Solar Energy in Africa

DIY-Guide for Solar Home Systems

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Preface: Solar Home Systems (SHS) for villages in Africa

No mains power in the villages for a long time

It will still take ages before villages in Burkina Faso (BF) are connected to the electric grid. The situation is similar in many other African countries. The supply of cities and industry has priority. The power consumption in the villages is too low for a network expansion to be considered worthwhile, especially in dispersed settlements. It will take a long time before village people will be able to buy energy-intensive appliances (refrigerators, big screen TVs, etc.). The villages therefore are not a market for the providers of electricity; city and commerce have priority.

Solar Home Systems can bring electricity to the villages by promoting do-it-yourself initiatives to build SHS

A Solar Home System (SHS) provides electricity for lighting, mobile phone charging, radios and other small electrical appliances. It consists of a solar panel, a charge controller, batteries, cables, switches and connection sockets for small electrical appliances.

This is a small solar home system (SHS) of 20 watts for lighting, cell phone charging and charging rechargeable batteries for flashlights.

It is easy to build such an SHS yourself. If all components can be bought in the local market, as is the case in Burkina-Faso, you only need to know which size of component and which performance fit together and how to assemble them. *This small assembly manual will help you do it.*

First it describes how the parts are mounted, later what dimensions fit together (output of the solar module, battery capacity, etc.) and how everything works.

Pilot projects in Burkina-Faso

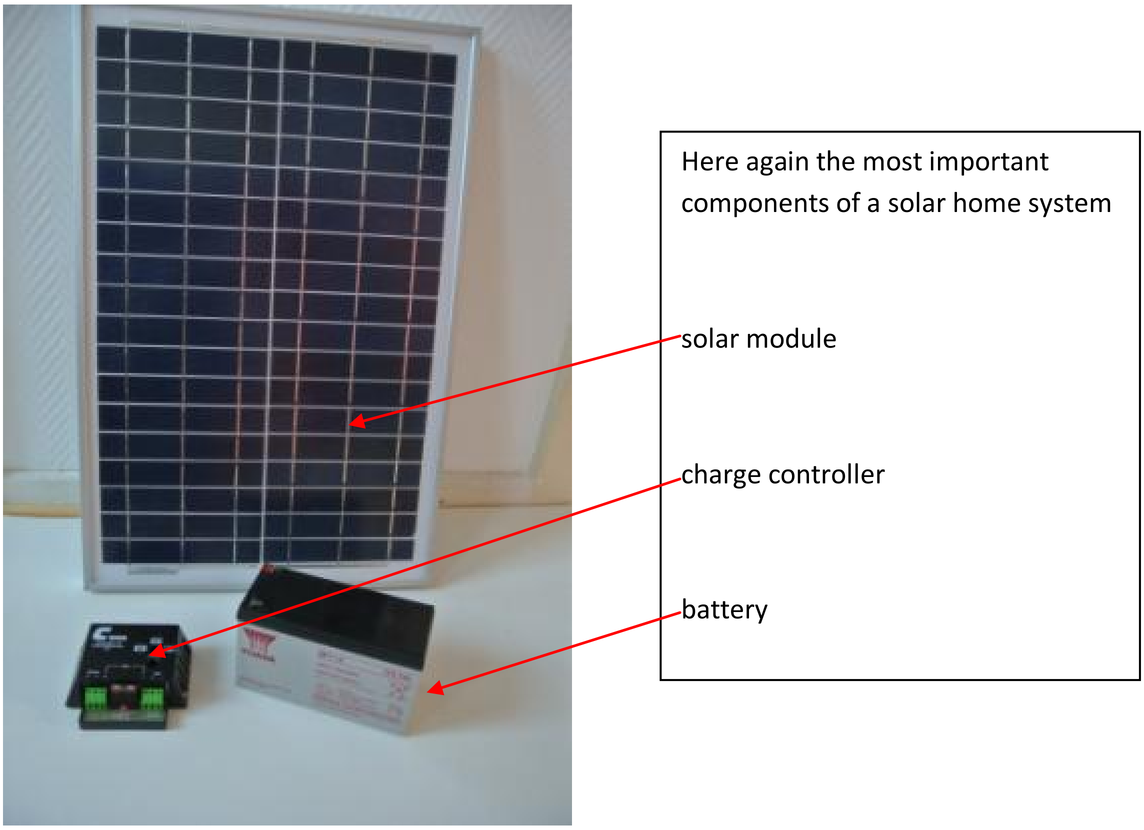
Trainees of the organic farm AMPO TONDTENGA at Ouagadougo learn to build solar home systems and take them to their villages. A project of Sahel e.V. This organic farm is the nucleus of the DIY-movement.

