



HOMEOWNER'S GUIDE TO SOLAR ENERGY STORAGE

HOW TO GET THE MOST FROM YOUR SOLAR
INSTALLATION USING ENERGY STORAGE

ABSTRACT

This guide will help you understand what solar energy storage is, how it can benefit you and what is involved to make it work. Ultimately, it should empower you to secure the best system for your home with confidence.

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Are you among the thousands of homeowners who have "seen the light" and gone all in tapping the sun's energy to power up your home? If not and you're reading this guide, it's likely you're gathering information and weighing your options before pulling the trigger on solar for your home. And business owners, you're in the right place – although this guide primarily addresses homeowners, the information contained herein applies equally well when considering solar for your commercial business.

This document logically follows the [BUYER'S GUIDE TO SOLAR ENERGY FREEDOM – 9 Steps to Securing the Solar Installation of Your Dreams](#). It offers plenty of useful insights into solar energy storage (also referred to as solar batteries) to assist you in fully capitalizing on the value of your existing or planned solar energy installation.

Defining Solar Energy Storage

During the day, most households cannot consume all the electrical energy their solar panels generate. Unless that surplus energy can be sent to the utility grid, it's wasted. By coupling a solar battery with solar generation, this surplus energy can be stored for use during peak periods and at night when solar generation falls to zero.



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Benefits of Solar Batteries

Solar batteries are the ideal solution to the challenge of matching energy generation with energy demand. Today, a range of solar battery solutions are more affordable and accessible than ever, driving the widespread adoption of solar + storage in both residential and commercial applications.

Adding a solar battery system to your solar installation enables you to:

- Harvest the energy your panels generate during daylight hours and store the excess energy for use in the early mornings, evenings and nighttime
- Access backup power during scheduled or unplanned outages to operate lights, HVAC systems, appliances, home medical apparatus and entertainment
- Replace expensive utility power during peak early morning and evening demand periods with low-cost solar electricity to save you money on your monthly electrical bill
- Supply the grid and get paid for your surplus energy if your utility offers net metering.

From the big picture perspective, widespread home solar battery adoption reduces the demand pressure on the electrical grid and may delay or eliminate the need for expensive utility infrastructure upgrades.

In a nutshell, solar batteries offer you the opportunity to achieve energy independence. By installing sufficient energy storage to match a properly sized solar panel array, you'll rarely, if ever, need to rely on utility-sourced electricity again.

For off-grid home applications where no electric utility is available to provide backup power, battery storage becomes mandatory. The capacity of the solar battery must accommodate the worst-case scenario when solar generation may be unavailable for several days.

When Solar Energy Storage Makes Sense

Solar batteries are not for everyone. If your solar installation is not large enough to generate surplus power during peak daylight hours, there's no need to install storage. Further, you may face budget and space constraints that don't accommodate energy storage.

Presently, solar battery costs range from about \$400 - \$750 per kilowatt-hour (kWh) of storage capacity. Adding installation costs can push the price to \$800 - \$1,300/kWh. Doing the math, a typical 10 kWh solar battery installation can run upward of \$8,000 to \$13,000. Fortunately, solar batteries are coming down in price as the technology improves.

Justifying a solar battery installation becomes easier if you face any one or more of the following situations:

- Your utility charges you time-of-use (TOU) rates. Peak TOU rates for power can be double that of off-peak rates – batteries allow you to use stored solar energy during peak times to avoid paying the premium.
- The utility imposes demand penalties based on your total electricity use. Batteries allow you to use inexpensive solar energy to reduce your reliance on utility electricity and avoid such charges.
- Your utility does not support net metering and will not pay for the surplus solar electricity you could supply to the grid. Or your utility agrees to pay you wholesale rates for your surplus electricity, yet they charge you more costly retail rates for the power they supply to your home. In these instances, consuming your battery-stored solar electricity ensures you maximize the benefit of your solar array and reduce your monthly electricity bill.

