Factsheet solar power

Pages 10

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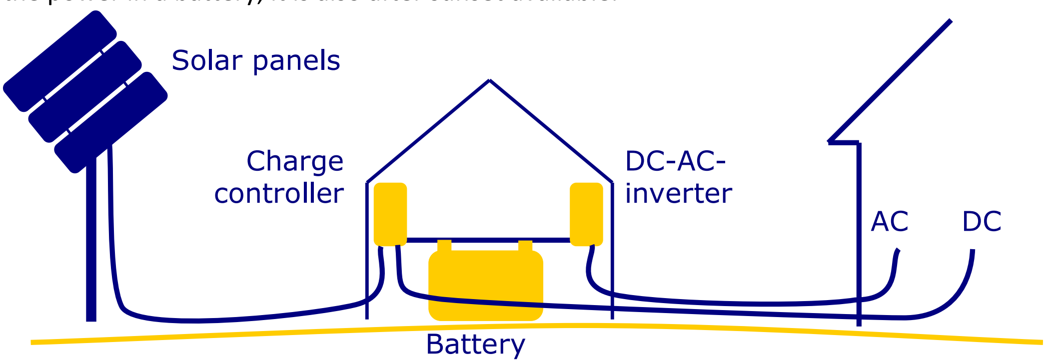
Introduction

At remote sites far away from the electricity mains, solar power can provide in a clever solution. In several projects Pico Sol gained experience with this technology. We would like to share this knowledge with you.

▲ Solar power system at Cambodian orphanage. About 70 children have enough power for lighting. Also a television and a computer is connected to the system. Inset: The inner part of the technical area provides space for batteries, a controller and inverter.

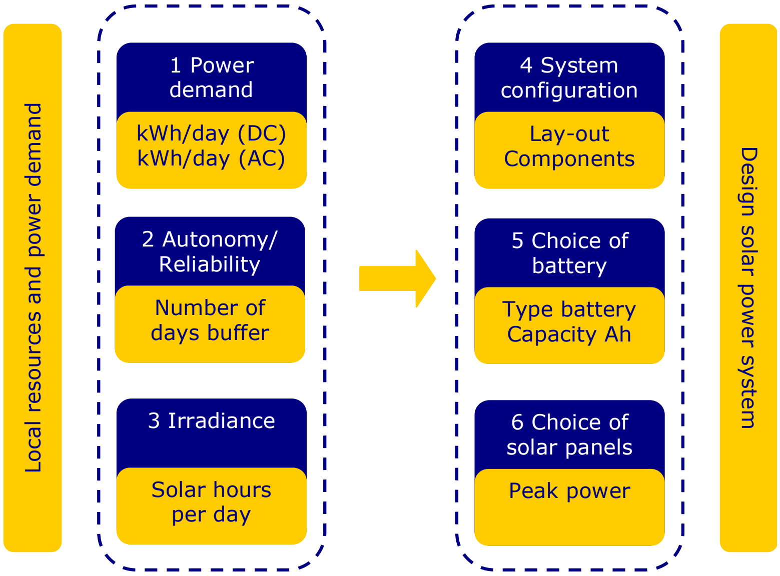
System lay-out

Solar power usually is associated with a sense of high-tech. In reality, it is quite simple and appropriate technology. A solar power system consists of solar panels, batteries and a charge controller. Daylight that strikes the solar panel, will be converted into electricity directly. The more light, the more power. By storing the power in a battery, it is also after sunset available.



▲ General set-up of the solar power system. Spider in the web is the charge controller. This device takes care of the battery: Not too full charged (switching off the solar panels) and not too deep discharged (switching off the appliances). The battery provides direct current (DC). By means of an inverter the system also provides alternate current (AC).

Design scheme



▲ Design of solar power system starts with a survey of needs and location data (step 1-3). With this result, a most appropriate battery and solar panel combination is obtained to design the right system configuration (step 4-6).

Step 1 Power demand

The first, most logical, but also the most difficult question concerns the power demand. Related to this is the purpose of the power: Lighting, domestic appliances, education, medical equipment? This survey needs to be executed. ◄

Text box 1: What is your reference?

