Australian PV Association

ABN 91 006 005 190

Best Practice Guidelines for Local Government Approval of (Solar) Photovoltaic Installations

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Cover Photo: Kyocera - Heyban roof tile

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Best Practice Guidelines for Local Government Approval of Photovoltaic Installations

WHAT ARE PHOTOVOLTAICS?

Photovoltaic (PV) systems produce electricity from sunlight. The electricity is produced by PV modules as direct current (dc) and is passed through an inverter to convert it to 240V alternating current (ac) for standard use. The dc electricity can also be used directly or via battery storage for applications such as street lighting or water pumping. PV systems should not be confused with solar flat plate or evacuated tube technologies which heat water from thermal energy from the sun, also referred to as solar water heaters.

Although Councils are not usually involved with electricity generating systems, photovoltaics are often installed directly on buildings, or used as a replacement for building elements such as roofs, walls or windows. Hence their use in urban areas overlaps with Council responsibilities for building structures.

PV Sunshades on the CSIRO Energy Centre, Newcastle (Source: R.Corkish)

WHAT ARE THE BENEFITS OF PHOTOVOLTAICS?

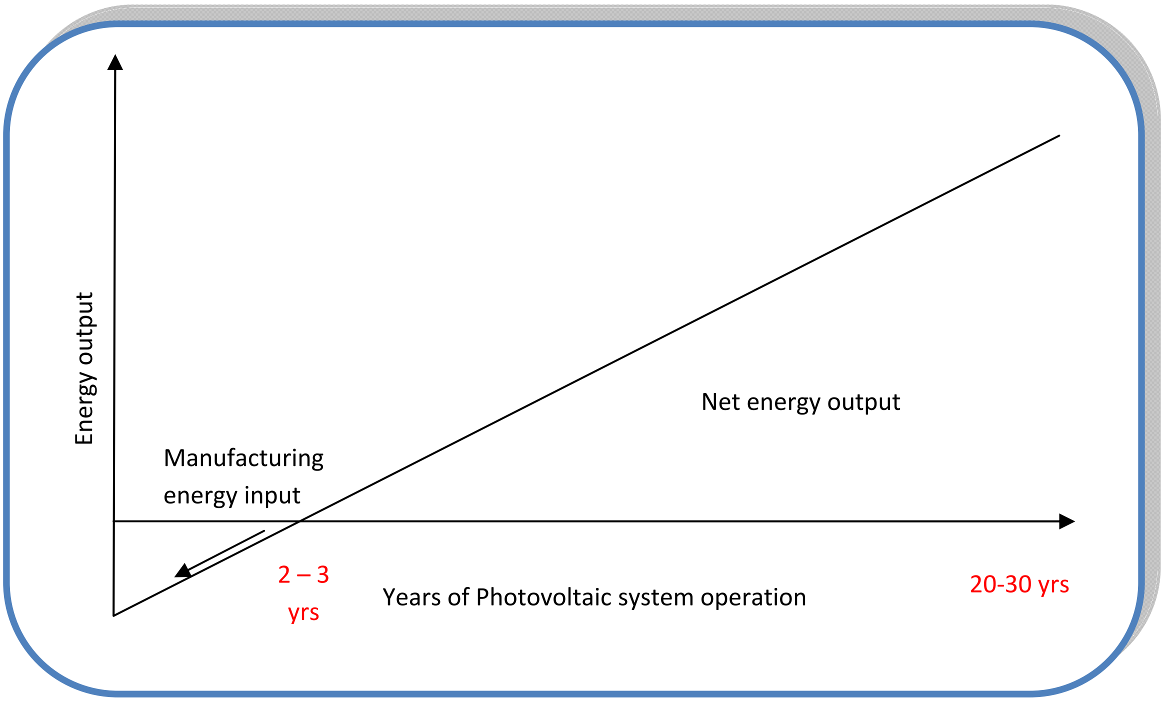
Compared to other electricity generating technologies, PV is easy to locate in urban areas, with a short installation time, and has no operating noise and few aesthetic concerns, a long lifetime, is emission-free and has no on-going requirement for fuel or water. It offers a wide range of potential values to different people:

- a building occupier can benefit from reduced power bills, as well as increased self reliance, and depending on the system, increased reliability of supply;
- a building owner can benefit from visual appeal, green image, enhanced property value and improved rental prospects;

- electricity utilities can benefit from reduced power costs at times of peak load, reduced line losses and deferral of the need to augment their networks;
- the broader community can benefit from local employment, reduced power outages or brown-outs, reduced local and global pollution levels, and where the installation is sympathetic to local aesthetics, from enhanced property values;
- the nation can benefit from employment creation, pollution reduction, and energy self reliance.

