

DO IT YOUR WAY SOLAR

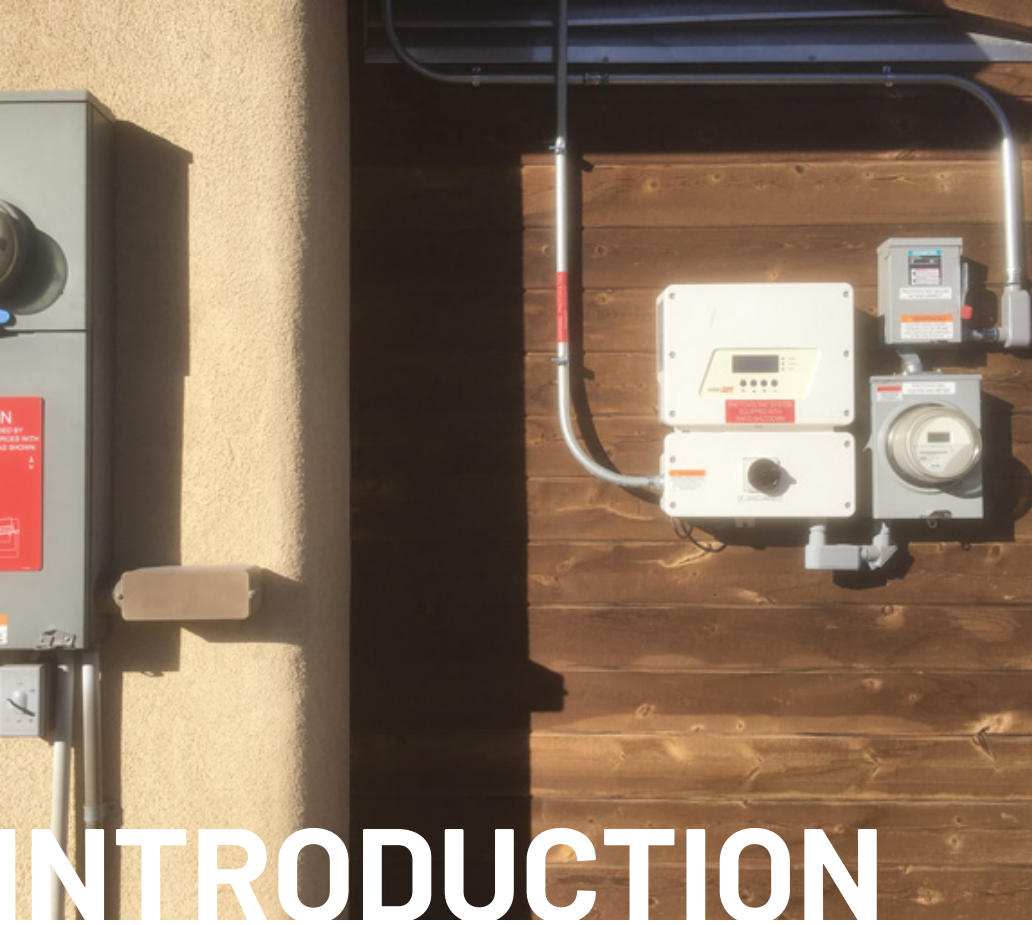
SOLAR INVERTER GUIDE



DO IT YOUR WAY



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INTRODUCTION

Thanks for downloading our solar inverter guide! This guide will teach you how to outfit your solar electric system with the right inverter, which manages the flow of power throughout your system.

What this guide covers:

- ➔ The key differences between off-grid and grid-tie inverters
- ➔ Sizing considerations and features to explore as you choose the right inverter for your system
- ➔ Our picks for the best inverter brands on the market

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WHAT IS AN **INVERTER**?

Your inverter manages the flow of power throughout your system.

When panels collect energy from the sun, they generate DC (Direct Current). But most home appliances use AC (Alternating Current).

At its core, the inverter has a simple job: it converts captured DC power into usable AC power.

“Your inverter manages the flow of power throughout your system.”

When you wire your system, the inverter lives between your solar panels and the appliances you intend to power. But the wiring diagram changes slightly depending on whether you are feeding power into the grid (the default choice if you have access to power lines) or into batteries (if you live off the grid). We'll go over the differences on the next page.