The investigation of the power need can result in high numbers if your reference is power from a diesel generator. Just as the fuel consumption of a car is not really dependent to the number of passengers, it does not really matter the generator if a light is switched on or off. For this reason, we found electrical installations at orphanages without any switch! The switching on and off of the generator simply was the switch. Between 6 and 10 pm there is power, and there is light everywhere. After 10, it is pitch-dark. In other words: There has never been an urgent need for saving electricity.

With a solar power system this is different. A kWh from the system is in the range of $1,00 (see price of a kWh). So energy efficiency is important. The replacement of all 36W TL tubes with 13W energy savers will both reduce the investment in solar energy as exploitation costs with 64% *). To halve the switch-on time will contribute for another 50% saving.

▲ Wringing out the power consumption is part of the standard procedure to make the solar system viable.

*) (36-13)/36 = 64%

The following table will help you with the survey. Note that the most energy efficient equipment is always the best way of action.

▼ Survey of power demand. The last column is the multiplication of the middle three columns, corrected by the partial factor in the last but one column (the fridge is switched on one third of the time).

Appliances	Power and number of appliances		Hours per day	Minutes per hour	Energy Consumption
	W	*#*	*hr/day*	*min/hr*	*kWh/day*
Example building					
1. Example lights	13	12	2.5	60	0.39
2. Example fridge	125	1	24.0	20	1.00
3. Example laptop	45	1	4.0	60	0.18
4. Example Radio	20	1	10.0	60	0.20
5. Example TV	50	1	3.0	60	0.15
6. Example Antenna	25	1	3.0	60	0.08
				total	*2.00*
Your building	*W*	*#*	*hr/day*	*min/hr*	*kWh/day*
1					0.00
2					0.00
3					0.00
4					0.00
5					0.00
				total	*0.00*

Text box 2 AC or DC?

Electricity is not by definition 230V AC. There are many reasons to plead for using only direct current (DC). This will prevent the expensive and inefficient conversion step via the DC-AC-inverter.

The battery system will be based on 12V of 24V direct current (sometimes 48V). For 12V many appliances are available. For 24V it is a little more difficult, and for 48V there is hardly anything.

The big disadvantagea of the low voltage (12 or 24V) is the need for expensive thick cables for the longer distances.

The big disadvantage of the inverter is that this device will help the end-user to waste energy after some time. If the point of departure is ‘no electricity’, the user will discover the advantages of electricity in the course of time. He will realise that many luxurious items from the big city will come within reach of his situation in the rural areas. It will be quite a temptation to buy the energy wasting ceiling fans, televisions, fridges, freezers, you name it. The laborious inventoried power need will not meet the reality after some time.

For a further deepening of the AC-DC discussion, see www.sundaya.com (click on animations general 7 reasons for DC)

After a good consideration of what appliances will be powered by DC and what by AC, the survey for the power demand is ready.