ENERGY PAYBACK TIMES

The most common myth about PV is "that PV does not pay back the energy used to create it". The energy payback time in which the energy input during the module life-cycle is compensated by electricity generated by the PV module depends on several factors, including cell technology, PV system application, irradiation, the sources of energy used in its manufacturing processes and the energy the PV will displace. Also important is "how many times the energy invested is returned by the system over its operating life. For a typical 2 kWp rooftop system, the energy payback time is 2 to 3 years using multi-crystalline modules and more than 7.5 times the energy used in its manufacture is generated over a 20 year life. For thin film modules, the payback time is half that of crystalline modules, but the lifetime may be shorter.



INSTALLING PV SYSTEMS

In urban areas, the most common type of PV installation is on a rooftop. Typically, the PV array is placed flush with the roofline, leaving a gap of at least 100mm to facilitate airflow needed for cooling. For optimum electricity output the array should be placed on a north-facing roof at an angle equal to the latitude of the location. Detailed latitude angles are provided in the table below for major cities of Australia and highlight the difference between Darwin (12.4°) and Hobart (42.8 °), but show only a 6 degrees range between Perth, Sydney, Adelaide, Canberra and Melbourne.

Table showing Latitude angles of Australian capital cities

CITY	Darwin	Brisbane	Perth	Sydney	Canberra	Adelaide	Melbourne	Hobart
Latitude	12.4°S	27.5°S	31.9°S	33.8°S	35.2°S	34.9°S	37.8°S	42.8°S

To find the latitudes and longitudes of other Australian towns and cities, see Charles Sturt University - http://www.csu.edu.au/australia/latlong/index.html

Suitable roof surfaces may of course not face directly north, while most residential roofs are at tilts of 20 or 25 degrees and commercial roofs at 5 or 10 degrees. There is, however, scope for some degree of variation from this ideal without significantly effecting output. For example, a north-east facing roof at 20 degrees might result in a output being reduced by less than 5%. For a Sydney rooftop, annual output would be reduced by around 15% if the array is faced east or west and 35% if faced south, as shown in the chart below. For low pitched roofs, the array may be placed on a frame or other support structure to raise it to the optimum tilt angle.

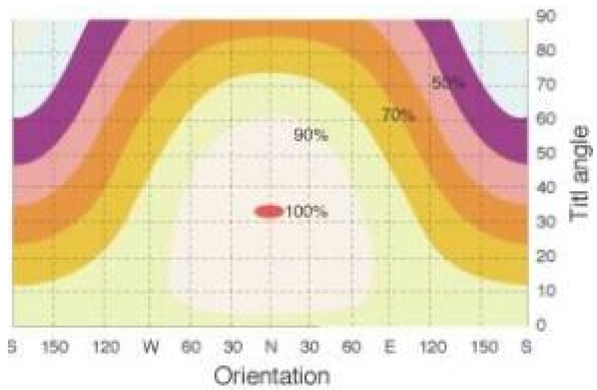
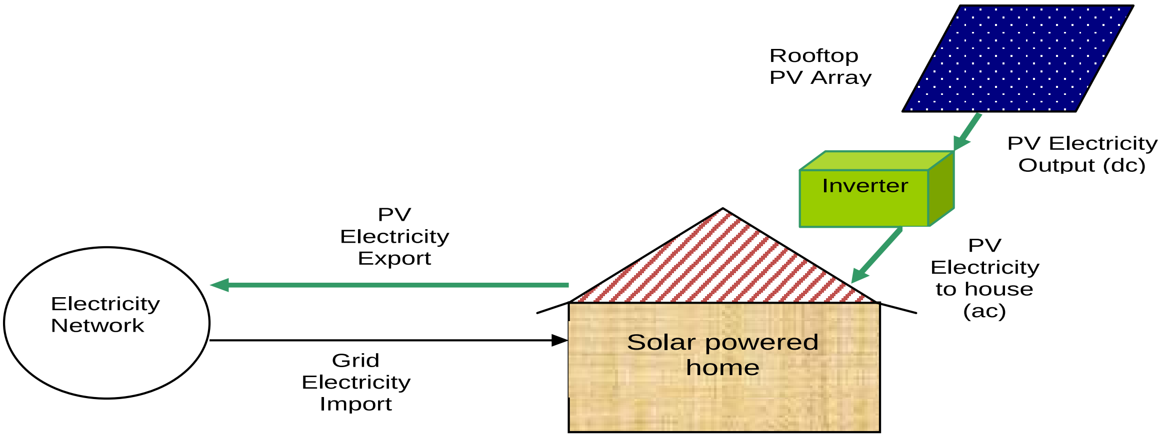


Chart for latitude 35°S showing effect of orientation and tilt on PV output (as a % of optimum)

Flush mounted PV array on a Queensland School building
(Photo: Ergon)



Layout of a typical grid-connected rooftop PV system

INSTALLATION: WHO DOES WHAT?

