TRAINING MANUAL FOR SOLAR PV LED LIGHTING SYSTEM INSTALLATION

For the Remote Communities of Pacific Island Countries

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For copies of this Manual contact

SOPAC Secretariat
Private Mail Bag, Suva
Fiji Islands
Ph: +679 338 1377
Fax: +679 337 0040

or visit SOPAC website
www.sopac.org

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The "Training Manual for Solar PV LED Lighting System Installation" has been developed as part of the Pacific Micro Energy Services Companies (PMESCOs) Project. The project was co-funded by REEEP (Renewable Energy and Energy Efficiency Partnership) and SOPAC (Pacific Islands Applied Geoscience Commission) in collaboration with the Solomon Islands Solar Entrepreneur, Willies Electrical and Solar Power (WILLIES) and the Kiribati Solar Energy Company Ltd (KSEC).

The PMESCOs project created an enabling environment for the purchase of affordable, efficient and reliable lighting needs for remote communities in the participating Pacific Island Countries (Solomon Islands and Kiribati), through the establishment of a micro credit facility. The micro credit facility has allowed rural communities to repay the cost of the solar PV LED lighting systems over a two year period using cash or cash crops.

The use of solar PV LED lighting systems has contributed to the sustainable livelihoods of remote communities through reducing reliance on imported kerosene for lighting and enhanced the use of solar energy with linkages to agricultural activities.

The training manual has been adapted (with permission) from the Light Up the World Foundation (LUTW) training and installation manual to assist solar entrepreneurs. The manual is particularly relevant for remote and outer islands of Pacific Island Countries and designed to increase their understanding and potential application of solar PV LED lighting systems. The manual includes details of system components, correct installation, maintenance and troubleshooting procedures. The manual will contribute to the promotion of solar PV LED lighting systems and encourage the adoption and the application of solar energy for rural electrification.
1. INTRODUCTION

The purpose of the Solar PV LED Lighting System\(^1\) is to provide a complete, off-the-grid lighting solution for homes, community halls and medical clinics operating in very remote areas where there is no grid connection and people rely on fossil fuel-base lighting such as kerosene lanterns.

Kerosene lanterns and the like are inefficient, typically only offering one fourth of the lumens of electric lights\(^2\), and are difficult to work, have been the cause of many household fires and provide a poor level of light to work or read from. Women and youth are often required to walk long distances to purchase kerosene required for household lights, particularly in remote regions.

The Solar PV LED Lighting System installed in remote areas and outer islands of the Pacific Islands must be:

- Reliable;
- Easy to install;
- Easy to maintain; and
- Low cost.

Low power consuming LED (Light Emitting Diode) lighting systems have been introduced through the PMESCOs project to replace kerosene lanterns in remote locations and provide a renewable, clean and reliable source of lighting. LED lights have the advantage over fluorescent lights of being more effective and energy efficient.

Installation of the solar PV LED lighting systems require a basic set of tools as outlined in Annex A.

The manual is divided into the following sections:

- Basic system overview and Parts List
- Solar Panel Installation
- Electrical Wiring
- System Powerup & Testing
- Maintenance & Troubleshooting

\(^1\) The system can be modified according to the energy needs of a household for lighting such as used in the PMESCOs project, includes 12W solar panel, 12V 18Ah Lead Acid Battery, LED lights and charge controller.

2. BASIC SOLAR PV LED LIGHTING SYSTEM COMPONENTS

2.1 Solar Panel

The Solar Panel is an energy transducer (a device that turns one form of energy into another) and consists of an array of photovoltaic cells that collects the energy from the sun and turns it into electrical energy. They are relatively expensive and complicated to make but simple to use and have a good life if maintained properly.

Solar Panel Type: Monocrystalline Silicon
Output Power: 10W
Lifetime: 20 – 25 years

2.2 Sealed Lead Acid Battery

A Sealed Lead Acid Battery is recommended for use in a solar PV LED lighting system. Sealed lead acid batteries are also referred to as maintenance free batteries as they require no maintenance. These types of batteries are suitable for remote areas where there is no technician available to provide maintenance. The battery stores electricity produced by the solar panel for use later, such as for lighting at night.

Battery Type: Sealed Lead-Acid Battery
Capacity: 12V, 18Ah
Weight (kg): 5.8 kg
Lifetime: 5 – 7 Years or 1000 recharging cycles.

2.3 LED Lights

The LED Lights are low powered lights and require very low amounts of power to operate. The LED is an electronic diode similar to other semiconductor diodes which are unique and designed to convert energy from the battery into visible light.