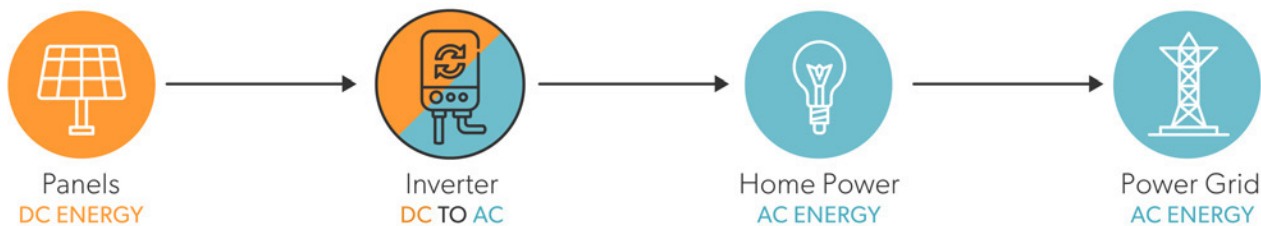
OFF-GRID VS GRID TIE INVERTERS

A grid-tied inverter takes DC power from solar panels, turns it into AC power, and uses that to power your appliances. Any excess energy gets sent into the grid for credit.

This system works a lot like a bank account. The utility company keeps track of how much energy you feed into the grid, which is credited to your account balance. When you withdraw power, the energy you use is deducted from your balance.

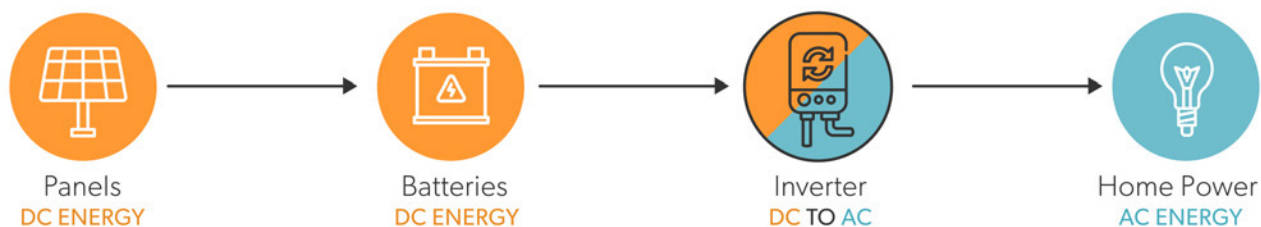
Grid-tied inverters are simpler and easier to wire since there are usually only two main components. The panels feed direct current (DC) into your inverter, which converts to alternating current (AC) to power your appliances. Any extra power flows out of the house into the grid for credit.

The **Grid-Tied** Inverter Power Flow



But an off-grid inverter needs a battery bank to function, so the power chain changes a bit. In off-grid systems, panels generate direct current (DC), which is fed through a charge controller into a battery bank and stored as DC energy. When you draw power, it's sent through the inverter to be converted to alternating current (AC), then used to power your appliances on demand.

The **Off-Grid** Inverter Power Flow





HOW TO CHOOSE YOUR **GRID-TIE INVERTER**

String Inverters

String inverters are the least expensive option, but they only make sense if you meet some specific conditions.

With this type of inverter, there are large groups of panels wired together into strings, and shade on one panel can affect the entire string. If your system is partially shaded, the efficiency of string inverters drops dramatically.

The reason for this is that string inverters are wired in groups of 6-12 modules, which means shade is going to have a bigger impact, because you can't optimize and monitor the output of each individual panel. If one panel is obstructed, every panel in the string is negatively impacted.

Provided you can build a system in full sunlight (like the system featured at the top of this page), you should opt for a string inverter. You'll save money without sacrificing quality or efficiency.

But if you need to account for obstructions to the array, there's a better option: string inverters with individual panel optimizers.



String Inverters with Optimizers

If you expect shade or other obstructions to cover the area where you plan to build your system, we recommend string inverters with individual optimizers on each panel.

The main function of the optimizers is to allow the inverter to control the output of each panel independently. If one panel gets shaded, the rest of the panels in your array will continue to produce at full strength.

Optimizers also allow you to monitor your system on a per-panel basis. Your monitoring software can be used to see if a panel is under-producing due to shade or technical malfunction.

