	YES / NO	
5	Is there any shadow on the solar panels?	YES / NO	

NO.	CHECKLIST	RESPONSE	REMARKS (ISSUE & ACTION TAKEN)
6	Are the solar panels clean and maintained?	YES / NO	
7	Is there any hot spot on the solar panel?	YES / NO	
8	Is the stability of the panels with MMS checked and the nut-bolts tightened during the visit?	YES / NO	
9	Are the cables intact and safe (Panel to Panel, Panel to AJB, AJB to PCU)?	YES / NO	
11	Are Earthing connections intact and safe?	YES / NO	
12	Is the Panel voltage measurement taken?	YES / NO	
13	Is the Panel ampere measurement taken?	YES / NO	
	BATTERY		
14	Are the Batteries cleaned and maintained?	YES / NO	
15	Are the electrolyte parameters (Distilled water levels to be filled till the optimum level, SG values) checked?	YES / NO	
16	Is the Battery Bank voltage measurement of Inverter checked?	YES / NO	
17	Is the battery health (string/individual) (Load testing) checked?	YES / NO	
18	Is battery bank rack stable?	YES / NO	
19	Is the battery room ventilated; dust free & moisture free?	YES / NO	
20	Is the battery physical condition (Body damages, terminal damages) checked?	YES / NO	
21	Is the cable connectivity and damages checked?	YES / NO	
22	Are the terminals (corrosion, tightness, caps & petroleum jelly coating) checked?	YES / NO	
	INVERTER		
23	Is the appearance/cleanliness of the cabinet and insulated surfaces checked?	YES / NO	
24	Is the inverter fan operating properly?	YES / NO	

NO.	CHECKLIST	RESPONSE	REMARKS (ISSUE & ACTION TAKEN)
25	Are the inverter connections intact & undamaged?	YES / NO	
26	Is there any tapping observed in solar load wiring?	YES / NO	
27	Is Inverter display functional and displaying all the parameters?	YES / NO	
28	Is the inverter configurations set as per the instructions?	YES / NO	
29	Are the inverter input power lines show normal values and are free from faults?	YES / NO	
30	Are the temperature checks on all breakers, connections and associated controls performed?	YES / NO	
31	Are all fuses checked for signs of heating?	YES / NO	
32	Is the state of AC/DC surge arrestors, cable connections and circuit breakers checked?	YES / NO	
33	Is the inverter room has active ventilation?	YES / NO	
34	Is the inverter room has any flammable materials stored?	YES / NO	
35	If the response to point K is 'YES', then was it informed to the health staffs for immediate removal?	YES / NO	
36	Was it verified that the vermin have not infested the inverter? Typical signs of this include spider webs on ventilation grills.	YES / NO	
	GRID INPUT PROTECTION BOX		
37	Is the connection status checked?	YES / NO	
38	Are there any damages to the box observed?	YES / NO	
39	Are the SPD, MCB & fuse condition, functionality & positions checked?	YES / NO	
	ARRAY JUNCTION BOX		
40	Is the connection status checked?	YES / NO	
41	Are there any damages to the box observed?	YES / NO	
42	Are the SPD, MCB & fuse condition, functionality & positions checked?	YES / NO	

NO.	CHECKLIST	RESPONSE	REMARKS (ISSUE & ACTION TAKEN)
	DC COMBINER BOX		
43	Is the connection status checked?	YES / NO	
44	Are there any damages to the box observed?	YES / NO	
45	Are the SPD, MCB & fuse condition, functionality & positions checked?	YES / NO	
	AC AND DC CABLES		
46	Are the cable connectivity checked properly?	YES / NO	
47	Are the DC cables, strings and terminations and end termination contacts checked?	YES / NO	
48	Are the cable damages and protections checked?	YES / NO	
49	Is the inspection of cable for insulation damage conducted?	YES / NO	
50	Are the AC distribution boards checked for any loose connections?	YES / NO	
51	Tightening of termination including replacement of MC4 connectors, if needed	YES / NO	
52	In case of replacement of cables/wires, was the proper rating and type ensured?	YES / NO	
	CHANGEOVER SWITCH		
53	Is the connection status checked?	YES / NO	
54	Are there any damages to the box observed?	YES / NO	
55	Are the SPD, MCB & fuse condition, functionality & positions checked?	YES / NO	
	EARTHING PROTECTION		
56	Is the connectivity status with equipment and earth pits checked?	YES / NO	
57	Is the physical condition of the pits checked?	YES / NO	
58	Is the resistance of the pits checked?	YES / NO	