Model: NemaLux LED
Input Voltage: 3 – 3.5V
Power Consumption (Typical): 1.8W (at full power)
2.4 Charge/Discharge Controller

The Charge/Discharge Controller is a device used to limit the output voltage from the solar panel to a safe level for the battery and at the same time limit the excessive discharge of the voltage from the battery.

The Charge/Discharge Controller prevents damage to the battery from over charging or excessive discharge that will contribute to prolonging the life of the battery.

Model: Nemalux LUTW Charge Controller
Wiring configuration:
Solar panel: single black cable
Battery: red cable to positive (+ive) pole and black cable to negative (-ive) pole.
LED lights: Yellow /White cable

A set of solar PV LED lighting system components sold out through the micro credit scheme for remote communities in Malaita Province, Solomon Islands.

Set of solar PV LED lighting systems lined up for households, Malaita Province Solomon Islands.
3. GENERAL INSTALLATION DETAILS

3.1 Planning the Installation

When planning an installation, make sure to follow these installation guidelines as well as bearing in mind that excessive distance between the solar panel, battery and lights should be avoided so as to reduce power losses in the wiring.

- Choose a clear obstructed area to mount the solar panel;
- Choose a safe place for the battery;
- Choose a location that will give the best lighting for the LED lights; and
- Choose an accessible place for the charge/discharge controller with built-in light switches.

Once all components have been placed and positioned, they should be mounted and wired as shown in Figure 1. A good time for the installation is at dawn in order to maximize the number of daylight hours for testing and fine tuning of the system once the sun is out at mid-day.

![Diagram of the solar PV LED lighting system installation and wiring overview.](image)
3.2  The Solar Panel

3.2.1  Check the polarity of solar panel with a multimeter.

The polarity of a solar panel is the arrangement of the positive pole (+ive) and the negative pole (-ive). It is simply a way of showing the direction of the electricity flow. The solar panel has a +ive and -ive lead. The +ive lead should be connected to the +ive pole of the controller and the -ive lead connected to the -ive pole of the controller.

In order to double check the polarity of the solar panel, follow the instructions below:

a. Place the solar panel outdoors with the monocrystaline side facing up in a sunlit location. This will produce a test voltage for you to measure.

b. Set the multimeter to the DC voltage range capable of measuring up to 24VDC.

c. Connect the +ive side of the multimeter to one terminal of the solar panel and the -ive side of the multimeter to the other side.

d. If the reading is +ive (as shown in Figure 2, Left) this is the +ive side of the solar panel.

e. If the reading is -ive (as shown in Figure 3, Right) the terminal markings are incorrect and should be marked correctly.

3.2.2  Aligning and Mounting the Solar Panel

3.2.2.1  For maximum solar efficiency mount the solar panel so that:

a. the photovoltaic side of the panel is directly facing in the direction of the sun.

b. It is at least 100 mm above the roof or its mounting surface so air can move all around the panel and keep it from getting too hot.

c. It is in a clear area away from any obstructing object that could cast a shadow on the panel.

Any shading on the solar panel will result in a dramatic decrease in output, resulting in poor battery charging and less lighting time.
3.2.2.2 To mount the solar panel follow these steps:

a. Determine if your location is in the Northern or Southern hemisphere, i.e North or South of the equator.

b. The photovoltaic panel faces due South if it is being installed in the Northern hemisphere.

c. The photovoltaic panel faces due North if it is being installed in the Southern hemisphere.

d. The tilt angle or angle of inclination should be set to an angle equivalent to the geographic latitude coordinate of the village.

Example: In a village at 20°N latitude, the solar panel should be installed facing due South and inclined 20° from the horizontal. In a village at 10°S latitude, it should be installed facing due North and inclined 10° from the horizon which is shown in Fig 4.

The Pacific Island Countries situated South of the equator such as Kiribati, Nauru, Tuvalu and Solomon lies at the latitude between 0° and 10°S. Whilst Fiji, Samoa and Vanuatu lies between latitude of 10° and 20°S. Tonga and Cook Islands lie at between 20° and 25°S. Most of the Northern Pacific countries, RMI, FSM and Palau lie at between 0° to 20°N.
3.2.2.3 Orienting a solar panel using shades projection method.

Any material (while preferably) could be used to build a shades projector, shown in Figure 6, as long as it is solid enough to keep all its wall straight. It is important that all angles are square (including the base), otherwise the solar panel will not be precisely oriented.

Place the shade projector over the solar panel as shown in Figure 7 below; then rotate them together and/or modify their degree of inclination until there is no projected shade at the bottom.

