POWER PARTNERS

Everything you always wanted to know about Solar Power*

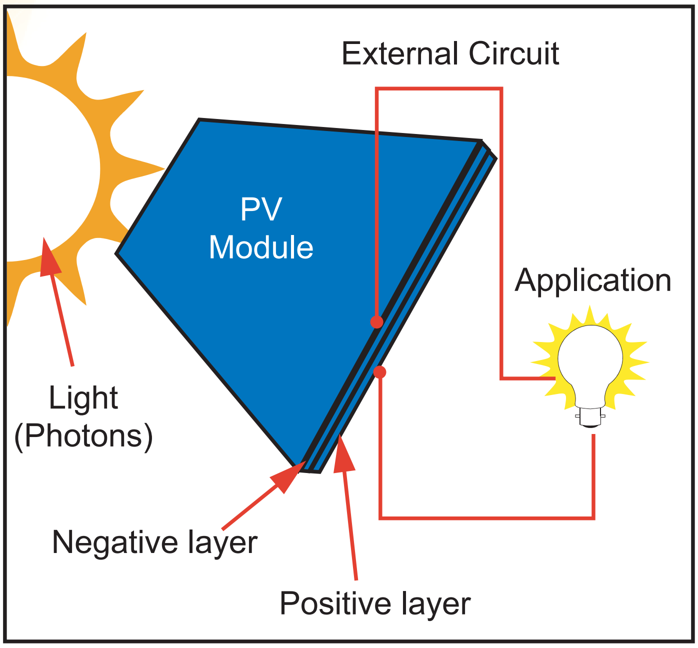
*(But didn't know who to ask)

What are photovoltaics?

Photovoltaics (PV) are solid-state semi-conductor devices that convert light directly into electricity. They are usually made of silicon with traces of other elements and are first cousins to transistors, LED's and other electronic devices.

How does it work?

A photovoltaic device (generally called a solar cell) consists of layers of semiconductor materials with different electronic properties. In a typical BP Solar crystalline cell the bulk of the material is silicon doped with a small quantity of boron to give it a positive or p-type character. A thin layer on the front of the cell is doped with phosphorous to give it a negative or n-type character. The interface between these two layers contains an electric field and is called a junction.



Light consists of particles called photons. When light hits the solar cell, some of the photons are absorbed in the region of the junction, freeing electrons in the silicon crystal. If the photons have enough energy the electrons will be able to overcome the electric field at the junction and are free to move through the silicon and into an external circuit. As they flow through the external circuit they give up their energy as useful work (turning motors, lighting lamps, etc.) and return to the solar cell.

The photovoltaic process is completely solid state and self-contained. There are no moving parts and no materials are consumed or emitted.

What can photovoltaics do?

Virtually any electric power need can be met by an appropriately designed PV power system. This includes power for lighting, pumping, refrigeration, radio transmission, etc. The only limitation is the cost of the equipment and occasionally the size of the PV array, although this is rarely a factor.

What does PV cost?

Although this depends greatly on the application, some general guidelines can be given. Systems containing 100 watts or more of PV will generally cost between A$10 and A$30 per watt of PV. Smaller systems will be more expensive on a per-watt basis. The PV modules will be between 1/3 and 1/2 of the total system cost. Each watt of PV array will generally produce between 2 and 6 watt-hours of energy per day depending on the season and location. Some very dark conditions will produce less energy and some very bright conditions will produce more energy than this range.

Using typical borrowing costs and equipment life, the life cycle cost of PV generated energy generally ranges from A$0.30 to A$1.00/Kwh. This cost generally limits the current application of PV to areas which are not served by an existing utility grid, although low-power applications may be cost-effective only a few feet from the power line.

Is PV difficult to use?

In a word, no. Although making PV cells and modules requires advanced technology, they're very simple to use. PV modules are generally low voltage DC devices (an array of PV modules can be wired for higher voltages) and typically requires no maintenance other than occasional cleaning (and even that is not imperative). PV systems with backup capability contain storage batteries which may require some watering and maintenance similar to that required by the battery in an car.

What is the environmental impact?

Photovoltaics are probably the most benign method of power generation known. They are silent, produce no emissions, and use no fuel (other than sunlight!). The production of photovoltaics of course varies among manufacturers. BP Solar makes extensive use of recycled materials and even uses waste from other industries as raw material. While some hazardous materials (primarily strong inorganic acids and bases) are used in solar cell manufacturing, these substances are not released into the environment. BP Solar PV technology is based on silicon, the second most common element on the earth's surface and non-toxic as used in PV modules.

What laws/ regulations cover PV? Do I need special permits? Will my insurance cover my system?

