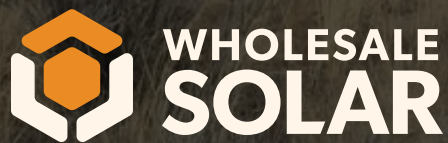


SOLAR BATTERY GUIDE

How to Choose the
Right Batteries For
Your Solar System





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Introduction

Thanks for downloading our Solar Battery Guide! Whether you're sizing a battery bank for your off-grid home or adding storage to a grid-tied system, this guide will teach you how to find the best batteries for your solar project.

What this guide covers:

- ➔ When you need to add batteries to your system (and when it makes more sense to skip them)
- ➔ The main battery types for solar applications: flooded lead-acid (FLA), sealed lead-acid (SLA) and Lithium Iron Phosphate (LFP)
- ➔ How to size your battery bank so that you don't under- or overcharge your batteries (potentially shortening their life cycle)
- ➔ Our picks for the best batteries for a variety of solar applications: off-grid, battery backup, mobile and industrial use

When To Add Batteries To Your Solar System

Batteries store the solar energy generated by your panels for later use.

Not all solar energy systems require batteries. If your property has access to power lines, a **grid-tied system** is your smartest option.

Grid-tied systems store energy in the utility grid, which feeds it back to the property when you need it. Batteries are not required for grid-tied systems.

“Not all solar energy systems require batteries.”

But if connecting to the grid isn't a viable option, you'll need to invest in an **off-grid system**. Since you can't bank energy in the grid, you need another place to store the energy you generate.

That's where batteries come in.

Batteries are the heart of off-grid systems. They store the energy created by your panels so it is available whenever you need to use it.

In addition to grid-tied and off-grid, there's a third system type: **grid-tied with battery backup**.

This system uses the grid as its primary storage method, but leans on a battery bank to supply backup power in emergency situations.

While batteries are not mandatory for grid-tied systems, adding one provides a fail safe during power outages. Battery backup is smart in regions with an unreliable power grid or severe weather.

In certain areas, grid-tied systems also use batteries to store power and use it later or sell it at the most valuable times. This is used in areas where the utility won't buy back your power, or they have have different utility rates such as Time-of-use rates or high demand charges.



The 3 Most Common Battery Types For Solar

We won't cover every battery type here - just the standard types used in the solar industry today.

When selecting a battery for your solar system, you have three common options: flooded lead-acid (FLA), sealed lead-acid (SLA), and lithium-ion batteries.

Lithium is the premium option by a wide margin. FLA and SLA batteries are closer together in performance and price, with FLA being the budget option due to frequent maintenance requirements.

While Lithium is a newer technology, lead-acid batteries have been used for the past 150 years. There are two types of lead-acid batteries: flooded and sealed.

Flooded Lead-Acid (FLA)

Flooded lead-acid (FLA) batteries are designed to handle daily charge cycling. They do emit hydrogen gas as a byproduct, so they must be ventilated properly.

They also require regular maintenance. The plates of every cell in the battery must be submerged in water to function properly (which is why they are called “flooded” batteries).

You’ll need to add water every 1 to 3 months to keep the plates submerged. The exact interval between adding water depends on temperature, discharge depth and other factors, but it’s a good idea to check on them at least once a month.

Another required maintenance step is an equalize charge, which is a controlled overcharge that helps restore FLA batteries. It’s a good idea to periodically equalize charge every 3 months, or as needed. An equalize charge helps prevent sulfation of the battery plates and can also be used to correct an imbalance between cells or batteries.

FLA batteries are ideal for people who prefer to be hands-on with their system. They’re the most affordable option, but require regular upkeep to work properly.

Sealed Lead-Acid (SLA)

If you won’t be around to perform regular check-ups on your battery, sealed lead-acid batteries are a better option. These batteries are spill-proof and non-hazardous. There are two types of sealed lead-acid batteries with fairly similar characteristics: AGM (absorbent glass mat) and gel.

