What is solar PV?

The term "photovoltaic" refers to a technology that uses a device to produce free electrons when exposed to light and thus create an electric current. The word photovoltaic derives from the Greek word "photo", meaning light, and the modern word "volt" or "voltage", meaning a unit of electrical potential (named in honour of the Italian physicist Alessandro Volta [1745–1827], who is credited with inventing the first chemical battery—this is the subject of debate, though, as working batteries may have been used in antiquity).

Photovoltaic (PV) technology converts sunlight into electrical energy in a direct way, as opposed to the more circuitous approach of solar thermal technologies that capture sunlight to heat a gas or fluid and subsequently use heat engines to generate electricity.

Individual solar cells create relatively low voltage, typically of around 0.5 V. Several cells are combined within a laminate with the cells effectively wired in series. The laminate is covered in a weatherproof housing and installed in a frame to form a PV module or panel. The panel will typically develop around 15 volts or more when under a load (e.g. while charging a 12-volt battery). Open-circuit voltage could be higher, perhaps 20 volts or more.

If panels are connected (electrically) in series, it is possible to obtain very high output voltages. In fact, a number of panels can be connected to form a PV string. Moreover, two or more strings can be fed to an inverter to create a PV array. Inverters are used to convert the DC current from the modules to AC. Figure 9 illustrates the typical elements of a PV system.

How is sunlight converted to electricity?

The most common PV technology uses solar cells made of semiconductor materials (such as silicon or germanium) dosed with small amounts of impurities (typically metals or metalloids). In simple terms, when sunlight strikes a cell, a certain portion of its energy is absorbed within the semiconductor material. The absorbed energy knocks electrons loose, allowing them to flow freely under the influence of electric fields.

Solar cells have inbuilt electric fields that force the freed electrons to flow in a certain direction. Metal contacts on the top and bottom of the PV cell enable the cell to generate a current in an external circuit. This current, together with the cell's voltage (which is a result of its in-built electric fields), defines the power (or wattage) that a solar cell can produce.

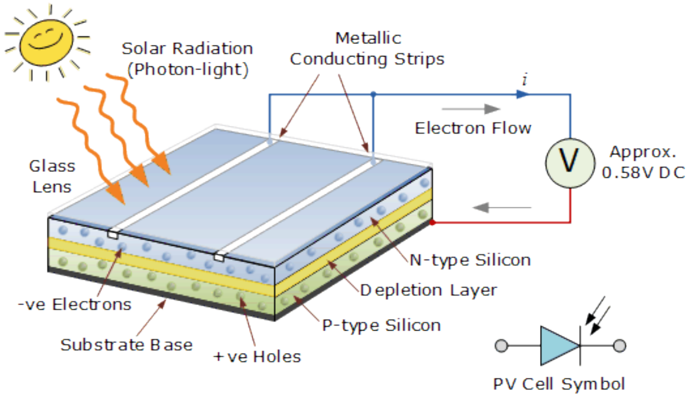

Figure 1. PV Solar Cell Construction

How do weather, environment and location affect solar?

Local weather can have a dramatic effect on the electricity production from a PV array. The most obvious factor is the amount and angle of sunlight hitting the panels, but air temperature, humidity and wind regime also play a role. Local environmental conditions and rainfall patterns affect the degree to which panels become dusty or otherwise fouled and this, of course, affects energy production.

As everybody knows, the amount of sunlight varies seasonally, both in intensity and duration. Summer brings long days and at any given time of day, the sun is higher in the sky and hence more powerful than in winter. Generally speaking, the smaller the angle of incidence onto a panel, the greater the potential production. The maximum sunlight intensity on a bright summer day may be around 1400 W/m^2, whereas it may be less than half that amount in winter due to the differing height of the sun during these seasons.

Figure 2. Sun Angles

To get the most energy production over a year in the southern hemisphere, solar panels are usually oriented true north (towards the equator) and tilted at an angle to the horizontal approximately equal to the site's latitude—in the case of Brisbane, this is about 27° south. In the subtropics, the sun in winter is not as low as in, say, Sydney or Melbourne. This means that in Brisbane and places further north, panel orientation and tilt is not so critical. Quite often, satisfactory output can be achieved at least cost by simply placing panels flat on low-angle roofs, even if this means they do not face north.

