1) Solar Panels - Basics

A solar cell, sometimes called a photovoltaic cell, is a device that converts light energy into electrical energy. A single solar cell creates a very small amount of energy so solar cells are usually grouped together in an integrated electrical panel called a solar panel. Sunlight is a somewhat diffuse form of energy and only a portion of the light captured by a solar cell is converted into electricity. The current generation of solar cells convert only 12% to 15% of the sun's light into electricity. However in recent years there have been significant improvements in their design. Some new cells on the market now have efficiencies around 20% while some laboratory prototypes even reach as much as 30%. Given this it is likely that solar cell efficiency will continue to improve over time.

The output of a solar panel is usually stated in watts. The amount of watts of electricity generated by a panel is determined by multiplying the rated voltage by the rated amperage. The formula for wattage is:

VOLTS x AMPS = WATTS

Let's use as an example a large solar panel measuring about 1 x 1,5m that might be used in a typical home energy system. The solar panel has a rated voltage of 26V and rated amperage of 7A. The wattage calculation would look like this:

26V x 7A = 182W

If a particular location has an average of 6 hours of peak sun per day, then the solar panel in this example can produce an average of 1092Wh (6 x 182) power per day or a little over 1kWh per day. Most homes use between 10-25kWh per day. Given this it is going to take a lot more than one solar panel to generate enough electricity to completely power a home. For a household needing 20kWh per day it would take approximately 19 panels to provide 100% of the electricity. Most houses do not have enough space on their south facing roof for this amount of panels.

Consequently, in most home applications where a connection to the grid is available, a solar panel system should only provide part, but not all of the necessary energy.

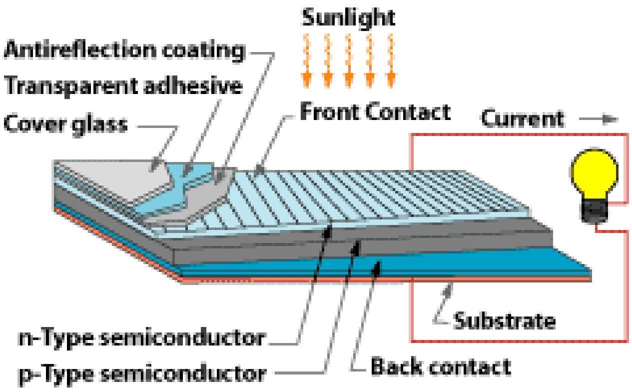
2) Solar Panels – Functionality

A solar cell is based upon the "photovoltaic effect" (PV-effect) discovered in 1839 by Edmund Becquerel, a French physicist. In his experiments he found that certain materials would produce small amounts of electric current when exposed to sunlight. Sunlight is made up of packets of energy called photons. When the photons strike the semi-conductor layer (usually silicon) of a solar cell a portion of the photons are absorbed by the material rather than bouncing off of it or going through the material. When a photon is absorbed the energy of that photon is transferred to an electron in an atom of the cell causing the electron to escape from its normal position. This creates, in essence, a hole in the atom. This hole will attract another electron from a nearby atom now creating yet another hole, which in turn is again filled by an electron from another atom. This hole filling process is repeated a few zillion times, thus creating an electric current.

3) Solar Panel – Structure

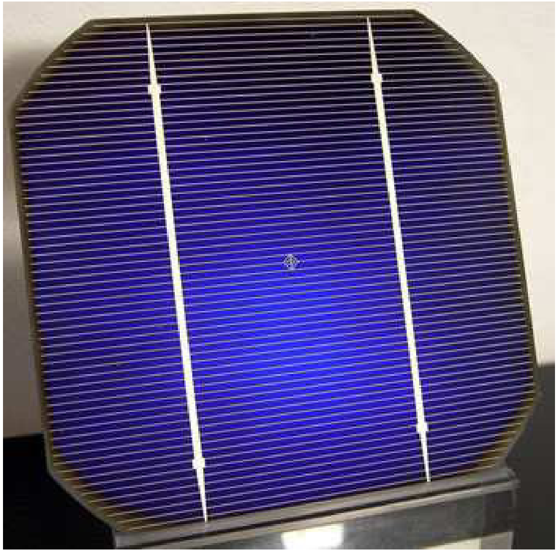
A typical solar cell is a multi-layered material. The layers are:

- *Cover Glass* - this is a clear glass layer that provides outer protection from the (weather) elements.
- *Transparent Adhesive* – to stick the glass to the lower layers of the solar cell.
- *Anti-reflective Coating* - this substance prevents light that strikes the cell from bouncing off so that the maximum energy is absorbed into the cell.
- *Front Contact* - transmits the electric current.
- *N-Type Semiconductor Layer* - This is a thin layer of silicon which has been doped with phosphorous.
- *P-Type Semiconductor Layer* - This is a thin layer of silicon which has been doped with boron.
- *Back Contact* - transmits the electric current.