Understanding Battery Terminology

When researching solar battery options to supplement your solar panel system, you'll run across terminology addressing characteristics that define their capabilities.

Capacity – A battery's capacity refers to the amount of electrical energy it can store, measured in kilowatt-hours (kWh). An average household will use about 30 kWh of electrical energy daily. A typical solar battery for home use may have a capacity of 10 kWh, sufficient to supply the home for $(10 \text{ kWh}) / (30 \text{ kWh}) \times 24 \text{ hours} = \text{eight hours of operation}$, assuming average hourly consumption. Additional solar batteries can be connected in parallel to an existing solar battery to increase storage capacity. For a given energy storage requirement, using higher capacity batteries means fewer batteries need to be installed, reducing the space required.

Power – A battery's power rating, measured in kilowatts (kW), is the amount of energy it can safely discharge at once.

Depth of discharge – Batteries can reliably discharge a portion of their stored energy without diminishing their expected life span.

Draining 100% of a battery's charge can shorten the life of the battery significantly. A battery's depth of discharge (DoD) is expressed as a percentage of its energy storage capacity. A battery with an 80% DoD rating can safely discharge twice as much energy as a battery of the same capacity with a DoD of 40%, allowing a homeowner to install half as many batteries to get the same energy output.

Round-trip efficiency – The round-trip efficiency of a battery is the ratio of the energy that can be recovered from the battery and the energy needed to charge the battery fully, expressed as a percentage. For example, a 10-kWh battery will accept 10 kWh of energy to charge fully. If the battery can only supply eight kWh of energy due to heat losses in the battery during discharge, the round-trip efficiency of the battery is $8/10 = 80\%$. Like capacity, higher efficiency batteries make more energy available for use and reduce the number of batteries needed for the desired energy output.

Cycles – A cycle refers to the process of charging and discharging a battery. A battery's warranty is commonly expressed as the number of charge/discharge cycles the battery can deliver before performance tapers off beyond a threshold value. Alternatively, a battery warranty may state the number of years it will perform to a specified standard (based on an estimated number of cycles per year).

Self-discharge rate – Batteries self-discharge over time. Newer batteries may lose 1-2% of their total charge per month, and older technology batteries may self-discharge 2% per week.

An important factor affecting the life span of a solar battery is the ambient temperature in which it operates. Subjecting a battery to freezing conditions or very warm to hot temperatures will shorten the battery's life. Some solar batteries come with built-in temperature control to avoid freezing or overheating.

Common Types of Residential Solar Batteries

Battery technology has made significant gains in performance, while the costs per stored kilowatt-hour of energy continue to fall. Currently, two battery types dominate the commercial market for residential solar energy storage.

Sealed lead-acid (SLA) batteries have been around for decades – these are the types of batteries used in vehicles and boats.

Advantages of SLA:

- Mature, well-proven technology
- Relatively inexpensive
- Well-established recycling regimen for end-of-life batteries.

Drawbacks of SLA:

- Bulky and heavy
- Modest energy storage density
- Relatively low depth of discharge capability (about 50%)
- Average round trip efficiency

- Moderate self-discharge rate
- Requires venting of gases during operation, restricting installed layout options
- Relatively short life span of 500-1600 charge/discharge cycles.

Lithium-ion (Li-ion) batteries have become the gold standard and most popular choice for residential and commercial energy storage. Lithium is a lightweight metal that conducts electricity efficiently. These batteries use a reversible electrochemical process to store and release electrical energy repeatedly – the same battery technology used to power cellphones, cordless tools and electric vehicles. Popular solar battery brands include the Tesla PowerWall, Sonnen, LG and Panasonic.