The Clean Energy Council (CEC) runs an accreditation system that covers both the design and the installation of PV systems. Even licensed electricians need to undertake this accreditation, because dc wiring is not covered in standard electrical training. In South Australia, installers are required to undertake additional training on roof inspection, to ascertain structural integrity, especially for systems weighing more than 100 kg. In cyclone areas of Queensland and the Northern Territory, additional requirements and inspections may also be necessary. In most cases, the PV installer will ensure that all necessary arrangements are in place. However, some may leave it to the building owner to organise prior to installation.

For grid-connected systems, approvals must be received from the electrical network service provider (NSP) for the connection. This means that inverters approved for use on Australian grids must be used, the NSP has to know the installation has been made and that appropriate signage and safety switches are in place in case work needs to be done on the electricity lines. Approval must also be sought from the electricity retailer, with arrangements for possible sale of electricity, and for installation of appropriate meters. In many cases, retailers provide small systems the option of 'net metering', where the price of electricity exported to the grid from the PV system is the same as that charged for electricity purchased by the household. Some retailers offer higher prices for electricity provided by the PV system to the grid during peak hours. In many States, 'feed-in tariffs' also operate, whereby exported power is paid a higher tariff. The tariffs vary by State – some are paid net of household use (net export FiTs), others for all PV electricity generated (gross FiTs).

Arrangements and costs for the above processes and meters vary from one electricity company to another, with some requiring additional inspections and fees and others relying on accredited installers.

PV modules mounted on a tilted frame on the South Australian Parliament House (Photo: SA Government)

KEY ISSUES FOR COUNCILS

Key issues from a development assessment perspective are those of urban planning and building:

- Will the installation be consistent with the character of the building and local area where it will be installed?
- Will the installation be structurally sound in its own right and not compromise the structural integrity of the building to which it is mounted?

In the first case, local government can assist proponents by giving clear guidance on what is required for Development Approval. Similarly, photos of successful installations can be of great assistance to someone finalising the details of their installation. Different panel brands and types have different aesthetic character and may be considered more or less appropriate for a given installation depending on the character of the building on which it is to be installed, roof type, colour etc. Photographic examples can be of great assistance.

Structural issues can be dealt with in a streamlined way through adherence to the Building Code of Australia, the use of Australian Standard or Engineer Certified framing systems and recognition of the training and skills of installers accredited by the Business Council for Sustainable Energy.

As more PV systems are installed, Councils need to consider the implications of Solar Access and maximising solar access benefits in landuse planning and Local Environment Plans (LEPs). Typically, solar access is measured by the number of hours that the sun can shine onto north-facing surfaces between the hours of 9 am and 3 pm on the shortest day of the year (winter solstice, 21st June). It is important to ensure that buildings do not infringe on the solar access provisions of a neighbouring property. The height of buildings, especially those located on a property's northern boundary, can be a critical factor in ensuring good solar access. Neighbourhood agreements, such as covenants, may be entered into between property owners to protect PV solar access.

