GGGI

Module 7 - **Trainers Guide**

Solar in the Community

ENGLISH - FIJI ISLANDS

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The module was refined by the regional project team, consisting of: Ulaiasi Butukoro (Programme Coordinator, GGGI Fiji), Afsrin Ali (Programme Coordinator, PIDF Fiji), Marilyn Tagicakibau (Director Programmes, PIDF Fiji), Paul Kaun (Senior Officer, GGGI Vanuatu), Jesse Benjamin (Senior Officer, GGGI Vanuatu), Benjamin Keni (Associate, Country Program, GGGI PNG), Hampton Pitu (Project Coordinator, PIDF Solomon Islands) and Alitia Sovunidakua (Intern, GGGI Fiji). Technical guidance and leadership were provided by Mohammed Tazil (Senior Officer- Regional, GGGI), Katerina Syngellakis (Pacific Programme Advisor) and Daniel Muñoz-Smith (Country Representative, Fiji, Kiribati, Tonga and Vanuatu).

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Cover photo: Community Solar PV training at Rukua Village. Source: Mohammed Tazil, GGGI, Fiji.

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GLOSSARY

AC current - Alternating current is the type of electricity that "alternates" or is always changing, typically produced by inverters, generators, and larger power systems.

Chemical energy - Energy stored in the bonds of chemical compounds, like atoms and molecules. This energy is released when a chemical reaction takes place.

Current (A) - An electric current is a flow of electric charge in a circuit or wire.

DC current - Direct Current is a type of electricity that is constant and is typically produced by solar panels and batteries.

Energy - Power derived from the utilization of physical or chemical resources, especially to provide light and heat or to work machines.

Harness (as PPE) - Is a form of personal protective equipment (PPE) that is designed to catch a person in case of falling while working at height.

Heat energy - Heat energy, also called thermal energy, is the energy an object has because of the movement of its molecules.

Hydrologic cycle - Is the continuous circulation of water within the Earth's hydrosphere and is driven by solar radiation.

Mechanical Energy- It is all the energy that an object has because of its motion and its position.

Name Plate - Identification sticker or sign that is attached to an appliance that indicates its name, manufacturer, and other details.

Radiation - Energy that travels by waves or particles, particularly electromagnetic radiation such as heat or x-rays. Electromagnetic waves that directly transport energy through space. Sunlight is a form of radiation.

Solar Energy - Energy from the sun that is converted into thermal or electrical energy.

Thermal Energy - Is the energy an object has because of the movement of its molecules.

Voltage - Is the potential difference between two points in a circuit and is what causes current to flow in a closed circuit.

TABLE OF CONVERSION

1000 Watt (W)	1 Kilowatt (kW)
60 seconds	1 minute
60 minutes	1 hour
1 Wh (Watthour)	1Watt x 1hour

The "Solar in the Community" training module is an introduction to the fundamentals of solar (photovoltaic) power systems.

Upon completion of the course, the learners will achieve the following learning outcomes:

- Describe Solar Energy.
- Explain the basic electrical parameters (V, I, P and E, AC, DC).
- Identify the various components used in a Solar Power System.
- Explain the function of each component in a Solar Power System.
- Describe the various types of Solar Power Systems.
- Discuss key factors to consider when purchasing solar power system and/or its components.
- Describe the importance of maintenance of Solar Power Systems.

OPTIONAL:

- Identify basic test equipment and demonstrate its correct and safe usage.

How to use this guide?

The trainer guide is provided with the class notes and includes activities which need to be done after each section of the course. The guide acts as a recommendation only. After seeing the situation on the ground in each community, the experienced trainers may use their judgment to modify their delivery and assessment techniques to achieve better results.

The Trainer Guide provides detailed notes written in the form that can be directly delivered to the learners. However, the very detailed notes are intended to broaden the knowledge of the learner as well. You are not required to read each paragraph from the Trainer Guide, but you are expected to know the materials sufficiently to train others. Firstly, you

must know what key concepts the learners need to learn. These are normally called learning outcomes. The learning outcomes are all listed at the start of the Trainer Guide, and you must ensure that at minimum, every learner achieves those 7 learning outcomes. You are required to take at least a week to go over the TG and go through the activities in the Learner Workbook. During the actual training you can refer to the Trainer Guide and explain it to the learners in your own words. If you are unsure of something always refer to the TG notes. Also note to take heed of the time recommended for each session and activity.

In case where learner literacy levels are low, trainers are advised to adapt to the situations and modify activities as appropriate. It is advisable to keep a continuous record of competencies of learners. All competencies are achieved when learners fulfil all learning outcomes.

HOW TO CONDUCT ACTIVITIES

- Activities are best done in groups or pairs. It is recommended that in each group there is at least one who is more literate or a more active learner who can help to translate and explain the training contents to learners who are slower to understand.
- You may divide the learners into groups of at least 2 and preferably 3-4 learners and ask them to carry out a rigorous discussion within the group. Some activities can be given to the groups for overnight preparation. The trainer needs to be aware of the dynamics of relationships in the community when dividing learners into groups. Sometimes women and youth are not free to share their views when the men from the communities are present. The trainer should ideally ask learners for their guidance when organising them into groups for discussions.
- Ideally the learners may present the results of their activities to the class and have a class discussion based on their findings.
- It is not necessary that all groups present in the same activity.
- However, it is important that all groups are given opportunity to present or verbally discuss their answers.
- At all times, encourage learners to be interactive and participative in class.
- Learners must be encouraged to be vocal and to contribute actively in class discussions.
- To better improve learning, the learners must be encouraged to strongly inquire about the topics through questions.
- The activities allow trainers to observe if the learners have achieved the learning outcomes. If possible, do keep record of the learner's achievement of learning outcomes so that you can help them learn better. A sample record table is given in this guide.
- Adapt existing activities and/or alternative suitable activities in case the desired literacy levels of learners are not met or the desired resources are not available.

TEACHING TOOLS

The following tools/items may be required to enhance learner learning:

- Laptop/ computer and projector to play videos or present notes to the whole class. This will depend on availability. In case this is not available, you are recommended to take large prints of the key concepts and display to the learners while teaching.
- Provide each learner with pen or pencil, and paper to allow them to participate.
- Whiteboard and markers or black board and chalk can be made available to allow both facilitator and learner to state a point.
- The Learner Progress Record sample given below can be used to observe learners, note their feedback, and assess if they have achieved the specific learning outcome. This recording is useful for both the learner and trainer so you can focus on those who are falling behind. Note there are no marks to be awarded and the record is only to improve learning. This is entirely optional.

TABLE 1: Learner Progress Record – optional for trainers to use

Learner Progress Record (Optional)	Date:
Learner's Name:	
Learning Outcome	**Achieved Outcome (Yes or No) and Comments**
1. Describe solar energy	
2. Explain the basic electrical parameters (V, I, P and E, AC, DC)	
3. Identify the various components used in a Solar Power System	
4. Explain the function of each component in a Solar Power System	
5. Describe the various types of Solar Power Systems	
6. Discuss key factors to consider when purchasing solar power system and/or its components	
7. Describe the importance of maintenance of Solar Power Systems.	
Optional: 8. Identify basic test equipment and demonstrate its correct and safe usage	

LESSON PLAN AND TIMES

TABLE 2: Lesson Plan and recommended time for each session

Chapter	Lesson Type	Recommended Time
1. Ice Breaker - Introductions	Theory and activity 1	30 minutes
2. What is Solar Energy	Theory	20 minutes
	Activity 2	30 minutes
	Activity 3	10 minutes
3. Basics of electricity	Theory	30 minutes
	Activity 4	20 minutes
4. Components of Solar Power systems	Theory	10 minutes
	Activity 5	25 minutes
5. Types of Solar PV Systems	Theory	30 minutes
	Activity 6	15 minutes
6. Safety in Solar PV Systems	Theory	20 minutes
	Activity 7	40 minutes
	Activity 8 (Optional)	20 minutes
7. Purchasing Solar Power Systems	Theory	30 minutes
	Activity 9	30 minutes
8. Maintenance of Solar Home Systems	Theory	30 minutes
	Activity 10	30 minutes
	Activity 11	20 minutes
	Activity 12	20 minutes

1

Ice Breaker Introduction

Trainers must understand that the learners who are attending the module have taken time from their usual daily activities which sustains their livelihood. Most will also be very nervous and unclear regarding what the module is all about. Hence the trainer must ensure that the learners are comfortable and not too nervous. It is important to make them feel at ease so that they can focus on the module and absorb as much knowledge as possible.

Tell them that this is an informative module and there will be no tests or marks in this. You must inform them that this module is being run so that they can take the information to help themselves to transition to renewable energy. Even if they do not use it, they can always use the knowledge to help others. In any way this module will better equip them to help grow their communities. Tell them to be at ease and focus on enjoying the day and asking as many questions as they want. Also tell them to not worry too much about complicated things as you will guide them through this.

ACTIVITY 1

Introduce yourself briefly to the learners. Ask if they are all comfortable at the venue. One by one ask them their names and tell them to give some details about themselves – such as what they would normally be doing at that time and what they hope to gain from the module at the end of the day. In addition, if time permits – ask them what they think about solar energy. There is no correct answer, and the goal of this activity is simply to get them relaxed and engaged into the session. You may crack few light jokes as laughter always lightens the mood and helps learners relax. Ask the learners about their prior experiences in solar energy and how much they know about the topic. Also ask them what they wish to gain from this training session and record their answers on paper so that it helps the trainer in setting a direction to the course. For example, if learners expect to know more about the operation of a solar home system, the learners can be taught more about their primary interest. This input will help the trainer direct the training to the learners needs.

2

What is Solar Energy

2.1 What is Energy

Legends have always mentioned the sun as all powerful. The sun gives energy to plants, and they feed humans and animals. The sun has a special place in all cultures. Energy may be described as something which has many forms and keeps changing form to give us something useful. Some of the forms of energy are:

- **Heat energy** – Recall when you started a fire to boil some water. When you come near a fire you feel hot due to this energy.

FIGURE 1: Can you recall how water gets heated?[1]

- **Mechanical energy** – this is the energy your boat engine gives to rotate the propeller to move the boat. Similarly, the energy a car engine gives to the tyres to move the car.
- **Chemical energy** – Inside batteries, chemicals are used to store energy so you can use that to turn on a radio, charge your phone or lights at night.
- **Electrical Energy** – this is the energy that flows through the wires to give power to your appliances.

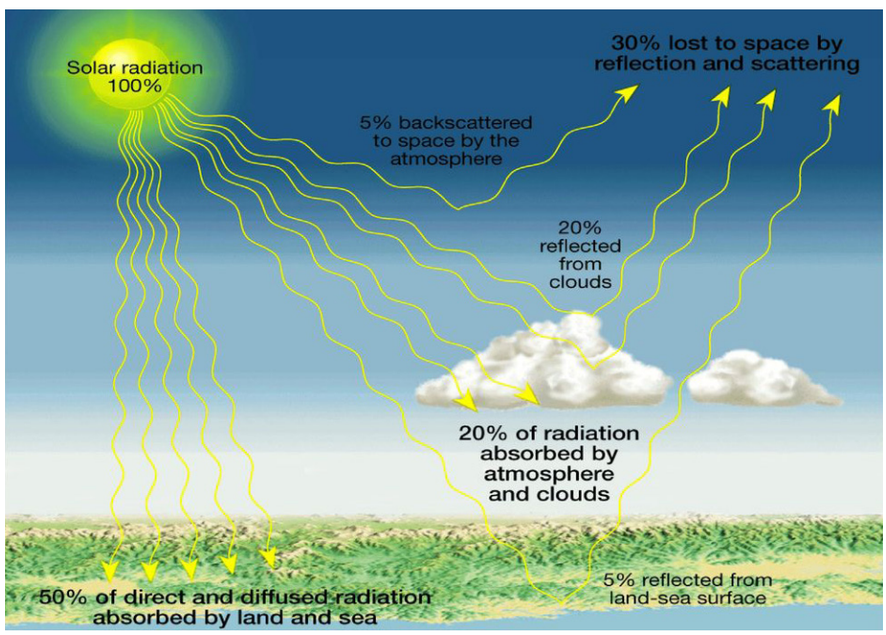
Solar Energy is the electromagnetic radiation emitted by the sun. It can be captured and turned into useful forms of energy, such as heat and electricity, using a variety of technologies. For example, Solar Photovoltaic (PV) panels can be used to convert solar energy into electricity. Also, thermal collectors, such as solar hot water systems can be used to heat water for shower for example.

The Sun is the primary source of energy for Earth. Almost all of the energy that drives the various systems (climate systems, ecosystems, hydrologic systems, etc.) found on the Earth originates from the Sun. The Sun warms the planet, drives the hydrologic cycle, and makes life on Earth possible.

Sunlight reaching the Earth can heat the land, ocean, and atmosphere. Some of that sunlight is reflected back to space by the surface, clouds, or ice. Much of the sunlight that reaches Earth is absorbed and warms the planet. Ultimately, energy from the Sun is the driving force behind weather and climate, and life on earth.

A lot of the Sun's energy is lost before it reaches the earth, as shown in Figure 2 below.

FIGURE 2: Details of total solar radiation[2]



1 Source: Pikrepo, https://p0.pikrepo.com/preview/673/890/black-cooking-pot-on-fire.jpg, accessed on 16 June 2021.

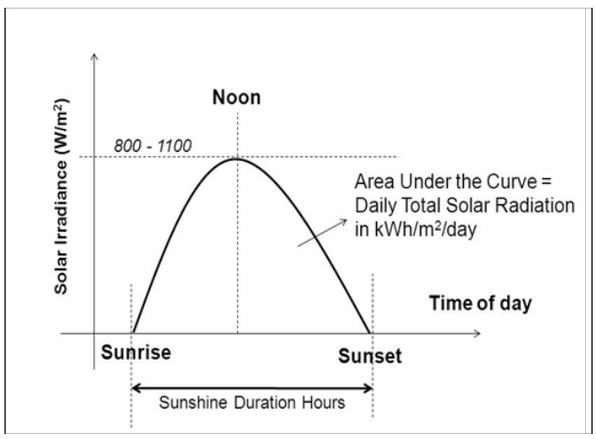
2 Source: SlidePlayer, "Slide 42 of Weather and Climate", https://player.slideplayer.com/72/12257222/slides/slide_42.jpg, accessed 25 June 2021.

