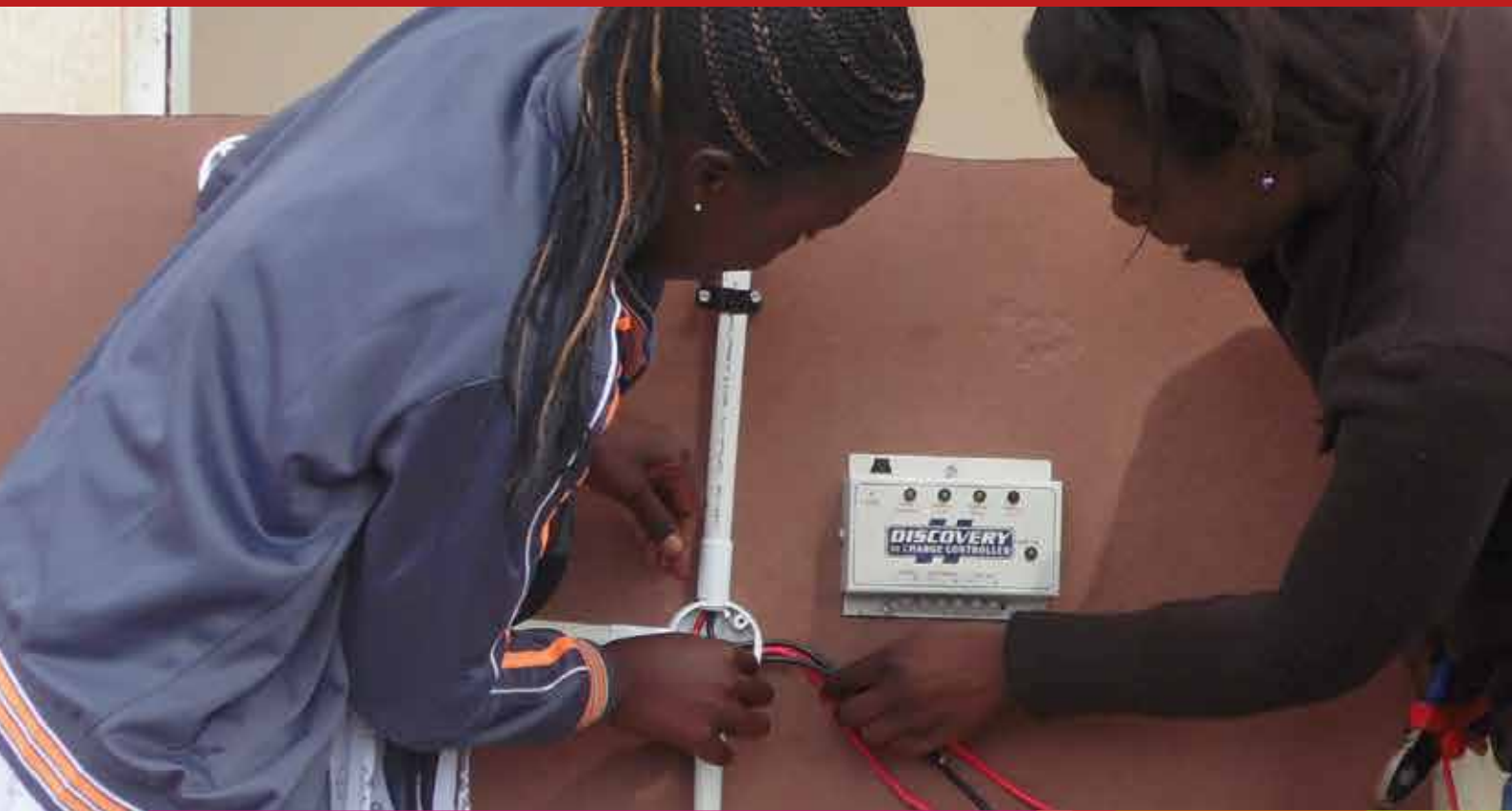




Solar PV Training & Referral Manual



SNV

Developed by SNV for the Rural Solar Market Development

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Supporting Booklet	

About This Manual

This Pico PV Referral Manual has been developed by SNV Zimbabwe to provide distributors, installers and users of PV systems with a quick reference and source of information. The manual covers the following:

- a) Background on Solar Technology
- b) Solar Systems
- c) Basic System Sizing
- d) Troubleshooting Guidance
- e) Safety Precautions

The manual is designed for use by anyone who wishes to obtain quick, basic, technical information with regards to PV systems. However, it is particularly targeted at those who engage in the business of distributing and installing PV products. This manual does not guarantee the quality of installations carried out by installers nor the quality of products supplied by distributors. It is recommended that all installations are carried out in a responsible and professional way. All electrical work should be performed by a qualified electrician to guarantee the installation and/or repairs.

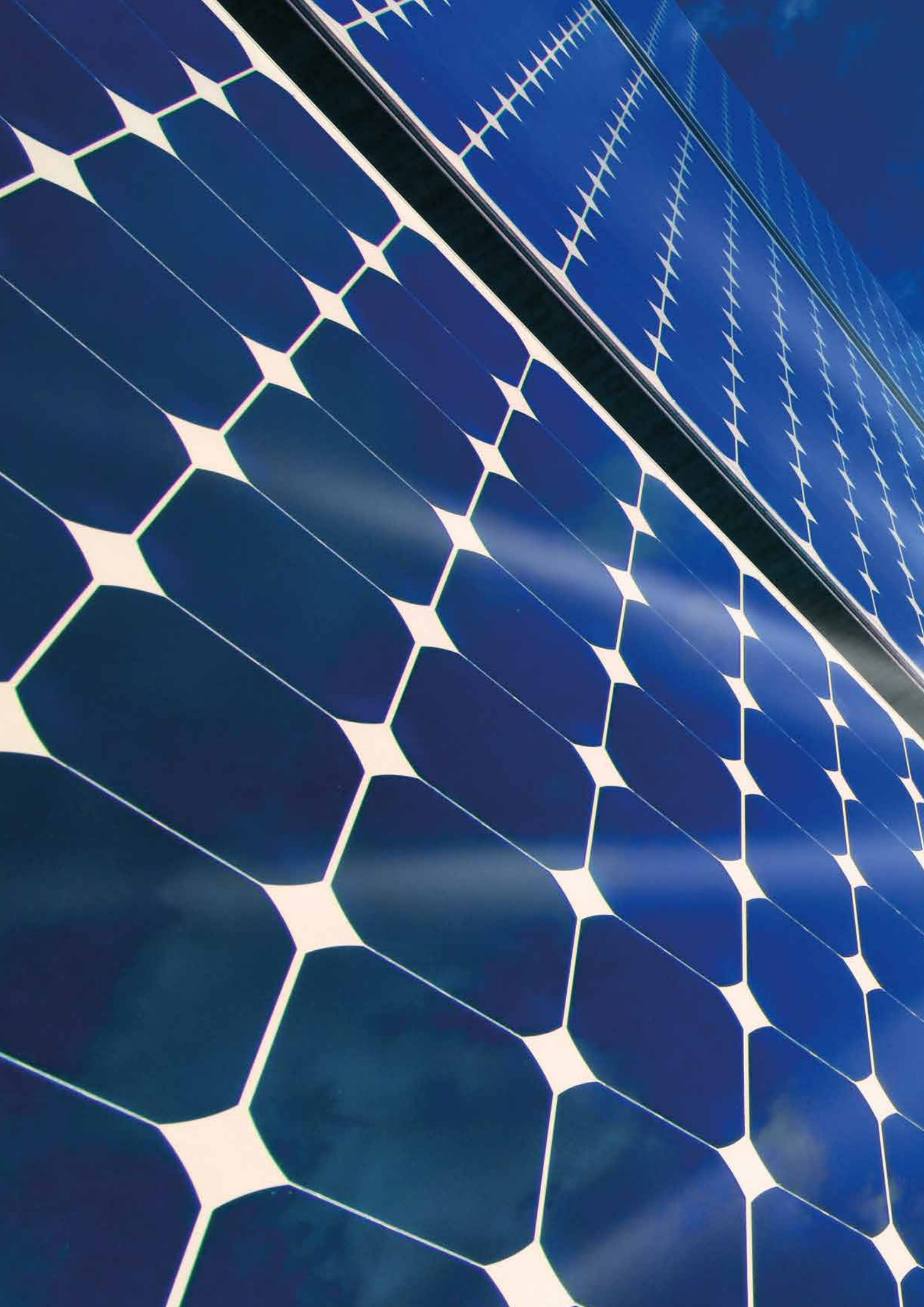
About SNV

SNV is a not-for-profit international development organisation. Founded in the Netherlands nearly 50 years ago, we have built a long-term, local presence in 38 of the poorest countries in Asia, Africa and Latin America. Our global team of local and international advisors work with local partners to equip communities, businesses and organisations with the tools, knowledge and connections they need to increase their incomes and gain access to basic services – empowering them to break the cycle of poverty and guide their own development.



ABBREVIATIONS

°C	Degrees Celcius
A	Amperes
AC	Alternating Current
Ah	Ampere hours
DC	Direct Current
E	Energy
FAQ	Frequently Asked Question
GWh	Gigawatt hour
I	Current
kW	Kilowatt
kWh	Kilowatt hour
m/s	Metres per second
MJ	Megajoule
MW	Megawatt
NGO	Non-Governmental Organisation
P	Power
PJ	Petajoule
PV	Photovoltaic
R	Resistance
REA	Rural Electrification Agency
SHS	Solar home system
STC	Standard Test Conditions
TV	Television
V	Volts
W/m ²	Watts per square metre
Wh	Watt hour



SECTION 1:

Background on Solar Technology

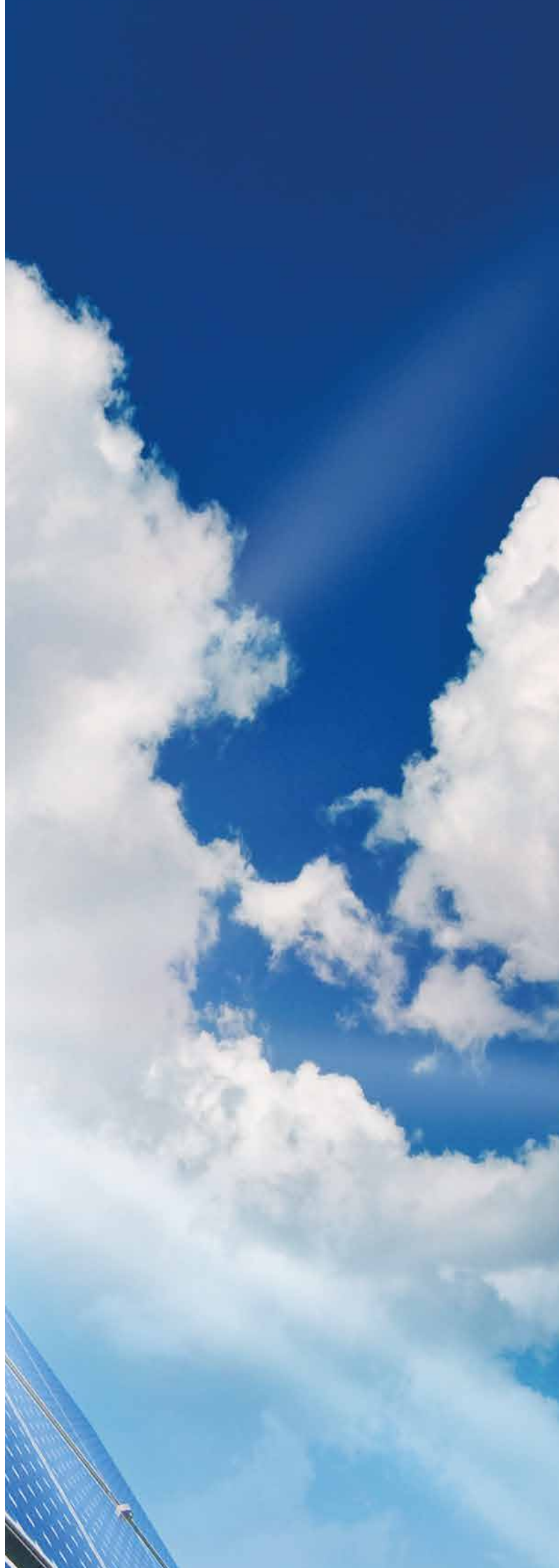
In this Unit:

What is Solar Energy?