Many string inverters, like the [SMA Sunny Boy](#), can function with or without optimizers. The optimizers are simply an extra cost to add the monitoring and shade mitigation functionality. You can add optimizers on part of the array where it's needed for shading.

However, other brands (notably [SolarEdge](#)) require mandatory optimizers—they simply will not function as stand-alone string inverters. Be sure to research your choice thoroughly and pick a product that's compatible with your needs! Your design consultant should be able to guide you through this choice.



Micro-Inverters

The concept of micro-inverters is simple: attach an inverter to every panel. There are two main cases where you should use micro-inverters:

- You want to start with a small system and be able to expand down the road.
- You want to monitor and optimize each panel independently.

In some ways, when you pair a micro-inverter with a panel, you're creating a self-contained single-panel solar energy system. Each will produce power regardless of how many panels you have. This eliminates the need to rewire and re-balance your panel strings if you add on to your system down the road.

This is a great option if you have a limited budget and want to start small and expand later—cutting out 50% of your power bill, for example, and working toward full offset in the future.

It's also useful if your energy use increases down the line. If you buy new appliances (especially heat or central A/C), build an addition to your home, or your family grows, your usage will spike. Micro-inverters allow you to add more panels without rewiring the entire system.

The last benefit of micro-inverters is ease of installation. Micro-inverters use standard AC wiring, which will be familiar to any electrician. The wiring process is easy to understand, which makes them great for DIY projects.



SIZING CONSIDERATIONS FOR GRID-TIE INVERTERS

Sizing Micro-Inverters

For grid-tied systems, inverters have a minimum and maximum range of input they can handle from a PV array.

Micro-inverters have a limited output—for example, the [Enphase IQ7+](#) micro-inverter outputs a maximum of 290 watts. This limitation should be taken into account when you choose which panel to pair with your micro-inverter.

A good rule of thumb is to take the panel wattage and assume 10% losses due to factors like weather and equipment inefficiencies. The panel should match the micro-inverter output, taking these inefficiencies into account:

325W panel * 0.9 inefficiency factor = 292.5W

A 325W panel should ensure the IQ7+ operates at its maximum output of 290W, without wasting too much extra output from oversized panels.

SIZING STRING INVERTERS

For string inverters, **string sizing** must be taken into account. A string is a group of panels wired in series into the PV input on the inverter. For example, you might have 8 panels strung into a single input.

So why does string size matter?

Inverters operate within a specific input voltage range, called the **operating range**. Your panel strings must output a voltage that falls within that range.

If the panels don't supply enough voltage, the inverter won't have enough power to turn on.

If too much voltage is supplied, you can damage your inverter and void the warranty.

Ideally, your panel strings should be sized to hit a sweet spot to keep your inverter running at its optimal efficiency — referred to as the **maximum power point (MPP)** range.

String sizing calculations depend on the specific voltage of your panels and inverter, as well as outside factors like temperature. Those calculations fall outside the scope of this guide, so we recommend doing more research online if you decide to design your system yourself. Miscalculating string size can cause your system to run at sub-optimal efficiency or worse, damage the inverter

Rest assured that our pre-assembled solar packages are designed with optimal string sizing in mind, so you don't have to do any calculations or guesswork. Your designer will make sure your system is configured to work as efficiently as possible.

BEST GRID-TIE INVERTERS

Best Grid-Tie Micro-Inverter: Enphase IQ7+

Micro-inverters are useful if you want to start small and expand your system down the line. They also provide the most flexibility for individual panel monitoring and optimization of power output.

We recommend the [Enphase IQ7+](#) micro-inverter for these applications. As of the time of publication (January 2019), these are \$142 apiece. You also need a mandatory [Q Cable](#) for each micro-inverter, which adds \$16 per panel.

You would pair them with a panel ranging up to around 330 watts. Each inverter and panel pairing works out to around \$325 (fluctuating depending on which products you pick).

So how does the math look when you're trying to build a full-sized system?

Let's say it would take a \$10,000 system to completely offset your energy bill, but right now, your budget is only \$3,000.

If you want to cancel out a portion of that bill right away, you might get about 8-10 panels with micro-inverters on them. You'd start saving money on electric bills right away, and you can easily add on to it a few years down the road until you hit your target of 100% energy offset.

