Energy baseline development, tariff study and tool, O&M plan and manual and capacity building for the 500 kWp solar PV mini-grid in Bissorã, Guinea Bissau

TASK 4 – O&M&M model and plan

Draft report

Prepared for:

UNIDO

June 2018

Project:	Energy baseline development, tariff study and tool, O&M plan and manual and capacity building for the 500 kWp solar PV mini-grid in Bissorã, Guinea Bissau
Client:	United Nations Industrial Development Organization
Consultant:	Trama TecnoAmbiental
Project code	UNIDO Purchase order (PO) number 3000050690 TTA Project code CI-17-0028

O&M Model and Plan

DELIVERABLE #4: O&M Model and Plan

Related Documents	**Type of document**	**Draft/final**	**Date of submission**
Inception report	PDF	Final	19/9/2017
Annex 1 – Chief questionnaire	Word	Draft	19/9/2017
Annex 2 – End-user questionnaire	Word	Draft	19/9/2017
Annex 3 – IPP questionnaire	Word	Draft	19/9/2017
Task 2 Report – Energy baseline v.2	Word	Draft	12/1/2018
Task 2 Report – Energy baseline	Word & PDF	Final	22/2/2018
Task 2 Tool – Energy baseline	Excel	Final	22/2/2018
Task 3 Report – Tariff study - final	Word & PDF	Final	05/06/2018
Task 3 Tool – Tariff tool - final	Excel	Final	05/06/2018

Financed by:	United Nations Industrial Development Organization

PRESENTATION

This report is the Deliverable #4 from the technical assistance offered to UNIDO for the development of the 500 kWp solar PV mini-grid in Bissorã, Guinea Bissau

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Abbreviations	Explanation
ABC	Anchor, Business and Community
ABREC-SABER	African Biofuel and Renewable Energy Company
AC	Alternating Current
ADPP	Ajuda de Desenvolvimento de Povo para Povo
ARPU	Average revenues per user
ACDB	Associação Comunitária de Desenvolvimento de Bambadinca
ATP	Ability to pay
BOO	Build, Own and Operate
DC	Direct Current
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
EPC	Engineering, Procurement and Construction
EU	European Union
GEF	Global Environmental Facility
GHG	Greenhouse Gas
KPI	Key performance indicator
kWh	Kilowatt-hour
kWp	Kilowatt peak (refers to installed photovoltaic capacity in STC)
LCoE	Levelised Cost of Electricity
MWh	Megawatt-hour
O&M	Operation and maintenance
O&M&M	Operation and maintenance and management
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PV	Photovoltaic
PSH	Peak sun hours
STC	Standard test conditions
TTA	Trama TecnoAmbiental
TOU	Time of use
UF	Utilisation factor
UNIDO	United Nations Industrial Development Organization
WAEMU/UEMOA	West African Economic and Monetary Union
WTP	Willingness to pay

1. Project background

Following the Call for Proposals issued by the United Nations Industrial Development Organization (UNIDO) in July 2017, Trama TecnoAmbiental (TTA) was awarded a contract for the “Energy baseline development, tariff study and tool, O&M plan and manual and capacity building for the 500 kWp solar PV mini-grid in Bissorã, Guinea Bissau”. The main objective of this project is to develop the soft issues around the 500 kWp solar PV mini-grid to ensure a sustainable and durable project.

This project is part of the Global Environmental Facility (GEF). The GEF Project (ID 5331) entitled “Promoting investments in small to medium scale renewable energy technologies in the electricity sector of Guinea-Bissau” is executed by UNIDO in close partnership with the Ministry of Energy and Industry of Guinea Bissau, the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) and the Small Island Sustainable Energy and Climate Resilience Organization (SIDS DOCK).

In this context, UNIDO, the West African Economic and Monetary Union (WAEMU/UEMOA) and the African Biofuel and Renewable Energy Company (ABREC-SABER) are partnering for the construction of a solar PV hybrid mini-grid for the city of Bissorã with a total installed solar PV capacity of 500 kWp. The company Prosolia Africa has been contracted to undertake the required civil works and turn-key installation of the power station.

2. Introduction to the O&M&M model

This report aims at serving as the operation, maintenance and management (O&M&M) model and plan of Bissorã solar PV mini-grid and others similar isolated stand-alone energy infrastructure projects that might follow within Guinea Bissau energy mix landscape.

The structure of the O&M&M model is as follows:

- Chapter 3 presents and compares the different management models for mini-grids as well as the main actors involved, and then develops a proposal for the Bissorã mini-grid management model.
- In Chapter 4, the typical structure of a mini-grids O&M model is described and the main tasks as well as personnel needs are presented.

3. Actors and management models

There is no standard, internationally agreed optimum management model for rural electrification and its selection depends on multiple factors. The consumer´s ability and willingness to pay and the type of consumers, the traditional and administrative structure of the community, the experience on other similar collective projects, the local technical capacity, the investor return expectations of the project and the available funds are amongst the factors that will determine the optimum model in each case. In the case of Guinea Bissau, local experiences of existing mini-grids in Bambadinca and Contuboel can also provide valuable information for the design of the Bissorã model.

3.1. Review of available management models

As aforementioned, there are various management models suitable for autonomous mini-grids, the choice of which is related to other parameters such as the project financing and the type of tariffs. The decision process and four main management model alternatives are illustrated in Figure 1 (see “Operator Models”).