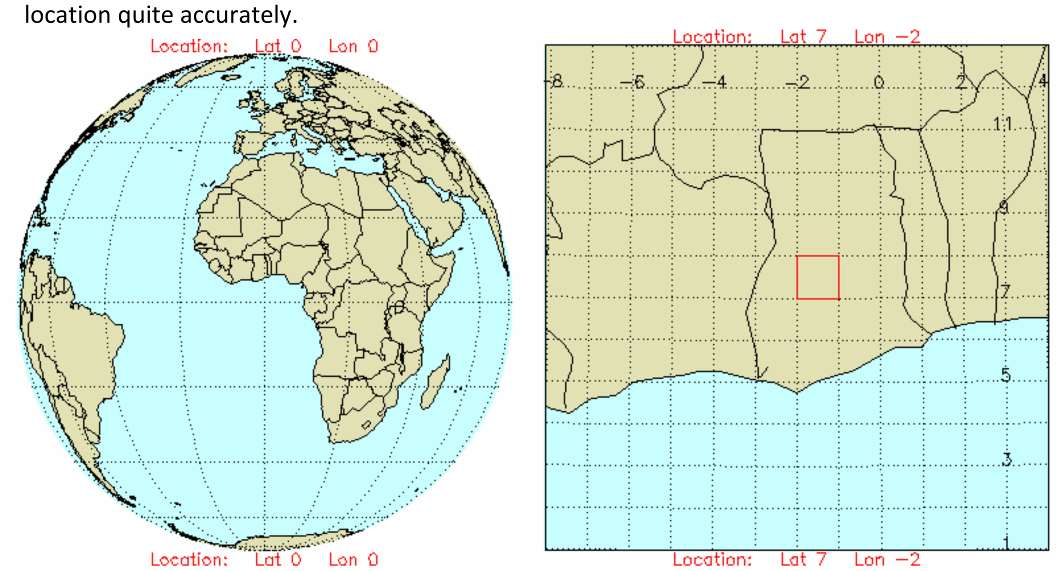
Step 2 Autonomy / Reliability

Solar power can provide in a reliable power demand. But everybody knows that the sun is not always the most reliable partner. In the wet season, he hides himself behind heavy clouds, sometimes for several days.
The concept Autonomy we define as the number of days the system will supply power without sunshine. In most countries a autonomy period of 3 days will be enough for most ordinary applications. There is a statistical chance that the power will drop now and then, but this could be considered as a fact of life. A larger number of autonomy days will decrease the chance. For professional applications sometimes a higher reliability is needed, for example cooling of medicines in a remote health centre. A period of 5-10 days could be considered.
The battery capacity directly results from the determined minimal autonomy period. In the example above (Step 1: Daily power demand of 2.00 kWh) the full battery should be able to provide 6.00 kWh at autonomy requirement of three days.

Step 3 Irradiation

The irradiation is obtained from the internet. The NASA developed a database based on information from satellites (cloud configurations during a long period). The database gives a good estimation of the solar irradiance on the ground. To find the relevant data, we direct you through the next steps. The result will be a table with monthly averages of the amount of "full sunny hours" at your project site.

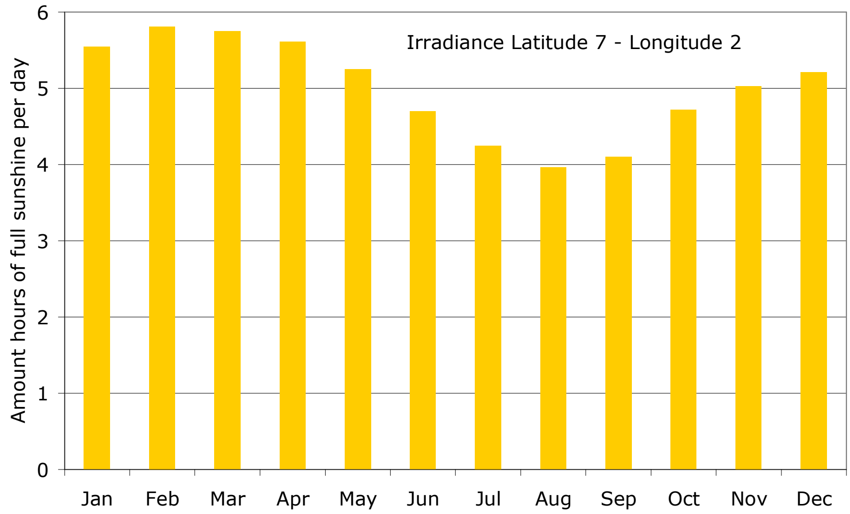
- Website: http://eosweb.larc.nasa.gov/sse/
- Click on Renewable Software Application Inputs
- Click on Retscreen International data access
- Register yourself as user
- Now you will enter a screen, in which the Longitude and the Latitude should be given. To know these numbers, you can also use the tool 'Pick a location graphically'. At zoom level 16 you can give your location quite accurately.



▲ Tool for looking up the co-ordinates of your project location.

- Now you click on 'Submit for data'
- You will obtain a table on your screen with the monthly averages of various meteorological parameters. The most important is the third column of this table 'Daily solar radiation - horizontal kWh/m^2/day'. This column presents the irradiance.