A very small amount of the solar energy reaching the earth is changed into electricity through the use of Solar photovoltaic cells.

During different times of the day, the radiation emitted from the sun differs and likewise the energy produced using different devices that uses this radiation to convert into useful energy also differs.

At sunrise, the irradiance is zero which means that the electricity produced by solar PV system (Panel) will be zero. As the sun comes up, more energy is produced until noon, when it's maximum, after which the irradiance reduces with decrease in electricity respectively until it becomes zero again in evening. This is shown in Figure 3 below.

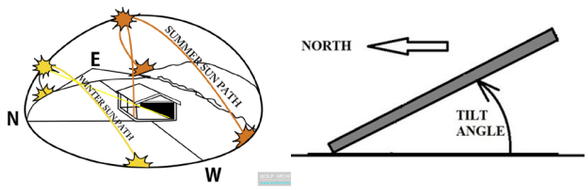
FIGURE 3: Solar Irradiance graph[3]



In order to ensure that we get the maximum amount of electricity from solar panels, the solar panel must be facing the sun all the time. Keeping the solar panel flat on the roof or facing away from the sun, causes a lot of loss in solar energy and this can cause energy shortages and shutdown of solar systems in the long run.

However, it is not possible to manually keep pointing the solar panel as the suns positions keeps changing in the sky. There are automatic solar tracking systems that do this, but these are expensive and not economically viable for smaller solar power systems. Luckily, there is a simpler fixed way to tilt and point a solar panel that ensures that you get the maximum amount of solar energy from your solar panels. The optimum tilt angle and direction of solar panel depends on the country you live in.

FIGURE 4: Path of the Sun during the year[4] and solar panel tilt[5]

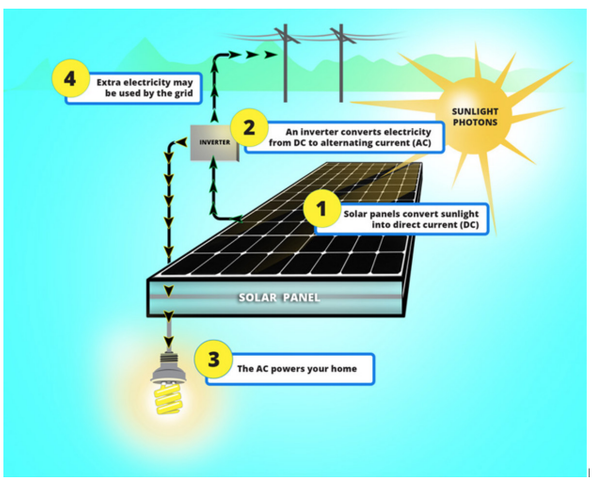


As you can see in Figure 4, the sun is higher up in the sky during summer (December) and much lower in the sky towards North in winter (June) for Fiji. Hence, in order to get maximum solar energy in Fiji, all PV modules should ideally be tilted between 15-20 degrees and facing towards North direction, in order to ensure maximum solar power generation from the modules throughout the year.

If you have a solar panel, are you pointing it at the optimal angle and direction?
If not, you may be losing solar power daily.

As discussed earlier, solar energy can be converted into two major forms of energy, such as electricity and heat, which can then be used to do other useful work. Figure 5 shows solar energy being converted into electricity using a solar PV panel.

FIGURE 5: Solar Power System (AC)[6]



Sun's energy is converted into electricity (direct current DC) with use of solar PV system (Panel). The DC current is then converted into alternating current (AC) using the Inverter. The inverter then provides the AC current (240V) to light bulb.

3 Research Gate, Journal of Energy Conversion and Management, https://www.researchgate.net/figure/Hourly-irradiation-curve-versus-peak-sun-hour-rectangle_fig1_264040352

4 Source: Wolf Architects, "Good orientation for energy efficiency", https://wolfarchitects.com.au/wp-content/uploads/2015/01/North-Facing.jpg accessed May 2021.

5 Mohammed Tazil, GGGI

6 Source: 93energy.com, "How Solar works", https://www.93energy.com/hubfs/Screen+Shot+2019-05-13+at+4.12.05+PM.png, accessed 25 June 2021.

Figure 6 to Figure 9 shows how solar energy is used in different forms. Figure 6 shows solar collector that uses sun's energy to heat water (does not produce electricity). Figure 7 shows women installing solar PV (Panel) to generate electricity (uses sunlight to produce electricity).

FIGURE 6: Solar thermal collector[7]

FIGURE 7: Women installing Solar PV[8]

FIGURE 8: Rural solar system[9]

FIGURE 9: Sun drying[10]

Figure 8 shows a pole mounted solar system in a rural community and Figure 9 shows Kava being dried using the suns energy (heat).

7 Source: Ozzie Solar Clean, "Residential hot water cleaning", https://www.ozziesolarclean.com.au/images/grid/residential-solar-hot-water-cleaning.jpg, accessed 25 June 2021.

8 Source: Barefoot College, https://www.barefootcollege.org/wp-content/uploads/2018/10/Barefoot_annualreport_2016-17_v7_online.pdf

9 Source: Ecoconomist, "Double powered solar panel", https://ecoconomist.com/wp-content/uploads/2020/01/twopanelpicture.jpg, accessed 25 June 2021.

10 Adapted from the Fiji Sun, "Kava Demand Creates Trade Opportunity Between Fiji, Madang, August 2018, https://fijisun.com.fj/wp-content/uploads/2015/11/Kava-1-750x403.jpg

ACTIVITY 2

1. Identify the source of energy in all pictures (Figure 1 to 9) and mark with letter "S"

Answer– Count the number of sun present in pictures (F1 – F9) from learner workbook. There are three (F2, F4 and F5).

2. Identify what converts solar energy to electricity (Figure 1 to 9) and mark with letter "E"

Answer– Count the number of solar panels in learner workbook. There are 10 panel (F5, F7 and F8).

3. Identify different forms of energy produced (Figure 1 to 9) and mark with letter "P"

Answer – Electricity (F5, F7, F8)

Heat (F1, F6 and F9)
(Refer to figures in learner workbook)

4. Is solar energy free?

Answer– Yes. While we do need to buy a solar system, using the suns energy is free. Unlike a petrol generator which you have to buy and keep paying for fuel as well

5. Is solar energy clean?

Answer– Yes. Using solar energy does not pollute the environment. Unlike a petrol generator, which emits harmful smoke and gasses into the environment.

6. Do clouds reduce solar energy?

Answer- Yes

7. Does the tilt angle of panel and direction affect solar energy conversion?

Answer - Yes. Pointing the panel directly towards the sun produces maximum electricity. The more you point away from the sun, the lesser the electricity production becomes.

8. Why is solar energy important to us?

Answer:

- Pacific island is highly dependent on fossil fuel imports and use of solar energy can help reduce the dependency on fossil duels.
- Solar energy is Free.
- Solar energy is clean.
- Abundant in supply.
- Solar Energy is available in remote rural locations.

9. Discuss in class how solar energy is used by Men and Women in your area?

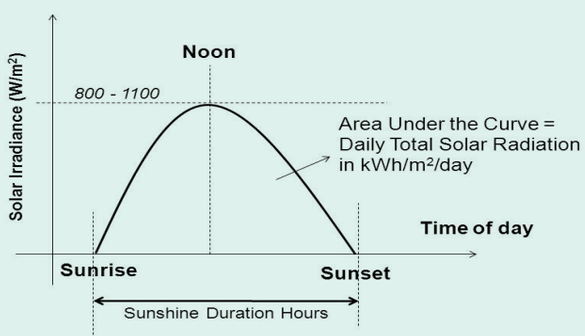
Answer (There are many different answers. Allow learner to explain)

- **Women uses solar energy by:**
  - Drying clothes
  - Drying fruits and pickles
  - Drying utensils
- **Men uses solar energy by:**
  - Drying woods for cooking
  - Drying Kava
  - Drying grasses and shrubs from farm to burn them
  - Drying fish

ACTIVITY 3

1. What time of the day will you get the most amount of solar power and why?

Answer - Allow the leaner to express their understanding and then by showing the graph as shown explain that at noon, maximum power is obtained.



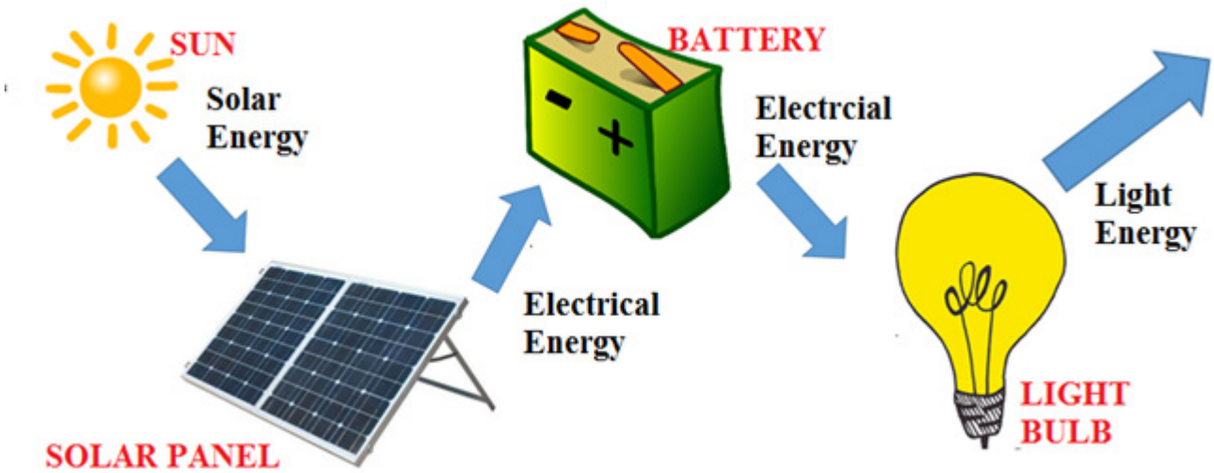
3

Basics of Electricity

3.1 Electrical Energy

Electrical energy is just another form of energy. Electricity can be generated in many clean ways, such as from hydro, wind, or solar energy. Electricity can also be generated from unclean sources such as petrol or diesel generators, or by burning coal, etc. We want to change the suns energy into electrical energy to help us use the electrical energy to power lights and other appliances. In the figure below we see how this happens.

FIGURE 10: How solar energy changes forms to give us light[11]

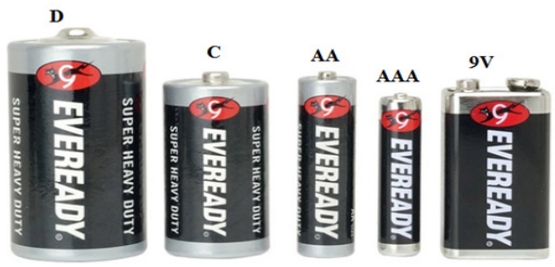


In Figure 10, we see that the sun's solar energy is changed to electrical energy by the solar panel. Since the sun only shines during the day and we need electricity at night also, we need to use an energy storage device, such as a battery, to store the electrical energy during the day. At night, we use this energy stored in the battery to power electrical appliances. Later on, we will see that a battery stores the electrical energy using chemicals.

SAFETY TIP: Energy of any form whether electrical energy from a panel or from a battery is very dangerous and can cause harm if we are not careful. Always follow safety rules when working with energy.

FIGURE 11: A Lead Acid rechargeable battery[12]

FIGURE 12: Different types of smaller batteries[13]



3.2 Energy in a battery

The energy in a battery is stored using chemicals. Some batteries cannot be charged (like those commonly used in radios, remote controls, etc. (as shown in Figure 12). Once these go flat, they are discarded. In solar systems, we use rechargeable type batteries, as shown in Figure 11.

11 Adapted from the Electricity Basics, Arizona State University (VOCTEC), http://voctec.asu.edu

12 Source: JICA.

13 Source: Lazada, "Eveready battery", https://ph-live-01.slatic.net/p/6abf377c3bd40ff76088f4764c8624cb.jpg_2200x2200q80.jpg_.webp, accessed 25 June 2021.

3.3 Power

Every electrical appliance, such as lights, radio, etc. needs power to work. Smaller or more energy efficient appliances use less power compared to larger or in-efficient appliances. Depending on the size of a battery, it can only store a fixed amount of energy. This means that if we want our appliances to run for longer on the battery, we must ensure to use smaller or more efficient appliances, that use less power. More details on how to find energy efficiency appliances is covered in the Energy Efficiency module.

The amount of power each appliance uses is usually written on the appliance. The units of power is Watts (W). We can know how much energy will be used from the battery if we know how much power each appliance needs. Power is also used to refer to the electrical energy generated by the panels as well.

FIGURE 13: A 4W Light Bulb[14]

FIGURE 14: Solar Panel[15]

Can you read from the figure above as to how much power this small solar panel can produce?

3.4 Voltage and Current

Understanding voltage and current can be quite confusing for those who are not familiar with electricity. We will hence try to use a water tank as an example to try to explain. Do not worry if you are still not able to fully understand this.

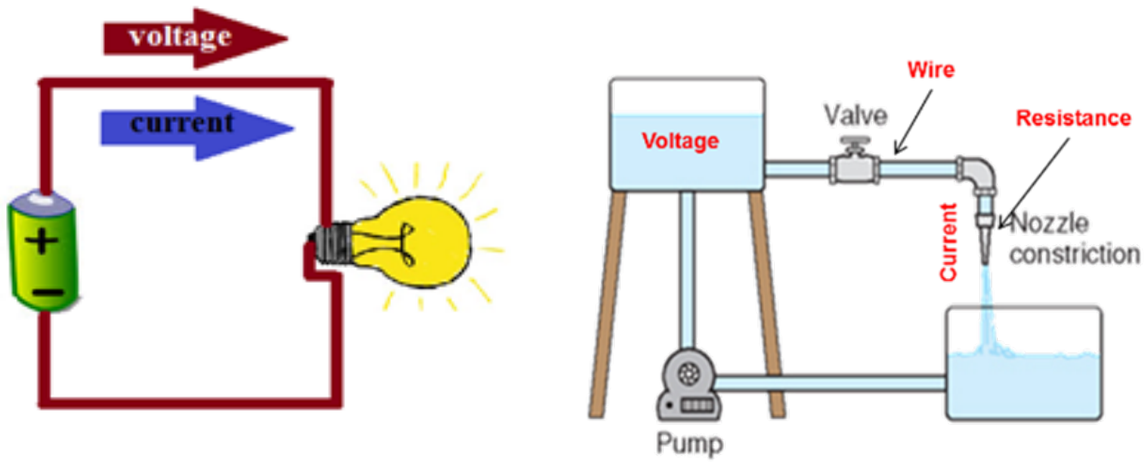
Voltage is the electrical potential, or the pressure that moves electrons through the wires (conductors) and can be compared to pressure in a water pipe. If you use a water tank at your place, then you will understand that in order to get more water pressure, you need to place the water tank at a higher place, right? Similarly, in electrical terms, more voltage will enable you to get more current flow in the wire, which translates to more power. Power is moved through the wires as voltage and current. So, in this example, voltage is similar to a water tank at a height, while the water flowing in the pipe from the tank to your house is similar to current flowing from a battery to your electrical appliance.