Advantages of Li-ion:

- High energy storage capacity (roughly twice that of SLA) makes them considerably smaller and lighter than SLA
- High depth of discharge capacity of 80+%
- High round-trip efficiency
- Long life of around 8,000-10,000 charge/discharge cycles (roughly 15-20 years in a typical residential application) when the depth of discharge doesn't exceed 80%
- Charges roughly four times faster than SLA
- Superior high-temperature performance, demonstrating about twice the cycle life at 55 degrees C (131 degrees F) than SLA operating at room temperature
- Low self-discharge rate (approximately 20% that of SLA)
- No off-gassing during operation, allowing a high degree of installation layout flexibility.



Drawbacks of Li-ion:

- Higher upfront cost compared to SLA
- Not readily recyclable.

Other batteries that show promise include:

- **Sodium nickel chloride batteries** use molten salts as the energy-storing electrolyte and exhibit high energy and power density with decent capacity. They contain no toxic substances. However, they are classed as a thermal battery and require an operating temperature of 250-350 degrees Celsius. Current models don't exhibit the same long life as Li-ion batteries and are more expensive.

- **Saltwater batteries** require no metals to operate and are more eco-friendly both in construction and final disposal. Using only a concentrated saline solution as an electrolyte, they are neither flammable nor explosive. They also exhibit an ability to recover from deep discharges. Where they fall short is in energy storage (saltwater batteries have roughly half the energy storage capacity of Li-ion batteries and about the same as lead-acid batteries) and offer slower charge and discharge rates.
- **Zinc bromine "flow" batteries** exhibit excellent cycling capabilities and suffer no appreciable degradation after many thousands of cycles. They can be fully discharged without damage, and they also employ readily recyclable materials. Presently, their higher cost makes them more suitable for utility-scale energy storage than for residential applications.

The Makeup of a Typical Home Solar Energy Storage System

A typical solar battery system comprises five main elements:

1. **Battery storage** – Lithium-ion batteries are currently the popular choice for residential and commercial applications, given the benefits they offer as outlined in the previous section.
2. **Charge controller** – Also referred to as a solar regulator, this device continually adjusts the variable voltage and current sourced from the solar panel array to optimally charge the battery while preventing damage from overcharging.

Basic charge controllers for small or micropower solar installations use pulse-width modulation (PWM) to control the amount of energy flowing to the battery by switching on and off rapidly. PWM controllers are usually applied in small 12-volt and 24-volt photovoltaic arrays because their input voltage must match the battery bank voltage. They offer a conversion efficiency (power out versus power in) of around 75%. PWM controllers are small, well-proven and cost-effective for such applications.

For larger grid-tied and off-grid solar installations where the solar battery may energize the whole home, maximum power point tracking (MPPT) controllers are the better choice.

They safely maximize the energy delivered to the solar battery and shorten charging times. MPPT controllers can work with 12-volt and 24-volt systems like a PWM controller, but they can also handle 36-volt and 48-volt up to 200-volt PV arrays with current ratings from 30 to 100 amps. MPPT controllers are larger and more costly than PWM controllers, but they scale nicely for larger PV applications and exhibit conversion efficiencies up to 99%.



MPPT SOLAR CHARGE CONTROLLER, COURTESY MORNINGSTAR

3. **Inverters** – These devices convert direct current (DC) electricity supplied by the batteries to alternating current (AC) electricity used by the home. Their power rating may limit how much power a battery installation can deliver at any moment, so correctly sizing them is critical.



SOLAR INVERTER, COURTESY SUNGROW

Some batteries include an integrated inverter and require AC-coupling to a home's solar panel array and the network grid. With this equipment, AC power supplied from solar panel inverters or the electrical grid is connected directly to the battery system. The integrated battery inverter converts the AC input to the battery to DC output to charge the batteries. Because they can be AC-connected directly, integrated inverter batteries are ideal for retrofitting homes with existing solar panels.

Other solar batteries require an external third-party inverter. Separate inverters will take up more wall space – a potential concern if space limitations restrict the use of such equipment.