In the figure below (next page), this third column of the table is presented in a graphical way

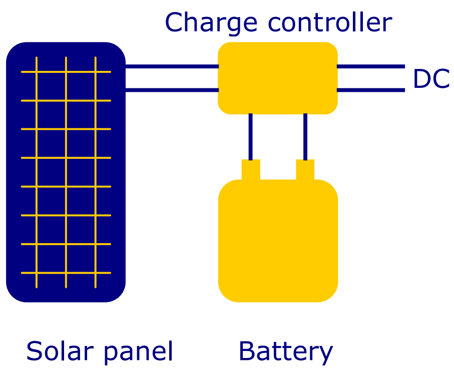


▲ Irradiation on project site Ghana (7ºLatitude -2º Longitude) in ‘kWh/m^2/day’. This unit can be translated into ‘hours of full sunshine per day’. Full sunshine is defined as irradiance of 1kW light energy.

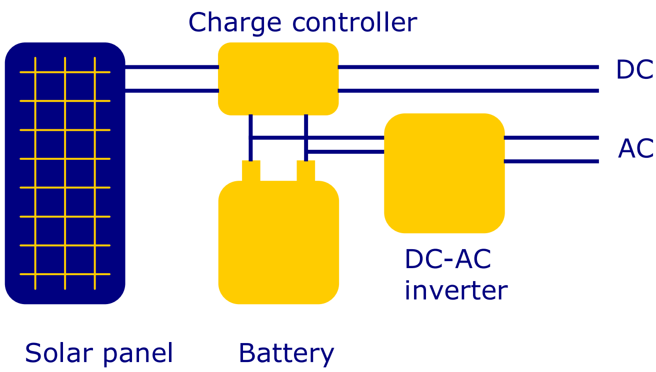
Step 4 System configuration and components

The general system lay-out of page 1 is not by definition the most logical for your situation. Local site information is needed to design your most appropriate system configuration. Do you have one or more buildings that need to be electrified? In case of more buildings you could consider to split up the system into more small system. Is there a freezer that may not defrost? It could be a reason to install a separate system for the freezer with increased autonomy.

Basic configurations

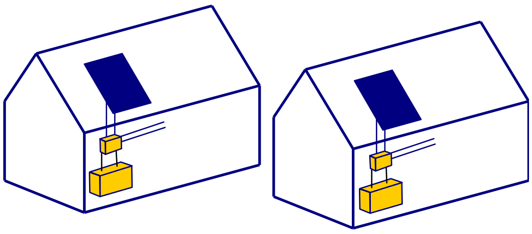


▲ Simple configuration. Most popular in Solar Home Systems

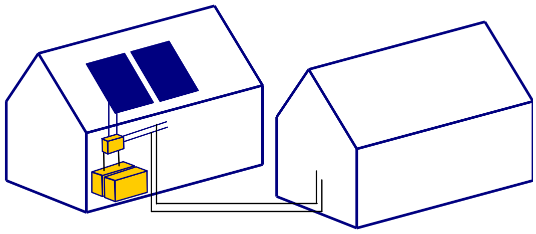


▲ Configuration with inverter. Mainly applied in bigger Solar Home Systems and also for (semi-) professional applications (orphanage, school, health centre, remote office)

Central of decentral

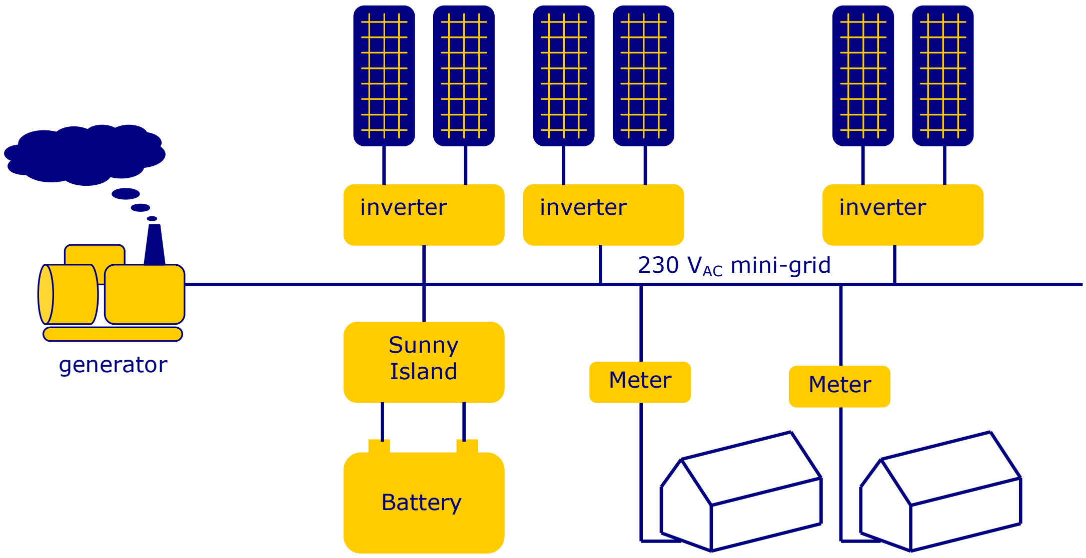


▲ More stand alone systems set-up in a decentralised way.