This is a great way to get started with solar and build out your system at your own pace. But that scalability comes at a slightly higher price than other options.



Enphase IQ7+

Price: \$158 apiece, which includes mandatory Q cable for each panel (54 cents/watt)

Wattage: 290 watts

Peak Efficiency: 97.6%

Warranty: 25 years

Best String Inverter: SMA Sunny Boy

String inverters are your least expensive option, and they thrive in full sunlight.

Our go-to pick for grid-tied string inverters is the [SMA Sunny Boy](#). It's a reliable string inverter that is far cheaper than other options assuming you meet the requirements.

Depending on the model, the Sunny Boy inverters have either 2 or 3 inputs, which means you'll have either 2 or 3 strings of panels wired to your inverter.

The SMA Sunny Boy also comes with a neat feature: a 2000 watt Secure Power System (SPS). The SPS is a feature unique to the SMA brand.

The SPS acts like a small backup power source in case of outages. While it's not a long-term solution, the SPS powers a dedicated 120v outlet that can power up to 2000 watts during the day if there is solar power available.

You can also buy optimizers and pair them with the inverter. This will help mitigate the shade problem, but as a tradeoff, you lose the SPS functionality.

It makes sense to add the optimizer if you previously built an SMA system, then needed to retrofit the array due to new obstructions. Adding optimizers onto the panels would be easier and more effective than ripping out and replacing your whole inverter.

However, if your goal from the start is to get the most output from a partially-shaded array, we would recommend a different inverter for that purpose.



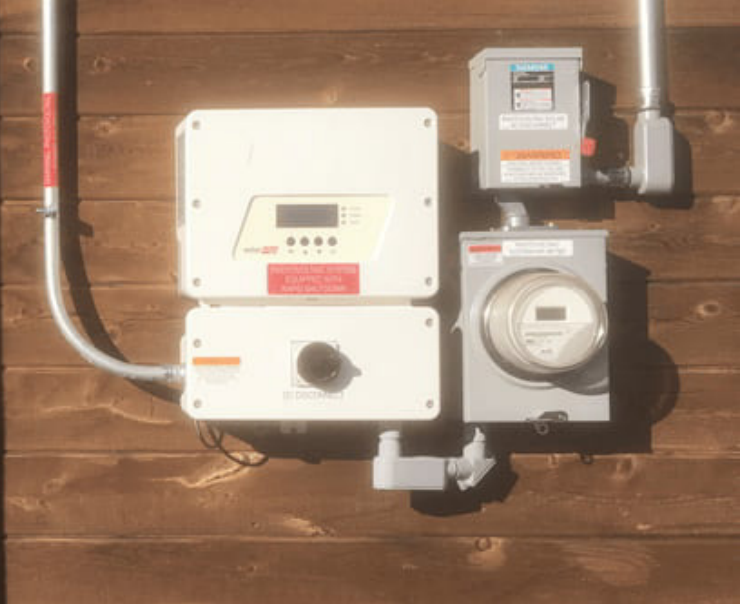
SMA Sunny Boy 7.7

Price: \$1725 (22 cents/watt)

Wattage: 7700 watts

Peak Efficiency: 97.5%

Warranty: 10 years



Best String Inverter w/ Optimizers: SolarEdge HD-Wave

Our best-selling residential grid-tied inverter is the [SolarEdge](#) line, a string inverter with optimizers. This is our go-to grid-tied inverter option because it offers the best of both worlds. You get the lower cost of a string inverter combined with the individual panel monitoring offered by micro-inverters.

The system is shade-tolerant thanks to the optimizers attached to each panel. And it's cheaper than micro-inverters once you scale to at least 8 panels (the minimum string size compatible with SolarEdge inverters).

In the end, SMA and Enphase are tailored to a specific application. The SMA Sunny Boy needs full sunlight, and Enphase micro-inverters are more appropriate if you start with a small system.

For other grid-tied applications, our default recommendation is the SolarEdge line. It's the workhorse of the industry: nothing too flashy about it, just versatile, reliable and easy to use.

Our most popular size is the [SolarEdge 7.6 kW HD-Wave](#) inverter, but they come in a range of [3.8 kW](#) to [11.4 kW](#) options for residential systems.