The more you open a water tap, the more water will come from the tank. Similarly, the larger the electrical appliance you use, the more current will flow to it from the battery. This is how a larger power appliance drains a battery faster.

14 Source: Shopee.com, Philips Led Lights 4 Watt Yellow and White Color, https://shopee.com.my/PHILIPS-4-WATT-LED-LIGHT-yellow-and-white-i.267756065.3536838685

15 Source: Ebay, "Solar Panel Kit", https://www.ebay.com.au/itm/40W-12V-Solar-Panel-Kit-Mono-RV-Camping-Power-Portable-Battery-Charger-Outdoor-/313164338615, accesssed 25 June 2021.

FIGURE 15: Both voltage and current make up power – voltage is like pressure in a water tank[16]



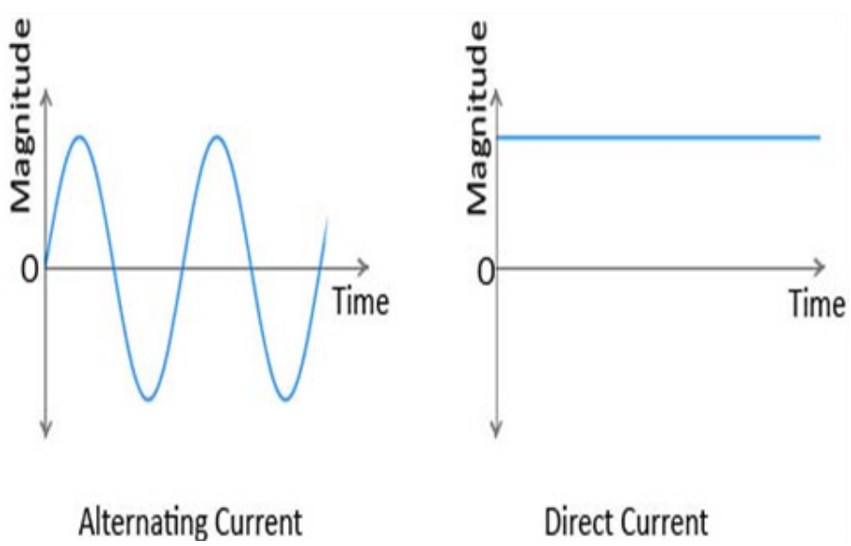
Voltage is measured in the unit Volts and current in measured in Amperes or Amps. We can say voltage is like the depth of a stream while current is the force/flow of the stream. Even in small shallow streams – if the force of water is too strong, it can drown us. Similarly, even in low voltage – current can be high enough to kill us.

SAFETY TIP: High Current and Voltage can cause serious injury and even death if they pass through your body. Always avoid bare wires and never ever work on live circuits. Always practice safety or get a qualified electrician.

3.5 AC and DC systems

Power from a battery flows steadily. The current we get from a battery, or a solar panel is called direct current or DC. DC current flows from the positive to the negative terminals in a constant way. Other devices, such as generators or inverters, produce AC or alternating current, where the current has a wavy form, as shown in Figure 16.

FIGURE 16: AC and DC have different voltage and current magnitude over time[17]



16 Adapted from the Electricity Basics, Arizona State University (VOCTEC), http://voctec.asu.edu

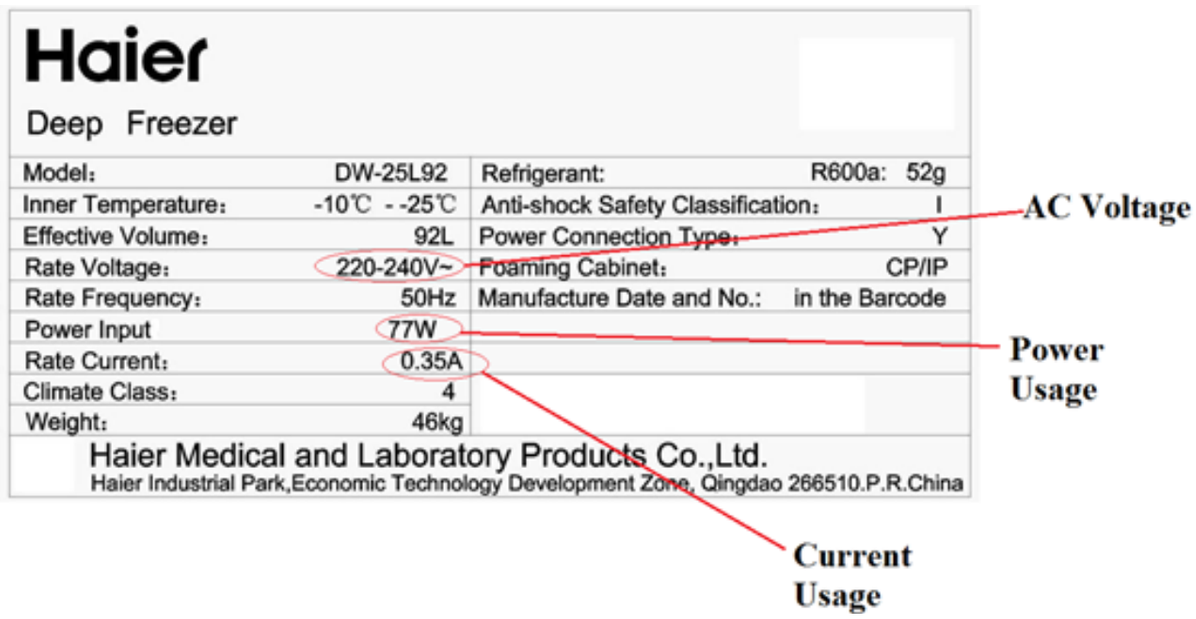
17 Adapted from System Components: Charge Controllers &Inverters, Arizona State University (VOCTEC), http://voctec.asu.edu

AC voltages are normally much higher, and most grid systems (power lines) use AC to transfer power to homes. Hence the power coming from the power lines to your homes and flowing in homes in AC. Most appliances such as TV's, Radio etc. are built to work within 220 to 240 Volts AC. This means that they will not work on a 12 volts DC solar power system. If you want to run 240Volts AC appliances from a 12V DC solar power or battery, we need to use a device called an inverter, which converts 12V DC to 240V AC. We will talk more about an inverter later.

Ensure to always read the appliances label to determine whether it is AC or DC and which voltage it works at, since making a mistake and connecting to a different voltage can cause serious damage. The back label or the name plate of an appliance also has many other useful information as shown below.

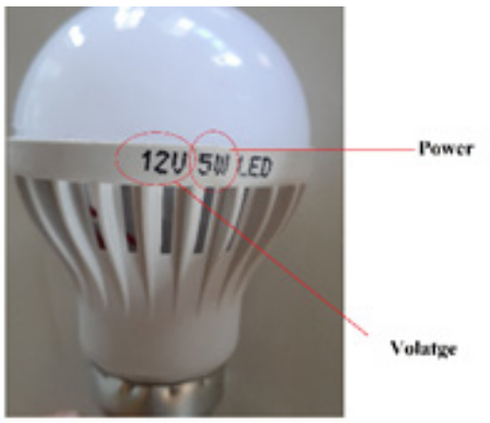
Here is a sample of a name plate of an AC powered chest freezer:

FIGURE 17: Sample Name plate label of a chest freezer[18]



Something interesting here is how power is calculated. Power is calculated by multiplying voltage and current together. In case of Figure 17, we see 220V multiplied with 0.35A current rating will give us a power of exactly 77W which is written on the Power input label. This may be useful if the power is not given directly, we can use the voltage and current to calculate. Here is a sample of a DC light name plate or label.

FIGURE 18: DC bulb label details[19]



18 Source: DocPlayer, "Deep Freezer-upright: HMRSM Haier Medical & Laboratory Products Co., Ltd.

19 Source: Amazon.com, "Led bulbs", https://m.media-amazon.com/images/I/31kJoFKty+L._AC_SY100_.jpg, accessed 21 June,2021.

ACTIVITY 4

Provide the learners with at least 2 AC appliance nameplates such as AC light bulbs and AC fan. Also provide them with 2 DC appliance nameplates such as a DC bulb and a DC fridge. You must be careful not to separate the devices for them. Help the learners do the following:

- Identify which devices are AC and which are DC.
- They must be able to read the voltage and current needed to run these devices.
- The must also be able to tell how much power each device will use.

(In case current rating is not given – you may calculate it from power and voltage and show the learners, some basic appliances do not show current on labels)

FIGURE 19: AC Bulb 220-240V, 3W, 0.01A[20]

FIGURE 20: AC Fan, 220V, 55W, 0.25A[21]

FIGURE 21: DC Light 12V, 6W, 0.5A[22]

FIGURE 22: DC Freezer, 12V/24V, 55W, 4.58 A/ 2.29A[23]

20 Amazon.com, "Led bulbs", https://m.media-amazon.com/images/I/31kJoFKty+L._AC_SY100_.jpg, accessed 21 June,2021.

21 Source:Khind.com, https://www.khind.com.my/index.php?route=product/search&search=AC%20Fan%2C%20220V%2C%2055W%2C%200.25A%20, accessed 25 June 2021.

22 Source: AliExpress.com, https://www.aliexpress.com/item/1316122622.html

23 Source: Made in China.com, "Solar Freezer", https://m.made-in-china.com/company-commercial-energy/ , accessed 25 June 2021.

4

Components of Solar Power Systems

Having covered the basics of solar energy and electricity, we are now ready to look at the components used in a small solar power system. The main components and other functions are shown in the table below.

ACTIVITY 5

While covering the notes on each component, show them each component from the VOTEC Kit and if possible, pass it around to the learner groups to observe these components. They can ask questions about these components during this session.

FIGURE 23: Solar Panel (PV Module)[24]

- Solar Photovoltaic (PV) modules use solar energy to generate electricity through the photovoltaic effect. It uses sunlight as a source of energy and generate direct current (DC) electricity. Solar panels connect to the charge controller to charge a battery.

FIGURE 24: Battery[25]

- A battery is a device that is able to store electrical energy in the form of chemical energy, and convert that energy into electricity. A common lead acid battery produces 12V DC. A battery connects to the charge controller.

FIGURE 25: Charge Controller[26]

- A charge controller primarily controls and regulates the charging of the battery from the solar panel. It prevents over-charging and over-discharging and may protect against overvoltage or under-voltage of a battery. Without these functions, battery performance or lifespan can get significantly reduced and may pose a safety risk as well. Hence a charge controller is extremely important to ensure maximum battery life.

24 Source: Audio Digital, http://www.audio-digital.com/tag-produk/sound/

25 Source: JICA

26 Adapted from System Components: Charge Controllers &Inverters, Arizona State University (VOCTEC), http://voctec.asu.edu

FIGURE 26: Inverter[27]

- An inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC).
- A typical power inverter device or circuit requires a relatively stable DC power source (12V, 24V, etc.) capable of supplying enough power to any connected AC appliances.

The AC output voltage of a power inverter is often regulated to be the same as the grid/power line voltage, typically 240 VAC.

FIGURE 27: Cables[28]

- Electrical cables are used to connect two or more devices, enabling the transfer of electrical signals or power from one device to the other. In a solar power system, cables are connected from solar PV modules to charge controllers, charge controllers to Batteries and to other DC appliances.

FIGURE 28: Breaker/Isolator[29]

- A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by excess current from an overload or short circuit. Its basic function is to interrupt current flow after a fault is detected.
- An isolator is a device used for isolating a circuit or equipment from a source of power.

FIGURE 29: Electrical Switch[30]

- A switch is an electrical component that is used to control power supplyto an electical appliance, like a light switch.

27 MorningStar, May 2021, https://www.morningstarcorp.com/products/suresine/

28 Source: Global Market, http://newimg.globalmarket.com/PicLib/group0/5e/73/c477defc613ecc9a0e47b82452f4_l.jpg

29 Source: Wave inverter.co, https://waveinverter.co.nz/shop/solar/solar-connectors/pv-dc-isolator-switch-mc4/ and POSO.com, http://poso.com.vn/wp-content/uploads/2020/04/1-2.png

30 Source: Trade Zone, https://www.tradezone.com.au/product/hpm-40-amp-1-gang-excel-vertical-internal-isolation-rocker-switch-gloss-white-16567.html, accessed 25 June 2021.

FIGURE 30: Electrical Power outlet[31]

- A power outlet (or powerpoint) is used to connect an electric equipment to the alternating current (AC) power supply.

1. What is the function of inverters?

Answer - An inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC).

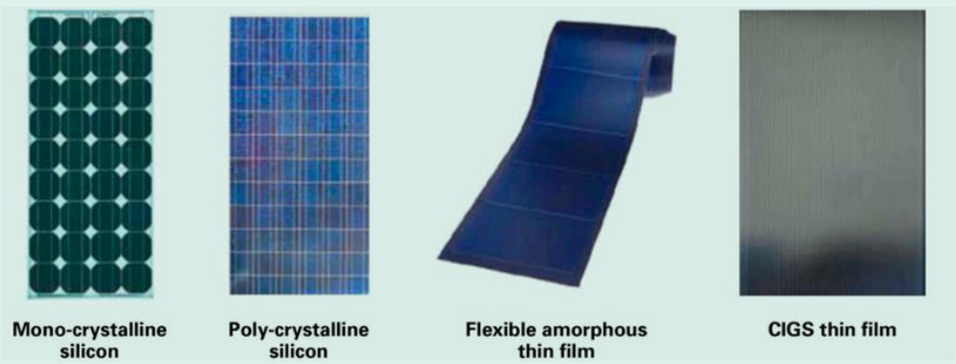
2. Why do we need batteries?