NO.	CHECKLIST	RESPONSE	REMARKS (ISSUE & ACTION TAKEN)
	LOAD SIDE		
59	Was it verified that only the specified critical loads are connected to solar?	YES / NO	
60	Was it checked that no new/additional lines are tapped from solar lines?	YES / NO	
61	Are all critical loads receiving solar-battery-grid-generator power?	YES / NO	
62	Are all critical loads installed are functional?	YES / NO	
	ORIENTATION TO HEALTH FACILITY STAFF		
63	Has an orientation to staff on basic maintenance & operations practice being provided during the visit?	YES / NO	
64	Record the feedback in the remark's column, if any	YES / NO	
65	Are the updated contact details shared with staff for registering complaints?	YES / NO	

TIME-STAMPED AND GEO-TAGGED IMAGES TO BE CAPTURED DURING THE SCHEDULED MAINTENANCE VISIT

NO.	IMAGE DETAILS	REQUIRED NO. OF IMAGES	TICK IF COMPLETE	REMARKS
01	Clear image of solar panels from a range which gives better visibility	2		
02	Clear image of batteries from a range which gives better visibility including the water level	1		
03	Clear image of inverter from a range which gives better visibility (Front and back)	2		
04	Clear image of the inverter switch controls	1		
05	Clear image of cable routing from the complete system	3		
06	Clear image of AJB	1		
07	Clear image of GIPB	1		
08	Clear image of Lightning Arrestor	1		
09	Clear image of Earthing pits	1		
10	Clear image of Changeover Switch	1		
11	Clear image of Do's and Don'ts Poster	1		
12	Clear image of Outdoor Light, if applicable	1		
13	Clear image of the Service Person with Health Facility Name Board	1		

FAULT RECTIFIED/REPLACEMENT DETAILS

NO.	COMPONENT NAME	MAKE	SERIAL NUMBER	QUANTITY	WATT/AH/ SPECS	COST UNDERTAKEN (INCL. GST)	REMARKS (Please mention if the service is under warranty or out of warranty?)

ADDITIONAL REMARKS

- **Fault Rectification Status (Completed/ Not Completed/Partially Completed)**
- **If not/partially completed, mention the schedule plan date for next visit:**

END USER (REMARKS)

END USER (SEAL & SIGNATURE)

SERVICE PERSON (REMARKS)

SERVICE PERSON (SEAL & SIGNATURE)

Date: _____

Contact No: _____

SERVICE MANAGER (SEAL & SIGNATURE)

Date: _____

Contact No: _____

ANNEXURE B

On Call Service Report

BASIC DETAILS

Service Person Name _____

Service Person Contact Number _____

Last Scheduled Maintenance Date	Date of Current Scheduled Maintenance	Date of Complaint
____ / ____ / ____	____ / ____ / ____	____ / ____ / ____
DD / MM / YYYY	DD / MM / YYYY	DD / MM / YYYY

Health centre name _____

Health centre Point of Contact (PoC) name with designation _____

_____

Health centre Point of Contact (PoC) contact number _____

System is within warranty period

YES / NO

Purpose of On-call visits (Tick appropriately)

- ☐ Shifting of entire system from one location to another
- ☐ Troubleshooting/Repair/Replacement
- ☐ Extended Connections
- ☐ Dismantling of solar components
- ☐ Others (Please specify)

ISSUES REPORTED

Issue reported by user _____

Issue detail (observation) _____

_____

Cause of issue _____

SHIFTING OF PARTIAL/ENTIRE SOLAR SYSTEM TO A NEW LOCATION

Whether the entire system was shifted to new location YES / NO / NOT APPLICABLE

If YES,

Date of Initiation of Shifting	Date of Completion of Shifting	Has the system been re-installed and commissioned?
____ / ____ / ____ DD / MM / YYYY	____ / ____ / ____ DD / MM / YYYY	YES / NO

If YES,	If NO,
Has the Installation completion report submitted? YES / NO **Date of system re-installation and commissioning** ____ / ____ / ____ DD / MM / YYYY	**Reason for not installing/ commissioning and timeline to do the same** _____ _____

RECTIFICATION/REPLACEMENT DETAILS (APPLICABLE ONLY IN CASE OF ANY FAULTS REPORTED/OBSERVED)

NO.	COMPONENT NAME	MAKE	SERIAL NUMBER	QUANTITY	WATT/AH/ SPECS	COST UNDERTAKEN (INCL. GST)	REMARKS (Please mention if the service is under warranty or out of warranty?)