SolarEdge HD-Wave

Price: \$1550, plus mandatory P400 optimizers at \$67 per panel. Comes to 42 cents per watt for a 24-panel system.

Wattage: 7600 watts

Peak Efficiency: 99%

Warranty: 12 years

Best Grid-Tied Inverter With Storage Capacity: Outback Skybox

If you want to add battery backup to the mix, you'll need a storage-ready inverter to protect against emergency outages and take control of your power, storing it for later or sending it into the grid.

This is used in areas where the utility bills have time of use (TOU) charges or residential demand charges. Energy storage allows you to store and consume the power you generate. You can even sell excess energy back to the utility for a profit.

Our recommendation in this category is the [Outback Skybox](#). It's our favorite battery backup option because it checks all the boxes:



Outback Skybox

Price: \$6,445

Wattage: 5000W

Peak Efficiency: 97%

Warranty: 5 years

- All components (inverter, remote control, breakers/load center and PV inputs) are included in one unit. Since all connectors for the PV array, the utility grid, and a backup generator are present in the main console, you only have to mount a single unit during installation. This makes it far easier to install than other systems, which require you to mount and wire anywhere from 3-6 different components together for interconnection.
- It works with any standard 48V battery bank. It's more flexible than the competing [StorEdge](#) option from SolarEdge, which is only compatible with a single battery (the LG Chem).
- It allows you to start as a pure grid-tie system and add batteries later without any additional parts or configuration changes. Other products don't have this flexibility. Outback's own [Radian](#) system requires you start with batteries, and the [Magnum MicroGT](#) will require additional components if you choose to expand into energy storage.

The Skybox's versatility makes it our preferred pick for energy storage systems.



HOW TO CHOOSE YOUR OFF-GRID INVERTER

Sizing Your Off-Grid System

The first step is to estimate your energy consumption based on the power draw from the appliances you plan to use. You'll need to fill out a [load evaluation worksheet](#) to estimate your usage.

Add up the wattage of all your lights and appliances to calculate the number of watts you'd need if everything was used all at once. (No, you're not likely going to use everything, but this is an easy way to be safe.)

Don't forget to consider the voltage—although most appliances run on 120Vac, some appliances, such as well pumps, require 240Vac.

Let's say you need 1,000 watts for your fridge, 500 watts for lights, and 200 watts for your phone & TV. That adds up to 1,700 watts. In this case, we'd suggest a minimum inverter size of at least 2,000 watts to give you a little extra headroom. (After all, you may add appliances in the future.)



Pure Sine Wave vs. Modified Sine Wave

You may hear some manufacturers talk about pure sine wave inverters. Without getting too technical, pure sine wave inverters produce “cleaner” power and operate more efficiently than modified sine wave inverters.

