Soak up the sun
A solar panel buyers guide

We've contacted photovoltaics manufacturers for details on warranties, cell types, size and price to help you decide which solar panels are best for you.

SOLAR photovoltaic (PV) panels have become a common sight in the Australian urban landscape. From powering domestic dwellings to providing power for camping or even hot water, PV panels are everywhere. In Australia there are around 1.7 million rooftop solar installations, totalling over 5.6GW of installed capacity.

However, there are still many homes without solar. This article aims to provide guidance for those looking at purchasing a solar installation, whether a new system or an upgrade. It includes types of solar panels and factors to consider when buying them. The guide focuses on PV panels only. For information on other components that may be used in a solar installation (e.g. inverters), system sizing and economic returns, see 'More info' at the end of the article.

↑ Over time, the average size of solar panels has increased to the point where panels over 250 watts are common, along with larger systems!

Solar panel types: monocrystalline, polycrystalline and thin film

Solar panels are made from many solar cells connected together, with each solar cell producing DC (direct current) electricity when sunlight hits it. There are three common types of solar cell: monocrystalline, polycrystalline and thin film. There are very few thin-film panels on the residential PV market—most panels are of the crystalline type.

Both monocrystalline and polycrystalline cells are made from slices, or wafers, cut from blocks of silicon (one of the most common elements on Earth). Monocrystalline cells start life as a single large crystal known as a boule, which is 'grown' in a slow and energy-intensive process. Polycrystalline cells are cut from blocks of cast silicon rather than single large crystals.

Thin-film technology uses a different technique that involves the deposit of layers of semiconducting and conducting materials directly onto metal, glass or even plastic. The most common thin-film panels use amorphous (non-crystalline) silicon and are found everywhere from watches and calculators right through to large grid-connected PV arrays. Other types of thin-film materials include CIGS (copper indium gallium di-selenide) and CdTe (cadmium telluride). These tend to have higher efficiencies than amorphous silicon cells, with CIGS cells rivalling crystalline cells for efficiency. However, the materials used in some of these alternatives are more toxic than silicon—cadmium, particularly, is a quite toxic metal.

Each cell type has some advantages and disadvantages, but all in all, modern solar panels do pretty much what they are designed to do. There are no moving parts to wear out, just solid state cells that have very long lifespans.

Crystalline cells are a very mature technology and have a long history of reliability, so a good quality crystalline PV panel will very likely perform close to specifications for its rated lifespan, which is 25 years or more for most panels. Crystalline panels are usually cheaper than thin-film types, with the cheapest being polycrystalline panels, although the pricing gap between cell types has diminished in recent years.

Recent developments in panel design

A variant on crystalline cells are PERCs (passivated emitter and rear cells). Already in use in some modules, these are designed for higher efficiency by reducing recombination in the cell (where electrical charges recombine before they have a chance to be used); however, this currently comes at a price premium.

Another recent development is the 'half cell' or 'half-cut cell' panel. Instead of, say, 60 large cells, the panel may have those 60 cells cut in half to form 120 cells half the size. This means that the connections between the cells are carrying half the current per series string, reducing resistive losses by a factor of four (losses are proportional to the square of the current) and increasing solar panel output (see Figure 1). Not only do half-cut cell panels produce greater output than full cell panels, they also have better shade tolerance as they have twice the number of cell strings, so a smaller area is affected if just one cell is shaded.

At least one manufacturer, Hanwha, is using reflective coatings on the rear of their Q.ANTUM cells to capture some of the energy that passes through the cell instead of letting it be lost, increasing efficiency of the cells somewhat.

There are a number of other features manufacturers are using in cell and panel design to improve efficiency, including bifacial cells and an increased number of busbars (the thin metal current-collecting strips on the surface of the cells). We look at these below.

Panel construction

In its most common form, a solar panel consists of a number of solar cells, usually between 36 and 144, connected together via thin, foil-like conductors (called busbars) soldered to each side of the cells. Originally most cells had just two busbars, but now up to six are used to reduce resistance losses and make for more efficient solar panels.

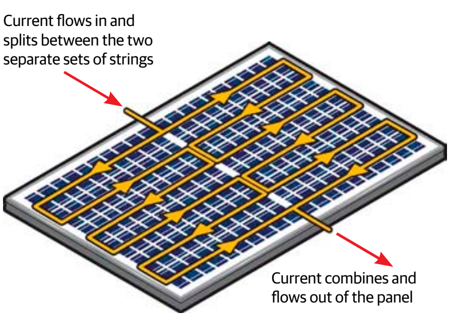

Image: REC Solar, www.recgroup.com

↑ Figure 1. Half-cell panels have two separate current paths so that the strings are only conducting half the current each, reducing resistive losses and hence increasing panel output by a few percent.

In most panels the cells are connected into series strings. For example, a 60-cell panel will have three strings, each of 20 cells in series. Those three strings are then also connected in series, with a bypass diode (or Maxim maximiser IC) across each string—the diode allows current to keep flowing through the unshaded strings should one (or more) strings of a panel be shaded.

The cells are usually coated in a plastic such as ethylene vinyl acetate (EVA) and sandwiched between layers of glass and/or plastic, or sometimes plastic and metal. The collection of cells is usually surrounded by a metal or plastic frame for strength and to allow easy mounting of the panel. Frameless panels for use with proprietary mounting systems also exist. A junction box (or boxes; panels with half-cut cells usually have two) is often mounted on the back of the panel for easy electrical connection, although many panels now have flying leads with standardised connections called MC4 connectors (made by the manufacturer Multi-Contact, these include a 4 mm² contact assembly pin, rated at 20 A and 600 V maximum, depending on the conductor size used).

Where glass is used as a covering for solar panels, it is usually low-iron glass to allow as much light transmission as possible, thus maximising energy output.

Some panels have a glass backing instead of plastic, making for a more rigid panel. This also allows for panels that can make use of reflected and diffuse light that strikes the back of the panel to increase output slightly—what's known as a bifacial panel. An example of these is the Yingli Panda bifacial panel.

Flexible panels also exist and are a spin-off of thin-film technology. They are manufactured on a plastic or thin metal substrate and can be rolled up or attached to curved surfaces. Semi-flexible crystalline panels also exist and are becoming more common—the RADpower and eArche panels are good examples. Flexible and semi-flexible panels are often used for camping and boating. They are generally more expensive on a dollar-per-watt basis (although the price difference between flexible and rigid panels is far smaller than just a few years ago) and are rarely used for domestic energy systems.

Image: Hanwha Solar

↑ Half-cut cell modules, such as this Hanwha Q Cells Q.PEAK DUO-G5, have their cells cut in half to produce twice as many cell strings. This reduces the current per string and reduces internal resistive losses. Combined with other features such as up to six busbars per string, half-cut cell panels can have a total module efficiency of 20% or more.

Panel wattage

When buying a solar PV system, the main specification that people will be familiar with is the system size in watts. This is based on panel wattage, e.g. a 3 kW system may be made up of twelve 250 W panels (this specification is known as the **rated peak power**). But what does panel wattage mean for energy generation?

Clearly a larger wattage system will generate more energy in the same installation, but actual energy generation will depend on many factors, such as sunlight hours, clouds, temperature, shading and panel orientation. As a rough rule of thumb, you can use the average peak sun hours per day in a particular location to get the average energy generation over a year. For example, a 1 kW system in Sydney with average peak sun hours of around 4 should generate around 4 kWh per day, on average, over a year—more on sunny days and less on cloudy days.

The size of the panels used tends to be up to the installer, but certain sizes can often be considerably cheaper than other panels of the same quality as they are made for the larger grid-interactive market.

Using larger panels has allowed a reduction in the number of panels installed, which reduces the framing requirements as well as the number of connections between the panels, making for faster installations. However, panels of any size can be used for any type of system, whether it be grid-interactive, stand-alone or hybrid. Indeed, for odd-shaped roofs a larger number of smaller panels may enable more generating capacity than fewer larger panels, but the final cost of the installation will most likely be higher. The largest panel sizes are really designed for ground-mounting in commercial-scale solar farms, and are difficult to man-handle onto a roof, so your installer may not offer them.

Other panel specifications

The ratings on panels, including the wattage rating, are generally what's called Standard Operating Conditions (SOC) figures. These are produced when the panel is tested under factory conditions. These figures, which are taken at an insolation level (strength of light falling on the panel) of 1000 W/m² and a cell temperature of 25 °C, do not represent what you are likely to get from the panel under real-world conditions.

Because SOC figures are rather unrealistic given that the panel temperature under typical Australian conditions can be up to 70 °C, a second set of more realistic ratings is sometimes provided, and these are stated to be at the nominal operating cell temperature, or NOCT. These are the ratings of the panel when the cells are running at solar irradiance (insolation) of 800 W/m², an air temperature of 20 °C and a wind velocity of 1 m/s (3.6 km/h), for panels mounted with their backs open to the breeze. Under these more realistic conditions, cell temperatures can exceed 50 °C and panel output can be considerably less than the SOC ratings.

Some panel manufacturers also test their panels at higher, more realistic, temperatures than the SOC figure of 25 °C, but this is not common yet, but is something to look for when comparing panel specifications. This is indicated in our table by the column **Cell temp at which panel is tested**.

A related rating is the **temperature coefficient:** this tells you at what rate a panel's output decreases with rising temperature. For instance, a panel with a temperature coefficient (of power) of -0.4%/°C means that for every degree of panel temperature above 25 °C, the output decreases by 0.4%. This doesn't sound like much of a decrease until you realise that the panel might be running at 70 °C in extreme conditions. In this case, the decrease is 45 (the increase above 25 °C) multiplied by 0.4, which equals 18%, a significant amount.