These adjustments should be performed ONLY when the sun is at its highest position also known as the local Solar Noon Position.

Determining Local Solar Noon Position

There is a very simple way to determine the local Solar Noon by averaging times of Sunrise and Sunset. For example if Sunrise was observed at 05:32 (5:32 AM) and Sunset was observed at 18:48 (6:48 PM) the night before. Solar Noon can be calculated by adding the two times and dividing the result by two as it follows:

\[
05:32 \text{ hours} + 18:48 \text{ hours} = 24:20 \text{ hours}
\]

Solar Noon Position Time = \( 24:20 / 2 = 12:10 \text{ hours} \) (12:10 PM)

**NOTE:** MINUTES MUST NOT EXCEED 60, IF THIS OCCURS, REDUCE MINUTES BY 60 AND ADD 1 TO THE HOURS.
3.3 Charge/Discharge Controller

The charge/discharge controller should be connected into the system according to the instructions which are provided by the supplier of the controller. The LUTW controller has two LED lights outputs and individual switches for each of the lights.

The charge and discharge controller should be connected to the correct sides of the solar panel with the +ive wire on the controller connected to the +ive side of the solar panel and the -ive wire from the controller to the -ive side of the solar panel. Refer to 3.2.1 for the polarity of the solar panel.

The controller should be solidly mounted in a cool place, protected from the sun and rain and as close to the battery as practical.

3.4 Battery

The safety of the sealed lead acid battery depends on where it is placed. The following guidelines indicate things to consider when locating the battery:

a. Primarily the battery should be located in a safe, secure and well ventilated place.

b. General points for consideration include:
   - Locate the battery close to the charge controller;
   - Protect the battery and terminals with a non conductive material such as wool or plastic box; and
   - Avoid damaging the battery seal as batteries contain corrosive, harmful chemicals which can cause injury.

c. DO NOT place any metal conductor directly between the +ive and -ive battery terminals. This can cause an electrical short circuit and the resulting large current could cause the battery to explode and/or be irreversibly damaged which can cause fire to the home.

3.5 LED Lights

3.5.1 The LED lights should be installed where required. Details of a typical system layout are provided in Figure 1.

A basic solar PV LED lighting system is supplied with cables but in case additional cable is required during the installation, a similar size of wire should be used. Also seek advice from the suppliers of the solar PV LED lighting system for additional cable.
Figure 10: Simple reinforcing wire hanger for mounting the LED lights.

Figure 11: Additional cable can be added to the solar PV LED lighting system as shown here. A KSEC Solar Technician measured the additional cable required.
4. SYSTEM PERFORMANCE AND MAINTENANCE

4.1 SYSTEM PERFORMANCE

The LUTW Foundation LED lights provide two levels of illumination, where the level is controlled by a switch on the controller such as shown in Figure 12.

![Charge/Discharge Controller with the two switches for LED lights](image)

Figure 12: A Charge/Discharge Controller with the two switches for LED lights.

The high brightness position gives more light output but drains the battery faster than the low brightness position.
- High brightness (100%), 75 lumens light output; and
- Low brightness (25%), 20 lumens light output.

The basic solar PV LED lighting system can provide up to 14 light hours per day for two LED lights (i.e. 7 hours per light) if the system is fully charged. A good charging day is having 4 to 6 hours of good sunlight.

Where daily sunshine hours are lower, on an overcast or cloudy day the battery may not fully recharge. In this instance the available electricity to power the lights will be limited and therefore the user will have to minimize the use of one of the LED lights in order to have sufficient lighting for one full night.

Additional LED lights can be added to the system but the hours of use per light will need to be reduced.

4.2 MAINTENANCE

4.2.1 Solar Panel

Keep the upper surface of the photovoltaic panel clean. The accumulation of dust reduces the efficiency of the panel and the amount of power it can produce. Use only water to clean the panel every 6 months or more frequently if very dusty. Do not use any chemicals as they can corrode the photovoltaic cells. It is best that cleaning the module is done early in the morning before the module; the frame and the roof (if metal) become too hot.
Connectors to the panel may become loose over time and therefore it is best that the wires are regularly checked, cleaned and lightly coated with grease if in a corrosive environment.

### 4.2.2 LED Lights

Keep the LED light lenses clean. The accumulation of dust and dirt reduces the effective amount of light. The lights are only meant for indoor use. They are not waterproof and should be mounted in a dry place. If water gets inside the LED light accidentally, switch it off immediately, open the case and let dry thoroughly before reassembling and using.