Street children in Bobo Dioulasso learn the basics of electrical installation and the construction of solar home systems in DORCASCENTER. A project of **Kinderhilfe Westafrika e. V**

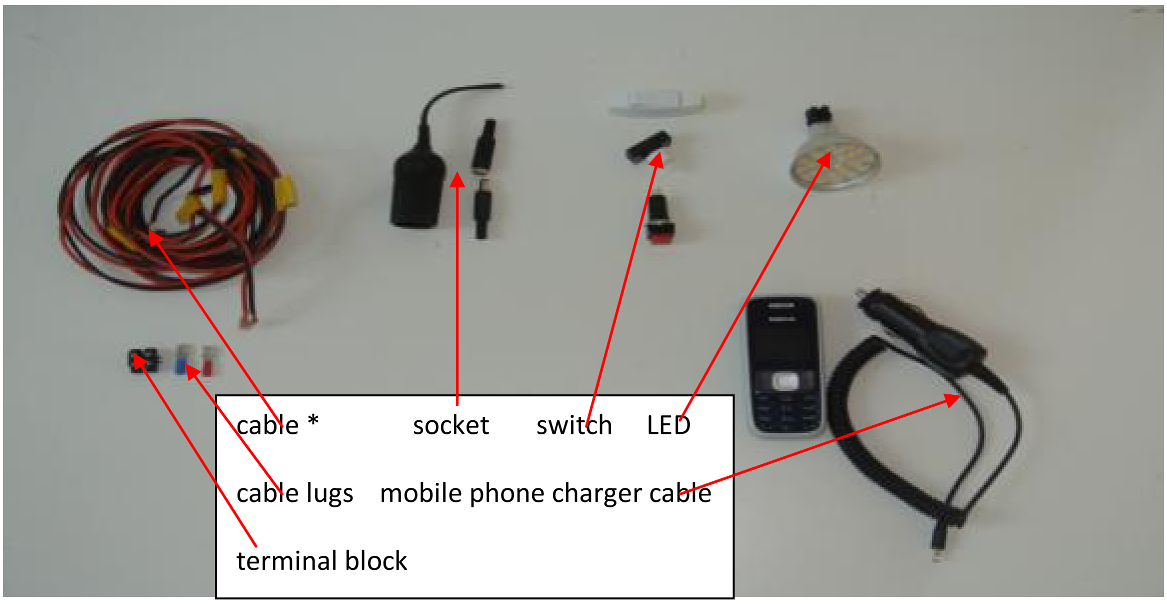
Young farmers from Gounghin, under the guidance of teacher Robert Quédraogo, build their own solar home systems. A project of **Lernen-Helfen-Leben e.V.**

