Photovoltaic systems

Photovoltaic technology has been used to power homes for many years, and with good reason. Sufficient sunlight falls on Australia to provide the nation's total energy needs. With a few solar modules the homeowner can capture some of this abundant energy. This sheet should be read in conjunction with Renewable Electricity.

Historically a niche product, photovoltaics are now being used to provide price-competitive, zero greenhouse emission energy to homes and businesses across the country.

All photovoltaic (PV) systems should be installed by a Sustainable Energy Industry Association (SEIA) certified installer.

SOLAR MODULES

Solar modules come in two distinct categories – crystalline silicon and amorphous silicon thin film. Both amorphous and crystalline technologies are commonly used in efficient grid connected and stand alone installations.

Mono and poly crystalline modules usually have 36 solar cells in a 9 x 4 matrix connected in series to provide an output voltage suitable for battery charging.

A typical module will provide a peak power output voltage of 17V and output current of 4.7A under optimum conditions, giving a rating of 80 Watts peak (Wp). Modules can be connected in series or parallel to form an array to provide higher voltage and current outputs as required.

Crystalline solar modules are covered with tempered glass on top and a tough ethylene vinyl acetate (EVA) material at the back. The glass and backing material protect the solar cells from moisture.

Crystalline modules need to be cool. Output efficiency of crystalline PV arrays decreases by 0.5 percent per degree Celcius over the standard test temperature of 25°C. Good ventilation is required at the back of modules. Exposure to cool breezes when siting modules is an important consideration.

Amorphous silicon is one of a number of thin film technologies. This type of solar cell can be applied as a film to low cost substrates such as glass or plastic in a variety of module sizes.

Advantages of thin film cells include easier deposition and assembly, low cost of substrates or building materials, ease of production and suitability to large applications.

Efficiency of thin film modules is lower than that of crystalline modules but all the types of modules are price competitive. Those currently on the market degrade in output by up to 10 percent when first exposed to sunlight but quickly stabilise to their rated output.

Thin film modules have various (often flexible) coating and mounting systems. Some are less susceptible to damage from hail and other impacts than those covered in glass.

Solar modules can be supplied with a frame, usually constructed of anodised aluminium, or as an unframed laminate.

More solar modules are being fabricated as building materials so that they can be integrated into the building fabric. They include solar roof tiles, wall materials and semi-transparent roof material for atriums and skylights.

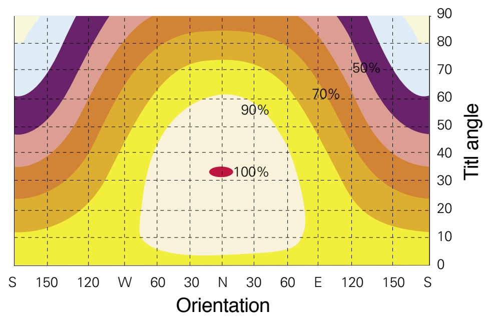
It is anticipated that further development of thin film technology will lead to a proliferation of cost effective, PV coated building materials that can be integrated with the building fabric to reduce costs, see 'Building Integrated PV'.

All PV modules need to be cleaned periodically to maintain their efficiency.

SITING

Orientation

Solar modules produce most power when they are pointed directly at the sun. It is important to install them so that they receive maximum sunlight. Ideally they should be in full sun from 9am to 3pm in mid winter.



Variation of solar module output with orientation and tilt angle for latitude 35°S

The above chart for latitude 35°S shows the effect of orientation and elevation on module output, expressed as a percentage of the maximum possible output. Note that a wide range of elevation and orientation angles will still provide useful output.

Elevation

For stand alone PV systems (SAPS), where winter operation is crucial, the angle should be the latitude plus 15 degrees.

For grid connected systems the angle should be latitude minus 10 degrees to maximise the amount of energy produced annually. Latitude adjustments for grid connected systems in most climates fit within an acceptable roof pitch range (eg. for Sydney's latitude this is 22 degrees, a common roof pitch).

Output power of an array is directly proportional to power received from the sun. This will vary throughout the day. The rated maximum output of the module might only be achieved occasionally, depending on the actual site.