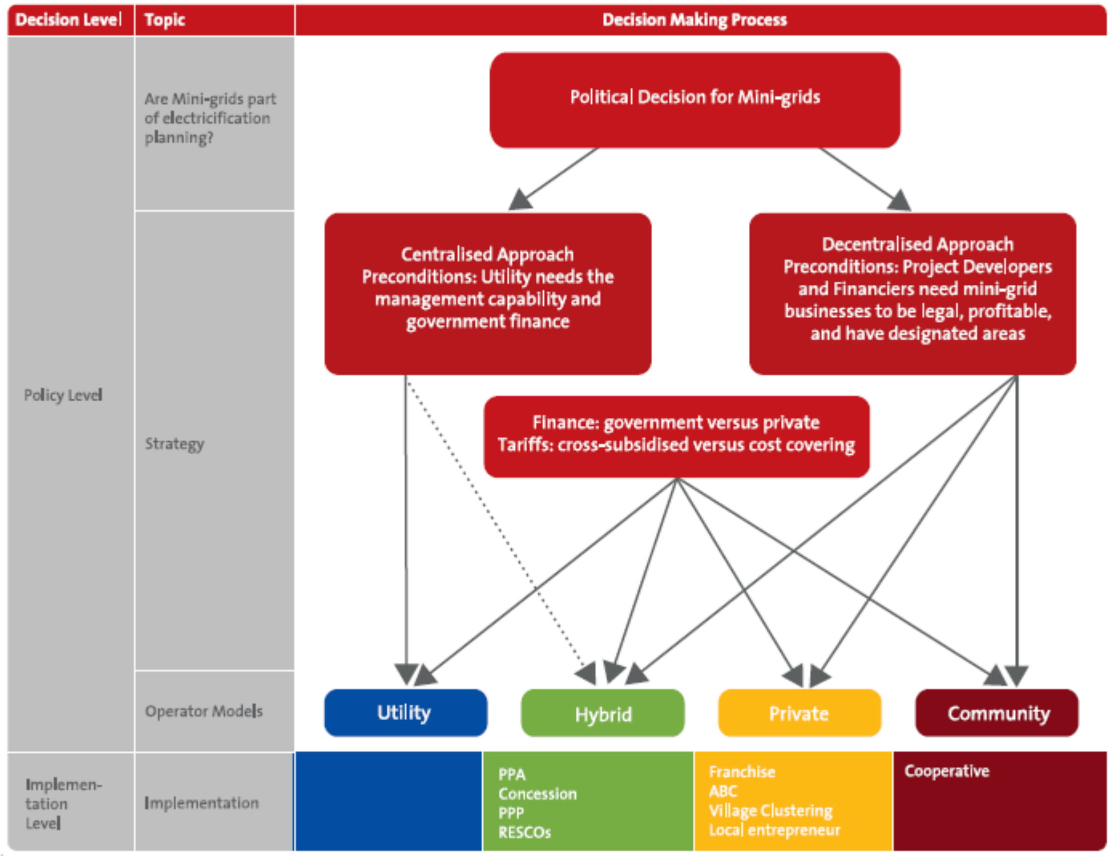

Figure 1: Decision tree for mini-grids (source: EUEI/RECP 2014)

The four basic options present different outcomes regarding government control and speed of delivery, as shown in Figure 2. The utility model has the highest government control while the private model is faster in terms of mini-grid deployment. Each option is discussed further in the remainder of this section.

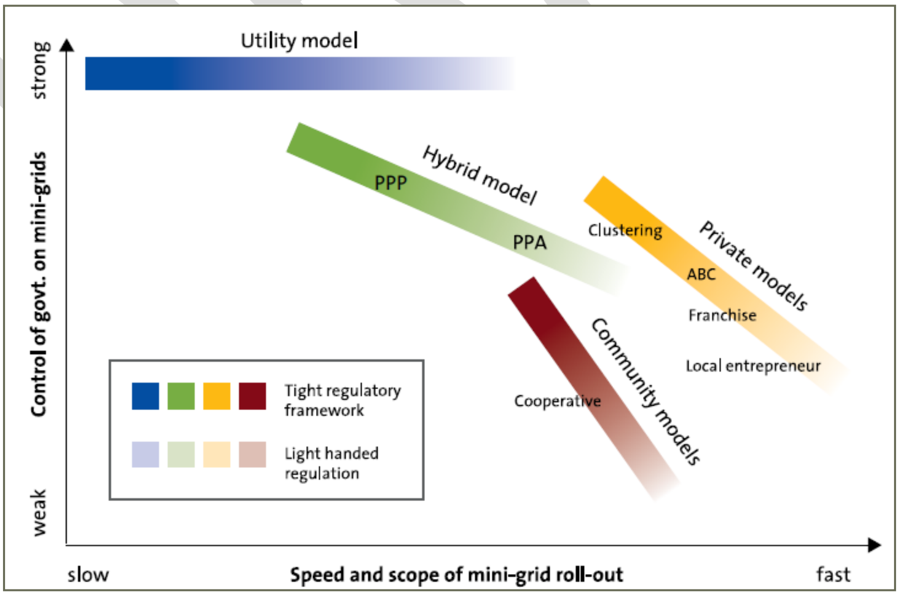

Figure 2: Model comparison (source: EUEI/RECP 2014)

3.1.1. Public (Utility) model

Under the public/utility model, the utility is the owner and operator of the mini-grid generation and distribution. The utility also finances the plant typically with public funds. Tariffs for public models are generally lower than cost-recovery tariffs based on the levelized cost of energy (LCOE). Therefore, to ensure the utility can cover its cost of capital, it must either cross-subsidize the costs from other customers (i.e. national grid customers) or seek an external subsidy.

