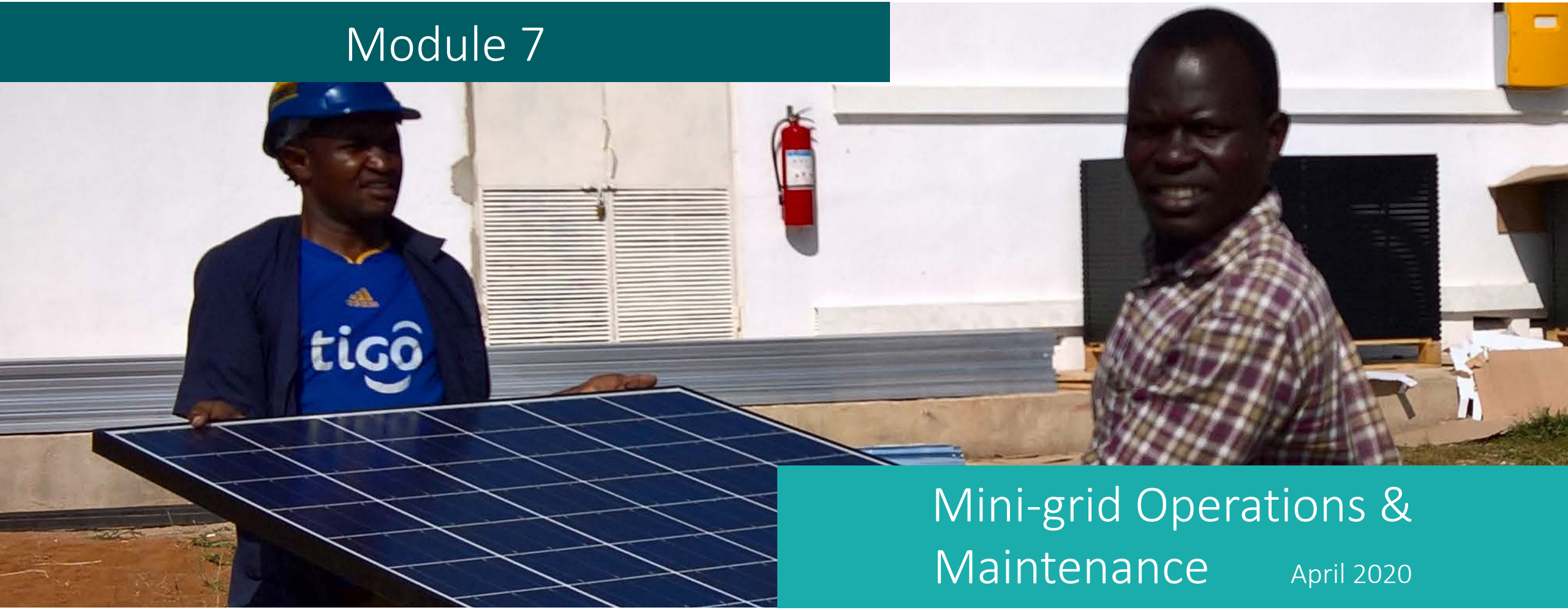
GREEN MINI-GRID HELP DESK

Module 7



Mini-grid Operations & Maintenance

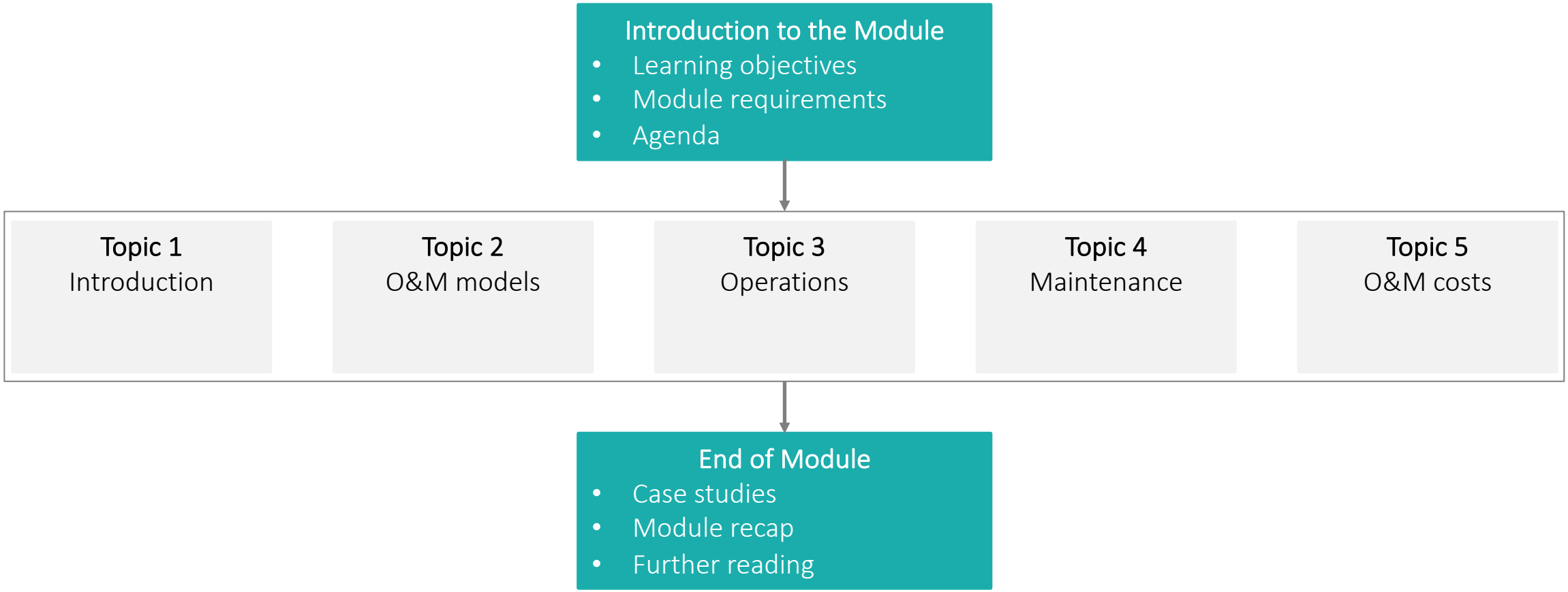
April 2020

ENERGY4IMPACT
ACCELERATING ACCESS TO ENERGY

INENSUS

SUSTAINABLE ENERGY FUND FOR AFRICA

Module overview



Objectives & Requirements

Learning Objectives

- Learn what Operations & Maintenance (O&M) means for mini-grids.
- Learn about the key features of a successful operational management system.
- Learn about the key features of a successful maintenance system.
- Understand the main components of mini-grid OPEX and how they can be reduced.

