OFF GRID SOLAR POWER HANDBOOK

The Ultimate Beginners Guide to Power Your Rv, Van, Cabin, Boat and Tiny Home in 7 Simplified Steps

Bradley Stone

OFF-GRID SOLAR POWER HANDBOOK:

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BRADLEY STONE

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INTRODUCTION

> *“We are like tenant farmers chopping down the fence around our house for fuel when we should be using Nature's inexhaustible sources of energy – sun, wind and tide... I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that.”*
>
> — THOMAS EDISON

Have you been thinking about setting up solar power in your off-grid home or wondered about the feasibility of setting up a fully powered off-grid home with solar panels? No matter what stage you have reached, you might have questions and concerns about solar panels, their installation, and the setup you want to achieve.

First, let’s briefly look at why you might want to install solar panels in the first place. For most people, this stems from a desire to live more simply and reduce their dependency on fossil fuels. We are all becoming increasingly aware of how damaging fossil fuels are and how destructive the extraction of fossil fuels can be. Still, few people currently feel that they have viable alternatives.

Every aspect of our daily lives revolves around the use of fossil fuels. Our cars, homes, and jobs are driven by coal, oil, gas, etc. We are utterly dependent upon these resources, yet we know they are also in minimal supply.

Americans use a startling amount of oil every year.

Did you know that if the whole world used the same amount, we would run out in just nine years?[1] That's a significant subject that many people wonder how to solve. Reducing our usage is only a start, and it does not go far enough to solve the problem – although it's certainly not wrong to reduce where you can!

You are probably already aware that there are no "easy fixes" to this issue. They are complicated and nuanced, and we have to acknowledge such if we want to get anywhere. Often, solutions involve compromise, and a perfect outcome rarely exists.

Even great technology like solar power is not perfect. There are environmental costs in creating and disposing of the panels, and they suffer from certain drawbacks. They are not, by themselves, a solution to climate change. However, we need to do what we can to improve the situation, even if the best outcome we can achieve is far from perfect.

There is no doubt that solar power is an excellent start to generating electricity and powering off-grid living for all its flaws. In many cases, installing solar panels on the roofs of houses generates almost enough for the household. If you are reducing your power usage because you're moving to off-grid living, you're even more likely to be able to achieve this.

For readers who can't cut back on the amount of power they use, know that you will still be massively reducing the strain placed on oil and gas when installing solar panels. An imperfect solution is preferable to no solution at all. Even halving your dependency on fossil fuels has a significant impact on your overall footprint.

One of the biggest issues you have probably encountered if you've started looking into setting up solar panels for an off-grid situation is that the whole thing is surprisingly complicated. If you've started to feel like you need a degree in electrical engineering by just thinking about it, you are not alone; This puts many people off trying to install solar panels before they have even started. It seems daunting.

Nevertheless, I've spent a lot of time looking into and analyzing solar panels, their use in off-grid setups of all kinds (boats, cabins, tiny homes, caravans, and more), and how you can make them work for you. I'm going

to cover everything you need to know about them, including the batteries, the fuses, the inverters, how to build your solar system, and the best panels to consider.

You should then have all the knowledge necessary to design and build a system that works for you at a fraction of the cost of one you might buy from a company. Ideally, you will be able to adapt much of the information held in this book to your situation and ensure that you can create a working and efficient system no matter what kind of off-grid home you are working on.

Of course, it is a good idea to look at your budget for adding solar panels before you start.

Installing a solar system is not cheap, regardless of your approach. However, it will represent immediate savings in electricity if you no longer use power from the grid. It will allow you to move off-grid and reduce your dependency on society. You should see lower ongoing costs for the energy you generate in either scenario.

I'm passionate about making solar more accessible to everyday people because I believe everyone should be able to add a functional and reasonably inexpensive solar setup to their homes. With more and more people moving off-grid and trying to soften their impact on the planet, this is becoming increasingly important.

It also seems to be one of the few ways in which America, and the world as a whole, can tackle some of the problems with fossil fuels. Almost all individuals can install solar in some form or another, and if everyone does so, we can massively reduce our need for fossil fuels. Because so many individuals can take this step, it is feasible to represent a fundamental change to the problems we face. A mass, joint move toward solar – even with a small population – would result in extraordinary shifts in the requirements for energy.

If you are thinking of setting up an off-grid system or improving a current system that you have already set up, don't be daunted by the amount of information that's out there. It is not the simplest thing in the world, but it

does not have to be so complicated that you can’t do it. Don’t be put off solar just because it is challenging; this system is well worth setting up.

We will start the next chapter by looking at the benefits of solar power, how it works and how solar panels generate energy, the components that a basic solar system requires, and the phases you will go through when you install solar panels.

Let’s start unlocking solar power!

1

EXPLANATION OF SOLAR POWER

> *"Solar energy will not pollute our air or water. We will not run short of it. No one can ever embargo the sun or interrupt its delivery to us. But we must work together to turn our vision and our dream into a solar reality… I dedicate, this afternoon, this solar heater, harnessing the rays of the sun to the benefit of those who serve our country at the White House."*
>
> — JIMMY CARTER

In 1979, American President Jimmy Carter acknowledged how vital and robust solar energy is. He recognized many things in his speech on solar power, including the dangers of pollution, the limitlessness and availability of solar power, and the need to work together to make solar power a viable reality in our world.

This speech and the dedication of the solar water heaters on the roof of the White House are indicative of just how significant solar has been in our world, *but where did it first come from? How did we start harnessing the sun, and when?*

It might amaze you to learn that solar power has existed since 1839, when a scientist named Edmond Becquerel experimented with electrolytic cells and realized that the cells would produce more energy if they were placed in sunlight. Technology has come a very long way since then, and indeed since Carter's day.

In recent years, solar panels and our ability to produce energy from the sun have undergone immense development and change, making solar panels a genuine, viable, and promising alternative to the fossil fuels that we have depended upon for so long.

WHAT IS SOLAR, AND HOW DOES IT WORK?

Solar is the energy that the sun outputs in the form of both light and heat.

We can harvest solar energy in a couple of different ways, including:

- Photovoltaics (PV)
- Concentrating Solar-Thermal Power (CSP)

You are most likely familiar with PV, as CSP is usually only used in big power plants and is not suitable for at-home setups. It involves using mirrors to concentrate sunlight onto receivers. For this book, we will be concentrating on PV solar power, as this is the kind that can be installed in homes and off-grid settings.

PV is the solar technology used for solar panels. It uses materials that naturally produce electricity when sunlight strikes them via an electronic process. These materials are called semiconductors, and they contain electrons freed by the energy contained in solar rays.

When these electrons are freed, they can be channelled into an electrical circuit which can either power a device or send energy into a battery or grid to store or transmit to other homes.

In short, the PV cells in the solar panels have been designed to absorb the energy from sunlight when it falls on them, and this forms an electrical charge we can utilize; This can be done at almost any scale.

You can get small solar panels, which can charge devices such as cell phones, batteries, flashlights, etc. You can also get much bigger solar panels, which generate enough electricity to power computers, heaters, and so on.

Today, we generally use crystalline silicon or thin-film semiconductor material to create solar cells. These have both come down in price significantly since they were developed, bringing solar into the reach of ordinary people. Each material has pros and cons.

The thin-film materials are not as efficient in gathering energy. However, they tend to be cheaper to make, and they are relatively simpler, thus making them more accessible for at-home projects.

Silicon cells have higher efficiency rates, but they are also more expensive to manufacture. They are the better option if you can afford them, but many people still find these are out of their price range.

There is an additional category, but they are highly specialized and only used in military and scientific operations. They are called tandem cells or multi-junction cells, but they will remain too costly for most people to use until the future.

HOW CAN YOU HARNESS SOLAR?

A solar panel made of one of the above categories of cells is needed to harness solar. Which category you use will depend on the application and what is deemed affordable, but you must have either a thin-film or silicon cell panel.

Next, you will need to decide on the size of the solar panel. In general, the bigger a solar panel is, the more energy it can generate. This discrepancy is often one of the biggest weaknesses of a solar panel – it needs space and requires a clear shot at sunlight. Without vast, open areas dedicated to many panels, it is challenging for the human race to generate enough electricity to meet our needs.

To generate enough solar power for our homes and infrastructure, we would have to clear vast swathes of land to install all the panels that would be needed. Despite recent developments in solar panels and improvements in their efficiency, this remains true.

Clearing large amounts of space is problematic because this may mean removing trees and animal habitats and taking up land that could be used

for farming. Areas around the solar fields would also need to be cleared to ensure sunlight falls on the panels with minimal interruption.

Rooftop solar panels are the solution to these two issues.

Roofs offer blank, empty canvasses to install panels on without needing to clear any new land, and they are elevated so that the panels will get maximum access to sunlight, with few objects blocking them. They are also located where the power is wanted – alongside buildings – so there is no need to send the electricity through long cable stretches.

HOW CAN SOLAR PANELS CONVERT SOLAR ENERGY INTO ELECTRICITY?

Solar panels convert solar energy into electricity because the energy makes electrons within the material move, generating electricity with varying efficiency rates.

On average, a single panel will produce somewhere between 250 and 400 watts. A domestic system for a house might have between four and ten solar panels, giving it a capacity between a kW and 4 kW. Over a single year, a 4kW solar panel system could produce almost 3000 kWh of electricity if operating in good conditions.[1] Of course, off-grid systems are often smaller due to space constraints and reduced consumption needs.

Understanding this allows people to calculate how many solar panels are needed for any given application to power it properly. However, it is essential to note that many domestic solar panels are surprisingly inefficient, although they can still produce plenty of energy in homes.

Even the best residential panels generally only operate at around 20% efficiency. Solar panels can be made far more efficient than this, achieving efficiency rates of up to around 50%, but unfortunately, this technology is still prohibitively expensive. In the future, it is likely to become cheaper, and we may be able to make better use of the sunlight that is available to us.

Overall, therefore, the process of converting solar energy into electricity is pretty inefficient at present but still valuable, especially in off-grid settings

where other sources of power may not be applicable. While solar panels are far from perfection, they are certainly a viable option.

OFF-GRID VS ON GRID SOLAR ENERGY

There are three different options you can set up your system with: you can be off the grid, on the grid, or utilizing a hybrid setup. Let's break down these three systems.

Off-Grid Solar Energy Systems

An off-grid system is what you may be interested in developing if you are keen to stop depending on the grid. A boat, an RV, or any other moving vehicle, or a cabin located a long way from the nearest town, will usually be set up using this kind of system because it cannot easily be connected to the primary grid.

An off-grid system will be closed-loop, and the energy you produce will be pumped into your system and stored in your batteries. You will not be contributing any energy to the electricity grid in your area, and you will not be pulling any energy from it either.

The energy that flows from the solar panel will be sent into a large battery, storing the energy and supplying it to your home. The effect will be the same as using energy from the local energy supplier, but your energy will be limited, and once it has been used up, you will need to wait for more to be generated by the solar panels.

Think of an off-grid system like growing your carrots. The carrots you produce in your garden go into your kitchen, feeding you and your family, and none of them goes anywhere else; they are kept in your home. You stock the refrigerator with your garden carrots (just as you stock your batteries with your solar panels). When your fridge is empty, you have to get more carrots from your garden, rather than from a store.

These systems are also known as Stand-Alone Power Systems (SAPS). They are great if you cannot connect to the grid or choose not to, but they have the pronounced disadvantage that if you outstrip the amount of power your system generates, you will simply run out of power.

They also tend to be considerably more expensive than an on-grid system because you need better solar panels and some excellent batteries. They can be prohibitively expensive to set up, and you will need enough room to store the batteries.

A third disadvantage of this system is that it has nowhere to go if you produce more power than you need. The power is wasted once the batteries are fully charged, rather than being fed to other homes.