Solar Heating

Solar PV Photovoltaics

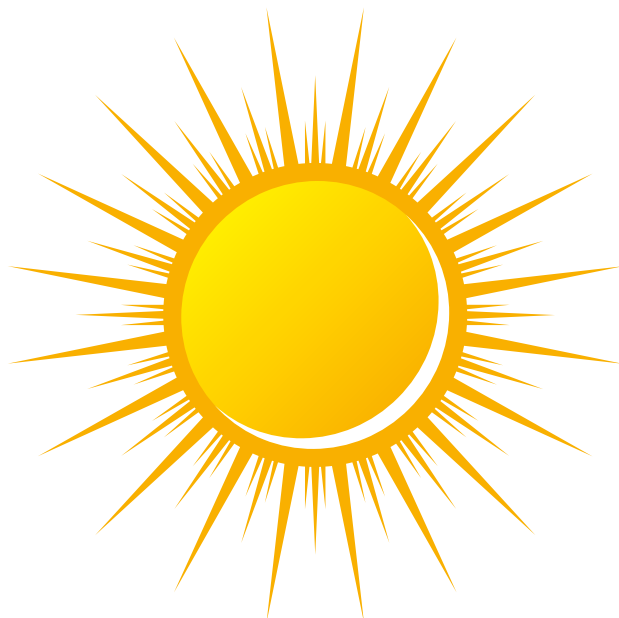
Why Solar Energy?



What is Solar Energy?

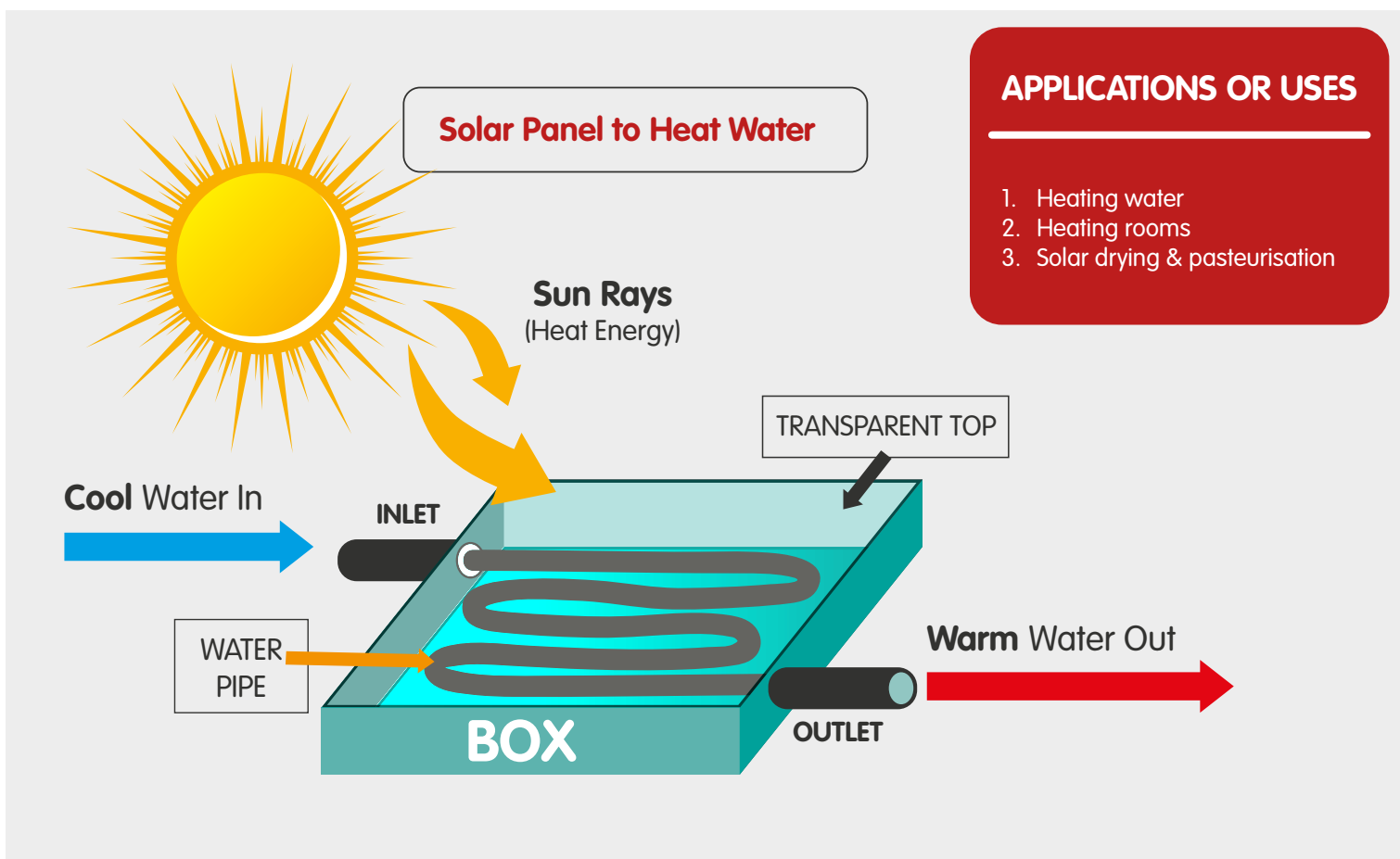
Solar Energy refers to radiant heat and light from the sun.

- It is renewable, which means it cannot be used up.
- It is harnessed and converted to heat or electricity using various technologies such as **Solar Heating** and **Solar Photovoltaics** (conversion to electricity).



Solar Heating - Solar Energy to Thermal

Solar thermal systems operate when radiation/heat from the sun is directed to a device which captures and concentrates the heat to a carrying media (air or water).

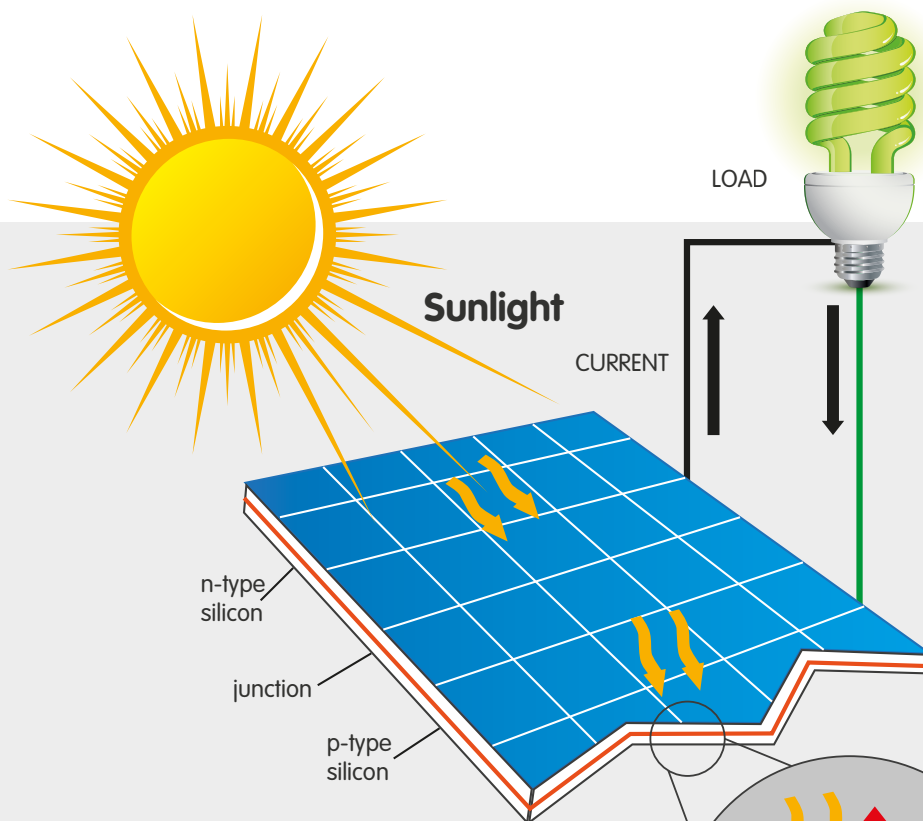


Solar PV (Photovoltaics) - Solar Energy to Electricity

Photovoltaic (PV) means electricity from the sun.

Photovoltaic technology is used to convert light energy into electrical energy.

This is based on the characteristic of some semiconductor materials, such as silicon, which generate voltage and current when exposed to light.



How a Solar Panel Works

APPLICATIONS OR USES

1. Lighting
2. Communication
3. Powering electrical gadgets
4. Water pumping
5. Charging appliances

Why Solar Energy?



1. Reliability
2. Durability
3. Low maintenance costs
4. No fuel costs
5. Reduced pollution
6. Flexibility due to modularity
7. Safety
8. Independence
9. Grid decentralisation
10. High Altitude performance

SECTION 2:

Solar Systems

In this Unit:

Electricity Basics

Solar PV Photovoltaic System

Portable PV System

Solar Home Systems

Solar Panel (Module)

Solar Charge Regulator/Controller

Solar Batteries

Solar Inverter

A summary of the Complete Solar Home System



Electricity Basics

Measuring Electricity

Voltage (V): the potential difference in electrical charge between two points measured in volts.

Volts = Power ÷ Current

$$V = P \div I$$

Volts

Current (I): the flow of electrons in a circuit/wire between two points measured in amperes.

Current = Power ÷ Volts

$$I = P \div V$$

Amperes

There are two types of current:

1. Alternating Current (AC) is the type of current most commonly used in households to power electrical appliances (for example TVs, refrigerators, radios and computers). Grid supplied electricity is alternating current.

2. Direct Current (DC) is produced by PV modules and stored in batteries.



Direct
Current



Alternating
Current

Resistance (R): the opposition to the flow of electrical current in the material through which it is passing measured in ohms the potential difference in electrical charge between two points measured in volts.

Resistance = Volts ÷ Current

$$R = V \div I$$

Ohms

Power (P): the rate of energy conversion measured in watts.

Power = Volts x Current

$$P = V \times I$$

Watts

Example:

If a solar panel produces 2 Amps of electricity at 12 volts, the total power it produces is 24 Watts. **(2 Amps x 12 Volts = 36 Watts)**

Energy (E): refers to the capacity for work i.e. the power used over time, measured in watt-hours.

Energy = Power x Time

$$E = P \times t$$

Watt-Hours

Watts vs Watt-Hours

WATTS (Power)

A **watt** is the amount of power that a solar panel can produce or that a light bulb consumes.

WATT-HOURS (Energy)

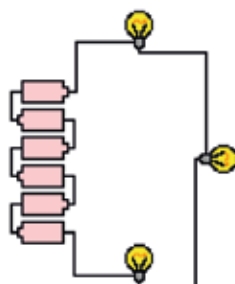
A **watt-hour** is the amount of energy that a solar panel can produce or a light bulb can consume in a certain number of hours.

Electrical Circuits

Loads and power sources in a circuit can be connected in series or parallel. Systems may use a mix of series and parallel wiring to achieve the required voltages and amperages.

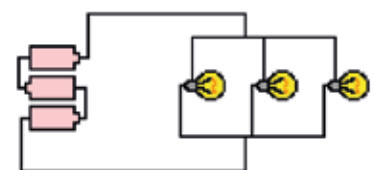
Series Connections

increase voltage but does not increase current.