Sealed batteries are a self-contained system. Unlike flooded batteries, they don’t need to be refilled with water.

For that reason, they work well at properties that aren’t occupied full-time, like an off-grid vacation cabin you visit once or twice a year. Sealed batteries won’t self-discharge as fast if they sit idle for extended periods of time while you’re away.

SLA can also be stored in any orientation—you can lay them on their side, for example. That’s not true of FLA batteries, which must remain upright so they don’t spill water.



Image courtesy of West Coast Sustainable

Lithium Iron Phosphate (LFP)

Lithium batteries are a newer technology that hit the market in the 1970s. They are common in laptops and cellphones, but have become more popular in the renewable energy space lately.

There are several different types of Lithium batteries. The chemistry we use for off-grid solar, Lithium Iron Phosphate (LiFePO_4 or LFP), has been formulated to be especially safe and durable for household use.

Lithium batteries are more expensive, but there are several benefits to justify the higher price tag:

- Longer lifespan
- No maintenance
- More efficient power usage
- More usable storage capacity (deeper discharges)
- No off-gassing / ventilation

The key difference: if you buy a Lithium battery, most are warrantied for 10 years, and many last even longer than that. With a lead-acid battery, you could replace the battery bank 2-3 times over that same time frame.

Key Battery Terms & Concepts

Here are some key terms you'll need to understand when picking your batteries:

Capacity: The amount of energy a battery can store and supply to your appliances. This is a function of voltage, amp hours and rate of discharge (which will all be explained in this section).

Battery bank: A group of batteries, wired together to work with an inverter or charge controller at a certain voltage (for example 12, 24 or 48 volts) and capacity (e.g. 400 amp hours.)

Voltage: Batteries are rated by voltage. Lead acid batteries are typically either 12 volts, 6 volts or 2 volts, and multiple batteries are wired together in series to achieve the right voltage. Generally speaking, smaller systems can use 12 volt batteries, while larger systems will use 6 volt or 2 volt batteries with higher amp hour capacity.

Most Lithium batteries for off-grid solar come in either 12 volt, 24 volt or 48 volt configurations.

Amp hours: Batteries are rated in amp hours (Ah), which is a measurement of how much current they output over time. This is used to compare the capacity of lead-acid batteries, which have more or less capacity depending on how fast you discharge. (Lithium batteries aren't affected the same way. They generally only have one amp hour rating.)

Hour Rate	Capacity / AMP Hour	Current / AMPs
@ 100 Hour Rate	569 AH	5.69 A
@ 75 Hour Rate	539 AH	7.49 A
@ 50 Hour Rate	509 AH	10.19 A
@ 20 Hour Rate	428 AH	21.4 A
@ 15 Hour Rate	402 AH	26.82 A
@ 10 Hour Rate	364 AH	36.38 A
@ 8 Hour Rate	342 AH	42.8 A
@ 5 Hour Rate	300 AH	59.92 A
@ 1 Hour Rate	154 AH	154.08

Amphère hour capacity ratings based on specific gravity of 1.280.
Reduce capacities 5% for specific gravity of 1.265 and 10% for 1.250.