Answer – To store excess energy from solar PV panels so that it can be used to supply electricity when solar energy is not available, such as night-time or during cloudy weather.

For further discussion: Types of Solar Panels

While there are various types of solar panels available, the most commonly used are the mono-crystalline and poly-crystalline as shown below. Each type has a different efficiency of converting solar energy into electricity.

FIGURE 31: Different types of PV modules[32]



31 Source: EuroTech NZ, "PDL 600 Series Power Points", https://www.kiwisparks.co.nz/collections/pdl-600-series-power-points/products/pdl-691, accessed 25 June 2021 .

32 Source: Hapres, J Sustain Res. "Building Integrated Photovoltaic for Architectural Facades in Singapore", 2020, https://sustainability.hapres.com/images/JSR_1263_Fig5.jpg

4.1 Types of Batteries

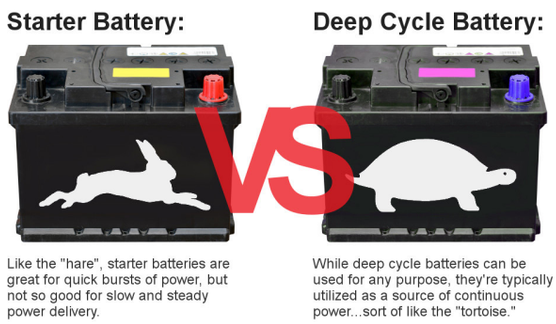
There are many different types of batteries used in a solar power system, most common of which is the lead acid type. These can be either:

- Flooded lead acid type: batteries that have caps on top and require regular filling with distilled water.
- Sealed Lead Acid Batteries and Gel Sealed Lead Acid: batteries that do not have any caps on top and do not need to be filed with water. These are also referred to as maintenance free batteries.

Sometimes, people try to use car starter batteries in a solar system. While this might work for some time, car batteries are not meant to be used in solar power systems and can fail very quickly. For solar power systems, deep cycle batteries are used, which are designed to operate daily and last longer.

The difference between starter and deep cycle batteries are explained in Figure 32.

FIGURE 32: Starter versus deep cycle batteries[33]



33 Source: Off Road Aussie.com, "Deep-Cycle vs Starter Batteries", https://offroadaussie.com/wp-content/uploads/2015/07/deep-cycle-vs-starter-battery.jpg, accessed 25 June 2021.

5

Types of Solar PV Systems

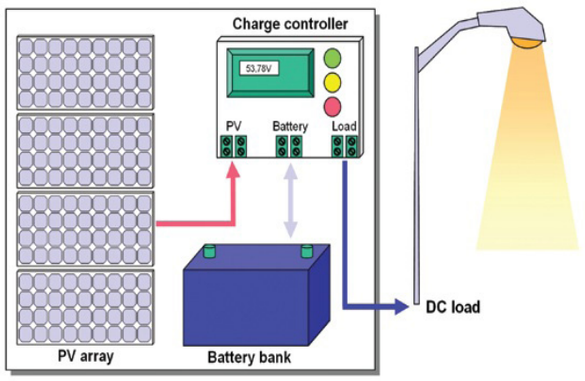
Having looked at the various components used in a solar power system in the previous chapters, this chapter will discuss the different types of solar PV systems.

There are three distinct type of solar power system. These are:

- Standalone (off-grid) solar power system.
- On-grid solar power system.
- Hybrid solar power system.

While there are numerous types of solar power systems, we will mainly focus of DC standalone systems (also referred to as Solar Home Systems) in this module to keep things simple for the learners.

FIGURE 33: Standalone DC Power System[34]



5.1 Standalone (off-grid) solar power system

Stand-alone systems are not connected to the electricity grid and typically are installed in remote areas where there is limited connection to the grid, or areas of low electricity demand. These systems must have batteries to provide DC power supply at night. An inverter can also be present, which will allow for powering of AC appliances.

5.1.1 Standalone solar DC power system

Standalone DC system will have the following components as shown below.

- Solar (PV) Panel (PV Module).
- Charge Controller.
- Battery.
- DC Loads (Light Bulb; Radio etc.)

A standalone DC system (also called a solar home system) is designed to power specific DC appliances in a house, mostly DC lights, phone charging, maybe a DC fan or radio, etc. Due to the absence of an inverter, this system cannot power larger AC appliances.

In this system, the solar panel uses sunlight to produce electricity, which is then connected to a charge controller, and then to a battery. The charge controller controls the battery charging process to avoid damage to the battery. Some charge controllers also come with terminals to connect DC load's, such as lights, as shown in Figure 33. Since the lights are connected through the charge controller, if the batter level goes very low, the charge controller is able to automatically turn off the lights to prevent damage to the battery.

It has to be noted that this standalone solar home system is designed to only power the loads that come with it or which it is designed to power. You cannot add more loads or larger loads to this system later on, as this will cause energy shortages and shutdowns, because more/larger loads require more power to run, which this system is not originally designed for.

5.1.2 Standalone solar (AC+DC) power system

A standalone AC+DC power system is similar to a DC power system, but comes with an inverter, that enables it to power AC appliances as well, as shown in Figure 34.

34 Source: From Sun to Power.com, "Off-grid solar photovoltaic systems", https://fromsuntopower.files.wordpress.com/2012/07/pv21.jpg, accessed 25 June 2021.

FIGURE 34: Standalone AC/DC Power System[35]

As discussed before, it has to be noted that this standalone AC+DC solar home system is also designed to only power the loads that come with it or which it is designed to power. You cannot add more loads or larger loads to this system later on, as this will cause energy shortages and shutdowns, because more/larger loads require more power to run, which this system is not originally designed for.

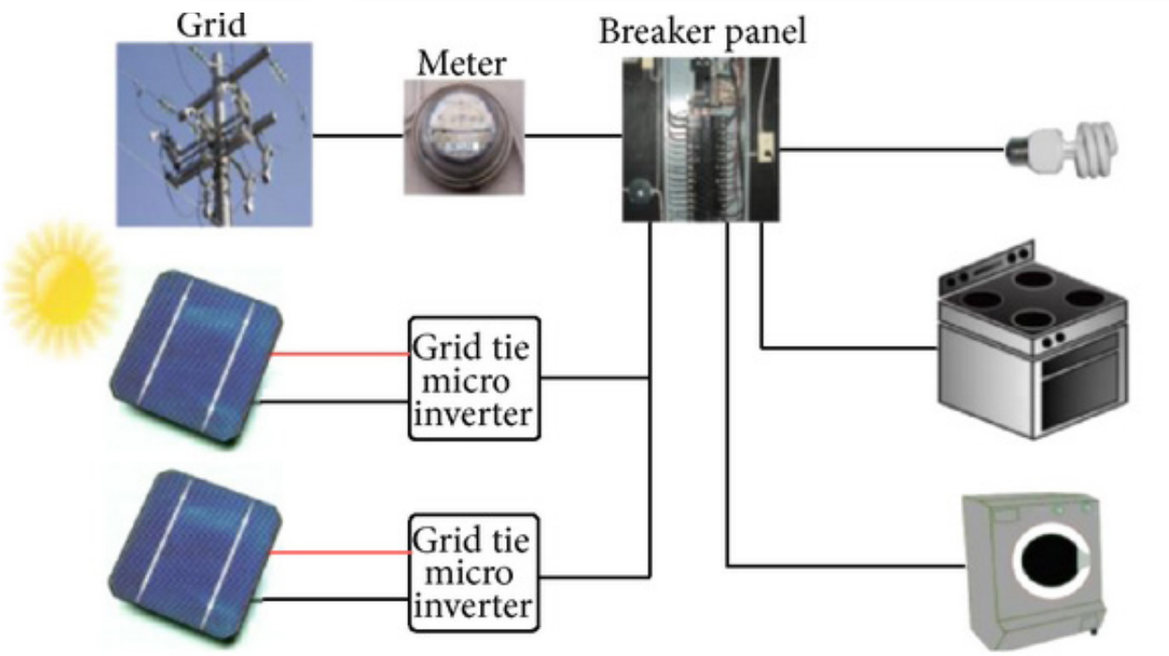
5.2 On-grid solar power system

This type of system is not applicable to remote rural communities who do not have access to grid electricity. This training module will not focus on this system, hence only minimum information is provided here for the learners understanding.

These types of systems are most common in areas where the grid infrastructure is suitable. The inverter converts the electricity generated by the solar system – which is direct current (DC) – into AC electricity so that the power generated is compatible with the grid. These systems cannot create their own grid, as they can only connect to an existing grid to supply power to that grid.

Houses with grid-connected solar systems use solar power first before sourcing electricity from the grid, hence causing a saving on the electricity bill. When the panels are not producing electricity at night, electricity is provided solely from the electricity grid. This type of system is not used in rural communities where either grid electricity is not available or to avoid complexity and instead, they can keep a simple standalone system.

FIGURE 35: Grid Connected Solar PV System[36]



35 Source: India mart.com, Solar Grid Tie Energy Storage System, https://5.imimg.com/data5/VV/TV/MY-11206303/solar-energy-storage-system-500x500.jpg, accessed 25 June 2021.

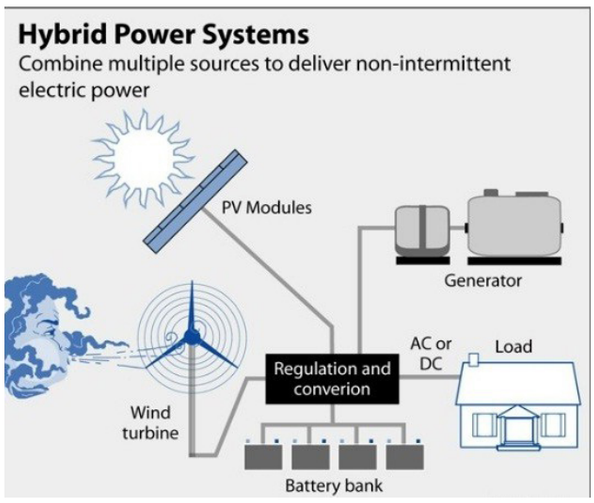
36 Source: Hindawi, "Journal of Renewable Energy", June 2021, https://www.hindawi.com/journals/jre/2013/785636/fig1/

5.3 Hybrid solar power system

This type of system, can operate both on-grid and off-grid, can supply large amounts of power and is expensive, therefore is not common in remote rural communities. This training module will not focus on this system, hence only minimum information is provided here for the learners understanding.

Hybrid solar PV systems are becoming increasingly popular. These types of systems are suited where attractive feed in tariff is provided to grid connected consumers by utility companies. Battery back-up systems can be a viable alternative as consumers use the electricity stored during the day to run their house at night. They also have the advantage of being able to supply power during power outages, via the use of other sources of energy such as that stored in the batteries, using a backup generator, or other Renewable Energy sources, such as wind, pico-hydro etc.

FIGURE 36: Wind Solar Hybrid system[37]



37 Source: www.energy.gov, adapted from, "What is Solar-Wind Hybrid Power Plant? Solar Mango, http://www.solarmango.com/ask/2015/10/23/what-is-a-solar-wind-hybrid-power-plant/

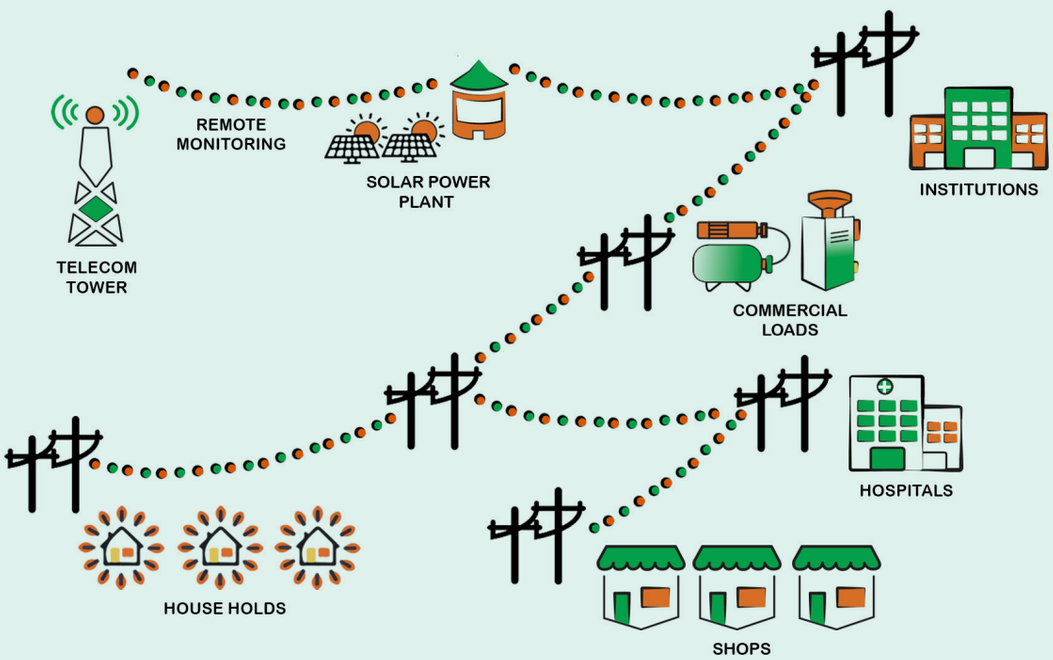
ACTIVITY 6

CASE STUDIES OF SOLAR MINI-GRID SYSTEMS IN FIJI

It is often very expensive or even not possible to extend the grid power lines from urban areas to very remote rural or island locations. So how can we provide clean power at a large scale to these remote locations? The answer is to use mini-grid systems. We will discuss some larger solar/hybrid mini-grid systems that have been installed in remote rural communities in Fiji.

A solar mini-grid system is a larger AC type system that is installed to power an entire community, rather than just a house. It can include some form of tariff metering system that counts the amount of energy each household uses, and hence each household is required to pay for the energy they use.

FIGURE 37: **Solar Mini-grid system**[38]



The quality of the power system is same as those provided from grid/power line in urban towns and cities, hence you can power all types of AC appliances on this, though there may be restrictions in place to prevent people from trying to power very large equipment that can overload the power system. The money collected from the metering system usually goes back to the authority who installed the mini-grid system, which can be used to do system maintenance, parts replacement, or pay for other expenses associated with running the power system.