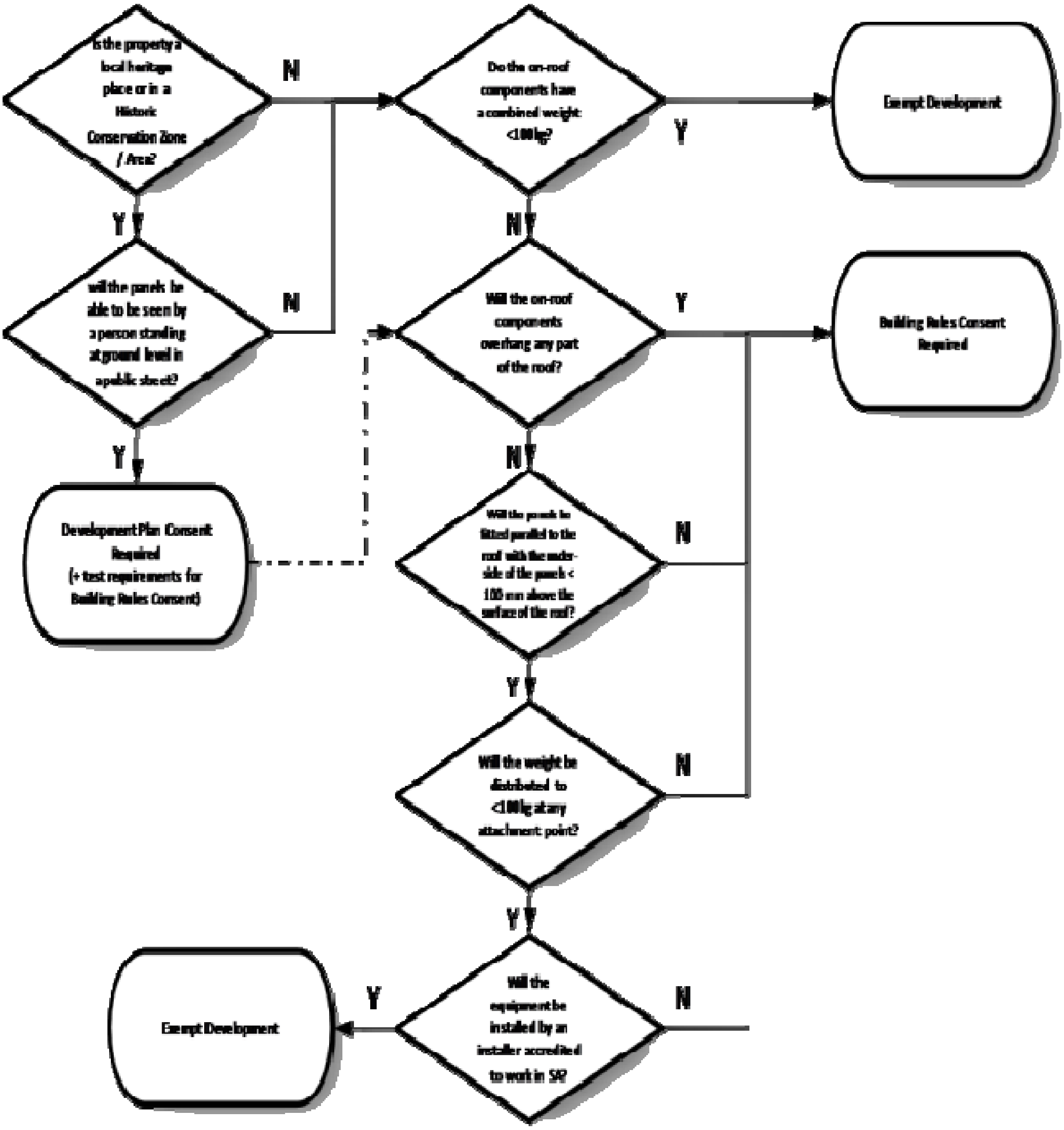
To assist in avoiding conflicts, landuse plans can take a lead in promoting good solar access zoning. Well orientated lots enable the future building to be more energy efficient, requiring less artificial heating, cooling and lighting and also have potentially greater roof space correctly orientated for solar water heaters and PV arrays. North-facing slopes improve opportunities for solar access; small lots are best suited to north-facing slopes with gradients of less than 15% (or 1:6). South-facing slopes impose a penalty on solar access; large lots and lowest densities are therefore best suited to south facing slopes.

Helpful solar access references are included at the end of this brochure.

Example of lightweight, insulating, self interlocking PV roof tiles which require no roof penetration (Photo: SunPower - Powerguard®)

THE APPROVAL PROCESS

The following shows the general planning process to be followed for photovoltaic (PV) system processing in South Australia. Anyone planning to install a PV system in SA should ask their installer the questions in the flow chart to determine what planning approvals, if any, are required.



WHEN IS COUNCIL INVOLVEMENT NOT REQUIRED?

In most States, Council involvement is not necessary for installation of standard PV systems, as long as accredited installers are used and systems meet Australian standards (see below).

South Australia

- accredited installers need to have undertaken additional training on verification of the structural integrity of the roof if systems weigh more than 100kg.

Northern Territory

- Cyclone areas (within 100 km of the coast) may need to follow requirements similar to those imposed on solar water heaters. These refer to certification of the structural integrity of the building as well as using products which are listed in the NT 'deemed to comply' manual.

WHEN IS COUNCIL INVOLVEMENT REQUIRED?

In most States and Territories, Council intervention only occurs when heritage or solar access issues arise, or for unusual or very large installations. For heritage or conservation areas, Council involvement may only be necessary if the PV array can be seen from the public domain. Solar Access may become an issue if trimming or removal of vegetation is involved, or if adjoining buildings apply for developments which would shade existing PV installations.

South Australia:

- Structural requirements are contained in the Building Rules Consent guidelines, which comply with the Building Code of Australia.

- Development Plan consent for PV installations is restricted to prescribed Heritage Areas and Conservation Zones and will require sufficient information to inform an assessment of the impact of the installation on the character of the building and area.

In heritage areas, it could be useful for Councils to provide examples of installation types which would be allowed. These could include specific types of PV which blend into the roofline, are hidden behind a building element, are installed on self supporting frames separate from the building, or on adjacent buildings.

Where roof structural strength is in question, examples of lightweight modules or those requiring minimal roof penetration should be discussed.

Example of PV roof tiles which blend into a slate roof and may be acceptable in a heritage area. (Photo: Solar Century)

WHAT CAN COUNCIL DO?