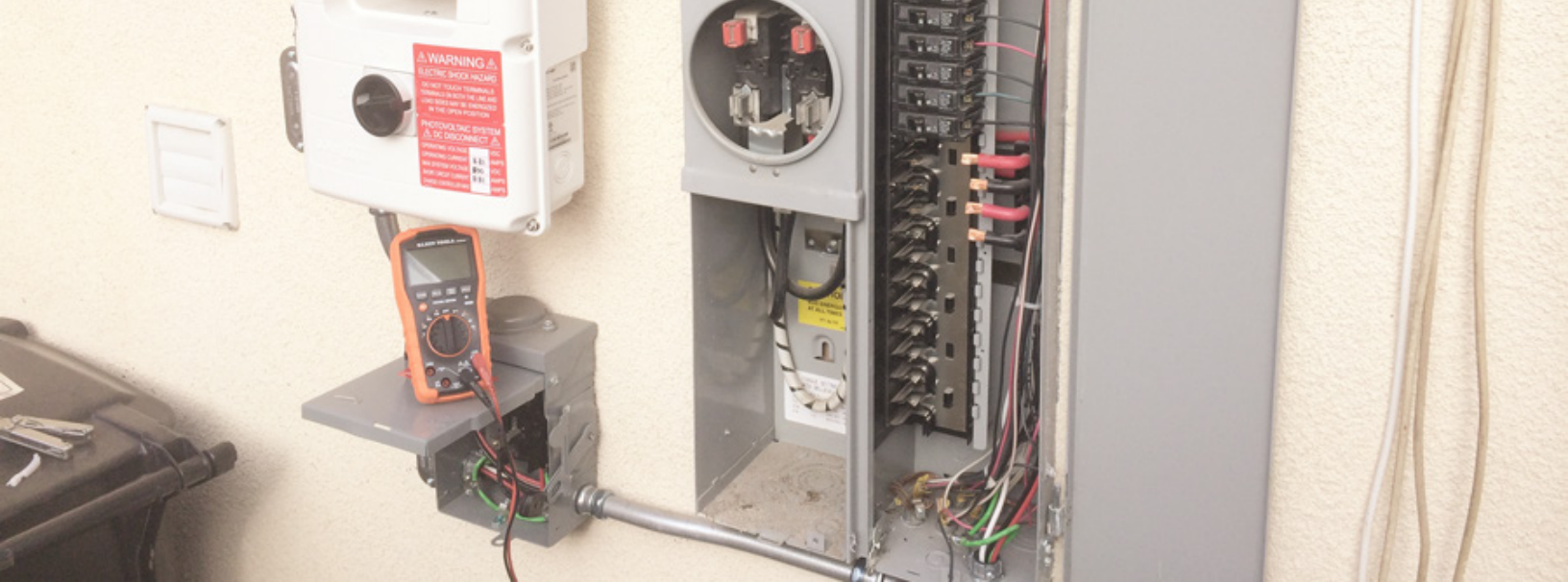
Pure sine wave inverters deliver higher quality power output, similar to (or better than) our power grid. Modified sine wave inverters are cheaper, but they deliver lower-quality power output.

For this reason, modified sine wave inverters can cause issues with certain appliances. Motors, pumps and compressors run hotter and wear out more quickly. Certain sensitive appliances like computers can be damaged, or they may not work at all. These inverters also typically cause background noise on a stereo, and reduced video and audio quality for certain TVs.

Most of our off-grid customers use pure sine wave inverters to avoid any potential issues.

Need a quick way to tell the difference? Look at your inverter’s total harmonic distortion (THD) rating. THD is an indicator of power quality output and will be listed on the spec sheet of any decent inverter.

To avoid running into trouble, choose a pure sine wave inverter with THD of 5% or less.



Technical Specs

Here are some other technical specs to consider:

- **Efficiency.** This is a measure of how much power from the batteries your inverter delivers to your home when it's operating in perfect conditions. A good peak efficiency rating is around 94% to 96%.
- **Self-consumption**, or no-load current draw. How much power will your inverter consume just sitting there? This should be as low as possible.
- **Surge capacity.** How much short-term overload can the inverter handle before it "trips?" Some appliances, like pumps or fridges, need as much as 2x–3x their running power to start up.
- **Battery charger output.** Many off-grid inverters include a battery charger, which is used to recharge your batteries during the winter months with a backup generator. The battery charger will have a rating, usually measured in amps. Good off-grid inverters will have a battery charger in the range of 50-100 amps DC.
- **Temperature range.** Inverters are sensitive to extreme heat. Pay careful attention to the temperature range if you plan on installing your system in your garage or anywhere it could be exposed to temperature extremes.
- **Warranty.** Off-grid inverter warranties start at 1 year and typically range from 3-5 years, with a few manufacturers offering a 10 year warranty extension option.

You can normally find information on all these features on the product spec sheets. Check with your system designer for help choosing the right inverter.



Additional Off-Grid Features

If you're building an off-grid system, look into these features for convenience and flexibility:

Battery charger: A charger allows your system to be charged from a backup AC generator. Most bigger inverters include this; these are called "inverter/chargers."

Grid-tied capability: Some off-grid inverters have the added capability of feeding power into the grid. Here are a few examples:

- Outback [FXR/VFXR](#)
- Outback [Radian](#)
- Schneider [XW+](#)
- SMA [Sunny Island](#)

This capability is useful if the grid becomes available in the future, or if you are setting up a grid-tied system with battery backup.

Automatic generator start: Usually you'll need an add-on accessory for this, although some inverters or charge controllers can take care of it.