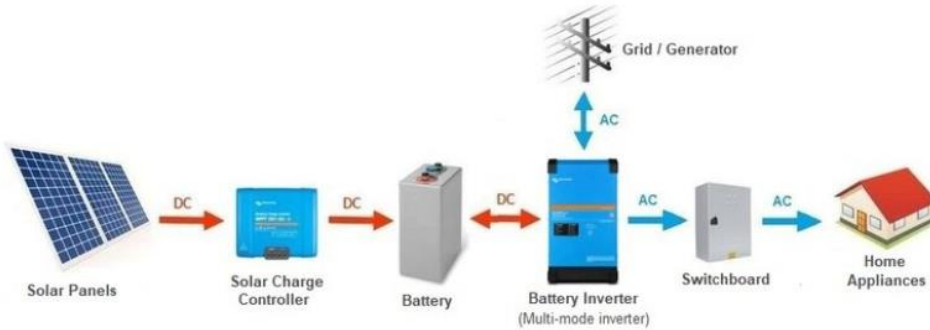
4. **Wiring and backup power configuration** – The battery installation can be sized and wired to supply your entire home's electrical needs or energize essential circuits only. Some whole-house battery backup configurations require you to manually shed nonessential electrical loads to avoid draining the batteries, posing a problem if no one is around to perform the switching.
5. **Smart energy management software and communications technology** – Such software usually comes with the solar battery package and is used to automate and monitor battery cycling. The common practice is to program the software to ensure batteries are charged using inexpensive solar energy from the PV array or non-peak utility energy and then discharged during peak hours to lower your monthly electrical bill. Solar battery systems can employ communication tools to ensure batteries are at full charge in advance of a scheduled power outage or imminent storm that may cause unscheduled outages. Further, programming the energy management software to automatically shed non-critical electrical loads and supply only essential circuits when a power outage is detected avoids draining the battery unnecessarily.

Solar Battery Configurations

Solar battery systems can be grouped into four major categories:

1. **DC coupled systems** are commonly associated with off-grid solar energy installations (where no utility power is available) and small automotive and marine applications. They employ solar charge controllers, also known as solar regulators, to safely charge batteries directly from solar panels. A battery inverter is also required to convert direct current from the battery to alternating current for use in the home. Some solar battery systems come complete with a charge controller built into the battery inverter to provide a neat, self-contained package.

DC coupled systems exhibit higher efficiency than AC coupled batteries as fewer conversions are required. However, retrofitting an existing grid-tied solar installation with DC coupled batteries requires the grid-tied inverter to be compatible with the battery inverter.



Basic layout diagram of a DC coupled (off-grid) solar battery system using an MPPT solar charge controller

2. **AC coupled systems** employ solar inverters and battery inverters to manage the power coming from solar arrays (or the grid or local generator) to keep the battery charged. These systems are now the most popular choice for modern grid-tied home systems and commercial applications.

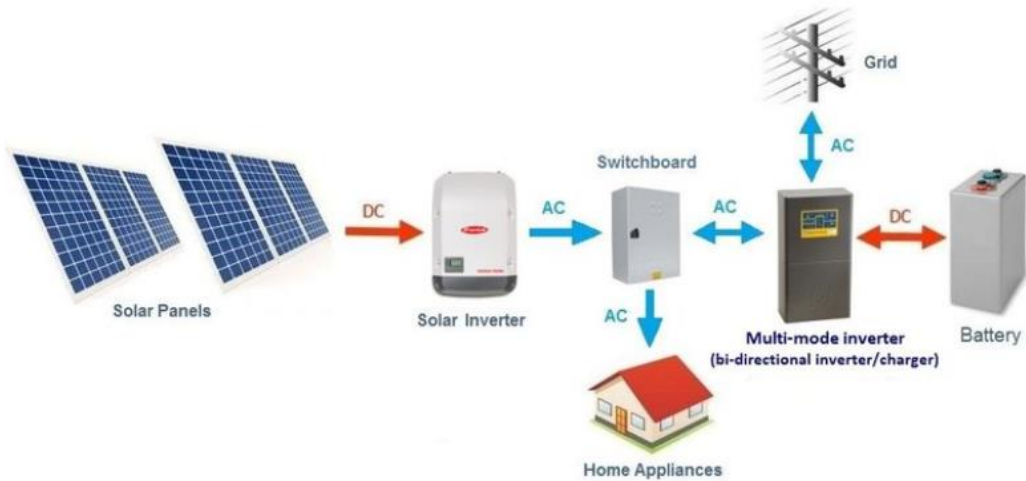
DC electricity generated by solar panels flows to a standard grid-tied inverter that converts DC to AC to power your home, charge AC coupled batteries or supply the electrical grid. AC coupled battery packages include electronics that convert AC from the solar inverter's output to DC to enable and monitor the battery charging process. This multi-mode converter also supplies AC power from the DC battery source to your home.