38 Source: https://www.taraurja.com/mini-grid-model/, Accessed on 4/11/2020

Case Study 1: Solar Mini-Grid System at Vio Island

FIGURE 38: Vio Solar mini-grid system

The solar mini-grid system installed at Vio Island, Lautoka, provides clean solar energy to over 200 residents. It was installed under the Fiji Rural Electrification Fund (FREF) in 2019.

This system (Figure 38)[39] uses the latest technology equipment, such as:

- Roof and ground mounted Solar PV panels,
- Battery and Solar inverters (yellow and red color on the wall),
- Large, sealed maintenance free lead acid batteries (grey color on the floor),
- Protection and distribution equipment (grey boxes on the wall)
- Backup diesel generator (far left) for powering the system during prolonged cloudy days,
- and more importantly, a smart metering system that allows for remote monitoring through the internet.

FREF is envisaged to electrify 300 rural communities over the next 10 years.[40]

39 Source: Clay Energy, 2020.

40 Source: Fiji Sun News, https://fijisun.com.fj/2019/05/03/pm-villagers-will-realise-true-economic-potential-new-business-opportunities, Accessed on 15/06/2021

Case Study 2: Solar Mini-Grid System at Nakoro Village

FIGURE 39: **Nakoro Solar Mini-grid system**

The solar mini-grid system installed at Nakoro village, Navosa, provides clean solar energy to over 200 residents from 41 households[41]. Installed in 2020, this system (Figure 39)[42] uses the latest technology equipment, such as:

- 50kW ground mounted Solar PV panels,
- Battery and solar inverters (inside the powerhouse),
- Large Lithium batteries (inside the powerhouse),
- Protection and distribution equipment (inside the powerhouse),
- Backup diesel generator (green color, far right) for powering the system during prolonged cloudy days,
- and more importantly, a smart metering system that allows for remote monitoring through the internet.

41 Source: Fiji Times, https://www.fijitimes.com/pm-bainimarama-commissions-hybrid-solar-power-system/, Accessed on 16/06/2021

42 Source: Clay Energy, 2020.

6

Safety in Solar PV systems

Whether you are a technician who often works with electricity, or a non-technical person who simply owns or operates a solar power system, safety should be the first concern when dealing with solar PV systems. A solar panel produces electricity, and a battery stores large amounts of electrical energy, which if not used or maintained correctly, can cause electric shock, fire and injury. No matter how small or large a power system is, you must never let your guard down when dealing with electrical systems.

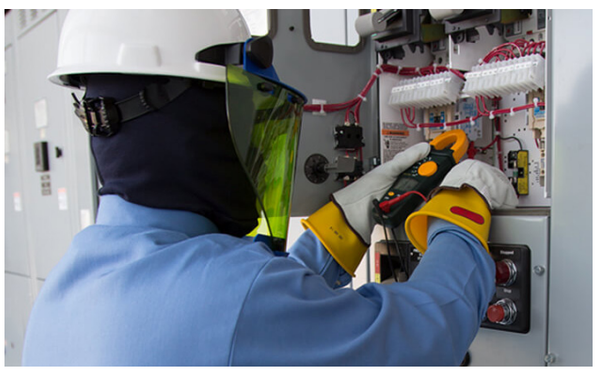
Here are some very important safety tips to follow to stay safe and keep others safe when dealing with solar PV systems.

1. Always turn the power off before making any additional connections, adjustments, or checks. Never attempt to work on a circuit which is still active with power.

FIGURE 40: Warning Signs[43]

2. If you are not a technical person and need to do any power system or house wiring that you do not understand, always get a trained electrician to do this for you. Never attempt to do house wiring yourself, because if this is not done properly, it can not only cause fire, but also risk electrocution, serious injury or even death.

FIGURE 41: Wear Insulated Gloves[44]



3. Always practice safety first and keep children away from electrical hazards. If you or someone else is working on high voltage equipment, try to wear PPE (personnel protective equipment) such as insulted gloves, eye goggles and safety footwear if available.

4. Never attempt to repair faulty batteries on your own. Batteries contain dangerous chemicals which can cause serious harm if dis-assembled or broken. Batteries also store a large amount of energy which can cause serious injury or death of the terminal are short-circuited.

FIGURE 42: Acid warning[45]

5. Never store batteries near a fire or inside living rooms – some batteries give off flammable or toxic gases even if we do not see it.

FIGURE 43: Fumes Warning[46]

6. Never store batteries in confined spaces or near fuels as they can cause a fire from sparks. Always place batteries in well ventilated areas.

43 Source: AviationPros, https://www.aviationpros.com/tools-equipment/safety-equipment/article/11148860/ground-handling-safety-signs
44 Source: Safety workblog.com, https://safetyworkblog.com/assets/understanding-the-2015-edition-of-nfpa-70e-the-arc-flash-hazard.jpg
45 MSDS online, https://www.msdsonline.com/2014/07/22/sulfuric-acid-safety-tips-sulfuric-acid-msds-information/
46 Source: National Safety Signs, https://nationalsafetysigns.com.au/wp-content/uploads/2020/02/D10332-Toxic-Fumes-sign.png

FIGURE 44: Battery Warning[47]

7. If available, wear a harness which is connected to a secure structure when installing solar PV panels on roofs or at a height. If you are not familiar with the technicalities, it is advisable to seek assistance from a technician to do this for you.

FIGURE 45: Wear a harness connected to a secure structure[48]

8. Note that a solar panel starts generating electricity in any amount of sunlight. Ensure not to touch the wires at any time, even during maintenance and cleaning.

FIGURE 46: Women working with solar panels[49]

9. Solar panels and its mounting and even the roof may get extremely hot in the sun so take care to wear gloves and other PPE (if available) when handling hot surfaces during maintenance and cleaning.

47 We Need Signs.com, "Ansi Battery Charging Safety Signs", http://www.weneedsigns.com/home.php?cat=403

48 For Construction Pros. Com, "The Sustainable Solar Roof Installer" https://www.forconstructionpros.com/business/article/10878093/the-sustainable-solar-roof-installer-best--practices-make-perfect

49 Flip the switch, https://www.imdb.com/title/tt9124366/

FIGURE 47: Wear gloves and PPE[50]

FIGURE 48: Practice ladder safety rules[51]

10. Always ensure you practice ladder safety rules when using a ladder to reach roofs for dealing with solar PV systems. Ensure the ladder has at least a 75-degree angle with the ground. Ensure the ladder is stable on flat ground. Ensure someone holds the ladder at the bottom to prevent it from slipping.

ACTIVITY 7: SETTING UP A DC SOLAR SYSTEM

For this activity, the trainer will take the lead to assemble and demonstrate a DC Solar system. Some active learners can be chosen to assist the trainer. The following equipment will be needed from the VOTEC Kit:

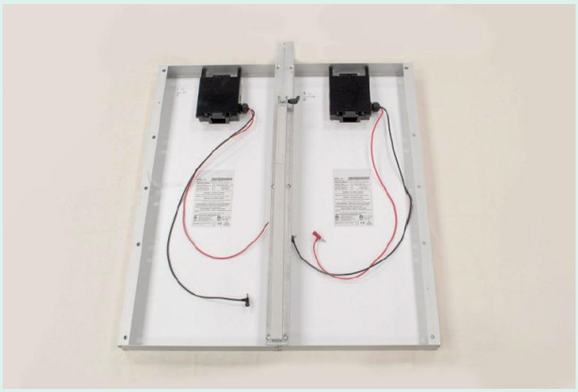
1. Solar Panel and Mounting Rack with screws.
2. MTT wiring board.
3. Safety Gloves and goggles.
4. Battery and Charge controller.
5. DC Circuit breakers.
6. Solar Mesh (for shading).

Start by assembling the solar PV Array using two panels. Follow the instructions given in the pictures below. Only allow learners to do minor tightening.

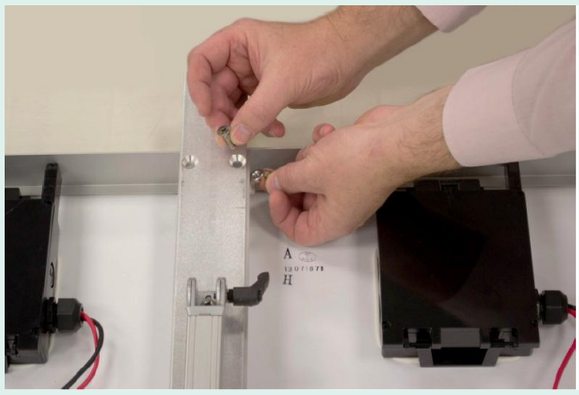
50 Dreamstime.com, https://www.dreamstime.com/stock-illustration-d-engineer-installing-photovoltaic-panels-conversion-solar-energy-to-electricity-rendered-cartoon-illustration-white-image84190049

51 Ladders Level, https://laddersnivoo.weebly.com/

1. Align both PV modules face down on a table and place module rack on inner frame between the modules, aligning the six screw holes.



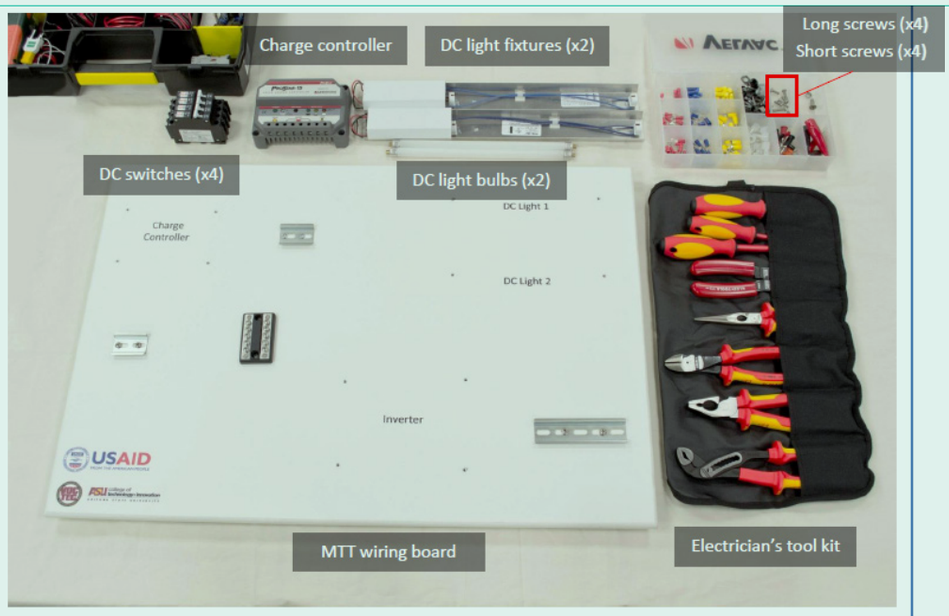
2. Insert rack screws (x6) from the top and handtighten rack wing nuts (x6) to the screws from the bottom.



3. Turn PV arraw around to attach sundial with sundial mounting screw.

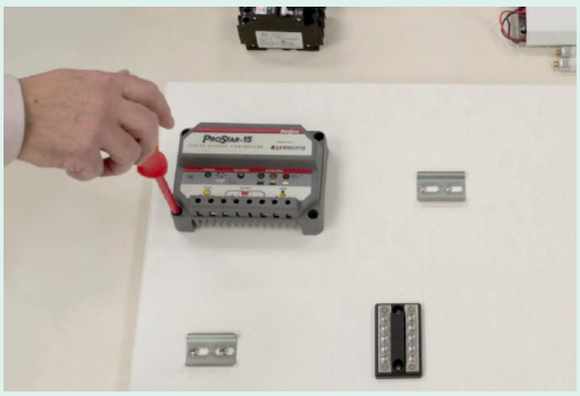
4. Align sundial on top of module rack through hole with threaded rack hole and hand-tighten mounting screw.

The following figure shows what all you will need from the VOTEC Kit.

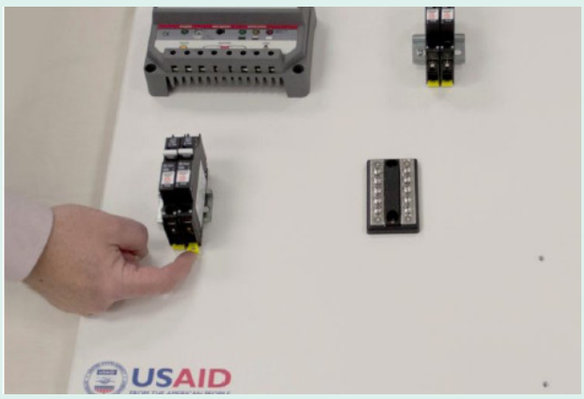


Once you have the components. Show them to the learners and start the installation. Ensure that on each step you tell them what you are doing. Allow them to watch and ask questions. If you are confident a learner can help in the installation, you may allow them to connect some components. The recommended steps are given below:

1. Attach charge controller with long screws to four threaded screw inserts on upper left corner of the wiring board.



2. Snap on four DC switches to DIN rails by pushing in yellow tabs at the bottom of the switch.



3. Attach DC light fixtures with small screws to threaded screw inputs on uper right corner of wiring board (DC light fixture with wires labeled 1 should go above DC light labled 2).

4. Snap in DC light bulbs to fixtures by gripping the metal ends of the bulb. (Insert bulbs into fixtures and gently torate bulbs until they snap into place).