1. Structure and connections of the solar home system (overview)

1.1. Solar module, charge controller, battery

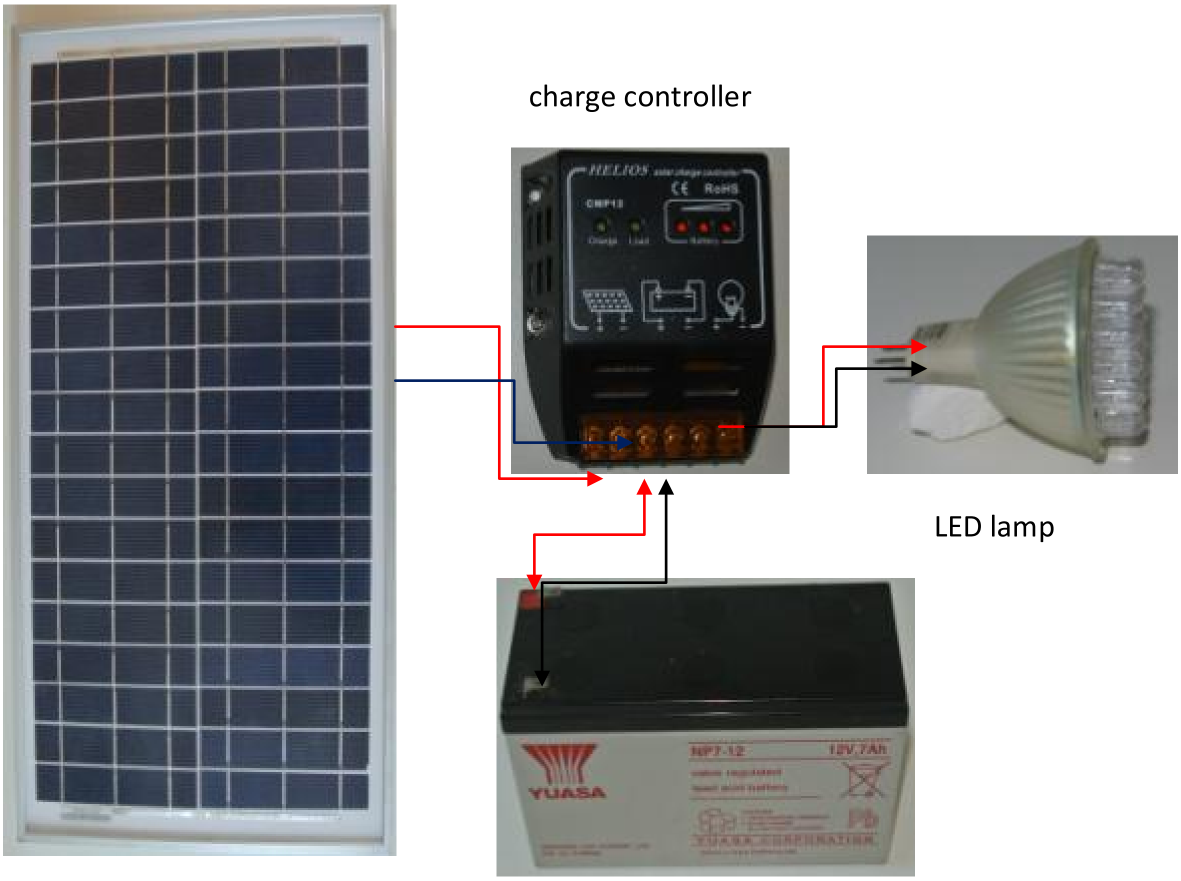


1.2 Other parts that are needed



* The cable connecting the solar module with the solar controller should be 2.5 mm thick and 5 m long; the cable to the light source should be 1 to 1.5 mm thick and 10 m long since the cables in West Africa are usually not made of copper but of an iron alloy. The stronger the cable, the better!

1.3. How a small solar home system works



The light falls on the solar panel and stimulates the production of electricity. Via the connecting cable (red for plus, black for minus), the current flows into the charge controller and from there to the battery. When a lamp is connected, the current flows back from the battery through the charge controller into the LED lamp, which is then lit up.

The **charge controller** is the heart of the solar home system. It prevents the battery from being overcharged and thus damaged. If the LED lamp and other small electrical devices consume power, the charge controller prevents the battery from being entirely discharged (deep discharge). That, too, would do serious harm to the battery.

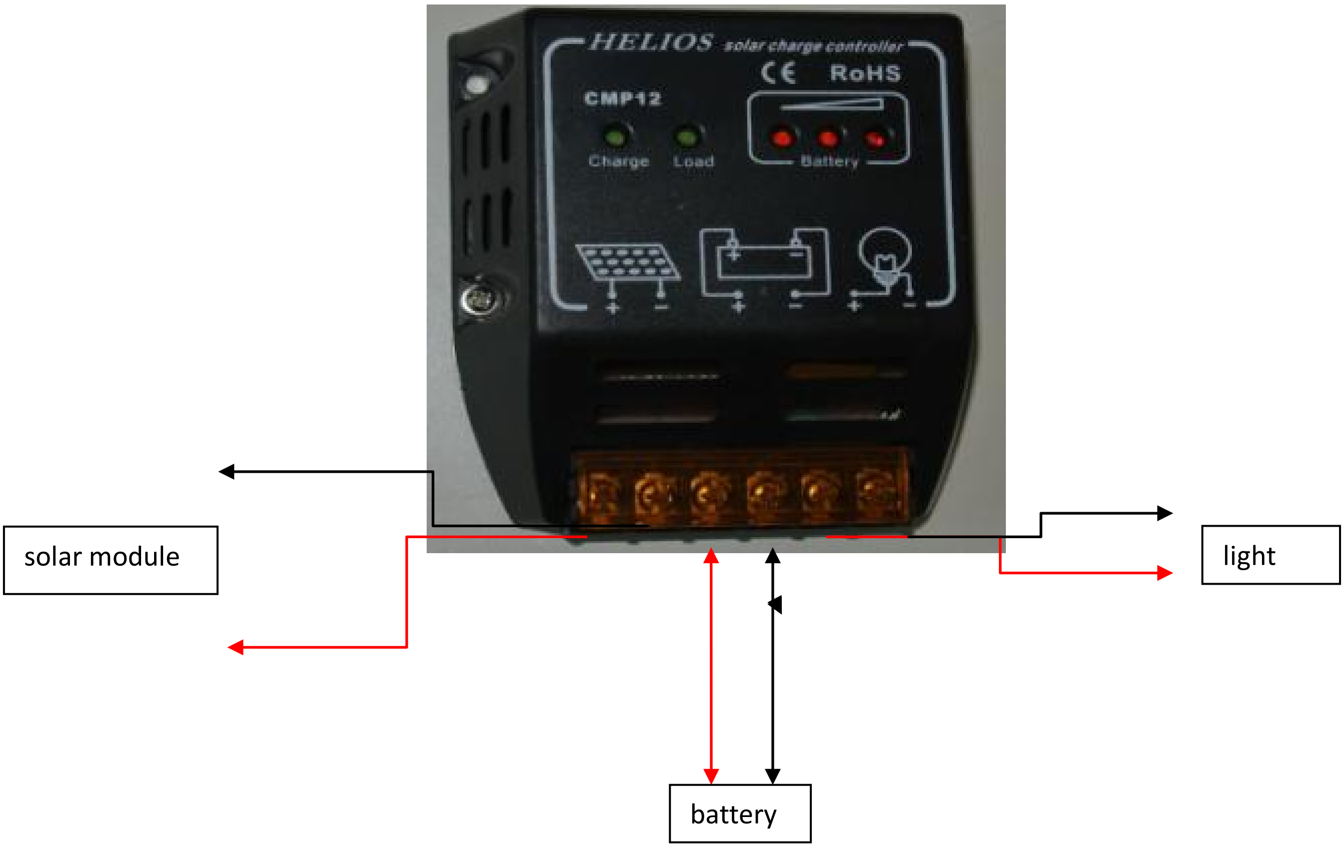
For all connections, make sure that the positive and negative contacts are at all times properly connected. In all parts of the SHS, "+" stands for plus and "- " for minus contacts. Usually red or brown cables are used for the plus connections, and black or blue wire for the minus connections. If other colours are used, they must be used consistently throughout the system for either plus or minus.