Module Requirements

- This module is targeted at mini-grid developers and operators at all stages of development.
- They are expected to have a basic understanding of rural, off-grid energy markets and community dynamics in developing countries.
- No prior knowledge of technical O&M around mini-grids is required.

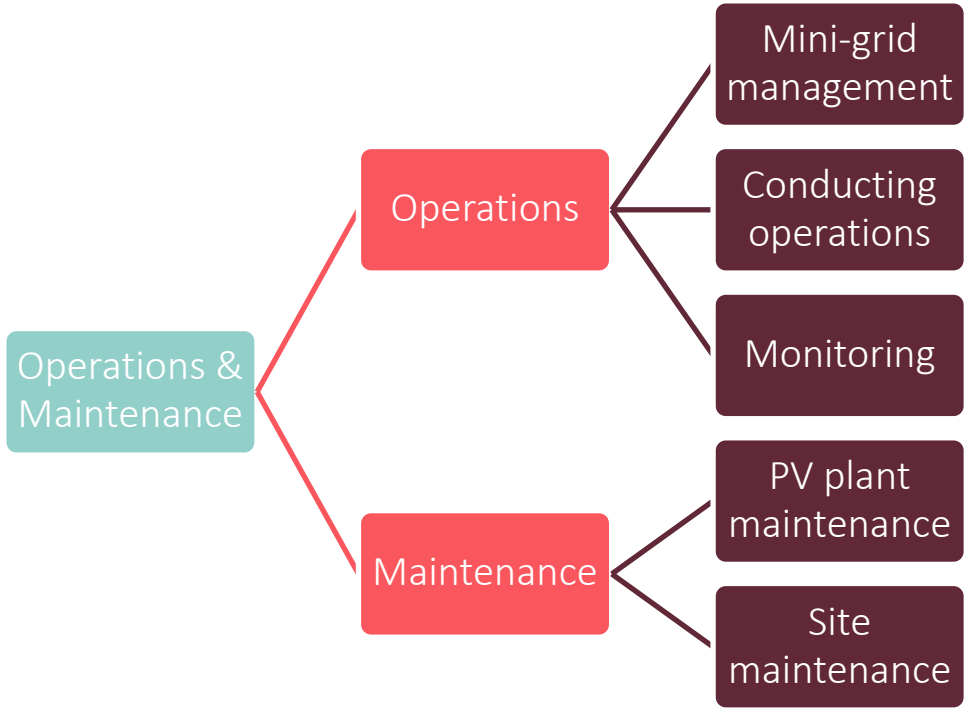
Agenda

1. Introduction
   - Overview of O&M
2. O&M models
   - Types of O&M models
   - Benefits and drawbacks of O&M models
   - O&M contracting
3. Operations
   - Definition
   - Overview of operations
   - Documentation & reporting
   - Budgeting
   - Management
   - Asset management
   - Customer management
   - Ticket management
   - System changes
   - Key performance indicators (KPIs)
   - Health & safety
   - Monitoring
4. Maintenance
   - Types of maintenance
   - Preventative maintenance
   - Reactive maintenance
   - Maintenance personnel
5. O&M costs
   - Overview of O&M costs
   - OPEX reduction

Overview of O&M

- Operations and maintenance (O&M) is a critical element for long term sustainability of mini-grids and ideally should be planned well in advance of the start of operations.
- O&M refers to all activities carried out after the mini-grid has been commissioned and handed over to the operator* up to its decommissioning.
- An effective O&M program enhances the likelihood that a system will perform at or above its projected production rate and cost over time.
- Optimal operations must strike a balance between maximising performance and minimising cost.

** If the operator is different from the developer*



O&M attributes

Types of O&M models

Mini-grid developers have adopted different models for O&M which include:

a) Developer-operated

- Own operation: a developer operates & maintains the mini-grid through own staff.
- Third party operated: a developer engages an O&M contractor to run and report on the mini-grid performance. On most occasions, the contracts are performance-based.

b) Community-operated: The community becomes the owner and operator of the system and provides maintenance, tariff collection, and management services.

c) Hybrid-operated (e.g. Public Private Partnership): The government and the developer may operate the mini-grid together sharing responsibilities.

Photo credit: Rafiki Power

O&M model selection

Model	Benefits	Limitations
Cooperative/ Community	+ Community is close to its members and may therefore be best placed to respond quickly to issues.	- Limited local capacity may inhibit ability to conduct operations. - Each mini grid needs their own trained community personnel.
Developer	+ Developer may have better understanding of technology deployed. + Can make use of economies of scale if operating multiple mini-grids at the same time.	- May lack local awareness. - Difficult for early stage developers who need to set up O&M processes from scratch.
Third Party	+ Does not require developer to build up own O&M team. + May bring in specialised team to carry out specific O&M aspects.	- Communication issues with developer may lead to slow / inefficient resolution of issues. - May be more costly for developer than doing own O&M due to additional margin payments.
Hybrid	+ Can combine the best approaches above.	- Need to put in place efficient communication mechanism to manage interface risk between different stakeholders

O&M model suitable scenarios

O&M contracting

Key factors influencing selection of an O&M contractor

- Familiarity of the contractor with site location and technology
- Location of the contractor's premises
- Staff technical capacity
- Experience and track record
- Financial capability

O&M contracts should define

- Services to be carried out and obligations of the owner and contractor
- Methodologies for calculating plant performance
- Methodologies for calculating liquidated damages / bonus payments in the event of plant under- or over-performance
- Legal aspects
- Payment structure
- Response time in case of faults

Case study: Talek Power third party contracting

Talek Power owns a 40kWp solar mini-grid in Kenya serving more than 100 customers. It is owned by the County Government of Narok.

Talek Power decided to contract PowerGen Renewable Energy to handle O&M at their site since they did not have the resources and technical capability to operate the mini-grid. They issued a Request for Proposal and selected their preferred contractor from the bidders. The contractor is responsible for:

- Remote monitoring;
- Maintenance activities, customer connections;
- Handling customer calls; and
- Performance reporting among other services.