If you cannot connect to the grid in any way because you are setting up your system in a live-in vehicle or an isolated property, this is your only option. However, it is worth understanding the other two and considering whether they could work for you.

On-Grid Solar Energy Systems

An on-grid solar energy system means that your solar panels are linked up with the nearby energy supply that supplies other homes. Your energy will be fed into this grid instead of into your home, and you will pull power from the grid.

You will not directly use your energy, but this doesn’t matter because the overall system will remain the same. The same amount of energy will be produced and used, and it is irrelevant whether this comes from the grid or your solar panels.

Think of this somewhat like supplying carrots to your local store. Instead of carrying the carrots into your kitchen, you carry them to the local store and put them in a big box of carrots. Other people also supply this box (whether individuals or energy companies, both green and fossil fuel dependent).

When you want carrots, you have to take them out of the box. You may not get your carrots back, but you have still contributed eco-friendly carrots to the box and reduced the overall use of “non-green” carrots. Your carrots have made the world greener, even though you are not directly using them.

However, if you use more carrots than grown, you depend on other carrot suppliers to meet your needs. That may mean you are still depending upon non-green carrots – or electricity. The advantage, of course, is that you do

not run out of carrots, even if your garden is not currently able to meet your requirements.

Some people would prefer to be using their solar energy before sending it into the grid, however, simply because this “feels” more satisfying. If that’s the case, you might be interested in building a Hybrid Solar Energy System.

Hybrid Solar Energy Systems

This is a system that utilizes a battery but also feeds into the grid. With this system, energy will first be stored in a battery, and as devices use this energy, they will draw on the battery until the battery levels are depleted.

The grid will also feed into the batteries during the low-demand hours. When electricity is cheap (which is generally between midnight and six in the morning), it will fill the batteries, ensuring that the system has the maximum amount of energy available.

If the battery gets depleted, the system can then tap into the grid and start pulling energy from there to supply your systems. This ensures that you have access to power even in bad weather when your solar panels are not generating much.

In some cases, hybrid systems are organized so that excess solar power can also be fed back into the grid, but not all do this.

Using our carrot analogy, a hybrid system is like growing your carrots, placing them in your fridge, and topping up your fridge from the store. With some systems, if you have excessive carrots and cannot use them all, they will be sold to the store, but only those that will not fit into your fridge (or battery).

Hybrid systems are popular for obvious reasons because they allow you to enjoy the best of both worlds. You can use your solar power, have it topped up by the grid and – in some cases – sell excess power back to the grid.

Of course, a significant disadvantage is that you must connect to the grid to use a hybrid system. If your off-grid setup cannot be joined up to the primary circuit (or you would rather not join it), you cannot utilize a hybrid system, and your only option is an off-grid system.

In this book, we will be looking predominantly at creating an off-grid setup. However, it is worth being aware that the other systems exist because you may utilize them in some situations. Don't dismiss hybrid or grid systems if your setup allows for them; they are often cheaper and better for the planet.

MAJOR COMPONENTS OF AN OFF-GRID SOLAR POWER SYSTEM

So, what do you need to create an off-grid solar power system? Different systems can vary enormously, so we will focus on the most typical kind of setup for a small off-grid system (the sort that you would set up for a van, RV, cabin, etc., as opposed to a large off-grid home).

A small-scale solar off-grid system usually uses MPPT solar charge controllers between the solar panels and the batteries that are being charged. Although instalments may vary, your system will likely include most or all of these components:

- Solar panels
- An MPPT solar charge controller
- HRC fuses
- A battery bank (or single battery)
- Your direct current loads (e.g. lights)
- An inverter
- Your 240V alternating current loads (e.g. laptops)

In some cases, one or the other of these components may be switched for something else that performs a similar job, but generally, all small scale off-grid systems will utilize these components. Let's break them down.

Solar Panels

You need solar panels to run a solar system. You will have to determine the number of panels you require to meet your electricity demands, calculate the size of the panels, the efficiency that the materials offer, and your needs.

Solar panels will generally be installed on a roof, but you should think about their placement and make sure that you have a suitable space.

An MPPT Solar Charge Controller

The MPPT stands for Maximum Power Point Tracking. Its job is to control the high voltage current sent by the solar panels and make sure it is converted into a current that is suitable for your devices. The controller also makes sure that the power coming in from the panels is utilized as efficiently as possible so that your batteries are getting charged.

This is a surprisingly complex process because the panels and the batteries will often be poorly matched. To maximize the efficiency of the power sent by the solar panels, the solar charge controller converts the direct current (DC) into alternating current (AC) and then converts it back to a different DC voltage and current – one that perfectly matches your batteries.

Without an MPPT solar charge controller, your solar panels are not compatible with your batteries or lighting. Usually, an MPPT solar charge controller is wired directly to the solar panels, and from there, linked to:

- The batteries
- The lights
- The inverter

It then makes sure that everything is getting the proper voltage and the right kind of current.

An HRC Fuse

High rupturing capacity (HRC) fuses will sit between the batteries and MPPT solar charge controller. These fuses have been designed to carry a short circuit current for a set period. As soon as a fault occurs, the fuse blows, breaking the circuit to prevent damage to the other components.

These fuses are usually made of glass, and they prevent your system from being blown up if the MPPT solar charge controller fails to do its job correctly.

A Battery Bank

Obviously, for solar panels, you will need batteries. These store energy while your panels generate it and hold it there for use when your panels are not. Not all of the energy your panels produce will go into the batteries in most systems. They are usually wired to supply directly to devices and then simply feed extra energy into the batteries.

Without batteries, you will have no reliable power source. Something as simple as a cloud could knock out your whole system, so it's essential to make sure you have batteries ready to install.

Direct Current Loads

These are loads that work on direct current rather than alternating current. Direct current is what your solar panels supply, so these can be wired in before your inverter (which will swap the DC into AC).

In general, DC loads will be things like your lights, rather than things like laptops, chargers, etc.

A 24V Converter

A battery inverter is crucial for your solar panel setup. Remember, your solar panels produce DC, and your plug-in devices require AC to function. Your battery inverter is one of the most critical parts to spend time selecting because it must be able to meet the needs of every appliance that could be plugged into it at all times and in all circumstances.

Your solar panels will have minimal use if you do not have a battery inverter. Installing an inverter lets you utilize solar energy for all your devices, such as cell phone chargers, toasters, laptops, fridges, etc.

It's important to avoid just buying the cheapest inverter you can find. Spend time researching different inverters, mainly how they handle power surges. When you first turn your system on, there will be a sudden and sharp demand for power as the high-power units (e.g. fridges, water pumps, etc.) turn on. If your inverter cannot handle this surge, it will fail.

We will cover how to choose an inverter suitable for your needs later in the book.

240V Alternating Current Loads

This is anything that you wish to plug into your system. Remember, the more devices you have, the greater the load on the system and the better your components need to be. If you plan to run high-energy devices such as fridges, dishwashers, vacuum cleaners, etc., you will need components that can cope with the demand.

Anything that is not directly wired into your direct current will be on alternating current.

INSTALLATION PHASES

Phase 1) Check That You Have Space

If you want to use solar power for your off-grid setup, you will need to find a space to install the panels, which can only be done on the roof in a moving vehicle, such as a boat, RV, or van. If you own a small piece of land, you could site the panels elsewhere, but the roof is still likely to be the preferable option.

Phase 2) Calculate Your Energy Needs

Once you know that there is room for solar panels, you need to work out whether you can build a viable system to meet your energy needs and whether you can afford this system; This will involve a bit of math, but it is not too complicated once you make a start.

You will need to begin by making a list of the appliances you want to run and how long per day. Check the appliance's power rating so you can calculate the amount of power it needs; This is done by multiplying the power rating by the number of hours it will run for.

Do this for each appliance you wish to run, always erring on the side of producing too much power. Next, remember that most solar panels cannot run at maximum efficiency most of the time. You will often lose about 30% of your energy or more.

If you are struggling with this, there are many load calculators available on the internet that should help you. Once you have a total for the amount of energy needed, you can move on to the next step.

Phase 3) Choose Your Solar Panels

We will talk about choosing solar panels in a dedicated chapter (Chapter Four), but this is the next installation phase.

You will need to make sure that your solar panels are suitable for charging your batteries.

You will also need to think about the amount of sun the panels will get most days, whether you can afford the more efficient (but more expensive) monocrystalline solar panels, or whether to go with the cheaper and less efficient polycrystalline panels or thin-film panels; This will all be explored in Chapter Four.

Phase 4) Choose Your Batteries

You need batteries for your solar panel setup, even if you only plan to run your appliances during the day. There are a few reasons for this.

1. We tend to use more electricity at night when it is dark. Even if you don't plan to do so, having an emergency supply is wise.
2. Solar panels produce direct current, which won't power any plugin devices. You need batteries and a converter to get an alternating current.
3. Even if you only want lights (direct current), you should still use batteries because they supply a constant rated voltage. Even in full sun, solar panels may fluctuate depending on what they supply; This is not good for your lights and won't produce a satisfactory system.

We will cover how to choose the best battery in Chapter Three. Be aware that although batteries have come a long way, they still lack efficiency, so you will constantly be losing energy even as your panels are charging the batteries. Therefore, it's essential to take care and choose a battery that will perfectly meet your needs.

Phase 5) Choose Your Solar Charge Controller

Again, you will need to select a solar charge controller that works with the other parts of your system. There are three kinds, but MPPT is the most

efficient and will be predominantly focused on in this book.

Phase 6) Choose Your Inverter

You will need an inverter to get any AC appliances running, and again there are several types. The inverter will need to be capable of handling the maximum watt load of your system, including the starting power of any devices (which is often higher than their ongoing power requirements).

Phase 7) Begin Wiring

You will need to decide whether you will create your system with series connections or parallel connections. In general, your wiring system will look something like this:

Solar Panels → Solar Charge Controller → Battery → Inverter → AC Load

There will be a further join on the Solar Charge Controller to any direct DC loads (lights). Usually, a breaker is installed between the battery and the inverter, and another breaker is installed between the inverter and the AC load. You may also have one between the solar panels and the charge controller or other places, but that is your basic system.

You will need to ensure that the cables you are using can handle the charge being sent through them and that energy loss is minimized.

Phase 8) Mount The Solar Panels

You can purchase a mounting stand for your solar panels, and then you will need to mount them on an elevated surface (usually a rooftop).

Make sure that the mounting stand is angled so that your panels will capture the maximum amount of sunlight (although this may be challenging if your off-grid home moves). You should also angle the panel based on your latitude, and you can find calculators to help with this online.

If you are mounting panels on a static off-grid home, consider anything that might obscure the sunlight nearby – such as trees, other buildings, etc.

Mount the panel stands according to the manufacturer’s instructions, and then mount the panels on them. You can then wire the panels into your main system.

Phase 9) Mount The Batteries And Inverter

You will need to put your batteries and inverter in an out-of-the-way spot. You may wish to put them up on a wall overhead in a covered box; this looks neater and protects them from bumps or damage.

However, remember that the inverter fan will need access to fresh air to keep the system cool and prevent it from overheating. The batteries will also benefit from some ventilation, so drill holes in your mounting box for air circulation and cables.

Mount your box and finish wiring up the system, and once the sunlight falls on your solar panels, you should soon have energy.

SUMMARY

Hopefully, from this chapter, you learned:

- How solar energy works and how we can start harnessing it to power our homes
- The potential power of solar panels
- The difference between on-grid and off-grid solar setups, as well as hybrid setups
- What components an off-grid solar setup requires
- The fundamental phases of installing solar panels

In the next chapter, we will cover some of the basics of electricity, including the differences between power and energy. You can get to grips with what your system is doing and how it works, which will help you choose the correct components for your solar power system.