Manufacturer Reputation

Knowing about the inverter manufacturer is also important. Check into their history and reputation. In our experience, there are only a handful of companies making high quality inverters designed to run 365 days a year and provide constant power to your appliances. We have found the following brands to be dependable for off-grid applications:

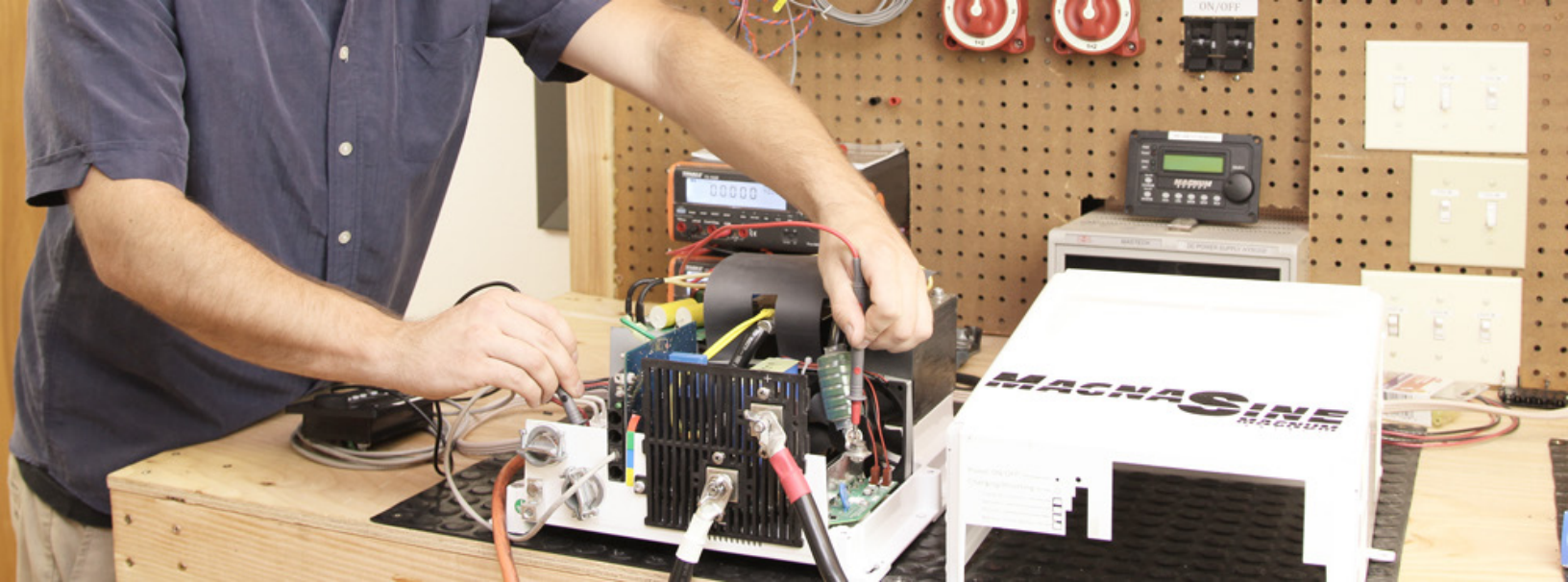
- [Outback Power](#)
- [Schneider Electric](#)
- [Magnum Energy](#)
- [Morningstar](#)

UL Listings & Certifications

Inverters have a few different certifications required in the US, for safety and also to ensure code compliance.

Inverters for your home need to be UL 1741 listed. Mobile inverters for boats and RVs should carry a UL 458 certification. There are a few other requirements for different applications such as UL 1778 for uninterruptible power supplies and KKK-A-1822E standard for emergency services, such as ambulances.

There are other standards required outside of the US such as CSA 107.1 in Canada and IEEE 1547 used internationally outside of North America.



Consider a Pre-Wired Power Center

When evaluating the price of the inverter system, make sure to account for the price of all the associated components required to hook up the inverter.

To make this easier, you might want to consider a [pre-built power center](#). A power center is a pre-wired off-grid inverter system that includes everything you need in one enclosure: an inverter, charge controller, remote control, and circuit breakers.

Most of the power centers we sell also include some additional components for monitoring and protection, including a battery monitor, and surge suppressors.

We assemble power centers with all of these components, and then wire them up and test on our workbench to make sure the system is wired correctly and working. You just need to make a few final connections to add them to your solar installation. We even label the connection points to make it even easier.