1.4 Different charge controllers

There are many different solar controllers on the market. Here are three of them:

Each charge controller comes with an instruction manual describing how it is connected to the solar module, the battery and the lamps etc.

The connections are marked by an icon or name and by plus and minus contacts. Here's an example:



Warning: In several West African markets controllers are sold under the name "Steca Solarix" **DIODE SOLAIRE** 60 W / 5 A. They are no charge controllers and do not protect the battery. They are counter-feits.

2. Assembly instructions for a Solar Home System

2.1 The beginning. What kind of solar module, charge controller and battery do I need?

The wattage of the solar module (W) determines how much power is available daily. An 80 W solar module generates more power than a 20 W module. Charge controller and battery capacity must be adjusted correctly to the performance of the solar panel.

The table in the appendix shows for solar panels from 10 to 80 W which solar controllers and batteries you need for which output. It also indicates for each solar module, how much power is available for daily consumption and which electrical appliances can be operated for how long (giving examples).

2.2 Construction of a casing

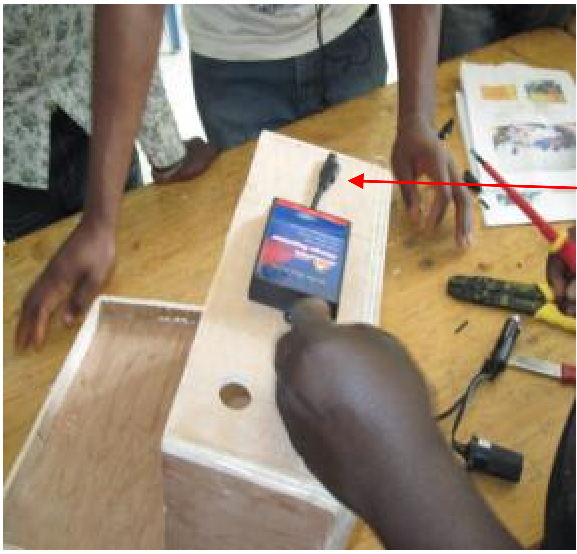
All components of a solar home system should be permanently installed in a casing to protect them against damage and to ensure easy use of cable connectors and switches.

To start with you should drill holes – using an electric drill or a hand drill - for the plug sockets, switches and the cable bushings. It is also advisable to drill some air holes for ventilation of the battery. Trapped heat will damage it.

All sorts of materials are suitable for making a casing, including larger calabashes with a wooden board as bottom. Number and size of the holes depend on the parts to be fitted. A small drawing before drilling will be helpful. The drawing will show where the charge controller, the connectors and the switches are to be fitted.

The casing should be covered with paint to protect it against moisture and mold.

2.3 Installation of the solar home system in the box

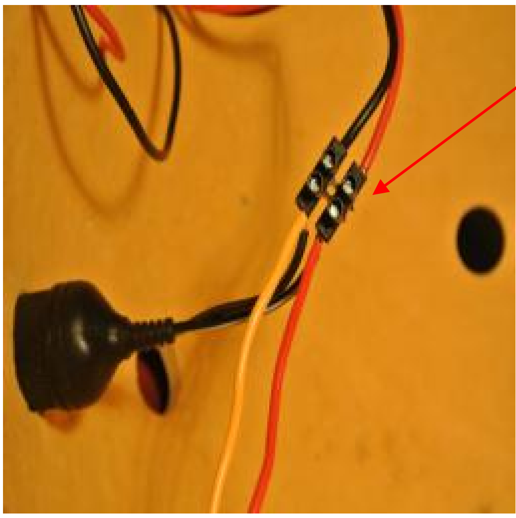


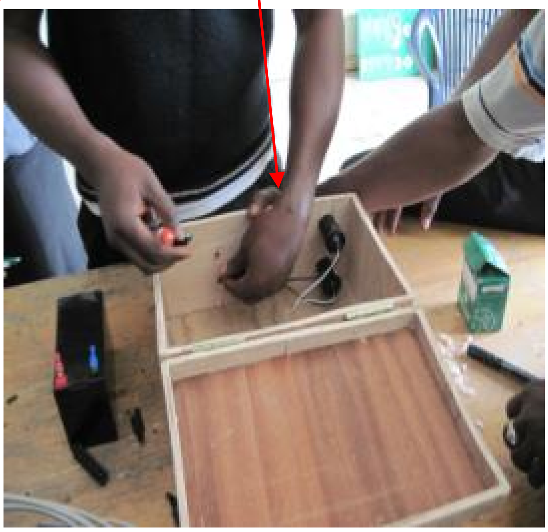
The charge controller is mounted on the outside.