If you live in a hot climate then you should look for panels with as low a temperature coefficient as possible. Temperature coefficients can be specified as a change in output voltage, output current or maximum power. Sometimes only the power figure is given, sometimes all are provided—and sometimes none are!

Another specification of interest is the **power tolerance.** Panels are usually rated with a nominal power output under SOC, but may actually produce more or less power, even under SOC, depending on the power tolerance. For example, a 300 watt panel with a power tolerance of 0% to +5% will produce anywhere from 300 W to 315 W under SOC. Some panels may also have a negative power tolerance range, meaning they might produce less than their rated output, so look for this.

Efficiency is another specification often stated, and often misunderstood. It simply means the conversion rate of the light falling on the panels into electricity. For example, a panel with 1200 watts of total insolation falling on it that puts out 230 watts has an efficiency of 230/1200 x 100 = 19.2%. Of course, the actual cell efficiency would be slightly higher as some parts of the panel, such as the space between the cells and the panel frame, don't factor into the energy conversion process.

Generally, efficiency is an indicator of the type of cell used rather than quality of a panel. A panel with 16% efficient polycrystalline cells may actually be better made than one with 18% efficient monocrystalline cells—the quality depends on more than just the cell type. How the panel is assembled and the other materials used also affect quality. What efficiency does determine is the size of a panel for its rated output—a panel with 18% efficiency will be a bit smaller than one with an efficiency of 16%. So, don't buy panels on efficiency alone, unless you are very pushed for roof space.

A simple visual representation of some of the panel specifications is given in the IV curves in Figure 2. Many solar panel datasheets include IV curves and it's worth asking the supplier for them if they aren't provided.

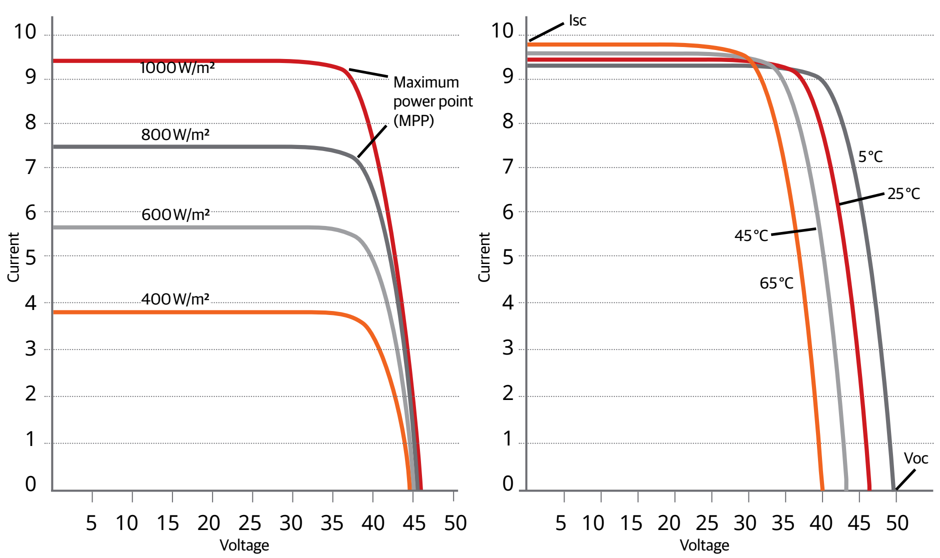

Figure 2: IV curves are graphs of output current versus voltage for different levels of insolation and temperature. They can tell you a lot about a panel's performance on overcast days (graph on the left) and its ability to cope with temperature increases (graph on the right). Here we see two typical IV curves from a polycrystalline silicon solar panel (Canadian Solar 72 cell). Notice how the voltage, and hence available power, decreases as temperature increases. Also note the various panel parameters such as open circuit voltage (Voc) and short circuit current (Isc)—see definitions under 'battery-based DC systems' as well as the maximum power points at the 'knee' of the curves.

AC panels with microinverters

Some panels come with a tiny grid-interactive inverter, a microinverter, attached to the back of the panel which converts the DC output to AC. In these systems, there is no DC wiring in the system at all and standard AC cables are simply run to each panel for connection, simplifying the installation considerably. Enphase microinverters are one example of panel-mounted microinverters.

One advantage with this system is that, because each panel operates independently, shading or failure of one panel has no effect on the rest of the array. Microinverter systems also usually allow remote monitoring of the array on a panel-level basis, so it's easy to see if a particular panel is performing sub-optimally.

Maximising output: MPPT and maximisers

Maximum power point tracking (MPPT) is a method of power conversion, used in all grid-interactive inverters, that allows the solar array to run at its maximum power point, i.e. at the voltage where the greatest amount of power is generated. MPPT controllers also allow the array voltage to be different from the grid (or battery) voltage—the MPPT controller steps the voltage from the array up or down to the required output voltage.

There are also devices called panel maximisers which shift the maximum power point tracking to the panel itself, rather than the inverter. The manufacturers of these devices claim that by performing maximum power point tracking at the panel, the system will perform more efficiently. In a regular installation where panels are connected in strings and wired to a central inverter, any panel that is underperforming due to damage, dirt build-up or shading will drag down the whole string. Maximisers eliminate this problem by interacting with each other while allowing each panel to operate independently at the maximum possible output, even when the panels are still connected in series.

Like microinverters, maximisers also give better system control and safety. For example, they monitor the panel performance and will disconnect a panel should a short circuit or overload be present. Further, like microinverters, they are usually networked and can be controlled from a central point. Monitoring data is also usually available from each unit, so faulty panels and underperformance issues are easily detected.

But are maximisers worth it? According to a study by Photon Labs in 2010, Tigo maximisers, one of the leading brands, increase yield by around 1% to 3% when modules are soiled and from 2% to 36% when partially shaded, as compared to modules without maximisers. So, for a partially shaded array they might be worth the extra money.

These devices are often sold separately but may be installed by some solar system installers by default and may even be included on some panels, albeit at a higher price than non-maximised panels.

A recent development has changed the game somewhat. Maximisers no longer need to be added to the panel externally. Maxim, makers of specialty semiconductors, provide their solar string maximiser ICs to a number

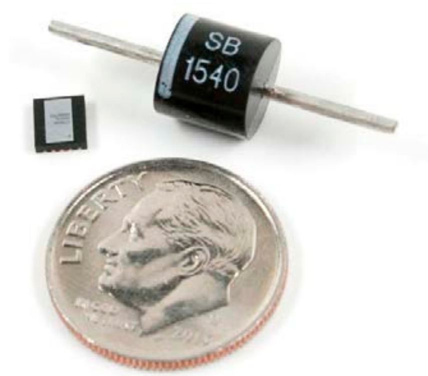

Image: Maxim Integrated

↑ The tiny IC on the left is the Maxim solar panel maximiser IC. It replaces the larger and far less effective bypass diode seen on the right.

Use in battery-based DC systems

Most PV panels are now used for grid-interactive systems, but originally all PV panels were designed for use in battery-based off-grid systems, in particular 12 V and 24 V systems. There are still many 12 V and 24 V panels available today—a typical 12 V panel will have a rated voltage at maximum power of 16 to 17 volts or so, with a 24 V panel being double that.

Battery system panels are similar to those for grid-interactive systems, apart from the different voltages produced, and so the same indicators for quality apply. Note that, with the increasing popularity of maximum power point tracking (MPPT) charge controllers for battery-based systems, the need to match the solar panel voltage to the battery voltage has been eliminated, and panels designed for grid-interactive systems are equally suitable and may be cheaper on a per-watt basis as they are manufactured for the massive grid-interactive solar systems market.

There are some specifications that can be useful to know for battery-based systems, especially if you are designing a solar energy system yourself. For example, the **nominal voltage (Vn)** is the system voltage that the panel is designed to be used in. For example, a 12 volt panel is designed for a 12 volt system, although it will produce voltages well above 12 volts as batteries need higher voltages to fully charge.

The nominal voltage specification generally only applies to panels used for battery-based systems, and usually for smaller systems, as larger battery systems and grid-interactive systems use maximum power point tracking energy control, which converts the panel voltage to the voltage required for the system. Panels designed for grid-interactive systems, which are the majority of panels made nowadays, have nominal outputs of 48 volts or even higher.

The **voltage at maximum power (Vmp)** is the voltage measured across the panel when the panel is producing peak power under SOC. Similarly, the **current at maximum power (Imp)** is the maximum current available from the panel at peak power, also at SOC.

The **open circuit voltage (Voc)** might seem a bit pointless; after all, it is the maximum voltage a panel will produce with no load on it. However, this specification is important in system design to know what maximum voltage an inverter or charge controller will see. A system must be designed so that the maximum output of the solar array never exceeds the safe working voltage of the inverter or charge controller. The Voc is usually around 21 volts for a 36 cell, 12 volt unit, but can be much higher for grid-interactive panels. Indeed, some panels can produce voltages approaching 100 volts.

The **short circuit current (Isc)** is another specification required for safe system design. It is the current obtained when the output of the panel is short-circuited under SOC. Knowing this is important for sizing safety equipment such as circuit breakers and switchgear.

of panel manufacturers. Each panel using these maximisers has three ICs, one for each cell string in the panel, which replace the bypass diodes. This allows the panels to be maximised on a string-level rather than a panel level, while adding very little to the cost of the panel (see www.bit.ly/MAXIM_SPM for an explanation). The JinkoSolar Smart Module is one example of a panel using Maxim maximiser ICs, but there are several others. Drawbacks with integrated maximisers like the Maxim compared to external maximisers are that the Maxim ICs offer no form of monitoring or external control and, unlike with an external maximiser which can simply be replaced, if any of the ICs fail the whole panel may become worthless.