On the positive side of such a model is that utilities are experienced in operating distribution grids, have access to financial resources and usually have local technical capacity. The drawback of the public model is that cross-subsidies are not a sustainable strategy, resulting in poor maintenance and lack of funds for component replacement (such as batteries). Some international experiences in other African countries provide examples of this problem (Kenya Power in Kenya for instance).

3.1.2. Private model

In this model, a private developer invests in, constructs, owns and operates mini-grids (in other words BOO model). Since such projects are capital intensive, the funds might be equity, loan and grants. If regulation allows, tariffs are cost-reflective allowing investors to obtain reasonable return on their investments.

There are a number of strategies that private mini-grid operators have pursued in order to make this business model more attractive. For example, when selecting mini-grid sites, developers often prefer those with at least one larger customer (known as "anchor" customer), providing them with some more certain revenues. This is often known as ABC model, where operators prioritize Anchor customers, then Businesses, then Communities. In addition to this strategy, clustering mini-grid sites (that is, operating more than one mini-grid in a given area) allows for more efficient O&M and provides economies of scale, which is crucial to obtain an attractive cash flow for investors.

In general terms, the private models can deliver a profitable investment for a private entity, especially if the upfront capital costs are partially subsidized. However, the success of such a model requires the customers to be able and willing to pay the tariffs and consume enough electricity for the cash flow to turn positive. In addition, even if the model is fully private, there are also significant policy and regulatory risks to be considered. For example, if government decides to extend the national grid up to such mini-grid locations, or in other cases nationalize the concessions that were given to private companies (as the case of Mali).

The Contuboel mini-grid, developed and operated by FRES Guinea Bissau, is an example of a private model in Guinea Bissau.

3.1.3. Community model

In this model, community members (usually organized under the legal entity of a cooperative) manage the decentralized system and are also responsible for the collection of the tariffs and the operation and maintenance. The community-based or cooperative model essentially operates the same way as the private model, with cost-reflective tariffs, but some adjustments to the cost inputs.

This scheme presents various advantages. The most important one is that the owners are also the consumers so the smooth operation and management of the system if of their direct interest. Also, the absence of any private investor and any obligation to generate additional profits minimises the tariffs paid by the consumers. In this case the tariffs are set in such a way as to cover running costs, pay back any existing loan and create a reserve for future expenses, such as the replacement of batteries or inverters after the end of their lifetime.

However, in a community-based model where the cooperative (or other community form) maintains the infrastructure plant, issues can arise in case of technical problems due to lack of skills within the community, which is often the case. In order to avoid such matters, it is important to give emphasis on the capacity building of the village that is time and resource consuming, something which can be done by an external (public or private) contractor. Besides technical aspects, capacity building should also focus on the social and economic aspects of the mini-grid.

The Bambadinca mini-grid project in Guinea Bissau is an example of a community-based model (ACDB/SCEB).

3.1.4. Public-private partnership (PPP) model

PPPs are considered the most flexible and better suited model for large mini-grids, such as the Bissorã one. Under a PPP model, there are different stakeholders financing, building and operating the assets.

In mini-grid projects, the public entity (Government, Ministry of Energy, Rural Electrification Agency…) typically retains the ownership of the distribution grid, and in some cases might also own the generation assets. Typically, the public entity may lease or give a concession to a private actor to ensure the management and operation of the mini-grid and collects revenues from tariffs, taking a number of commercial risks through this process. Sometimes private operators might also be involved from the construction phase, either solely as contractors or also as investors, recovering these funds through mini-grid operation later on.

The following table displays three common schemes, where the role of public and private actors differ.

Table 1: Various PPP models (source: Inensus, modified by Author)

	Type A	Type B	Type C
Public entity	Procures, owns and installs generation and distribution assets. Commercializes electricity to the end-users.	Procures and owns generation and distribution assets	Procures and owns distribution assets
Private entity	O&M under a Power Purchase Agreement	Installation, O&M and commercialization of electricity to end users	Invests in, installs, operates and maintains generation assets, sells electricity to end customers
End users tariff	Usually national tariff	Usually cost-reflective	Cost-reflective

Starting from left to right, Type A is the scheme with the highest degree of public involvement, with the private entity only ensuring technical O&M and getting paid a fixed price for the electricity generated. Note that in this case, the commercial and demand risk, as well as any differences between the PPA price and the end user tariff are taken by the public actor.

In type B model, the private actor gets additional responsibilities as the commercial operation (end-user sales, customer management, technical losses, etc.) is now part of its role. This entails higher commercial risks but also provides an incentive to perform efficiently and be able to generate profits out of the mini-grid operation. As it will be discussed later on, this would be the closest scheme to the Bissorã mini-grid, where the initial investment has been provided by a public entity (a donor in this case) and a private operator is sought in order to do the technical and commercial operation.

