Solar panel and battery for an nbn Wireless Non Standard Installation

A fixed wireless connection may be achieved by installing the nbn ODU and NTU at a location remote from your home. It must be sited on your property (or a neighbour by arrangement), with sufficient signal to achieve service commissioning. The current signal limit cut-off is -96dBm, however I understand there are plans by nbn to decrease this to -99dBm, which will benefit a number of otherwise failed installations.

This paper identifies the **solar panel** (PV), **battery** and **solar regulator** requirements for a remotely mounted nbn wireless installation; when domestic power or another solar facility is not available.

Note: You may use the principles applied here to design any static system.

It does not deal with requirements of the mount, mast and equipment cabinet. That may come as a future addendum, when nbn addresses the various aspects of free standing non-standard installations.

Costs for a non-standard installation must be borne by the premise owner.

Equipment energy requirement

This paper assumes that the installation will consist of an nbn ODU plus NTU and a wireless bridge to the home.

The combined load of the nbn wireless NTU and ODU is 9-10 watts continuous.
See this post on the Whirlpool forum for the details.

When a wireless AP is included at the site, the wireless AP will add an average 6 watts continuous. The total load is now 10w + 6w = **16 watts** continuous or **1.3A** continuous (@ 12.2V).

The daily load is 16w x 24hr = **384Wh/day**, or let's say **400Wh/day** rounded up.

Solar Panel requirements

The solar panel must support the 400Wh/day load and keep the battery well charged. Importantly, the solar panel average production and its worst day's production will vary dramatically, depending on where you live.

Let's start with some broad annual solar panel production figures which are available for a number of locations around Australia. This data is taken from the *Clean Energy Council* - Consumer guide to buying Household Solar Panels (photovoltaic panels). The *Clean Energy Council* is the Solar Industry peak body organisation.

This particular document is no longer in print, but importantly, it captures typical daily small PV production values for a number of capital City and Regional sites around Australia. I have provided a link to this pdf document here. See Page 5 of the pdf.

This document replaced by newer consumer information, but they are more about consumer costs than consumer production. See http://www.solaraccreditation.com.au/consumers/purchasing-your-solar-pv-system.html. The business documents do include production estimates.

Average Daily Production					
City	**1 kW system**	**1.5 kW system**	**2.0 kW system**	**3.0 kW system**	**4.0 kW system**
Adelaide	4.2 kWh	6.3 kWh	8.4 kWh	12.6 kWh	16.8 kWh
Alice Springs	5.0 kWh	7.5 kWh	10.0 kWh	15.0 kWh	20.0 kWh
Brisbane	4.2 kWh	6.3 kWh	8.4 kWh	12.6 kWh	16.8 kWh
Cairns	4.2 kWh	6.3 kWh	8.4 kWh	12.6 kWh	16.8 kWh
Canberra	4.3 kWh	6.45 kWh	8.6 kWh	12.9 kWh	17.2 kWh
Darwin	4.4 kWh	6.6 kWh	8.8 kWh	13.2 kWh	17.6 kWh
Hobart	3.5 kWh	5.25 kWh	7.0 kWh	10.5 kWh	14.0 kWh
Melbourne	3.6 kWh	5.4 kWh	7.2 kWh	10.8 kWh	14.4 kWh
Perth	4.4 kWh	6.6 kWh	8.8 kWh	13.2 kWh	17.6 kWh
Sydney	3.9 kWh	5.85 kWh	7.8 kWh	11.7 kWh	15.6 kWh

Data Source: PV-GC spreadsheet based on the CEC GC Design Guidelines
The rated output is that achieved in perfect laboratory conditions. The CEC design summary software takes these deratings into account when predicting average for any given system.

Note: The above results are for grid connected systems and include the DC to AC inverter inefficiencies.

To simplify the maths let's focus on the production of a 1Kw system from the table above.

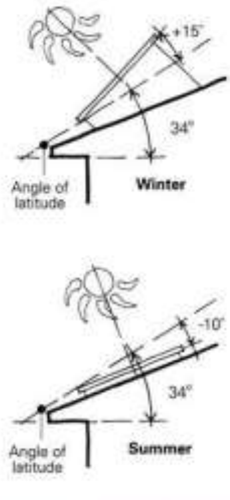
The 1kW panel results range from **3.5kWh/day** in Hobart, to **5.0kWh/day** in Alice Springs.