↑ A north-facing roof is not a prerequisite for installing a PV system. This home has a split array facing both east and west. This results in less peak generation and a flatter (wider) generation curve, providing more energy in the morning and evening—ideal for those away from their home during the day.

Heat and shading

As mentioned earlier, panel performance is affected by temperature. This is more of a problem with crystalline panels than with thin-film units, which suffer less output loss with increasing temperature. However, even crystalline panels have improved over the years in this regard, with lower temperature coefficients than a decade or so ago.

Shading affects different panels in different ways. The reduction in performance of crystalline panel types, even when a single cell from a panel is shaded, be it from a tree, TV antenna at certain times of the day or dirt or bird poo for the entire day, is quite considerable, and can drag the entire array output down by a third or more, although this can be mitigated somewhat by some form of maximiser.

Thin-film panels often perform somewhat better, especially panels which have bypass diodes built into each cell. Also, thin-film panels usually have cells that are long and thin, so they are less likely to have individual cells fully shaded by debris build-up.

However, shade falling on the panels should be eliminated if at all possible. For systems where panels are connected in strings of several panels in series, partial shading can reduce the output of the entire system considerably. If the shading causes the string voltage to fall below the minimum required by the inverter, the inverter will simply shut down, producing no output at all. There is not much point investing large amounts of money in power-generating equipment if you don't allow it to do its job!

As mentioned earlier, microinverters allow each panel to act independently, so shading of one or two panels will only reduce system output by that amount.

Is PID an issue?

A term that has cropped up in recent years in regards to PV panels is PID (potential induced degradation). This can be a problem with crystalline silicon panels where the most negative panel in a series string has a negative potential (voltage) relative to ground. The problem can result in a temporary or permanent reduction in panel output and is exacerbated by heat and humidity.

PID can cause a reduction in panel output in two ways: polarisation, which is reversible by using an offset box, such as the one developed by Ilumen; and ion migration, which causes permanent degradation and reduced output. PID only occurs on grid-interactive systems, as the inverter requires that some of the string is positive in respect to ground, some negative.

A simple solution is to ground the negative-most panel in the string, if the inverter allows for this. Manufacturers have recognised PID as an issue and many, if not most panels are now PID resistant.

More info: www.bit.ly/AE-PID and www.bit.ly/SOLON-PID

Material use and embodied energy

As far as material use is concerned, crystalline panels use a great deal more semiconductor material than an equivalent-output thin-film panel. This occurs for two reasons. The first is that a lot of material is lost in the process of cutting the silicon boule or ingot into wafers. The cutting is done with a diamond saw or wire, which may well be thicker than the resulting wafers, so more than half of the silicon may be lost in this process. Manufacturers have been working on reducing this wastage, and reusing the waste silicon in cell production, but it is still a considerable proportion of the total material.

The other reason for greater material use with crystalline cells is that, because they are handled as individual cells, they must be robust enough to withstand mechanical handling—so a good proportion of the cell is actually there just to provide support to the active junction. This is also an issue that manufacturers are working to improve upon. Cells have gradually become thinner in recent years, with some cells now so thin that they can be incorporated into semi-flexible panels.

Thin-film panels don't have these problems and so use a lot less semiconductor material, in many cases less than 1% of that used by a crystalline panel.

The main reason why silicon use can be an issue is the embodied energy of the silicon—it takes a lot of energy to make the highly purified silicon used in solar panels. Embodied energy is the amount of energy required to produce the panel and includes all energy used to make every part of the panel, including cells, frame, cable or junction box and assembly (final transport miles after panels leave the factory are not included). Some panels, especially the thin-film units, will repay their energy 'debt' within a year or less, while others, especially monocrystalline panels, take longer. We have requested the embodied energy payback period from manufacturers but only some have this information available (or are willing to supply it). Generally, embodied energy payback appears to be just a few years, and all panels on the market will produce much more energy than they use over their lifetime, if installed and used correctly.

Panel quality

It's not only at the cell level where quality counts; the overall manufacturing of panels is also crucial. If assembly systems are not near-perfect, some issues can arise that may shorten the life of solar panels or cause increased degradation over time.

One issue for crystalline cells is that of microcracks—tiny cracks in the cells that can enlarge over time with thermal cycling (as the panels heat up and cool down each day) or with less than ideal handling. Microcracks have the potential to reduce the current generating capacity of any cells affected, and hence the overall output capacity of the panel.

Panel quality is very important. In years gone by, many of the cheaper Chinese panels have been of variable quality; however, the overall quality of Chinese panels has improved enormously in the last few years due to intense competition, to the point where almost all of the recognised brands are made in China.

A term you will hear when looking at solar panels is the tier system. Many suppliers will claim their panels are Tier 1 panels, but what does this mean? And, are Tier 1 panels really better than Tier 2 and Tier 3 panels? Is there any such thing as a Tier 1 panel?

The answers to these questions are actually fairly complex.

The tiering system is not an official system. A number of analysis organisations use a range of criteria to assess manufacturers into tier groups, although the company referenced the most seems to be Bloomberg New Energy Finance, whose Tier 1 list (they don't publish lists for other tiers) is only available by subscription.

The criteria vary somewhat between the analysis companies (a solar manufacturer that appears on one analyst's Tier 1 list may not appear at all on the list from another company), but the main ones seems to be: level of R&D done by the manufacturer; level of manufacturing automation (how much assembly is done by robots and how much is done manually); how long the manufacturer has been making solar panels; financial position of the company; volume of production—larger manufacturers are higher up the tier scale; level of vertical integration of the company; sustainability policies; panel quality, performance and reliability; level of service and support.

Most of this refers to the company itself, not the actual product. The Tier 1 list only lists companies, not individual products, so there's no such thing as a Tier 1 panel other than referring to panels made by a Tier 1 company. While buying a panel from a Tier 1 company should guarantee a fairly high level of quality, it doesn't guarantee that the panels you buy will be fault-free for their entire lifespan.

To further complicate matters, there are panels from manufacturers that aren't on the Tier 1 list that are of extremely high quality with long product warranties. A good example is Solarwatt, who make high grade glass-glass panels with both 30-year product and performance warranties, yet they are not considered a Tier 1 company.

To address these issues, the Smart Energy Council (formerly Australian Solar Council) has introduced their Positive Quality program, a due diligence program between manufacturers and customers, including a rigorous factory inspection which aims to raise the quality standard in Australia. The inspection includes three key steps: a certification check, a factory inspection and a product quality inspection. However, since our last version of this guide in 2016, there have been no new manufacturers listed in the Positive Quality program, with only three manufacturers listed at the time of writing. There are plans to update the Positive Quality program to encourage more manufacturers to come onboard, but at time of writing the timeline for this was uncertain. See www.positivequality.com.au for more information.

One solar panel testing site worth a visit is the Desert Knowledge Solar Centre site. Based in Alice Springs, the DK Solar Centre has around 37 individual solar arrays of various brands and models being continuously tested. Many are older panels, but the results are interesting nonetheless. Go to www.dkasolarcentre.com.au to check out the data.

Another source of information on panel quality is from those who own them. Solar system owners like to write reviews on their systems, both good and bad, so look around in the popular forums for owner experiences. One of the most popular Australian forums is Whirlpool Green Tech at forums.whirlpool.net.au/forum/143 and another potential source of discussion are the ATA's forums at www.ata.org.au/forums. For information on installers themselves, check out the CEC's solar accreditation website at www.solaraccreditation.com.au and check company reviews at www.productreview.com.au.

So just how likely is it that you will get good quality panels? According to Solar Quotes, the Clean Energy Council found problems with a significant proportion of panels they tested: "CEC testing found that five out of 30 manufacturers had an average of over 20 microcracks per panel." There should be no microcracks in a new panel.

Interestingly, the CEC also found other problems with some solar panel manufacturers: "of the panels they tested, the CEC found that 45% of their BoMs (bill of materials—the materials used in the panel) were fraudulent and the panels did not contain the components claimed."

Things get even more complex, with the possibility of multiple variations of a particular panel from the same manufacturer, some variations using higher quality components, and therefore able to meet their rated specifications (referred to as a premium-grade panel), than other variations of the same panel. In such cases you have to rely on the importer/distributor to import the highest quality version of each model number available—but there is no easy way to know if that is the case.

Note that the CEC does not test every panel, only the panels they have received complaints about, so it stands to reason that they would find a higher than expected rate of failure and sub-standard materials in panels that they had received complaints for. Read the Solar Quotes post at www.solarquotes.com.au/blog/solar-panel-quality for an excellent summary of problems found by the CEC.

You are more likely to get a premium-grade panel if you buy panels from a Tier 1 manufacturer and you buy their highest grade panel available through your chosen supplier. Knowing which panels are the premium ones can really only be discovered by reading datasheets, searching manufacturer websites, viewing independent test reports or contacting the manufacturer directly.

Mounting systems

Most solar panels are surrounded by an aluminium frame which gives them rigidity and makes for easy mounting of the panels to racking (the rails that hold panels to the roof) or bracket systems. There are several mounting systems in use by installers of PV panels. These usually consist of slots in the frames that mounts or bolts can be slid into, or systems that clamp the panel in place against the racking.

Most mounting systems use a series of roof mounts and rails, to which the panels are then clamped or bolted, but some mounting systems are designed to attach directly to the panels without the need for separate rails—but usually the panels have to have a specific frame design for this type of system.

Which mounting system your installer uses may not mean much to you, but it can affect installation time and therefore the final cost, as well as the visual amenity of the installation.