2

BASICS OF ELECTRICITY

> *“And God said, 'Let there be light,' and there was light, but the Electricity Board said He would have to wait until Thursday to be connected.”*
>
> — SPIKE MILLIGAN

Electricity is something that very few of us stop to think about. It is part of our lives and integral to almost everything we do. *We all know our phones, televisions, and computers are powered by electricity, but what about things like streetlamps, fridges, freezers, stoves, and everything else that we use daily?* Alarms, monitors, printers, emails – electricity is integral to every single aspect of our lives now.

We often have to take it away to understand how much we depend on it. If you have ever experienced a power cut, you have had a taste of this. When I was younger, power cuts were a regular occurrence, and we could lose our electricity for days at a time.

It was an adventure for the first hour or two, and then it became a nuisance. Doing homework by candlelight and eating takeouts because we couldn’t cook was frustrating. Going to bed in a freezing bedroom because all of our heating was electric was downright unpleasant.

Anyone who has trialed their mobile home without electricity will be familiar with these challenges and with the sense of panic as a battery is dying and you just haven’t quite finished making dinner or sending a work

email. As time passes, this becomes truer and truer as our dependency on electricity increases.

Very few people now are happy to live without electricity, but very few of us understand how we get connected and where the power comes from. We flick the switch and watch the device boot up. When I first started to study solar panels and how to utilize them, I was surprised by how little I knew about where the power in the home comes from, what the options for powering homes are, and how it works.

In this chapter, we will run through some of the basics of electricity and how it can be generated.

Solar power is fundamentally about creating the right amount of electricity to power your system and ensuring that it is being utilized efficiently, so this chapter will give you the foundations you need to understand this process.

We are going to cover:

- The basic forms of power that exist
- The differences between power and energy
- The fundamentals of solar power

BASIC FORMS OF POWER

There are many ways in which we can generate electricity. Often, it is generated by burning fossil fuels, and we all know how problematic this is for the environment. More and more people are trying to reduce their use of fossil fuels, but they remain our go-to source for energy. Even in recent years, only around 11% of global primary energy was generated using renewable technology.[1]

So, what are the basic forms of power that we can use? All of the major ones are as follows:

- Coal (fossil fuel)
- Oil (fossil fuel)

- Natural gas (fossil fuel)
- Nuclear fission
- Wind
- Wave
- Geothermal
- Hydroelectric
- Biomass
- Solar

Some are non-renewables, including coal, oil, natural gas, and nuclear. Others are renewable, including wind, wave, geothermal, hydroelectric, biomass, and solar. We can depend upon these sources in the future because they are not finite resources, and we can generate power from them indefinitely.

If we continue to depend upon non-renewable resources, we will run out, no matter how carefully we use them; This is a simple fact. These resources are not regenerating (or so infinitesimally slowly as to count as non-regenerating). Even if we halve or quarter our use, we will run out.

Every item we use that requires electricity will be generated from one of these sources. They have different pros and cons. Non-renewable sources suffer the significant disadvantage of running out, and they are enormously damaging to the environment – but they are also attractive because they produce lots of power.

Of course, the amount produced does vary depending on the source in question. Coal, oil, and gas produce reasonable amounts of power, whereas nuclear produces massively more for the materials it needs. However, nuclear energy uses rarer materials and has many other drawbacks in disposing of them. Overall, the reward for using fossil fuels and nuclear fuel is high, but the payoff is also very high and not viable in the long term.

Renewable energy has trailed a long way behind fossil fuels in terms of how much power it can produce. Yet, this gap is closing, and recent advancements have meant that renewables are becoming a viable alternative to non-renewable energy in many instances.

So, our options are currently:

- Fossil fuels, with a medium power output but pollution
- Nuclear fission, with superb power output but many disadvantages
- Renewable energy, which currently suffers from either a low (but improving) amount of power output or from being very location specific (geothermal works very well in some areas, but not in others), is a long-term solution

At present, the human population is making compromises and finding a best-case scenario for power use. We depend upon a combination of all of these things. Swapping to one or the other as a global movement is not currently viable. Still, individuals can choose to move toward renewables – and this will usually be solar, which we will discuss a little later in this chapter.

DIFFERENCES BETWEEN POWER AND ENERGY

It is essential to understand the difference between power and energy when talking about electricity because they are not the same thing, even though many people use these terms interchangeably.

Energy is the capacity to make something happen, the driving force of change. Moving something uses energy. To do that, you have to expend energy stored in your muscles and convert it into something different – the movement.

Energy is never destroyed or created. When we generate energy from something (like coal or sunlight), we simply convert the energy from one form into another. When we burn coal, we release the energy to produce heat and power. When solar panels create energy, they convert this energy from sunlight into electricity. Although we talk about generating energy, we mean converting it.

As an example, think about how you convert your food into energy. When you go to the gym, you are putting energy into moving something (whether weights, your legs on a treadmill, etc.), which burns energy stored in your body. The energy has not gone, but you have converted it into another

source; This is the same with any form of energy. It does not disappear and cannot be destroyed or created.

In physics, energy is usually measured in joules. However, energy is often measured in kilowatt-hours when working with electrical systems. One kilowatt-hour is equal to 3600000 joules. You will have seen kilowatt-hours on your electricity bill.

Power is a measure of how fast energy is being put into something. It means the amount of energy spent per unit of time; This is why a high power engine can do more work and is needed for situations in which a low power engine would be too slow. The low power engine might still be able to do the job, provided it has enough fuel (energy), but it would take too long to be practical.

Power is usually measured in watts or kilowatts. It is important not to get kilowatts confused with kilowatt-hours. A kilowatt-hour is 3600000 joules of energy – the amount of energy that something requiring a kilowatt of power to run would use if it were left running for an hour.

Think of it in this way:

If you want to carry a heavy box from A to B, it takes 10 units of your energy to move the box in one hour. It might take another person 10 units of their energy to move the box in a day. The same amount of energy is required for the box to move, no matter who moves it. However, one of you can carry the box more quickly because you are a more powerful person. Your muscles are stronger. You can therefore do the same job faster.

It does not take less energy, but having more power improves the time ratio. In some cases, improvement is needed for the device to function this time. A weak motor might not be able to make something move even slightly. A light bulb provided with insufficient wattage might not just be dimmer; it may fail to light up at all.

Recognizing the distinction between energy and power is crucial because it helps you understand why we need to look at the energy output of something and its power. If you are thinking of using a battery that stores 5 kilowatt-hours, you also need to know how fast it can release this energy to the devices you’re running. If it can only output it at a rate of 1 watt, the

battery will last a long time without going flat, but it doesn’t serve you very well because it won’t give your device enough power quickly.

The amount of power that a device needs is often the most relevant factor, and this should be given to you in the manual or on the device. If the device receives 1 watt when it needs 20 watts, it will likely not function at all. To calculate the energy that your solar panels should generate, it is crucial to recognize how much power your devices need and whether the energy your solar panel's output can meet that demand.

SOLAR POWER BASICS

Solar power is one of the most promising renewable energy sources, partly because it is applicable wherever you go. It is also improving very quickly, and today’s solar power technology is vastly more useful and viable than the technology from fifty years ago.

One of the big myths about solar panels is that you need direct sunlight for them to work at all, and on a cloudy day, you will not get any energy; This is not true. The sun is outputting energy all the time, and less energy does not equate to no energy. Modern solar panels can generate electricity even on cloudy days, and they do not stop working just because of a shadow passing over the panel.

It is vital to recognize if you live in a part of the world that does not enjoy as much sunlight. You can still utilize solar panels, although you may not get as much efficiency from them as someone who lives somewhere with a lot of sunshine.

If you live somewhere with only a limited amount of daylight hours, solar panels will not serve you as well because they are getting less energy, and therefore they will output less power. When the sun no longer falls on them at all, they have nothing to convert, and they cannot charge your batteries.

Of course, solar power does suffer from some other major disadvantages, such as:

- It is an intermittent source of power, as many of the renewables mean unreliable; This is frustrating for a system that you may need to power basic essentials such as cookers, fridges, and lights. If you do not get enough daylight, your panels cannot operate properly.
- It tends to produce the most power when you least need it (when you want your lights on at night, your panels are not producing any power), so energy storage is needed, and this is expensive. When you are using significantly more energy for heating and cooking in cold, dark weather, your panels may struggle to keep up.
- It is fairly expensive still, despite the constantly reducing costs. This puts it out of reach for many people who own tiny homes, despite offering such good cost savings going forward.
- The energy storage solutions are not yet very efficient, so you will have to buy large batteries that need to be stored. This is not ideal when space is already limited in your home. Additionally, these batteries are expensive and may not be very green, and they will have a maximum lifespan, leading to pollution when they are eventually disposed of.
- It takes a significant amount of space to produce enough power for most situations. You will have to dedicate space on your roof, which might have been utilized for additional storage (depending upon your setup).
- The components will not last forever, so there will be future costs to maintaining the system as parts need to be replaced.

However, there are some significant advantages:

- You can have power without being linked up to the grid, which is ideal if you wish to move your home around or live a long distance from society. This provides the freedom that has previously been very limited unless you are happy to live without power.
- You are not dependent on energy production from other companies, so you will not be affected by crises or power cuts outside of your control.
- You will reduce your living costs because you can power your home without buying batteries or paying to charge them regularly. You

will not have energy bills and standing charges to pay for the grid's service.
- You can create a more environmentally friendly space because you have moved away from fossil fuels. Adding solar power to your home will massively reduce your carbon footprint. How big this reduction is will depend heavily on your situation.
- You are not affected by rising energy costs, so as fossil fuels become scarcer, and in greater demand, you will not be paying exorbitant prices to keep your power on.
- Almost anyone can fit solar panels, and they can be used almost anywhere, making them ideal for homes that move. Instead of having to access society every few days/weeks to recharge your batteries, buy new ones, or exchange power sources (e.g. gas canisters), you can go where you please, provided enough light for the panels.

Solar panels are attractive for these reasons and compared with many of the other renewable sources, they are an excellent way to power your home.

Even compared with the non-renewables, they are attractive because they make you independent of society and generate power wherever you are. The ongoing costs are low (although parts will need to be replaced at times), so if you can afford the upfront costs, you will massively reduce your ongoing bills.

In terms of the other renewables, solar tends to win for several reasons, which will be explored below.

SOLAR VS WIND

Wind is massively more efficient than solar, but it has some major disadvantages that make it inapplicable in most residential situations – especially for tiny homes/mobile homes.

- It is noisy
- It is ugly (in most people's view)

- There is usually not enough steady wind in a residential area to work well
- Wind turbines need more maintenance
- Wind turbines may not be as easy to fit into your mobile setup

In general, wind is vastly more preferable for a large scale setup, but solar wins every time for a small one.

SOLAR VS OTHER RENEWABLES

None of the other renewable energy sources can be used in most mobile home setups. Things like wave and hydropower require you to be alongside water, even if we discount the size of the necessary equipment.

Geothermal energy is also impractical, as is biomass. Solar is, therefore, your only option, besides wind, for generating electricity while on the go in most off-grid situations. Of course, there are exceptions, but on the whole, solar is the best method for reducing your dependency on civilization and fossil fuels.

Summary

In this chapter, we've covered:

- How we can currently generate power, including both renewable and non-renewable fuel sources
- The difference between power and energy and why it is key to understand this when creating a solar power setup
- Some of the essential advantages and disadvantages of a solar panel system and why you might use solar power instead of other renewable resources for an at-home setup

In the following chapter, we will start choosing the appropriate battery for your solar power system. Remember, the battery is crucial because it will power your home any time there is not enough daylight to generate electricity.

3

CHOOSING THE RIGHT BATTERY

> *“Every great device, gadget, electric car, and robot would be even greater if batteries didn't suck so badly.”*
>
> — STEVEN LEVY

You are bound to be aware of batteries' impact on our daily lives. Every portable electronic device depends upon them, and many of us find that our lives also – to a degree – depend upon them. *How often have you felt a jolt of horror upon realizing that your cell phone’s battery is almost dead and you can’t do the important thing that you depended upon it for?*

This can leave you unable to navigate, make an emergency call, submit documents, coordinate with group members, help out a friend, or a whole host of other things. It is a major inconvenience and is becoming more so that we become more dependent on our cell phones every year.