The cable connection to the solar panel also remains outside.

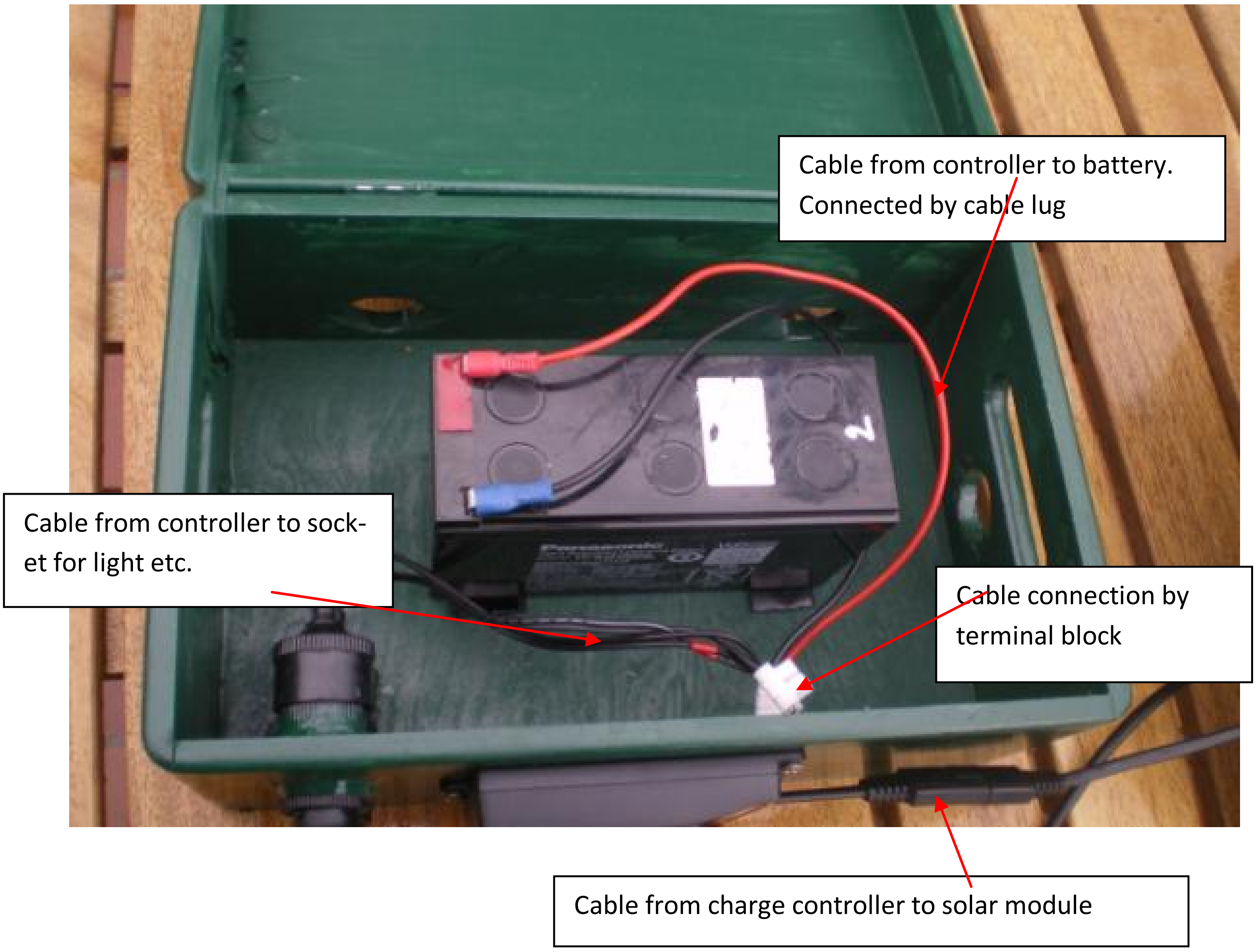
The cables from the solar controller to the battery and also to the sockets for light etc. are introduced into the casing through the previously drilled holes.

Connections are made by means of a terminal block.





This is what the connections look like:



This is the simple finished solar home system for lighting and charging of mobile phones

3. Smaller and larger solar home systems. What belongs together, how much power do the systems generate?

From the attached table you can see how to assemble your SHS. Considering that people in Africa do not have much money for making an SHS, the components shown in the table indicate the minimum equipment necessary from a technical point of view.