Finally, in Type C model, the private party develops the generation assets with private funds, alleviating the financial burden for the public entity. In this model, it is particularly important that the tariff is cost-reflective, taking into account that it must recover not only O&M costs but also the initial investment made by the private entity.

3.2. Proposal for Bissorã

3.2.1. Proposed management model

In order to define a management model for the Bissorã mini-grid, it is essential to consider the previous arrangements and commitments that different actors have played in this project. Basically, since the project has been grant financed by an external actor (SABER-ABREC) which will not play a significant role during mini-grid operation, the task is to identify the best actor and best contractual framework that can perform such operator role.

In addition, it has to be taken into account that the assets will belong to the Government of Guinea Bissau as soon as the construction phase is finished and the project is delivered by the contractor. This means that the management model for Bissorã will have to consider the role of the Government (or the Ministry, for practical reasons) as owner of the mini-grid assets (generation plant and distribution).

Given the financing nature of the project and ownership, the management model should look for a mini-grid operator, which should then provide the electricity services and collect the revenues from tariffs (ideally allowing operation to be self-sustainable). Actors that could play this role theoretically include (public) utilities, local community associations and private operators (i.e. electrical contractors with some degree of experience). In the case of Bissorã and Guinea-Bissau, the following additional aspects should be mentioned:

- The national utility EAGB (Electricidade e Agua da Guiné Bissau) is only operating in Bissau and surroundings, and is generally perceived as lacking the technical and commercial expertise to operate mini-grids efficiently.
- There is an NGO with local presence in Bissorã, ADPP, which in addition is running a vocational school where young people can attend trainings related to electricity. However, based on the consultants' interaction with them, our recommendation would be to keep them as a potential community partner, rather than as the main actor concerning the mini-grid operation. Recent management problems being experienced with the community model used in Bambadinca mini-grid also suggest that this option would be risky.
- The European Union (EU) is supporting Guinea Bissau in defining a concession framework for decentralized energy services, with a specific focus on mini-grids. Related to this, there is interest from the EU and other donors (SABER-ABREC) to finance more mini-grids in the country, meaning that a management model that lends itself to replication in other places, ideally generating economies of scale (e.g. one single operator for multiple mini-grids), would be beneficial.

As consultants for this project, **our view is that these circumstances quite naturally push the management model to be defined towards a Public Private Partnership (PPP),** where the **government keeps the ownership** of the mini-grid and then defines a **concession-type contract with a private mini-grid operator**.

3.2.2. Recommendations for implementation

In order to implement such PPP (concession) approach, we suggest considering two different phases; a pilot, short-term operation that can be implemented quickly to avoid delays in providing electricity service in Bissorã, and a longer-term concession, which can then be thoroughly defined and for which a different operator might be selected following a competitive process.

3.2.2.1. Short-term operation

The main benefit of defining a short term (pilot) phase, would be to have the mini-grid operative as soon as possible and avoid potential problems (social discontent, vandalism, etc.). In addition, it should allow to collect real data about the mini-grid (for example in terms of demand and average revenue per user) and test specific management and operation arrangements (tariffs, interaction with local community, etc.)

In order to structure this short-term phase, contracts needed would include:

- Operation contract: main contract between the government and the operator, stating the terms and conditions of this short-term concession. This would include tariffs, service quality indicators and reporting to be submitted periodically, etc.
- Client policy: contract to be signed by the interested clients, defining their rights and obligations vis à vis the operator.

From a financial management perspective, we suggest that such short-term operator could be allowed to keep the integrality of tariff revenues to pay for O&M costs and other eventualities, without the need to save money at this stage for future component replacements. From the demand and tariff study already performed, it is estimated that this would allow to generate some profits if the operator is able to have at least 40% of the initial 470 users connected (and consuming electricity) during the first year, moving towards 60% at the end of it.

Through previous visits to the Bissorã plant and exchanges with Prosolia (EPC contractor for this project) management, it has been confirmed that Prosolia would be interested in ensuring the mini-grid operation over this pilot phase. Prosolia explained that they already have experience in this mini-grid concession models in other West African countries and that consolidating their position in this market is part of their strategic plans. While having them as operators would have some significant advantages (they are familiar with the plant of Bissorã, they are participating in the maintenance of Bambadinca's mini-grid, they already have local presence and have technical and administrative personnel) a more in-depth examination of their technical and organizational capabilities, as well as of proposed management and operation approach, should be conducted before entering negotiations.

Table 2: Short term operation: key aspects

Duration	12 months, with an option to extend for a second year
Contracts needed	O&M contract, client policy
Financial flows	Operator is entitled to collect tariff revenues, having to perform O&M tasks and cover all O&M costs needed to provide the service levels agreed
Service level	24/7 power Downtime; less or equal to 5% Voltage service level ±10% at the end of the lines (measured at the end-user point)
Operator selection	Prosolia as preferential candidate, pending satisfactory assessment of capabilities and O&M approach

3.2.2.2. Long-term operation

Once the mini-grid is operative under the short-term solution, it would be possible to start defining the longer term model to be used. As already stated, this would ideally be done in coordination with country-wide developments in this field, as it is the case of the concession framework being developed with EU support.