Talek Power is responsible for procurement of all equipment and customer records management.

Indicators for plant performance are part of the contract and these are documented in a performance report. Payments to the contractor are based on technical, customer management and revenue performance.

Photo credit: GIZ

Short exercise

- Imagine you are developing a mini-grid
  - Outline the context (environmental, social, political, financial) under which you are developing the mini-grid, who owns the assets and any other relevant information.
  - Pick which option of an operator model you would consider most suitable and write down its structure, benefits and limitations for your specific context.

Definition of mini-grid operations

Operations concerns all aspects in dealing with customers during the operations of the mini-grid, as well as the overall management of the grid and generation assets. Operations informs maintenance scheduling and activities. This function is usually carried out by highly skilled personnel in management and analysis.

Overview of operations (1)

The management of the mini-grid must typically perform the following tasks:

- Strategic planning (including planning for eventual upscaling or roll-out of mini-grid systems);
- Accounting, budgeting, and financial reporting (to tax authorities, donors, financiers) and cashflow management;
- Legal compliance;
- Personnel management;
- Monitoring local O&M activities;
- Data management;
- Marketing and sales;
- Stakeholder engagement; and
- Communication and outreach activities.

Overview of operations (2)

	Management	Conducting Operations	Monitoring
Role	Management	Conducting Operations	Monitoring
Definition	Enduring effective management and control of O&M	Ensuring efficient, safe & reliable O&M	Analysis of data to remain informed on system status
Personnel	- Asset manager - Asset owner	- O&M manager - Technical lead	- Analyst - Monitoring & evaluation experts
Scope	- Curation of as-built diagrams - Equipment inventory management - Records curation - Budgeting - Contracting	- Site inspections - Rectifications - Work order preparation - Performance assessment - Customer management	- Metering for revenue - System status reviews - Performance reporting - Handling alarms & warnings

Operations structure
Source: NREL, 2018

Documentation & reporting

- O&M activities should be documented properly in pre-defined reporting templates which allow the mini-grid's management to monitor performance.
- Grant programmes have specific documentation and reporting requirements which include:
  - Payment and consumption data;
  - Site visit reports including vehicle utilisation log;
  - Log of operational issues (on customer and asset basis) and maintenance carried out;
  - Overview of existing and potential sites and customers;
  - Overview of all internal processes, procedures and policies; and
  - Overview of operational costs.
- Developers may use commercial software e.g. AMMP and Infinite Fingers to assist in creating O&M outputs.

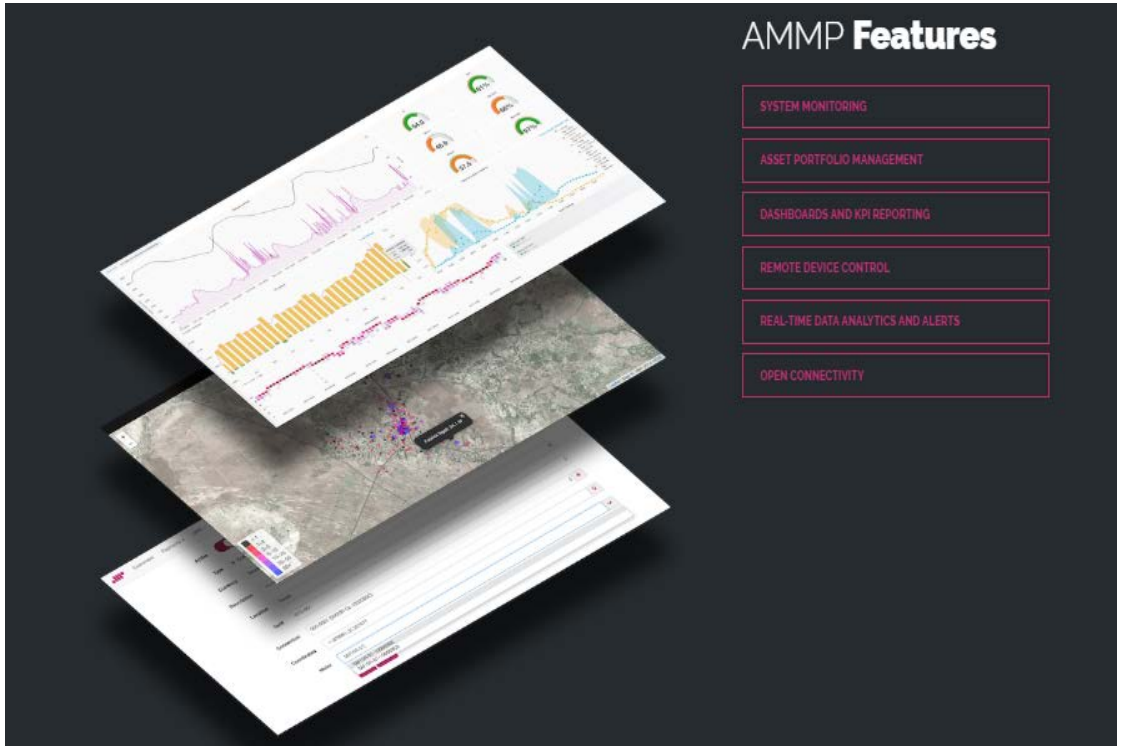


Photo credit: AMMP

Budgeting

- Budgeting should be done on a regular basis to encourage targeted spending. From an operational perspective, a budget needs to contain all items categorised as operational costs.

- At the end of each budgeted period, relevant personnel should compare the actual costs with the budget and provide information on any cost deviations.

- Budgeting based on historical data may not always be reflective of future costs due to factors such as:
  - Economies of scale whose effects should be considered when further sites are installed;
  - Changes in operational processes/procedures which may lead to less/more efficiencies and a corresponding change in costs; or
  - Costs which may be limited to a point in time (e.g. site visits) and therefore need to be considered for each period.

Process management

- One of the key aspects in operational management is that processes are well documented. This helps to:
  - Identify bottlenecks and areas in which operational management could be made more efficient.
  - Reduce costs through standardisation of tasks.
- Each process carried out in operations should be written down in an action-based sequence with each of the steps at minimum containing inputs, responsible party, action timelines, methodology and the outputs.
- For a simpler overview, these processes may be put in a flowchart using any available tools.