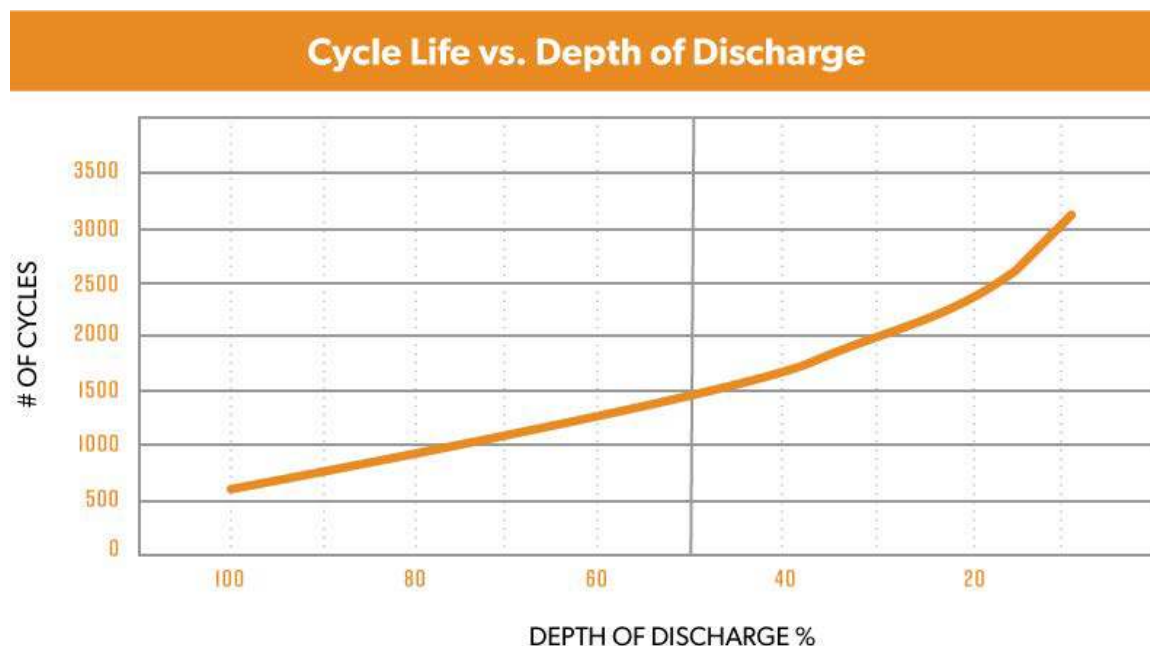
For example, this chart from the Rolls S-550 battery manual shows that a battery that discharges for 20 hours (a day's worth of usage) has a capacity of 428 Ah.

Watt hours or kilowatt hours (kWh): Kilowatt hours measures power used over time. Your utility company charges you based on how many kWh of electricity you use each month.

This can be used to quantify total storage capacity for a given bank, based on voltage and amp hours, using the formula: **Voltage x Ah = capacity (in Watt-hours)**.

For example, **12V x 100 Ah = 1,200 Wh**. A 12-volt battery that runs for 100 amp-hours produces 1,200 watt-hours (1.2 kilowatt-hours) of energy.

Cycle: Every time a battery is discharged and then recharged, that's one cycle. The best way to estimate the true life of a battery isn't based on time (for example, a 3-year warranty), but by estimated **cycle life**—the number of times a battery can charge and discharge over the course of its lifespan.



Most lead-acid batteries have a chart in the spec sheet that shows how many cycles they can handle. Here is an example from the Rolls S-550 manual.



Depth of Discharge (DOD): The amount of energy pulled out of a battery during each charge/discharge cycle.

For example, running a battery at 75% depth of discharge means you will use 75% of its capacity before recharging.

Depth of discharge plays a crucial part in determining the life of your batteries. Lead-acid batteries will last longer with a shallow discharge depth, and wear out more quickly the deeper they are discharged.

Efficiency: Batteries are not 100% efficient. Some power is lost in the charge and discharge process.

Lead-acid batteries are 80-85% efficient, while Lithium batteries are about 95-98% efficient.

For example, if your solar panels produce 1,000 watt hours of power, lead-acid batteries would be able to store about 800 watt hours due to inefficiencies in the charge and discharge process. With a Lithium battery, you'd have 950 watt hours available in the same circumstances.

Sizing Battery Banks

The hardest part about shopping for batteries is understanding how to size the battery bank properly for your system.

The size of a battery bank is based on how much power you'll use on a daily basis, measured in kilowatt hours per day. If you're not sure how much power you'll be using, our [off-grid sizing calculator](#) will help get you on the right track:

If you're using 10kWh per day, you need a battery bank capable of storing that much power after accounting for battery efficiency, discharge depth and a few other things.