A significant benefit of using AC coupled batteries – they can be added to any grid-tied solar installation without the need to modify the existing setup and change the grid-tied solar panel inverter. However, each conversion of DC to AC and AC to DC degrades system efficiency.



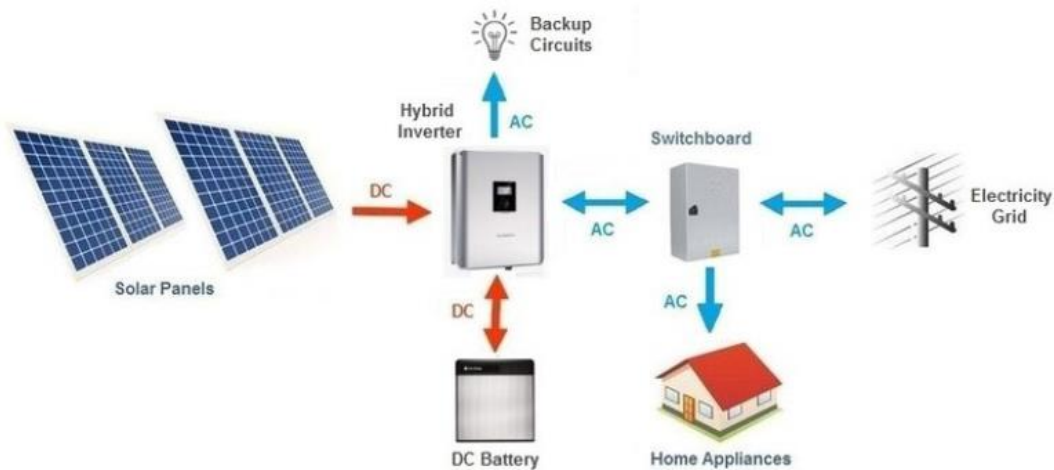
Basic layout diagram of an AC coupled solar battery system - Grid-tie (hybrid) setup

3. **AC battery systems** contain an integrated module consisting of lithium battery cells, inverter/charger unit and battery management system. The Tesla Powerwall 2 is an example of an AC battery. These systems are ideal for retrofitting energy storage to existing solar installations.



Basic layout diagram of an AC coupled solar battery system - Grid-tie (hybrid) setup

4. **Hybrid converter systems** are grid-connected and DC coupled solar battery arrangements. The term hybrid refers to modern inverters that combine higher voltage solar MPPT controllers and battery inverter/chargers in one package. Higher voltage batteries operate in the range of 120 VDC to 500 VDC whereas traditional battery systems operate at 48 VDC.



Basic layout diagram of a hybrid solar inverter with DC battery system

Combining both AC and DC coupling allows an AC coupled configuration that has no backup generator to instead rely on backup DC battery charging directly from solar panels through a solar controller.



Combination AC and DC Coupled system - Can be configured as Grid-interactive or Off-grid with generator

Sizing a Battery Backup System

The first step to properly sizing and pricing the most practical battery backup system for your home's solar panel array is identifying critical loads, such as in-home medical equipment, communications, lighting, refrigeration and perhaps heating and cooling. Also, list the "nice to have" loads like your entertainment center, stove, and washer and dryer – those conveniences that you'd enjoy having but can live without for a day or two. Then determine what size battery system will see you and your family through an extended outage of several hours or a day or two (as your experience with your utility dictates) with the loads you impose on it. Qualified solar battery contractors can assist you through this entire process.