In order to streamline processes, reduce costs and hence encourage the use of PV installations, Councils could:

- Provide training on PV for Council staff likely to have to deal with enquiries
- Provide information on PV to ratepayers (see below), including local accredited installers and components approved for use in Australia
- Provide clear definitions of PV systems which do not require Council consent
- Provide a simple guide to the processes required for approval of PV systems which require DAs
- Work with other Councils and with Local Government Associations to standardise processes across Councils and States/Territories
- Waive fees
- Consider pre-approved PV types for heritage areas
- Better define elevations from which PV should not be visible in heritage areas, for instance, to allow installations which may be visible from little used back lanes
- Consider facilitation of bulk purchase arrangements which reduce PV costs for ratepayers
- Support moves to standardise insurance of installers and systems, in line with normal building codes.

WHAT INFORMATION CAN COUNCIL PROVIDE

There is a great deal of community interest in PV and Councils may increasingly be asked for information. Councils should be able to provide ratepayers with relevant information on Development Applications, Heritage or other requirements. For information on PV systems, the resource list below provides a number of useful websites and documents which ratepayers should be referred to.

Councils may wish to have copies of the booklets "*Electricity from the Sun: Solar PV Systems Explained*", "*Solar PV Systems – Users Maintenance Guide*" or "Photovoltaic Systems" (available from http://www.yourhome.gov.au/technical/fs67.html) available for perusal by ratepayers.

In addition, Councils may wish to keep a list of local accredited PV designers and installers. The up-to date list of accredited installers by suburb or postcode is available from http://www.cleanenergycouncil.org.au/info/AccInstallers%20List%20-%20all%20post%20-%20090610.pdf.

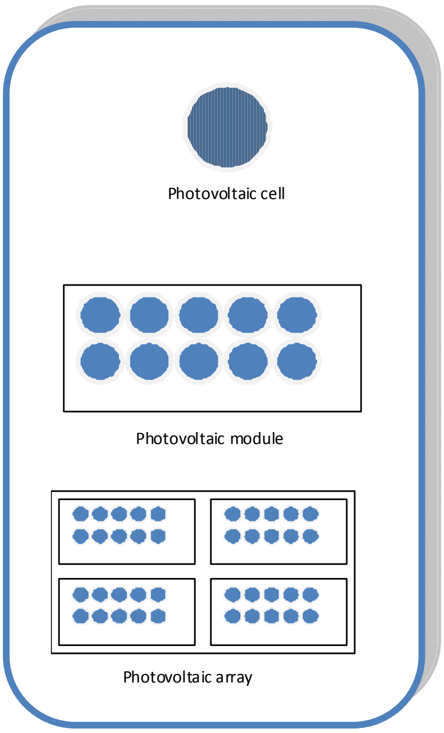
In general, Councils may not wish to provide advice on price or PV brands, but could refer enquiries to the list of PV modules and inverters approved for use in Australia: http://www.cleanenergycouncil.org.au/info/IEC%20PV%20Module%20list%20090626.pdf

http://www.cleanenergycouncil.org.au/info/Inverters%20List%20090526.pdf

Ratepayers should be advised to seek several quotes, to check for accreditation and to ascertain warranty, insurance and maintenance information.

TECHNICAL DETAILS OF PHOTOVOLTAICS

Most photovoltaic devices, or solar cells, are manufactured from semiconductors, which can conduct electricity when electrons are freed from their atoms using the energy from photons of sunlight: the *photovoltaic effect*. Cells are connected to an external circuit to allow current flow. Since the voltage and current of a single cell is low, cells are usually connected together to create solar 'modules' or 'panels' with the desired voltage and current. Similarly, modules are connected together to form arrays and systems.



At present most solar cells use semiconductor silicon, which has a bandgap in the visible spectrum, i.e. can use photons with energy from sunlight to release electrons. Cells can be sliced from a single large crystal (c-Si), or from a cast of multi-crystalline silicon (mc-Si) material. Cells made from single crystal silicon have a higher efficiency then multi-crystalline cells, because there are no grain boundaries to block electron flows or to provide recombination sites. However, multi-crystalline silicon is cheaper and less energy intensive to produce and so has become increasingly popular.