If you don't have enough battery capacity, you'll run out of power and end up using a lot of generator fuel. On the other hand, buying too much battery capacity can be a waste of money and you might need to add more solar or a bigger generator to be able to fully recharge your oversized battery bank.

A Note on Expanding Your Battery Bank

Another reason it's crucial to dial in on your battery capacity is because it can be difficult to expand a battery bank. With lead-acid batteries, adding new batteries to an old bank causes the new batteries to take on the capacity and other characteristics of the existing bank, meaning you are effectively aging your new lead-acid batteries when installing them with old ones.

If you are expanding within the first year, this might not be an issue, but you really can't expand an old lead-acid battery bank.

Most lithium batteries can be expanded because each battery will have a battery management system (BMS) which controls charge and helps regulate the different batteries in a bank. For a truly expandable battery bank, we recommend a Lithium battery like the Discover AES line.

How to Calculate Battery Capacity

Once you know how much power you'll be using, use this method for calculating battery capacity:

1. Start with your daily usage (for example, 10kWh per day)
2. Add in the battery inefficiency factor (80% for lead-acid or 95% for Lithium)
Lead-acid: $10\text{kWh} \times 1.2$ inefficiency
Lithium: $10\text{kWh} \times 1.05$ inefficiency
3. Account for the discharge depth (typically 50% for lead-acid and 80% for Lithium)
Lead-acid: $10\text{kWh} \times 1.2 \times 2$ for 50% DOD
Lithium: $10\text{kWh} \times 1.05 \times 1.25$ for 80% DOD
4. Add in another inefficiency factor for the inverter and charge controller (5-10% will work for most equipment)
Lead-acid: $10\text{kWh} \times 1.2 \times 2 \times 1.05$ inefficiency
Lithium: $10\text{kWh} \times 1.05 \times 1.25 \times 1.05$ inefficiency
5. Account for the impact of temperature, which can reduce battery capacity.
Lead-acid: $10\text{kWh} \times 1.2 \times 2 \times 1.05 \times 1.11$ temperature multiplier, based on 60° F ambient temp. See spec sheet for other temperature multipliers.
Lithium: $10\text{kWh} \times 1.05 \times 1.25 \times 1.05 \times 1.05$ temperature multiplier, based on 60° F ambient temp. See spec sheet for other temperature multipliers.

This gives us an idea of how much battery capacity (in kilowatt hours) is required based on our usage, the equipment, battery DOD and temperature. Let's look at both examples:

Lead-acid: $10\text{kWh} \times 1.2 \times 2 \times 1.05 \times 1.11 = 28 \text{ kWh}$ lead-acid capacity

Lithium: $10\text{kWh} \times 1.05 \times 1.25 \times 1.05 \times 1.05 = 14.47 \text{ kWh}$ Lithium capacity

These numbers are the **minimum** capacity of your battery bank, because the formula is based on supplying one day's worth of power. Your solar array (and backup generator) will need to be designed to recharge the batteries every day.

The Lithium battery bank has less overall capacity because it can handle deeper discharges and has a higher efficiency.



Most batteries are rated in amp hours. To find a suitable battery bank, divide the overall capacity (from the previous step) by the voltage:

Lead-acid: 28kWh to Ah conversion:

$28\text{kWh} / 48 \text{ volts} = 583 \text{ amp hours}$

$28\text{kWh} / 24 \text{ volts} = 1,166 \text{ amp hours}$

$28\text{kWh} / 12 \text{ volts} = 2,333 \text{ amp hours}$

Lithium 14.47kWh to Ah conversion:

$14.47\text{kWh} / 48 \text{ volts} = 301.46 \text{ amp hours}$

$14.47\text{kWh} / 24 \text{ volts} = 602.92 \text{ amp hours}$

$14.47\text{kWh} / 12 \text{ volts} = 1,205.83 \text{ amp hours}$

Generally speaking, a higher voltage (24 or 48 volts) is used for bigger systems where you have more battery capacity and larger inverters. This is because the higher voltage is more efficient, uses smaller wire, and allows you to install more solar power on each charge controller. Most bigger inverters are going to be either rated for 24 or 48 volts.