ADDITIONAL REMARKS

EXTENDED CONNECTION DETAILS (APPLICABLE ONLY IN CASE OF ANY CONNECTIONS EXTENDED IN THE SAME HEALTH FACILITY)

NO.	COMPONENT NAME	MAKE	SERIAL NUMBER	QUANTITY	WATT/AH/ SPECS	COST UNDERTAKEN (INCL. GST)	REMARKS (Please mention if the service is under warranty or out of warranty?)

ADDITIONAL REMARKS

SERVICE STATUS

Advise to the end user for prevention of issue _____

_____

Service Completion Status COMPLETED / NOT COMPLETED / PARTIALLY COMPLETED

If not completed, details and plan/schedule for next visit _____

_____

CHECKLIST DURING ON-CALL SERVICE VISIT (TO BE FILLED BY SERVICE PERSON)

NO.	CHECKLIST	OBSERVATIONS	REMARKS (ISSUE & ACTION TAKEN)
59	Are the systems (Panels, Battery & Inverter) cleaned by the user?	YES / NO	
60	Is there any shadow noticed on the solar panels?	YES / NO	
61	Panel voltage measurement taken (Please mention in remarks)	YES / NO	
62	Panel current measurement taken (Please mention in remarks)	YES / NO	
62	Battery bank voltage measurement taken (Please mention in remarks)	YES / NO	
62	Any tapping observed on solar load wiring?	YES / NO	
62	Are there any heavy or extra loads running on solar?	YES / NO	

ADDITIONAL REMARKS

END USER (REMARKS)

END USER (SEAL & SIGNATURE)

SERVICE PERSON (REMARKS)

SERVICE PERSON (SEAL & SIGNATURE)

Date: _____

Contact No: _____

SERVICE MANAGER (SEAL & SIGNATURE)

Date: _____

Contact No: _____

ANNEXURE C

List of Spare Components

SOLAR PANEL	Spare panels of installed capacity, brackets, bolts, nuts and washers, clamps and fasteners for panel mounting hardware. For Panel connectors and cables – Y Connectors, MC4 connectors, extension cables, fuses and fuse holders, cable ties and clips, SPDs, sealant and tapes, solar PV cables.
SOLAR INVERTER	Spare inverters of various installed capacity, SMPS with Connector, display card, control PCB card, 2/3/4 module PCB, IGBT module, SCR switch, mother board, Digital Signal Processor (DSP), Solar charging coil, display PCB, AC and DC Fuse/Circuit breakers and disconnect switches, cooling fans, heat sinks, capacitators and surge protectors, On-Off switch, LCD screens/display panels, Control buttons/keypads, communication modules such as Wi-Fi, Bluetooth or RS-485, SPD, Bus bars and terminal blocks, cables, ties and connectors, lugs, nut-bolts and washers, input-output relay.
SOLAR BATTERY	Spare batteries of various installed capacity, DC cables and connectors to handle battery charging, compatible charge controllers, distilled water, petroleum jelly, battery caps, lugs for replacing worn or damaged connectors, spare terminals and clamps, fuse kits.
ELECTRICAL AND WIRING COMPONENTS	DC extension cables (for extending panel wiring when repositioning or replacing panels), AC cables, Solar PV cables of various sizes like 1/1.5/2.5/4/6/10/16/25/50 sq. mm., MC4 connectors, MC4 - Y connectors, compression lugs, crimp connectors, DC and AC junction box with surge protection, fuses and terminal blocks to manage AC and DC connections, MCBs (as per the ratings), String combiner box, DC fuse and fuse holders, AC fuse and circuit breakers, surge protectors, DC and AC disconnect switches, Sealant for junction boxes to prevent water/insect ingress, Insulation tapes, PVC pipes, Flexible pipes, saddle clamps
EARTHING AND GROUNDING KIT	Copper wires, grounding rods, down conductors, ground rod clamps, compression lugs, bolt connectors, U-bolt and pipe clamps, cable glands, protective conduits, anti-corrosion gel/paste, protective paints and coatings, nuts, bolts and washers, grounding lugs.
LIGHTNING ARRESTOR	Mounting brackets and clamps, insulated mounting kits, high-quality and corrosion-resistant grounding wires/cables and connectors, air terminal rods and elevation pole, insulators, bolts, nuts and fasteners, sealant and gaskets for outdoor application.
GIPB/AJB/DCCB/ ACDB/ISOLATOR BOX	Fuses, SPDs, MCBs, RCCB, MCCB
OTHER COMPONENTS	Lights, Fans, Fan Capacitor, Fan coils, Switches, Regulators, Sockets, AC and DC cables, change-over switches.

Powering the Future

A Sustainability-Focused Maintenance Guide for Decentralised Solar Energy in Public Institutions

2025

SELCO Foundation

For more information, get in touch!

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www.selcofoundation.org