In this case, since the mini-grid would already be operative under the pilot phase, evidence and learnings from this phase can be used to better adjust some relevant contractual parameters: tariffs, service levels, interaction with Bissorã community, etc.

In addition, the contracts for such longer-term concession would need to pay specific attention to a number of issues, such as the following:

- **Component replacement costs**: as batteries and other mini-grid components have limited lifetimes, tariff calculations need to take into account these replacement costs. And beyond tariff calculation, specific mechanisms to ensure that part of the revenues are kept in the project to pay for these replacements might also be needed. For example, an agreement could be reached with component manufacturers receiving a fraction of the total payment every year, instead of one single payment.

- **Potential interconnection of Bissorã to the national grid**: As plans for interconnecting Bissorã (and 13 other towns) to the grid are progressing, this scenario has to be considered in the contracts. Several options could be viable and should be assessed carefully when the time comes.

- **Potential mini-grid distribution expansions in Bissorã**: as explained in previous deliverables, the current LV grid does not reach every Bissorã neighbourhood. It could be interesting to enlarge the current distribution grid and provide service to these areas, especially if total demand is below the maximum output of the PV plant. This scenario and the responsibilities and costs associated to it should be defined in the contracts.

- **Tariff revision clauses and mechanisms**: it is important to identify which specific circumstances should lead to a tariff revision, and how and when it would be done. For example, inflation related tariff revisions, demand related tariff revisions, etc.

- **Lessons learned from initial O&M phase** (short-term)

Finally, when it comes to the operator selection for such long term concession, a competitive approach could be followed were mini-grid operators are invited to submit proposals and the best option is chosen on the basis of a set of criteria. Eventually, when it comes to the financial evaluation, tariff could be used as the parameter to be tendered. Aside from a tender approach, other options could also be considered (direct negotiation with interested operators, etc.).

Table 3: Long term operation: key aspects

Duration	Up to 20 years, with the possibility of 10 initial years and an automatic renewal for another 10 years if performance met
Contracts needed	Concession contract, client policy, others as defined by national concession framework
Financial flows	Operator is entitled to collect tariff revenues, having to perform O&M tasks, cover all O&M costs needed to provide the service levels agreed and replace components at their end of life. Finance grid extensions (or at least partially)
Service level	24/7 power Downtime; less or equal to 5% Voltage service level ±10% at the end of the lines (measured at the end-user point)
Operator selection	Competitive selection, specific details to be defined.

3.2.3. Summary of roles and responsibilities

The clear definition of appropriate roles and respective responsibilities in the very beginning of the project is a key element in the development of any effective PPP. Individual responsibilities need to be outlined clearly so that there is no ambiguity in the tasks that each party is expected to perform. The expected key stakeholders and a summary of their responsibilities in the Bissorã mini-grid are listed in

Table below.

Table 4: Key actors and responsibilities

STAKEHOLDER	MAIN RESPONSIBILITIES	SPECIFIC ACTOR (EXISTING OR EXPECTED)
0. USER	Receives the service for a fee	- Households - Small and medium businesses - Industries - Institutions: schools, health centres, etc. - Local government
1. FUNDER/DONOR	Provides initial investment for the mini-grid plant and the distribution grid.	SABER-ABREC
2. EPC CONTRACTOR	Procurement of material and equipment (with corresponding guarantees and other documentation). Installation, start-up and commissioning (optional) of the generation plant and distribution line	Prosolia
3. OWNER AND REGULATOR	Defines the framework for operation and management of the mini-grid (tariffs, quality criteria, subsidies, etc). Selects service operator.	Government of Guinea Bissau and Ministry of Energy
4. SERVICE OPERATOR	Controls the mini-grid operation, commercial service and users' payments. Performs grid monitoring	To be defined. Short-term operator and long-term operator might differ.
5. LOCAL COMMITTEE	Represents the interest of local users and institutions	Local committee to be defined
6. NGOs	Support role in providing general awareness and training about electricity to the population. Support to productive use activities.	ADPP (Bissorã), TESE.
7. DEVELOPMENT PARTNERS	Provide financial and technical support to the Government of Guinea Bissau and the Ministry of Energy for the Bissorã mini-grid (e.g. demand studies, tariff recommendations, management model, etc.).	UNIDO, ECREEE, Consultants (TTA)

4. O&M plan overview

The present chapter provides general guidance on operation and maintenance procedures for the various components of a mini-grid facility. Operation and maintenance routines of a mini-grid are carried out by the mini-grid operator through a network of staff. O&M starts right after commissioning of the mini-grid and subsequent provision of electricity services to the end-user. All O&M activities are supposed to comply with set terms between the owner of the mini-grid and operator and all relevant regulations affecting the service and infrastructure.

There are two types of maintenance categories that can be distinguished:

Preventive Maintenance is understood as the work and *routine* activities that is designed to keep the equipment in optimal conditions and to ensure the adequate use of the plant and the service by the final users.

The preventive maintenance is composed by specific routines and tasks at various frequencies varying from daily, weekly, monthly and annual.

Corrective Maintenance is understood as the work that needs to be done concerning the replacement of any equipment that may become damaged.