Item	Description	Example
Input	Which document/ process manual is required for this activity	List of suppliers
Person responsible	Who is the person responsible?	Productive Use Head
Manager	Who is accountable for this step?	Head of Customer Service
Action	What is being done?	Purchase of PU appliances for customers
Timeframe	How long does the step take?	1 month
Methodology	What is the process for carrying out this activity?	Issue RFQs to vetted suppliers and select best fit.
Output	What are the desired outputs?	Machines purchased and installed

Management processes workflow

Asset management (1)

- Asset Management aims at ensuring optimal profitability of the PV power plant by supervising energy sales, energy production and O&M activities.

- This role is usually done by the developer's executive team and it involves reporting to stakeholders on mini-grid performance.

Trends in Asset Management

- Automated operations of the plant: Intelligent mini-grid technology can take operational decisions e.g. when to charge the batteries or to start the diesel generator. Consider whether to use load following (better for low renewable fraction) or cycle charge settings (best for high renewable fraction) for generators.

- Remote monitoring of a mini-grid system reduces need for manual checking which may otherwise require specialised tools and man hours.

Asset management (2)

Equipment end-of-life management

- Most countries in SSA do not yet have policies and regulations on electronic waste management. However developers should be aware of the expected lifetimes of the components used and existing in-country intervention efforts to help develop an end of life strategy.

- Solar e-waste consists of all materials and component parts that make up off-grid solar products. This ranges from lead acid and lithium-based batteries to copper cabling and the silicon in solar panels. Some of these materials have cash value while others do not.

- The economics of solar e-waste are challenging given the current market dynamics and costs associated with product take-back and collection.

Photo credit: GOGLA

Asset management (3)

Power assets

Power assets include:

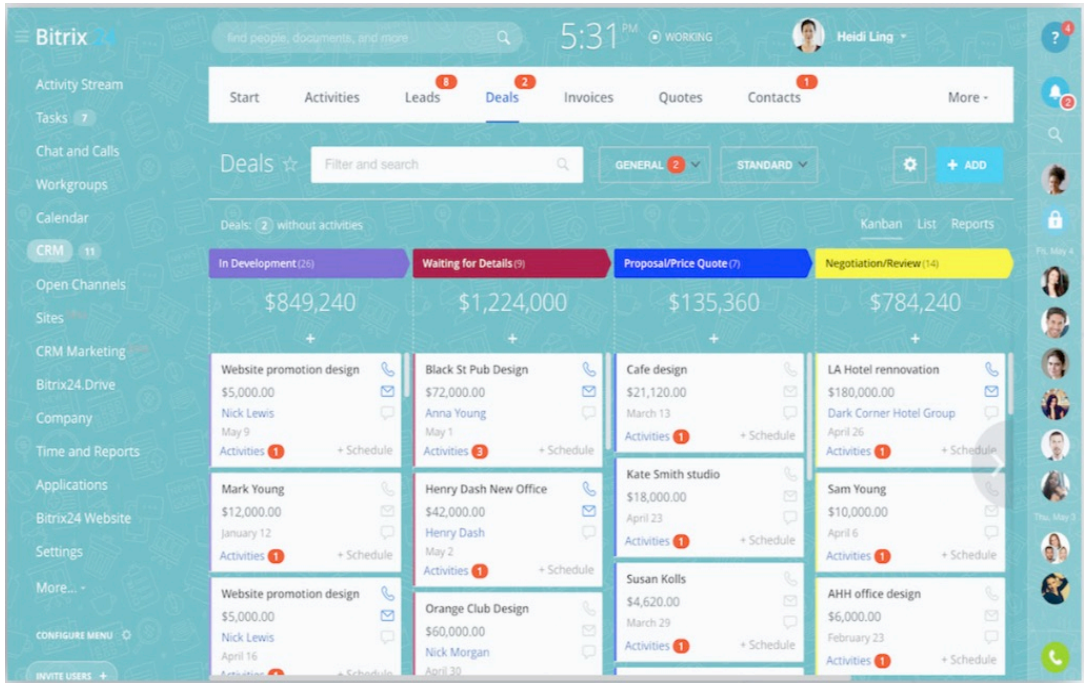
- Generation assets e.g. solar PV arrays, batteries and other storage options, hydro turbines, inverters, cables, etc.
- Distribution assets e.g. poles, transformers, meters etc.
- All assets should be in correct operating condition. Any deviations from this should be addressed as soon as possible.
- Real time monitoring and periodic inspections important for the decision-making process.
- Manufacturer recommendations should be considered when planning revisions, etc.
- Any issues should be ticketed, and work orders generated for the field teams.

Photo credit: Havenhill

Customer management

Practices in customer management

- Smart meters and automatic billing platforms
- Demand side management interventions such as load limiters and time of use tariffs to match supply with demand
- Customer hotlines for receiving customer calls and messages. Automatic voice response used by some developers to deal with large numbers of customers and offer 24/7 response
- Regular site visits by customer service teams to identify potential for new connections and re-train customers.
- Customer relationship management tools e.g. Bitrix24, Microsoft Dynamics CRM etc. to record interactions with customers for better tracking and improved service delivery.

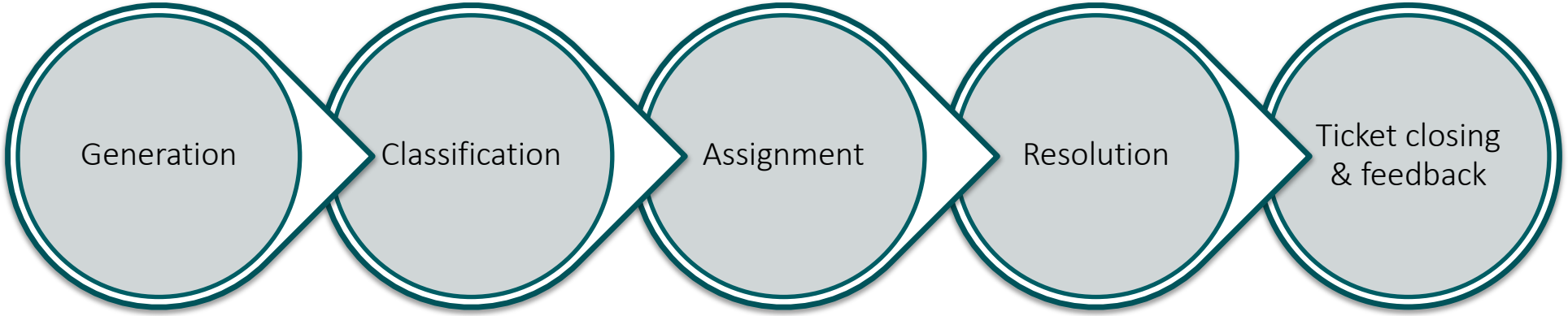


Britix 24 CRM platform

Ticket management

- Software can be used to raise and track tickets from customers. Tickets can be classified based on their severity i.e. risk to equipment, number of customers affected etc.