Warranties

Any solar panel worth buying will come with a long warranty. If the manufacturer doesn't have enough faith in their product to offer a good warranty, why would you buy it? Most smaller panels come with a warranty

Payback periods and maximising your investment

After a period of very low feed-in tariffs (FiTs) for exported solar energy, many places in Australia have now seen mandated or recommended rises in FiTs, which, combined with falls in the price of solar, has resulted in shorter payback periods. Recent analysis by the ATA (www.ata.org.au/ata-research/bigger-solar-is-better) suggests good results from larger systems (4 to 6 kW, or even more), as panel prices are so low (in the range of $1 to $2 per watt installed in most states of Australia). Things can change with different policy settings and STC prices (the rebate for solar's contribution to the RET), so evaluate quotes at the time of purchase to estimate your payback period and determine the best system size for your situation. The ATA's free online tool can help with this: www.ata.org.au/ata-solar-advice, or you can get targeted advice via a full solar energy consultation.

We will never return to the premium FiT levels of a few years back, but most FiTs are now at a decent level that reflects the value of the energy in the wholesale market and, in many cases, other value it contributes to the energy system as a whole, including (in some states) the value of the emissions reduction. See bit.ly/2kQCt9O for ATA's position on how a fair FiT should be calculated, though note it was written prior to recent FiT increases. Importantly, while some retailers will offer higher FiTs than others, you also need to check the rates they charge for electricity you import from the grid to ensure you're getting the best deal possible.

With feed-in tariffs generally lower than grid import rates, one thing you should do is to maximise the use of energy at the time it is generated. This way you avoid the cost of importing that electricity from the grid.

This can be done by shifting loads to run during the middle of the day, when generation is at a maximum. This is easily done using timers and applies best to intermittent loads such as dishwashers, washing machines, water heaters, electric vehicle charging, pool pumps and even clothes dryers. A slightly smarter way to load shift is to use a system which diverts excess power (that would otherwise be exported) to a particular load, such as a water heater element. Some diverters are built in to inverters and some are add-on systems at extra cost. Because the amount of power diverted will vary, generally only non-complex loads like heating elements can be used with diversion systems, although some may support the use of heat pumps. See 'Life after feed-in tariffs' in *ReNew 136* for more.

What about batteries?

Another way of maximising on-site use of solar electricity is to store it for use when you need it, rather than when it is generated. Battery systems have been around forever, but they are generally complex and expensive. That is slowly changing with the introduction of simpler modular battery systems such as the Enphase AC battery and the Tesla Powerwall 2. The modular aspect means that you can start with just one battery unit and add more if and when needed.

However, current battery costs mean they are unlikely to be a better investment than just solar on its own; though that should change as prices continue to drop over the next couple of years. We look at this in more detail in the Energy Storage Buyers Guide in *ReNew 141*, including some of the other pros and cons of battery storage. A positive economic return is not the only motivation for installing batteries with your solar PV system; there are a range of other reasons, including backup for grid outages, community/grid benefits and early-adopter trials. Also consider whether you want to ensure that a solar system you purchase is battery-capable in the future. For more information on issues to be considered when adding batteries, see 'Just Add Batteries' in *ReNew 137*.

Should I upgrade my small system?

In the early days of grid-connected solar systems, most systems were small—1.5 kW or less. If you have an existing small system, you might be tempted to upgrade it by adding more panels to the existing inverter (if it has capacity), replacing the inverter and connecting the old and new panels to it, or adding a new system while keeping the existing one, if roof space allows.

Such changes may affect your feed-in tariff—if you are currently on a high FiT, chances are an upgrade will cause you to lose that rate. Contact your energy retailer to find out and get their response in writing.

A larger system at current lower prices may still be worth it financially and will produce more renewable energy for the grid, an environmental advantage. If completely replacing the system, consider the impacts of replacing an existing system that hasn't reached the end of its service life. Will you recycle the panels and inverter, or on-sell them? Being older devices, neither are likely to still be eligible for use in a new system, so they may have very little resale value and recycling might be the only option.

of at least five years and warranties on larger panels, including those designed for grid-interactive systems, are usually 20 or 25 years.

A warranty is only as good as the company that provides it. If the company disappears in a few years, you might be left unable to make a warranty claim should failures occur. Unfortunately it's not possible to know the future of any solar panel manufacturer or installer, as some of the biggest players over the years have simply disappeared.

Most panel warranties have two parts—a construction/materials warranty and a power output warranty. The first covers the actual manufacturing quality of the panel and warrants the panels to be free of manufacturing and materials defects for a given time, usually 10 years or so. The performance warranty covers the actual panel power output, and is given in the form of a percentage after a certain number of years. For example, a power output warranty might state that a panel will still produce 90% of its rated output after 10 years and 80% after 25 years. Or it might be stated as a linear warranty with just one figure, say 85% after 25 years. Any high quality panel would be expected to still produce at least 80% of its original rating after 25 years.

What to look for

It's important to buy a panel that has the correct ratings for your use, with consideration given to their performance specifications. You also need to look for a few other things when buying, such as construction quality, frame type and colour, panel dimensions and weight. Some panels may be more suited to your roof shape than others, especially when used on small buildings such as sheds.

Also bear in mind that crystalline panels have a different look to thin-film panels, the latter having a more homogenised surface appearance. Certain crystalline panels have cells that are quite obvious (they may have dark coloured cells on a white background, for instance), while others are designed to make the appearance of the cells less obtrusive. If this is a concern, make sure you see good photos of the panels before purchasing—ask the installer if they have any photos of complete installations with those panels.

As mentioned above, check datasheets carefully for different versions of the same panel, and make sure you will be buying panels with all the features you are expecting to get. Talk to the supplier/installer and get a full part number for the panels, including any part number suffixes—that way you can be sure you know which variation of panel you are receiving. Also check out the manufacturer—if they are not a Tier 1 company, or a company with a long established reputation in the industry, then you are taking a bigger risk in buying their products.

Obviously, you want a long warranty. Pretty much all panels now have at least a 10-year materials warranty and 25-year power warranty.

Also consider the mounting system and how it will appear on your roof (if that's an issue for you). Systems that use racking usually have the rack rails extending past the edges of the solar array, and this can look unsightly if the array is in a very obvious position. Mounting systems that require no rails might be the better option, but these may be available only for certain panels that have the appropriately designed frames. But this choice depends on what your chosen installer usually uses for panel mounting—they will have a preferred system and may be reluctant to use anything else. ✱

Building-integrated PV

Solar PVs can also be used as a building material (known as building integrated photovoltaics, or BIPVs), although this is relatively rare at present. There are a number of ways to do this, but one area that is increasing in popularity is using them as roofing tiles (see more in 'A roof over your head' in *ReNew 138*).

There are now at least three suppliers of BIPV systems in Australia: Monier's SolarTILES, www.monier.com.au/Products/Solar; Star 8 Solar, www.australia.star8.green/building/solar-tile; and Tractile's Eclipse solar roof tile, www.tractile.com.au. Note that the previously available Stratco Solatile has been discontinued. Tesla's solar tiles are now available to order in Australia (only the Textured and Smooth versions so far; see www.tesla.com/en_AU/solarroof).

There are also panels designed to replace windows and other glass in architectural uses. These may have glass on both sides of the cells or they may use thin-film technology to provided a 'tinted window' look that generates electricity, such as Star 8's solar glass (www.australia.star8.green/building/solar-glass).

You can also use standard PV panels as sunshades and pergolas—or in a solar car park, as in our story on page 56!

With all building-integrated PV, the home owner can offset some of the cost of the solar panels, as the panels themselves double as building materials, though it may still be more expensive than buying the building materials and standard panels separately. Costs will change over time though, and aesthetics can be a driving force here too.

About the table

The table lists a range of solar panel suppliers who provide panels suitable for domestic solar power systems. It includes a summarised version of the data on available panels, including a panel size range, panel type and warranty information. Due to the large number of different panel sizes and models, it was not possible to include the complete table in the magazine. Full information on individual panels is provided in the detailed table available on the *ReNew* website at www.renew.org.au/photovoltaics/solar-panel-buyers-guide-2018.

More info:

Solar Electricity Booklet (ATA, 2017). A thorough yet concise overview of what you need to know before choosing and installing a solar energy system: shop.ata.org.au/shop/solar-electricity

Your Home: www.yourhome.gov.au

Your Energy Savings: www.yourenergysavings.gov.au

Clean Energy Council: www.cleanenergycouncil.org.au

Solar Accreditation find an installer page: www.bit.ly/CECFAAI

ReNew Inverter, Regulator and Battery Buyers Guides: www.renew.org.au/buyers-guide

For help in choosing the right solar system, consider using ATA's free basic or paid solar advice: www.ata.org.au/ata-solar-advice

ATA's Sunulator allows for specific system modelling: sunulator.ata.org.au

ATA's solar FAQ: www.ata.org.au/news/solar-frequently-asked-questions

About the table

The table lists a range of solar panels suitable for solar power systems for which suppliers provided information. It includes the important information such as type of panel output (panels now come in both DC and AC—the latter have embedded grid-interactive inverters), maximum power, voltage and current (usually rated at 25 °C), power tollerance, panel efficiency, cell type, power temperature coefficient, panel construction and dimensions, including weight, warranty, and the rated lifespan. While we asked for embodied energy data, most companies failed to supply this information; however, it is generally accepted that embodied energy for any properly utilised photovoltaic panel is under two years.