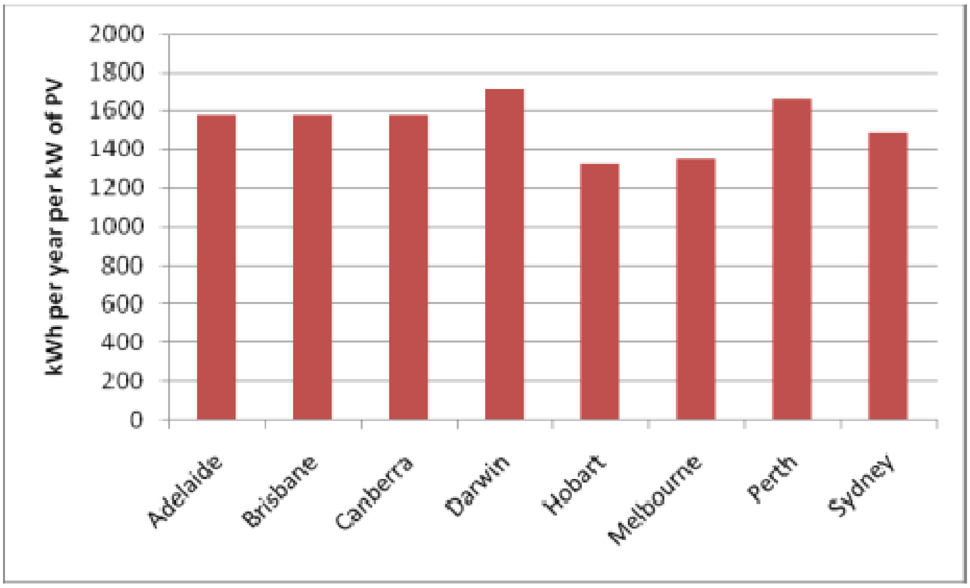
The silicon purification and wafering processes are energy intensive and one of the main cost components of crystalline Silicon solar cells. The cells are coated to minimise reflection of light or etched to increase reflection of scattered light back into the cell and to hence to maximise conversion of incoming light to electricity. Cells can be made 'bi-facial', allowing light to enter from both surfaces or they can have rear surface treatment to encourage internal reflection of light and hence enhance light capture. Metallic grids on the surface of the cells carry the current to the external circuit.

In order to reduce silicon usage and remove the expensive ingot and wafer processes, various methods are used to deposit semiconductor layers as 'thin films' directly onto useable substrates such as glass, metals, such as roofing sheets, and plastics of various types, including flexible sheets. To date the most successful of the thin film technologies is that of amorphous silicon, a disordered, non-crystalline allotrope of silicon, which can be deposited on a wide range of substrates in low temperature, continuous processes. Amorphous silicon cells are widely used in small consumer products, such as calculators and watches. In general, they have not yet achieved the efficiency and stability levels of crystalline silicon modules, but are finding a growing market in photovoltaic building products and other special purpose applications, as well as in large-scale solar power stations or 'solar farms' where their lower cost is an advantage, as it is for other thin film products.

Multi-junction a-Si products, using layers of other materials, including Germanium, silicon carbide and nano crystalline silicon, are often used as means of increasing efficiency and stability. A range of novel concepts are under investigation and are expected to capture an increasing share of the PV market over time. Some of these, such as nano silicon cells, aim to combine the high efficiencies of crystalline products with the low manufacturing cost of thin films. Others, such as organic cells use entirely different processes and may form the basis of very low cost PV products, even if efficiencies remain relatively low. These technologies may provide a new range of PV applications, built into consumer products, clothing or building materials and replacing batteries in a wide range of appliances.

ENERGY OUTPUT

The energy produced by the PV system will depend on the technology, the location and how close the installation is to optimum orientation. There are several important factors that impact on or can be used to improve the energy output from PV systems.



Typical Output from 1 kW of grid-connected PV installed at the appropriate orientation and inclination

1. Since PV modules rely on energy from the sun, the most important factor impacting performance is the amount of sunlight falling on the module. Hence, systems in sunny clear areas will generate more power than those in locations with less sun. The output from typical systems is shown above.

2. Because PV modules are made up of interconnected cells, shading on even a small part of a module can mean that no current flows through and the annual system output is disproportionately impacted. Similarly, depending on how the array is wired, shading of a single module may mean no current flows through the entire array. Shading can occur from adjacent buildings, trees, chimneys, power poles, satellite dishes or any other obstruction at roof height. A small amount of shading early morning or late afternoon may be tolerable, but shading of any part of the array during peak daylight hours should be avoided.

3. The output of silicon PV modules reduces as temperature increases. Amorphous Silicon PV modules have a lower temperature co-efficient than crystalline products, resulting in less output degradation and therefore relatively greater energy yields at higher temperatures. The temperature of a PV module can be kept as low as possible by ensuring that the mounting method allows adequate ventilation at the rear of the module. This is more of an issue for roof-top and building integrated PV than it is for field arrays, since the former have more restricted rear ventilation.

4. Amorphous silicon and other thin film products have a different spectral response to that of crystalline silicon products, some performing better in cloudy conditions where more energy is present in the blue wavelengths between 400 and 500nm.

5. Solar PV array orientation has a large effect on energy yield. Typically, fixed PV arrays are oriented for maximum annual yield, with the array inclination favouring the summer period where radiation levels are higher. For off-grid installations, inclination is usually set to maximum winter yield when solar radiation is at a minimum, so as to provide as consistent an output as possible over the year. A fixed PV array may also be oriented to maximum yield at one point during the day when electricity demand is highest or spot market prices are at a peak (e.g. west facing to meet late afternoon peaks).