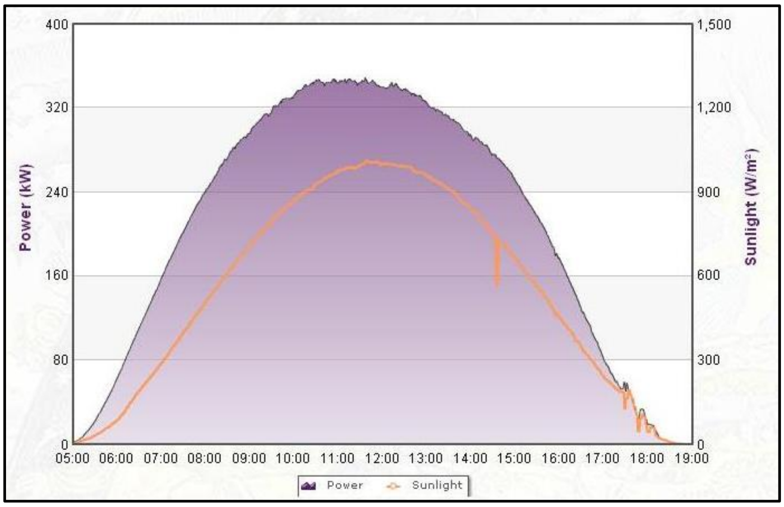

Figure 3. Generation vs. Irradiance (sunlight) Curves

The potential electrical power from a PV panel falls as the temperature of the panels rises. High panel temperatures are usually caused by bright sunshine; overall, the high level of sunshine usually compensates for the temperatures de-rating of the panels and PV output rises with increasing sunshine levels. The interplay of sunlight and panel temperature and ambient air temperature is complex, however.

Cool yet sunny conditions can occur in Brisbane, especially after southerly wind change has moved through South East Queensland. Such conditions along with a clear sky can be expected to produce high power outputs. The most dramatic effect of temperature can be seen when the sun breaks through on a cool, very cloudy day. As the cool panels are suddenly exposed to bright sunshine, the power output will soar.

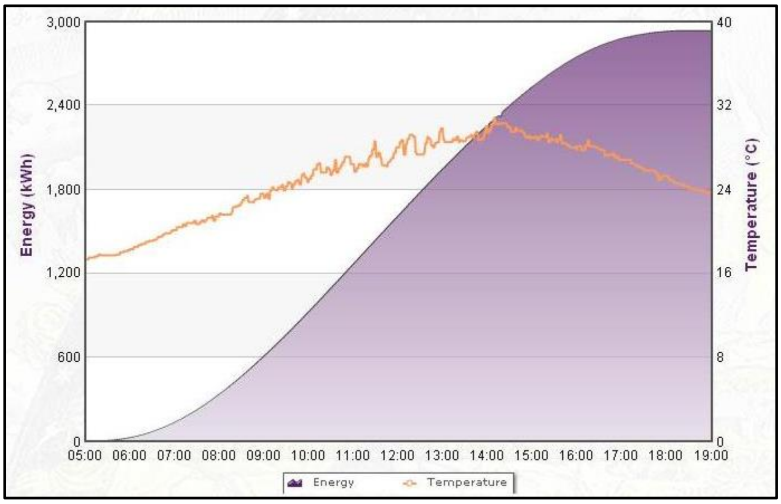

Figure 4. Generation v. Temperature Curves

Rain associated with clouds and a rainy environment is usually not conducive to good PV production. Infrequent, short duration heavy rain can play a positive role, however. Solar panels increasingly use special transparency glass, sometimes with special surface treatments such as anti-reflective coatings. This expensive technology can be undone if the panels become fouled with dust, leaves and other bird droppings. Flat to near-flat panels are particularly vulnerable to fouling. Even if only a few cells are covered by debris, then the output of a whole panel can be disproportionately reduced. Similarly, an under-performing panel in a PV string can seriously reduce the output of the whole string.