3.1 Explanation of some technical terms

For a correct understanding of the table and for competent shopping you should be familiar with some basic technical know-how. You should know what the terms watt (W), volt (V) and Amp (A) mean and what a direct current (DC) is versus an alternating current (AC).

Below you find a brief explanation:

Electric current consists of tiny electrically charged particles called electrons. When “assembled” in huge quantities and pressed under high pressure through a cable to a lamp, they produce light. **The pressure** which is exerted on the electrons, **is called voltage and is measured in volt (V)**. **The amount of electrons** which is pressed through a cable, **(i.e. the current) is measured in amperes (A)**. Multiplying V by A, we obtain **the power measured in watt (W)**, which this current can deliver to the consumers - lamps, radios, cell phones.

For example: a given **solar module** exposed to full sunlight generates a pressure/voltage of 17.88 volts on the electrons. The size of the solar module determines the quantity of electrons, i.e. 1.12 A. 17.88 (V) multiplied by 1.12 (A) is 20,03 W. The solar module is therefore a 20 W module.

You can find these data [maximum voltage (Vmp) - maximum current (Amp) and maximum power (Pm)] - on the label at the back of the solar module.

Solar modules with a voltage of about 18 V, are referred to as 12 V systems. If their voltage is twice as high, i.e. 36 V, they are known as 24 V systems. The classification as 12 V and 24 V systems is due to the fact that the corresponding batteries are either 12 V or 24 V batteries. The battery voltage therefore determines the designation of the module.

The performance of the solar module is dependent on its size (area). Therefore, Table 1 shows the dimensions (length x width in cm as well as m^2) for all solar modules. Their purchase should be based on these data. The value in m^2 is crucial.

On the market, the dimensions may vary slightly. Sometimes you find solar modules which are referred to as 20 W modules, but which are very different in size; up to twice the size. You should only buy a panel that corresponds to the size mentioned in the table, never a smaller one.

The description of a solar controller contains information about what voltage (V) and current in amperes (A) it withstands. These values must not be exceeded. A solar controller that can accommodate 12 V, must never be used in a 24 V system, unless it is designed for both

12 V and 24 V. If this is the case it is mentioned on the solar controller and in the data sheet. The stated amperage (A) must not be exceeded, either.

3.2 Battery characteristics, performance and service life

Batteries come as either 12 V or 24 V systems. The table only lists solar modules, charge controllers and batteries for a 12 V system. The amount of electricity (electrons) that a battery can store is measured in ampere-hours (Ah). A 7 Ah battery can emit the amount of 1 A current for seven hours. Converted to Watt this is 12 V x 7 Ah = 84 watts. This means that a 5 W lamp can produce light for about 16 hours. 84 Wh: 5 W = 16 h (hours).

3.3 Direct current (DC) versus alternating current (AC)

All parts of the SHS function as a DC system. **Direct current (DC)** means that the current flows in only one direction: from the solar module to the charge controller and from there to the battery. When a lamp is connected and switched on, the current continues to flow in one direction towards the lamp. Many electrical devices such as lamps, radios, cell phones can receive DC and operate with it. The connections of the appliances are marked accordingly. The marking on a lamp will therefore be: *12 V / 5 W*; at the current input of the device it will read: *input DC 12 V*.

For devices running on alternating current the DC must be converted into **alternating current (AC)**. With alternating current the current is constantly changing direction. The alternating current in our power system has a **voltage of 230 V**. You must never connect devices that only work with 12 V DC to an AC 230V power source. It would not work, the devices can be damaged.

3.4 Recommendation: DC and low-power devices save money

If you want to use an AC appliance in a 12 V SHS, an **inverter** must be connected to the battery. The inverter converts the battery's 12 V DC into 230 V AC. In this operation it consumes between 5% and 20% of the power (for more information on the inverter please refer to the box on the last page).