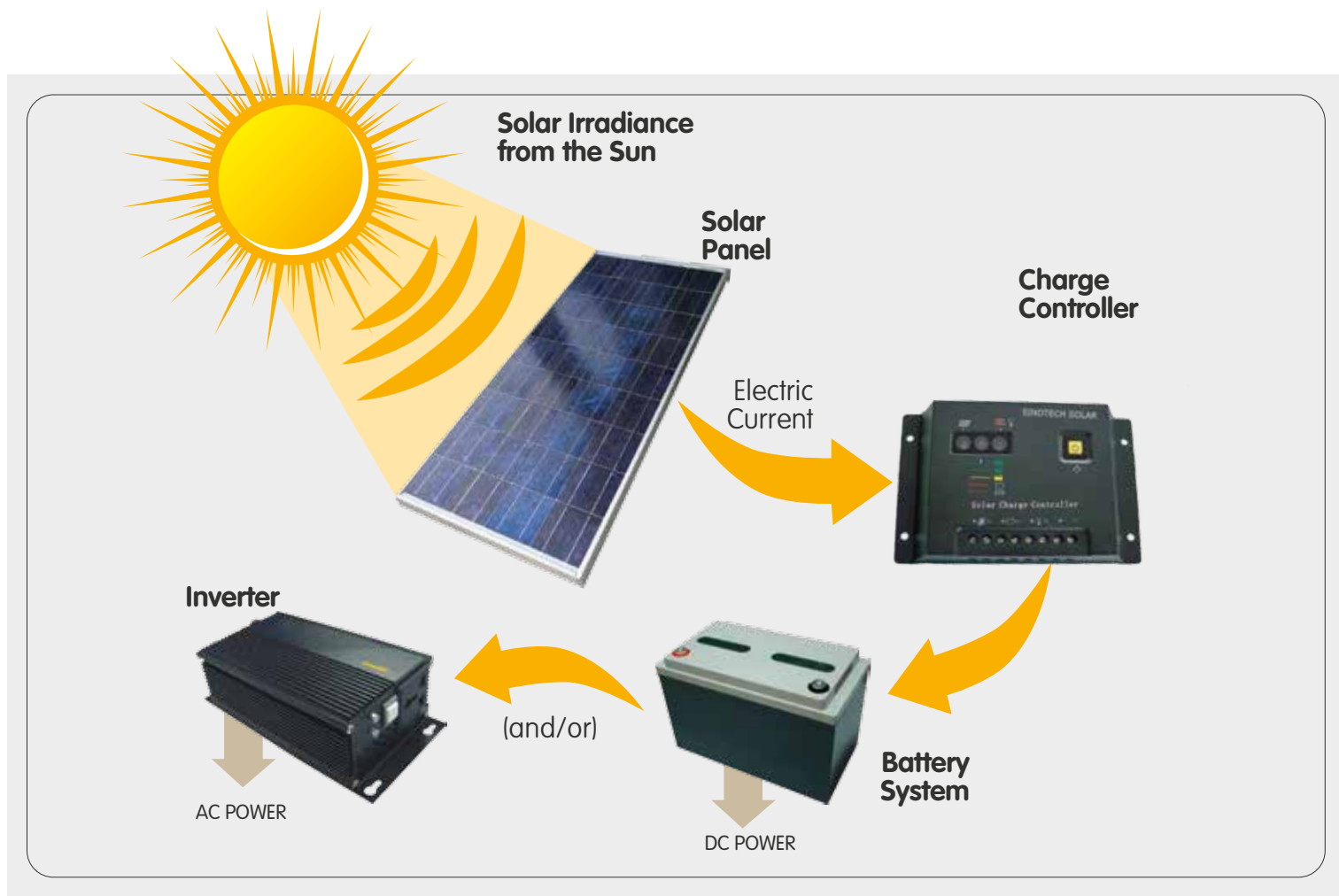
Parallel Connections

increase current but voltage is not affected.



Solar Photovoltaic (PV) System

A Solar PV System converts solar energy in form of light to electrical energy by the use of a solar module (**solar panel**).



Photovoltaic systems consist of some or all of the following components:

- **Solar Panel** - Converts sunlight to electricity
- **Battery(s)** - Store electricity
- **Charge Controller** - Manages the flow of electricity between the solar panel battery and load
- **Inverter** - Converts DC power from the solar panel and battery to AC power.
- **Load** - Application for electricity, e.g. lights, computer, radio, TV
- **Wires** - Connect the other

Portable PV System

These are portable lighting systems. They can be classified into classic and multifunctional:

- Classic systems provide lighting only
- Multifunctional provide lighting as well as facilities for mobile phone charging and radios.



Components of the System

- Solar panel [can be separate or inbuilt]
- Battery for electricity storage (often integrated in the lamp)
- Lamp
- Mobile Phone charging Unit

Main Uses

- To enlighten one single room
- Recreational uses such as camping
- Mobile phone charger (depending on the model)
- Radio (depending on the model)

Advantages

- Loads can be carried elsewhere without the panel
- Replacing traditional light (kerosene/ paraffin lamps and candles)
- Easy installation (plug and play)
- User-friendly application
- Low investment costs
- Little maintenance required (Refer to maintenance section)
- The prices are generally affordable and within the payment capacity of most rural people in developing countries.

MAINTENANCE & CARE

- Do not operate in explosive atmospheres such as in the presence of flammable liquids, gases or dust. Electrical products create sparks which may ignite the dust or fumes.
- Do not expose adapters to rain or wet conditions. Water entering an adapter will increase the risk of electric shock.
- Do not abuse the power cord. Never use the power cord to carry the adapter or to pull the plug from an outlet. Keep the cord away from heat, oil, sharp edges or moving parts. Replace damaged power cords immediately as they increase the risk of electric shock.
- Check for loose screws often.
- **WARNING:** Make sure the power switch of the solar lantern is in its 'OFF' position and that the adapter is unplugged from its electrical outlet before performing any inspection, maintenance or cleaning procedures.

Troubleshooting a Portable PV System

Issue	Causes	Solutions
<p>Battery only lasts a few hours</p>	<ol style="list-style-type: none"> 1. Solar panel is dirty or in shade 2. Bad Connection 3. Cloudy day 4. Old battery 5. Battery misuse 	<ol style="list-style-type: none"> 1. Clean the solar panel. Move the panel so that it is not in shade. 2. Check all wiring connections. 3. Recharge the battery on sunny days. 4. Test and replace battery. 5. Test and replace battery.
<p>Lamp does not work</p>	<ol style="list-style-type: none"> 1. Not switched on 2. Bad connection 3. Incorrect wiring 4. Lamp broken 	<ol style="list-style-type: none"> 1. Switch on the lamp. 2. Check all wiring connections. 3. Check positive and negative connections. 4. Replace lamp.
<p>Dim light</p>	<ol style="list-style-type: none"> 1. Solar panel not charging properly (dirt, shade) 2. Bad connection 3. Battery misuse 	<ol style="list-style-type: none"> 1. Clean the solar panel and check if it is not shaded during charging. 2. Check the connections. 3. Test the battery and replace it if it no longer works.

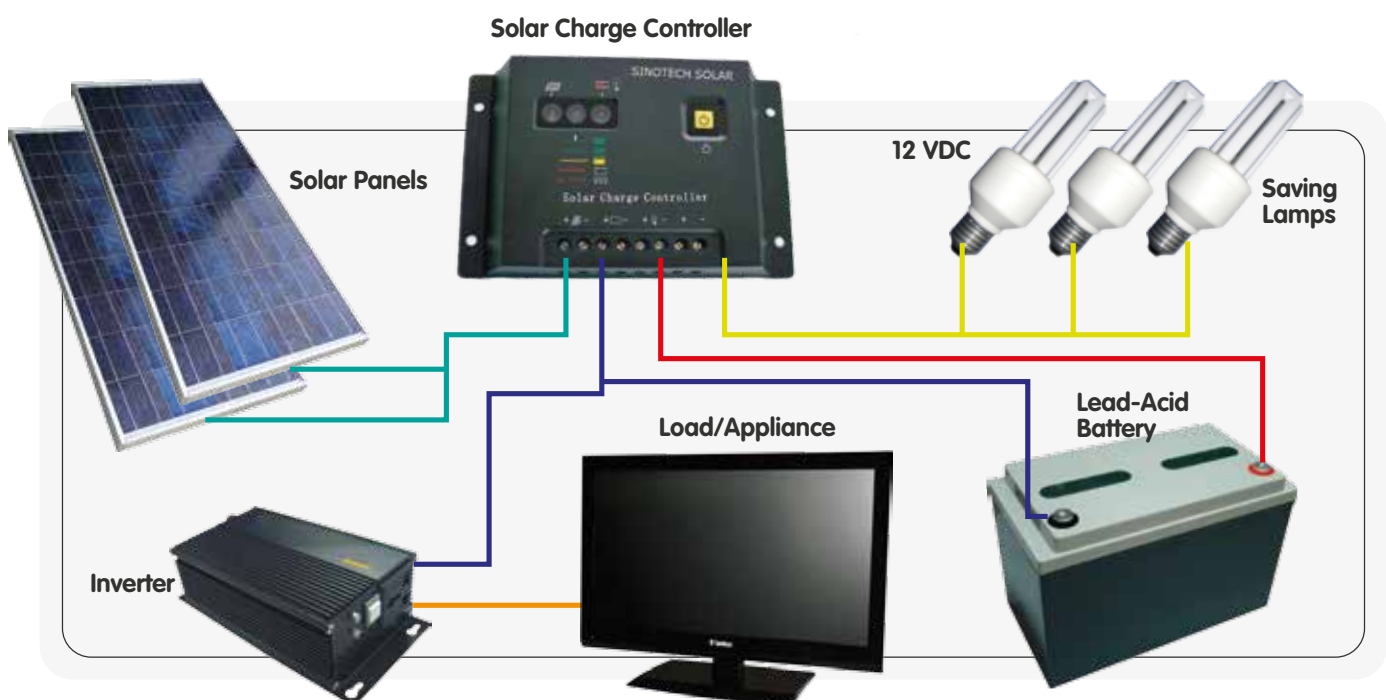
Solar Home Systems (Plug & Play)

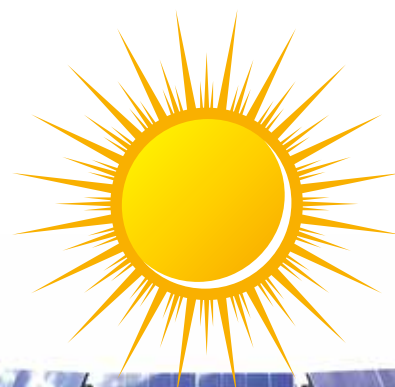


These tend to be Pico PV Systems up to 500W in capacity.

Components of the System

- Solar Panel - Converts sunlight to electricity
- Battery (s) - Store electricity
- Charge Controller - Manages the flow of electricity between the solar panel battery and load
- Inverter - Converts DC power from the solar panel and battery to AC power.
- Load - Application for electricity, e.g. lights, computer, radio, TV
- Wires - Connect the other various components together

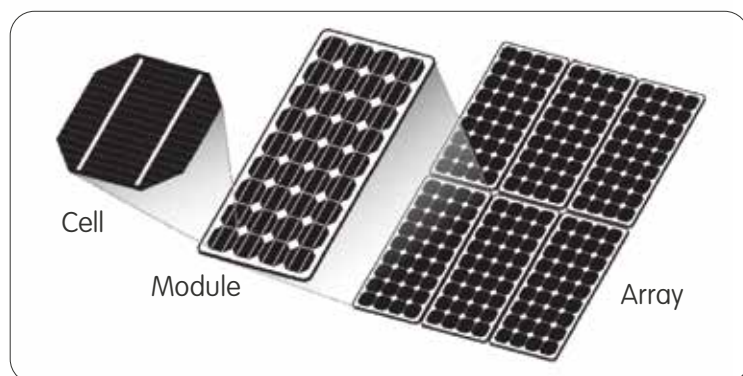




Solar Panel (Solar Module)

The solar panel produces electricity when there is sunlight by converting it into DC. Photovoltaics (PV) or solar cells are the building blocks of solar panels. They are made of semiconductor materials and convert sunlight into direct current (DC) electricity.