This extends to every area of life that includes batteries. A flat battery on your car, your laptop, your tablet, or even just your remote control can range from devastating to inconvenient, but there’s no doubt that when batteries fail, it is never a good time, and it is always frustrating. More than anything, batteries are a technology that we depend upon heavily and very often, they let us down.

However, in each of these scenarios, you are only dealing with one item that has gone flat and become unavailable for use. It might be very important in that instant, but it is still just one thing. However, the batteries in your solar

panel system are supporting everything – and that's why it's so crucial to choose as well as you possibly can within your budget.

Getting the right battery will make a massive difference to your experience with solar panels. Batteries are notoriously inefficient and suffer from many other problems, such as how much space they require, the maintenance that is needed, and the end of life disposal issues.

The battery is the store you depend upon most of the time, and it is therefore extremely important to choose correctly, so, in this chapter, we're going to look at:

- Lithium-ion batteries
- Flooded Lead-Acid batteries
- Sealed Lead-Acid batteries
- Nickel-Cadmium batteries

For each, we will explore the advantages and disadvantages associated with them and the setups they are most appropriate for. This should put you in a great position to choose the most viable for your off-grid solar power system.

We'll then cover choosing the best battery and which specs matter the most.

LITHIUM-ION BATTERIES

This is one of the newest kinds of battery technology. It has been climbing in popularity recently, especially with the increasing uptake of electric vehicles – which require good energy storage in a very limited space.

They are an excellent option in many applications, and if you can afford them, you may find them good for an off-grid setup. Of course, no battery is perfect, but many people are turning to these as a solution for their power storage. They are currently one of the most widely used in solar battery banks because of the advantages they offer.

Don't be deterred just because they are new technology. As evidenced by their popularity, they are a particularly attractive option at present, and they

often outstrip the other batteries for a number of reasons.

Pros:

There are a few major advantages to these batteries, including:

- They are low maintenance
- They do not require as much space as other batteries tend to
- They last for considerably longer than most other batteries (generally at least ten years, usually longer)

Let’s break each section down below.

They are low maintenance. In general, batteries require you to look after them and perform a few basic tasks on a regular basis to keep them running (see below for further information). You might be willing to do that, but if you are operating an off-grid setup that you are often away from for long periods of time, this can be very problematic.

Even if you are present, it is annoying to have to keep servicing your batteries, as this is an ongoing chore and one that you must keep track of if you want to keep the batteries in good condition.

They are smaller. A major advantage in an off-grid setup where space is lacking, being smaller makes these batteries a far more attractive option than many of the competing products. Instead of having to dedicate large amounts of space to your battery bank, you can reduce the footprint of the setup and keep it to a contained area.

On a boat or an RV, this is enormously attractive and may be the biggest factor in the popularity of lithium-ion batteries. Anywhere that space is at a premium, the compactness of these batteries makes them extremely attractive.

It should also be noted that this reduction in size and weight may help you to make financial savings in areas like fuel. If you install solar panels on a moving vehicle, adding heavy batteries is not an attractive option. Lithium-ion batteries are considerably lighter.

They last much longer. These batteries allow the system to pull more of the stored energy from them before they require more charge to be put in. This is known as a higher depth of discharge, and it helps to lengthen the battery's lifespan because it is charging in a significantly more efficient way.

This is attractive for very obvious reasons, making you less dependent on society, reducing the environmental footprint of the materials you use, and costing you less money in replacing parts of the system.

Cons:

There are also a few disadvantages associated with these batteries, in spite of their popularity, including:

- They cost significantly more than other batteries
- They are more of a fire risk

Let’s explore in more detail.

They are more expensive. Although this is the case, it’s important to remember that some of this cost will be offset in the long term by their increased life expectancy. They do cost more to buy, but they should last longer, making them more comparable despite the upfront costs. However, you will still need to be able to afford those upfront costs to install these in your system.

If you are on a tight budget, you may find that you have to purchase a cheaper battery, at least initially. You can then save up for a more efficient battery in the future if you find that this is possible, and choose this option then. In general, this is the biggest reason to avoid purchasing a lithium-ion battery when you first start setting up your system; these batteries are almost always considered superior to the other options in every way except the cost.

They are more of a fire risk. This might sound like a considerable downside, but it should be noted that although lithium-ion batteries do pose a slightly bigger risk of catching fire, this is only the case when they are improperly installed.

The risk is caused by something known as thermal runaway, and in most setups, this will not be an issue. As long as you thoroughly research how to set these systems up or you hire professionals for this part of the job, you should not have any problems. However, it is still wise to have good fire detecting equipment and an alarm that is regularly checked so that you further minimize any risk of fire damage being caused by these batteries.

Don’t install lithium-ion batteries without having a good understanding of what you are doing, and you should not have any problems with the fire risk.

Overview:

In general, lithium-ion is the most promising and useful battery for at-home use, especially in off-grid setups where space is very limited. If you don’t have room for large battery banks and you are looking to minimize the weight of your home (in a mobile setup, for example), then lithium-ion batteries are certainly the best option in almost every given scenario. This is true despite the cost.

FLOODED LEAD-ACID BATTERIES

Also, in common use, lead-acid batteries have been the standard for many years, and although they suffer from quite a few disadvantages, they are a reliable storage solution that has stood the test of time. We’ll look at flooded and sealed lead-acid batteries, starting with flooded.

Suppose you cannot afford lithium-ion batteries and you have a stationary off-grid home. In that case, these are certainly a reasonable alternative, and they remain popular in solar panel systems despite their disadvantages. Let’s explore the benefits and drawbacks.

Pros:

- They are a reliable and much-tested solution
- They are pretty easy to recycle
- They tend to cost less

They are reliable. These batteries have been used for a long time, partly because they are highly dependable and very stable. This makes them suitable if you are heavily dependent on your power system and have a viable space for them (see the cons list to understand what this entails). In some circumstances, they are the preferable option.

They are easy to recycle. The disposal can be a major issue for some kinds of batteries, and if you are setting up a solar system with the well-being of the planet in mind, this really matters. Fortunately, these batteries are easy to recycle.

They cost less. Cost is probably a huge factor in your setup, and a flooded lead-acid battery is highly appealing if you are on a budget because the upfront cost is far lower than that of other batteries.

Cons:

- They are bulky
- They need to be stored upright in a ventilated, temperature-controlled area
- Their depth of discharge is poor
- They don’t last as long as other batteries
- They need maintaining

They are bulky. In many off-grid setups, size really matters, and these batteries are not small. A bank of these will require plenty of space, and because of the poor depth of discharge, you will need more than one battery.

They need special storage conditions. Many off-grid setups will not have a suitable spot for these batteries. They need to be kept in a ventilated space and sensitive to temperature fluctuations. You cannot store the batteries sideways, making them even trickier to assign space. If you own land and have a dedicated building that you can place them in, this may work, but they aren’t suitable for off-grid homes in many cases.

They have a poor depth of discharge. As mentioned above, the depth of discharge refers to how much power you can pull from the battery before it

needs more power to be put in. With a low depth of discharge, these are inefficient – and will die more quickly.

They don’t last well. Contributed to the depth of discharge, they have a relatively short lifespan, which decreases the attractiveness of the low starting cost. The lifespan will depend heavily on the usage and the individual battery, but it can be as low as two years (some batteries lasting more than twelve years).

They need maintenance. You will need to top up the water as it is lost from the battery to keep it operating correctly, which has an ongoing cost in terms of your man-hours and possibly your water supply (if this is limited).

Overview:

There are some scenarios in which a flooded lead-acid battery is the best option, but in general, you will find other solutions better unless you are on an extremely tight budget and you have a suitable space for them – in which case they become attractive.

SEALED LEAD-ACID BATTERIES

In a low-maintenance version, the sealed lead acid batteries don’t require you to top up the water and do not have a high risk of toxic gasses escaping while the battery is recharged. Otherwise, these share similar advantages and disadvantages to the flooded lead-acid batteries, although they may be somewhat more expensive and have a reduced lifespan overall.

These batteries are similar to car batteries, although they are usually considerably larger.

NICKEL-CADMIUM BATTERIES

Another battery that has stood the test of time and improved significantly in recent years, nickel-cadmium batteries (Ni-Cd batteries), are also an option. Still, they are not allowed in some countries due to high toxicity levels.

They are still available in the USA, but you should consider the environmental impact of selecting one of these batteries; they are generally considered a poor option.

Pros:

- Reliable storage solution
- A very durable battery that should last long
- Not affected by temperature extremes

They are reliable. This technology has existed for over 100 years, so it is considered very reliable, and it has been well-refined.

They are durable. On the whole, these batteries are built to last, and they will handle being bumped occasionally without any issue. Depending upon your setup, this could be significant.

They aren't affected by temperature. If you don't have a means of protecting the batteries and you want to mount them outside, this could be significant, especially if you live in a very cold or very hot place. Protecting other batteries from temperature damage will be critical, but nickel-cadmium batteries are good at coping with temperature changes.

Cons:

- The toxicity levels are high
- The battery is tough to recycle
- The battery must be discharged before it can be recharged, affecting the storage space

They are toxic. Many people have moved away from these batteries for both health and environmental reasons.

They are hard to recycle. Tying in with the above point, the end-of-life of these batteries is very bad for the planet. Few – if any – of the components can be removed and reused, so these batteries tend to end up in landfill sites. Because of the toxicity, this is a massive problem.

They need to be fully discharged. This is another huge issue, as you will generally want your solar panels to top up the battery whenever energy is available. However, nickel-cadmium batteries often "remember" the point from which they were last recharged, preventing them from being recharged effectively by the panels. This massively reduces the storage space that they offer, making them a very unattractive solution.

Overview:

In general, you will find that other options are far more appealing than nickel-cadmium unless your battery bank cannot be protected from the elements by any means. In these scenarios, nickel-cadmium batteries may remain a viable option.

WHICH SPECS SHOULD YOU LOOK AT?

Even once you have chosen the type of battery for your off-grid home, you will need to look at the various batteries within that category and the specs they can offer you. It is important to narrow down the category first. The comparison is simply too huge to deal with, but now that we've looked at categories, let's explore the specs and which ones are particularly important when you're shopping for a battery.

Capacity:

Potentially the most important element in choosing a battery is its capacity. This means the maximum amount of energy stored in that battery. When the battery is full, your solar panels will not be able to store up any more energy.

It is imperative to look at this number and measure it against your needs. Suppose your battery cannot hold enough power to be helpful. In that case, it will constantly cause problems within the system, and you will find you perpetually run out of power when your solar panels aren't operating (e.g. overnight).

Make sure that your battery can manage for at least one night, or consider the minimum power storage acceptable for you. This calculation should be

reasonably easy to do when you know approximately how much power you will use during 24 hours.

Stackability:

If you buy a battery, it is always worth thinking about the future and what you may need then. It is beneficial to expand your energy storage system later, so it is important to look at whether your solar batteries are stackable.

This may not be a deciding factor, but if you want to build a large power bank, it is worth exploring stackability and ensuring that your battery can be expanded when necessary.

Cycles warrantied:

All batteries have a set number of times to recharge and be fully powered. This number varies according to other stats, but it's imperative to consider the number of recharges guaranteed by the manufacturer.

You will constantly be draining and recharging your solar battery, and over time, the amount of power it will hold (and how long it will keep it for) will decrease as the battery becomes less efficient. Usually, manufacturers provide a warranty that tells you how the battery will perform after several charging and discharging cycles.

Looking at this number will give you a good idea of how long the battery should last, which will help you to choose a high-quality product that suits your needs. Remember, batteries with better guarantees are likely to cost more upfront but should not need replacing as quickly and will usually offer protection if something goes wrong with them.