▲ Central system

Large systems with more energy sources



▲ System configuration based on the Sunny Island concept of the German manufacturer SMA (www.SMA.de). The solar power is converted into AC-power by inverters that feed a mine-grid. Various other energy sources, like a diesel generator or a wind generator can be connected to the grid, resulting in a very reliable power system. In case the demand for power is lower than the supply, the power is buffered in the battery backup. This system could have advantages for small communities with several houses and buildings. The system is easily extended with extra solar panels if the power demand will change (for instance: a new building will be connected to the system).

The charge controller

In the standard system configuration, the charge controller is the spider in the web. He controls the power of the solar panels to the battery and to the appliances. He also controls the power to and from the battery. Points of interest are summarised in the table below.

Characteristic	Description
Overcharge protection	Basic function of the controller. Not fuller than full: Switch off the solar panels
Under charge protection	Optional, but important characteristic; Not emptier than e.g. half empty. Switch off the load.
Indication state of charge (SoC)	Usual: Green-orange-red. More expensive: LCD-display with percentage of SoC.
Amperage	Maximal current of the solar panels (eg. 20A). A 600Wp system with system voltage 24V needs minimal 600/24=25A.

Temp-compensation	Necessary, especially for tropical countries.
Wet-dry setting	Switch for wet or dry batteries. Wet batteries may go beyond 14V; dry batteries max 13.8V.

Step 5 Choice of the battery

The choice of the battery is crucial. The battery will determine the investment in solar power for 20-30%. But the battery will determine the resulting price for power for 40-50% due to the lower lifetime (see text box 3). If the battery is chosen badly, this percentage can be higher (and the end-user's worries also).

Determination of battery capacity needed

The battery capacity is given in Ah (Ampere-hour). A 12V battery of 50Ah can supply 1A during 50 hours at a voltage of 12V. In kWh, the capacity is 50A x 12V = 0.6 kWh. However: for the lifetime for the battery it is not wise to discharge him completely. **Therefore, the basic principle is to utilise only half of the full capacity.**
In step 2 the minimal autonomy was determined. In the example of 3 days of autonomy with a daily power demand of 2.0 kWh, the battery capacity should be 6.0 x 2 = 12.0 kWh. In the case of a 12V system, this would imply to buy a battery of 1000 Ah; in case of a 24V system, a 500Ah battery is needed.

Choice of the battery type

Lead –sulphur acid batteries still are the best option for solar power systems. Still there is quite some to be chosen in type, quality and price. The table below gives an overview.

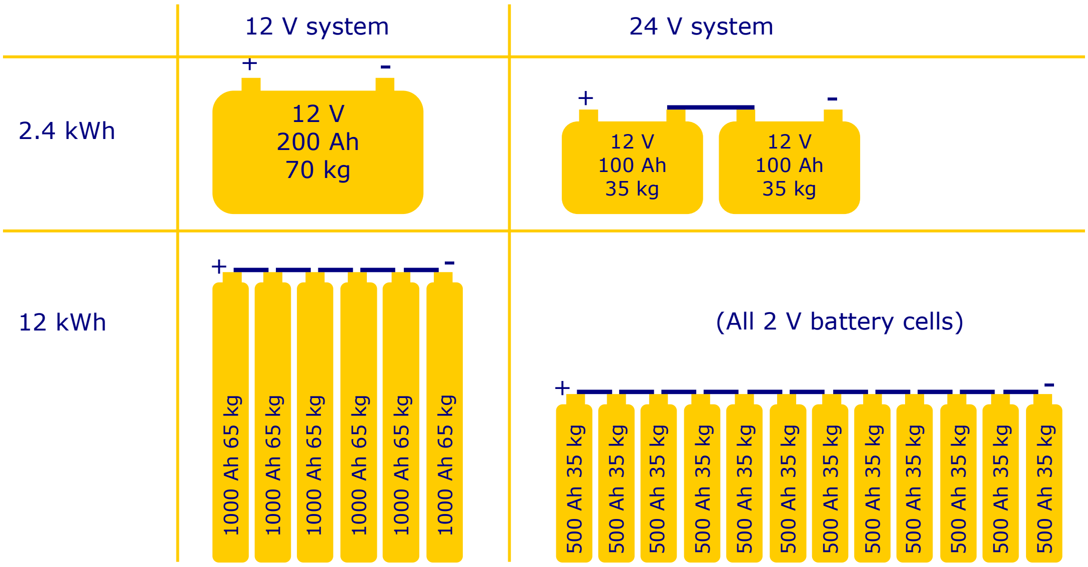
▼ Simple subdivision of batteries and appropriateness for solar power systems.