- Customer support or technical teams generate tickets after a customer call. The ticket creation and resolution process is illustrated below.



System changes

- System changes may be needed where demand does not grow as expected (too slow or too fast) or technology updates need to be made.
- Potential interventions include system expansions, software updates, extensions to distribution network, and retrofits.

System Change Interventions

Expansions:	Updates:	Extensions:	Retrofits:
Increasing the generation and storage capacity of the mini-grid due to high demand by increasing generation assets.	Software and firmware updates to ensure systems are current, secure and operate without glitches.	Addition of more customer connections from the existing distribution network or by adding poles and cables.	Addition of new support hardware or software to the mini-grid e.g. a new SCADA system

System Change Interventions

Key performance indicators (KPIs)

- KPIs are based on investor or management requirements. They should be developed by the developer for continuous performance monitoring and comparison.

- Examples of KPIs include:
  - Revenue KPIs
    - Average Revenue per User (ARPU)
    - Average Consumption per User (ACPU)
    - Average OPEX per User
  - Technical KPIs
    - Uptime of the grid
    - Unscheduled downtime
    - System losses (grid and power system)
  - Customer related KPIs
    - Tickets per month
    - Ticket resolution time
  - Learning & Development
    - Personnel skills development
    - Innovations

KPI management process

Health and safety

Implement safety and anti-theft protection measures to secure the generation assets, distribution system and control power theft. The following best practices can be adopted:

- Use glass fibre reinforced remote alarm systems to improve security. Few operators install CCTV camera-based systems. Most hire local part time security guards for theft protection.
- Integrate energy theft protection with the smart meters. Real-time monitoring of consumption data from smart meters can reduce theft of electricity by individual customers and also lead to savings on labour costs.
- Form an operating committee for the mini-grid that includes customers to build sense of local ownership.
- Develop a company health and safety policy, train all staff on it and take measures to ensure it is followed.

Photo credit: JUMEME

Monitoring (1)

- Two types of monitoring
  - Physical: Personnel on site visually inspect assets and report back to operator / owner.
  - Remote monitoring: Data acquisition systems and platforms allowing remote monitoring capability.

- Monitor and analyse data against normal usage patterns and degradation of plant components
- Use predictive techniques to determine condition of key components and when and whether maintenance should be performed.
- Make sure remote monitoring systems have separate Uninterruptible Power Supply on site.
- Ensure interoperability between operating platforms. In many cases there is a lack of standardisation in the data protocols and channels used which means either multiple platforms must be used or a single platform is adopted that combines all data.