A battery system's energy capacity, measured in kilowatt-hours (kWh), and the inverter power output, measured in kilowatts (kW), need to match your household electrical demands at night when the battery is partially discharged from supplying power throughout the evening. The inverter's power-handling capacity will determine the number of loads you can feasibly supply from your battery. An inverter may not be capable of providing the momentary motor startup current required by air conditioners and other large appliances (often several times the steady-state current draw). The result? These appliances will never start. Correcting this deficiency means installing additional inverters if you have the budget and space.

The math behind sizing the battery system is straightforward. If a battery is discharged over the evening down to three kWh of remaining energy, then it's capable of operating a 10-kW electric stove for $(3 \text{ kWh}) / (10 \text{ kW}) \times 60 \text{ minutes/hour} = 18 \text{ minutes}$. A large air conditioning

unit drawing five kW of power will discharge the battery in 36 minutes. In these examples, the battery cannot supply such large loads for a useful duration. Your options are to add more battery capacity if budget and space constraints allow or eliminate these power-hungry loads from the battery. Keep in mind that your solar energy system should be of sufficient size to recharge the battery at least partially, even on a cloudy winter day.

Combining available financial incentives with the downward-trending costs for batteries, inverters and smart control technologies allow more homes to power up with battery storage to augment their solar energy systems.

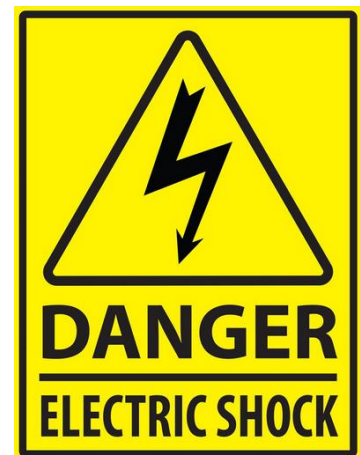
Solar Battery Installation Considerations

Homeowners considering energy storage are subject to regulations that impact the installation and use of backup power and storage, as noted below.

- Local building requirements: It's important to discuss your plans for energy storage with qualified electricians and energy storage installers who are familiar with the local building codes and can guarantee your installation will satisfy code requirements.
- Utility interconnection requirements: Connecting a battery storage system to your utility's power grid requires abiding by federal and state regulations for safety and reliability. Qualified energy storage installation contractors will complete the interconnection application your local electrical utility requires before installation can commence.
- National Electrical Code (NEC) requirements: Solar energy storage systems must conform to NEC specifications regulating their installation, operation and maintenance. Again, qualified installation contractors will ensure your system meets all regulations and codes.

Energy storage systems employ a "make before break" high-speed automatic transfer switch that seamlessly and automatically switches your home's electrical supply to your solar battery when an outage occurs. The transfer switch electronically detects utility power and connects the battery before the utility power connection is broken. This critical piece of equipment must be certified by Underwriters Laboratories (UL Standard 1008).

Homes with solar + battery storage may be capable of "islanding" from the power grid during an outage; meaning, the solar panels are allowed to recharge the battery during an outage without affecting the utility grid. From a utility standpoint, islanding can pose a safety hazard for utility workers. They face the possibility of electrocution while working to restore power after an outage if a home's solar installation can inadvertently feed power to the grid. Homeowners looking to install solar batteries need to check with their equipment supplier and installer to determine if their energy storage system can accommodate islanding and review their utility interconnection agreement to ensure that islanding is allowed. If a utility does not allow for islanding, solar panels and solar battery systems must shut down during a power outage, leaving these homes without power.



Purchasing a Solar Battery System

Deciding to proceed with a solar energy storage solution to complement your solar energy installation generally makes a great deal of sense in most applications. Approaching the idea in a logical sequence can ensure the decision you make will serve you well for years to come.