6. Tracking systems, usually ground mounted, increase yield by allowing the array to follow the sun over the course of the day, while the array mounting can also be adjusted for inclination to achieve a better yield across the year.

7. Higher efficiencies and lower costs can be achieved by concentrating sunlight, using low cost reflectors or mirrors onto small areas of photovoltaic cells. Such systems are described by their concentration compared to 'one sun' or 1000 W/m^2. Concentrations of up to 500 suns have been achieved. Special purpose PV cells are used due to the high temperatures and the need to collect and transfer larger amounts of electricity per unit area. Concentrator PV systems (CPV) require clear sky solar conditions to allow focussing and generally perform better in dry desert areas. Concentrator systems also require the use of trackers, and hence introduce a mechanical component into the PV system.

USEFUL REFERENCES & WEBSITES

Australian and New Zealand Solar Energy Society
www.anzses.org.au

Australian PV Association
www.apva.org.au

Best Practice Guidelines for Local Government Approval of Photovoltaic Systems, Australian PV Association for the Department of Environment, Water, Heritage & the Arts, June 2009.
www.apva.org.au.

Bureau of Meteorology
www.bom.gov.au/climate/

Clean Energy Council
www.cleanenergycouncil.org.au

Examples of PV systems
www.demosite.ch

How PV works
www.howstuffworks.com/solar-cell.htm

International Energy Agency PV Power Systems Programme
www.iea-pvps.org

NSW - SEDA (2005) Solar Access for Lots. Guidelines for Residential Subdivision in NSW
www.energysmart.com.au/brochures/Solar_Access_for_Lots_Guide.pdf

Planning Guide for PV
http://pvcityguide.energyprojects.net/

PVSyst (PV simulation tool)
www.pvsyst.com

Queensland Government Dept. of Public Works - Smart & Sustainable Designs - Designing for Queensland's Climate - www.build.qld.gov.au/smart_housing/pdf/qld_climate.pdf

Search engine for latitudes and longitudes of Australian cities and towns Charles Sturt University - http://www.csu.edu.au/australia/latlong/index.html

Solar Access and Lot Orientation - Ambrose, M. and Miller, A. (2008) - http://yourdevelopment.org

Solar Homes & Communities
http://www.environment.gov.au/settlements/renewable/pv/index.html

Standards, Training, Accreditation and Approved PV Products
http://www.bcse.org.au/home.asp

State Environmental Planning Policy (SEPP) 65 supported by the Residential Flat Design Code - Part 03 Building Design, 'Rules of Thumb'. A minimum proportion of 70% of solar access is sought by Residential Design Flat Code.
www.planning.nsw.gov.au/asp/pdf/06_0127_appf_sepp_65_comp_table_taa.pdf

Sustainability Victoria - information fact sheet: siting and solar access
www.sustainability.vic.gov.au/resources/documents/Siting_and_solar_access.pdf

Your Home Sustainable Design Guide and PV
www.yourhome.gov.au/technical/index.html

RELEVANT AUSTRALIAN & INTERNATIONAL STANDARDS

- AS/NZ 1170 Structural design actions: Minimum design loads on structures.
- AS 1170.2 Part 2 Wind loads.
- AS 1319 Safety signs for the occupational environment.
- AS 1530 Methods for fire tests on building materials, components and structures.

- AS 1530.4 Part 4 Fire resistance tests of elements of building construction.
- AS 1768 Lightning protection.
- AS 1931.1 Part 1 High voltage - Test techniques - General definitions and test requirements.
- AS 1940 Storage and handling of flammable and combustible liquids.
- AS 2279 Disturbances in mains supply networks.
- AS 2481 All-or-nothing electrical relays (instantaneous & timing relays).
- AS/NZ 3000 Electrical installations – Buildings, structures and premises "SAA Wiring rules".
- AS 3008 Selection of Cables.
- AS 3100 Approval & test specification - General requirements for electrical equipment.
- AS 3300 Approval & test specification - General requirements for household & similar electrical appliances.
- AS 3595 Energy Management Programs.
- AS/NZS 3131 Approval and test specification – plugs and socket outlets for use in installation wiring.
- AS 4509 for Stand-alone systems.
- AS 4777 Grid connection of energy systems via inverters. Part 1 installation, Part 2 Inverter requirements and Part 3 protection requirements.
- AS/NZS 5033 Installation of Photovoltaic (PV) Arrays.
- AS/NZS 6805 for stand-alone system inverters.
- IEC 61215 Crystalline silicon terrestrial photovoltaic (PV) modules: Design qualification & type approval.
- IEC 61643 Low voltage surge protective devices.
- IEC 61643-12 Part 12: Surge protective devices connected to low voltage power distribution systems-Selection and application principles.
- IEC 61646 Thin film terrestrial photovoltaic (PV) modules—Design qualification and type approval.
- IEC 61730-1 Part 1: Photovoltaic (PV) module safety qualification: Requirements for construction.
- IEC 61730-2 Part 2: Photovoltaic (PV) module safety qualification: Requirements for testing.
- EN 50380 2003 Datasheet and nameplate information for photovoltaic modules.