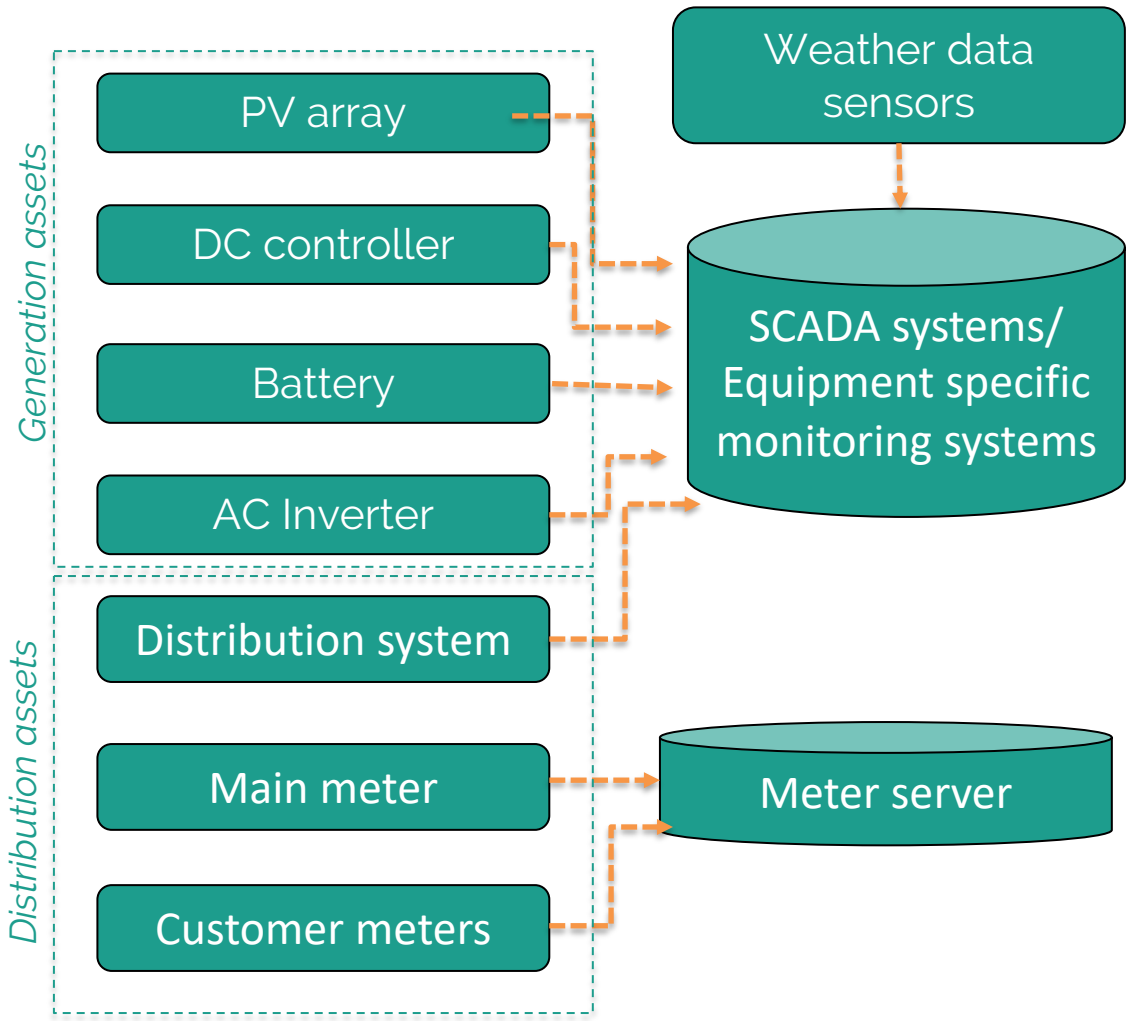
Data analysis on main equipment

Trigger technical inspection to be embedded in preventative maintenance plan

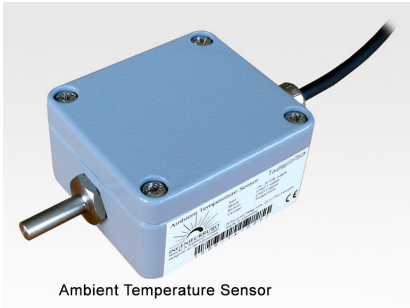
Reactive

Trigger reactive maintenance

Monitoring (2)



Layout & tools of distribution and generation assets



Sensors used

SCADA providers

SIEMENS

eLum ORCHESTRATE ENERGY & DATA

Equipment specific systems

SMA

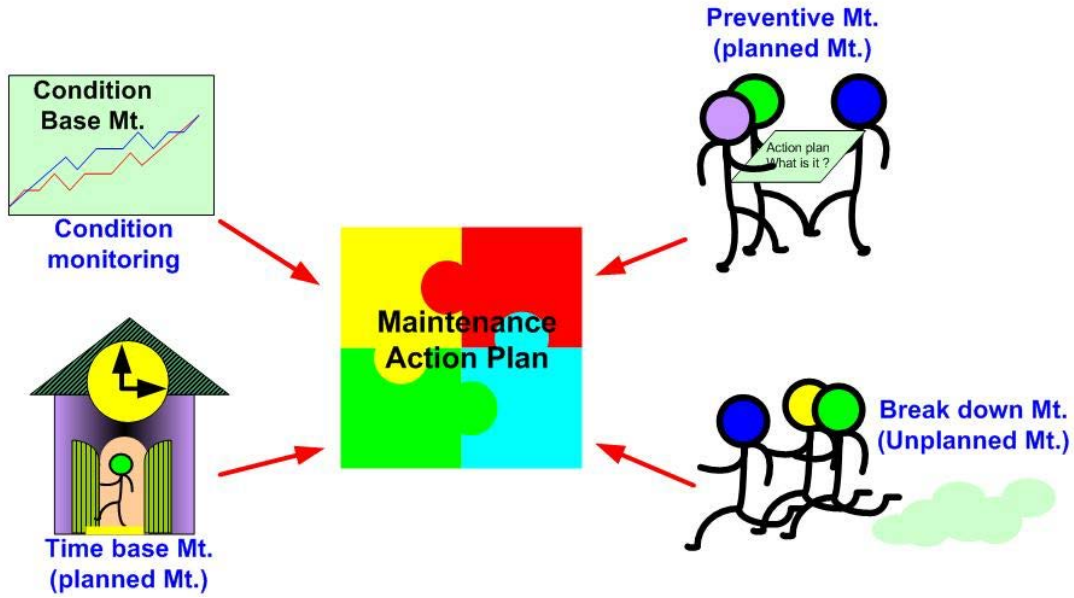
victron energy BLUE POWER

Schneider Electric

Types of maintenance

- There are three forms of mini-grid maintenance
  - Preventative maintenance [PM]: Includes routine inspection and servicing of equipment which helps prevent breakdowns and reduce energy yield losses. PM is usually a scheduled activity.
  - Reactive maintenance [RM]: Includes repairs of faulty equipment. Usually happens in response to such failures.
  - Condition-based maintenance [CBM]: Involves monitoring of condition of equipment and plant operations on a real-time basis and addresses potential problems early to prevent downtime. This requires a robust plant performance monitoring system.

Compared to other power generating technologies, solar PV power plants have low maintenance and servicing requirements.



Maintenance action plan

Preventative maintenance (PM)

- Activities to maximise production and prolong the life of the plant.
- Frequency of PM is determined by:
  - Technology selected;
  - Environmental conditions of the site;
  - Warranty terms;
  - Seasonal variations; and
  - Manufacturer's recommendations.
- PM activities that require plant shutdown should be done at off-peak hours.
- PM has a cost implication, therefore the developer should seek the optimum balance between the cost of scheduled maintenance and increased yield over the life of the system.

Example of PM activities

- Solar panel cleaning
- Vegetation management
- DC & AC electrical subsystem cleaning
- Checking integrity of connections and terminations
- Mechanical inspections
- Documentation
- Physical observations
- Thermographic imaging to identify potential failure-prone modules or components
- Electrical tests for solar panels, inverters, batteries etc.

Reactive maintenance (RM)

- Key parameters of RM to consider:
  - Diagnosis
  - Speed of response
  - Repair time
- Need to balance the benefits of faster response time in terms of increased energy yield against the increased costs of shorter response times.
- If a developer has outsourced maintenance to a contractor, the agreed response times should be stated in the O&M contract and will depend on the site location and whether it is manned.
- Depending on the type of fault, a reasonable contracted maximum response time could be 48 hours, with liquidated damages payable by the contractor if this limit is exceeded.
- A well-constructed mini-grid should not need much RM.
- It is good to have an inventory of spare parts to facilitate rapid response in case of equipment failure.

Examples of RM activities

- Failure analysis
- Emergency maintenance
- Repairs and replacements
- Replacement of fuses and meters
- Rectifying SCADA/remote monitoring systems faults
- Rectifying tracking systems

Maintenance personnel

- Staff on the ground must be properly trained, follow defined O&M procedures, and have access to more qualified technicians as required.
- The mini-grid's executive team must ensure that local staff understand and follow the O&M procedures and give feedback if they have questions or suggestions for improvement.
- Local staff should be the first line of defence for troubleshooting and reporting.

.