As a very rough rule of thumb, a solar panel produces an average of four times its rated power per day over a full year of operation. A 1Kw panel will average 4kWh per day, a 100W panel, 400Wh/day and a 200W panel 800Wh per day and so on.

The key to understanding how your static PV system will perform, is the impact of the worst month and the worst days of the worst month for your location. It is at this time that many under-resourced static systems fail.

It is also critical that your solar array is aligned to provide maximum production during the worst month(s) particularly as you move further south. In the tropics a panel tilt equal to latitude is fine. However, as you move out of the tropics, it is advisable to increase the inclination by latitude **+15 degrees** for an optimum winter performance.

The diagram to the right shows a typical panel alignment in Sydney. The panel azimuth is generally set to true north.



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

Sizing your Solar Panel system at your location

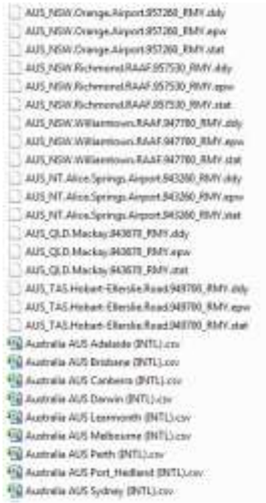
You are now probably ready to rush out and buy a 100w panel to power your system. After all, I have already indicated that a 100W panel could generate around 400Wh/day, on average over a full year.

However to determine the performance, at your location and to establish the impact of the worst days of the year, we need some additional information. The worst days determine the necessary size of your panel for a 100% autonomous system.

Fortunately there is an excellent program and long term solar data for a number of locations around Australia that can assist us. The program is SAM and the solar data is here. Additional solar radiation files for Australia are available here.

Download and install SAM and find the site most likely to represent your location and download the necessary ZIP file(s).

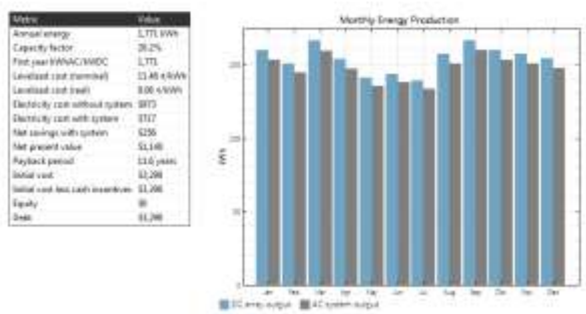
Determine where SAM is installed, which is most likely *C:\SAM\2015.1.30\solar_resource*, open the *solar_resource* folder and copy in the unzipped location data. My file for Australian data currently looks something like this ->



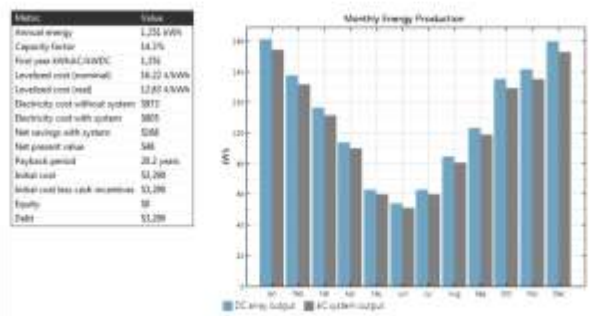
Note: I believe that only the *RMY.epw* or *.csv* files are required for each location, however I just dropped in the lot from the zip file. If you open the *.stat* and *.ddy* file in a text editor, it will reveal some background and extent of the data in the *.epw* file.

You are now ready to open and run SAM.

But first let's compare some SAM results to the Energy Council data we looked at earlier. It should compare pretty well, otherwise the this process is flawed. From earlier, the 1kW panel results range from **3.5kWh/day** in Hobart to **5.0kWh/day** in Alice Springs. What does Sam indicate for these two locations using a 1Kw panel as the input?



Alice Springs



Hobart

Let's do the maths for a 1Kw panel system at these two locations. From the SAM charts above you will see that the Hobart site generates 1,251kWh and Alice Springs generates 1,771kWh per annum.

Divide each by 365 days of the year and we have 1251/365 = **3.43kWh/day** and 1771/365 = **4.85kWh/day**.

I left the SAM AC generation input data at their default values. They are conservative; however I believe the results are a good match. Our design is a bit simpler, as we are using DC generation, which is a bit more efficient, as there is no AC inverter.

With verification of the SAM model and the data sources, let's delve a little deeper. You may already have noticed the fairly dramatic difference in the monthly energy plots when comparing Hobart on a winter's day, against sunny Alice Springs. We can be certain that the static panel requirements for these two locations will be quite different.

For my in depth study I will use a brand new solar location; **Mackay** in the tropics of far north Queensland.

Battery Capacity required for 3 days autonomy @ 400Wh per day

The fundamentals of this static panel system are:

- battery supports the system load for 3 days (without any input)
- battery is not discharged below 50% of its rated capacity

A load of **400Wh/day**, for 3 days is 3 (days) x 400Wh = **1,200Wh**.

A 200Ah battery has **100Ah** (50%) of useable capacity. At 12.2 volts it has a useable power of (P=EI) of 12.2 x 100 = **1,200Wh**.

Therefore a **200Ah** battery is required to support a **1,200Wh** load for 3 days.

Mackay - nbn wireless PV dimensioning

Open SAM select *Start a new project*, then *photovoltaic (PV Watts)* then *No Financial model* then *OK*.

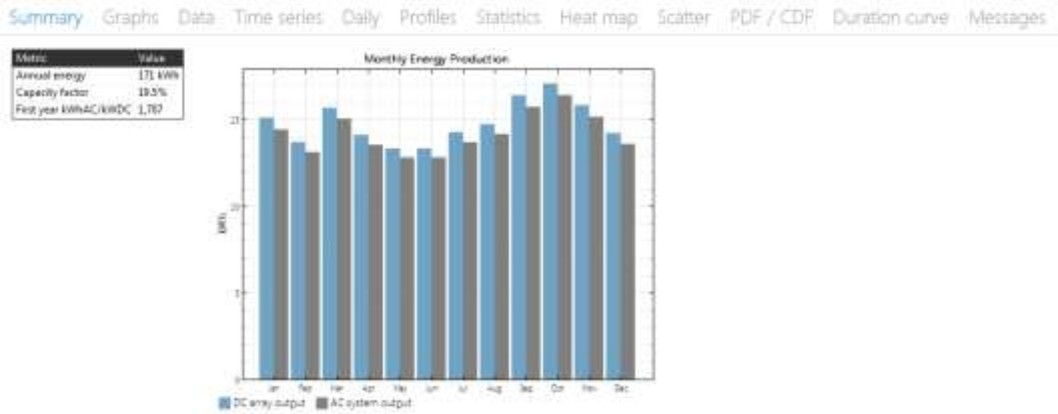
Select your *desired location* from the list of sites available (you may need to refresh the library if you have added data) and check the information displayed for your selected site. Along with other interesting observations, it includes the latitude. Note the latitude value. For Mackay it is 21.12 degrees.

Select *System Design*. This is where you set the system panel size and panel orientation. As SAM is designed in the northern hemisphere, the first thing you must change is the panel *Azimuth*. Set it to **0** (or north) in the southern hemisphere. Set *Tilt* equal to your locations latitude (or +15 if further South).

For Mackay set **21.2**.

Set the *system nameplate size* to **100w**. You may set it to your best guess at this stage, but 100w is a nice easy number to multiply and relate to our systems 400Wh/day load.

Now press *Simulate* and the following screen is displayed. By changing the various input values e.g tilt etc, you may observe the changes in output over a year's PV production.

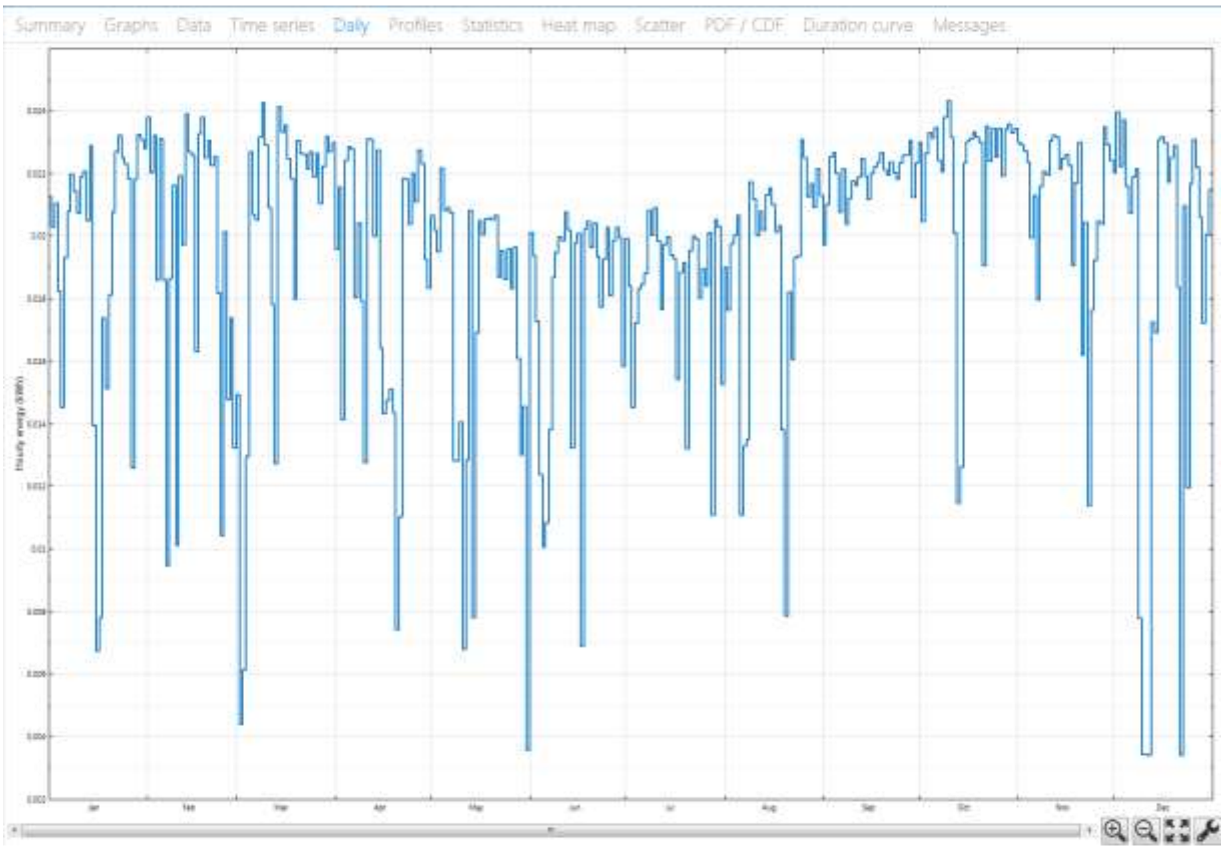


The annual (AC energy) production for a 100w panel in Mackay is 171kWh/annum or **468.5Wh/day**.

There is a plenty of useful data reported by SAM; but first you should save your first project by going to the top left corner and clicking on the PV array graphic.

You can generate graphs or check data tables for a range of data (you'll notice that DC generation is higher than AC generation), but the key report for us is the *Daily* report. Click on *Daily* and you will see a plot covering the entire year with an hourly generation estimate for each day.

The next graphic shows the hourly plot for Mackay, Queensland:



There are tools to zoom and investigate the daily production, but firstly, how is this graph calibrated? The hourly production is the hourly production taken over a full 24 hour period. To arrive at the daily production, you must multiply the hourly kWh figure by 24. If we look at the graph above the hourly peak is around 0.024kWh and the hourly low around .004kWh per day. Multiply by 24 and we have **576Wh/day** on a good day and **96Wh/day** on a bad day. The odd bad day is not a problem if the days either side are good.

Mackay is quite remarkable in that it does not have long runs of bad days; or at least the historical data indicates this. Remember we have no way of predicting the future.

You can look at this data in detail in the table data area and look at the hourly production numbers and then manipulate this. 1 hr intervals over 365 days is a long csv table (365 x 24 to be precise).

The zoomed graph can also be used to give us a sufficiently accurate answer.

Zooming in on that bad run of days from the 9th through to the 14th of December we can see that there are 6 days where production falls below the norm.

Reading from the graph gives 0.008, 0.0035, 0.0035, 0.0035, 0.017, 0.017kWh on consecutive days.

Convert these values to Wh/day by multiplying by (24 x 1,000) giving 192, 84, 84, 84, 408, 408 Wh/day.

Our chosen **200Ah** battery, 100% charged, supplies a nominal **1200Ah**.

The table tracks the progressive battery capacity in **%** over the 6 days for a **100W** solar panel.

Wh/day	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**
100W Panel	192	84	84	84	408	408
Battery inputs	208	316	316	316	-8	-8
Load requirement	**400**	**400**	**400**	**400**	**400**	**400**
Battery charge	992	676	360	44	52	60
Battery Charge %	90	77	64	52	52	52

The battery charge falls to within 44Ah of the 50% discharge point ie it has almost depleted its nominal 1200Ah reserve. It is also probable that the battery does not commence with a 100% charge ie something less than a nominal 1200Ah and that the battery dips below 50% capacity.

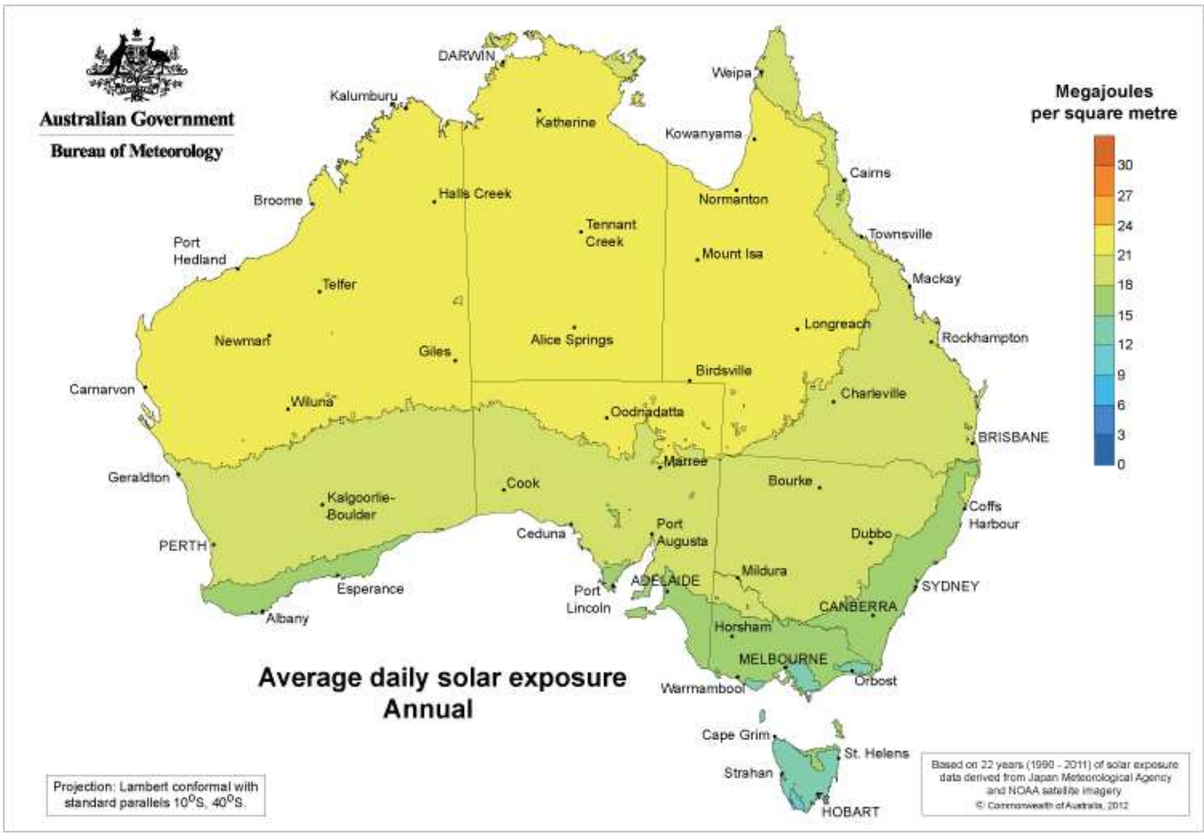
My recommendation is to oversize the PV by a minimum of **50%**. For Mackay, **150watts** would be the minimum PV size. The following table tracks the progressive battery capacity for a **150W** panel at Mackay.