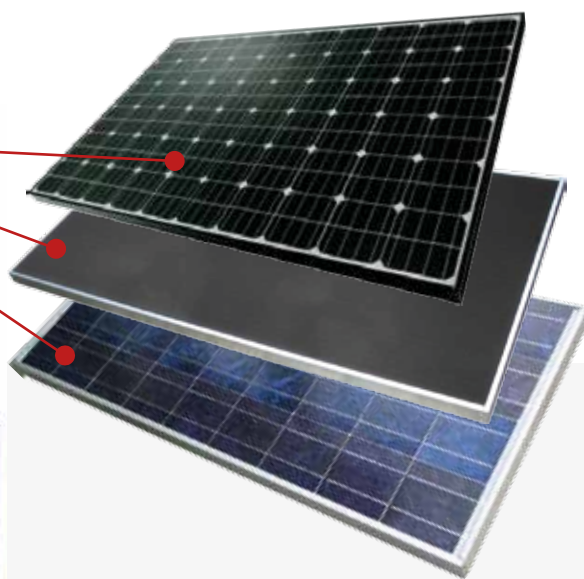
- Every solar panel has a rated power output.
- The rated output of the panel is determined by the voltage and current that the solar panel can produce.
- Generally, solar panels produce electricity at either 12 or 24 volts.
- The amount of current the solar panel produces determines the amount of power the solar panel produces.



Different Types of Solar Panels



Monocrystalline
Amorphous
Polycrystalline



Testing & Certification of the Solar Panel

To ensure product quality the solar panel has to be tested and checked for certification by recognised boards, for example:



SAZ standards for PV: ZWS 322:1993: Applies to terrestrial photovoltaic modules used for converting solar radiation into electric energy and is limited to mobile applications producing up to a maximum of 300 V. | ZWS 522:1999: Specifies the minimum requirements for batteries to be used in photovoltaic systems. ZWS 524:1998: Specifies the requirements for charge controllers which shall be fitted on all battery-based photovoltaic electric systems.

Testing Procedure for Solar Panel Output & Polarity

To test the **output** of a solar panel you use a multimeter. A multimeter can also be used in the testing of polarity.

Please refer to Appendix 1, page 50 for the **Basic Anatomy of a Multimeter**, and Appendix 1, page 51 for step by step instructions on **How to Test the Solar Panel's Output** and **How to Test the Solar Panel's Polarity**.

It is ideal to test the solar panel before purchasing and before installing to ensure the quality of the product.

Multimeters



Digital



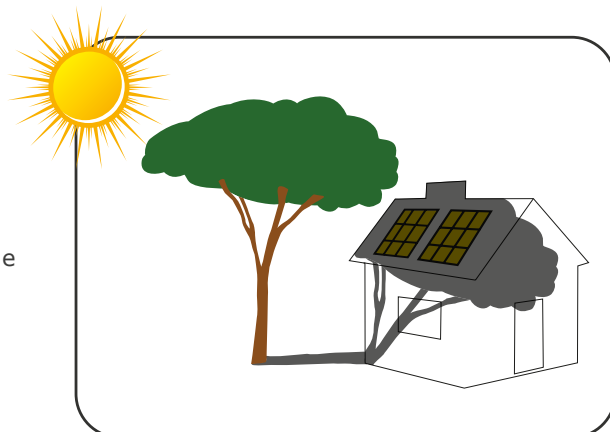
Analog

Care for the Solar Panel

1. Protecting Your Panel from Shade

When part of the solar panel is shaded wholly or partly, for example by tree branches and/or building shadows, it captures less energy from the sun.

Please refer to Appendix 1, page 52 for step by step instructions on **How to Check the Voltage on a Panel Affected by Shade.**



DO	DO NOT
<ul style="list-style-type: none"> • Make sure that all objects that might shade your panel are removed 	<ul style="list-style-type: none"> • Concentrate torch, electrical or fire light directly onto your solar panel as it may cause damage
<ul style="list-style-type: none"> • Make sure that ONLY direct sunlight falls on your panel 	

*** Artificial Light:**
 1. Light from a bulb or LED concentrated or focused on the panel using a mirror.
 2. Sunlight concentrated and focused on the panel using a mirror.

2. Cleaning Your Panel

The solar panel must be kept clean at all times.

DO	DO NOT
<ul style="list-style-type: none"> • Inspect your solar panel regularly for dirt such as dust or bird droppings. 	<ul style="list-style-type: none"> • Use soap or detergent.
<ul style="list-style-type: none"> • Clean your solar panel once every 3 months (or when dirty) using clean water and a soft cloth. 	
<ul style="list-style-type: none"> • Tilt the panel when installing to enable self-cleaning (as dirt/grime simply slides off) 	

3. Ensuring the Security of Your Panel

During installation, the solar panel must be firmly fixed to the roof of the house.

DO NOT
<ul style="list-style-type: none"> • Fix wire mesh around the solar panel as it is already secured during installation. The wire cast cast shadows that will cause the panel to produce less energy.

4. General Safety

The solar panel consists of a glass top which can easily break.

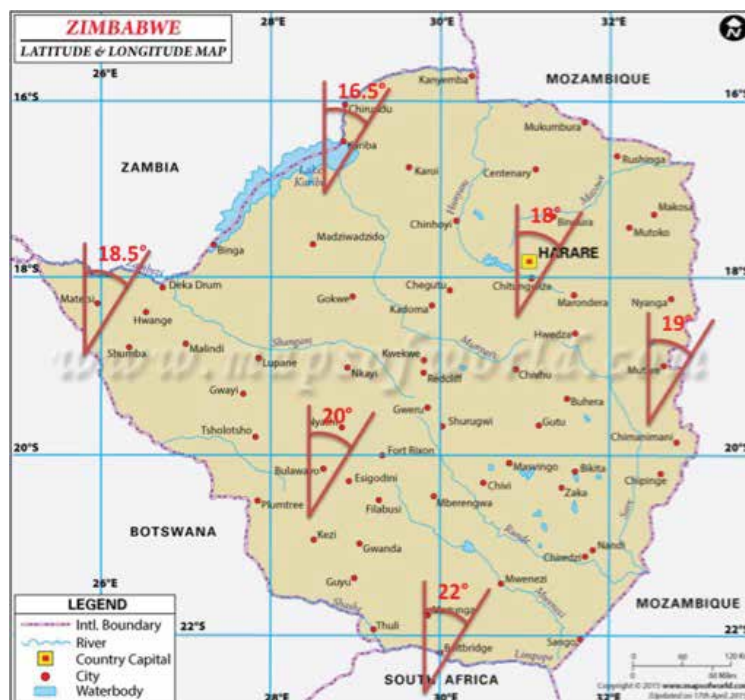
DO NOT



- Throw objects at the solar panel.
- Stand or step on the panel.
- Try to repair your solar panel if it breaks because once the panel is broken, **it cannot be repaired**.
- Carry out modifications on your system without technical guidance from your system supplier or a qualified technician.

How to Position the Solar Panel

- Once we know the solar resource, it is very important to mount the panel correctly so that we capture as much sunlight as possible.
- Solar panels produce the most electricity when they are perpendicular to the sun.
- Since the sun moves all day, it is not practical to keep moving the panel all day to keep it perpendicular to the sun.
- In general, the best average position for mounting the panel is tilted towards the equator (facing northwards) at an angle approximately equal to the latitude of the location.



Handling of the Solar Panel During Installation

- Make sure you read and understand the user manual which comes with each kit.
- Protect the solar panel, it should not fall or come into contact with hard surfaces during handling.
- Decide on where to mount the solar panel (on the ground or the roof).
- During wiring connections cover the solar panel.
- Make sure the wiring connections are secure (avoid naked wires).
- Make sure that positive and negative wires are connected correctly.

The Charger Regulator / Charge Controller

The solar charge regulator/ charge controller is a voltage and/or current regulator which is connected between the solar panel, the battery and the load. Its main job is to keep the batteries from overcharging and over discharging.



DO



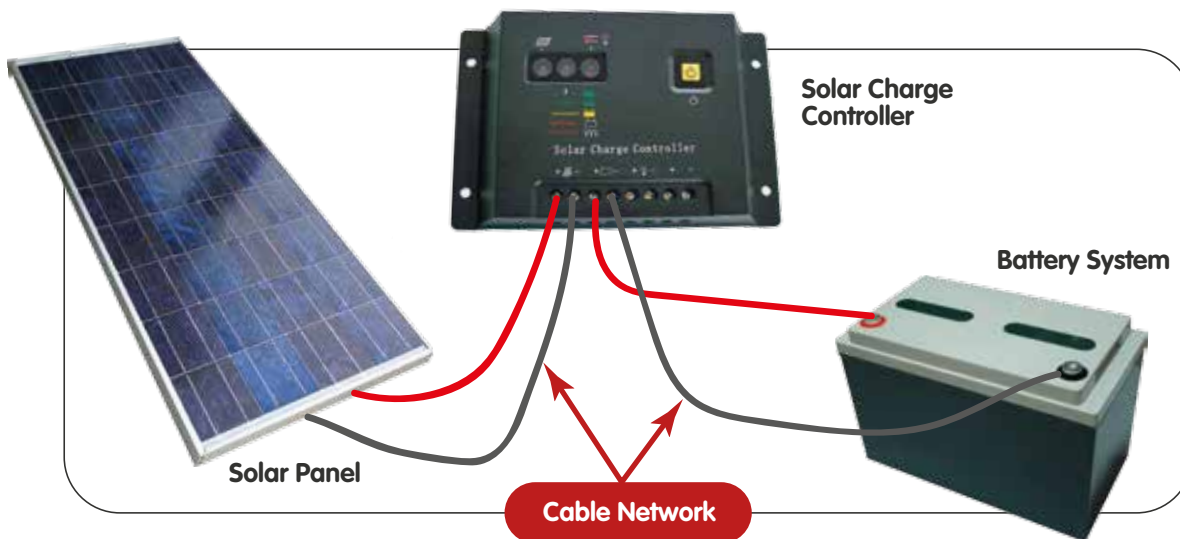
- Ensure connections are firm. In case of a problem, consult your solar installer or supplier.

DO NOT



- Tamper with the charge controller.
- Place it where water can penetrate.

Connecting a Charge Regulator / Controller to the Solar Panel



- Ensure that the collector (the solar panel) is shaded to avoid the danger of electric shock.
- Using the right tools, loosen the screws at the correct terminals, below the solar panel picture, as shown in the image below:



- Fit the positive electrical cable from the solar panel to the positive terminal of the charge controller.
- **Some have colour coding:**

RED is positive (+)

Connect the **Positive**
(Solar Panel) to the **Positive**
(Charge Controller)

AND

BLACK is negative (-)

Connect the **Negative**
(Solar Panel) to **Negative**
(Charge Controller)

Why Use a Charge Controller?



- It monitors the battery voltage
- It stops charging when the battery is fully charged
- It extends battery life
- It regulates power from the solar panels, protecting the battery from overcharging. Overcharging damages batteries and reduces battery life
- It prevents overly deep discharge which damages the batteries
- It protects your appliances and gadgets

Dangers of Bypassing a Charge Controller

Bypassing the charger controller will cause:

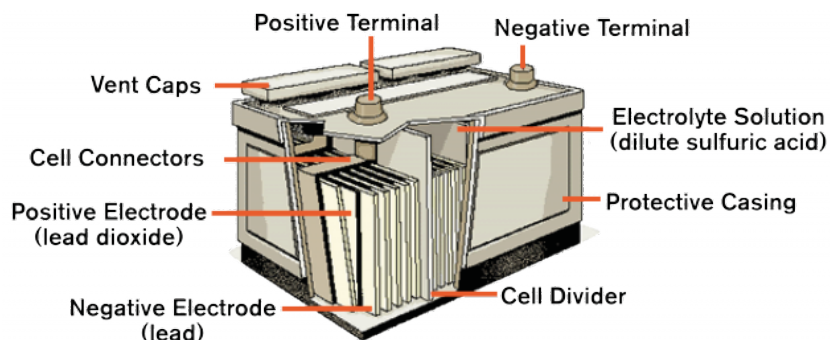
- damage of batteries because there is no regulation of power
- damage of electrical appliances

Care for the Cable Network

	DO NOT 
<ul style="list-style-type: none"> • Inspect the cable network every 3 to 5 years to ensure there are no exposed wires. 	<ul style="list-style-type: none"> • Try to make connections when you are not sure. Seek expert advice and help.
<ul style="list-style-type: none"> • Protect your solar wiring from damage as this can result in the failure of your system. 	
<ul style="list-style-type: none"> • Avoid short-circuiting your cables as this can lead to system damage. 	