While this will vary from jurisdiction to jurisdiction, PV systems are generally subject to the same electrical, building, and fire safety codes which govern the installation of electrical wiring and equipment in residential, commercial and industrial buildings. In Australia the Electrical wiring standards are the accepted standard in most areas, and their guidelines should be followed in designing and installing PV systems. Properly installed PV systems are covered by most insurance policies in the same way as any other electrical equipment installed on the insured property, but the individual policy should be consulted to determine the limits of coverage. It is important to select components with appropriate safety approvals such as those given by Underwriters Laboratories (U.L.) or Factory Mutual Research (F.M.) to ensure safety and insurance eligibility.

How are modules rated/ certified?

PV modules are rated at a well-defined set of conditions known as Standard Test Conditions (STC). These conditions include a PV cell temperature of 25°C (77°F), a light intensity of 1kW/m², and a particular spectral distribution of the light (air mass 1.5 or AM 1.5, which is the spectrum of sunlight that has been filtered by passing through 1.5 thicknesses of the earth's atmosphere). These conditions correspond to noon on a clear sunny day with the sun about 60° above the horizon, the PV module directly facing the sun, and an air temperature of 0°C (32°F). In production, PV modules are tested on a device known as a flash simulator. This test equipment contains a flash bulb and filter designed to mimic sunlight as closely as possible. It is accurate to about ±1%. Because the flash takes place in only 50 milliseconds, the cells do not heat up appreciably. This allows the electrical characteristics of the module to be measured at one temperature (the ambient temperature of the module/factory), which is usually close to 25°C allowing for only minor adjustments to be made to correct the 25°C standard temperature.

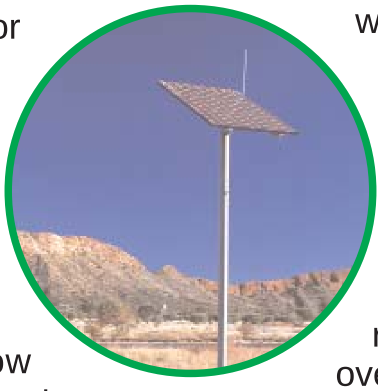
Most manufacturers give only nominal power ratings and a tolerance (usually±10%) for a given type of module. BP Solar also gives, in addition to its STC rating, a rating at operating conditions of 80% sun and a cell temperature of 47°C which represents conditions more common in actual operation.

PV modules are certified for a number of characteristics including safety, durability, and output by a number of agencies around the world. The most significant rating agencies are U.L., F.M., and the Commission of the European Communities (C.E.C).

When will PV be economical for widespread use?

Over 2 billion people in the developing world have no access to electricity. For these people PV is probably the most economical power source today, so in the broadest sense the answer is now. However, if the question is, 'when will PV compete with traditional power sources in countries with extensive electrical infrastructure, like Australia and the United States', the answer is that grid-connected use of PV is expanding each year.

Incorporating solar electric arrays as integral parts of new building construction, or when retrofitting older buildings, has become possible in the last decade. In fact, grid connected use of solar power is growing at 30% each year for both residential and commercial buildings. Some of this growth is also based on concerns with global warming and carbon dioxide emissions. Therefore, providing clean, renewable electrical power in urban areas can allow participation in energy conservation and pollution mitigation programs.



Who uses PV?

Individuals, businesses, governments, and non-profit organizations use PV. Anyone requiring electricity with or without connection to the existing grid is a potential PV user.

Can PV be used for heating pools or domestic hot water?

While it is technically feasible to use the electricity produced by a PV array to heat water, it does not usually make economic sense. If hot water is desired it can usually be produced much more cheaply by a solar thermal system (which uses heat absorbing panels filled with water).

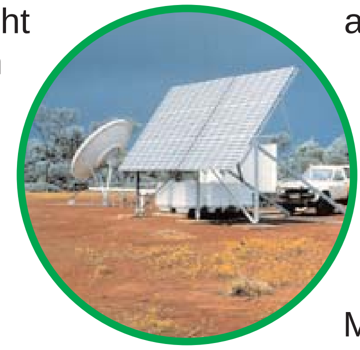
Does PV work in the cold?

Yes, very well in fact. Contrary to most peoples' intuition, crystalline PV's actually generate more power at lower temperatures, other factors being equal. This is because PV's are really electronic devices and generate electricity from light, not heat. Like most electronic devices, PV's operate more efficiently at cooler temperatures. In temperate climates, PV's will generate less energy in the winter than in the summer, but this is due to the shorter days, lower sun angles and greater cloud cover, not the cooler temperatures.

Does it work in cloudy weather? How about indoors?