### 4.2.3 Battery

Sealed lead acid batteries are preferable to use as they require less maintenance and also there is less likelihood of accidents involving spilt battery acid.

Care should be taken to avoid any accidental short circuit of the battery terminals as this will damage the battery.

The efficiency of sealed lead-acid batteries depends on three main factors:
- Temperature;
- State of charge; and
- Recharging cycles.

#### 4.2.3.1 Temperature

When a battery is fully charged and there is no load it will naturally discharge a small amount of electricity. This is called "self-discharge". Heat (temperature) increases the rate of self-discharge and also degrades the battery by promoting the corrosion of the +ive plate grids. The self-discharge should therefore be kept as low as possible to minimize the number of recharging cycles and increase battery life.

Extreme cold reduces the speed at which chemical reactions occur, thus limiting the ability of a battery to the delivery rated capacity. Extreme cold also introduces the possibility of damage by freezing of the electrolyte. Batteries in a discharged state are particularly susceptible to freezing damage.

A safe temperature range to operate most batteries, as recommended by battery manufacturers is 0° to 40°C. Avoid exposing batteries to temperatures below -15°C or above 50°C as this may damage the battery.

#### 4.2.3.2 State of Charge

A sealed lead acid battery will gradually fail if kept in a low state of charge due to crystal growth of lead sulphate. The accumulation of lead-sulphate on the plates insulates that portion of the plate requiring extra power to remove the deposits. Batteries SHOULD NOT be kept in a discharged state as this will result in permanent loss of capacity. Due to the self-discharge property of batteries, unused spare batteries should be charged periodically. Avoid keeping the battery in discharged state for long periods of time.

#### 4.2.3.3 Recharging Cycle

An 18Ah 12V sealed lead acid battery typically can last 5 to 7 years or 1000 recharging cycles, which ever comes first. If the battery is charged or discharged excessively, the excess current will generate waste heat and form lead-sulphate that cannot be subsequently removed by charging.
5. TROUBLESHOOTING

Troubleshooting for a solar PV LED lighting system should be carried out by a trained community or island solar technician who can operate and use a multimeter.

5.1 LED LIGHTS FAIL TO TURN ON

It is highly improbable that both lights have failed simultaneously. It is more likely that a system problem such as broken wire, bad connection or a battery, charge/discharge controller failure has affected both lights.

If both lights are connected and have power applied but neither light turns on, turn the power off by disconnecting the battery and follow the steps below to check for problems.

5.1.1 Check Solar Panel

Check that the solar panel is in good condition and that nothing is obstructing it from receiving sun light and check all the wiring at the solar panel, the charge/discharge controller and at the battery terminals. If all the wire installation is good and LED lights do not turn on then check the solar panel orientation as discussed in Section 3.2. If the lights still do not turn on, then connect the LED lights straight to the battery, if the lights go on, the solar panel is damaged or not charging and has to be replaced.

5.1.2 Check the Battery

Check the battery voltage (using the multimeter); it should be between 12.2V and 14V. If the battery voltage is below that range then either the solar panel is not charging the battery or the battery needs to be replaced. A typical sealed lead acid battery should last for approximately 5 to 7 years with continuous use. On the other hand if the battery voltage falls within that range, then check the wire installation and connections, check the switches, which often can fail.

Note: When replacing the battery, replace with the same type and size of battery as was installed with the solar PV LED lighting system.

5.2 LIGHTS ONLY ON FOR A SHORT TIME

As discussed above, during normal conditions the solar PV LED lighting system provides at least 7 hours of light a day for one LED light. If the number of hours are reduced dramatically (e.g. 2 hours), then either the battery or the solar panel are not working properly so check the solar panels performance and the battery as discussed in Section 5.1.1 and 5.1.2 respectively.
6. SOME USEFUL TIPS

In order to allow your solar PV LED lighting system to last longer and provide the best lighting for your family at night, keep in mind the following:

a. Do not try to disconnect and move your solar PV LED lighting system around to camping areas or other houses.

b. Do not charge other people’s battery other than the battery provided.

c. Do not connect other appliances other than LED lights.

d. Regularly check that the solar panel is not shaded from any tree or branches.

e. Check that the wires are always in tact in particular on the solar panel and at the battery terminals.

f. Always check for wire damages.

g. Use your solar PV LED lighting system with care.

Figure 13: Solar panels put on top of roofs should be protected from fallen branches, leaves or coconuts.

Figure 14: Do not charge other batteries other than the battery provided with the system.