System designers calculate the output energy from the peak sun hours, which is a measure of the available solar energy. It is numerically equal to the daily solar radiation in kWh/m^2 (Note: it is not the same as the number of hours of sunlight). Peak sun hours varies throughout the year. Peak sun hours are usually averaged and presented as a monthly figure.

The following table shows the monthly and annual peak sunhours for various locations in Australia.

	MELBOURNE	SYDNEY	BRISBANE
January	6.9	6.7	6.5
February	6.4	5.8	6.2
March	5.2	5.7	5.7
April	3.8	4.4	4.8
May	2.8	3.6	4.2
June	2.4	3.4	4.1
July	2.7	3.3	4.2
August	3.3	4.4	5.2
September	4.3	5.2	6.0
October	5.3	5.8	5.9
November	6.1	6.3	6.0
December	6.6	6.9	6.3
Annual	4.6	5.1	5.4

The peak power output of modules is rated in kilowatt peak (kWp), and is measured under standard test conditions. The table below indicates the annual load in kilowatt hours (kWh) that can be met by a 1kWp grid connected system and a stand alone system for different annual average peak sun hours. Output over the year will vary in line with the monthly sunhours as shown in the table above.

The figures for the systems differ due to the different efficiencies of associated equipment such as inverters and batteries.

ANNUAL PEAK SUNHOURS	4	4.5	5	5.5	6
kWh/YEAR GRID CONNECT	1120	1260	1400	1540	1680
kWh/YEAR STAND ALONE	810	910	1015	1115	1215

A typical Sydney household has an electricity usage of about 5,000kWh per year. A house with energy efficient appliances and using non-electric cooking, heating and hot water could use as little as 1,000kWh pa.

Shading one of the cells in a module is similar to opening a switch in a circuit and stopping the current flowing. This results in a loss of power from many cells, not just the one that is shaded. Partial shading can cause "hot spots" that can damage the module. This occurs in mono and poly crystalline modules but not in amorphous modules. Arrays should not be located near trees that will grow and shade the modules.

Standard solar modules are supplied with junction boxes on the back to facilitate electrical interconnection. Some modules used in grid connected systems now have leads and plugs/ sockets for easier installation.

Bypass diodes are supplied within junction boxes for mono and poly crystalline modules. These bypass diodes allow current to flow through them when cells are shaded, minimising the possibility of cell damage from shading.

At night solar cells act as a resistance and current will flow from the battery bank into the module. The amount of power lost due to this process is greater in poly crystalline modules than mono crystalline modules. Blocking diodes should be installed in junction boxes to prevent this.

In SAPS the PV array needs to be installed as close as possible to the batteries to minimise the power loss between the modules and the batteries. The system designer will determine the size of the cable to minimise the power loss between the modules and the batteries.
[See: Batteries and Inverters]

If modules are mounted some distance from batteries, they can be wired in series to allow higher voltage and lower current. An electronic component called a maximiser is used to convert output to the correct battery voltage.

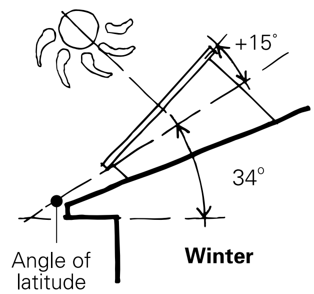
INSTALLATION

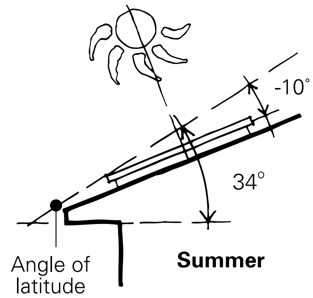
Modules can be fixed on the ground, wall or roof with a frame mount, or integrated into the building fabric.

Array frames

Solar array frames are tilted so that the modules face the sun. In Australia modules face north. In tropical areas this means the sun will be south of the array for part of the summer but this does not greatly affect output, see 'Orientation and elevation'.

Array frames can be fixed, adjustable or tracking. System designers choose the right frame for your system.





Solar panels must face due north.
Sydney angle of latitude is 34°

Fixed frames are set at the optimum tilt angle for the system. Optimum tilt angle is dependent on the type of load and available solar power.