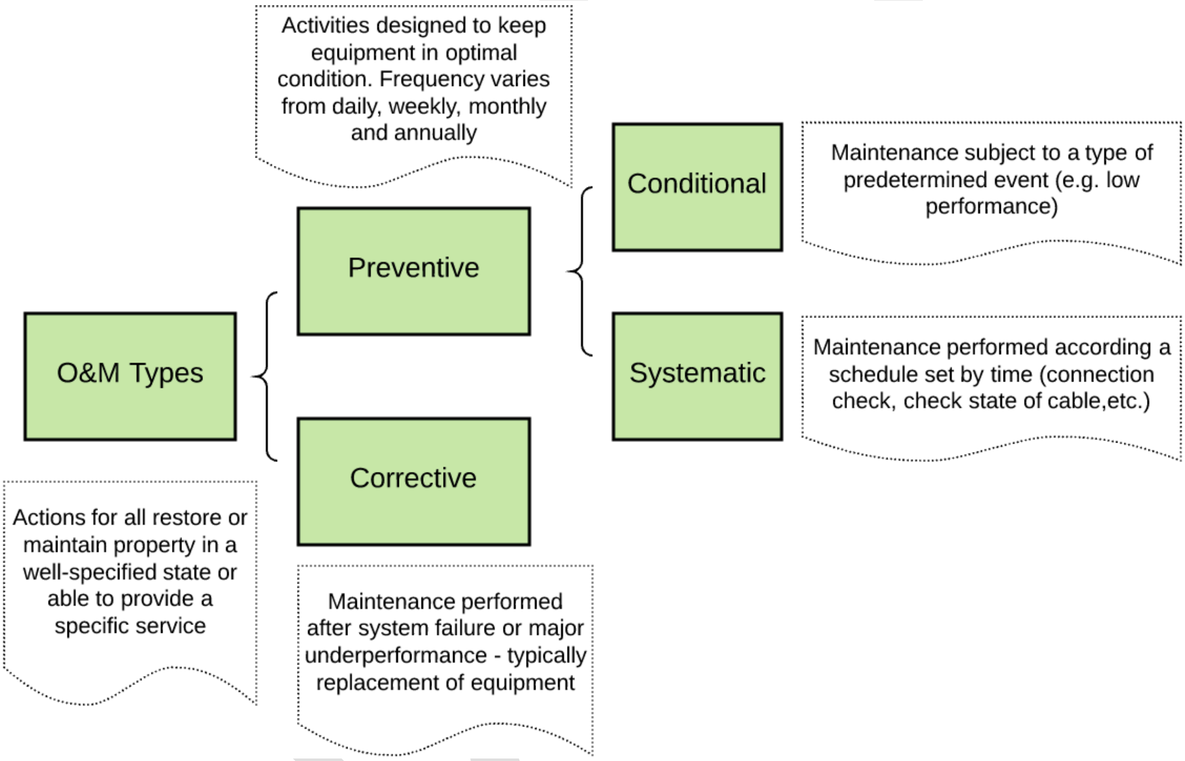

Figure 3: Maintenance types overview

Both types of maintenance need to start right after the commissioning of the mini-grid and the subsequent start-up of the electricity service.

The relevant tasks are divided amongst **three levels**, as shown below:

Level 1 - Caretaker(s)

- Basic up keeping,
- Continuous monitoring of the operation parameters, plus routine inspections of the installation, as well as,
- Recording and reporting any breakdowns to the service officer, which may be detected by notification from customers.

Level 2 - Specialised Maintenance Technician

- Specialised preventive maintenance duties and/or repairs,
- Periodic technical inspection of the installation,
- Indentify socio-cultural usage factors (if possible),
- Make recommendations to customers to facilitate the optimisation of their consumption.

Level 3 - Plant Engineer

- Monitoring and evaluating plant performance data,
- Supervising activities at both Level 1 and Level 2,
- Diagnosing any important breakdowns that occur and taking charge of the replacement of components' parts and dealing with the manufacturers/distributors of the equiment,
- Authorising new customer connections, depending on the plant's capacity.

Figure 4: Levels of O&M

4.1. O&M tools and forms

There are several tools and forms that should be prepared accordingly in order to ensure the operational and maintenance plan is achieved.

4.1.1. For Level 1 - Caretakers

A. Caretaker Response Protocol

This document provides a summary description, broken down into periods (daily, monthly and quarterly), of the basic maintenance work to be done on the mini-grid that is the responsibility of the Caretaker.

B. Incidents Control Sheet

This is the sheet on which the Caretaker describes any technical incidents related to the equipment and the whole grid, along with the solutions that have been taken to remedy them. In case it is necessary the Caretaker should call in the Specialist Maintenance Technician.

C. Visitor's Log book

This sheet is to keep a track record of the visits received at the project site, including both external and internal project representatives.

D. Material Log book

The Caretaker will be responsible of looking after the material and registering any material transaction in the material log book (previously approved by the Specialist Maintenance Technician or Plant Engineer).

E. Generator Log book

Whether the system is designed with a diesel generator as a prime source of energy generation or as a back-up a generator log book is required. Therefore the generator will run intermittently and rarely along the year. This sheet is to keep a track record of the generator utilisation.

These tools are used to define a simplified monitoring and control protocol for the installations.

4.1.2. For Level 2 - Specialized maintenance technician

A. Maintenance Technician Response Protocol

This document provides a summary description of the maintenance work required for the mini-grid, to be done by the Maintenance Technician.