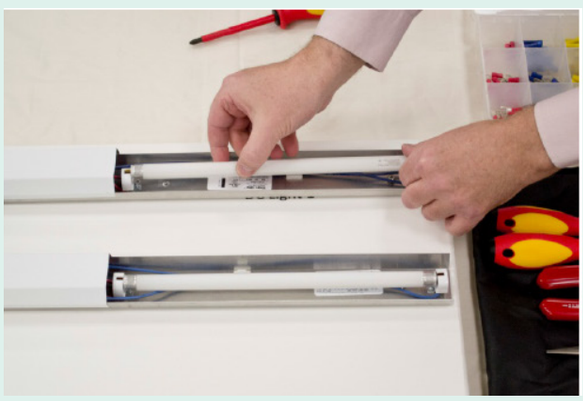
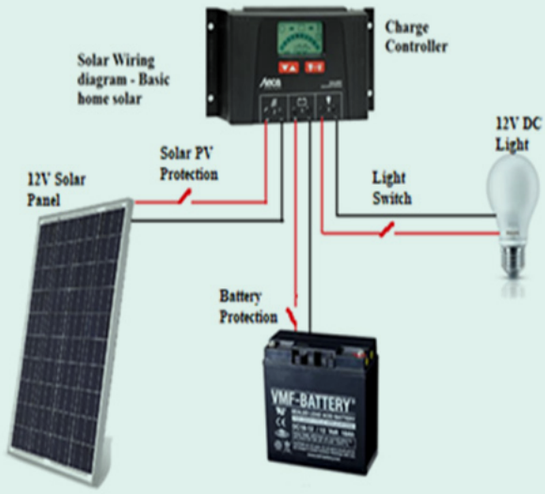
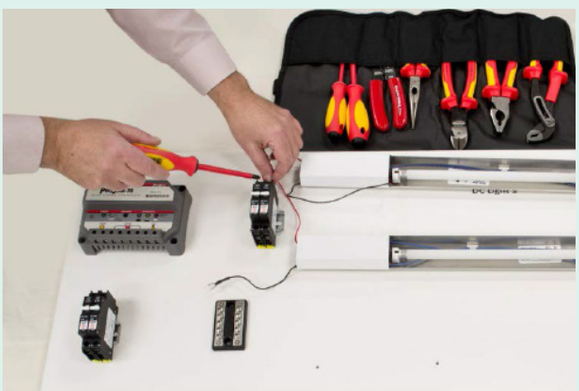


FIGURE 49: Connection diagram[52]



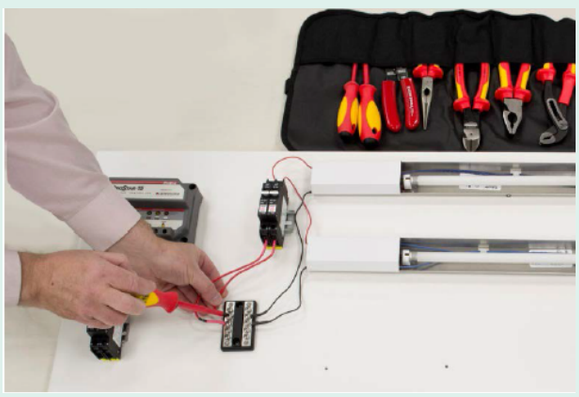
Wiring Steps

1. Insert **red wires** labeled 1 respectively 2 of DC lights 1 and 2 to upper screw terminal inputs of DC switches.

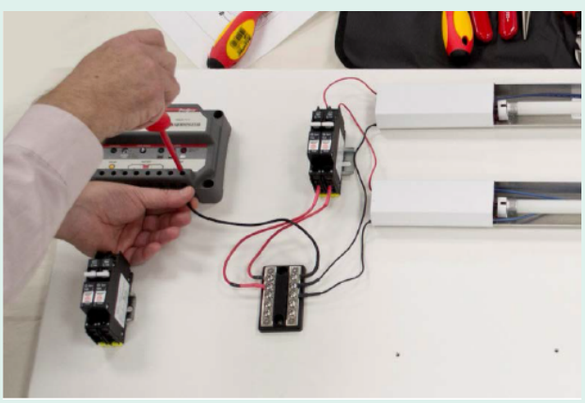


2. Connect **black wires** #1 respectively #2 the DC lights 1 and 2 to right side of distribution bar.

3. Connect both DC switches to the left side of distribution bar with short **red wires** #1 and #2 (Flat terminal end goes into lower terminal input of DC switches).

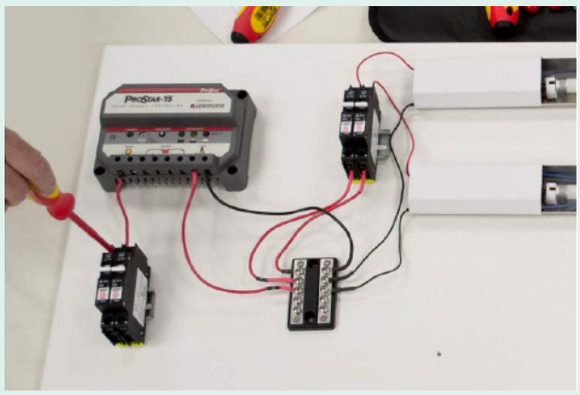


4. Connect charge controller to distribution bar with one **black** and one **red wire** #3. (Red and black pin terminals go into charge controller's load positive respectively negative terminal input).

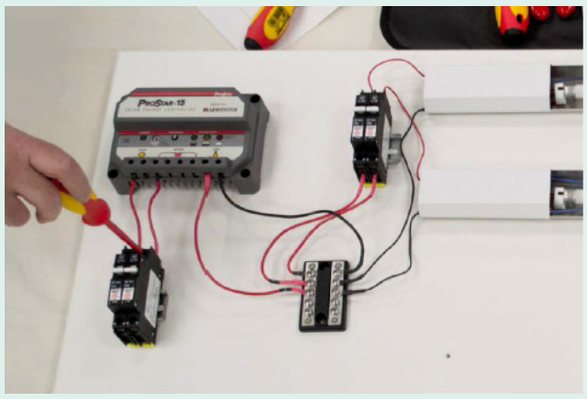


52 Adapted from the Electricity Basics, Arizona State University (VOCTEC), http://voctec.asu.edu

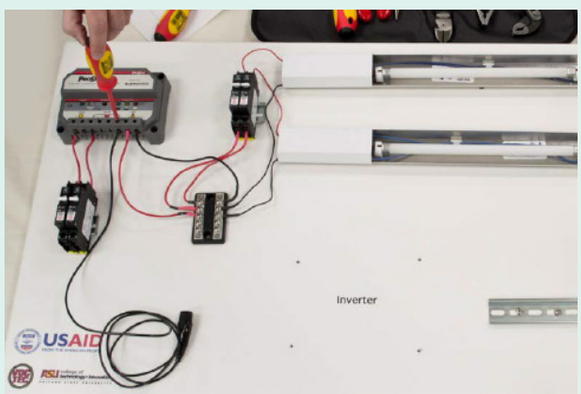
5. Connect charge controller to left DC switch with short **red wire** #8 (**Red** pin terminal goes into charge controller's solar positive terminal input).



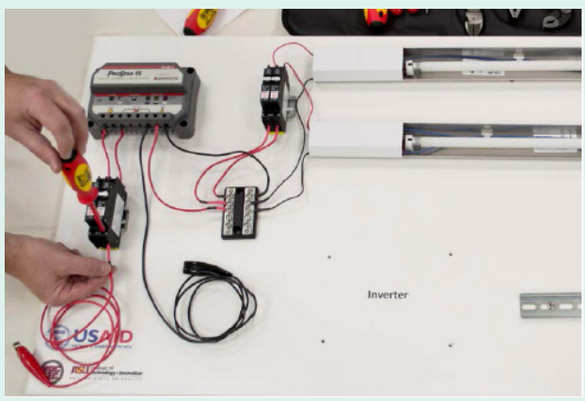
6. Connect charge controller to right DC switch with short **red wire** #7 (**Red** pin terminal goes into charge controller's battery positive terminal input).



7. Connect long **black wire** #7 into charge controller's battery negative terminal input (Black pin terminal end goes into charger controller).

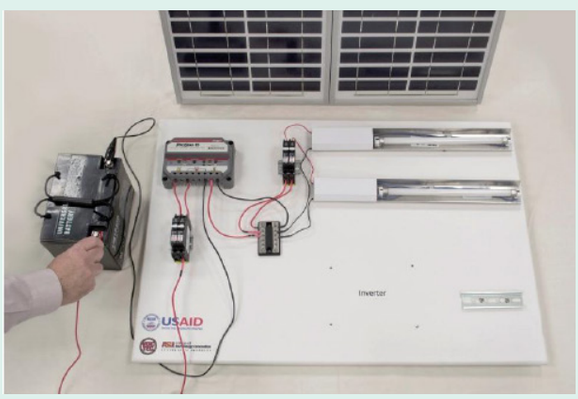


8. Connect long **red wire** #7 into right DC switch terminal input (**Red** flat terminal end goes into DC switch).

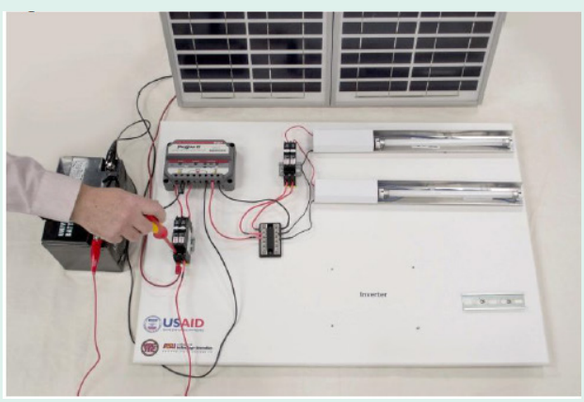


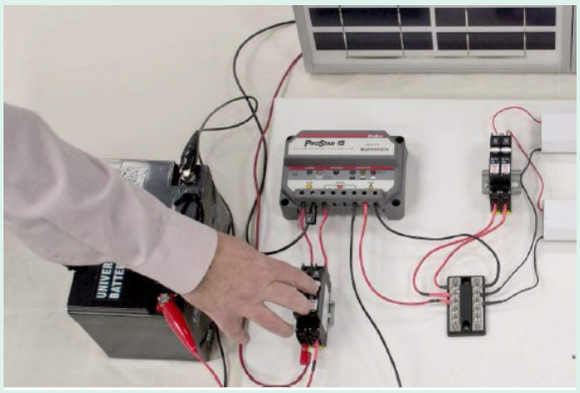
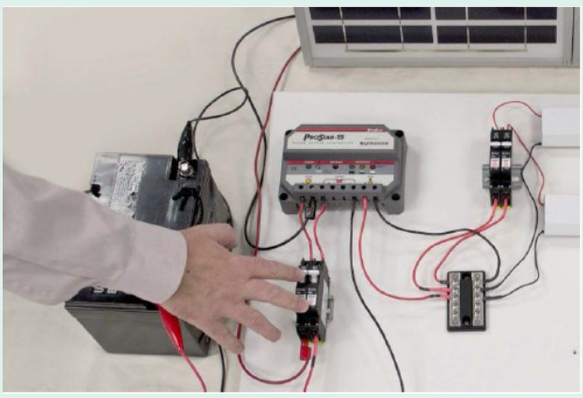
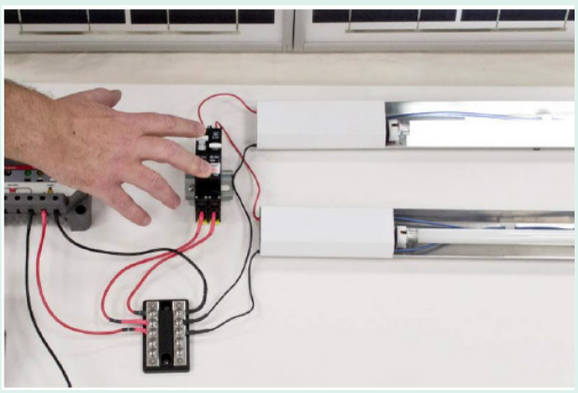
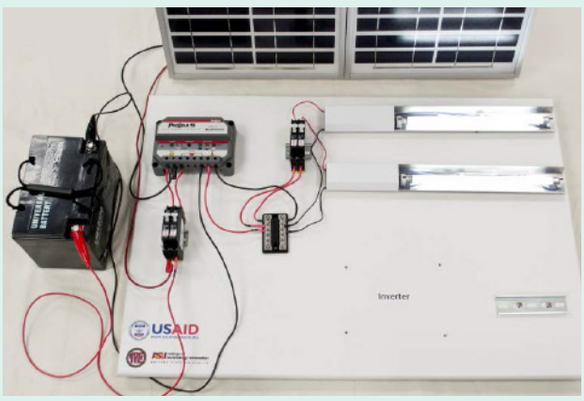
Final Assembly of System

1. Connect **red wire** #7 to positive pole of battery and **black wire** #7 to negative pole of battery (make sure switch is in off position)



2. Connect PV array's negative connector (**black**) to charge controller's negative input terminal and positive connector (**red**) to left DC switch terminal input.



3. Switch on the right DC battery disconnect switch (charge controller will power up and battery lights will flash green, yellow and red). 	4. Switch on the left PV disconnect switch (if sunlight is incident on PV modules, green charging light on the charge controller will turn up). 
5. Switch on DC light disconnect switches (DC lights will come on). 	6. Completed DC System. 

You may allow direct sunlight onto the panels and switch the circuit breakers to on position while wearing appropriate PPE to show them that the solar energy from the panel is being used to charge the battery and run the DC lights. Once the setup is switched on, the charge controller should be charging the battery and the DC lights will be switched on. Allow the learners to observe the system and ask any questions they have. Answer and clarify their queries accordingly.

ACTIVITY 8: EFFECTS OF SHADING ON SOLAR PANELS

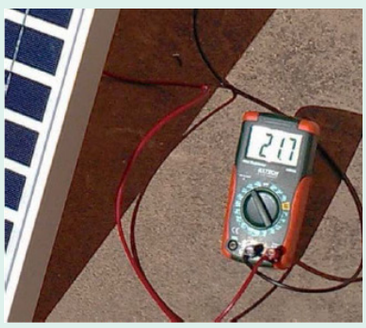
If time permits, this activity can be done to show learners how shading affects reduces power output from solar panels. This activity is done using the solar panels only by measuring the panel's voltage and current when different amounts of shades are applied.

This activity also demonstrates how to use multi-meters or clamp meters. Note that it is not critical for the community level learners to own or know how to use these test meters, as this is more for technicians and hence covered in greater detail in the "Solar O&M Basics" Module.

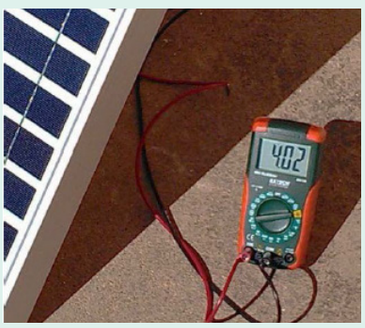
The steps are given below.