Level 1: Local O&M team	Level 2: Specialised technical team	Level 3: Operator/ service agents
• PV cleaning • Lubrication of movable parts • Battery checking • Dusting and cleaning power room • Safety training for customers • Extensions advisory	• Troubleshooting • Works on core components • Retrofits • Configuration	• Monitoring • Training • Performance monitoring • Customer care

Increasing complexity of tasks

Overview of O&M costs

O&M costs depend on:

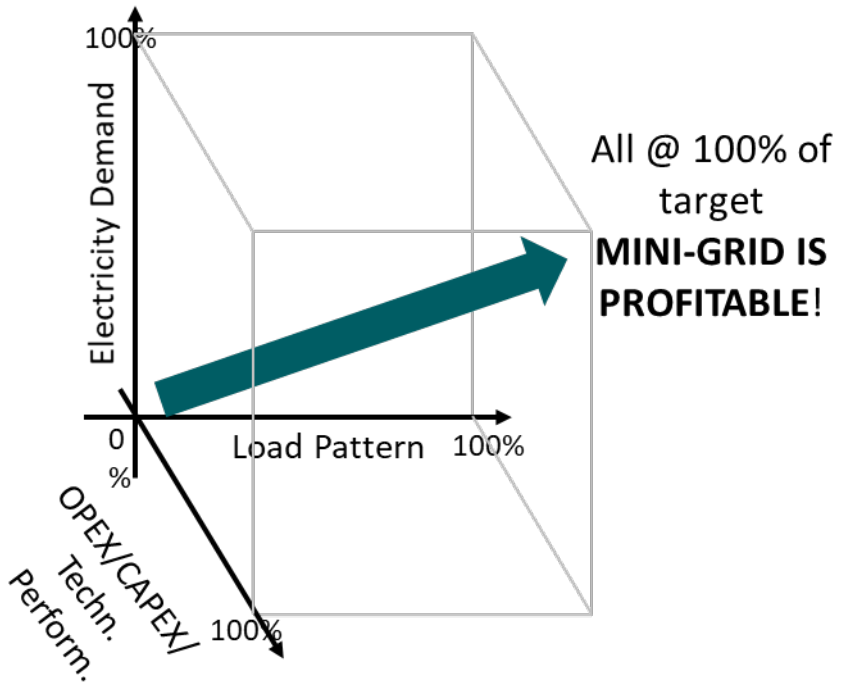
- Location of mini-grid
- Solar PV mounting
- Quantity of components
- Warranty coverage
- Environmental conditions

- O&M costs include
  - Administrative costs – personnel, software costs, land leases, fuel costs for generators etc.
  - Preventative maintenance costs
  - Reactive maintenance – cost of replacements

- Reserve account: fund to cover the cost of major component failures

See Module 6 for information on funding and financial models

Reducing opex is critical for project profitability and therefore requires monitoring

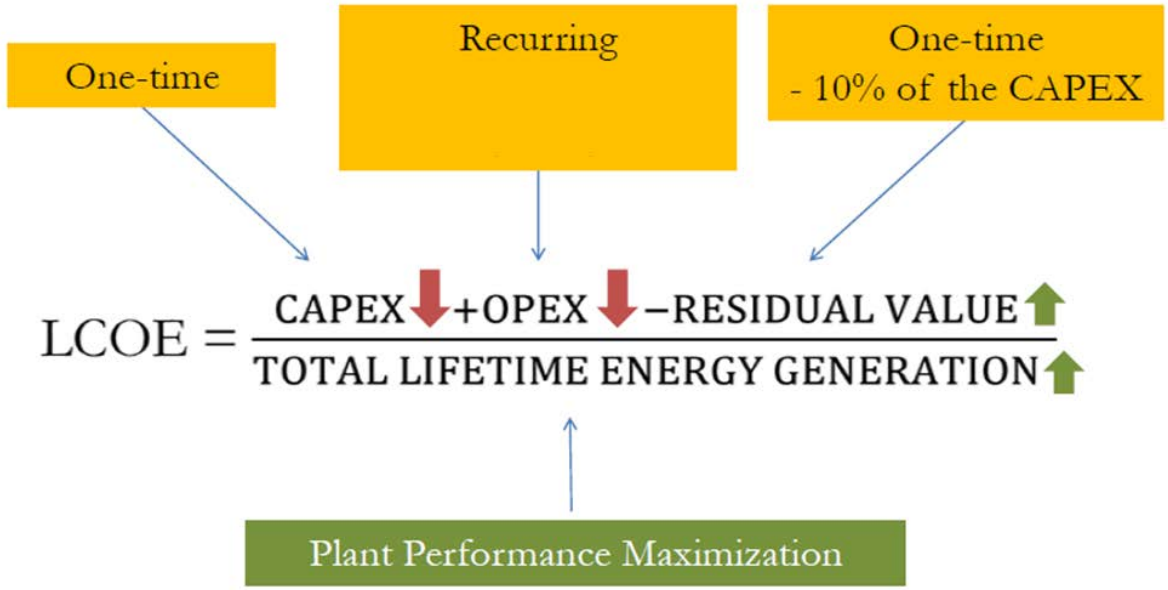


O&M Costs x Grid Profitability

OPEX reduction

OPEX reduction strategies

- Automation reduces the need for physical visits and encourages better planning
  - Payment collection using mobile money.
  - Asset management using data acquisition software and online monitoring platforms.
- Establishment of a customer service centre and hotline to resolve issues by phone or online
- Allocation of tasks to local mini-grid personnel
- Shared resources between different mini-grid sites. e.g. storage facilities, maintenance trips.



Plant performance maximisation

Case study: Energicity OPEX management

Energicity is a mini-grid developer with more than 10 grids active in Ghana and Sierra Leone, currently serving over 5,000 beneficiaries.

Energicity has managed to cut costs in its O&M approach through:

- Standardisation: The company's proprietary operations platform allows for unification of processes and procedures across sites.
- Development of a "**hub and spoke**" model: Locally trained staff who live close to the mini-grids provide the first level of service, while more skilled staff are available at central hubs to address more serious or complex issues.
- Customer-centric strategy: Consistent customer engagements at all levels of the organisation enables Energicity to anticipate customer issues, mitigate them and avoid O&M related costs.