Solar Batteries

Solar batteries store electrical energy generated by the solar panels. They are available in various forms and designs depending on the use and also on the maker.



Types of Batteries

Flooded Type

- This is a lead acid type battery.
- While these are good batteries, this type **needs to be stored outside of your home** or in an area with lots of air as they emit gas and can be dangerous in your home if not handled carefully.
- This type of battery is economical and will last for years if maintained properly.
- The most popular brands of this type of battery are **Trojan**, **Surrette** and **Deka**.
- Make sure to ventilate this type of battery if in an enclosure.



Gel Type

- This type of battery does not have vents and will not emit gas so it is safe to use indoors.
- Being able to use it where the temperature is at a constant is definitely a plus because it helps the battery to perform better and last longer.
- Although this is a good battery for solar applications, it takes a low charge to recharge which may cost you more.



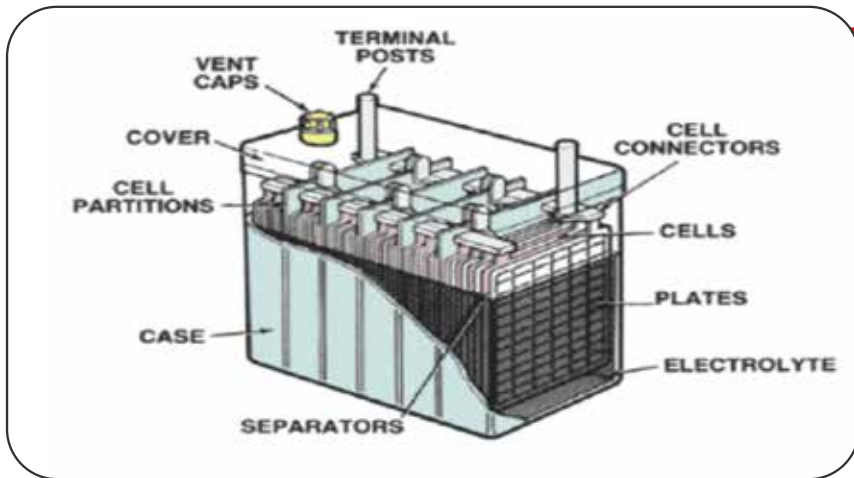
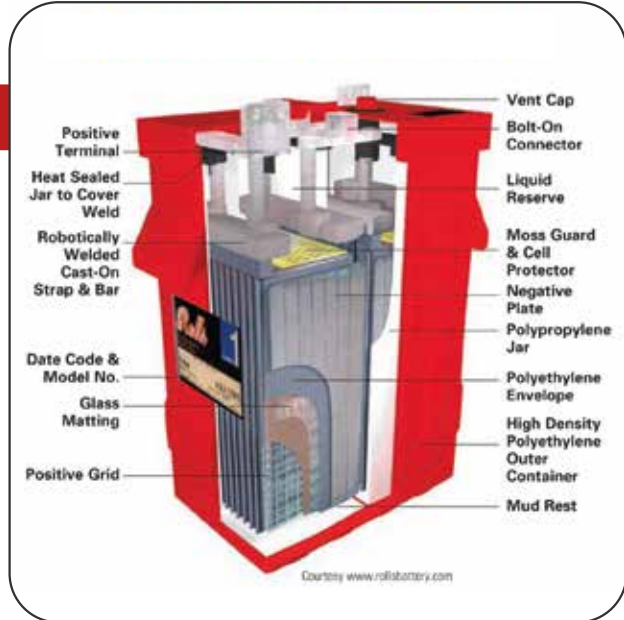
Absorbed Glass Mat (AGM) Type

- This type of battery has a woven glass mat in between cells to help sustain charging longer.
- This type is considered by most solar users to be the best as it holds charges for longer and the battery lasts longer.
- They are leak proof, spill proof and do not emit gas, making them the safest and most easy to maintain.
- Even though this type is more expensive it is worth it.
- These types of batteries are used in airplanes, hospitals and remote communication centres.
- The most sought after brand of this type are the **Sun Xtender** and **the Concorde**.



Dissected Batteries

Flooded Type



Gel Type



Absorbed Glass Mat (AGM) Type



Why Not Use the Car Battery?

- Its capacity is too small for continuous charging so they would not last very long.
- It might seem like a good idea in the beginning because of cost, but you'll pay for it in 9 months or so.
- Car type batteries discharge too quickly and don't last very long. In addition, after they get discharged to a certain extent they don't work well at all.



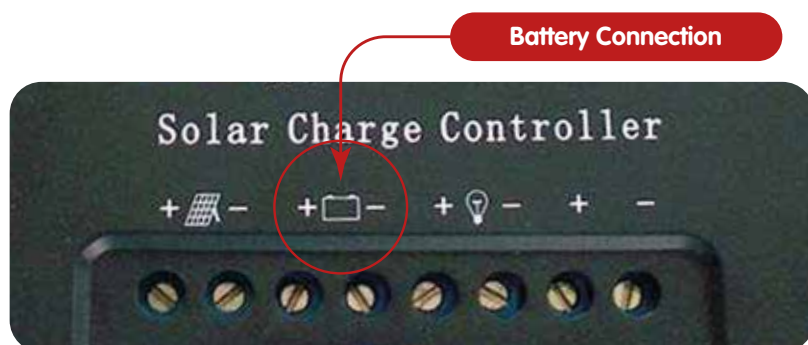
Conclusion: DO NOT USE CAR BATTERIES ON YOUR SOLAR SYSTEM

Battery Testing

Please refer to Appendix 1, page 52 for step by step instructions on **Battery Testing Using a Multimeter**.

Connecting a Battery to a Solar System

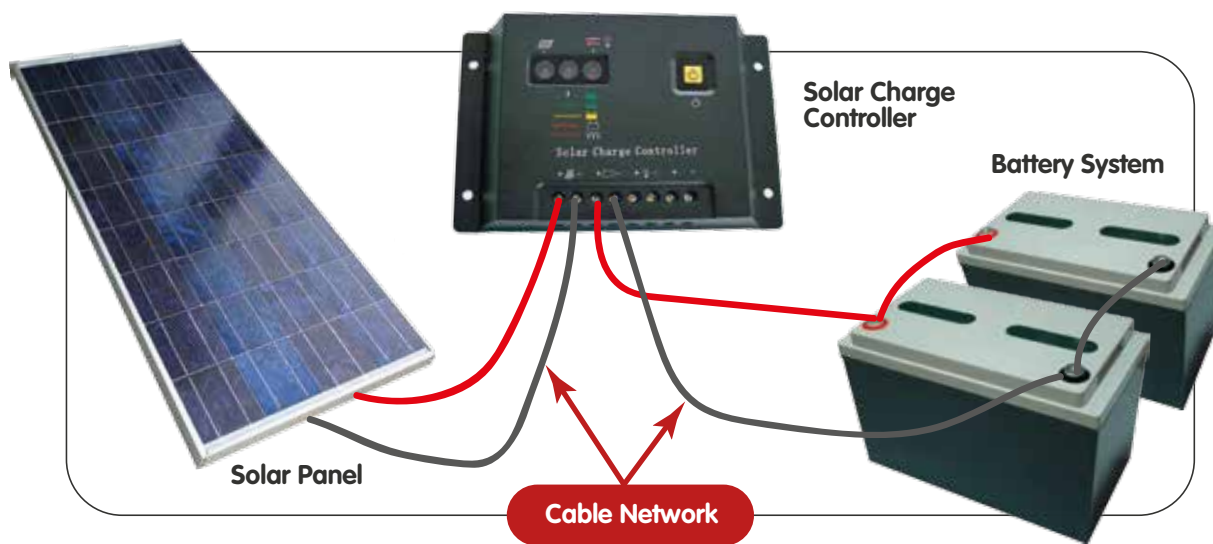
- **Before you begin the process of connecting**, please ensure that the panel is shaded/covered (no sunshine reaching the collector) to avoid danger of electrical shock.
- Using the right tools, loosen the screws for the battery connections on the battery section as indicated by the arrow in the image below:



- Fit the cable to the positive terminal of the charge controller and to the positive terminal of the battery.
- Fit the cable to the negative terminal of the charge controller and to the negative terminal of the battery.

The connections are displayed on the diagram on the next page.

Battery Connection Diagram



- Ensure that the fitted cables are secured tightly onto the terminals and that there are no naked wires.

Troubleshooting a Solar Battery

Issue	Causes	Solutions
<p>Battery only lasts a few hours</p>	<ol style="list-style-type: none"> 1. Solar panel is dirty or in shade 2. Bad Connection 3. Cloudy day 4. Old battery 5. Battery misuse 	<ol style="list-style-type: none"> 1. Clean the solar panel. Move the panel so that it is not in shade. 2. Check all wiring connections. 3. Recharge the battery on sunny days. 4. Test and replace battery. 5. Test and replace battery.

DO

- Keep the solar battery in a clean environment.
- Place the solar battery on a stable surface to prevent it from falling or tilting.
- Keep the solar battery safely inside a well-ventilated wooden box.
- Always check the level of electrolyte in every cell of your battery. If the level has gone down, add some distilled (or de-ionized) water.
- Top up the solar battery with distilled water from a good source, never use tap or rain water since they have impurities which may damage your battery.
- Apply Vaseline, not grease or oil, onto both battery terminals to prevent acid mist (a white substance) forming on them.
- Clean the terminals and battery's top surface regularly with hot water to prevent accumulation of acid mist which causes batteries to self-discharge.

DO NOT

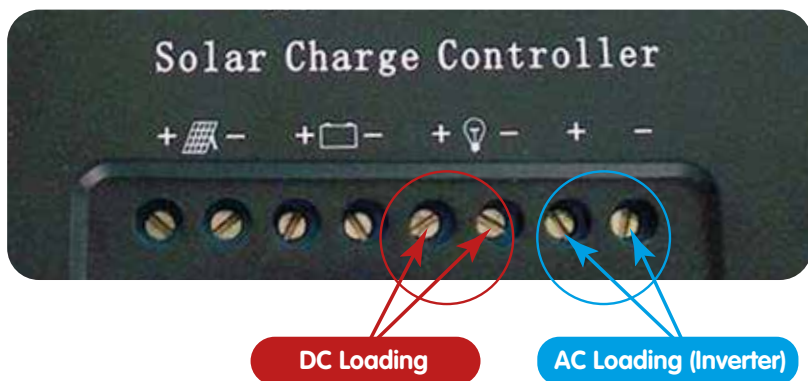
- Short-circuit the terminals of your battery. Your solar battery stores huge amounts of energy. If you connect the terminals directly, the stored energy will be released in one go, causing the wires to melt or fire to start. All power must be consumed through the installed regulator. This will protect your solar battery for a long time.
- Pour out the acid and fill with fresh acid as it damages the battery.
- Add acid to your solar battery at ANY time.
- Accept advice on battery repairs from unauthorized persons. Rather, contact battery suppliers directly.
- Keep the solar battery near open flames as there is danger of explosion.
- Take your old batteries for repair.

Inverter

- Used when there are AC loads to be used in the solar system.
- It converts DC from the batteries to AC.