BEST OFF-GRID INVERTERS

Best Small Off-Grid Inverter: Morningstar SureSine-300

This inverter is small. At just 300 watts of output power, it can handle lights, charging phones and tablets, and an efficient TV—and that’s about it.

But the [SureSine](#) is renowned for being extremely durable. It’s also used for industrial applications, powering remote equipment in harsh conditions all over the world.

It’s efficient, with very low self-consumption, which makes it ideal for smaller systems like a hunting cabin.

It’s also perfect for industrial remote power systems that require a small amount of 120Vac power.



Morningstar SureSine-300

Price: \$252

Wattage: 300 watts

Peak Efficiency: 92%

Warranty: 2 years

Best Off-Grid Inverter For Cabins & Small Homes: Magnum MS-PAE

The MS-PAE inverter series comes in two sizes: [4kW 24-volt](#), or [4.4kW 48-volt](#). The 24-volt option is suited for small cabin-style systems, while the 48-volt version is more suited to delivering power to larger off-grid systems.

Magnum Energy inverters are fairly easy to set up and use. They have good surge capability and powerful battery chargers. They also have a nice Magnum Panel system that includes a back plate and breaker panel (to make a complete power center).

Installing these inverters on a Magnum Panel bumps up the standard warranty from three years to five.

There are accessories available, including a battery monitor, automatic generator start (AGS) and MagWeb kit for remote monitoring.

MS-PAE Magnum Power centers have been our best selling power centers for years, both for off-grid cabins and for small homes.

Multiple MS-PAE inverters can be stacked together—up to 4 inverters, or 17.6kW total—which makes this inverter also suitable for bigger off-grid homes.

The 4kW 24-volt model can work with smaller battery banks and solar arrays; that's ideal for cabins.

Magnum inverters are available in a wide range of sizes, and they are relatively affordable and easy to set up, which makes them a great choice for off-grid cabins and homes.



Magnum MS4448PAE

Price: \$2,195

Wattage: 4400 watts

Peak Efficiency: 94%

Warranty: 3 years



Best Large Off-Grid Inverter: Schneider Conext XW+ 6848

The XW+ inverter comes in two sizes: [5.5kW](#) or [6.8kW](#) output power. Both work with a 48-volt battery bank.

Multiple inverters can be stacked together, and groups of three can be combined for three-phase power systems.

Schneider offers several accessories including a power distribution panel, automatic generator start, and battery monitor. The Schneider XW+ system really excels with bigger, multi-inverter systems.

Schneider supports multiple clusters of inverters for large industrial and commercial applications, up to 102kW output power. They also support Lithium batteries.

All of these features, plus the ability to stack clusters of inverters, make the XW+ our choice for large off-grid power requirements.



Schneider Conext XW+ 6848

Price: \$4,500

Wattage: 6800 watts

Peak Efficiency: 95.7%

Warranty: 5 years

Best Off-Grid Inverter With Grid-Tied Battery Backup Capability: Outback Radian GS8048A-01



The [Outback Radian](#) is an off-grid inverter that can also tie into the grid to sell your excess power.

The key distinction between this and the Skybox grid-tied system (featured on page 12) is that the Skybox requires connection to the power grid to function. In contrast, the Radian is a fully functional off-grid inverter, but it can also tie into the grid at any time.

This is the ideal option if you want the combination of battery backup and grid-tied solar, or if you're off-grid but you think access to the grid will become available in the future.

The Radian inverter system includes advanced software, called Optics RE, for remote monitoring and control, allowing you to monitor your system, get alerts about any faults, and change settings remotely. It can also control generators for basic automatic start and stop.

It's available in two sizes, [4kW](#) or [8kW](#), and multiple inverters can be stacked together for up to 80kW of power.

This is our best selling inverter for grid-tied with battery backup; most customers opt for either one or two of the 8kW inverters (either 8kW or 16kW).

Outback Radian GS8048A-01

Price: \$4,396

Wattage: 8000 watts

Peak Efficiency: 96%

Warranty: 5 years

CONTINUE YOUR RESEARCH

More Resources

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 Panel Guide

Learn the key factors that influence solar panel pricing and find the perfect panels for your system.

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 »