Type of battery		**Description**	
Wet batteries (batteries with caps, to top-up with distilled water)	Start-batteries	Designed for short and high currents, like starting an engine. Not appropriate for solar power systems	$
	Semi-traction batteries	Suitable for partial day-night-cycling like most of the solar power applications.	
	Traction batteries	Designed for daily complete cycling, like fork lift trucks. Not for solar power systems.	
Dry (maintenance free) batteries. Also known as VRLA = Valve Regulated Lead Acid	AGM batteries (Absorbed Glass Mat)	Are commonly used for UPS-systems (Uninterruptible Power Supply). Suited for short time power supply. They can be used for solar power systems.	
	Gel batteries	Most expensive, but also most sustainable choice for solar power system. Really suited for partial cycled behaviour (day-night), can be discharged deeply, long lifetime.	$$$$

A readable, understandable and interesting technical treatise about batteries is found in chapter 2 of Reinout Vader's booklet "Energy Unlimited" (http://www.victronenergy.com/upload/documents/Book-EN-EnergyUnlimited.pdf).

Battery configuration

It is possible, but not desirable, to connect more battery stings in series. The problem that can occur is that the batteries at their end of life will discharge in each other, in stead of supply power to the load. Therefore, our guideline is to connect maximal two strings in series.



▲ Batteries are preferable connected in series

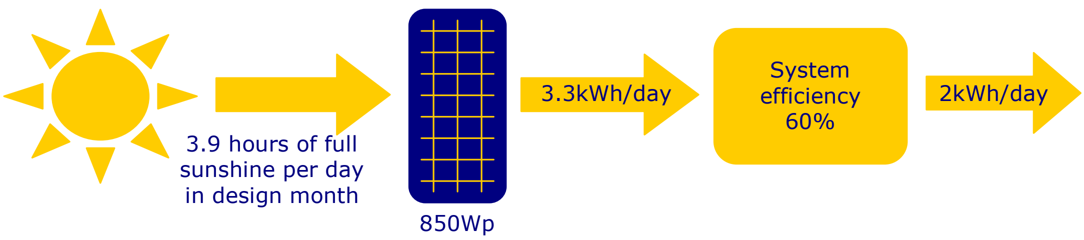
Step 6 Choice of solar panels

The concept of Watt-peak (Wp)

The performance of the solar panel is expressed in units of Watt-peaks (Wp). This is the power that is generated under 'standardised' sunshine of 1000 Watts per square meter. This international standard is comparable to the solar irradiation of a sunny bright day in July in The Netherlands. A crystalline silicon solar panel (see below) of one square meter will supply about 100-150 Wp. The daily performance (in Wh, say Watt-hour) is calculated by multiplying this number with the amount of hours of full sunshine (see step 3). This number is a calculation unit to express the amount of light per day, because also diffuse light will contribute to the performance of the solar panels. So also if the sun does not shine, it can contribute to the hours of full sunshine. Of course, in that case, it will take longer than an hour to come to an hour of full sunshine.