Connecting the Inverter

- The inverter is connected to the charge controller at the terminals indicated in the image below (+) and (-).
- The terminals are loosened and the cable from the inverter is fitted with the same polarity:



Comparison of AC & DC

In electricity generation there are two distinct types of electricity which are **direct current electricity (DC)** and **alternating current electricity (AC)**.

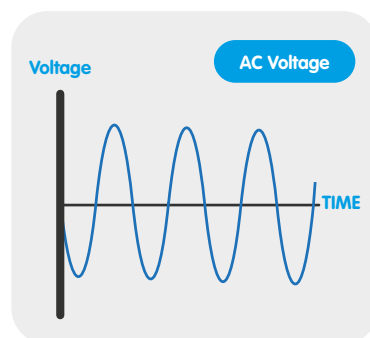
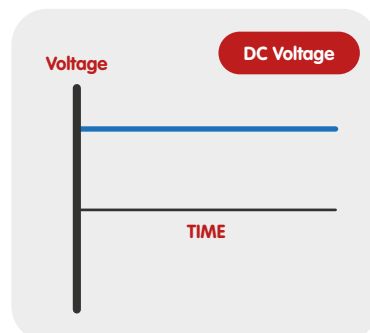
Direct Current (DC) is used mostly in houses that are not connected to the grid, and are running with batteries.

Alternating Current Electricity (AC) is the type of current most commonly used in households that are connected to the grid to power electrical appliances (for example TVs, refrigerators, radios, lighting and many others).

Loading or the Load

- This is where the electrical energy is to be used.
- Solar energy can power both DC and AC appliances or gadgets.
- **DC loads include:**
 - Radios
 - Light bulbs
- **AC Loads include:**
 - Refrigerators
 - Televisions
 - Computers

A bad installation can cause problems to the entire electrical system.

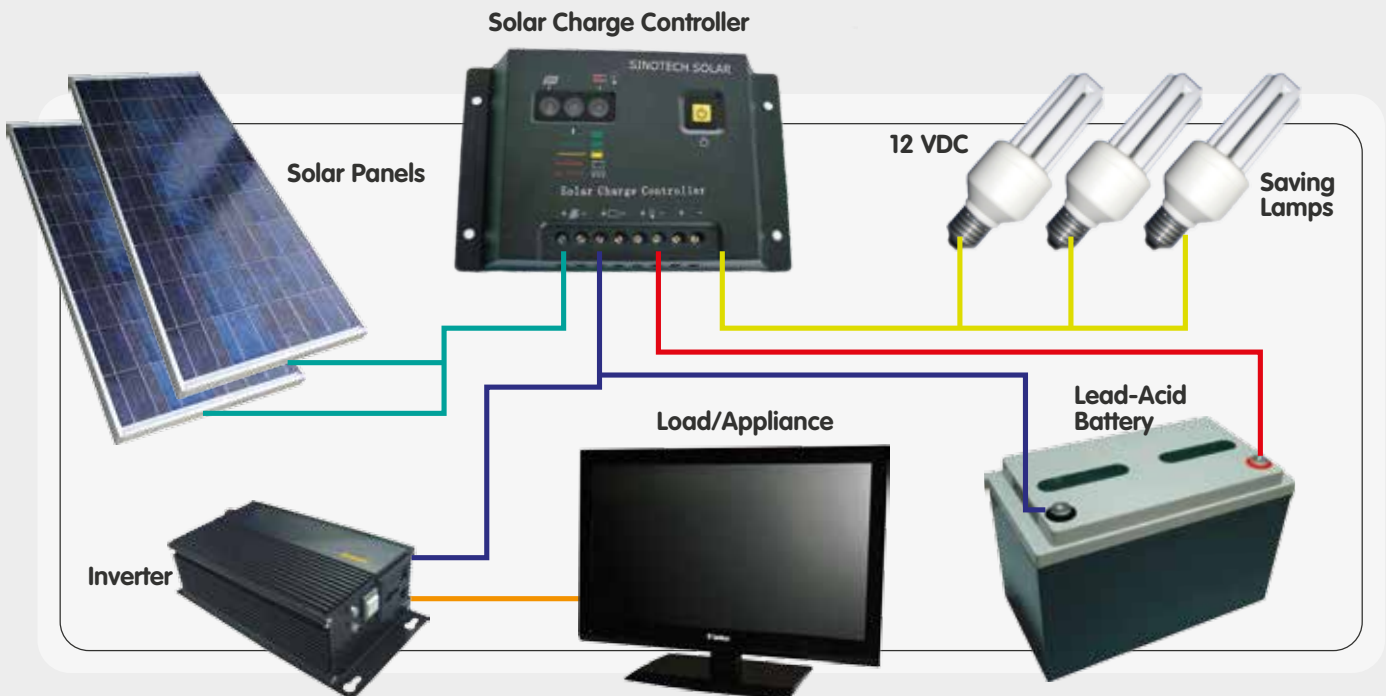


Visual Representation difference between AC & DC

On some electrical devices DC and AC Voltage are represented by signs as follows (these are the signs that are used on most multimeters to indicate the two voltages):



A Summary of the Complete Solar System



- Goal
- Radiation is converted into electrical energy (as DC) by the solar panels.
 - The solar panels are connected to the charge controller so as to regulate the battery charging.
 - Power is distributed from the charge controller to the inverter and also to DC loads.
 - The battery is also connected to the charger controller and the inverter.
 - AC loads are then connected to the inverter.

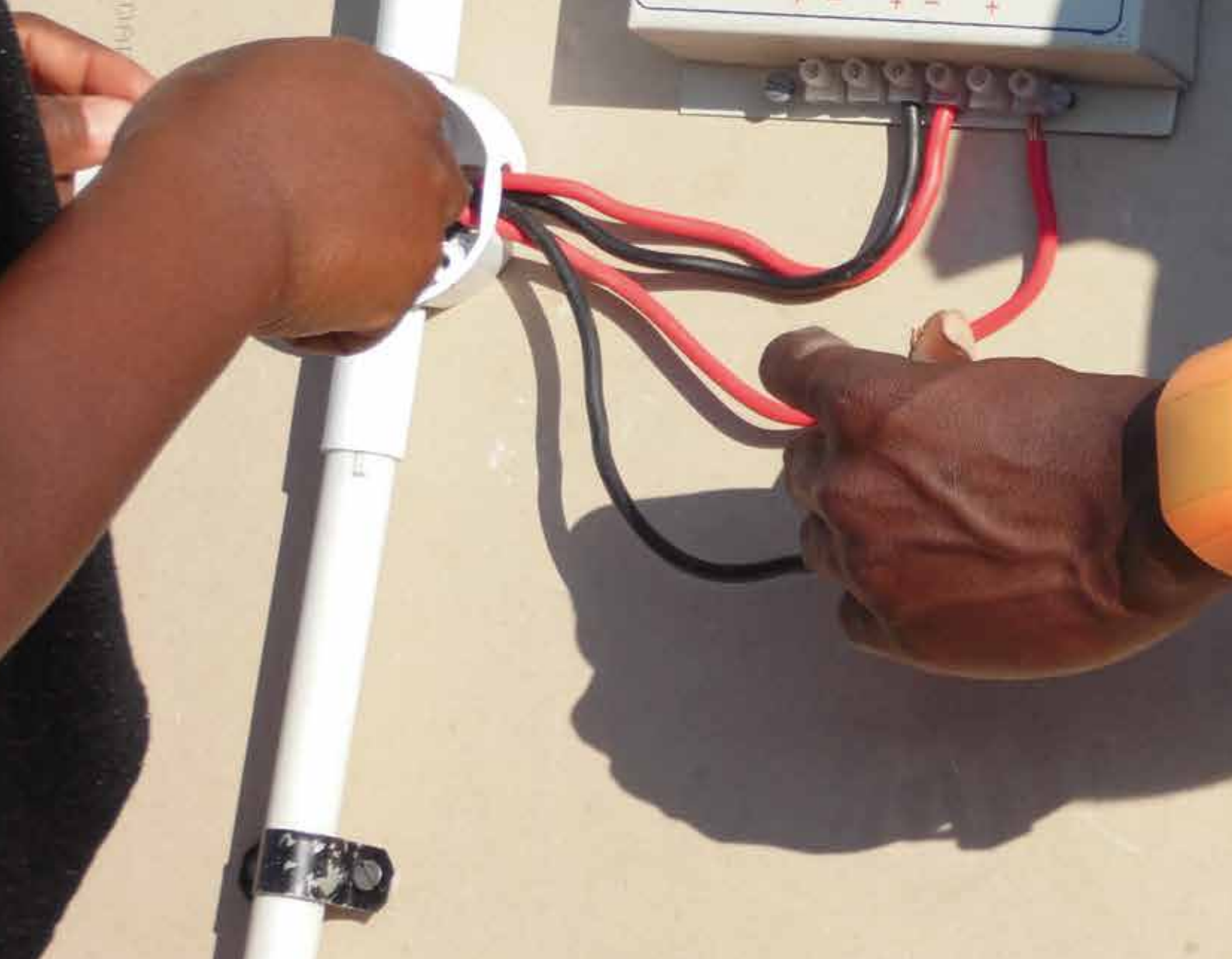
The Solar Charge Controller thus forms the **CENTRAL UNIT** of the entire Solar System - **protecting the whole system.**

ECO-SPEL MFLER



LEIFERHAGE

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SECTION 3:

Basic System Sizing: Practical Exercises

In this Unit:

Worksheet 1: Systems Loads

Worksheet 2: Battery Sizing

Worksheet 3: Array Sizing

Worksheet 4: Charge Controller Sizing

Worksheet 5: Inverter Sizing

Worksheet 6: Wire Sizing

Useful Information:
Typical Power Ratings on
Selected Appliances & Gadgets

Answers to Worksheets

General Troubleshooting Notes



Worked Example

Design a Stand Alone PV System for the following household electrical appliances:

- 29 Inch Colour TV
- Multichoice Decoder
- 2×15 W light bulbs

Location:
Mutare

Geographical Coordinates
19.0°S, 32.7°E

Answers**Page 41 - 44****Worksheet 1: System Loads (Practical)**

Use this worksheet to determine the total amp-hours per day used by all the loads in your system.

Step 1

Calculate your AC loads. If no AC loads, skip to **Step 2**.

1. List all AC loads, wattage and hours of use per week in the spaces below. Add up all the watt-hours per week to determine AC watt-hours per week (can also be done per day).

Description of Load Watts x Hrs/Wk = WH/WK

Line 1

Line 2

Line 3

Line 4

Line 5

Total AC watt-hours per week: _____

NOTE: Wattage of appliances can usually be determined from tags on the back of the appliance or from the owner's manual. If an appliance is rated in amps, multiply amps by operating voltage (120 or 240) to find watts.

2. Actual AC watt-hours per week:

Multiply *line 1* by **1.15** to correct for inverter loss. _____

3. Inverter DC input voltage:

Usually 12 or 24 volts. This is DC system voltage. _____

4. Divide *line 2* by *line 3*.

This is total amp-hours per week used by AC loads. _____

Step 2

Calculate your DC loads (Loads which use Direct Current)

5. List all DC loads in the spaces below.

Description of Load Watts x Hrs/Wk = WH/WK*Line 6*

Line 7

Line 8

Line 9

Line 10

Total watt-hours per week: _____

6. DC system voltage. Usually 12 or 24 volts. _____

7. Total amp-hours per week used
by DC loads. Divide *line 5* by *line 6*. _____8. Total amp-hours per week used
by AC loads from *line 4*. _____9. Add *lines 7* and *8*. This is the total
amp-hours per week used by all loads. _____10. Divide *line 9* by 7 days. _____**This is the total average amp-hours per day.****NOTES**

Worksheet 2: Battery Sizing

Use this worksheet to determine what size battery is required for your system.