B. Incidents Control Sheet

This is the sheet on which the Maintenance Technician must make a note of and describe any technical incidents related to the equipment and the system, along with the solutions that have been taken to remedy them. In case it is necessary the Maintenance Technician should call in the Plant Engineer (level 3).

C. Monthly Monitoring Visit Protocol

The Monthly Monitoring Visit Protocol basically consists of a visual inspection and measurements of the main equipment. It is important for the Maintenance Technician to do this work jointly with the Caretaker.

Monitoring data must be provided on a regular basis to the Engineer (level 3), in order for a detailed analysis of the data to be carried out.

D. Quarterly Inspection Visit Protocol

Every quarter the Maintenance Technician will perform an inspection to conduct preventive maintenance work and check the status of the mini-grid.

The inspection data must be passed on, on a regular basis, to the Engineer, in order for a detailed analysis of the data to be drawn up.

4.2. Task description for different levels and frequencies

4.2.1. Level 1 – Caretakers

4.2.1.1. Daily tasks

At the Technical Room:

- Check the screen readings and the light indicators on the inverters. Make a note of any incidents that occur on the Incidents Control Sheet. If a red light comes on this means that an incident has been detected, note it down in the Incident Control Sheet and report it to the Maintenance Technician (level 2).
- Inspect the electrical equipment and, if they are dirty, clean them using a clean, damp cloth.
- Inspect the room and make sure that all the material is organized. If the room is dirty clean the dust or any other remaining dirt.

At the Battery Room

- Inspect the tops of the battery cells and, if they are dirty, clean them using a clean, damp cloth. If there is a lot of dirt remove the covers and clean them separately.
- Inspect the room and make sure that all the material is organized. If the room is dirty clean the dust or any other remaining dirt.

At the Generator Room

- Inspect the generator and, if it is dirty, clean it using a clean, damp cloth.
- Inspect the room and make sure that all the material is organized. If the room is dirty, clean the dust or any other remaining dirt.
- Register every time the generator is started (following Maintenance Technician instructions) on the Generator Log book.

At the PV array

- Carry out a visual inspection of any possible damages or breakages affecting the panels. If any, note down in the Incident Control Sheet and report it to the Maintenance Technician (level 2).
- Make sure that no shade falls on the solar field (plants, objects, etc.). If any shade is found then it must be removed.
- Clean the panels using a damp cloth.

At the Project Site

- Carry out a visual inspection of the Project site. Make sure that the site is clean and all the material is properly stored and organized.
- Make sure that the Project site is secured at all times. Close the doors and gates when leaving the site.
- Register every visitor on the Visitor's Log book, including the technical team.

Material

- Make sure that the Project Material is properly stored and keep track of the Material Log book.

Figure 5: Cleaning techniques of solar panels

4.2.1.2. Monthly tasks

- Support the Maintenance Technician during the Monthly Monitoring Visit.
- Provide the monthly sheets to the Maintenance Technician and check that everything is correct
- Confirm that the Caretaker is in possession of all required tools (protocols and sheets) to perform the work.

4.2.2. Level 2 – Specialized maintenance technician

4.2.2.1. Monthly tasks

Basic maintenance work

- Checking the solar panels: Check that no shadows are cast on the panels during the central hours of the day (from 9:00 am to 3:00 pm), due to extensive objects, trees or nearby buildings. Also check the integrity of the modules, in particular the front glass sheeting that protects them.
- Checking the structural mounting: Check that the bolts that attach the panels to the structure, along with the bolts that hold the structure together and the pergola bolts, are well fixed in place and have not rusted.

- Checking the connections boxes: Check that the connections boxes are hermetically sealed and that there is no dirt or insects inside them and that the connections are well fixed.
- Checking the cabling: Check whether any of the modules or their cabling have suffered mechanical and/or corrosion damages.
- Checking the state of the batteries: Visually inspect the batteries, evaluating the levels of the liquid and the condition of their terminals. If necessary apply Vaseline, or some other grease, to the terminals to avoid corrosion.
- Checking equipment cleanliness: Inspect the equipment and verify their state of cleanliness, in particular make sure that the ventilators are working properly.

Preventive maintenance work

- Check the screen readings and the light indicators on the inverters. Make a note of any incidents that occur on the "Incidents Control Sheet".
- Run the inspection tests and fill in the "Monthly Monitoring Visit Protocol" sheet.
- Inspect the tops of the battery cells and, if they are dirty, clean them using a clean, damp cloth. If there is a lot of dirt remove the covers and clean them separately.
- Make sure that the battery connections are sufficiently tight and, if not, tighten them.
- Carry out a visual inspection of any possible damages or breakages affecting the panels.
- Carry out a visual inspection for possible panel damages or breakages.
- Make sure that the nuts and bolts, along with the structure of the panels, are not lose or rusted.
- Make sure that no shadows fall across the solar field.
- Clean the panels using a damp cloth.
- Check the cables in order to avoid stripped cables and possible short circuits.
- Check the electrical connections (splices).
- Run a visual check on the interior electrical installation is in good condition, in terms of cabling, casings, earths, lights and sockets.
- Make sure that the electrical equipment is in good condition and that there is no danger of provoking short circuits.
- Make sure that the complementary accessories and the spare parts for the installation are complete and in good condition.
- Keep the electronic equipment free of dust and humidity. Make sure that the ventilators are not obstructed.
- Make sure that there are no defective diodes in the solar panels.
- Measure the voltage and the output current from each solar field box, calculating the charge power

Report to the Plant Engineer

- Every month the maintenance technician should create a short report with monthly averages of key performance indicators (KPIs). Those can be either collected and calculated manually or created automatically by a plant controller and data logger, if available. Those KPIs include:
  - Performance ratio
  - Total yield of PV plant
  - Solar fraction
  - Times and duration of service interruption
  - Alarms produced by the power electronics: inverters, charge controllers, etc.