Also included (where provided) are recommended retail prices including GST, but not including installation or the rebate for STCs (small-scale technology certificates, see www.bit.ly/CER_STCs for an explanation of STCs. The number of STCs you are eligible for varies by location). However, prices should be taken with a grain of salt. Price usually depends on the number of panels purchased at the time and many dealers will offer panels at lower cost, so don't settle for the first price you are given—ring around!

Ingress protection (IP) numbers, such as IP67, describe the level of resistance to the ingress of water and dust. See https://en.wikipedia.org/wiki/IP_Code for details.

Note that some suppliers/manufacturers failed to provide data for the guide table. This is noted in the comments for those listings. Data for those suppliers has been collated from manufacturers' datasheets for each product range.

Table 1. Solar panels. Table data supplied by manufacturers/importers.

Brand (made in)	Model	Rated power (watts)	Voltage at max power	Current at max power	AC or DC output	Maximisers included	Power tolerance	Panel efficiency (%)	Cell type and quantity	Cell temp at which panel is tested °C	Power temp coefficient (%/°C)	Construction	Size in mm (L x W x T)	Weight (kg)	Warranty (years)	RRP Inc GST ($)	Cost per Watt ($)	Embodied energy (yrs)	Rated lifetime (years)	Comments
AC Solar Warehouse www.acsolarwarehouse.com	AU Optronics (AUO)	260 to 325			DC				Poly and mono						10 or 12 years product (depending on model), 25 years linear power					AC Solar Warehouse failed to provide updated data for this guide, so we have included abbreviated data on their product range.
	Jinko	270 and 330			DC				Poly						10 years product, 25 years linear power					
AustraEnergy www.austraenergy.com.au	BYD	260 to 310			DC				Poly						12 years product, 25 years linear power					All PV Australia failed to provide updated data for this guide, so we have included abbreviated data on their product range.
	Longi	300 to 360			DC				Mono						10 years product, 25 years linear power					
	CSUN	270 to 340			DC				Poly and mono											
	Luxor	200			DC				Mono						12 years product, 25 years linear power					
Australian Premium Solar www.australianpremiumsolar.com.au	Mono series	230 to 260			DC				Mono						12 years product, 30 years power					Australian Premium Solar failed to provide updated data for this guide, so we have included abbreviated data on their product range.
	Poly series	230 to 250			DC				Poly											
Canadian Solar www.canadiansolar.com/au	Ku series half-cell	Up to 360			DC				Poly and mono half cells						10 years product, 25 years power, non-cancellable warranty insurance					Canadian Solar failed to provide updated data for this guide, so we have included abbreviated data on their product range.
	Dymond series double glass	260 to 340							Poly and mono											
	Superpower series	290 to 3075							PERC mono											
	Maxpower series	310 to 345							Poly and mono											
	All-black series	275 to 300							Mono											
	SmartDC series with optimisers	260 to 295			Optimised DC				Poly and mono											
	60-cell standard series	260 to 290			DC				Poly and mono											
eArche (Sunman, available through Energus) ph: 1300 090 187 www.energus.com.au	SMD085P-2X10	85	10.5	8.1	DC		0/+5W	13.90%	Poly (6 inches)	25°C	-0.41	Patented lamination process to encapsulate the silicon cells. Anodized aluminium alloy frame.	1662 x 369 x 5.6	2.8	10 years product, 25 years linear power	POA	POA	-	25 Years	eArche panels are semi-flexible. The bending angle is 248 degrees. eArche is the first lightweight solar panel to receive CEC approval for sale in grid-connected PV systems in Australia. eArche panels are 1/3 lighter than traditional glass + aluminium panels.
	SMD105P-2x12	105	12.7	8.27				14.40%			-0.41		1979 x 369 x 5.6	3.3						
	SMD105P-4x06	105	12.7	8.27				14.80%			-0.41		1027 x 689 x 5.6	2.9						
	SMD110M-2x12	110	13	8.47				15.10%	Mono (6 inches)		-0.42		1979 x 369 x 5.6	3.3						
	SMD110M-4x06	110	13	8.47				15.50%			-0.42		1027 x 689 x 5.6	2.9						
	SMD160M-4x09	160	19.1	8.38				15.50%			-0.42		1503 x 689 x 5.6	3.9						
	SMD175P-4x10	175	21.2	8.26				15.30%	Poly (6 inches)		-0.41		1662 x 689 x 5.6	4.3						
	SMD180M-4x10	180	21.4	8.42				15.70%	Mono (6 inches)		-0.42		1662 x 689 x 5.6	4.3						
	SMD210P-4x12	210	25.4	8.27				15.40%	Poly (6 inches)		-0.41		1979 x 689 x 5.6	4.8						
	SMD215M-4x12	215	25.7	8.37				15.80%	Mono (6 inches)		-0.42		1979 x 689 x 5.6	4.8						
	SMD265P-6x10	265	31.9	8.31				15.60%	Poly (6 inches)		-0.41		1662 x 1019 x 5.6	6.6						
	SMD270M-6x10	270	32.1	8.42				15.90%	Mono (6 inches)		-0.42		1662 x 1019 x 5.6	6.6						
	SMD320P-6x12	320	38.2	8.38				15.90%	Poly (6 inches)		-0.41		1979 x 1019 x 5.6	7.7						
	SMD325M-6x12	325	38.5	8.45				16.10%	Mono (6 inches)		-0.42		1979 x 1019 x 5.6	7.7						
	SMD50	50	6.2	8.07				14.70%	Poly (6 inches)		-0.41		998 x 340 x 6	1.5						
eArche (made by Sunman in China) Solar 4 RVs, Solar 4 Boats ph: 1300 765 273 info@solar4rvs.com.au www.solar4rvs.com.au	SMA050M2x6	50	6.2	8.07	DC		+/-5W	13.5	6 mono cells	25°C (STC)	-0.42	Thin, lightweight (no glass), with 20mm square edge black anodised aluminium frame	345 x 1070 x 20	1.8	10 years product, 25 years power (at least 80.2% in the 25th year)	155.00	3.10		25+	Made with a patent-pending composite material similar to those used in airplane windows. These panels are approved by the Clean Energy Council for grid connection in residential and commercial applications yet they don't have a heavy, rigid frame or glass.
	SMA105M4x6	105	12.7	8.27				14.8	12 mono cells				666 x 1070 x 20	3.3		310.00	2.95			
	SMA160M4x9	160	19.1	8.38				15.5	36 mono cells				666 x 1546 x 20	4.1		465.00	2.91			
	SMA180M4x10	180	21.4	8.42				15.9	40 mono cells				666 x 1705 x 20	4.6		525.00	2.92			
	SMD050M2x6	50	6.2	8.07				13.5	6 mono cells			Thin lightweight (no glass), with 6mm thin black anodised aluminium frame	370 x 1096 x 6	1.5		155.00	3.10			
	SMD105M4x6	105	12.7	8.27				14.8	12 mono cells				690 x 1095 x 6	2.6		310.00	2.95			
	SMD160M4x9	160	19.1	8.38				15.5	36 mono cells				690 x 1570 x 6	3.7		465.00	2.91			
	SMD180M4x10	180	21.4	8.42				15.9	40 mono cells				690 x 1730 x 6	4.1		525.00	2.92			
	SMS050M2x6	50	6.2	8.07				13.5	6 mono cells			Thin lightweight (no glass), with 8mm EPDM rubber edge seal	345 x 1070 x 8	1.4		155.00	3.10			
	SMS105M4x6	105	12.7	8.27				14.8	12 mono cells				666 x 1070 x 8	2.5		310.00	2.95			
	SMS160M4x9	160	19.1	8.38				15.5	36 mono cells				666 x 1546 x 8	3.2		465.00	2.91			
	SMS180M4x10	180	21.4	8.42				15.9	40 mono cells				666 x 1705 x 8	3.6		525.00	2.92			
First Solar Inc ph: (02) 9002 7700 www.firstsolar.com	Series 4	92.5 to 122.5			DC				Thin-film CdTe						10 years product, 25 years linear power					First Solar failed to provide updated data for this guide, so we have included abbreviated data on their product range.
	Series 6	420 to 445																		
Hanwha Q Cells Australia www.q-cells.com.au	Q.PEAK-G4.1	295 to 305			DC				Mono Q.ANTUM						12 years product, 25 years linear power					Hanwha Q Cells Australia failed to provide updated data for this guide, so we have included abbreviated data on their product range.
	Q.PLUS BFR-G4.1	275 to 285			DC															

Table 1. Solar panels. Table data supplied by manufacturers/importers. (cont)