Photo credit: Energycity

Module recap

- O&M is a critical element in the long-term sustainability of a mini-grid.
- O&M can be done by different parties: the developer themselves, third-party contractors, the community or through a hybrid arrangement (e.g. a Public-Private Partnership). Each arrangement has its own benefits and drawbacks.
- For O&M to work well, the developer needs to consider many areas of their business: proper documentation and business processes, financial planning, customer engagement and ticketing, hardware, software and and technical system changes, performance monitoring, and health & safety. Systems may be monitored remotely or on site or both.
- There are three types of maintenance: preventative, reactive and condition-based. All three are fundamental to the successful operation of a mini-grid.
- It is important that staff at all levels of the mini-grid business (from corporate management to the local ground staff) are involved in O&M.
- Many factors affect the costs of O&M, including location, technology, and warranties. Strategies to reduce these costs include automation, sub-contracting to local personnel, and sharing resources between mini-grids.

Further reading (1)

Bhatia, M., & Angelou, N. (2015). *Beyond Connections, Energy Access Redefined.* Washington: The World Bank Group. https://openknowledge.worldbank.org/handle/10986/24368

Blodgett, C., Dauenhauer, P., Louie, H., Kickham, L., (2017). *Accuracy of energy-use surveys in predicting rural mini-grid user consumption.* Energy for Sustainable Development. https://www.sciencedirect.com/science/article/pii/S0973082617304350

Booth, S., Li, X., Baring-Gould, I., Kollanyi, D., Bharadwaj, A., & Weston, P. (2018). Energy 4 Impact and NREL. *Productive Use of Energy in African Micro-Grids: Technical and Business Considerations.* https://www.energy4impact.org/file/2039/download?token=8ardN8he

Boursier, S., et.al. of INENSUS, and Otieno, B., et.al. of Energy 4 Impact (2019). *Billing, Revenue Collection and Metering Models for Mini-Grids.* Green Mini-Grid Help Desk. https://greenminigrid.se4all-africa.org/sites/default/files/billing_models_for_minigrids_april_2019.pdf

Boursier, S., et.al. of INENSUS, and Browne, C., et.al. of Energy 4 Impact (2019). *Demand Side Management for Mini-grids.* Green Mini-Grid Help Desk. https://greenminigrid.se4all-africa.org/sites/default/files/afdb_gmg_dsm_report_final_draft_cb.pdf

DOE Office of Indian Energy. (2015). *Project Operations and Maintenance.* DOE Office of Indian Energy. Retrieved from https://www.energy.gov/sites/prod/files/2015/06/f23/7a%20Step%205%20Project%20Operations%20and%20Maintenance.pdf

Elmar Steurer, D. B. (2017). *Standardized Risk Management Procedure (SRMP) for Mini Grids Case Study: Mini-Grid Sunderbans, West Bengal, India.* India: Elsevier Ltd. Retrieved from https://www.researchgate.net/figure/Key-functions-of-a-mini-grid-for-decentralized-electrification_fig1_319476721

ESMAP. (2000). *Mini-Grid Design Manual.* Washington: The World Bank. https://www.esmap.org/sites/esmap.org/files/TR_minigriddesignmanual21364.pdf

Further reading (2)

ESMAP. (2019). *Mini Grids for Half a Billion People : Market Outlook and Handbook for Decision Makers*. World Bank. https://openknowledge.worldbank.org/handle/10986/31926

GIZ. (2016). *What size shall it be?*. https://energypedia.info/wiki/Mini-Grid_Sizing

IFC. (2015). *Utility-Scale Solar Photovoltaic Power Plants: A Project Developer's Guide.* Washington: IFC. https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/sustainability-at-ifc/publications/publications_utility-scale+solar+photovoltaic+power+plants

IFC. (2018). *Benchmarking Mini-Grid DESCOs 2017 Update.* https://www.ifc.org/wps/wcm/connect/87b7df8f-94da-43ed-b168-3099b1edff45/IFC+Mini-grid+DESCO+Benchmarking+2017+Update.pdf?MOD=AJPERES

Josh Haney, A. B. (2013). *PV System Operations and Maintenance Fundamentals.* Solar America Board for Codes and Standards. Retrieved from www.solarabcs.org/O&M

Kong, T. R. (2005). *Construction site safety handbook.* Hong Kong: The Real Estate Developers Association of Hong Kong. Retrieved from http://www.safetypartnering.com/smd/pdf/handbook_e.pdf

Munoz, P. (2017). *Mini-grids in Africa: experience from the field.* Rue des Casernes: Studer Innotec. Retrieved from https://www.solarwirtschaft.de/fileadmin/user_upload/Session2_2_Presentation_of_Studer_Innotec_Intersolar_2017.pdf

Nampoothiri, M. (2013). *Solar PV O&M – The Indian Experience.* Mumbai: Re-solve. Retrieved from https://www.slideshare.net/re-solve/om-presentation-intersolar-2013-ver-30

Further reading (3)

NREL. (2015). *SAPC Best Practices in PV System installation*. https://www.nrel.gov/docs/fy15osti/63234.pdf

NREL. (2016). *Best Practices in Photovoltaic System Operations and Maintenance.* https://www.nrel.gov/docs/fy17osti/67553.pdf

Robert W. Schultz, A. S. (2015). *EnDev2: Inspection guide for Photovoltaic Village Power (PVVP) systems.* GIZ. https://energypedia.info/images/3/39/Inspection_Guide_for_PVVP_150524_(GIZ_2015).pdf

SolarPower Europe. (2018). *Operation & Maintenance Best Practice Guidelines/ Version 2.0.* Brussels. http://www.solarmaintenancemark.com/wp-content/uploads/2018/06/OM-Best-Practices-Guidelines-V2.0.pdf

TCN. (2005). *The Grid Code For The Nigeria Electricity Transmission System*. https://www.nbet.com.ng/wp-content/uploads/2018/05/Grid-Code-Final-Version-before-Approval.pdf

USAID. (2018). *What Are The Technical Components Of A Mini-grid?* https://www.usaid.gov/energy/mini-grids/technical-design/components

USAID. (2019, June). *Mini-Grids Ownership Models*. From Mini-grids Toolkit: https://www.usaid.gov/energy/mini-grids/ownership

Weston, Peter, Kalhoro, Wakar, Lockhart, Eric, Reber, Tim & Booth, Sam. Energy 4 Impact and NREL (2018). *Financial and Operational Bundling Strategies for Sustainable Micro-grid Business Models*. https://www.energy4impact.org/file/2074/download?token=WZ183t75

Williams, Nathan, Booth, Samuel S, and Baring-Gould, Edward I (2019). NREL. *Survey Use in Micro-Grid Load Prediction, Project Development, and Operations: Review and Best Practices*. https://www.nrel.gov/docs/fy19osti/72339.pdf