Capacity of solar panels

In step 3 the irradiation on site has been determined. The month of lowest irradiation is the design month for the system. In the example of Ghana, this is August (3.9 hours of full sunshine). Furthermore, it is important to realise that the total system has an efficiency that is lower than 100%. Due to charging/ discharging of the battery, a mismatch between the solar panel and the battery and some more effects, not all the power generated by the panel will reach the load. A system efficiency of 60% is indicative for a wide range of applications.



▲ Due to system losses, not all the power will be utilised. For generating 2kWh per day in the darkest month (Ghana) in total 850 Wp of solar panels is needed.

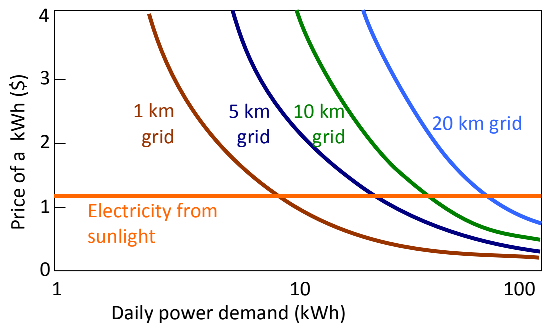
Types of solar panels

Characteristic	Description
Material solar cell	99% of the solar cells is made of silicon. We distinguish crystalline silicon (blue or black wafers) and amorphous silicon (dark brown strips on glass). Most commonly used are crystalline solar cells. Poly crystalline: Blue speckled; mono crystalline: evenly dark.
Number of solar cells	For crystalline (both mono-crystalline and poly crystalline) silicon, the number of 36 is holy. 36 cells are needed to charge a 12V battery. Usually panels contain 4x9, sometimes 6x6 cells. For 24V systems, there are large panels with 72 cells.
Quality certificate	Crystalline solar panels: "IEC 61215" is mentioned on the specification sheet Amorphous silicon solar panels: Idem, but other number: "IEC61646"

Text box 3: The price of a kWh

Everybody knows that power from solar panels still is not competitive to power "from the plug point" With increasing fuel prices and decreasing costs of solar panels, these prices will meet each other more and more in the future.

When there is no electricity available at all, the situation is different. Both the investment in solar power as the installation of a power grid to the remote site will be high. In many cases it will appear that solar power will be economically most viable, due to the relatively low power demand.



From the figure this becomes visual clear. At low power demand the price of electricity from a solar power system will be lower than in case of grid extension, even at relatively short distances. Per location this graph will be different. The curves will depend on many local factors, like the landscape, the level of salaries, material costs.

Another comparison is the price of solar power and power from a generator. In this case, solar power does not need to compete with cheap electricity from the mains, but with expensive power from the generator. With the current fuel prices the competition becomes more and more fair: A kWh from a diesel generator approaches the $1.00 from below. A kWh from a solar power system approaches the $1.00 from above. In some situations, solar power is already cheaper than a diesel generator.

Below an example is elaborated for the Cambodian situation.

1 kWh from a 100 Wp system in Cambodia

Part	Price	Life time	Annuity
Solar panel	$ 600	20	$ 52.31
Battery 100Ah	$ 150	4	$ 43.29
Controller	$ 100	10	$ 13.59
Various	$ 150	20	$ 13.08
Total	$ 1.000		$ 122.26

Interest	6%
Annual hours of full sunshine Cambodia	1900
System efficieny	60%
Resulting number of kWh per 100Wp	114
Price of a kWh	$ 1.07

At interest of 6%, 1900 hours full sunshine and system efficiency of 60%, the 100Wp solar power system will provide 114kWh annually. The average kWh-price will be $122,26 / 114 = $1,07.

The calculation of the kWh-price from a generator works in a comparable way. Let's consider a 25kVA-machine, able to supply 20-25kW maximal, but rarely does, because this power is not always needed. Usually it operates in partial load. Compare it to a coach able to carry 50 passengers, which is transporting only 10 persons. The efficiency of this bus is lower compared to a full loaded situation.

1 kWh from a diesel generator in Cambodia

Generator 25kVA Power kW:	20.0
Efficiency at partial load	15%
Use of diesel per hour (litres)	2.0
Nett kWh generated per hour	3.0
Price of a litre diesel	$ 1.25
Maintenance and depreciation per hour	$ 0.25
Price kWh	$ 0.92

▲ Installation of solar panels at an orphanage in Cambodia