1. Total amp hours per day required from **Systems Load Worksheet**, *line 10*. _____
2. Maximum number of continuous days of cloudy weather expected in your area during one year. (5 to 10 days in most areas) _____
3. Multiply *line 1* by *line 2*. _____
4. Divide *line 3* by **0.8** to maintain a 20% reserve after deep discharge period. If no special condition, skip to *line 10*. _____
5. Select the multiplier below which corresponds with the batteries' wintertime average ambient temperature. _____

Battery Temperature Multiplier

Battery Temperature °C	Multiplier
26.7	1.00
21.2	1.04
15.6	1.11
10.0	1.19
4.4	1.30
-1.1	1.40
-6.7	1.59

6. Multiply *line 4* by *line 5*. This is your optimum battery size. _____
7. Amp-hours of battery chosen (i.e. L16 is 360 amp hours). _____
8. Divide *line 6* by *line 7*. This is the total number of batteries in parallel required. _____
9. Round off to the next highest whole number. _____
10. Divide the system voltage by the battery voltage. _____
11. Multiply *line 9* by *line 10*. _____

This is the total number of batteries required.

Worksheet 3: Array Sizing (Solar Panel Sizing)

Use this worksheet to figure out the total number of solar panels required for your system.

1. Total average amp-hours per day from the Systems Loads Worksheet 1, *line 10*.

2. Multiply *line 1* by **1.2** to compensate for loss from battery charge/discharge.

3. Average sun hours per day in your area.

4. Divide *line 2* by *line 3*. This is the total solar array amps required.

5. Optimum or peak amps of solar module used. See module specifications.

6. Total number of solar modules in parallel required. Divide *line 4* by **5**.

7. Round off to the next highest whole number.

8. Number of modules in each series string to provide DC battery voltage.

DC Battery Voltage	Number of Modules in Each String
12	1
24	2
36	3
48	4

9. Multiply *line 7* by *line 8*.

This is the total number of solar modules required.

Worksheet 4: Charge Controller Sizing

A charge controller with a higher current rating than the PV System's maximum load current should be selected.

1. System voltage (usually 12 or 24V). _____
2. Divide *line 5* in Worksheet 3 by *line 1*. _____
3. Round up the result in *line 2* to the nearest 10. _____

This is the required amperage for the charge controller

Worksheet 5: Inverter Sizing

Most inverters have a DC to AC conversion efficiency of 85%.

1. PV Array Rating (*line 5* of Worksheet 3). _____
2. Divide Line 1 by Inverter Efficiency (0.85). _____
3. Round up the result in *line 2* to the nearest 10. _____

This is the required rating for the inverter

NOTES

Worksheet 6: Wire Sizing

A wire sizing chart is used to determine the wire size for a solar system.

It must be noted that voltage losses in the table are theoretical, calculated using Ohm's Law. As such the state of wires must be considered.

Wire Sizing Chart

Voltage loss per 100m of wire run (volts per 200m of wire)			
Flow (Amps)	Wire Cross Section (mm ²)		
	1.5	2.5	4.0
0.1	0.21	0.14	0.08
0.2	0.43	0.27	0.17
0.3	0.64	0.41	0.25
0.4	0.86	0.54	0.34
0.5	1.07	0.68	0.42
0.6	1.29	0.81	0.51
0.7	1.50	0.95	0.59
0.8	1.72	1.08	0.68
0.9	1.93	1.22	0.76
1.0	2.15	1.35	0.85
2.0	4.29	2.70	1.69
3.0	6.44	4.05	2.40
4.0	8.58	5.41	3.38
5.0	10.73	6.76	4.23
6.0	12.87	8.11	5.08
7.0	15.02	9.46	5.92
8.0	17.16	10.81	6.77
9.0	19.31	12.16	7.62
10.0	21.45	13.51	8.46

USEFUL INFORMATION: TYPICAL POWER RATINGS

Appliance	RATING IN WATTS
Cellphone Charger	10
Laptop	45
Desktop PC	240
17"flat screen monitor	70
Inkjet printer	250
Desk fan	60
Fridge 12 cu. Ft	280
Fridge-freezer 20cu. Ft	420
Solar energy saving fridge	5
Hair dryer	1000
Fan heater	2000
Halogen spot heater	1000
Iron	1000
Steam iron	1500
Kettle	2000
Light bulb – energy saving	11
Light bulb –flourescent	60
Light bulb – incandescent	60
Microwave oven – small	900
Photocopier	1600
Radio	15
Sewing machine	75
Shaver	15
TV – 15" LCD	50
TV – 20" LCD	80
TV – 24" LCD	120
TV – 32" LCD	200
DVD Player	80
Decoder	25
Toaster	1200
Freezer - upright	250
Water heater – immersion	1000

NB:

It is best to measure each appliance's power demand or to use its rating. These figures are guidelines only for initial project analysis.

Worked Example Answers

Worksheet 1: System Loads (Practical)

Step 1

Calculate your AC loads. If no AC loads, skip to **Step 2**.

1.

Loads	Quantity	Watts	Hrs/day	Watt-hrs /day
29 Inch Colour TV	1	110	4	480
Multichoice Decoder	1	15	4	60
Total		125		540

2. Actual AC watt-hours per week:

Multiply *line 1* by **1.15** to correct for inverter loss.

$$540 \times 1.15 = 621$$

3. Inverter DC input voltage:

Usually 12 or 24 volts. This is DC system voltage.

$$12V$$

4. Divide *line 2* by *line 3*.

This is total amp-hours per week used by AC loads.

$$621 \div 12 = 51.75 \text{ Ah/day}$$

Step 2

Calculate your DC loads (Loads which use Direct Current)

5.

Loads	Quantity	Watts	Hrs/day	Watt-hrs /day
Fluorescent Lamp 15 W	2	30	4	120
			4	
Total		30		120

6. DC system voltage. Usually 12 or 24 volts.

$$12V$$

7. Total amp-hours per week used by DC loads. Divide *line 5* by *line 6*.

$$120 \div 12V = 10 \text{ Ah/day}$$

8. Total amp-hours per week used by AC loads from *line 4*.

$$51.75 \text{ Ah/day}$$

9. Add *lines 7* and *8*. This is the total amp-hours per week used by all loads.

$$10 + 51.75 \text{ Ah/day} = 61.75 \text{ Ah/day}$$

10. Divide *line 9* by 7 days.

$$61.75 \text{ Ah/day}$$

Worksheet 2: Battery Sizing

1. Total amp hours per day required from **Systems Load Worksheet**, *line 10*.

61.75 Ah/day

2. Maximum number of continuous days of cloudy weather expected in your area during one year. (5 to 10 days in most areas)

3 days

3. Multiply *line 1* by *line 2*.

$61.75 \times 3 = 185.25$

4. Divide *line 3* by **0.8** to maintain a 20% reserve after deep discharge period. If no special condition, skip to *line 10*.

$185.25 \div 0.8 = 231.563$

5. Select the multiplier below which corresponds with the batteries' wintertime average ambient temperature.

1.04

6. Multiply *line 4* by *line 5*. This is your optimum battery size.

$231.563 \times 1.04 = 240.825$

7. Amp-hours of battery chosen (i.e. L16 is 360 amp hours).

100

8. Divide *line 6* by *line 7*. This is the total number of batteries in parallel required.

$240.825 \div 100 = 2.408$

9. Round off to the next highest whole number.

3

10. Divide the system voltage by the battery voltage.

$12 \div 12 = 1$

11. Multiply *line 9* by *line 10*.

$3 \times 1 = 3$ Batteries

Worksheet 3: Array Sizing (Solar Panel Sizing)

Use this worksheet to figure out the total number of solar panels required for your system.

1. Total average amp-hours per day from the Systems Loads Worksheet 1, <i>line 10</i> .	61.75 Ah/day
2. Multiply <i>line 1</i> by 1.2 to compensate for loss from battery charge/discharge.	$61.75 \times 1.2 = 74.1$
3. Average sun hours per day in your area.	7
4. Divide <i>line 2</i> by <i>line 3</i> . This is the total solar array amps required.	$74.1 \div 7 = 10.586$
5. Optimum or peak amps of solar module used. See module specifications.	5.5
6. Total number of solar modules in parallel required. Divide <i>line 4</i> by 5 .	$10.586 \div 5.5 = 1.925$
7. Round off to the next highest whole number.	2
8. Number of modules in each series string to provide DC battery voltage.	1
9. Multiply <i>line 7</i> by <i>line 8</i> .	2 Solar Modules

Worksheet 4: Charge Controller Sizing

A charge controller with a higher current rating than the PV System's maximum load current should be selected.

- | | |
|--|--|
| 1. System voltage (usually 12 or 24V). | <u>12</u> |
| 2. Divide <i>line 5</i> in Worksheet 3 by <i>line 1</i> . | <u>$210 \div 12 = 17.5$</u> |
| 3. Round up the result in <i>line 2</i> to the nearest 10. | <u>20A</u> |

This is the required amperage for the charge controller

Worksheet 5: Inverter Sizing

Most inverters have a DC to AC conversion efficiency of 85%.

- | | |
|--|---|
| 1. PV Array Rating (<i>line 5</i> of Worksheet 3). | <u>210</u> |
| 2. Divide Line 1 by Inverter Efficiency (0.85). | <u>$210 \div 0.85 = 247.059$</u> |
| 3. Round up the result in <i>line 2</i> to the nearest 10. | <u>250W</u> |

This is the required rating for the inverter

System Trouble Shooting

Case 1

It has been sunny all day but there is not enough power in your solar battery.

Possible reasons:

- The television or radio may have been used during the day
- The lamps may have been left on during the day
- There could be some loose connections
- The panel may be faulty, dirty or shaded
- The battery may be old
- The electrolyte level in the battery could be low

Case 2

You were watching television and the rooms were well lit for several hours. Suddenly the television goes off and you are in total darkness.

Possible reasons:

- The charge regulator may have disconnected the loads because battery voltage was low.

Possible corrective measure:

- Check if the charge regulator shows "load off". If the blackout is due to the regulator, turn off the main switch. It will reconnect the power on its own when the battery is recharged.
- If the charge regulator is not responsible for the blackout and the lights and television do not function at all the next evening, contact your solar electric system supplier.

Case 3

There are frequent power blackouts.

Possible reasons:

- The solar electric system may be too small for your demands
- The solar battery may be very old
- The solar battery may be damaged
- There may be loose or corroded connections in your solar electric system
- The electrolyte level in your battery could be low

Possible corrective measures

- Contact your solar electric system supplier
- Reduce the load demands on your system
- Upgrade your system
- Check the electrolyte level and top up if low

Case 4

During the cold and cloudy seasons the power supply is lower than usual.

Possible corrective measure:

- Continue using the solar electric system but exercise greater conservation of power. The power supply will rise to normal when the sunny season resumes.

Case 5

The solar battery acquires full charge earlier than normal and blackouts still occur.

Possible corrective measures:

- Test the battery's state of self discharge and if high, replace with a new one
- If the problem occurs and the battery is in working order, the charge regulator could be faulty.
- Check battery terminals for a possible loose connection



FAQs

Frequently Asked Questions on Solar PV



Frequently Asked Questions

Q1. Where can I get the solar lanterns?

Answer: Solar lanterns are sold and distributed by various solar supplier companies such as D-Light, Barefoot, One Degree Solar, Sun Transfer, and Sunlar among many others. In most cases, the solar supplier companies have offices or sales executives in major towns. In other cases, suppliers use courier companies or deliver orders to towns that are nearest to their retailers.

Q2. Where do I find the suppliers? Do I need to travel far to buy stock?

Answer: You do not need to travel to their offices or their distribution centres in order to place your order. You can use their sales executives on the ground to place the order.

Q3. Who are the best suppliers? Which are the fast moving products in the market?

Answer: A good supplier is one who meets your needs within the shortest time. How fast a product moves will all depend on your: convincing power, marketing skills and avenues, positioning and networks and how well you understand your market and customers.

Q4. How do I deal with suppliers to ensure my orders are delivered on time?

Answer: Most suppliers will work hard to ensure you are served on time, and in case there is a delay, remember that they are only a call away.