The same problem arises with leaves, pollen and other tree-sourced debris. Careful pruning of nearby trees can reduce the problem and regular heavy rain can help as well. Dust is a particular problem in dry inland areas. Technological development is alleviating this issue, but it will still be better to have a clean panel than one that is fouled. A panel-washing program matched to the local environment may need to be developed.

Solar mounting structures (i.e. flat- v. single-axis tracking v. dual-axis tracking)

Fixed-axis arrays are made up of PV panels mounted on rigid, static structures. Generally, these structures are built facing true north (in the southern hemisphere), and tilted at the site latitude to maximise potential generation. As they can't track the sun, they have a distinct generation profile that shows maximum peak potential towards the middle of the day (blue curve in Figure 8).

Figure 5. Gatton SF Fixed-Axis

Single-axis tracking (SATs) arrays are made up of PV panels mounted on a structure pivoting on a single axis, tilting from east to west throughout the day (following the sun's path) to maximise energy output. Since the array follows the sun, the generation profile will often show output for a much longer period. However, it will often have a lower peak than fixed-axis arrays because SATs are not tilted to match latitude (red curve in Figure 8). While this technology outperforms a fixed-axis system, it falls behind a dual-axis one.

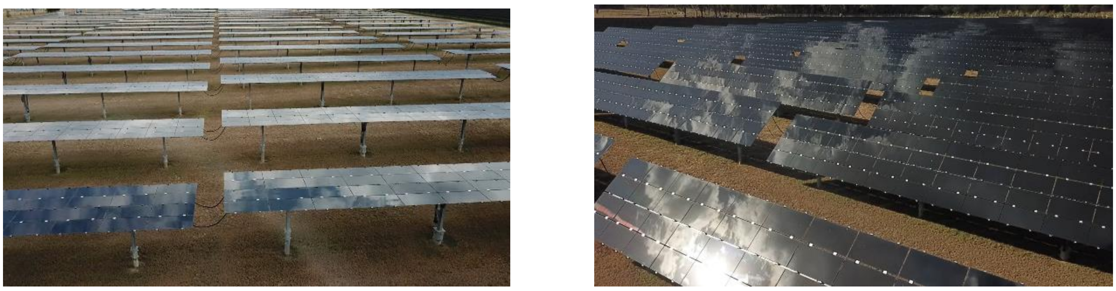

Figure 6. Gatton SF Single-Axis

Dual-axis trackers (DATs) are capable of a 340+ degree slewing motion and 180-degree tilt that allow the panels to directly face the sun at all times and thus maximise output power. DATs will produce more energy compared with a fixed-array or SAT array of the same power rating (both peak output and duration), as the array is always aligned with the sun at the optimum angle (purple curve in Figure 8).

Figure 7. Gatton SF Dual-Axis

Though dual-axis systems outperform the other two methods, they are far more costly to build than either fixed- or single-axis systems. Most large-scale PV projects have extensive modelling (output and economic) undertaken before a mounting technology is selected.