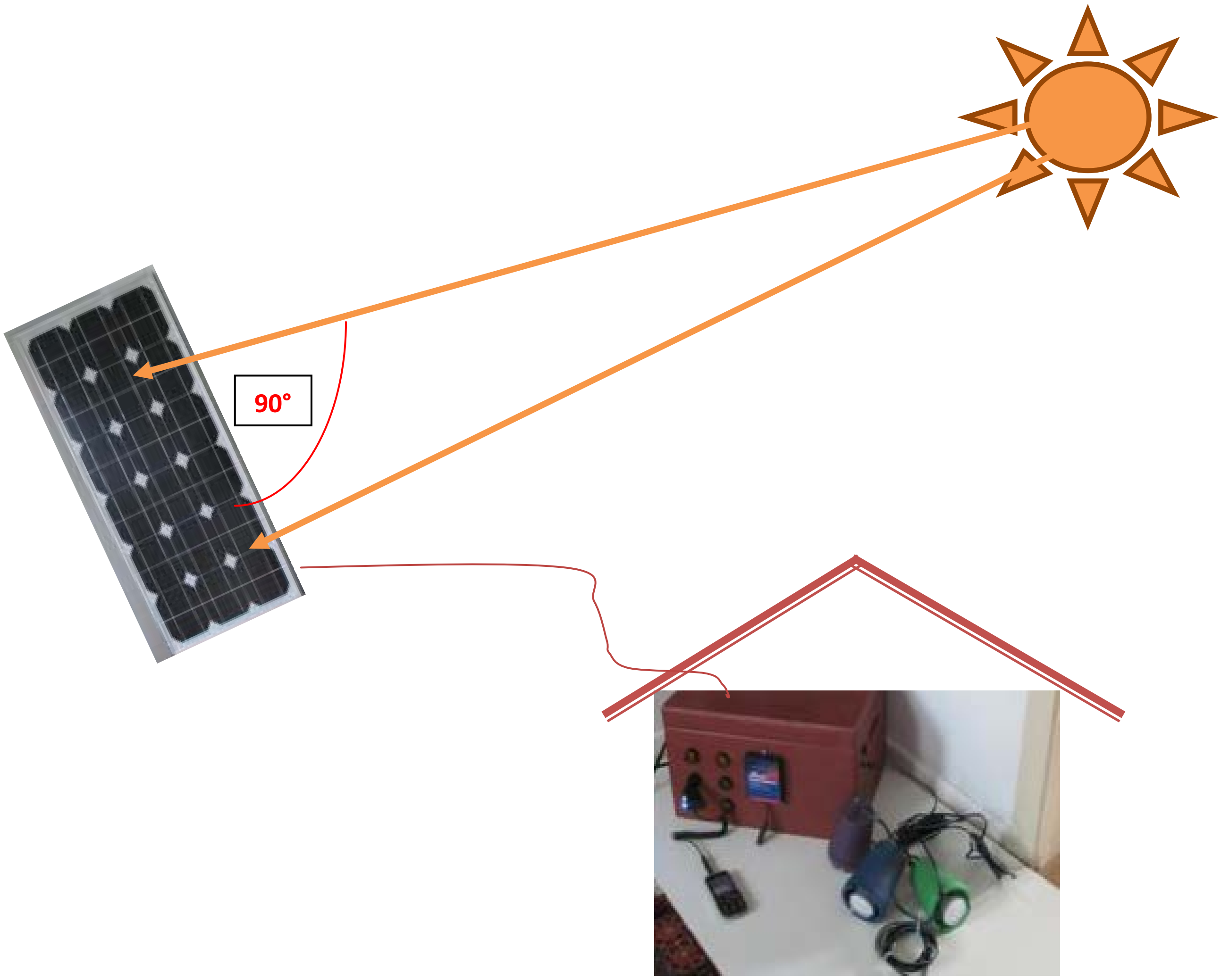
For this reason, it is best to use only devices that operate on DC power. Only if there is no other alternative an inverter should be used. But it makes only sense for an SHS using a solar module of 60 W or more. Another recommendation for small SHSs is to use energy-saving devices wherever possible. These include for instance LED bulbs instead of energy-saving lamps. When buying a radio you should ask for the power consumption and buy the radio with the lowest power consumption. There are also smaller energy-efficient TVs that consume only 25 to 30 watts per hour.

4. Some important points on the operation of solar home systems

The solar panel in the sun - the battery box in the shade (inside the house)

Orient the solar panel towards the sun (90 °), Make sure that no shadow (tree, house) falls on the panel; keep it free of dust; attach it firmly.

- Never put the battery box in the sun / protect it against moisture



Battery box always in the shade / the house

- Recharge the battery every day - all day long– with the solar module (light output depends on the daily duration of insolation; clouds and rain reduce the insolation and hence the light output of the lamps)

- Protect against theft (lock up at night)

Table: Performance of solar modules and charge controllers; battery capacity; total daily performance; potential consumption (with explanations)