Figure 15: Do not connect your solar PV LED lighting system with other electrical appliances, for example CFL shown in the diagram. CFL consumes more power (7 W) compared to LED lights (1.8 W).
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Alternate Current.</td>
</tr>
<tr>
<td>Ampere hours (Ah)</td>
<td>The unit of measure used for comparing the capacity or energy content of a battery with the same output voltage.</td>
</tr>
<tr>
<td>Capacity</td>
<td>The electric energy content of a battery expressed in “Watt hours”. Batteries with the same output voltage also use “Ampere hours” for comparing capacities.</td>
</tr>
<tr>
<td>DC Volts</td>
<td>Direct Current.</td>
</tr>
<tr>
<td>Discharge</td>
<td>The change from chemical energy within the cell into electrical energy to operate the external circuit, for example LED lights.</td>
</tr>
<tr>
<td>Energy Transducer</td>
<td>A device that converts one form of energy into another.</td>
</tr>
<tr>
<td>LED</td>
<td>Light Emitting Diode – it is a semiconductor device that emits visible light when conducting current.</td>
</tr>
<tr>
<td>Lead-sulphate</td>
<td>A chemical compound found on the +ive and -ive plates of a lead battery during discharging.</td>
</tr>
<tr>
<td>Multimeter</td>
<td>Also known as a volt/ohm meter or VOM is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter may include features such as the ability to measure voltage, current and resistance.</td>
</tr>
<tr>
<td>Photovoltaic cells</td>
<td>Also called solar cells, cells that made up a PV panel. 30 to 36 solar cells on a panel can charge a 12V battery.</td>
</tr>
<tr>
<td>Photovoltaic (PV) panel</td>
<td>A part of a photovoltaic system that converts the energy in light into electrical energy. Also called a solar panel or a PV panel.</td>
</tr>
<tr>
<td>Self discharge</td>
<td>Capacity loss during storage due to internal current leakage between the +ive and -ive plates.</td>
</tr>
<tr>
<td>Solar irradiation</td>
<td>Emission or transfer of energy in the form of electromagnetic waves from the sun.</td>
</tr>
<tr>
<td>State of charge</td>
<td>Is defined as the available or remaining capacity of a battery expressed as a percentage of its rated capacity for example, 100% or 80%.</td>
</tr>
<tr>
<td>Short circuit</td>
<td>A short circuit is when an electric current travel along a different path from originally intended.</td>
</tr>
<tr>
<td>Volts</td>
<td>Is a measure of electrical pressure which is the force that pushes electricity through a wire.</td>
</tr>
<tr>
<td>Watt</td>
<td>A unit of power, the rate of doing work. Watts = Amps x Volts = One Joule per second.</td>
</tr>
<tr>
<td>WattHours or Wh</td>
<td>A measure of the capacity of a battery. The amount of work done in one hour.</td>
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## APPENDIX A

### RECOMMENDED TOOLS FOR LIGHTING SYSTEM INSTALLATION

In this section a list of the tools necessary to perform the typical installation of the complete solid state lighting system are presented. More tools may be needed, depending on the complexity of the installation.

<table>
<thead>
<tr>
<th>Tool Description</th>
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<tbody>
<tr>
<td>High quality wire strippers (18 AWG included)</td>
</tr>
<tr>
<td>Pliers</td>
</tr>
<tr>
<td>Crimping Tool</td>
</tr>
<tr>
<td>Multiple-tips Screwdriver (User friendly)</td>
</tr>
<tr>
<td>Low cost multimeter (consider extra batteries)</td>
</tr>
<tr>
<td>Electric Drill (rechargeable batteries, 12V car adapter)</td>
</tr>
</tbody>
</table>

Miscellaneous wood screws, screws and nuts might be needed to install battery boxes and solar panels respectively. They should be purchased according to the climate and type of household construction where the installation takes place.
APPENDIX B

CONTACT INFORMATION

Willies Electrical & Solar Power
P.O. Box 169, Ranadi, Honiara
Solomon Islands
Tel: (677) 30508
Fax/Tel: (677) 30477
Email: dlf@solomon.com.sb

Kiribati Solar Energy Company Ltd
P.O.Box 493, Betio, Tarawa
Kiribati
Tel: (686) 26058
Email: Terubentau@gmail.com

SOPAC Secretariat
Private Mail Bag, GPO
Suva, Fiji Islands
Tel: (679) 3381377
Fax: (679) 3370040
www.sopac.org

Light Up the World Foundation
ECE, 2500 University Drive NW,
Calgary, Alberta, Canada.
T2N 1N4
info@lutw.org
www.lutw.org
NOTES