As a rule of thumb, if the main loads are in winter months when solar availability is reduced, tilt angles should be more vertical (approximately equal to latitude plus 15°) to maximise exposure to the low winter sun. If major loads are cooling and refrigeration the tilt angle should be reduced (approximately latitude –minus 10°) to maximise output during summer. For grid connect systems the summer optimum angle should be used to maximise annual output of the modules.

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Adjustable frames allow the tilt angle to be varied manually throughout the year to maximise output year round. In practice it has been found that although many people change the tilt angle of the frame in the first few years of operation, they forget to do this as the years progress. If this situation is likely, it is best to fix the array at optimum angle.

Tracking array frames follow the sun as its path across the sky varies throughout the day and year. They are controlled either by an electric motor or the use of a refrigerant gas in the frame that uses the heat of the sun to move the gas around the frame to follow the sun. Trackers are more expensive than fixed array frames but by following the sun they provide more power throughout the day. They are most beneficial at higher latitudes where the available solar energy is lower. However, tracking arrays, being mechanical devices, require maintenance and may reduce system reliability.

The outputs of crystalline modules are affected by temperature. As the temperature increases, the output of the solar module will decrease. Amorphous solar modules are less affected. To keep mono and polycrystalline modules cool they should be well ventilated, with a gap of at least 150mm behind them to allow airflow.

Array frames must be designed to meet Australian wind loading standards.

Avoid corrosion. If the array frame and module frame are made of different metals they must be separated by an isolating material to prevent electrochemical corrosion. This also applies if mounting a module on a metal roof.

For PV systems of more than 1kWp, it is worth considering the installation of a maximum power-point tracker. This is a control device that ensures that there is always the maximum energy transfer between the modules and the load. Grid interactive inverters generally have a MPPT built in. For stand alone systems the benefit will depend on the particular application, and the designer will advise whether it is appropriate.

BUILDING INTEGRATED PV (BIPV) MODULES

True building integration requires that the PV product is either fully integrated into or replaces an existing building element.

PV installations are currently a considerable additional expense, but if done well BiPV construction should add considerable value to a home.

BiPV products requiring few additional installation details beyond standard construction practice are beginning to appear. These are not yet common in Australia. PV can be integrated into roofs, facades, skylights or awnings. Facade systems are not recommended in Australia as the energy output is lower due to vertical elevation and generally high sun angles.

Many BiPV installations do not allow effective cooling of crystalline modules which results in lower output. This needs careful consideration in the design.

Don't hide BiPV systems. Expose them as a prestigious element of modern architecture.

New buildings should be designed so that PV elements face north at the near optimum tilt angle, see 'Orientation and elevation'.

ROOF INTEGRATION

Rooftop systems can be either partially or fully integrated. In the latter case the elements must also fulfil the usual functions of strength, watertightness, drainage, etc. Careful detailing is required.

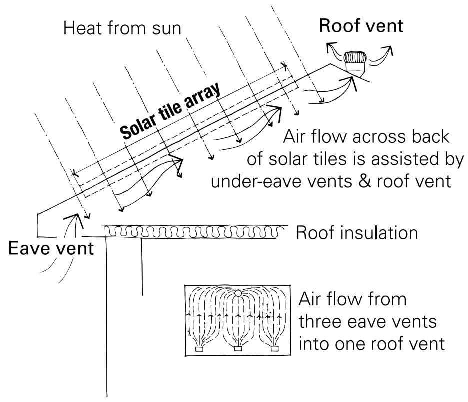
Mirvac Lend Lease Village Consortium

Partially integrated systems use special mounting structures to hold the cells, but require an additional waterproof layer. This is the approach used at the Newington Olympic Village.

Solar tiles or shingles are designed to replace conventional tiles or roofing. They allow easy access to the rear of the tiles for ventilation and maintenance. The roof space must be ventilated to keep the tiles cool.

Roofs are often at a pitch that is close to the optimum PV module tilt angle. For example, the optimum tilt angle for a grid connected system in Sydney is about 24 degrees, which is very close to the most common roof pitch. PV roofing elements need to be compatible with any non-PV elements for structural and aesthetic reasons.

Shading elements such as BiPV awnings reduce cooling load at the same time as generating electricity. They are usually quite accessible for cleaning purposes.



Semi-transparent PV modules can replace glass skylights and glass roofing in many situations. The dappled light quality can be used effectively by skilled designers.

ADDITIONAL KEY REFERENCES
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