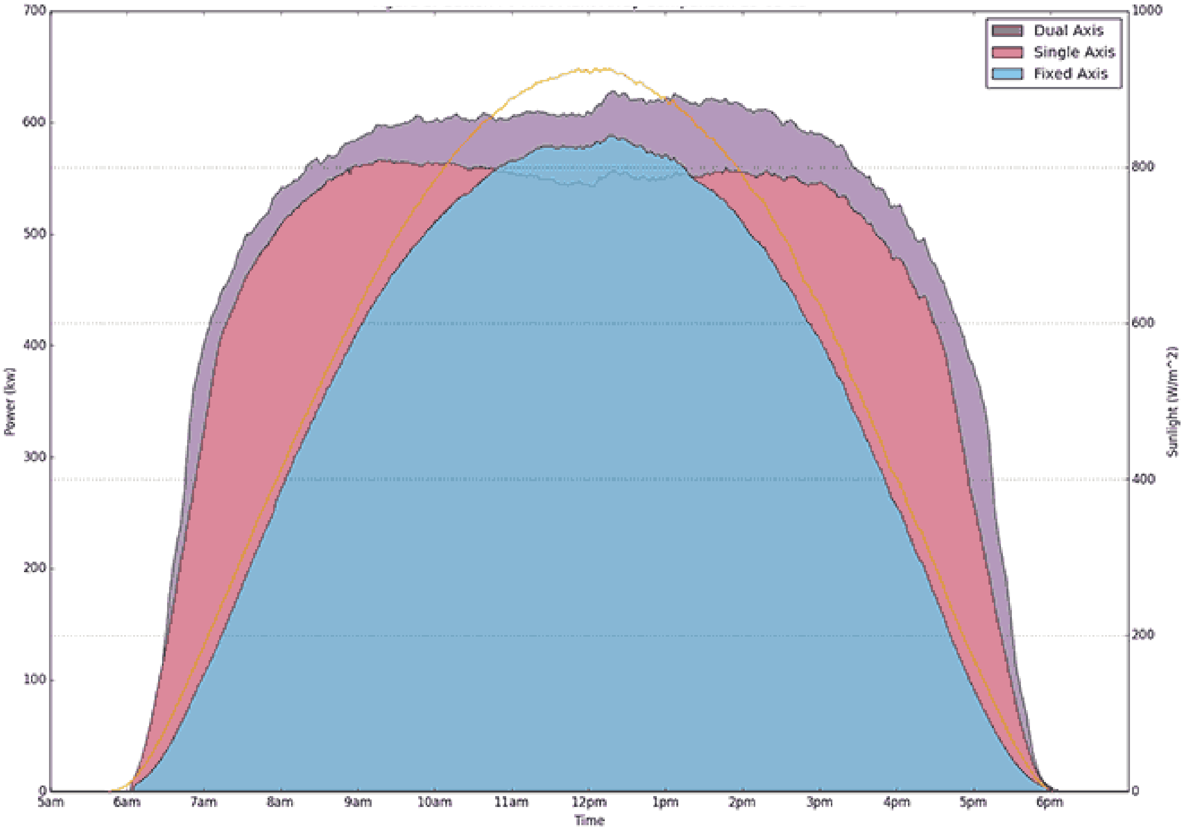

Figure 8. Multi-technology Generation Curves

UQ's solar installations

Our infrastructure includes the 3.3 MW Gatton Solar Research Facility, the biggest of its kind in the southern hemisphere, a 2.14 MW integrated PV system at the St Lucia campus, one of the largest integrated PV installations in the country, plus other rooftop arrays across the St Lucia and Gatton campuses and all other UQ sites (rooftop total of approx. 3 MW).

The University currently has 47,648 solar panels in operation, and these generated almost 9 million kWh of clean energy in 2016—enough to power over 1,500 typical Queensland homes.

Warwick Solar Farm
The solar farm will be located at Sladevale, about 5 km north of the Warwick town centre in the Southern Downs region of Queensland. The solar farm is expected to total around 64 MWac and 78 MWdc. The project site is around 154 hectares, of which just under 30% will be covered by solar modules. The balance will be made up of the spacing between each row of panels, 16 inverter stations, access roads, screening vegetation to be planted and several small buildings, including a site office and a visitor/learning centre.

The Warwick Solar farm will be built with SAT technology. Experience from the Gatton Solar Research Facility and industry trends have confirmed that this technology offers the best balance between maximising energy generation and minimising the land area required for panels, while also still being cost-effective and durable enough for a 25-year project life.