Q5. How do I pay the suppliers when buying stock from them?

Answer: It is highly advisable that you pay for your order through the provided channels. Do not give cash to suppliers/agents on the ground.

Q6. How long should it take for the order to be delivered after I make the payment?

Answer: Most solar supplier companies will meet your order within 5 days.

Q7. In case delivery of the order takes longer than expected, how do I deal with the customers who keep asking for the lanterns?

Answer: Good customer care is important in such times. Understanding your customer, promising them what is possible, but also assuring them that you are taking care of their order is very important.

Q8. What are the wholesale prices of the various solar lanterns?

Answer: Most solar supplier companies will give you their price lists. They will give a wholesale price and a recommended retail price.

Q9. How do I price my solar lanterns to cover my costs and make a profit?

Answer: Solar Supplier companies will give a recommended retail price which guides you on the retail price and the margins. Ensure that you consider the following factors when you price: cater for the cost of the product, the expenses incurred to get the product to the customer and your profit margin.

Q10. How do I raise capital for the solar business?

Answer: Solar business is a business like any other. Capital for solar business is raised using sources that you have come across. These include: savings, donations from friends and relatives, loans among others.

Q11. If I were to get a loan from a financial institution to expand my solar business, what are some of the factors financial institutions would consider?

Answer: For you to access a bank loan to expand your business, your business must be bankable. It must meet the C 'S of Credit - Capacity, Capital, Character, Collateral, Cash Flow and Conditions.

Q12. Can I get the solar lanterns on credit and then pay after I have sold?

Answer: A few supplier companies will allow trade credit – where they supply portable lanterns on credit and allow you to pay them later. Most of them will have you pay before sending your order, making it very important for you to maintain a healthy cash flow in your solar business.

Q13. How do I market my solar lanterns?

Answer: There are many avenues that you can use to market solar lanterns. However, it is important to note that a market does not have to be physical. A market is a place with a buyer, a seller and a product, a place where a transaction can take place. This means that if a solar entrepreneur meets a potential buyer by a road side, it is a market. This makes personal selling a very effective way of selling solar lanterns. Different avenues can however be used to reach out to more customers:

- Self-help groups
- Institutions like schools and churches
- Financial institutions
- Using promoter model

Q14. How do I convince people to buy my solar lanterns whereas some have installed electricity?

Answer: It is always important to know the benefits of using solar energy in relation to other sources of energy. Ensure that you have the benefits at you finger tips. These include: low cost, readily available, green energy, no pollution. For example, during black-outs households using solar energy are well lit.

Q15. There are many types of solar lamps in the market, some are cheap - especially those from China. Why should I sell the ones that are more expensive?

Answer: Cheap at times can be very expensive. We advocate for products approved by Lighting Africa, a joint initiative of IFC and the World Bank that accelerates the development of markets for clean off-grid lighting products in Sub-Saharan Africa. These products have been tested over time. For these products, the supplier gives a warranty and in cases of default, the products can be returned and replaced during the warranty period.

Q16. How do I manage to maintain a healthy cash flow yet customers get the products on credit?

Answer: It is the work of the business manager to maintain a healthy cash flow for the business. Cash flow is the daily fuel that runs a business and without it, a business will die. Healthy cash flow enables a business person manage the daily operations of a business. Selling on credit denies a business the fuel to run the day to day operations of a business. If you keep selling all your solar lanterns on credit, you will soon be out of business.

Q17. How do I deal with solar lanterns that have been returned by customers because they are not functioning?

Answer: Most Solar Lighting Africa approved products are sold on a warranty. A warranty is a representation made by a seller or company to a purchaser of a product or service that a refund, repair, or replacement will be made if the product or service proves defective or unsatisfactory, especially within a given time period. This means that a solar lantern that does not function well within the warranty period can be returned to the manufacturer and replaced at no extra cost. The defect should however not be caused by the purchaser.

Q18. Do I have to keep records of all the solar lanterns I sell? Isn't it a very hard job?

Answer: Record keeping is an important aspect of the business. It is only through record keeping that an entrepreneur can tell the performance of their business.



APPENDIX 1

Additional Notes & 'How To' Tests

In Appendix 1:

Basic Anatomy of a Multimeter

How to Test Solar Panel Output

How to Test a Solar Panel's
Polarity

How to Check the Voltage on a
Solar Panel Affected by Shade

Battery Testing Using a
Multimeter

APPENDIX 2

Handy Pullouts

In Appendix 2: (Separate Booklet)

Complete Solar Home System

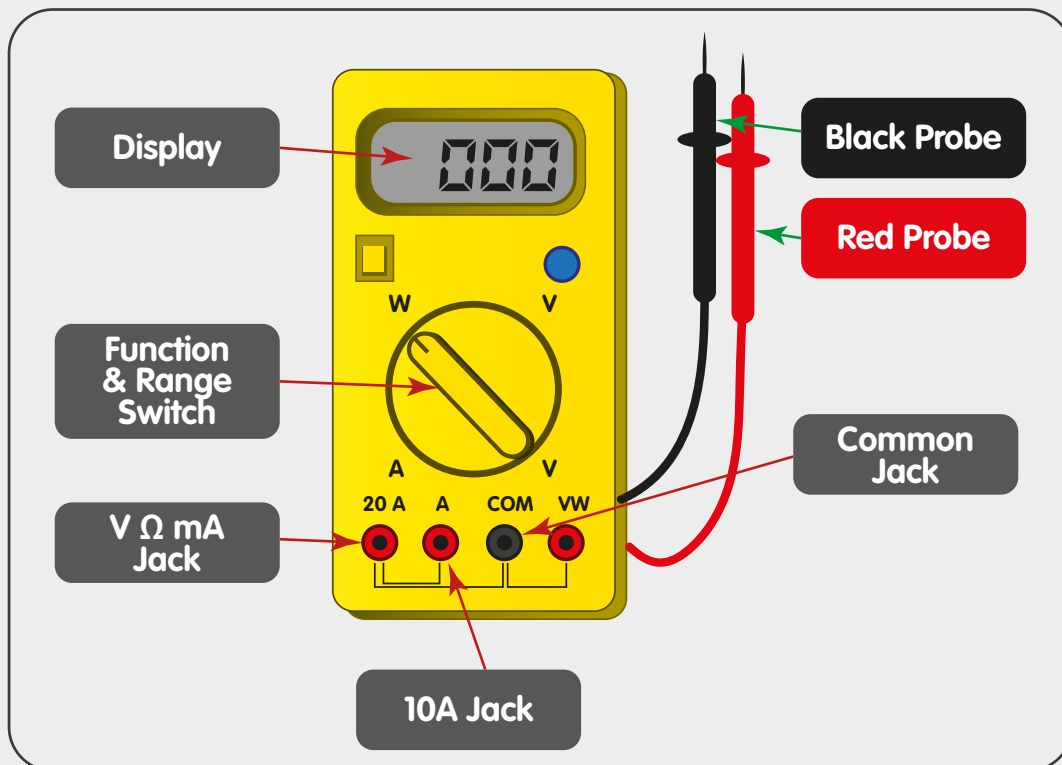
How to Care for Your Solar Panel

Solar Batteries

Safety During Installation, Operation &
Maintenance



i. Basic Anatomy of a Multimeter



Meter Leads

Red Meter Lead

- Is connected to voltage/resistance or amperage port
- Is considered the **positive** connection

Black Meter Lead

- Is always connected to the common port
- Is considered the **negative** connection

Probe (Black & Red)

- Are the handles used to hold tip on the tested connection

Tips

- Are at the ends of the probes and provide a connection point

Examples of Multimeters



Digital



Analog

ii. How to Test Solar Panel Output

Using a multimeter:

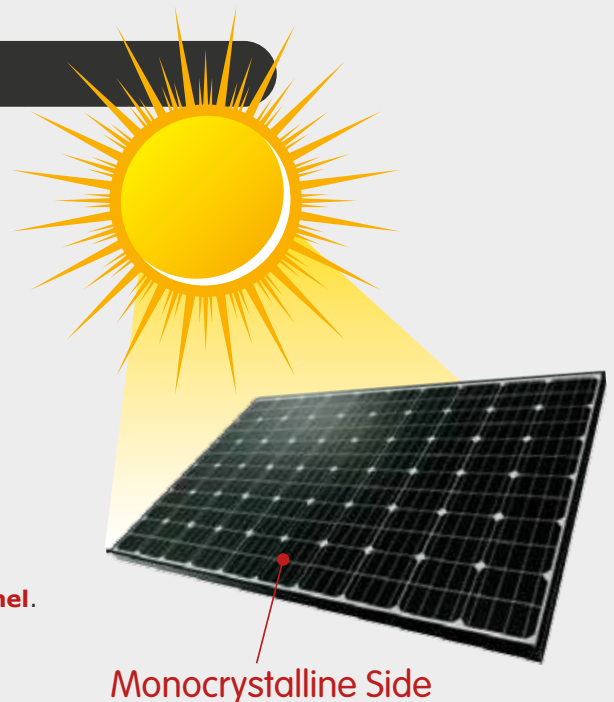
- Set the multimeter to the correct scale and voltage range.
Solar panels produce Direct Current (DC).
- Ensure that the collector is on a secured place, where there is enough sunshine.
- Connect the multimeter terminals to the positive and negative terminals of the solar panel.
- Read and note the voltage.
- Compare the **tested output** voltage with the output voltage indicated on the solar panel.
- If there is a difference in the values, **then the solar panel is not a good product.**

It is ideal to test the solar panel when purchasing and before installing it to the system.

iii. How to Test a Solar Panel's Polarity

In order to check the polarity of the solar panel:

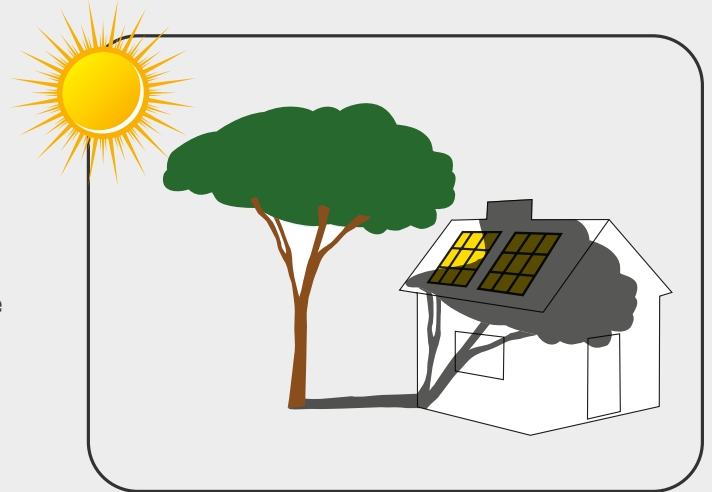
- Place the solar panel outdoors with the monocrystalline side facing up in a sunlit location.
- This will produce a test voltage for you to measure.
- Set the multimeter to the DC (direct current) voltage range capable of measuring up to 24VDC.
- Connect the positive side of the multimeter to one terminal of the solar panel and the negative side of the multimeter to the other side.
- If the reading is **positive, this is the positive side of the panel.**
- If the reading is negative, the terminal markings are incorrect and should be re-marked correctly.



iv. How to Check the Voltage on a Solar Panel Affected by Shade

This can be done using a solar water pump or using a multimeter:

- Ensure that the multimeter is at the correct scale and within the range of the solar panel's voltage.
- Place the collector in a position that it can receive maximum radiation.
- Connect the multimeter on the **positive** and **negative** terminals of the solar panel.
- Note the voltage and record it.
- Do not remove the multimeter from the terminals.
- Shade the solar panel, starting from one end to the other.
- Take note of the voltage change until the solar panel is fully shaded.



v. Battery Testing Using a Multimeter

- Use a multimeter.
- Set the multimeter to the correct scale (DC, direct current).
- Connect the multimeter to the positive and negative terminals of the battery.
- Read the voltage as indicated on the multimeter.





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