Power rating:

You need to know how much power your battery can supply to your system all at once. A battery may have a significant amount of energy stored in it, but if it only outputs this at a trickle speed, it will not supply all your appliances at once. This is particularly true if you have devices that demand a lot of energy, such as vacuum cleaners or fridges.

You should look at the kilowatts that the battery you consider can provide. Often, you will find two different power ratings: one is an "instantaneous

power rating", and the other is a "continuous power rating." As you might expect, the continuous power rating tells you how much the battery can supply if it is steadily drained. The instant power rating tells you how much power the battery can give in one short burst. This is useful if you have appliances that require a lot of power to start up but little while running.

Familiarize yourself with both of these stats and factor them into your equation to know what power rating you need to get the most from your system.

Battery size:

This will matter a lot more in some setups than others, but it is important to bear the size of the battery in mind when you're weighing up your options, especially if space is limited in your home. You need to minimize how much you dedicate to your battery bank, as this will be a permanent feature of the system.

Even if you can tuck it out of the way, it's a good idea to look for small, compact, lightweight batteries, especially if you are operating a mobile home rather than a fixed off-grid setup. Of course, this does cost more, but it's generally worth the extra expense to give yourself long term convenience.

SUMMARY

In this chapter, we've covered:

- The different kinds of batteries, including lithium-ion, flooded lead-acid batteries, sealed lead-acid batteries, and nickel-cadmium batteries
- The advantages and disadvantages offered by each kind of battery, as well as the situations in which they are most likely to be used
- The specs you should pay attention to when choosing a battery to ensure you get the correct one for your needs

In the next chapter, we will move on to looking at solar panels and how you can choose the perfect solar panel for your system. We'll look at the

different price options and the different kinds of technology available, simplifying the various kinds you can choose from so that you know which is right for you.

4

CHOOSING THE RIGHT SOLAR PANEL

> *“Solar power is the last energy resource that isn't owned yet – nobody taxes the sun yet.”*
>
> — BONNIE RAITT

You are probably already aware of how important it is to get the right solar panel for your system and energy needs. *Not doing so could undermine your entire system and make it almost useless to you – but how do you pick?*

This technology has advanced at an extraordinary rate. While that means that we have access to technology that has made great leaps in terms of its efficiency, it also means that there is a lot of information out there, and much of it has become quite confusing. In this chapter, I will break down the different kinds of solar panels available and discuss why some are preferable to others, along with the situations you might want to use them for your off-grid solar panel setup.

Whatever kind of solar panel you decide to use, make sure that you do some thorough research around it to check that it exceeds your needs. You should always go for considerably more power than you anticipate needing, as this allows you to scale up if necessary, and the only downside is slightly increased upfront costs.

Aiming to hit the exact need may seem a more economical option because it means you are not purchasing equipment that you don’t require. Still, often,

this is a false economy because you will find that your system either fails to meet your needs (because you have underestimated them) or that it soon stops meeting your needs (both due to increased needs and degradation of equipment). It is important to remember that solar panels do not offer perfect efficiency and that the rating of the equipment is not what you will achieve on most days, even if you live in an ideal climate with excellent weather.

Provided that you over-estimate your needs, you should find that your solar panels can keep up, but if you under-buy in an attempt to keep your budget down, you may find that you have to completely rebuild the system and buy new panels because your original purchase simply isn't powerful enough. If in doubt, always choose the more powerful option because it is much better to have a system that is over-powered than one that cannot meet demand.

MONOCRYSTALLINE SOLAR PANELS

The most expensive kind of solar panel, monocrystalline solar panels, are also currently the best option on the home market (although some better ones exist for military use at present). They will offer you the best productivity for the space that they take up, so if you can afford them, these are generally the option that you should go for.

Pros:

- Currently, the best commercially available option for converting light into energy
- They do not need as much space to generate energy
- They last for longer than other panels
- They cope better with reduced levels of sunlight

They are currently the best option for converting sunlight into energy. Because they contain more silicon, they will work better, and they can achieve efficiency levels of up to 20% in some circumstances. This ensures that you get the maximum energy from whatever sunlight is available, which is optimal for your setup.

They need less space. Because the panels are more efficient, you need fewer of them overall. That means that although the panels are more expensive, you may not need as many. You will also be able to maximize the space you do have if it is limited and would not otherwise provide enough power (for example, on a boat's roof).

They last for longer. Like buying the best kind of battery, when you accept a higher upfront cost, you do enjoy reduced ongoing costs because the monocrystalline solar panels should last for considerably longer than other kinds of solar panels. Some manufacturers offer as much as a 25-year warranty, so if you are able to afford this kind of panel, it is well worth the investment and will probably mean that your system lasts for longer overall.

In general, this kind of solar panel should last up to 50 years.

They perform well in cloudy areas. Another advantage of the particularly efficient solar panels is that they will do well even when the weather is cloudy and dim. Where other panels may not produce any power because the weather is too bad, you will still be getting some charge from your panels, making them a significantly more useful piece of equipment, especially in some parts of the world where sunlight is more limited.

Cons:

- The price makes monocrystalline solar panel setups pretty expensive
- This kind of panel has very wasteful manufacturing processes
- They are the most expensive solar cells on the market and so not in everyone's price range
- The performance levels tend to suffer if the weather is hot. However, it is a small loss when compared to other forms of solar cell
- There is a lot of waste material when the silicon is cut during manufacture

The panels are expensive. As the most expensive solar panels on the market, these are not a great option for people on a tight budget. Although you will enjoy a product with a significantly longer lifespan, it is still a

problem if you don’t have a lot to spend on your solar panels – especially if you need a lot of them.

In general, the panels cost between $300 and $700 each, which can get expensive fast, especially when you take the other component costs into account.

The panels don’t like being heated. Getting really hot is not good for any solar panels, so this is not a major con. You will find that solar panels do much better when kept cool, but if you can’t avoid the system getting hot occasionally, these should cope better than polycrystalline solar panels do.

The manufacturing process is wasteful. One of the biggest cons of these panels, from an environmental perspective, is that they have a high material cost when it comes to manufacturing them. A lot of silicon is cut off because all four sides of the cells are sliced. This drives up the financial and environmental costs for manufacturing the panels, so if you are looking for both a cheap and a green option, these panels are not the right choice.

However, this balances against the increased efficiency, which means that they will always be creating more energy than their cheaper-to-manufacture alternatives. It isn’t possible to do a hard calculation on which is the better option, either environmentally or financially, because it will depend very heavily on the operating circumstances, but it is worth remembering that the high manufacturing costs (environmental and financial) will be offset at least to a degree by the increased efficiency and extended lifespan of the panels.

Overview:

Monocrystalline solar panels are the top technology in terms of solar panels, and that makes them preferable to pretty much every other option if you can afford them. Additionally, their space-saving is enormously attractive for most off-grid setups, as space tends to be more limited in places like RVs and cabins, so maximizing the efficiency is crucial to making solar panels viable.

POLYCRYSTALLINE SOLAR PANELS

Although they are similar to monocrystalline solar panels, polycrystalline solar panels are a preferable option for many people. They enjoy several advantages, as they are cheaper than monocrystalline solar panels, and they create considerably less waste in terms of their manufacturing.

Instead of silicon being cut away and therefore wasted, polycrystalline solar panels use up all of the silicon that is associated with manufacturing them, which makes them vastly preferable in terms of the “green” impact. Being greener and more affordable, they are an excellent choice, but they are not as efficient. They are still made using silicon solar cells, but these are cooled differently, creating multiple crystals rather than just one (hence polycrystalline vs monocrystalline).

Pros:

- They are a reasonably efficient way of converting sunlight into energy
- The manufacturing process wastes massively less silicon compared with monocrystalline solar panels
- They are considerably cheaper than monocrystalline solar panels
- They should last for at least 25 years

A reasonably efficient way of converting sunlight into energy. Polycrystalline solar panels suffer somewhat from negative associations because they were considered very inefficient in the past. However, they have been massively improved in recent years, and although they are still worse than monocrystalline solar panels, they are an excellent option. They can reach efficiencies of around 15 to 17%.

The reason the efficiency is lower is that having multiple silicon cells within the panel slows down the movement of the electrons, and therefore some energy is constantly being lost due to this resistance.

The fact that the silicon purity is lower also affects the efficiency, but overall, many people find these panels are a great choice.

The manufacturing process is less wasteful. Because the silicon is not as pure, all of the material gets used in the panel, massively reducing the waste. For a product that is often marketed based on its green credentials

and as a means of helping the planet, this is vastly preferable to the monocrystalline manufacturing process.

They are cheaper. This is a big factor in choosing the panels because opting for the expensive monocrystalline solar panels can massively increase your costs. In general, polycrystalline solar panels cost around $200-$500 per panel, which is significantly cheaper than the monocrystalline $300-$700, especially if you need multiple panels.

They last long. Like monocrystalline solar panels, polycrystalline solar panels should last pretty well – usually upward of 25 years. Many manufacturers offer guarantees about the lifespan of their products, so make sure you look at this when choosing your panels. Cheap panels with a very short warranty are not usually a safe gamble; choose slightly more expensive ones with a better warranty for peace of mind. You don't want to have to reinstall the whole system a few years down the line!

Cons:

- They are less efficient than monocrystalline solar panels
- They take up more space than monocrystalline solar panels
- They struggle in warm temperatures
- They (often) have a lower power rating
- They can be fragile

They are less efficient. As expressed above, the loss in silicon purity comes at a cost in efficiency. Where monocrystalline solar panels can achieve efficiency levels of 20%, polycrystalline will generally only reach 17% at best. While that may sound like a small difference, it can be surprisingly significant.

However, recent advances have been made in polycrystalline solar panels, and new processes are improving efficiency, closing the gap between the two kinds of panels and making polycrystalline ever more attractive (especially to those concerned about the waste produced by monocrystalline solar panels).

Given a few more years, it is likely that polycrystalline solar panels will draw level with monocrystalline solar panels or come even closer to

matching them.

They take up more space. Unfortunately, loss in efficiency means that you will need to dedicate more space to the solar panels in order to generate the same amount of energy. Suppose you have lost 3% efficiency (comparing a top polycrystalline solar panel with a top monocrystalline solar panel). In that case, you will need to either accept less power or build more panels to compensate for that loss.

In a confined setting, such as an RV, this may not be possible, which makes polycrystalline panels somewhat less appealing.

They don’t cope well with heat. All solar panels suffer in high temperatures, but polycrystalline solar panels are truer than monocrystalline ones. If temperatures in your area are regularly above 80 degrees F, you will find that polycrystalline solar panels do not perform well at all. They will lose a lot of efficiency whenever the weather is hot, decreasing the value of sunny days and making it hard to generate enough energy. The efficiency can drop by as much as 23% in hot weather.

They are not as powerful. Because polycrystalline solar panels are not as efficient, they are also less powerful on the whole. They will usually only have an output of up to 300 watts, although some expensive ones do have higher power ratings than this. If you need powerful solar panels, you may look at monocrystalline ones.

They can be fragile. Polycrystalline solar panels seem to be more vulnerable to physical damage than many other options. They are more likely to get broken if they get knocked, or something falls onto them, such as a branch.

If you regularly move around, you may be more concerned about physical damage. Equally, if you live in a heavily forested off-grid area, tree branches or even smaller debris brought down by high winds could do damage to your panels. This might lead to the need for expensive repairs or replacements.

Overview:

Polycrystalline solar panels tend to be one of the most popular options for home installations because they combine green manufacturing with low costs. This means they are a realistic financial outlay for many more households, making solar panels viable where monocrystalline would simply prove too expensive.

If you have enough space to set them up, these are likely to be your best option for generating solar power for your home, but you should be aware that they have not yet caught up with the efficiency offered by monocrystalline solar panels yet.