GLOSSARY AND ACRONYMS

Alternating current (AC): Electric current in which the direction of the flow is reversed at frequent intervals. In Europe and Australia, this occurs 100 times per second (50 cycles per second, i.e. 50 Hertz (Hz)) and 120 times per second in the USA. Also see direct current (DC).

Balance of systems (BOS): The parts of the photovoltaic system other than the PV panels including switches, controls, meters, power-conditioning equipment, and any supporting structure for the panels and storage components.

Building integrated photovoltaics (BiPV): The integration of PV into the external building skin.

Clean Energy Council (CEC): Is the organisation that implements the PV installers' accreditation scheme in Australia.

Development Application (DA): A document submitted by a resident or developer to the Local Planning Authority/Council that specifies the types and nature of alterations/developments they wish to undertake.

Development Control Plan (DCP): A document produced by Local Planning Authorities/Councils that specifies the types and nature of developments permitted in their area.

Direct current (DC): Electric current in which electrons are flowing in one direction only. Also see alternating current (AC).

Energy payback time: The time required for any energy producing system or device to produce as much useful energy as was consumed in its manufacture and construction. For PV the energy payback time is between 6 months and 4 years.

Final annual yield: Total photovoltaic energy delivered during one year per kilowatt of power installed. Unit: kWh per annum per kW installed.

Grid-connected PV system: System installed on consumers' premises, and connected to the local electricity grid, usually on their side of the electricity meter. This includes grid-connected domestic PV systems and other grid-connected PV systems on commercial buildings, motorway sound barriers, etc.

Inverter: Device that converts the direct current (DC) produced by a PV system into alternating current (AC), that can either be used in the home or exported to the grid.

Kilowatt-hour (kWh): Unit of energy (power expressed in kW multiplied by time expressed in hours).

Load: The amount of electric power that is being used at any given moment. Also, in an electrical circuit, any device or appliance that is using power.

Mandatory Renewable Energy Target (MRET): An obligation placed on electricity retailers by the Federal government, that requires them to source at least 9,500 GWh of electricity from renewable sources by 2010, and to maintain this level until 2020. This has been superceded by the Renewable Energy Target.

Off-grid PV system: System installed in households and villages that are not connected to a utility's distribution network (grid). Usually uses batteries to store electricity, most commonly lead-acid batteries. Also referred to as stand-alone photovoltaic power systems (PV-SPS) or remote area power supplies (RAPS).

Peak power: PV modules are rated by their peak power output. The peak power (or installed power) is the amount of power output a PV module produces at standard test conditions (STC). Unit: Watt peak (Wp). See below for an explanation of STC.

Photovoltaic effect: The process of photons of light exciting a semiconductor material in a PV panel to produce an electric current of volts, thus producing electricity from sunlight.

Photovoltaic power system: A system including photovoltaic modules, inverters, batteries (if applicable), and all associated installation and control components, for the purpose of producing solar photovoltaic electricity. Also commonly referred to as PV or photovoltaics.

PV: Abbreviation of photovoltaics and depending on the context, can refer to cells, modules or systems – where a system is made up of modules and a module is made up of cells.

Renewable Energy Certificates (RECs): Each REC corresponds to 1 MWh or electricity from renewable sources. They must be surrendered to government by retailers to prove

Renewable Energy Target (RET): An obligation placed on electricity retailers by the Federal government, that requires them to source at least 45,000 GWh of electricity from renewable sources by 2020, and to maintain this level until 2030. It supersedes the Mandatory Renewable Energy Target.

Renewable energy: Energy sources recently derived directly or indirectly from the energy of the sun, the earth's core, or from lunar and solar gravitational forces that are renewable over short timeframes. These include solar, wind, biomass, tidal, wave, hydro and geothermal energy.

Standard test conditions (STC): The testing conditions used to measure photovoltaic cells' or modules' nominal output power where the irradiance (sunlight) level is 1000 W/m2, the reference air mass is 1.5 times the solar spectral irradiance distribution and with a cell or module junction temperature of 25°C.

Watt (W): Unit of power. One Watt is equal to one Joule per second, with 1kWh equaling 3.6 MJ. Multiples like kW (1000 W) or MW (1000 kW) are also used. In this publication, it is understood to be power output under standard test conditions (STC). Also written Wp (peak Watt) by PV professionals to mean peak power at STC.