Module power in Watt (W) Dimensions in cm/**m²**	Charge controller in Volt (V) / Ampere (A)	Battery capacity in Ampere hours (Ah)	Daily total output in watt-hours (Wh)	Consumption of individual devices in watt (W)	Total consumption of devices in watt hours (Wh)
1	2	3	4	5	6
10 W 31x29/**0,09**	12 V / 3 A	7/12 Ah	**42 Wh**	1 lamp (5 W) x 5 hours (h) 1 x mobile phone charging (5 W) 1 radio (1 W) X 7 h	25 Wh 5 Wh 7 Wh **37 Wh**
20 53x30/**0,16**	12 / 3	14/18	**84**	2 lamps (5 W) x 5 h (5 W) 1 radio (2 W) x 7 h	50 10 14 **74**
30 51x45/**0,23**	12 / 3	18/30	**126**	3 lamps (5 W) x 5 h 2 x mobile phone charging (5 W) 2 radios (2 W) x 7 h	75 10 28 **113**
40 54x53/**0,29**	12 / 3	28/40	**168**	4 lamps (5 W) x 5 h 3 x mobile phone charging (5 W) 2 radios (2 W) x 7 h	100 15 28 **143**
50 63x53/**0,34**	12/5	35/50	**210**	5 lamps (5 W) x 5 h 5 x mobile phone charging (5 W) 3 radios (2 W) x 7 h	125 20 42 **187**
60 81x54/**0,44**	12/5	42/60	**252**	5 lamps (5 W) x 5 h 5 x mobile phone charging (5 W) 3 radios (2 W) x 7 h 1 TV (30 W) x 2 h	125 20 42 60 **247**
70 90x55/**0,5**	12/7	50/70	**300**	5 lamps (5 W) x 5 h 5 x mobile phone charging (5 W) 3 radios (2 W) x 7 h 1 TV (30 W) x 3 h	125 20 42 90 **277**
80 100x55/**0,55**	12/7	56/70	**336**	5 lamps (5 W) x 5 h 5 x mobile phone charging (5 W) 3 radios (2 W) x 7 h 1 TV (30 W) x 4 h	125 20 42 120 **307**

Notes to Table:

Column 1

The performance of the solar module is measured in watt. The module achieves it only with full sunshine and a temperature of 25 °. If the sun is overcast by clouds or the temperature of the module is higher than 25 ° - as is usually the case in Africa, the performance is considerably lower.

The dimensions, especially **m²**, serve as guidelines for purchasing a module.

Column 2

A charge controller must be designed for so many amperes (A) as the solar module provides at maximum power (Imp) in full sunshine. This information is found on the back of the solar module or in the data sheet. The charge controller must at least achieve the ampere values specified in Column 2. Most charge controllers on the market can handle 3, 6, 7, 12, 30 or more amps.

Column 3

The battery capacity is measured in ampere-hours (Ah), e.g. 12 V / 7.2 Ah. A solar module of 20 W provides a maximum of 1.12 A. Under full sunlight a solar panel in West Africa generates six times more Ah per day, than is specified on its label (6 x 1.12 A= 6.72 Ah). A battery should have at least twice the capacity, i.e. about 14 Ah. And it is even better if the battery capacity is higher, e.g. 18 Ah. This provides a power reserve for cloudy days. In addition, a higher capacity is better for the battery because it is only half discharged. In Column 3, the first number shows the minimum capacity, the second the recommended capacity (e.g. 20 W module: battery capacity 14 Ah / 18 Ah).

Column 4

In full sunshine the 20 W solar module generates 20 watts per hour. As already mentioned, in West Africa the power generation is 6 times higher, i.e. 6 x 20 Wh = 120 Wh per day. Due to the high temperatures of the solar module of above 25 °, due to resistance there is a power loss in the cables, the charge controller and the battery of up to 30% of the output; it is not available for lighting, radio etc. The daily available wattage is therefore: 120 Wh minus 36 Wh (30%) = 84 Wh.

Columns 5 and 6

Here you find examples of calculations showing which appliances can be operated for how long with the total daily output shown in Column 4. For this you need to know which device can be operated for how long at what level of consumption in Wh. For example: an SHS with a 20 W solar module can provide energy for two lamps that consume 5 watts per hour during 5 hours per day (hrs.). In addition, a mobile phone can be charged twice at 5 Wh and a radio that consumes 2 Wh, can be operated for 7 hours. In that case, total consumption is 74 Wh. There still remains a reserve of 10 Wh, since the total power is 84 Wh (Column 4). This means the lamp could be used 2 hours longer, or one could save the reserve in the battery for times when more power is needed.

Information on the inverter

An inverter converts 12V DC power into 230 volts AC. The voltage of the alternating current varies between 220 and 240 V.

The power of the inverter is given in watt (W). There are always two performance data shown on the inverter itself and in the data sheet, e.g.: W 100/300 W. This means that the **continuous power** is **100 W**, but that it can run at a **peak power of 300 W for a short time**. This is due to the fact that many electrical devices need a much higher power for starting which can be up to 10 times the continuous current rating for a few seconds only. This is called the **switch-on or starting current**. In other words, a 25 W TV requires for starting a 10 times higher current i.e. 250 W, but only for 1-2 seconds. A 50 W TV requires up to 500 W for start-up. This high current (500 W) would overload an inverter of 100 / 300 W and would switch it off automatically. In a cheap inverter of poor quality the fuse may blow, and it can only be replaced with great difficulty.

If one or more devices are connected to an inverter, they must not exceed the stated continuous power.

Due to the high inrush current, an inverter should only be connected **to the battery** and not to the charge controller. Charge controllers are usually not designed for the high starting currents so that its fuse might blow, or the charge controller might be damaged.

When buying an inverter make sure that it has a protection against deep discharge of the battery. Without this protection, the battery will be completely discharged and damaged.

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The author: Arwed Milz has conducted many workshops for the assembly of small solar home systems in West Africa and Germany.

Supporters of the SHS DIY movement:

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