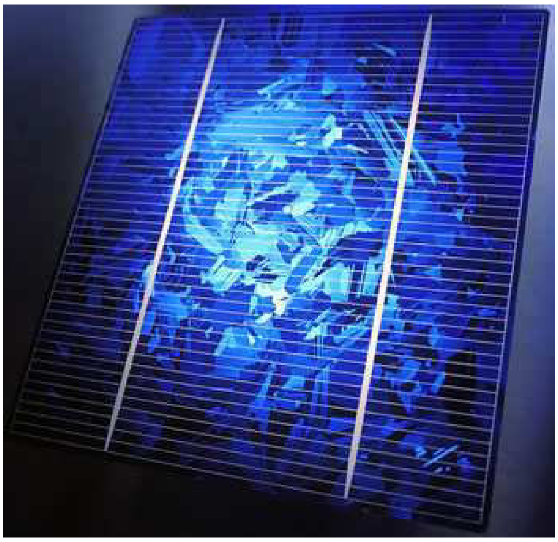
4) Solar Panels - Types

There are a number of different types of solar panels manufactured today. Briefly, they are:



Mono-crystalline -This type of solar cell uses a single layer of silicon for the semi-conductor. In order to produce this type of cell, the used silicon must be extremely pure which means it is the most expensive type of solar cell. However, they are the most efficient type of solar panels. Their performance is somewhat better in low light conditions (but not as good as some advertising hype would have you believe). Overall efficiency on average is about **12-15%**. Most panels of this type are warranted for 20-25 years. They are usually blue-grey in colour and have a fairly uniform consistency.

Poly-crystalline - To make polycrystalline silicon cells, liquid silicon is poured into blocks that are subsequently sawed into plates. This type of approach produces some degree of degradation of the silicon crystals which makes them less efficient. However, this type of approach is easier and cheaper to manufacture. Currently, poly-crystalline solar panels are the most common. They are slightly less efficient than single crystal, but once set into a frame with 35 or so other cells, the actual difference in W/m² is not that high. Poly-crystalline cells look somewhat like shattered glass and have a dark blue to almost black colour. Overall efficiency on average is about **11-13%.**

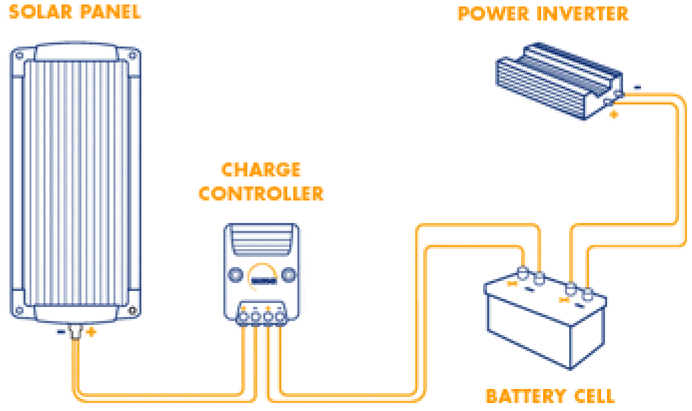


Amorphous - Amorphous solar panels are also referred to as "thin film" solar panels. This type of solar cell uses layers of semiconductor that are only a few micrometers thick (about 1/100th the thickness of a human hair). This lowers the material cost but makes it even less efficient than the other types of silicon. However, because it is so thin this type of cell has the advantage that it can be placed on a wide variety of flexible materials in order to make things like solar shingles or roof tiles. Because they can be put on to flexible backings they have proven very valuable in certain types of applications where flexibility is more critical than power. For example, these types of solar panels are often used in portable products such as solar backpacks and solar bags. Overall efficiency on average is about **5-6%.**

Another way of defining solar cells is in terms of the types of materials they are made of. While silicon is the most commonly used crystal a number of other materials and substances can be used as well. Different types of substances perform better under certain light conditions. Some cells perform better outdoors (e.g. optimized for sunlight), while others perform better indoors (optimized for fluorescent light).

5) Solar System - Overview

A complete solar system consists of a solar panel, a battery and a charge controller. In some cases, a power inverter is also required.



Composed of multiple solar cells in series or in parallel, a solar panel produces direct current (DC) power; when a solar panel is connected to a battery, this power is stored in the battery. A charge controller connected between the solar panel and the battery monitors the battery and prevents the solar panel from overcharging the battery while assuring a complete charge.