THIN-FILM SOLAR PANELS

As the most budget option, thin-film solar panels also lack efficiency (at least for the commercially available options) at present. Up until a few years ago, most had an efficiency rating below 10%, and even now, most are only able to achieve up to 13% efficiency, despite technological advancements.

Few residential installations with limited space will find that thin-film solar panels can generate enough energy to support a household, as they need a large area to make up for the inefficiency. However, if you do have a lot of space (for instance, on or around a fixed abode such as a cabin) and a tight budget, they may be worth considering. They can also be suitable in some limited space setups if you just want to generate a small amount of power – for example, on a boat, they might keep batteries charged and provide emergency power.

They also perform better in high temperatures than any other kind of solar panel, making them viable in warm climates.

It is worth noting that there are four different kinds of thin-film solar panels (Dye-sensitized Solar Cells, Cadmium Telluride, Copper Indium Gallium Selenide, and Amorphous Silicon), but they generally share their advantages and disadvantages, so we will cover them all in this section.

Pros:

- They offer improved temperature performance
- They are a cheaper option
- They can be made on flexible surfaces
- They often look more appealing than other solar panels
- They are lightweight
- They are less susceptible to getting dirty
- They are versatile
- They cope well with indirect light

They have improved temperature performance. Interestingly, although these solar panels are the cheapest, they are your best option if you live in a climate with consistently high temperatures. If you live somewhere like Arizona, with temperatures easily reaching the high 80s even in spring, these are certainly a good option to consider. Unlike monocrystalline and polycrystalline solar panels, they should not lose much efficiency when temperatures climb.

They are cheaper. Thin-film solar panels are often preferable if you are on a very tight budget because they will almost always win in terms of costs. Manufacturers offer shorter warranties for these panels, which reduces their costs, and the process of making them tends to be less pricey.

They generally also use fewer materials, and this makes them attractive from an environmental standpoint. However, it is important to note that the different thin-film panels will have different environmental costs, and Cadmium Telluride, in particular, has some problems. It uses raw tellurium, which is extremely rare on Earth. If you want to consider environmental costs, this needs to be weighed up according to the kind of thin-film that you wish to purchase.

They can be made flexible. This may not prove an advantage in some off-grid setups, but the fact that these panels are not rigid can be a massive bonus in certain niche situations. Unlike the rigid crystalline-based solar panels, they can be wrapped around surfaces and made to conform to rounded shapes. On a boat, this can be very useful.

However, you should note that this flexibility is only applicable during the installation, and once installed, they become rigid. They also do still tend to

be installed flat, like other solar panels, so unless your unique situation particularly needs a curved panel setup, you may not find this offers any particular benefits.

They look more appealing. Thin-film solar panels tend to have a homogeneous appearance, making them more attractive to look at. Polycrystalline solar panels, by comparison, create a mosaic of different colors because they are made from slices of silicon, and this makes them look messy and unattractive.

They are light. Depending on what the film is poured onto during the manufacturing process, thin-film solar panels can be very light. This may be appealing if you are in a moving vehicle and you don't want to add to your fuel costs by increasing the load with additional solar panels. Crystalline-based solar panels weigh considerably more, and although they will offset this cost in power savings, it is still worth bearing it in mind as something that adds to the fuel cost of moving and to the wear and tear on your vehicle.

The lightness of thin-film solar panels also means that they can be installed in situations where other solar panels would prove too heavy.

They are versatile. Because the film can be poured onto almost any surface, even something like paper, they are far more versatile than either of the other two panels. The film can be used to coat roofing tiles or roof substances (for RVs, etc.), making it even more subtle on top of your vehicle and taking up less space. However, remember that you won't be able to put things on the roof, even if your tiles/surface are coated, because you will block the light from the solar cells.

You can turn your entire roof into a solar panel using this substance, although it will admittedly be a less efficient solar panel overall, and this may prove fairly expensive.

They are good in indirect light. Although all solar panels require sunlight to operate, these far outstrip the competition when it comes to operating well with indirect light. If your roof is north, east, or west facing, there may not be enough sunlight for the crystalline-based solar panels, which is a good solution.

This also means that they operate better in states (or countries) with less sunlight and more rainy and cloudy weather because they will draw more energy overall, despite the decreased efficiency rating.

Cons:

- They are less efficient
- They require more space
- Other equipment may come at a higher cost
- They often do not last as long and may come with a shorter warranty
- The overall system can cost more, despite lower panel costs
- It is a relatively new technology
- Some of the thin-film substances raise toxicity concerns

They are less efficient. The biggest deterrent from installing thin-film solar panels is that they do not offer a good deal in terms of their efficiency. They are significantly worse than polycrystalline or monocrystalline solar panels. You will not be able to generate nearly as much power using them unless you have vastly more panels.

They need more space. To set up a viable thin-film solar panel system, you will need to install a large number of them, and this requires a wide area of uninterrupted space. This makes them unattractive for many off-grid setups, especially in the tiny home, RV, and boating areas. You are unlikely to have this sort of space to spare, and that means you will only be able to generate small amounts of electricity from your panels – which may not be enough to make the system worthwhile.

Other equipment will cost more. Frequently, the lack of space efficiency will also mean that you require a lot of other equipment, such as longer cables, more support structures, etc. This comes at an increased cost and can further reduce the efficiency, as you will have to transport the electricity over greater distances, which results in a loss. It is important to budget carefully when building a system using thin-film solar panels. Make sure that the apparently cheap solar panel cost doesn’t just win you over. Other expenses can add up fast.

They don’t last as well. This con may prove false as this technology is still being tested, but at present, it seems that thin-film solar panels do not last as well as either polycrystalline or monocrystalline solar panels. This is evidenced by the fact that they come with a shorter warranty. You are likely to have to replace your system much sooner if you opt for thin-film solar panels, which may mean greater overall costs, even if the upfront costs are lower.

In the future, this may change as improvements in technology are made, but at present, it seems that thin-film solar panels are not a lasting solution.

The overall system is more expensive. Often, you will find that despite the low price for an individual panel, your overall system costs more. This is because you will need so many more panels and the additional cost of equipment mentioned above. You may find that it is more economical to buy polycrystalline solar panels, even if the individual panels cost more.

Of course, this depends upon your setup and the prices in your local area, as well as the kind of thin-film solar panel that you choose. When looking at costs, try to consider the overall system costs, as well as the costs for the individual elements.

The technology is quite new. Thin-film technology is relatively new, and this means that there are quite a few unknowns in terms of operation, longevity, etc. It remains to be seen whether the disadvantages in efficiency can be overcome.

Some of the ingredients may be toxic. This is heavily dependent on the material that you choose, but there are certainly concerns about toxicity for some of these panels, especially Cadmium Telluride. These panels should not have any effect on residents when installed on rooftops, but it is still important not to dismiss the issues of Cadmium, which we discussed in the previous chapter on batteries.

Overview:

Although monocrystalline and polycrystalline solar setups tend to be better, there are situations in which thin-film solar panels are more attractive. They are more versatile and easier to find an installation spot for (if you only need a small amount of power), and they are considerably cheaper in terms

of their upfront costs. Crystalline-based panels will be preferable in many situations, but do not dismiss thin-film as unviable because they certainly have their uses.

SUMMARY

In this chapter, we've covered:

- The benefits and drawbacks of monocrystalline solar panels
- The benefits and drawbacks of polycrystalline solar panels
- The benefits and drawbacks of thin-film solar panels
- The different situations in which each panel might be most useful, depending upon your setup and where you are located

In the next chapter, I will move on to the other components required for a solar panel system, so we can break down the things you will need and help you understand how to choose the best of each kind. We'll look at wires, fuses, and inverters so you can fine-tune your system to maximize the power that you get and the convenience you enjoy.

5

CHOOSING THE BEST WIRES, FUSES, AND INVERTER

> *"Watch the little things; a small leak will sink a great ship."*
>
> — BENJAMIN FRANKLIN

The batteries and the panels are the most obvious part of your system that needs to operate well, and unfortunately, it is far too easy to focus on just those parts and forget about all the needed bits to make them run well. When it comes to building a solar panel system, you need to pay attention to the panels and batteries you buy, but you also need to think about every other part that makes your system work properly.

Think of it a little like the human body: you have vital organs such as the heart, the lungs, the kidneys, etc., but if you don't also have the veins connecting them and the blood running through them, they won't work. Similarly, if you don't choose the right wires, fuses, and inverter for your system, it will not work properly, if at all.

It's crucial to pay attention to this part because without these bits and pieces, your system could end up as an actual hazard.

In this chapter, we are going to look at:

- How to choose cables and wires that are the right size
- How to earth your system to make sure it is safe
- What to do about the risk of lightning

- How to specify your inverter and the charge controller
- How to pick fuses that are the right spec for your system

This should put you in a great position to build a functional, efficient, and safe solar panel system that will make life easier for you off the grid.

CHOOSING CABLES AND WIRES

What Is The Difference Between Cables And Wires?

Many people use these terms interchangeably, but they are not actually the same thing at all, and it's important to understand the distinction.

A wire is a single conductor; it is just one strand of metal. Multiple wires can be twisted together and sometimes have a thin layer of PVC to cover them. Wires are measured according to their diameter, using a gauge number. Smaller gauges indicate thicker wires. Larger wires (with smaller gauges) carry more current, so the thicker your wiring is, the more dangerous it becomes to handle.

Cables, by contrast, are groups of conductors and will usually be covered by an insulation jacket (often thick rubber or something similar) that protects the cable and holds the twisted conductors together. Cables tend to contain a hot wire which transports the current, a grounding wire which makes the system safe, and a neutral wire that completes the loop. The wires making up a cable can have different gauges, and usually, the number of wires will be used to classify the cable.

Why Does It Matter?

Your first question when you start a section on choosing the correct cables and wires is likely to be why it matters what the size is and whether you use cable or wire. It matters because you will minimize both heat issues and energy loss if you choose the correct size. A wire that is not sized correctly will get very hot and could create a fire risk – so it's not safe to use wires or cables until you know what size you need.

How Do You Choose?

The size of the wire will be heavily dependent on the amount of power that your solar panel can generate. Larger amounts of power require bigger wires to carry them, or the wire will get too hot.

The distance also matters a lot. If you are transporting electricity over long distances, you need bigger wires to do it, so if your system is spread out, larger wires will be needed. Be aware that this will usually cost you more, but using small wires is unsafe, so this is not an area where you can cut costs by using different materials. The wires and cables must be sized to match your solar panel if you want the system to be safe.

Often, you will be using a multi-stranded cable with flexible wires inside, and it's a good idea to stick to the standard colors for your country to ensure that there is no confusion for either you or anyone else who looks at it later.

If any of the cabling runs outdoors (at least some is almost certain to do), you need to make sure that its coating is weatherproof and resistant to ultraviolet light to ensure that it will last well.

To calculate the thickness of the cable required for a task, you will need to have two pieces of information: the maximum number of amps it will carry and the distance that it will carry it.

You can calculate the maximum current by inspecting your appliances, which should tell you what you require. If your appliance only offers information about the watts, divide this number by 12 for 12V appliances and 24 for 24V appliances.

To calculate the distance, use a flexible measuring tape to check how long the cable will be. Remember, the longer it is, the greater the power loss will be. There are many tools online that will help you to calculate cable thickness according to these two stats, and you should ensure that your voltage drop is not more than 5% (or you will simply be wasting a lot of power).

Remember, a thicker cable is always preferable to one that is too thin. It will not carry any disadvantages besides slightly increased upfront costs, and it may last better overall. Don't ever opt for cables or wires that are less than what you need because you then have reduced efficiency and an increased risk of fires.

EARTHING THE SYSTEM PROPERLY

Even if you live in an area that rarely experiences electrical storms, you must make sure that you correctly ground your solar panel system. Not doing so could lead to the destruction of the system and its components and even fire and further damage to your home. An unearthed system is extremely unsafe and is not something that you should consider installing. As well as lightning strikes, an unearthed system is vulnerable to short circuits, which could also be very dangerous.