STEP 1 – Check with your insurance provider to confirm that they will insure a home solar battery installation. You'll want to know upfront the expected premium for this insurance and any restrictions they may place on coverage. What they tell you may be important information to share with your installer.

STEP 2 – Seek to acquire at least three bids from qualified energy storage providers. Often, solar energy system installers also offer energy storage. So, if you already have a solar energy system installed and the contractor did good work for you, it makes sense to contact them to bid on your solar battery project. Ensure that whichever company you choose, their contractor licenses are valid and current. Ask for local references from installers and contact these references. Do some online research on the outfits you prefer, contact the Better Business Bureau about them, and consider calling the local building permit department to get additional insights. This effort could save you the headaches of dealing with less-than-ethical contractors.

STEP 3 – Review your quotes carefully and ask questions. Well-structured quotes and responses from the contractors will identify:

- The price for the installed system
- A full list of supplied equipment meeting Underwriters Laboratories (UL) and National Electrical Manufacturers Association (NEMA) safety standards, including details on battery capacity, power rating, inverter capacity to deliver maximum power and the expected loss of battery performance over time
- Details advising the home circuits and loads that the solar battery will energize and for how long and if islanding is allowed



- Whether upsizing the battery system can be accommodated if required
- The projected savings on your electrical utility bill
- The estimated time to achieve a return on investment
- Control system features, including whether the controls will automatically switch to battery power when an outage occurs, how the system manages battery charging during outages and monitors system temperature and charge/discharge rates, if smart management software allows remote shut-off and if you can monitor system performance
- What maintenance services they include, such as 24/7 remote monitoring and performance tweaks, automatic notification should equipment fail or the system does not perform to specifications, automatic dispatching of a technician to repair problems and who is responsible for what and when
- The expected life span of the battery installation – it should be 10-15 years before battery and component replacement is necessary
- Financing terms that apply to an outright purchase of the system, securing a loan to purchase, or leasing details if that option is available (including who owns the system at the end of the lease)
- Warranty details on the complete system and each component – financial terms and incentives available to support the purchase of a solar battery installation may depend on the warranty being sufficiently long
- All financial incentives, including tax deductions, rebates, and grants that may apply to your energy storage project
 - Incentives available to promote solar installations from local, regional, and federal sources will often cover solar batteries as well – in the U.S., the current Federal Investment Tax Credit (ITC) of 26% applies to battery storage systems charged by and paired with solar or other renewable energy sources
 - Local power utilities may offer a rebate or grant to support your energy storage project
 - Incentives can vary according to your income status, your need to keep medical or other essential equipment and appliances powered up, your geographical location, and the likelihood of planned outages in the event of wildfires or other calamities
 - The [Database of State Incentives for Renewables & Efficiency](#) (DSIRE) provides American residential and commercial/industrial customers an updated federal and state-by-state listing of available programs and incentives and how to apply for them.

STEP 4 – Be prepared to modify your energy consumption habits to get the most value from your solar battery installation. You may discover that the return on investment of your energy storage solution from lowering your monthly utility bill is longer than the warranty period of your system. However, the peace of mind you can experience by installing a solar battery to offer clean, reliable, noiseless and nearly instantaneous backup power during an extended power outage can easily outweigh other concerns.



Amplifying the Voice of Clean Energy

If this guide has done its job correctly, you'll now have practical working knowledge of why energy storage makes sense for many residential solar installations. You'll appreciate all of what such a system entails. And you'll understand how to approach contractors and ask the right questions so you can be confident that your solar battery system will serve you well over the years.

When all is said and done, you should be proud of your efforts to enhance your family's safety and comfort while doing your part to respect your environment. The right solar battery installation will help you do just that!

If you have questions and seek more information that can impact your solar project, or if you want to learn more about the fascinating world of renewable solar energy to power your world, visit www.SolarEnergy.com.