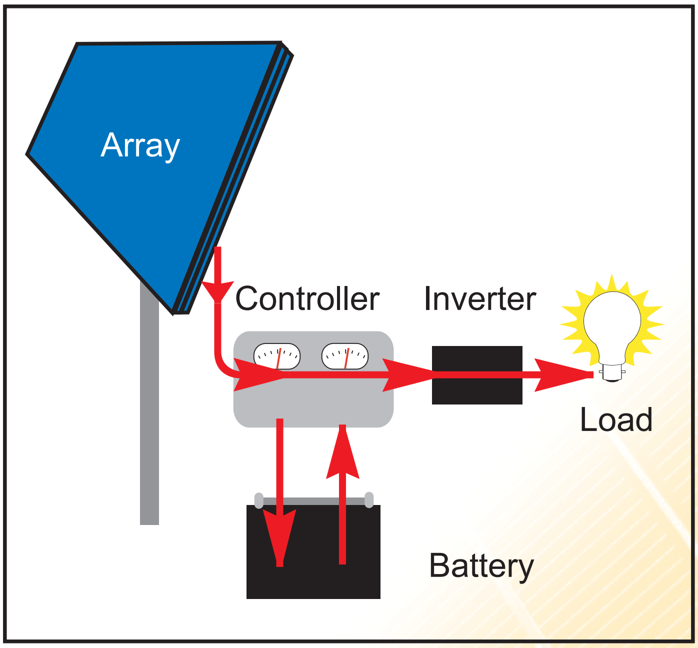
PV's do generate electricity in cloudy weather although their output is diminished. In general, the output varies linearly down to about 10% of the normal full sun intensity. Since flat plate PV's respond to a 180° window, they do not need direct sun and can even generate 50-70% of their rated output under a bright but overcast condition. A dark overcast might correspond to only 5-10% of full sun intensity so output could be diminished proportionately.

Indoor light levels, even in a bright office are dramatically lower than outdoor light levels, typically by a factor of several hundred or more. PV's designed for outdoor use will generally not produce useful power at these light levels, since they are optimized for much higher intensities. On the other hand, PV's designed for lower light levels like the cells found on calculators are optimized for those conditions and perform poorly in full sunlight.



Aside from PV modules, what else do I need in my PV system?

Although a PV system can be as simple as a module and a load (such as a direct driven fan), most PV systems are designed to supply power whenever it is needed and so must include batteries to store the energy generated by the PV array. Systems with batteries also need electronic devices to control their charging or limit the discharging of the batteries. Since PV's and batteries are inherently DC devices, larger systems usually include DC/AC inverters to supply AC power in local voltages and frequencies. This enables the use of standard appliances in the system. Otherwise special DC appliances (usually from the RV or marine industry) must be used. On the electrical side, protective devices such as diodes, fuses, circuit breakers, safety switches and grounds are required to meet electric code safety standards. In general PV systems also require mounting hardware to support and elevate the PV modules and wiring to connect the PV modules and other components together.



Why are solar cells so inefficient?

This is a matter of comparison. Modern single junction mass produced solar cells are about 13% - 16% efficient. This is a little more than half of the theoretical maximum efficiency for such devices. Multi-junction cells could theoretically achieve efficiencies up to 50% and laboratory cells have achieved over 30% efficiency. The challenge is to increase the efficiency while reducing the cost.

Since the "fuel" is free, efficiency is not the major factor limiting PV today. Usually more than enough area is available to generate the energy required. Cost is usually the limiting factor.

In comparing PV's with other methods of energy generation, it is important to start from the same point. Since all fossil fuels originally got their energy from the sun, if one were to measure electrical generation from fossil fuels relative to the original solar energy source the efficiency would be a fraction of a percent! In this comparison, PV's win hands down.

Will tracking improve the performance of my system? How about using reflectors to concentrate more light on the modules?

The effectiveness of tracking depends a lot on the climate and the application. Areas with a lot of haze or clouds won't get much benefit from trackers because the light is scattered. Also, applications where the load is the same in every month will also derive little benefit because tracking doesn't improve the performance of the system very much under worst case (usually winter) conditions.

Under ideal conditions, trackers improve PV output per day up to 40% but they add to system complexity and expense and are not generally as robust as fixed mounting systems. Their use is generally limited to applications where the increased output matches increased demand (such as livestock watering,) in drier areas (e.g., the Australian outback).

Reflectors can increase the output of PV arrays somewhat although their effect is not linear because the increased light intensity causes the module to operate at higher temperatures, which reduces its efficiency. More importantly, the elevated module temperatures and light intensities can lead to premature failure of the module and for this reason, the use of artificial reflectors is not recommended and will in fact void the module's warranty.

Is PV cost effective for residential applications?

For years PV was generally not considered directly competitive with electricity generated by local utility companies. However, as the cost of PV has continued to decline and utility costs have risen, suburban homeowners have been installing PV systems to control their utility costs. And as interest in energy efficiency and energy conservation grows, the use of PV for homes is increasing. It is now more economically feasible than ever to install a PV system with a battery back up as a home option that provides reliable electrical power during power outages or to reduce utility bills. Some environmentally motivated individuals have chosen to disconnect from their local utility and use a solar electric system to provide all of their home's power.