System voltage is based on a few factors, but battery capacity (in kilowatt hours) is the best place to start designing an off-grid system. Start by understanding how much battery capacity you need on a daily basis, then size the other parts of the system (like your panels and inverter) to meet that demand.

Battery Recommendations & Pricing

Different batteries shine in different environments. Here are our battery picks for a broad range of solar applications.

Best Battery For Off-Grid Homes (Premium Option)

If you live in an off-grid home full time, you need a battery that can keep up with your power demands on a daily basis.

Our recommendation for the best overall battery for off-grid homes is the [Discover AES Lithium battery](#). It has long lifespan, high efficiency, fast recharges and affords flexibility if you want to expand your system down the road.

We favor Discover's line of Lithium batteries for larger applications. They have the best price-per-capacity for larger scale systems (SimpliPhi can be a bit more cost-effective in smaller battery banks). They also offer relatively large, high-capacity batteries, which speeds up the installation process because there are fewer batteries in the bank.

The battery management system (BMS) monitors and protects the battery, keeping track of the state of charge, charging parameters, faults and data logging. Discover's BMS and battery design allows it to charge and discharge much faster than most competing options.

Read More: [Discover vs. SimpliPhi Lithium Battery Comparison »](#)



DISCOVER AES 6.6KW

- **Price (as of 10/18/18):** \$6,900
- **Capacity:** 6.6 kWh
- **Voltage:** 48V
- **Amp hours:** 130 Ah
- **Warranty:** 10 years

Best Battery For Off-Grid Homes (Value Option)

Looking for a more cost-effective option? The best value battery for off-grid systems is the [Crown CR430](#) flooded lead-acid battery.

People who live the off-grid lifestyle tend to be more comfortable with hands-on DIY projects. If you don't mind doing the occasional maintenance on your battery bank, the CR430 is an excellent option. The 430 amp-hour capacity can't be beat for the price, and Crown is a reliable American manufacturer. CR430s are built in Fremont, Ohio at Crown's advanced manufacturing plant.

Flooded lead-acid batteries are tried-and-true technology, which means a lot of folks have experience and successful history with them. CR430 batteries have the lowest upfront cost compared to any other option, while still offering solid performance. This is the best battery option if you are looking for the lowest upfront cost and don't mind spending a little time on maintenance.



CROWN CR430

- **Price (as of 10/18/18):**
\$325
- **Cycles (at 50% DOD):**
1200
- **Voltage:** 6V
- **Amp hours:** 430 Ah
- **Warranty:** 3 years

Best Battery For Off-Grid Vacation Homes

What if you have an off-grid vacation home that you don't visit on a regular basis? You want a battery that doesn't require regular maintenance, since you'll only be on site a few times a year.

In these cases, a sealed AGM battery is the best option. Our recommendation is the [Crown 6CRV390](#). The lower capacity is fine because you don't need year-round storage. We also skipped out on the premium lithium option, because it's overkill for a system that will only be used a few times a year.

These batteries are relatively inexpensive, so you don't have to make a huge investment into a property where you won't be spending that much time.

We'd also recommend the [415Ah FullRiver DC400-6](#) for this application. We like the Fullriver DC 400-6 because it has slightly more capacity and a longer warranty at a slightly higher cost.

It's definitely an option we recommend on a regular basis, along with the Crown 6CRV390. Opt for the Fullriver if you want the peace of mind of a longer warranty, or when you need a little more capacity.

Sealed lead-acid batteries are ideal for off-grid vacation homes because they are maintenance-free and relatively inexpensive. They also have a fairly high tolerance for cold temperatures when they are charged.