Brand (made in)	Model	Rated power (watts)	Voltage at max power	Current at max power	AC or DC output	Maximisers included	Power tolerance	Panel efficiency (%)	Cell type and quantity	Cell temp at which panel is tested °C	Power temp coefficient (%/°C)	Construction	Size in mm (L x W x T)	Weight (kg)	Warranty (years)	RRP Inc GST ($)	Cost per Watt ($)	Embodied energy (yrs)	Rated lifetime (years)	Comments
JinkoSolar (made in China) JinkoSolar Australia ph: 1300 326 182 aus@jinkosolar.com www.jinkosolar.com.au	JKMXXXPP-60	270 to 275	31.7 to 32V	8.52 to 8.61A	DC	No	3%	16.5 to 16.8	60 poly cells	25	-0.4	Anodised aluminium alloy frame, high transmission tempered glass with low iron	1650 x 992 x 40	19	10 years product, 25 years power	POA			25+	
	JKMXXXM-60	285	32V	8.9A		No		17.41	60 mono cells		-0.4									
	JKMXXXM-60	295 to 300	32.4 to 32.6V	9.10 to 9.21A		No		18.02 to 18.33	60 mono perc cells		-0.4									
	JKMSXXXPP-60	270 to 275	31.7 to 32V	8.52 to 8.61A		SOLAREDGE OPJ300-LV		16.5 to 16.8	60 poly cells		-0.4									
	JKMSXXXPP-60-MX	270 to 275	30.1 to 30.5V	8.97 to 9.06A		MAXIM GEN II		16.5 to 16.8	60 poly cells		-0.4									
	JKMXXXPP-60H	280	32.3V	8.66A		No		16.95	120 poly half-cells		-0.38		1665 x 992 x 40	18.5						
	JKMXXXM-60H	290 to 295	32.2 to 32.4V	8.98 to 9.08A		No		17.56 to 17.86	120 mono half-cells		-0.37									
	JKMXXXM-60H	310 to 315	33 to 33.2V	9.4 to 9.49A		No		18.77 to 19.07	120 mono PERC half-cells		-0.39									
	JKMXXXPP-72	325 to 330	37.6 to 37.8V	8.66 to 8.74A		No		16.75 to 17.01	72 poly cells		-0.4		1956 x 992 x 40	26.5						
	JKMXXXM-72	335 to 340	38.4 to 38.7V	8.72 to 8.79A		No		17.26 to 17.52	72 mono cells		-0.4									
	JKMXXXM-72	355 to 365	39.3 to 39.7V	9.04 to 9.20A		No		18.31 to 18.82	72 mono PERC cells		-0.39									
	JKMXXXPP-72H	335 to 340	38 to 38.2V	8.80 to 8.88A		No		17 to 17.25	144 poly half-cells		-0.38		1987 x 992 x 40							
	JKMXXXM-72H	345 to 355	39.39.4V	8.83 to 8.99A		No		17.5 to 18.01	144 mono half-cells		-0.37									
	JKMXXXM-72H	370 to 380	40.1 to 40.5V	9.23 to 9.39A		No		18.77 to 19.28	144 mono PERC half-cells		-0.37									
Krannich Solar www.krannich.com.au	Jinko	270 to 330			DC				Poly						10 years product, 25 years linear power					Krannich Solar failed to provide updated data for this guide, so we have included abbreviated data on their product range.
	LG	300 to 360			DC				Mono						25 years product, 25 years power					
	Trina	270 to 355			DC				Poly and mono						10 years product, 25 years power					
LG Electronics (South Korea) 2 Wonderland Drive Eastern Creek NSW 2766 ph: (02) 8805 4038 www.lgenergy.com.au	LG300S1C	300	31.7	9.47	DC	No	0 to plus 3%	17.50%	Mono	25	-0.41	60 cells, EVA embedded cells, tempered glass with anti-reflective surface treatment, aluminium frame with piano black finish, double wind load of standard panels	1686 x 1016 x 40	18	12 years product, 25 years linear power, (84.8%) for Mono X plus and NeON2 range. 25 years product, 87% linear power for NeON R range	POA	POA	<1.8 years	25+	LG panels won Top Brand Award in 2016 and 2017; NeON 2 has12 multi-wire busbars. For panel purchase please contact our distributors Solar Juice (02) 9725 1111 and Supply Partners (07) 3122 7584, Krannich (03) 9339 5106, L&H on 0401 714 530 or MMEM group (02) 8839 9080.
	LG320N1K	320	33.3	9.62	DC	No	0 to plus 3%	18.70%	Mono		-0.37		1686 x 1016 x 40							
	LG335N1C	335	34.1	9.83	DC	No	0 to plus 3%	19.60%	Mono		-0.37		1686 x 1016 x 40							
	LG365N1C	365	36.7	9.95	DC	No	0 to plus 3%	21.10%	Mono		-0.30		1700 x 1016 x 40							
Low Energy Developments www.lowenergydevelopments.com.au	Low Energy Developments	10 to 250			DC				Poly and mono						Up to 25 years depending on panel					Low Energy Developments failed to provide updated data for this guide, so we have included abbreviated data on their product range.
MPower Australia www.mpower.com.au	Suntech	265 to 325			DC				Poly and mono						12 years product, 25 years linear power					MPower Australia failed to provide updated data for this guide, so we have included abbreviated data on their product range.
	Powerhouse 12V series	10 to 150			DC				Poly						5 years product, 25 years power					
Powerark Solar www.powerarksolar.com.au	Jinko	255 to 320			DC or optimised DC				Poly and PERC mono						10 years product, 25 years linear power					Powerark Solar failed to provide updated data for this guide, so we have included abbreviated data on their product range.
	HT-SAAE	265 to 280			DC				Poly						10 years product, 25 years power					
	Longi	280 to 300			DC				Mono and PERC mono						10 years product, 25 years linear power					
	Link Energy	250 to 280			DC				Poly and mono						25 years linear power					
	Hanover black series	360 to 270			DC				Mono						12 years product, 25 years linear power					
	Astro Energy	255 to 275			DC				Poly						10 years product, 25 years linear power					

Table 1. Solar panels. Table data supplied by manufacturers/importers. (cont)

Brand (made in)	Model	Rated power (watts)	Voltage at max power	Current at max power	AC or DC output	Maximisers included	Power tolerance	Panel efficiency (%)	Cell type and quantity	Cell temp at which panel is tested °C	Power temp coefficient (%/°C)	Construction	Size in mm (L x W x T)	Weight (kg)	Warranty (years)	RRP Inc GST ($)	Cost per Watt ($)	Embodied energy (yrs)	Rated lifetime (years)	Comments
Powertech (China) Jaycar Electronics ph: 1800 022 888 techstore@jaycar.com.au www.jaycar.com.au	ZM9053	5	17.5	0.29	DC		+/-5%		Mono	25	-0.39	High transparency 3.2mm tempered solar glass, 36 monocrystalline solar cells, composite film, aluminium frame, junction box	245 x 193 x 18	0.73	1 year product, 25 years power (80%)	29.95	5.99		25	
	ZM9054	10	17.5	0.57									304 x 270 x 18	1.12		49.95	5.00			
	ZM9055	20	17.2	1.16									664 x 259 x 18	2.12		89.95	4.50			
	ZM9056	40	17.2	2.33									664 x 402 x 25	3.5		99.95	2.50			
	ZM9057	80	17.6	4.55									664 x 760 x 25	5.5		179.00	2.24			
	ZM9058	120	17.6	6.8									1179 x 664 x 35	10.5		249.00	2.08			
	ZM9059	150	18.1	8.31									1479 x 664 x 35	11		299.00	1.99			
	ZM9155	100	17.8	5.62								PET board, 32 Sunpower monocrystalline solar cells, composite film, junction box	1100 x 570 x 2.5	2.1	1 year product, 5 years power (80%)	349.00	3.49		5	
	ZM9166	50	18	2.78								PCB board with PET film, 4 pcs of solar panel arrays	325 x 360 x 30	2.76		299.00	5.98			
	ZM9168	100	18	5.55								PCB board with PET film, 8 pcs of solar panel arrays	340 x 360 x 80	5.18		499.00	4.99			
	ZM9174	100	17.8	5.62								High transparency 3.2mm tempered solar glass, 36 monocrystalline solar cells, composite film, aluminium frame, junction box	525 x 665 x 75	10.3		249.00	2.49			
	ZM9176	120	18	6.66									525 x 665 x 75	13.2		299.00	2.49			
	ZM9178	160	18	8.88									665 x 759 x 75	15.5		399.00	2.49			
RADpower Solar 4 RVs, Solar 4 Boats ph: 1300 765 273 info@solar4rvs.com.au www.solar4rvs.com.au	RP18S	18	19.8	0.91	DC		+/-3%	Encapsulated cell efficiency: 20.5 to 22.4%	6 mono SunPower Maxeon Gen II cells	25°C (STC)	-0.38	Semi-flexible: low texture ethylene tetrafluoroethylene (ETFE) top sheet, multilayer ethylene vinyl acetate (EVA), Tedlar	440 x 280 x 3	0.3	2	105.00	5.83		Not declared	These semi-flexible panels are ideal for mobile use such as caravans and boats – not on the Clean Energy Council approved module list. Installed using adhesive sealant (no glass, frame or mounting brackets). Available in thin junction box, or square junction box, or junction box underneath, or solder tabs underneath. Available with or without eyelets. Available in black or white background.
	RP30S	30	17.6	1.7					10 mono SunPower Maxeon Gen II cells				385 x 540 x 3	0.6		135.00	4.50			
	RP60S	60	17.5	3.4					21 mono SunPower Maxeon Gen II cells				725 x 540 x 3	1.1		205.00	3.42			
	RP80S	85	16	5.35					28 mono SunPower Maxeon Gen II cells				930 x 540 x 3	1.5		270.00	3.18			
	RP110SP	110	19.2	5.7				Encapsulated cell efficiency: 22.8 to 23.7%	32 mono SunPower Maxeon Gen III cells		-0.30	Semi-flexible: high texture ETFE top sheet, multilayer EVA, Tedlar	1060 x 545 x 3	1.7		300.00	2.73			
	RP120SP	120	21.7	5.7					36 mono SunPower Maxeon Gen III cells				1175 x 545 x 3	1.9		328.00	2.73			
	RP135SP	135	24.1	5.7					40 mono SunPower Maxeon Gen III cells				1310 x 545 x 3	2.1		350.00	2.59			
	RP150SP	150	26.5	5.7					44 mono SunPower Maxeon Gen III cells				1445 x 545 x 3	2.3		389.00	2.59			
REC Solar Australia apac.recgroup.com	TwinPeak 120 half-cell series	275 to 285			DC				PERC poly half-cells						10 years product, 25 years linear power (maximum reduction of 0.7% p.a.)					REC Solar Australia failed to provide updated data for this guide, so we have included abbreviated data on their product range.
	Peak Energy series	250 to 275			DC				Poly											