The best way to represent the performance of the mini-grid is through normalised graphs showing, for each day of the month, the aggregated values of the energy flows. The normalised graphs are constructed by dividing the daily energy flow to the PV generator's rated power. Furthermore, at this graph it should appear the solar fraction, the minimum SOC of the day. An example is shown below:

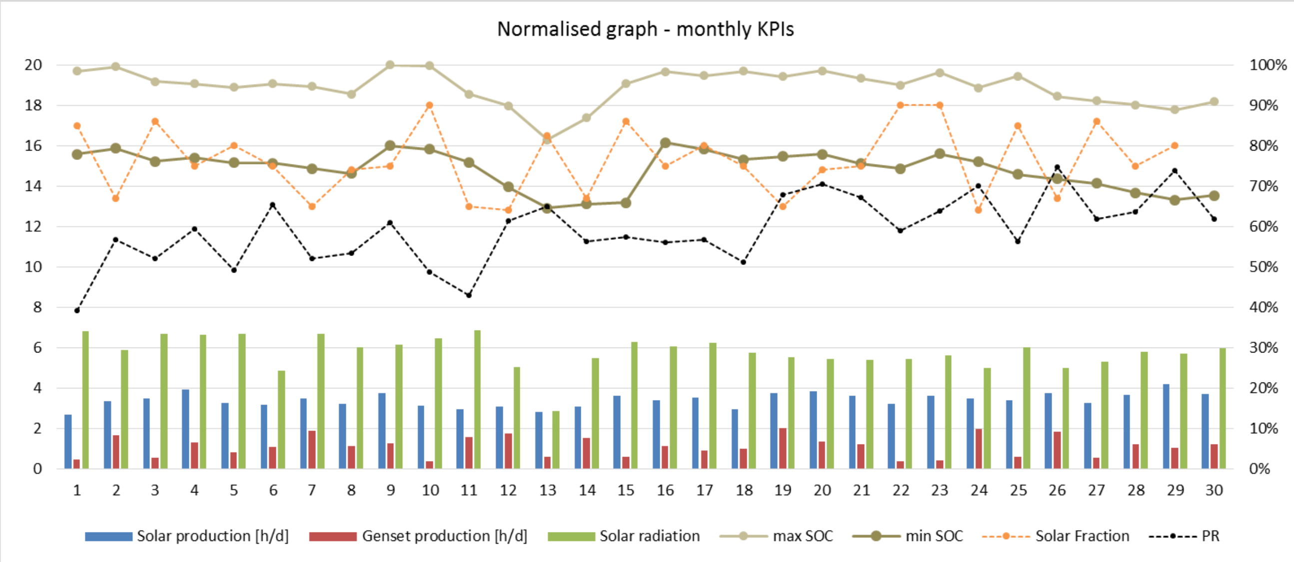

Figure 6: Example of a normalised graph, illustrating important KPIs (source: TTA)

4.2.3. Level 3 – Plant engineer

The plant engineer is responsible for the overall operation and maintenance of the plant.

4.2.3.1. Weekly tasks

- On an agreed day and time once a week, the Plant engineer discusses with the specialised maintenance technician about the performance of the plant(s), any errors occurred 8like service interruptions) and preventive measures there should be taken
- If available, visit web page of the project and check plant indicators to ensure the plant is performing as predicted and that certain parameters are within the allowable thresholds.

4.2.3.2. Monthly tasks:

- Every month the plant engineer should receive all reports from the Specialised Maintenance Technician the Quarterly Inspection Visit Protocol, the KPIs and the normalised graphs. The plant engineer then assesses and evaluates this information, and draws conclusions and recommendations to enhance the operation and performance of the plant.
- Once a month the plant engineer talks directly to the caretakers to discuss any possible issues

4.3. Health and safety

4.3.1. Precautions

As a general rule concerning the health and safety of the O&M staff (as well as the installers and other personnel that have access to the production plant and other installations of the mini-grid), any person subject to risk should be trained on hazards and on prevention means.

The two major risks in an installation are the drop of a height and electrical hazards. Some preventive measures for those two risks are:

1. Drop from a height:
   a. Collective protection: establishment of fences, scaffolding.
   b. Personal protection: Installation of a lifeline to secure, harnessing.

2. Electrical hazard (voltage > 60 V DC or 50 V AC)
    a. Collective protection: physical distance, barrier or insulation
    b. Individual protection: using gloves and helmet with facial screen or following regulations of the installation

4.3.2. Protection equipment and signs

In all circumstances, the following protection equipment should be available on site for personal protection: gloves (1), helmet with face shield (2) and insulated tools

(1)

(2)

(3)

Junction boxes and AC/DC cabinets should be indicated with appropriate signs, and the O&M staff should be able to correctly interpret them, after the adequate training sessions: