How to Size a Battery Bank and PV Array using the Sunshine Coast Renewables Solar System Calculator

PV Array and Battery bank sizing can be one of the more complex and important calculations in your system design. If the battery bank is oversized, you risk not being able to keep it fully charged; if the battery bank is sized too small, you won't be able to run your intended loads for as long as you'd planned.

Most renewable energy systems on Savary Island incorporate batteries as they are all off-grid. The energy stored in the batteries can be used directly to power DC loads or it can be inverted to power AC loads. The batteries recommended are deep cycle batteries – Flooded Lead Acid Batteries are still the battery of choice as AGM and Lithium Batteries have not declined in price significantly yet. To ensure you have enough reserve capacity to provide the electricity you need (without running a generator everyday), invest the time to size your battery bank properly.

Before tackling the calculations, start by identifying a few key pieces of information:

- Watt-hours of electricity usage per day (See **Solar System Calculator**)
- Number of Days of Autonomy (as low as 1 day with back-up generator)
- Depth of Discharge limit (minimum of 50% to maximize Battery Life)
- Capacity of Solar Panel Array

Electrical Usage

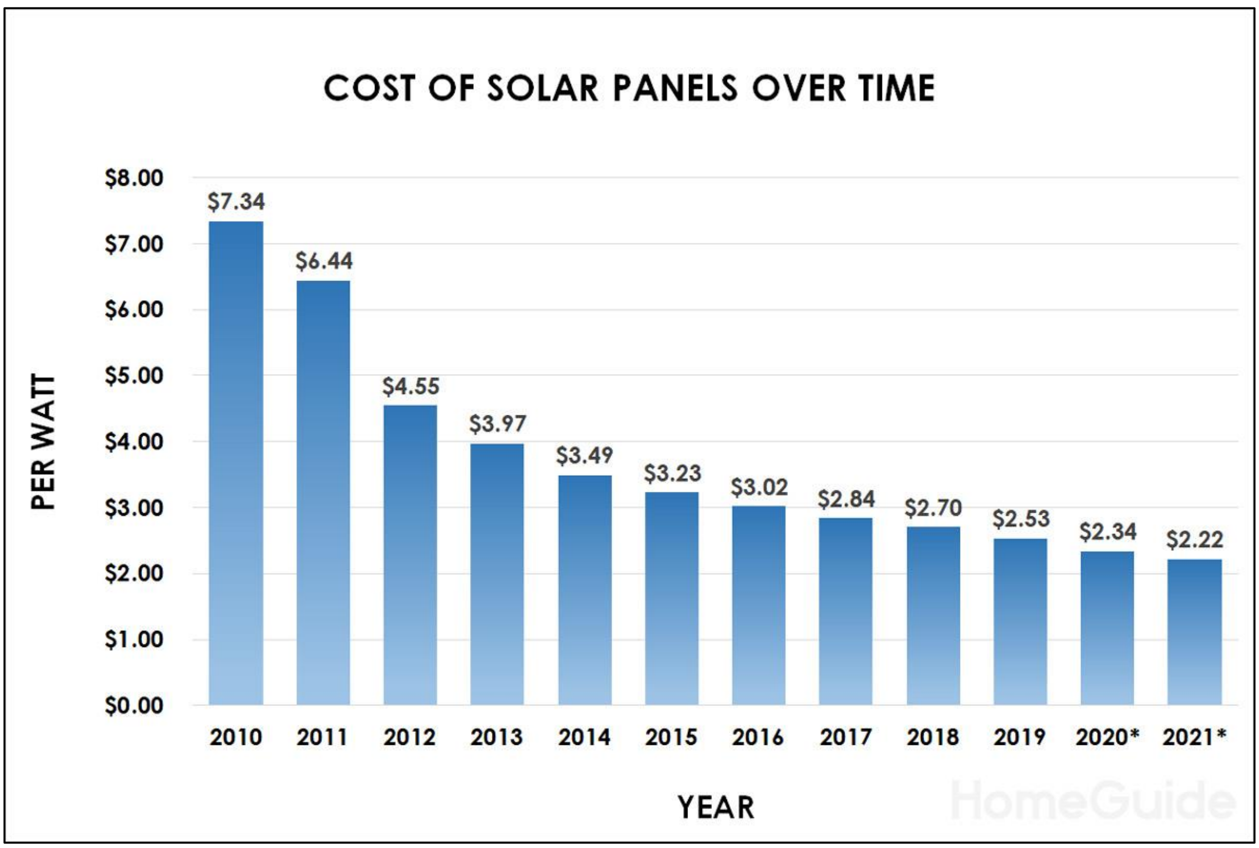
The first thing you'll need to know is the amount of energy you'll be consuming per day. It's worth the time to do a careful evaluation of exactly what loads (appliances, electronics, etc.) you plan to use and for what lengths of time. Keep track of this information using the **Sunshine Coast Renewables Solar System Load Calculator** supplied on our Website.

An example of a typical cabin on Savary Island is shown on Table 1. This cabin has a 24 cubic foot electric fridge, TV, internet, 2 computers and a 9000 BTU Heat pump that is used for an average of 3 hours per day year-round. The homeowners also have a standard washing machine and propane dryer that is used twice a week. Based on their lifestyle, they anticipate using approximately 5800 Watt Hours per day of Power.

Days of Autonomy

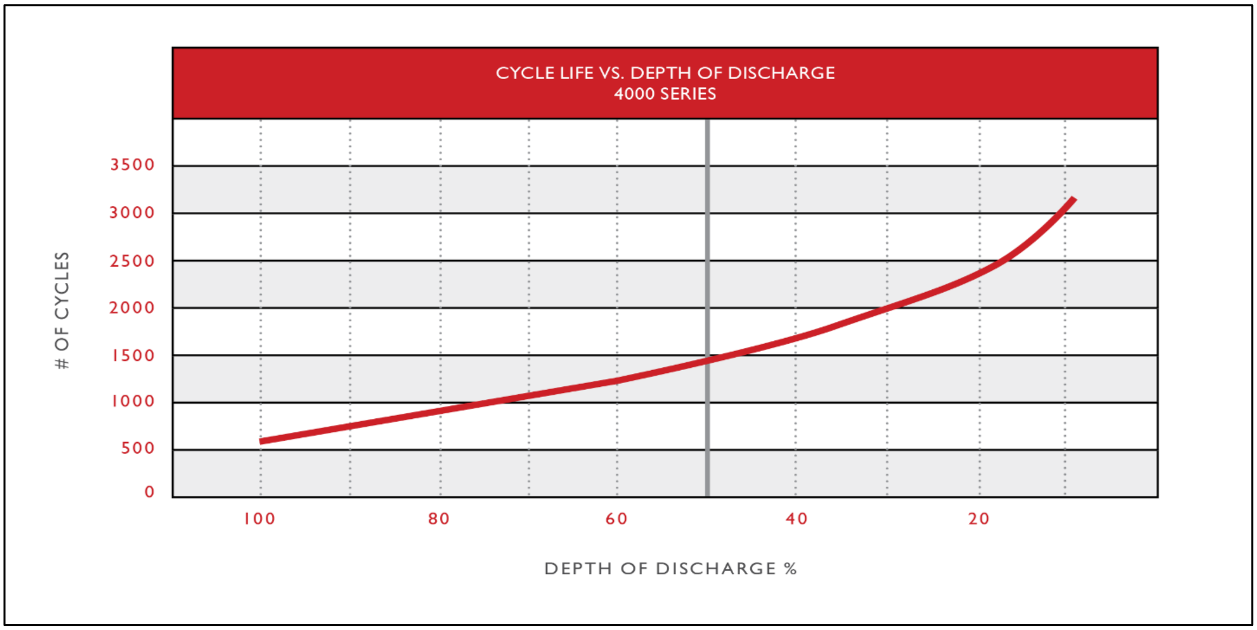
Next, you must determine the number of days of battery back-up that you want to have on hand. In other words, if you are unable to charge your batteries by any means, and you still need to draw power, you must provide this additional storage by increasing the size of your battery bank. For solar panel powered systems (PV), Days of Autonomy represents the number of very cloudy days in a row that might occur and for which you intend to store energy and prefer NOT to run your generator.

In recent years with the relentless decline in the price of Solar Panels, systems have moved towards more PV Panels and smaller battery banks (fewer days of Autonomy) as Battery costs have **NOT declined in cost to the same degree…**



Depth of Discharge

Another factor to consider is the planned Depth of Discharge (DoD) of your battery bank. Flooded lead acid batteries (FLA), sealed AGM batteries and sealed gel batteries are all rated in terms of charge cycles. A single cycle takes a battery from its fully charged state, through discharge (use), then back to full charge via recharging. The depth of discharge is the limit of energy withdrawal to which you will subject the battery (or battery bank). DoD is expressed as a percent of total capacity. The further you discharge a battery, the fewer cycles that battery will be capable of completing. Simply stated, deeper discharge shortens battery life.



Battery Life based on Depth of Discharge

It's recommended that you never discharge a deep-cycle battery below 50% of its capacity; however, many battery manufacturers recommend even shallower DoDs. For off-grid applications, a 25% DoD will extend battery life significantly. On the other hand, if you're only using the batteries occasionally, as a backup system, you can factor in a DoD of 50% or perhaps more. For our example, we will assume a DoD of 50%

Temperature

Battery life and capacity are affected by temperature. Unlike PV modules, batteries perform best in moderate temperatures. In fact, the temperature standard for most battery ratings is 77° F. Cold temperatures tend to reduce battery capacity while high temperatures tend to shorten battery life. In a moderate climate like BC's Sunshine coast, temperature is a not a significant design consideration.

System Voltage

By this point, you will have identified your system voltage. This is typically 12V, 24V, or 48V and often depends on the Inverter that you have chosen.

Calculations

Once you've pinpointed all these variables, it's time to calculate the size of your PV array and battery bank using the **Sunshine Coast Renewables** **Solar System Calculator**!

Let's go through the steps below, using the following example system:

- A system load of **5800 Watt-hours** per day
- Two Days of Autonomy (back up) chosen
- Planned Depth of Discharge (DoD): 50%
- 5 hours of full sun exposure and 75% efficiency expected from PV Array based on Panel location and orientation
- A 24V system

Result: Minimum required Battery amp-hour rating = **483 Amp-hours**

Selecting batteries to meet the Amp-hour capacity

Now that you know the Amp-hour (Ah) capacity that will give you the storage you need, you may need a little guidance in selecting specific batteries. Keep in mind that it's best to keep the number of parallel strings of batteries to three or fewer. If you parallel more than three strings of batteries, you risk shortening battery life due to uneven charging. The ideal battery bank has no parallel connections but is comprised of one or more series-connected batteries. Though parallel connections are not to be avoided at all cost, fewer such connections tends to reduce the chance of charging problems over time.

When batteries are cabled together in series, the voltage is additive. For example, you can put two 12V, 100 Ah batteries in series for a 24V bank. The capacity of that bank would still be 100 Ah. When batteries are connected in parallel, the voltage remains constant and the Ah capacity is additive. In our example with the 12V, 100 Ah batteries, connecting them in parallel would result in a 12V system with a capacity of 200 Ah.

The batteries you select must meet both your system voltage requirements AND the Ah Capacity you calculated. In our example of the 24V system, we calculated that we needed 483 Ah to produce 5800 Wh per day with 2 days of storage. More than one configuration of batteries can meet this need. For example, you could have two 12V batteries in series, each with a capacity of 500 Ah or more. Or you could use four 12V batteries wired in two parallel strings where each battery had a 250 Ah capacity. Or you could use twelve 2V batteries in series, again with appropriate Ah capacities. In any given case, there may be multiple solutions. Your choices will be limited by battery availability and budget.

Building the bank: Amps, then Volts

To build your bank, try first to select a battery that is rated close to the Ah capacity you calculated above (483 Ah). Ignore voltage for a moment. If you can't find one that's very close, look for one that has a capacity either one-half or one-third your needed Ah figure. Popular readily available Deep cycle batteries at the present time are either 2V or 6 V. For a 24 V system, that means you should consider one of the following choices:

- One parallel strings of twelve 2 Volt batteries in series each with an Ah (20 hr) rating of 500 or more
- Two or more parallel strings of four 6Volt batteries in series each with an Ah rating of 260 Ah (typical Golf cart battery) or more.

For the best value in the long run, refer to the Manufacturers Specifications on the number of cycles achievable with each Battery type and depth of discharge designed for. For example, the Rolls Surrette 5000 series 2V batteries are rated for up to 5000 cycles at 20% discharge. A typical Golf cart battery, while cheaper up front is typically rated for only about 250 cycles…

Load Type / Scheduling considerations

A final consideration when designing a Solar system is the types of loads and what time of the day they will occur. For example, a refrigerator is assumed to operate all day, whereas a washing machine could be run at any time of the day to take advantage of maximum Solar contribution and therefore avoid drawing on battery storage capacity.

Another good example of this would be the use of a **Heat Pump**. In the summer time, the Heat Pump is primarily used as an Air Conditioner in the afternoon as the air temperature peaks around 2:00 – 3:00 pm. For many well oriented systems, the PV panels have been charging the battery bank since early morning and the system Voltage is likely high (battery bank approaching fully charged status) meaning much of the PV panel **capability** is being wasted. Programming the Heat Pump to begin a 2-3 hour cycle at this time means it will utilize Solar power that would otherwise not be utilized or stored effectively.

Scheduling Loads efficiently can reduce the size of the battery bank required and save significantly on overall system cost. Given the dramatic decline in PV Panel costs over the past 10 years, it is now **much more cost effective to add additional PV panels** than to expand the battery bank.

Sunshine Coast Renewables

Off Grid - Solar Load Calculator

One of the most important things to do **BEFORE** installing a solar system is to calculate the amount of electricity you will require. You will use this information to determine the size of solar power system you will need. Our Solar Load Calculator can help you calculate your system loads, number of PV Panels required and Optimal Battery Bank size.

Load Calculator Instructions:	Fill out each field for each appliance, estimating how many appliance will be in use and how frequently they will be used.

Electric System Load Calculator

	INPUTS					RESULTS
Appliance	**Quantity**	**Watts**	**Minutes On/Hour**	**Hours On/Day**	**Days On/Week**	**Average Watt Hours/Day**
			(0 - 60)	(0-24)	(0 - 7)	
Clock radio		10				0
Window fan		150				0
Hair dryer		1540				0
Microwave oven	1	1000	5	1	7	83
Laptop computer	2	50	60	3	7	300
Phone Charger	2	5	60	2	7	20
Freezer (17 cubic ft.)		45				0
40" LED flatscreen tv	1	45	60	2	7	90
50" Plasma flatscreen tv		109				0
Toaster	1	1100	5	1	7	92
1/2 hp well pump	1	525	60	2	2	300
60 watt incandescent bulb		60				0
100 watt incandescent bulb		100				0
20 Watt LED bulb	10	20	60	2	7	400
30 Watt LED Bulb		30				0
9000 BTU Heat Pump	1	800	60	2	7	1600
Coffee maker		1050				0
Natural gas clothes dryer	1	300	45	1	2	64
Personal computer		250				0
Home stereo		100				0
Game console (XBOX 360)		135				0
DVD/Blu Ray player		30				0
Satellite receiver or cable box		35				0
RV water pump		100				0
Cable Modem or DSL	1	6	60	24	7	144
Clothes washer	1	425	30	1	2	61
Dishwasher	1	1800	30	1	7	900
Ceiling fan		120				0
Clothes iron		1400				0
Computer monitor		150				0
Refrigerator (24 cubic ft.)	1	60	60	24	7	1440
Hot plate		1200				0
Vacuum cleaner	1	1220	15	1	3	131
Smoke Detector	1	5	60	24	7	120
1 hp well pump		1050				0
Total Power Required:						**5745**

Solar Panel Calculator

Solar Panel Calculator Instructions:	Fill out proposed solar panel rating (Watts), number of panels proposed and estimated hours of sunlight based on panels location and orientation. Efficiency estimate from 50% to 75% is reasonable for typical Savary Island summers

	Quantity	Rating	Estimated Hours of sunlight	Estimated Efficiency	Resulting Total Watts generated per day**	
PV Panels		(Watts)	(hours)	(percentage)	(Watts hours)	** Note: The total power (watts) generated from PV array should meet or exceed the Average Total Power Required above. In most Solar Energy systems, a small generator is used to make up any shortfall required for average daily demand.
	6	400	5	75%	**9000**	

Battery Bank Size Calculator

Battery Bank Size Calculator:	Input voltage and number of proposed batteries (2 Volts or 6 Volts) to achieve **Desired System Voltage** (12, 24 or 48V), and days of Autonomy. Choose Batteries with Cell storage rating that meets or exceeds **Minimum Battery Amp-hour Rating** shown below:

	Battery Voltage	Proposed Number of Batteries	Desired System Voltage	Average Daily Total Power Required	Days of Autonomy	Minimum required Battery Amp-hour Rating
Batteries	(2V, 6V or 12V)		(V)	(Watts)	(days)	(amp-hrs)
	2	12	**24**	**5745**	**2**	**479**