Grounding a system means that you create a “path of least resistance” for the electricity to follow when lightning strikes (or surges through a short-circuited system). This prevents the power from racing through your system and creating a surge that will knock out and damage the various components, and instead channels it into a safe area.

To ground a system, you will essentially be connecting every component using a piece of bare copper wire, which is then connected to several copper pipes that are buried in the ground (we will cover grounding mobile systems shortly). When the lightning strikes, it will follow the least resistant route to the earth, and therefore it will run through this copper wire and into the pipes, getting safely channelled away from your equipment and your home.

If you are creating a solar panel system in a home that already has a grounding system established (perhaps because of previous on-grid electrical connections), it is very important to tie the two systems together so that your solar panels use the same grounding system as everything else. Not doing so creates a risk of the electricity behaving in unpredictable and dangerous ways, so make sure you implement this with your setup. Do not create a separate grounding system for solar panels if a grounding system is already in place.

Of course, you cannot use this system for a mobile setup because you are constantly moving, so you can’t bury a series of copper pipes 6+ feet underground. Many people do not bother to ground their solar panels when they add them to something like an RV, but it should be noted that this is extremely dangerous, and you should not do it. You are at risk of getting a

serious and possibly deadly electric shock if you touch the hull when it is wet, and there is any power leakage from the solar panels.

You will need to attach the panels to your RV's grounding system. To begin with, locate the grounding lug, which is usually near the bottom of each panel and should be marked. Attach your grounding wire to this lug, and connect this to the rest of the panels using a series connection (not a parallel connection).

Next, you will need to connect this to the metal of the chassis (where there is no paint, plastic, or anything else to interrupt the flow of electricity). You should make at least two connections to allow for failures. When you have done so, your system is grounded.

Similar systems can be set up for boats by simply linking the solar panels into the existing ground system.

Never set up and use a solar panel system that is not grounded. Although you may only have a small number of panels on a mobile vehicle, it is still crucial that you protect your system, your home, and yourself from the dangers of surges, and you can only do this by ensuring that the system is earthed correctly.

REDUCING THE RISK OF LIGHTNING

As well as grounding your system, you should also take steps to try and reduce the risk of lightning striking it in the first place. You may not feel this is necessary for your area, but it is worth doing; climate change creates unusual weather patterns across the globe, and although grounding will make the system safer, a lightning strike could still cause damage.

Fortunately, there are a few things that you can do to reduce the risk of lightning striking your solar panels, so let's explore these next.

One of the first pieces of equipment you may wish to install is a lightning arrestor. These are designed to help the surge bypass all the wiring and equipment, and you should install them at either end of any significantly long pieces of wire in any part of your system. You can get these in various

voltages, and they will absorb the spikes, protecting your system from being damaged by having too much power put through it.

You may also wish to install lightning rods, but these will only work if you are looking at a static off-grid setup, as they are again intended to be connected into the ground. Their job is to provide a safe path for the lightning to follow, redirecting it safely into the ground. They also discharge any static electricity that buildings up around the panels, which helps reduce the chance of lightning striking in the first place.

In general, lightning rods will only be used in areas with extreme electrical storms, so you are unlikely to need these for your setup, especially as you will probably only have a relatively small number of solar panels, and they, therefore, may carry a low charge.

CHOOSING AN INVERTER AND CHARGE CONTROLLER

The inverter and the charge controller are crucial parts of your solar panel system, too, so you need to take the time to choose well.

To recap briefly, the inverter converts DC to AC so that you can attach home devices to it. The charge controller is used to stop the batteries from getting overcharged by your solar panels (overcharging will destroy the battery much more quickly than if it is charged to the correct level).

Inverters

There are a few different kinds of inverters, and they have different pros and cons.

String inverters are the most basic, and they are formed from chains of panels that are all connected up into a series. The panels must all be orientated in the same way to maximize efficiency.

Microinverters have an inverter in every panel, rather than one inverter to all panels. These tend to be hooked up to a computer system to identify and rectify any issues quickly.

Optimized inverter systems are a hybrid version of these two systems. They have optimizers behind each inverter panel, which isolate failures and

provide a steady voltage to the central inverter (which increases the efficiency). Again, these are connected to the internet to deal with faults quickly.

As well as the kind of inverter you buy, you also need to think about its size. Often, you will only need a small inverter for an off-grid home because you will be using small amounts of power, but as always, it is better to have a large inverter than one that cannot keep up with your system. However, a huge inverter will cause a reduction in efficiency levels if you don't need it, so you should aim to be as close as you can to your needs.

Inverters are rated both in Continuous Watts and Surge Watts, and you need to pay attention to both of these statistics.

The measure Continuous Watts lets you know how much the inverter can handle consistently. If you have a 1000 watt inverter, it can supply a steady 1000 watts. Larger inverters will supply more.

Of course, you are unlikely to be running just one thing from your inverter, so make sure that you add up the Continuous Watts of all the appliances that you want to use at one time. This will let you know whether your inverter can handle the demand or whether you need a more powerful one.

Surge Watts lets you know how much power your inverter can offer in terms of a surge. This will be higher than the Continuous Watts rating and lets you know what the inverter can handle in a short burst. Many appliances take significantly more power when booting up, which is the "surge" power.

If your inverter struggles when you try to start up an appliance that has a high startup demand, you may need a more powerful inverter. The Surge Watts rating needs to be higher than the greatest draw of your appliances' surge watts rating. This can usually be found on the stickers on the backs of appliances or in the instruction manual.

Add up all the devices that might be powered up at once, and this should help you to calculate the Surge Watts that you need for your inverter. If the surge watts add up to 5000 watts, you will need an inverter with more than 5000 watts.

Charge Controllers

The charge controller is another vital component that needs to be chosen correctly. This serves several jobs, all of which help to make your batteries last longer and function well. Batteries are often among the most expensive components in any solar panel system, so this needs to be chosen with care.

Typically, a charge controller will be placed between the battery bank and the solar panels. It limits the amount of power that goes into the battery and how fast it goes in. This prevents the batteries from getting overcharged, damaging them and reducing their overall life expectancy. A battery that gets overcharged can even explode, so this is a pretty major job, and you must have a reliable charge controller.

Furthermore, the charge controller prevents the battery bank from getting drained too heavily by your system. It does this by measuring the battery's voltage and disconnecting it when it drops below a certain level. This stops the battery from being completely drained (which would reduce its overall capacity and reduce the effectiveness of your system overall).

Finally, a charge controller stops any reverse flow going into your solar panels at night when they are not charging. This prevents damage to them. Therefore, the charge controllers protect the system in several different ways – *so how do you choose the correct unit?*

Your charge controller needs to be able to handle more energy than your solar panels can generate, and again, it is better to have one that allows a bit more than you need, as this will ensure it can cope with any spikes.

As I mentioned in Chapter One, a particularly common kind of charge controller is an MPPT (Multi Power Point Tracking). These are generally used if you have solar panels with much higher voltages than your batteries – up to ten times higher. None of the current will be lost in pulling this down to the right level for the batteries, and this makes the controller very efficient (often between 92 and 95%).

To size an MPPT controller, you just need to select one that is higher than the maximum full potential of the solar panels. Unlike a PWM (Pulse Width Modulation) controller, an undersized MPPT controller will not damage

your system, but it will prevent you from getting the full benefit of the energy your solar panel's output.

To maximize efficiency, you need to make sure that the MPPT controller is capable of outputting a voltage at least as high as your battery’s rating and that it can handle sufficient current to transfer all the power generated by your panels at that voltage. As the power transferred through a wire is equal to the voltage times the current, you can calculate the necessary current capacity by dividing the power output of your solar panels by the voltage of your batteries.

If your solar panels output a maximum of 1000 watts and your battery can handle a standard 24 volts, the current needed to transfer all of that power to the battery without exceeding the voltage would be calculated by dividing 1000 watts by 24 volts, which equals just under 42 amps. When in doubt, it is best to round up the calculation.

Most standards suggest that you then increase this by an additional 25% in order to handle any spikes in power that may occur, meaning the optimal MPPT controller, in this case, needs to be capable of handling at least 24 volts and 53 amps. This will ensure it functions at maximum efficiency even when your solar panels are outputting the maximum power.

The other option is a PWM controller, but this does only achieve efficiency levels between 75 and 80%. To size a PWM controller, you should look for one that has a voltage rating and an amperage that is higher than both your battery and your solar array. Once you have done this, check what the rated current of your battery is, and again choose a charge controller that exceeds the amp rating for the solar array. 25% is usually a sufficient margin. Multiply the amp rating of your solar panels by 1.25, and then look for a charge controller with a higher number.

SELECTING FUSES FOR THE SYSTEM

To recap, the purpose of a fuse is to break the circuit if something is going wrong and the wiring is getting too hot. A fuse is a means of protecting the system from damage if it short circuits; it is a weak point that ensures the

system’s circuit will break before doing major damage to any of your expensive components.

You do not have to use fuses for a system to work, but they are key to safety and to protect your equipment. A system without fuses won’t blow if something goes wrong, which could lead to the whole setup catching fire because heat will continue to be generated in the wires until they are dangerously hot. Of course, you may be lucky, and this may never occur, but it is still very strongly recommended that you use fuses in your solar panel system.

Ideally, you should have fuses in three locations: between your battery bank and the inverter, between the charge controller and your battery bank, and between the solar panels and the charge controller. Having the “weak points” in these spots will ensure that no major components are likely to get damaged if something goes wrong with the system; This could save you a lot of money, making your home safer.

So, how do you choose the correct fuses? You need the right size: an incorrectly sized fuse will either fail to blow when something goes wrong (and therefore won’t serve any purpose), or will blow constantly even when nothing is wrong (which is extremely frustrating).

You will need different fuses for the three different locations; I will explain how to size each one below.

The fuse between the battery bank and the inverter:

This is often the simplest fuse size to figure out because your inverter will state what size is needed in its manual, and some inverters already have fuses or breakers built into them – in which case you should not need to add another. Before installing an inverter, check whether it comes with an inbuilt fuse or if you need to install one manually.

The fuse between the charge controller and the battery bank:

Figuring out what size fuse is needed between your charge controller and your battery bank should also be very simple once you know the amperage of your charge controller. If you have a 20 amp charge controller, you

should need a 20 amp fuse. There is no need to do a calculation here; just match the amperage and work correctly.

The fuse between the solar panels and the charge controller:

This is probably the trickiest of all the fuses in your system to make sense of, so be careful. Firstly, you need to look at how you have connected your panels (parallel, series, or series/parallel), as this makes a big difference to what kind of fuse is needed.

For parallel connected solar panels, the amperage of the panels adds up, but the voltage remains the same. In this case, you will need to add together the amperage for each panel and then add an extra 25% safety margin (per industry rules). This will give you the fuse size. If you have five panels producing 10 volts and 10 amps each, your total output would be 10 volts and 50 amps. Multiplying this by the safety margin of 1.25 equals 62.5 amps. You should always round up, not down, so a 70 amp fuse would be suitable.

For a series connection, the voltage is added up, but the amperage stays the same each time – which is why you need a very different calculation. To use the same example, if you have five panels producing 10 volts and 10 amps, your total output would be 50 volts and 10 amps. Again, take the amperage and multiply it by the industry safety factor of 25%. This would be 10 amps x 1.25. You should get 12.5, which translates into needing a 15 amp fuse (the nearest equivalent).

According to your specific setup, don’t neglect to do these calculations properly. It might look slightly complicated, but it should not take you long, and as you can see, it makes a big difference to the kind of fuse that you will end up using. If you don’t fuse this connection properly, a short circuit could destroy your panels and your charge controller, which would be very expensive to replace. It is a good idea to check instruction manuals for advice on fusing and look online to see whether recommendations have been updated since the time of writing.