Residential use of PV, however, remains most economical in areas where there is no power present at the site. For these remote homes or cabins, PV is frequently used for all of the most common electrical needs (except heating, which is best provided by gas, wood, or solar thermal systems) and is very competitive with other sources of electricity.

PV is also frequently used in residential areas. Where power is present, for decorative and security lighting, where power lines would have to be run and PV provides a less costly, easier, and safer alternative.

How long will my PV system last? Do PV modules lose power over time?

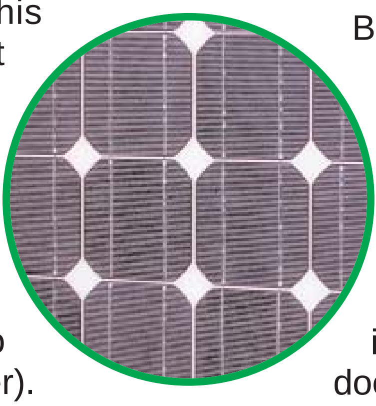
In general, the PV modules are the longest-lived component of a PV system. Top quality modules, such as those in BP Solar's range, are designed to last at least 30 years and carry a 20-year limited warranty. They are designed to withstand all of the rigors of the environment including arctic cold, desert heat, tropical humidity, winds in excess of 200kph (125 mph), and 25mm (1 inch) hail at terminal velocity.

Batteries will last up to 10 years (high quality industrial types). Smaller sealed units will typically last 5 to 7 years. Automotive batteries are poorly matched to the characteristics of PV systems and should not be used. Some types of PV modules (using thin film silicon) have a predictable fall off in output in the first few months of operation, which slows down and stops after some time. The modules' output from then on is relatively stable. This is a comparatively small effect in current BP Solar thin film modules, which carry an 80%

power warranty for 20 years. Polycrystalline modules such as BP Solar's range do not experience this kind of degradation and in fact are warranted to produce 80% of their original minimum power rating for 20 years.

What about breakage? Don't most modules contain glass?

The most reliable, longest-lived PV modules use a glass superstrate. BP Solar's range uses low-iron tempered glass laminated with layers of plastics. This construction is very durable but given a strong enough impact, it will break. If the glass is shattered or punctured the module will eventually fail due to water getting into the solar cells and causing corrosion. It may take years for the module to completely fail (produce no power).



On the other hand, if the module is damaged in such a way that the two electrical connections between any given pair of cells are both severed there will be no path for the current and the module will have no output. BP Solar makes a series of products called Lite modules, which use a stainless steel substrate rather than a glass superstrate. These modules are designed for light weight and ruggedness in applications such as camping and are shatterproof. In a permanent installation however, they will not last as long as equivalent glass front modules. This is because the plastic covering used is not as inert as glass and the stainless steel is not as good a match (for thermal expansion) as glass is to the silicon solar cells. In summary, given enough force anything will break. The most effective protection against vandalism, theft and other catastrophes is property/casualty insurance.

What should I look for when purchasing a PV module?

An informed buyer will look at a number of items when buying a PV module. First, ask the seller what external agencies have tested, qualified, or otherwise approved the module. In Australia, look for a listing from Underwriters Laboratories (U.L.) and Factory Mutual Research (FM), organizations which certify the safety and performance of PV products. In Europe, look for approval by the Commission of the European Communities (CEC). Ask if the module passes the tests established by the U.S. Jet Propulsion Laboratory (JPL Block V) to verify long-term reliability. Find out if the manufacturer regularly qualifies production units (rather than laboratory samples) to international standards.

Next check out the module. Pick it up. Does it have a solid feel? Or does the frame easily twist. Look at the junction box. Is it solidly attached? Can it accommodate standard electrical fittings? Can it take heavy gauge wire? Can connections between modules be made in the box? Will it accommodate diodes and regulators if needed?

Are the module bus bars open and well isolated or are they folded behind the cells where they can cause electrical shorts or de-lamination?

What is the manufacturer's tolerance on power (how far below nominal can the power be and the module still be considered within specifications)? Ask the seller if it is not readily apparent. Does the module have enough voltage to charge batteries under all conditions (at least 16.5 volts at maximum power)?

Examine the warranty. Is it vague or does it guarantee a specific level of performance?

Finally, look at the manufacturer. How long have they been manufacturing photovoltaics? Are they an organisation likely to still be in business in ten years?

What is their reputation? Have their products proven reliable in many years of operation? Do they have a trained sales force and authorised distributor team to back up their products in the field?

Power Partners invite you to put us to the test. We are confident that you will find BP Solar photovoltaic products to be the best in the industry and we hope that the information in this booklet will help you to make PV part of your life.

POWER PARTNERS

www.power-partners.com.au

For more information contact your nearest Power Partner