Subject to detailed design, the solar farm is forecast to have a yield of around 1,970 kWh per kWp in Year 1. This translates to total generation of around 153,700 MWh per annum—enough to power about 27,000 average homes. Due to the use of SAT technology, the project will also produce a relatively 'square' power generation curve, which maximises energy output in the morning and evening shoulders.

https://solar-energy.uq.edu.au/
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http://solar.uq.edu.au/user/reportPower.php

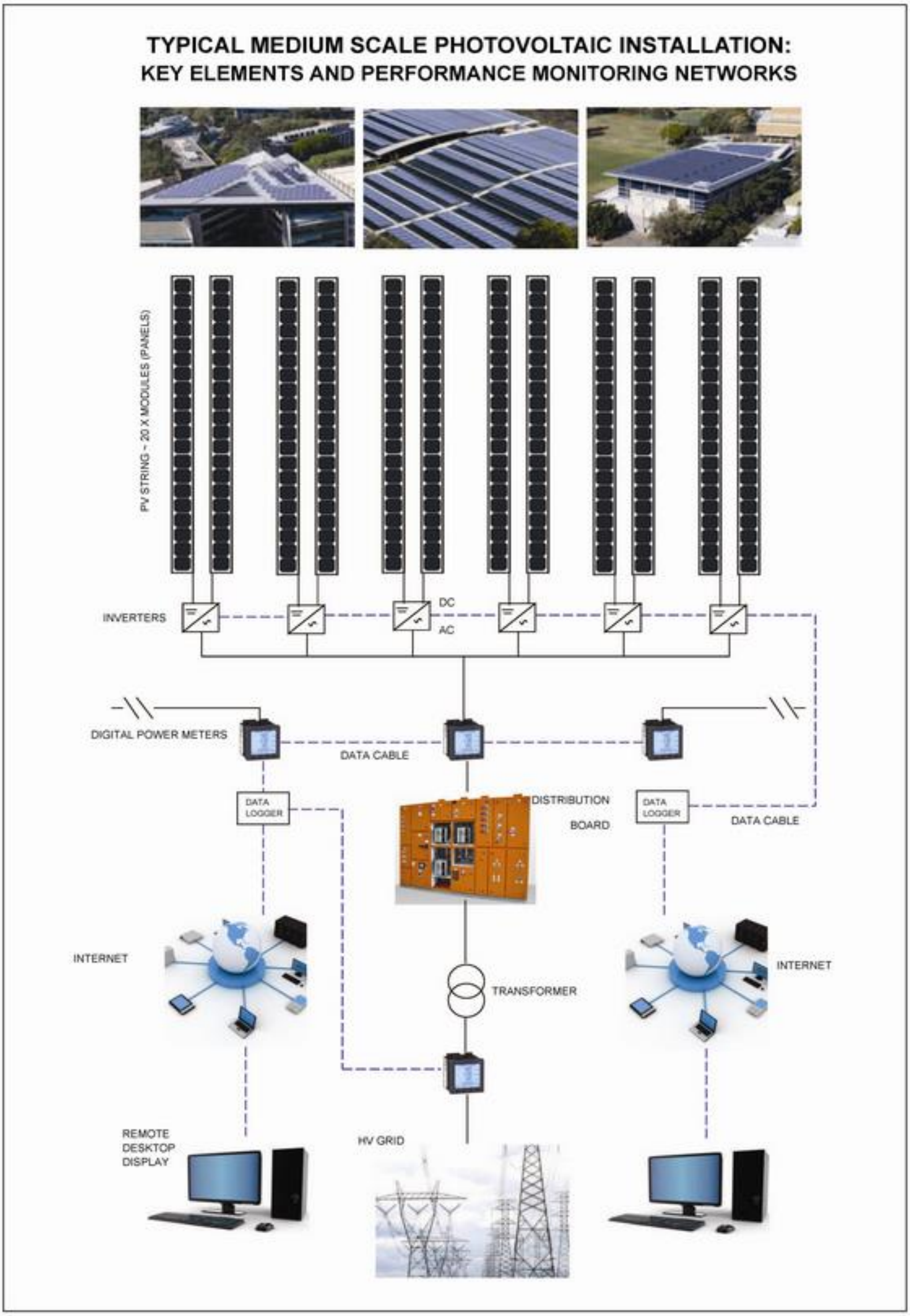

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Figure 9. Typical PV System Elements