Table 1. Solar panels. Table data supplied by manufacturers/importers. (cont)

Brand (made in)	Model	Rated power (watts)	Voltage at max power	Current at max power	AC or DC output	Maximisers included	Power tolerance	Panel efficiency (%)	Cell type and quantity	Cell temp at which panel is tested °C	Power temp coefficient (%/°C)	Construction	Size in mm (L x W x T)	Weight (kg)	Warranty (years)	RRP Inc GST ($)	Cost per Watt ($)	Embodied energy (yrs)	Rated lifetime (years)	Comments
Seraphim Solar (SAE Group) ph: 1300 182 050 info@saegroup.com.au www.saegroup.com.au	SRP-260-6PB	260	30.9	8.42	DC		(0+4.99)	15.98	Poly	25	Pmax=-0.41 Voc=-0.32 Isc=+0.05	3.2mm tempered glass, low iron, anodised aluminium alloy frame, IP67 junction box, 400mm cables 900mm cable length & MC4 compatible connectors	1637 x 992 35mm	18.5kg	10 years product, 25 years linear power	POA	POA		25+	
	SRP-265-6PB	265	31.1	8.53	DC		(0+4.99)	16.29	Poly	25		3.2mm tempered glass, low iron, anodised aluminium alloy, frme, IP67 junction box, 400mm cables 900mm cable length & MC4 compatible connectors	1638 x 992 35mm	18.5kg		POA	POA		25+	
	SRP-270-6PB	270	31.3	8.63	DC		(0+4.99)	16.6	Poly	25		3.2mm tempered glass, low iron, anodised aluminium alloy, frme, IP67 junction box, 400mm cables 900mm cable length & MC4 compatible connectors	1639 x 992 35mm	18.5kg		POA	POA		25+	
	SRP-275-6PB	275	31.6	8.71	DC		(0+4.99)	16.9	Poly	25		3.2mm tempered glass, low iron, anodised aluminium alloy, frme, IP67 junction box, 400mm cables 900mm cable length & MC4 compatible connectors	1640 x 992 35mm	18.5kg		POA	POA		25+	
	SRP-290-E11B	290	35.35	8.21	DC		(0+4.99)	17.05	Poly	25°C (STC)		3.2mm tempered glass, low iron, anodised aluminium alloy, frme, IP67 junction box, 400mm cables 900mm cable length & MC4 compatible connectors	1632 x 1048 x 40mm	19		POA	POA		25+	
	SRP-320-E01B	320	36.4	8.8	DC		(0+4.99)	18.81	Poly	25		3.2mm tempered glass, low iron, anodised aluminium alloy, frme, IP67 junction box, 400mm cables 900mm cable length & MC4 compatible connectors	1633 x 1048 x 40mm	19		POA	POA		25+	
	SRP-350-6MA	350	38.1	9.19	DC		(0+4.99)	18.04	Poly	25		3.2mm Tempered glass, low iron, anodised aluminium alloy, frme, IP67 junction box, 400mm cables 900mm cable length, & MC4 compatible connectors	1955 x 992 x 40mm	23kg		POA	POA		25+	
	SRP-355-6MA	355	38.3	9.27	DC		(0+4.99)	18.3	Poly	25		3.2mm tempered glass, low iron, anodised aluminium alloy, frme, IP67 junction box, 400mm cables 900mm cable length & MC4 compatible connectors	1956 x 992 x 40mm	23kg		POA	POA		25+	
	SRP-360-6MA	360	38.5	9.36	DC		(0+4.99)	18.55	Poly	25		3.2mm tempered glass, low iron, anodised aluminium alloy, frme, IP67 junction box, 400mm cables 900mm cable length & MC4 compatible connectors	1956 x 992 x 40mm	23kg		POA	POA		25+	
Solarwatt GmbH Made in Germany Local subsidiary Solarwatt Australia	Vision 60P	275	31.2	8.89	DC			16.7	Poly	STC & NOCT conditions	-0.41	Tempered glass with anti-reflective 2mm finish, EVA, solar cells, EVA white, solar glass 2mm, anti-PID technology	1680x990x40	22.8	30 years product, 30 years power	POA			See warranty	Founded in 1993 and active globally, Solarwatt is a leading German manufacturer of photovoltaic systems. The company is a European market leader for glass-glass panels and one of the largest suppliers of home battery storage products. All products are developed in-house, manufactured in Germany and are premium quality.
	Vision 60M Style	285	31.9	9.12				17.3	Mono		-0.39									
	Vision 60M High Power	300	31.9	9.5				18.2	Mono		-0.39									
Sunpower Corp www.sunpower.com.au	E series residential	320 to 327			DC				SunPower Maxeon mono						25 years product, 25 years linear power					Sunpower Corp failed to provide updated data for this guide, so we have included abbreviated data on their product range.
	X series residential	335 to 345			DC															

Table 1. Solar panels. Table data supplied by manufacturers/importers. (cont)

Brand (made in)	Model	Rated power (watts)	Voltage at max power	Current at max power	AC or DC output	Maximisers included	Power tolerance	Panel efficiency (%)	Cell type and quantity	Cell temp at which panel is tested °C	Power temp coefficient (%/°C)	Construction	Size in mm (L x W x T)	Weight (kg)	Warranty (years)	RRP Inc GST ($)	Cost per Watt ($)	Embodied energy (yrs)	Rated lifetime (years)	Comments
SF Suntech Australia ph: (02) 8188 2450 sales@suntech-power.com.au www.suntech-power.com	STP265 - 20/Wfw	265	31	8.56	DC		0/+5 W	16.2	Poly	25	Pmax=-0.41 Voc=-0.33 Isc=+0.067	60 cells. 3.2mm low iron tempered solar glass, Tedlar backsheet, anodised aluminium frame, IP68 junction box, 100cm 4mm output cables with genuine MC4 connectors.	1650 x 992 x 35	18.3	12 years product, 25 years linear power				25+	5 busbar model, VDE extended hail tested, IP68 junction boxes, 100% PID-free module, twice electroluminescence tested, 5400Pa snow load and 4200Pa wind load, tested for harsh environments (salt mist, ammonia corrosion and sand blowing testing: IEC 61701, IEC 62716, DIN EN 60068-2-68) Atlas 25+ Long-term reliability tests and quality control measures meeting ISO 9001: 2008, ISO 14001: 2004 and ISO 17025: 2005.
	STP270 - 20/Wfw	270	31.1	8.69	DC		0/+5 W	16.5	Poly	25									25+	
	STP275 - 20/Wfw	275	31.2	8.82	DC		0/+5 W	16.8	Poly	25									25+	
	STP265 - 20/Wfi	265	31.43	8.45	DC		0/+5 W	16.1	Poly	25	Pmax=-0.39 Voc=-0.32 Isc=+0.049	60 cells. 2mm low iron heat strengthened solar glass front and back, IP67 junction box, 100cm TUV 4mm output cables with genuine MC4 connectors.	1662 x 990 x 5	19.6	12 years product, 30 years linear power				25+	Double glass module. 5 busbar model, VDE extended hail tested, IP67 junction boxes, 100% PID-free module, 2 x EL tested, 2400Pa snow and wind load, tested for harsh environments (salt mist, ammonia corrosion and sand blowing testing: IEC 61701, IEC 62716, DIN EN 60068-2-68) Atlas 25+ long-term reliability tests and quality control measures meeting ISO 9001: 2008, ISO 14001: 2004 and ISO 17025: 2005.
	STP270 - 20/Wfi	270	31.6	8.55	DC		0/+5 W	16.4	Poly	25									25+	
	STP275 - 20/Wfi	275	31.9	8.62	DC		0/+5 W	16.7	Poly	25									25+	
	STP290S - 20/Wfm	290	31.7	9.15	DC		0/+5 W	17.7	PERC Mono	25	Pmax=-0.40 Voc=-0.34 Isc=+0.060	60 cells. 3.2mm low iron tempered solar glass, Tedlar backsheet, anodised aluminium frame, IP68 junction box, 100cm TUV 4mm output cables with genuine MC4 connectors.	1650 x 992 x 35	18.3	12 years product, 25 years linear power				25+	Advanced PERC mono. 5 busbar model, VDE extended hail tested, IP68 junction boxes, 100% PID-free module, 2 x EL tested, 5400Pa snow load and 3800Pa wind load, tested for harsh environments (salt mist, ammonia corrosion and sand blowing testing: IEC 61701, IEC 62716, DIN EN 60068-2-68) Atlas 25+ Long-term reliability tests and quality control measures meeting ISO 9001: 2008, ISO 14001: 2004 and ISO 17025: 2005.
	STP295S - 20/Wfm	295	32.2	9.17	DC		0/+5 W	18	PERC Mono	25									25+	
	STP300S - 20/Wfm	300	32.6	9.21	DC		0/+5 W	18.3	PERC Mono	25									25+	
	STP290S - 20/Weg	290	31.9	9.09	DC		0/+5 W	17.6	Mono	25	Pmax=-0.38 Voc=-0.30 Isc=+0.048	60 cells. 2.5mm low iron heat strengthened solar glass front and back, IP67 junction box, 30cm TUV 4mm output cables with genuine MC4 connectors.	1658 x 992 x 6	22.5	12 years product, 30 years linear power				25+	N-type bifacial solar module (more efficient than P-type, no LID loss), back side can produce up to 90% of front side efficiency. 4 busbar model, VDE extended hail tested, IP67 junction boxes, 100% PID-free module, 2 x EL tested, extended snow and wind load, tested for harsh environments (salt mist, ammonia corrosion and sand blowing testing: IEC 61701, IEC 62716, DIN EN 60068-2-68) Atlas 25+ Long-term reliability tests and quality control measures meeting ISO 9001: 2008, ISO 14001: 2004 and ISO 17025: 2005.
	STP295S - 20/Weg	295	32.1	9.19	DC		0/+5 W	17.9	Mono	25									25+	
	STP300S - 20/Weg	300	32.3	9.29	DC		0/+5 W	18.2	Mono	25									25+	
	STP315 - 24/Vej	315	36.8	8.56	DC		0/+5 W	16.1	Poly	25	Pmax=-0.41 Voc=-0.33 Isc=+0.067	72 cells. 2mm low iron heat strengthened solar glass front and back, IP68 junction box, 110cm TUV 4mm output cables with genuine MC4 connectors.	1980 x 990 x 5	23.5					25+	Double glass module. 4 busbar model, VDE extended hail tested, IP68 junction boxes, 100% PID-free module, 2 x EL tested, 2400Pa snow and wind load, tested for harsh environments (salt mist, ammonia corrosion and sand blowing testing: IEC 61701, IEC 62716, DIN EN 60068-2-68) Atlas 25+ long-term reliability tests and quality control measures meeting ISO 9001: 2008, ISO 14001: 2004 and ISO 17025: 2005.
	STP320 - 24/Vej	320	37.1	8.63	DC		0/+5 W	16.3	Poly	25									25+	
	STP325 - 24/Vej	325	37.3	8.72	DC		0/+5 W	16.6	Poly	25									25+	
	STP315 - 24/Vfw	315	36.8	8.56	DC		0/+5 W	16.2	Poly	25	Pmax=-0.41 Voc=-0.33 Isc=+0.067	72 cells. 3.2mm low iron tempered solar glass, tedlar backsheet, anodised aluminium frame, IP68 junction box, 110cm TUV 4mm output cables with genuine MC4 connectors.	1960 x 992 x 40	22.1	12 years product, 25 years linear power				25+	5 busbar model, VDE extended hail tested, IP68 junction boxes, 100% PID-free module, 2 x EL tested, 5400Pa snow load and 3800Pa wind load, tested for harsh environments (salt mist, ammonia corrosion and sand blowing testing: IEC 61701, IEC 62716, DIN EN 60068-2-68) Atlas 25+ long-term reliability tests and quality control measures meeting ISO 9001: 2008, ISO 14001: 2004 and ISO 17025: 2005.
	STP320 - 24/Vfw	320	37.1	8.63	DC		0/+5 W	16.5	Poly	25									25+	
	STP325 - 24/Vfw	325	37.3	8.72	DC		0/+5 W	16.7	Poly	25									25+	
	STP320 - 24/Vfw (1500V)	320	37.1	8.63	DC		0/+5 W	16.5	Poly	25	Pmax=-0.41 Voc=-0.33 Isc=+0.067	72 cells. 3.2mm low iron tempered solar glass, Tedlar backsheet, anodised aluminium frame, IP68 junction box, 110cm TUV 4mm output cables with genuine MC4 connectors.	1960 x 992 x 40	22.1					25+	
	STP325 - 24/Vfw (1500V)	325	37.3	8.72	DC		0/+5 W	16.7	Poly	25									25+	
	STP330 - 24/Vfw (1500V)	325	37.5	8.81	DC		0/+5 W	16.9	Poly	25									25+	
	STP335S - 24/Vfw	335	37.5	8.94	DC		0/+5 W	17.2	Mono	25	Pmax=-0.41 Voc=-0.34 Isc=+0.060	72 cells. 3.2mm low iron tempered solar glass, Tedlar backsheet, anodised aluminium frame, IP68 junction box, 110cm TUV 4mm output cables with genuine MC4 connectors.	1960 x 992 x 40	22.1					25+	
	STP340S - 24/Vfw	340	37.7	9.02	DC		0/+5 W	17.5	Mono	25									25+	
	STP345S - 24/Vfw	345	37.9	9.11	DC		0/+5 W	17.7	Mono	25									25+	
Tindo Solar www.tindosolar.com	Karra series	265 to 285			AC or DC				Poly						10 years product, 25 years power					Tindo Solar failed to provide updated data for this guide, so we have included abbreviated data on their product range.