1. Use sundial to position PV array towards sun *(transmittance of 100%)*

2. Measure **Voltage** of PV array **(V_{oc1})**



3. Measure **Current** of PV array **(I_{sc1})**



Note on voltage measurement:

Refer to Annex A for details on how to do voltage measurements. Summary is provided below:

- Voltage measurement is done in parallel to measure open circuit voltage of the panel.
- The test meter should be set to "**DC Voltage**" measurement mode.
- The **red probe** should be connected to the "**V**" red terminal of the test meter.
- The **black probe** should be connected to the "**COM**" black terminal of the test meter.
- Connect the test meters **red probe** to the positive wire of the solar panel.
- Connect the test meters **black probe** to negative wire of the solar panel.
- The test meter should display the solar panels voltage.

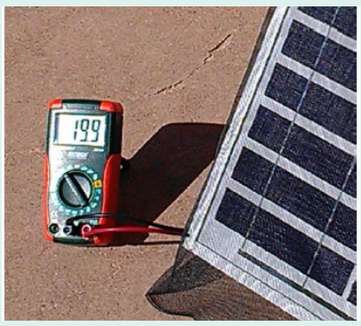
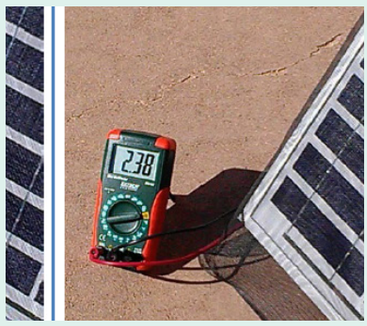
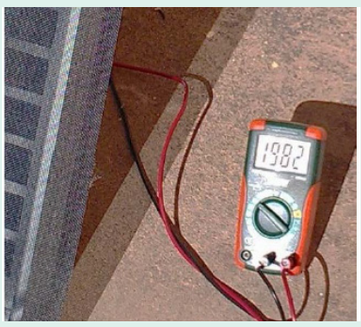
Note on current measurement:

Refer to Annex B for details on how to do current measurements. Summary is provided below:

- Current measurement is done in series to measure short- circuit current of the panel.
- The test meter should be set to "**DC Current**" measurement mode.
- The **red probe** should be connected to the "**A**" red terminal of the test meter.
- The **black probe** should be connected to the "**COM**" black terminal of the test meter.
- Connect the test meters **red probe** to the positive wire of the solar panel.
- Connect the test meters **black probe** to negative wire of the solar panel.
- The test meter should display the solar panels current.

SAFETY TIP: NEVER DO CURRENT MEASUREMENTS ON A BATTERY. This will short a battery and cause damage to equipment and can cause serious injury. Current measurements can only be done on single solar panels or normal circuits with loads.

Repeat the above steps to measure voltages and currents for two more shaded conditions shown below:

1. Shade PV array with solar shade #1 *(transmittance of 100%)* 	2. Measure **Voltage** of PV array **(V_{oc2})** 	3. Measure **Current** of PV array **(I_{sc2})** 
4. Shade PV array with solar shade #1 *(transmittance of 30%)* 	5. Measure **Voltage** of PV array **(V_{oc2})** 	6. Measure **Current** of PV array **(I_{sc2})** 

You will see that as you put more shade on the panel or as you point the solar panel away from the sun, the voltage and currents become lower accordingly, which leads to lower solar power production from the solar panel. Explain to the learners on what has been observed and why putting panels in shaded locations or not pointing at the correct direction and tilt is a bad idea while you are demonstrating this activity.

7

Purchasing Solar Power Systems

Having learnt about the basics of solar PV systems, let us look at how to use the knowledge while shopping for a good PV system or buying good replacement parts.

7.1 Buying solar lighting kits

These are fairly easy to buy as the entire system is sold together. Normally there is a panel, a solar power box and a few lights. The solar power box or solar generator box has the battery, charge controller and connection ports for the lights, and in some case, USB ports for charging mobile phones.

FIGURE 50: **Solar Ready Built Lighting Kit**[53]

These are easy to buy as everything can be bought at once and there is no need for installations of batteries and charge controller separately. The lights come ready fixed to lead wires with switches and these can be easily hung from the ceilings.

When buying ready built lighting kits, always check for reputable brands and ask for the warranty period. If the product brand is of good quality and the seller is confident of the product, a long warranty will be provided. Poor quality products often do not have warranty or come with very short warranty periods. These products can easily fail, and you have no way to get them fixed. To avoid making a loss, always check if warranty is provided. If a warranty is provided – ask for proof of warranty. For example, it may be stated on the receipt of purchase or the products packaging. As an indicator, good quality products can come with 2 years warranty, while lower quality may have a few months warranty provided only.

Also ask the seller if they do their own repairs and keep replacement parts in stock nearby or at the same shop. This is in case if the kits go bad, you can always get it repaired or replaced under warranty quickly and easily, rather than waiting for a long time for parts to arrive.

Another way to ensure if the lighting kits are of good quality is to check if a solar kit is listed under the Lighting Global website (https://lightingglobal.org) or on Verasol database (https://data.verasol.org/). Solar kits that have been quality tested and verified are listed here, hence you can buy them with confidence.

7.2 Buying a solar home system (SHS)

Unlike portable lighting kits, a solar home system is bigger, can provide more power and can include lights, fans, freezer, inverter, battery, charge controller and other items.

Note that you cannot simply go and buy a SHS to run your appliances. A SHS needs to be specifically sized, designed, and fabricated by a solar power system expert to power specific appliances only. As such, a SHS can come in various sizes and different brand of components, whereby each component has been put together to build the SHS system. For simplicity, we will not cover the calculation and sizing steps of a SHS in this module, as it is advisable to talk to a solar expert to do this for you. A basic SHS system sizing exercise is provided in the "Solar Operation and Maintenance Basics" training module if you are still interested.

Some questions to ask the seller

1. Does the product have any warranty? – what if you take a SHS system home and the inverter stops working after 3 days- will the seller replace or repair it? A warranty assures you that any faults for a certain time period will be taken care of by the seller. A longer warranty is always better. For example, buying a solar panel with 10-year warranty is better than a solar panel with 2-year warranty. Regardless of which solar component it is, ask if they give warranty. It is better to spend a few extra dollars and get a good quality product with warranty as it will last longer.

53 Source: Amazon, "Complete Solar Lighting Kit", https://www.amazon.co.uk/Off-Grid-Lighting-System-Lights-Battery-White/dp/B00HOEGHSY, accessed 25 June 2021.

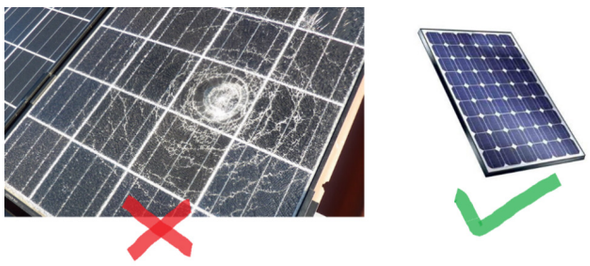
FIGURE 51: Warranty Label[54]

2. Does the solar panel come with mounting fixture? While smaller lighting kits with single solar panels may not require mounting fixtures, SHS systems with multiple larger solar panels may need to be mounted on rooftops or poles. You should ask if they come with the mounting brackets. Otherwise, it will be difficult to securely mount these without the necessary brackets.

FIGURE 52: Mounting Fixture[55]

3. Check for signs of damage – Do not buy damaged products. Always ask the seller to show you all the products and demonstrate that it works e.g., lights or battery. If panels appear cracked, dirty or damaged, do not buy them. If batteries appear leaking or bloated – do not buy them.

FIGURE 53: Damaged Panels[56]



4. For batteries you may ask the seller to measure and show you the battery voltage. For a 12V lead acid battery, the voltage must not be below 12V. If voltage is very low, then it may indicate that the battery has been lying around for a long time without being charged properly, in which case, you should not buy it.

FIGURE 54: Ask seller for assistance[57]

5. Look for quality branded products – Search for product with proper brands and logo and instruction manuals. Do not buy products with no brands, poorly written or missing instruction manuals. There are unlimited brands of products out there and it is very difficult to determine which ones are good. Ask around your families and friends about their experience with particular brands to try to find out if they have good experience with certain brands which you can go for as well.

54 Source: PNGWING, https://www.pngwing.com/en/free-png-kfvth

55 Renewables Now, "Global solar BOS market to fall to USD 25bn by 2020, https://renewablesnow.com/news/global-solar-bos-market-to-fall-to-usd-25bn-by-2020-461526/

56 Twitter.com, Solar Energy World, https://twitter.com/solareworld/status/1186417038610386945

57 Amazon.com, "Electric Measuring instrument", https://www.amazon.com/Electric-Measuring-Instrument/s?k=Electric+Measuring+Instrument, accessed 25 June 2021.

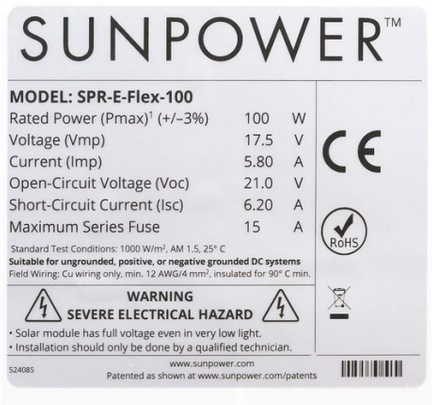
FIGURE 55: Quality branded products[58]

6. When selecting inverters, ask the seller if the output of the inverter is a pure sine wave, as these produce clean quality output power. Cheaper inverters usually only produce modified sine wave outputs, which can cause problems with some sensitive AC appliances Check the inverters name plate and ratings to be sure.

FIGURE 56: Inverter[59]

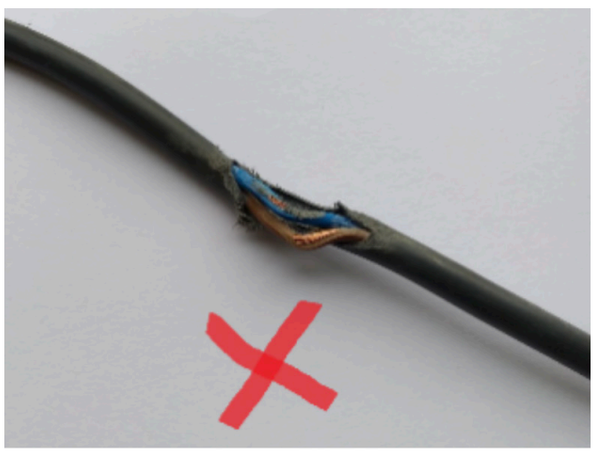
7. Inspect the name plates of all components in detail. The product can be mistakenly packed in wrong boxes – so always read the name plate to find the right voltage, current or wattage of the components that you are paying for.

FIGURE 57: Nameplates[60]



8. Ensure all products are safe to use. Do not buy products that appear damaged, or if you see there are exposed wires, or the product looks poorly designed and may cause accidental injury.

FIGURE 58: Do not buy damaged products[61]



9. Always shop around and compare the prices, quality, warranty, sizes, brands, safety etc of the products that you want to buy. Ask others who have solar systems about where they got theirs from and ask them direction to the shops. Once you visit the city or town it will be easier for you to find the right shops and ask the questions mentioned above.

58 Coulee Energy, "How to choose a right panel solar", https://couleenergy.com/how-to-choose-a-right-solar-panel/
59 Goughlui.com, "The Power Inverter", https://goughlui.com/2014/07/30/review-teardown-hip-300-300w-pure-sine-wave-power-inverter/
60 Source: Pinterest, "SunPower Marine Flexible Solar Panels, https://www.pinterest.com/pin/714735403339440675/
61 Source: IOL, "How to fix frayed cables", https://www.iol.co.za/technology/how-to-fix-frayed-cables-49412981

ACTIVITY 9: BUYING SOLAR SYSTEMS

Ask the learners to get in groups. Display the solar panel, battery, inverter, charge controller and lights from the VOTEC Kit. Ask the learners to approach a desk where all these products are set up nicely. The learner must then imagine the trainer is the seller and use the above-mentioned tips to ask the trainer more information about products. Help the learners by guiding them to ask the right questions. Allow the learner to take their products and discuss in teams if it was the right 'purchase'.

Some important questions they need to ask are:

1. How much does it cost?
2. How much is the voltage, current or power rating?
3. Do you provide warranty – for what period of time?
4. Can you show me the voltage (in case of battery)?
5. Can you test to see if this works (in case if lights)?
6. Do you have replacements of these?
7. Do they come with an instruction manual?
8. Can you show me how to use it or install it?

8

Maintenance of Solar Home Solar Systems

All solar power systems require some form of regular maintenance in order to ensure safe and proper operation as well as to get the maximum life from the system Without regular maintenance, the system may not function at its maximum potential, and this can also lead to malfunctions or early component failures that can lead to costly repairs or replacements.

One misconception in the communities, can be that maintenance of solar home system is dangerous or needs to be done by a qualified technician only. While this is true for large systems that contain hazardous voltages and complex hardware, a solar home system, on the other hand, is reasonably simple, does not require a technician and can be done by a household member, provided you have knowledge of the system and the safety precautions to follow, all of which has now been covered under this training module.

This chapter will cover the basic maintenance that you can do on your solar home system for free without requiring a technician (whom you might have to pay to do the maintenance).

8.1 Why do some solar power systems fail?

There are many reasons why a solar power system may start giving problems. We may notice a failing system in advance sometimes, while at other times, a system may fail all of a sudden without any notice. Understanding how your solar power system works and doing regular maintenance is the best way to avoid system failures. A simple maintenance checklist is a very good way of doing this.

8.2 Component Maintenance

Let us look at how we can carry out regular maintenance on different components of solar PV systems.

8.2.1 Solar Panels

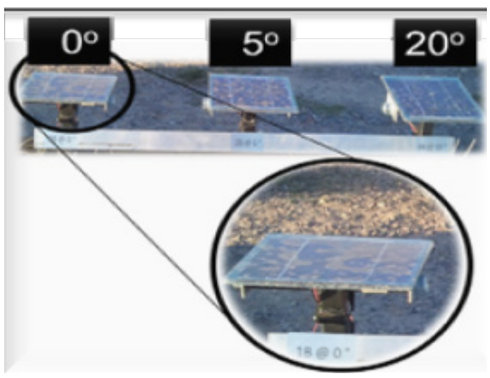
- Inspect solar PV panels for any signs of physical damage, such as impacts or fractures.
- Surface of the panel must be clean and clear of any dirt or debris.