CROWN 6CRV390

- **Price (as of 10/18/18):**
\$475
- **Cycles (at 50% DOD):**
1000
- **Voltage:** 6V
- **Amp hours:** 390 Ah
- **Warranty:** 3 years



Best Batteries For Grid-Tied Systems With Battery Backup

If you have a grid-tied system with battery backup for emergencies, you won't need a battery with a tremendous amount of storage power. It will only see use when your power goes out, and hopefully that doesn't happen more than once a year.

Similar to the previous section, you want a battery that doesn't require maintenance – it should simply work in the rare cases you need it. For that reason, we recommend the same battery as above: the [Crown 6CRV390](#) in a sealed AGM format.

Similarly, you can also opt in to the [415Ah FullRiver DC400-6](#) for a bit of extra capacity if it suits you better.



CROWN 6CRV390

- **Price (as of 10/18/18):**
\$475
- **Cycles (at 50% DOD):**
1000
- **Voltage:** 6V
- **Amp hours:** 390 Ah
- **Warranty:** 3 years

Best Battery For Storing and Selling Energy

In certain areas, the utility company charges more during peak use times – around 4 to 9 pm, when people get home from school and work.

Energy storage allows you to store energy and sell it back to the utility company for a profit.

The goal is to store energy generated during the day, and sell it back in the evening, when rates hit their peak.

For this type of use, we recommend the [SolarEdge StorEdge](#) inverter with the [LG Chem RESU10H](#) battery. It is designed to store energy and sell it back during peak use periods, and can also provide a limited amount of backup power during an emergency outage.

This helps protect you from future changes in your utility rates, and is a must if you live in an area with time of use rates (TOU), high demand charges, or no net metering.

SolarEdge is a leading manufacturer of grid-tied inverters, and they've put their expertise in making the StorEdge system one of the most versatile and cost-effective options for grid-tied energy storage.



LG CHEM RESU10H

- **Price:** Check with LG
- **Capacity:** 9.8kWh
- **Voltage:** 400V
- **Amp hours:** 63 Ah
- **Warranty:** 10 years

Best Battery For Small Off-Grid Use (RVs, Boats & Remote Industrial Applications)

This guide has mostly covered residential use cases. But what if you need to power a smaller application, like an RV, boat or small outbuilding on your property?

Let's say you have a wood shed on your property and want to power it independently. The shed has some lights but there's not much else to power. In a situation like this, you just need a compact battery with modest capacity.

For a light use cases like these, we recommend the [Crown 6CRV220](#) sealed AGM battery. This battery was originally designed to power golf carts. As a result, it has a small profile, but can still withstand deep cycling over a long lifespan.

We'd recommend this battery for tiny homes, boats, and RVs – any application where space is at a premium and you just need to power the essentials. You can also go with the [Crown 12CRV110](#), which is the exact same size and overall capacity in a 12 volt format.

This is also our pick for remote industrial applications. It can power small-scale industrial equipment in remote areas not accessible by power lines. Common applications include lighting, pumps, traffic signs and monitoring equipment.



CROWN 6CRV220

- **Price (as of 10/18/18):** \$260
- **Cycles (at 50% DOD):** 1000
- **Voltage:** 6V
- **Amp hours:** 220 Ah
- **Warranty:** 3 years

CONTINUE YOUR RESEARCH

More Resources

Getting Started with Solar

We all start out in the dark. Download our Getting Started Guide to learn the basics of solar.

[Get the Guide »](#)

Solar Permitting Guide

Permitting is the most time-consuming part of the process. Get a head start with our Solar Permitting Guide.

[Get the Guide »](#)

Solar Cost Calculator

Estimate how much it would cost to go solar based on your location, personal energy usage patterns, and other factors.

[Get an Estimate »](#)



Talk to a solar expert.

Ready to get to work? Connect with our design team for a free consultation.

[Request a Consultation »](#)