Table 1. Solar panels. Table data supplied by manufacturers/importers. (cont)

Brand (made in)	Model	Rated power (watts)	Voltage at max power	Current at max power	AC or DC output	Maximisers included	Power tolerance	Panel efficiency (%)	Cell type and quantity	Cell temp at which panel is tested °C	Power temp coefficient (%/°C)	Construction	Size in mm (L x W x T)	Weight (kg)	Warranty (years)	RRP Inc GST ($)	Cost per Watt ($)	Embodied energy (yrs)	Rated lifetime (years)	Comments
Trina Solar www.trinasolar.com.au	Duomax Plus series glass-glass	270 to 305			DC				Mono						10 years product, 30 years linear power					Trina Solar failed to provide updated data for this guide, so we have included abbreviated data on their product range.
	Duomax series glass-glass	260 to 280			DC				Poly											
	Honey series	260 to 280			DC				Mono						10 years product, 25 years linear power					
	Tallmax series	320 to 335			DC				Poly											
Upsolar Australia www.upsolar.com/au	Upsolar standard series	265 to 365			DC				Poly and mono						12 years product, 25 years linear power					Upsolar Australia failed to provide updated data for this guide, so we have included abbreviated data on their product range.
	Optimised series	185 to 310			Optimised DC															
WINAICO (Taiwan) (Win Win Precision Technology - WINAICO) WINAICO Australia Pty Ltd ph: (02) 8091 2771 australia@winaico.com www.winaico.com	WST-285P6	285	31.3	8.97	DC		0+5W	17.1	Poly 60 cell	STC & NOCT conditions	-0.43	100% aluminium frame, precision cut, finished, anodised and pressure assembled; highly transmissive, low iron, anti-reflective coated and strengthened glass; EVA encapsulant; white back sheet with adhesive tape for module sealing; MC4 connectors. Electroluminescence and flash tested.	1666 x 999 x 35	19	15 years product, linear 25 years power	POA	POA		25 years	WINAICO customers receive 2 years of complimentary 3-in-1 WINAICO system insurance cover against: All risks, reduced yield and interruption of service; Latest technology includes: PERC poly/mono-crystalline modules for high efficiency; Fully automated production line with strict quality control procedures; Hail resistant up to 35mm ice ball at 98kph; Anti-PID, ammonia resistance, salt-mist resistance, hotspot protection; Direct from the manufacturer with comprehensive local engineering and warranty support from warehouses across the country.
	WSP-310M6	310	32.9	9.42				18.6	Mono 60 cell – PERC				1665 x 999 x 40	19.6						
Yingli Green Energy (China) Australian Sales and Technical office ph: 1300 309 489 australia@yingli.com www.yinglisolar.com/au	YGE 60 Series	270	30.7	8.80	DC		Positive tolerance 0 to +5W	16.6	Poly 60 cell	STC & NOCT conditions	–0.42	High transmission low iron tempered glass with an anti-reflection coating. Clear EVA encapsulant. White backsheet. Genuine MC4 connectors. Premium tape seal. All black module available on request with black silicon cells, black backsheet and black frame.	1640 x 992 x 35	18.5	10 years product, 25 years power: maximum 2.5% reduction after the first year, 0.7% every subsequent year.	POA	POA	-	See warranty	Yingli Solar has been manufacturing solar modules for over 14 years and was the world's largest manufacturer in 2012 and 2013. Yingli Solar modules sold in Australia, NZ and the Pacific Islands are supported by a local Australian team with full sales and technical services headquartered in Sydney's CBD.
	YGE 72 Series	320	37.0	8.64				16.5	Poly 72 cell				1960 x 992 x 35	22						
	PANDA BIFACIAL 60 Series	285	32.0	8.91				17.1	Mono PERC bifacial 60 cell		–0.38	Glass-on-glass construction. The anodised aluminium frame is a hollow boxed extrusion without a rear flange, minimising the rear shading. Three slim-line junction boxes which do not shade the solar cells, instead of one large box. Also available 'frameless' on request. Frameless version comes with white corner protectors and a protective bumper edge seal around the perimeter for easier handling and care.	1666 x 998 x 32	24.5	10 years product, 30 years power: maximum 2% reduction after the first year, 0.5% every subsequent year.					
	PANDA BIFACIAL 144HC Series	350	39.2	8.99				17.1	Mono PERC bifacial 144 half-cell				1956 x 1046 x 32	29.2						
Zeus Appollo Solar ph: (07) 3123 6148 sales@zeusappollosolar.com.au www.zeusappollo.com	Z2OP260C	260	30.67	8.48	DC		0 to +3%	15.98%	Poly	25	-0.43	Tempered glass, EVA, aluminium frame. Anti-reflective glass. Anti-PID technology (APT).	1640 x 992 x 40	18.9	12 years product, 25 years linear power	POA	POA	-	See warranty	
	ZA1ZDNY-260P60	260	31.91	8.15				15.88%			-0.40+/-0.05		1650 x 992 x 40	19	10 years product, 25 years linear power					
	ZA1ZDNY- 310P72	310	38.02	8.16				15.98%					1956 x 992 x 45	23						
	ZA1ZDNY-200C	200	36.95	5.42				15.60%	Mono				1580 x 808 x 35	15						
	ZA1ZDNY-250C60	250	31.17	8.03				15.30%					1650 x 992 x 40	19						
	ZA1ZDNY-300C72	300	37.62	7.98				15.40%					1956 x 992 x 45	23						