A solar system requires an inverter when the DC power needs to be converted into alternating current (AC) power to operate appliances or supply power to the utility grid.

6) Solar panels – series or parallel

To increase voltage or amperage of a solar system, the solar panels can be placed in series (higher voltage) or parallel (higher amperage) or a combination of both.

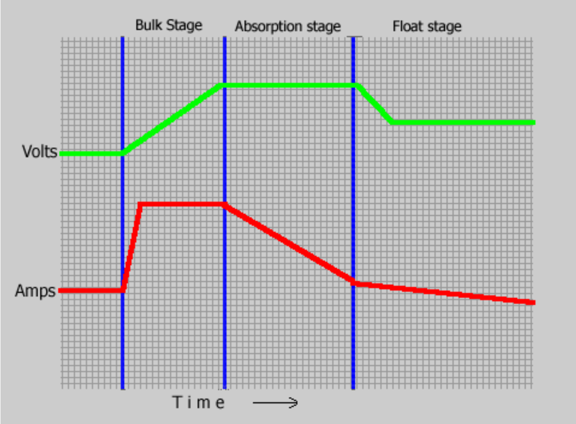
Series wiring: connect the positive terminal of one panel to the negative terminal of the next. The resulting voltage between the outer positive and negative terminals is the sum of the panel voltages, but the amperage stays the same as for one panel.
E.g. 2x 12V/3A panels in series produce 24V at 3A.
4x 12V/3A panels in series produce 48V at 3A.

Parallel wiring: connect the positive terminals to positive terminals and negative to negative. The resulting voltage stays the same, but amperage becomes the sum of the panel amperages.
E.g. 2x 12V/3A panels in parallel produce 12V at 6A
4x 12V/3A panels in parallel produce 12V at 14A

Note: in most cases it is not profitable to provide a high input voltage to a charge (shunt) regulator as part of it will probably be dissipated as heat.
E.g. When placing 5x 12V/3A in series, 60V is produced at 3A
a 24V regulator might 'waste' 36V (heating of the regulator)
Consider placing the panels in parallel.

Remark: when in doubt contact an experienced solar panel professional.

7) Solar System - Why a charge controller is necessary



The brighter the sunlight, the more voltage the solar cells produce. This excessive voltage could damage the batteries. A charge controller is used to maintain the proper charging voltage on the batteries. As the input voltage from the Solar panels array rises, the charge controller regulates the charge to the batteries preventing overcharging.

Most quality charge controller units have what is known as a 3 stage charge cycle:

1) *BULK phase*: the voltage gradually rises to the bulk level (usually 14,4V - 14,6V) while the batteries draw maximum current. When bulk level voltage is reached the next phase begins.
2) *ABSORPTION phase*: the voltage is maintained at bulk voltage level for a specified time period (usually an hour) whilst the current gradually tapers off as the batteries charge up.
3) *FLOAT phase*: after the absorption time passes the voltage is lowered to float level (usually 13,4V – 13,7V) and the batteries draw a small maintenance current until the next cycle

When using for example 4 x 80W/12V solar panels, the charge controller should be rated up to 40A. For 8 x 80W solar panels, a 2 x 40A charge controllers is needed to handle the power or the system voltage could be increased to 24V to use just one 40A charge controller.

Notice that the charge controller in the above example seems heavily over-dimensioned. But even though the solar panels don't normally produce that much current, there is an 'edge of cloud effect' one has to take into consideration.

Clouds affect solar panels. The amount of power your solar panels can produce is directly dependent on the level of light they receive. In full, bright sunlight, solar panels receive maximum levels of light. During those "peak" sunlight hours, your solar panels will produce power at their maximum capacity.

When clouds cover the sun, light levels are reduced. This does not shut down power production, however. If there is enough light to cast a shadow, in spite of the clouds, your solar panels should operate at about half of their full capacity. Thicker cloud cover will reduce operations further. Eventually, with heavy cloud cover, solar panels will produce very little useful power.

The effects of clouds on a solar panel can however turn out positive; your solar panels will deliver their ultimate amount of peak power during cloudy weather!

As the sun moves into a hole between the clouds, your solar panels will see full direct sunlight combined with reflected light from the clouds! They will absorb more energy than they could on a cloudless day!

The effects of clouds on a solar panel could produce peaks at or above 50% more than its direct-sun output. Due to this phenomenon it has been seen that 4 x 80W/12V panels (4 x 6,66A=26,66A) pump out over 32A. This is well over their rated maximum.