FIGURE 59: **Damaged Solar Panels**[62]

- Soiling on solar panels decreases its power output over time Ensure that solar panels are not lying flat and have a minimum of 10-degree tilt to allow for self-washing of the panel when it rains. Do you remember what is the ideal tilt angle of a solar panel for Fiji? As you can see in Figure 60 below, higher tilt angle helps keep the panel clean.

62 Jim Dunlop Solar

FIGURE 60: Effect of Tilt Angle on Soiling Loss[63]



8.2.2 Battery Maintenance

Battery maintenance involves various tasks depending on the type of battery and manufacturer requirements, including:

- Inspecting and cleaning battery racks, cases trays and terminations.
- Measuring battery voltage if you have a multi-meter or by simply reading the battery voltage from the charge controller. For e.g., a 12V battery must not go below 12V for long times. If it does, then you may be overusing it (reduce your load in this case), or the system is not charging it properly (poor weather or dirty solar panels), or battery may be nearing its end of life and cannot hold its charge, etc.
- Some charge controllers have display screens while some simpler ones just show the amount of charge level of the battery with led lights.

FIGURE 61: LED lights indicate the battery charge level[64]

- Some charge controllers display the battery voltage and other measurements directly on their display screen. You will need to consult the manual of these controllers to see how different measurements can be displayed.

FIGURE 62: Charge controller with battery voltage display[65]

- Periodic battery maintenance should include checks of all terminals for corrosion and proper tightening of terminals. If battery is of flooded type, then check battery water and replace with distilled water if the level is low. Try to do this every 2 – 4 weeks as required.
- Use a steel brush to clean any oxidation buildup at connections, ensuring not to accidently short the terminals. Wear insulation gloves if available.
- Check for loose wires and connections and damaged wires. Get immediate help to repair any damaged wires.

63 Source: ASU PV/ Reliability Laboratory

64 Source: Sundaya Apple, "Sundaya Apple Regulator, Quick Start Manual", https://assets.website-files.com/5a2fb65f5701c800018e826f/603e4f42254a71b39b6e33a9_Sundaya%20apple%20-%20English.pdf

65 Source: Amazon, "iSunergy MPPT Solar Charge Controller", https://www.amazon.com/iSunergy-Controller-Intelligent-Regulator-Batteries/dp/B081GSFDKC, accessed 25 June 2021.

FIGURE 63: Cleaning Terminal Corrosion[66]

SAFETY TIP: It is recommended to use safety goggles and rubber gloves when servicing batteries. If you are working with flooded type batteries, then wear old clothes in case you can get acid on them. Keep an open box of baking soda and a plastic pan of water, in case of a spill, you can pour the baking soda in the water, stir it, and use the mixture to quickly neutralize any spilled acid.

Do not accidently drop your tools on the battery, as it can short the terminals and cause serious injury and equipment damage.

A sample system maintenance checklist is provided below. If you find any faults that you cannot resolve yourself, contact an electrician immediately. Know your limits and do not try to forcefully do any repairs that you do not understand completely.

66 Source: Jim Dunlop Solar

8.3 Basic Maintenance Checklist

TABLE 3: Basic Home Solar Maintenance Bi- Weekly -Monthly Checklist

Item	Weekly Checklist - Basic	Done (tick)
1	Check panel for damage.	
2	Check wires for damage or loose connections.	
3	Clean solar panel orientation and tilt.	
4	Check to see panel is not being shaded or dirty.	
5	Check panel mounting is secure.	
6	Check panel voltage and current in charge controller display - if possible. Ensure the system is charging batteries during daytime and gets fully charged by 4pm daily in good weather.	
7	Check battery voltage in charge controller - if possible. The battery voltage should be between 12V (when low on charge) to 14V (when fully charged).	
8	Check and clean battery terminal for any corrosion.	
9	Check and tighten any loose terminal connections.	
10	If flooded battery, check battery water level and refill with distilled water if level is low.	
11	Check battery storage area is cool and well ventilated.	
12	Check that all lights and appliances of the system are working.	
13	Check and keep all other appliances clean and free from dirt and dust. Clean ventilation holes with dry cloth only.	
14	Ensure that small insects cannot enter sensitive equipment.	

ACTIVITY 10: MAINTENANCE CHECKLIST

Create a maintenance checklist of what all routine tasks needs to be done to extend the life of your solar power system. Allow the learners to form groups and write down a set of regular checks that they would need to do to ensure their solar system works well and for longer. Help them by referring to the above checklist, giving them more hints and facilitate further discussion around the maintenance needs of each component and why it is important.

ACTIVITY 11 – ROLE PLAY: CHANGING TO SOLAR

The purpose of the exercise is to get all members of the community to appreciate the key role women play in decision making and, in the management, and use of the solar technology. Read them this case study and help them answer the questions. You may need to animate the narration to make the dialogues more realistic. Nominate two characters to perform this role play, Mario, and Sala.

How women bring about change

Sala and her husband Mario live in Rukua village, on Beqa Island in Fiji with their 3 children. They do not have electricity in their village. Mario is a fisherman and must be out to sea before sunrise to catch the finest fish and deliver to the fishery station, which has the only ice room on the island. Sometimes Mario brings the smaller fish home for cooking. They have 3 children, Lilly aged 9, Timoci aged 10 and Salote aged 13 who all go to a school that is about 4 km away from their house. It is about an hour's walk from their home to the school. They also have a large garden at home. Lots of sweet potatoes, yams, cabbage and tomatoes for their daily needs. Mario's elderly parents also live with them. Mario works hard and normally has a lot of other things to do such as repairing the boat, getting ice and taking passengers to other islands in his boat in the evenings. Sala is equally busy with looking after Mario's parents, taking care of the house, looking after the children, and keeping up with community obligations.

One evening their 13-year-old daughter, Salote was studying using the kerosene lamp. The smell of kerosene filled the house as they had 3 lamps lit that night. Mario was yet to return from a neighbors' place where he had gone for some grog. Their 9-year-old, Lilly, complained a lot as the smell of kerosene made her feel sick. An argument broke out between the kids because Timoci and Salote both wanted to use the lamp. Lilly jokingly picked the lamp and ran around playfully. As they chased each other around the house, the lamp suddenly fell from her hands, landed on the mat which caught fire instantly. Sala yelled for help and the neighbors rushed to put the fire out but most of Salote's books were ruined by the fire. Lilly was now too afraid to use the kerosene lamp. Late that evening Sala told Mario about what happened:

Mario: Relax – no one got burnt, I will get her new books by end of this week. Why are you worried?

Sala: I think it is time we stop using these kerosene lamps in our house.

Mario: What? Are you crazy – what else will we use for lighting?

Sala: Well, I noticed that our neighbor Lusi and her family recently bought a solar system and now they use lights at night like the hotels. They even have a fridge to keep their fish and food for longer. In addition, their eldest Tima has started doing well in school since she can study easily under the bright light.

Mario: Wow, you have been paying so much attention to Lusi recently. You women are always… (Sala interrupts).

Sala: What do you mean "you women".

Mario: Umm.

Sala: We women must drive the change because we feel how life is without electricity. I have to wake up when it is dark and light that smelly kerosene lamp and cook the food. I must take care to store the extra food and fish, so it does not go bad and make us sick. I must make sure the kids' homework is done in the dim light of the lamps. I must save money to spend on kerosene.

Mario: Ok I agree we need to get a solar system. I would like to have a solar powered freezer to keep our fish. But Jone has been telling me that the solar system he bought stopped working in a week. What if it goes bad or does not work? In addition, the solar system is going to cost us money.

Sala: Oh my God, let's try at least. We can save a bit of the money you make from the fish you sell each week and if we save every week from now until Christmas, we should have enough for a system. And don't worry about the maintenance. I heard that women from one of the villages on the other side of the island are trained to maintain these systems. One of them went to India for training. I hear they offer solar training to others these days. I will go and attend one of these sessions so I can learn it all. Then, I can also help fix the other systems in the village and we can make some extra money.

Mario: That is a great idea Sala. I am so glad we are able to agree on this and I am happy to take care of the kids and my parents when you need to go for training on the solar system.

End of play

After the story has ended, get the participants into groups, and help them think of all they have learnt and ask them to help sala and Mario answer these two questions again:

What things should Sala and Mario look for when buying a Solar PV system?

Answer: Given in notes under "Some questions to ask the seller"

How should Sala and the women take care of the solar PV system, so it lasts longer?

Answer: The answer is provided in the maintenance section of the module.

ACTIVITY 12 – ROLE PLAY: INVOLVE EVERYONE

This role play is on a group of young people who are sitting under a tree in a rural village having a conversation. Nominate three characters to perform this role play, Amelia, Santos, and Daniel.

Amelia: Hey Santos, I overheard my grandmother talking the other day about the solar training that she attended.

Santos: Really? I think that's the one my grandmother attended as well. Isn't it cool that they are still learning technical things at their age?

Amelia: Yes, my grandmother is really cool – she has been telling me a few things about what she learned which is some of the things we learn in school.

Santos: Ok, what did she tell you?

Amelia: Well, you know that at different times of the day the energy from the sun is different and more energy is produced on the day when the sun is at its hottest.

Santos: Yes, we all know that right?

Amelia: We do, but it's kinda of cool hearing my grandmother talk about it and trying and teach me.

Santos: We also learn that because we live in the southern hemisphere, the solar panels we use should be facing towards north and tilted at the ideal angle to get maximum solar energy.

Amelia: Yes, I never really thought about that – when I saw them installing the solar panels – I just thought as long as it's on the roof – it should produce energy – but depending on the country we live in, we have to consider installing it correctly, else we will lose a lot of solar energy throughout the year.

Daniel (joins conversation): Yes, its stuff we know but its great to see our grandmothers doing this and helping to bring lighting to the village. It makes a real difference to see all the houses lit up at night.

Amelia: Yes, I also feel safer walking through the village at night because of the light. What a great idea.

Santos: In the past we have only seen the men do these technical things so it's a nice change to see our grandmothers become solar technicians.

Daniel: Yes, it has also brought them a lot of respect so there are many good things about it – we just need to ask them to pass on some of that knowledge to us as well so we can support them with the maintenance.

Amelia: Yes, I think that's what my grandmother was starting to do with me. I am also keen to learn more about it. Understanding how a solar home system works and how to maintain it is very simple. We should all take the initiative to do this ourselves and share correct knowledge with others. There are a lot of wrong information being spread around and the only way to ensure that our solar systems last long is to learn it the correct way by motivating every adult in the household, especially women.

End of play

After the story has ended, help the learners think about all the lessons learnt from this module.

What all have you learnt from this module that you did not know before?

Answer: Can be a variety of things.

Do you think that you are in a better position to buy, operate and do basic maintenance of solar home systems?

Answer: Can be a variety of responses.

Who do you think should be in-charge of operating and doing basic maintenance of your solar home system?

Answer: A good quality solar system is usually costly to purchase, which means that it is extremely important to operate and maintain it correctly to make it last for a long time. Most often, it is the women and children who use it the most, while men are outdoors in farms or fishing trying to earn for the family. As such, every adult in the household should be motivated to learn to operate and maintain the solar system correctly, so that if someone becomes busy or forgets, then others can remind and do the regular maintenance checks as well. In either case, always practice safety first, know your limits and seek assistance from qualified technicians if you are unsure or not comfortable with anything.

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Appendices

Annex A: Measuring Voltage with a Multi-meter

We use a device called a "multi-meter" to measure current, voltage and other parameters in an electrical circuit. A multi-meter is very useful in making basic measurements. Let us look at a simple multi meter.

FIGURE 64: Parts of a multi meter[67]

Steps to measure DC Voltage:

FIGURE 65: DC Voltage measurement schematic[68]

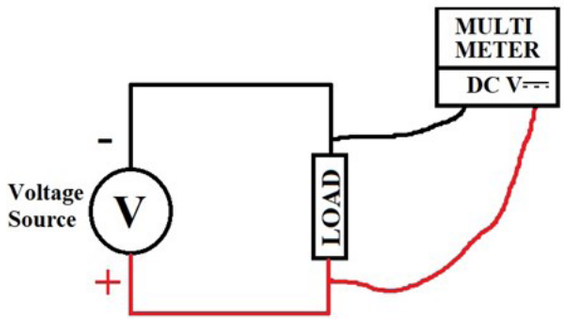

FIGURE 66: DC Voltage measurement on multi-meter[69]

Steps:

1. Set multi-meter dial to DC Voltage mode (DCV or V=).
2. Ensure probes are connected to "V" and "Com" ports of the clamp meter.
3. Touch the end of probes across the load in the circuit to measure its voltage. Voltage measurements are done in parallel to the load. Multi-meter screen with show measured voltage.

67 Source: Garage Tool Advisor, https://cdn.sciencebuddies.org/Files/4803/16/series-circuit-parallel-circuit.png,accessed 21 June 2021.

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Annex B: Measuring current with a multi-meter

FIGURE 67: DC current measurement schematic[70]

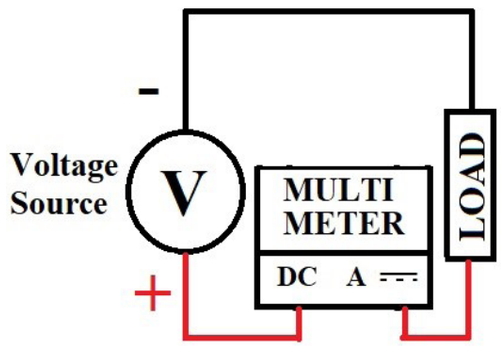

FIGURE 68: DC current measurement on multi-meter[71]

Steps:

1. Turn OFF the circuit.
2. Set multi-meter dial to DC current mode (DCA or A= or mA=).
3. Connect the red probe to the "A=" or "mA=" port of the multi-meter and black probe to "Com" port of the multi-meter. Ensure that the measured current does not exceed the maximum rated current of the meter. If the current is very small, then you can use the "mA=" port and "mA=" meter mode to measure smaller currents more accurately.
4. Connect the multi-meter in series to the circuit. This means that the circuit must be broken to connect the meter in series.
5. Turn ON the circuit.
6. The multi-meter screen will show the measured current in the wire.

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