Wh/day	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**
150W Panel	288	126	126	126	612	612
Battery inputs	112	274	274	274	-212	-212
Load requirement	**400**	**400**	**400**	**400**	**400**	**400**
Battery charge	1088	814	540	266	478	690
Battery Charge %	94	83	72	61	69	78

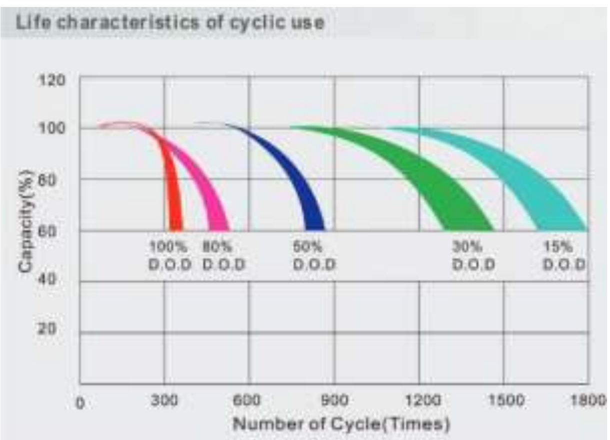
The **150W** panel has improved the batteries minimum capacity from **52%** to **61%**. A larger panel may be deployed to further improve the batteries minimum capacity; however it is important to ensure that the solar regulator has matching specifications.

Mackay is in the tropics. It does not have the run of bad days that many southern locations experience. A **150watt** solar panel would likely be the minimum size required for a remote nbn wireless installation in the high solar production areas of Australia.

Further south you may need twice that capacity, or more. SAM is your guide.



Here is a typical battery life cycle and a flooded cell State of Charge (SoC) chart. For long battery life, it is imperative that any static solar system is properly designed, in order to minimise the depth of battery discharge.



Regular 'Wet' Lead Acid Battery.
Readings taken via voltmeter after resting "off charge" or load for 2 hours plus.
Stated voltages assume a 'set' or 'pack' temperature of around 25 degree's Celsius

State of charge	12v battery	Voltage per cell (if comprised of separate 2v cells)	Comments
100%	12.70v+	2.12v	Cycling your battery in this zone will ensure a reasonable life expectancy
95%	12.60v	2.10v	
90%	12.50v	2.08v	
80%	12.40v	2.06v	
70%	12.30v	2.05v	
60%	12.20v	2.03v	Occasionally dropping into this zone is OK but not recommended
50%	12.05v	2.00v	
40%	11.90v	1.98v	
30%	11.75v	1.95v	
20%	11.55v	1.92v	Cycling a battery into this zone is certainly not recommended unless unavoidable. Battery life will be massively shortened
10%	11.30v	1.88v	
Below 10% DEAD	10.5v Or less	1.75v Or less	

Temperatures below 30 degrees Celsius (below freezing) can reduce capacity by 30% or more

The Solar Regulator - Specifications

The selected solar regulator must meet the both the load and the power of our solar panel.

For Mackay we have determined the following minimum requirements:

12 volt Solar Panel - **150 watts**

12 volt battery – **200Ah**

Load – **1.3A**

Specifications of a typical **150W 12 volt** solar panel:

Model	SY-150M156
Maximum power (W)	150
Optimum power voltage (Vmp)	17.5
Optimum operating current (Imp)	8.57
Open circuit voltage (Voc)	22.5
Short circuit current (Isc)	9.21
Solar cell:	156 x 156 monocrystalline

- Maximum Power (W) –the maximum rated power of the panel
- Vmp - the voltage at which the panel produces the most power.
- Imp - the optimum current that will be generated (at Vmp)
- Voc – the maximum voltage that the panel can produce (panel open circuit)
- Isc – the maximum current that will be produced (under a short circuit)

Your selected regulator (PWM or MPPT) must meet or exceed these specifications. The most critical values to exceed are Isc @ **9.21A** and Voc @ **22.5v**.

Note: In my opinion an MPPT regulator is a bit overkill for small 12v PV. You may realise a 10% increase in production by selecting a suitable MPPT regulator. It's up to you.

However if you are using a higher voltage or home PV system panel, then you **must** use an MPPT regulator to efficiently convert from 30-50volts (or so) Vmp. It is critical that your 12volt MPPT regulator also satisfies the higher Voc, which may exceed 60v, depending on the module.

For this panel a nominal **10A** regulator that accepts a Voc greater than **23volts** will be sufficient.

Note: A 10A regulator is sufficient for most 12v 150W solar panels.
A 20A regulator is sufficient for most 12v 300W solar panels.