SUMMARY

In this chapter, we've covered:

- The differences between cables and wires, and how to choose cables that are correctly sized for your system
- How to ground your system, both for stationary homes and mobile homes, and how to reduce the lightning risks
- The purposes of inverters and charge controllers and how to select the correct ones
- The fuses that you need and the various points of the system that will benefit from being fused correctly

Hopefully, you now feel that you have all the information required to calculate which components you need to create a functioning, efficient, and safe system.

In the next chapter, we will bring together the information contained in the previous chapters and unlock the steps for actually building a solar system. We'll look at the various setups that are workable and practical for RVs, boats, and small homes, and then we'll uncover the available connection methods. Hence, you know how to turn this theory into a functional system that will give you power wherever you are in the world.

6

BUILD YOUR OWN SOLAR SYSTEM

“I have no doubt that we will be successful in harnessing the sun's energy. If sunbeams were weapons of war, we would have had solar energy centuries ago.”

— GEORGE PORTER

You’re probably already aware that every solar panel system – especially the DIY ones – is slightly different from the others, even if most of the components remain the same. It’s vital to set up solar panels in a way that suits the environment they are operating in, and that means adapting the standards to make them work for you.

Now that we have explored in detail all the different major components of setting up a solar panel system, it’s time to look at actually setting one up. There is no point in knowing what kind of inverter and fuses you need if you don’t know how to mount the panels and set the system up, so in this chapter, that’s what we are going to start covering.

We’re going to explore the various situations in which you may be mounting panels. Although all the components are likely to be pretty similar whether you are creating your solar panel setup on an RV, a cabin, a boat, or somewhere else, the mounting options and methods will certainly change. At this point, therefore, I’m going to start breaking it down, so you know how to mount panels effectively regardless of the setup you have.

These are the steps you’ll be following once you have calculated the size of the system you need and chosen the components, ensuring you know what

you fit. Before you purchase anything, you should build a map of your system and check that everything works. You may find that while you wanted five panels, only four will fit on your roof – and this will change the calculations for every other aspect of your system too. Measuring up is a key part of building any solar system, whether on a boat or a mansion.

Remember to calculate for weight and physical size and check that your roof (or other fitting areas) is strong enough to hold the panels. Also, mark where you will need to drill holes for cables or fans and store the battery bank. You might find it helps to create a scaled model of your home and fit the components into it. This will help you to avoid any nasty surprises later.

Once you're sure everything fits as planned, you can start buying items. You don't have to have every component purchased and ready to go before you start setting the system up, but you should have a strong sense of the dimensions, cable lengths, and weight so that you know what you can fit where.

MOUNTING SOLAR PANELS ON AN RV

Step One: Measure Up. As mentioned, you will start by checking that all your components fit. It is best to begin by measuring the roof, as this will let you know how many panels you have space for. Try to avoid mixing and matching solar panels of different sizes, and make sure you take into account vents and aerials, as these will need to be worked around.

Step Two: Consider Key Questions. A few of the crucial elements you need to cover are:

- Will I fix the solar panels permanently, or do I want removable panels?
- Do I want to wire the panels in series or parallel?
- Do I need roof space for anything else, or can I dedicate all areas to solar panels?
- What tools do I need, and do I need to buy or borrow any?
- How am I going to get access from inside the RV?

Step Three: Purchase Your Components. Ideally, you want to have as many necessary components as possible before you start. This will let you layout a skeleton design and check that everything is compatible and working before you start fixing parts of the system together. Any errors can be corrected, and you can ensure you're satisfied with the layout and compatibility before you start fitting the system. This will also allow you to return any components that are not compatible and have been purchased in error and replace them if necessary.

Step Four: Assess Inevitable Damage. When installing solar panels, you will inevitably do some damage to your RV unless you have not yet kitted it out. If you are building the whole system from scratch, you should fit solar panels before you fit insulation and linings because then you can fit these around your cables. However, if you are retrofitting solar panels (as many people will be doing), you will need to assess how you can minimize the damage and cost up any repairs that need to be done after you have finished the fitting.

Step Five: Assemble Components And Purchase Extras. As well as all of the components discussed in the previous chapters, you will need some other bits and pieces for fitting everything together. You should have:

- Solar panels
- A solar charge controller
- A battery bank
- Solar mounting brackets (for fitting the panels to the roof without drilling holes in it)
- MC4 connectors (for extending solar cables safely)
- Solar cables (for carrying the current from solar panel to charge converter)
- A solar panel gland (for sealing the hole around the cables that run from the panels into the RV)
- Fuse holders and fuses
- Battery cut off switches (so you can isolate the battery if necessary)
- Battery terminal eyes (for connecting the solar panel cable to the battery)
- Heat shrink (for joining bare wires)

Step Six: Test Your Equipment. Before you spend time putting everything together, it's a good idea to test that everything you have bought is in working order so you can return any faulty units without having to spend hours undoing your work; This can make a huge difference if you are unlucky enough to end up with something faulty.

Step Seven: Install Your Battery. Start by installing your battery, isolator switches, and fuse holders. Your battery should be fitting in a secure area and firmly fixed down so that there is no risk of it moving or falling while you are travelling or in the event of an accident. You should attach it to the hull of the RV, rather than any movable internal components, and then make sure that you ground it promptly.

Next, fit the isolator switches and the fuse holders, but do not put the fuses in place yet. Test that everything is secure. Flip all isolator switches to the "off" position.

Step Eight: Fit The Solar Panels. It is best to do as much work as possible from ground level, but you will undoubtedly need to access the roof for this step. If possible, use cardboard templates to mark where your panels will fit and where the mounts should be attached, as this is easier than working with the panels directly and reduces the risk of damaging them.

Cables should be installed to be accessed when the panels are in place, especially when mounting fixed panels. You don't want to have to remove everything to change a cable.

Test each of your solar panels works well by placing them in the sun and using a multimeter; this is important to do before mounting them, as it could save you a lot of work if one of the panels is faulty.

Once you have done this, attach the mounts to your solar panels using the instruction manual. Usually, you will be using Z brackets, which will be fitted to pre-existing holes in the panel's frame using the supplied bolts.

Some people also use VHB tape and butyl tape on the bottom of the Z brackets to increase adherence to the roof.

This gives a better attachment because it adds thickness to the screw hole, and the butyl tape also waterproofs the hole that has been made, reducing

the risk of rust and water buildup. You may want to fit the panels without this tape, to begin with, to test that they fit well, and then add the tape once you are satisfied with the positioning.

Note that your brackets need to be mounted with maximum contact with the surface below, so work around any ridges or lumps on your RV roof. Don’t put mounts in positions that reduce the contact, or the mounts may come off, and the panels will fall.

Once you are ready, lift the panels to the roof and make sure that the cables are pulled free so they don’t get trapped underneath. Use a power drill to drive the self-tapping screws into the roof and check that each is secure. Your panels should be fitted tightly, with no wobbliness. You can add a further coat of sealant over the screws if you like.

Next, mark the holes for the cables, and then drill them. Fit the cable glands, prime and paint the hole edges to seal them. The cables will be added later.

Fit your solar panels to the mounts and check that they have firmly bonded in position. It is best to have at least two people for this job to pass tools and equipment up onto the roof while the other works.

Step Nine: Wire Up Your Panels. You may find that it helps to draw yourself a diagram to show how the panels should be wired before you start. Your panels will usually have a meter of positive and negative cable fitted to them, ready to use. If you need to extend this, make sure you use the correct connectors of a suitable voltage.

Attach the gland collars to the cables and double-check that all of your connections are correct and secure. Use the multimeter to ensure everything is working correctly, and then feed the cables through the cable gland and get the collars in position. Tidy up all of the wirings so that nothing is loose or trailing.

Step Ten: Install The Charge Controller And Inverter. This will be done inside the RV, and again, the charge controller and the inverter must both be securely fixed to a solid wall. Use the manufacturer’s directions to wire up the controller and the inverter, as the directions may vary from unit to unit.

Note that you may not need an inverter in an RV, as your RV's battery may already have one of these.

Finally, add your fuses, turn the isolator switches to "on," and test the system. If there are any issues, immediately cut the switch to the battery again, take out the fuses, and start inspecting the system until you can locate the issue. Once you have done so, rectify it and test again. Always test your system before a long trip to ensure nothing has come loose or been damaged.

MOUNTING SOLAR PANELS ON A BOAT

Some of the early steps for mounting solar panels on a boat will overlap with those for mounting on an RV – so check out the full instructions in the above section if you need more information. A few aspects mentioned there may not apply to boats, but most will.

Step One: Measure Up. As with mounting panels on an RV, you first need to measure up, but in this case, you need to first think about where you will be positioning the panels. This will depend heavily on the kind of boat that you have. Many people will mount their panels on the roof of the boat as this overcomes issues with shading and maximizes space, but there are some situations in which this may not be suitable.

If you have a sailboat, you might want to look at mounting the panels on the cockpit dodger, although you will usually need flexible panels to achieve this. Some people mount a panel on the stern rail, while others may even mount them on the deck.

Of course, there are some disadvantages to mounting the panels on your deck; you will encounter more shade, and you need to buy expensive, robust solar panels that will tolerate constant foot traffic. You also need to think about allowing for a little airflow beneath the panels.

Once you have decided which space is the most suitable for adding solar panels, make sure that you measure it accurately, taking into account any bars, poles, or other interruptions that will eat into the space available for

the panels. You should also pay attention to the curve because you must deal with this when mounting the solar panels.

Step Two: Consider Key Questions. See the RV section for some of the most important questions.

Step Three: Purchase Your Components. The components will be similar to those of other systems, but you should always look for marine-suitable options. Your solar equipment will be perpetually exposed to dampness and possibly splashing, as well as salt (if you ever set sail on the ocean), and that means you need to ensure everything will hold up properly. Do not use ordinary wire; you will need tinned marine-grade, or the wire will likely lose its conductivity after a few months.

Step Four: Assess Inevitable Damage.

Step Five: Assemble Components And Purchase Extras.

Step Six: Test Your Equipment.

Step Seven: Mount Your Panels. There are many ways to mount solar panels on a boat, and it will depend a bit on the solar panels you want to use. If you intend to go for a simple setup, you may find that mounting the panels on the boat's roof is the best option – and this will be similar to mounting them on an RV.

Again, it’s a good idea to use cardboard templates to see how the panels will fit, and this will also help you to determine whether the curve of the boat is going to cause issues. Any interruptions, like aerials, will be easy to spot if you lay the full solar panel system out in cardboard before adding the real panels.

Remember that if the solar panels will charge your boat’s battery, they will need to be connected to it, often involving drilling through the deck. You will still need a charge controller.

Again, you can use Z brackets or mounts that come with your solar panel if applicable. You will need to ensure that they are suitable for the surface you plan to attach them to. If the surface is curved, you may have to purchase mounts specifically designed to mount curves. Using mounts intended for

straight surfaces will result in poor adhesion between the panels and the boat, which could cause an accident.

Again, thoroughly seal holes with waterproof sealants, and make sure that the cable hole is fitted with a gland to prevent water from getting into the boat.

If you would rather not mount fixed solar panels on the roof of your boat, consider any of the following options:

- Purchasing marine solar panels with zips can be sewn to any fabric components of the boat (e.g. roofing). This keeps the panels out of the way and makes mounting them relatively easy. Remove the roof's fabric, measure up the panels, and sew them into place. They should be stretched taut once the fabric is reinstalled, but this is a great way to get panels out of the way and ensure they get plenty of sunlight.
- Mounting solar panels on a frame near the back of the boat. You will need to purchase a strong metal frame for your panels and ensure that this is very securely attached to the back of the boat. All cables must be protected from splashing.
- Mounting solar panels using Velcro. This method may sound unsafe, but Velcro's proper strength is viable for mounting flexible solar panels. You must maximize the security and always build in a margin for error when considering the strength of the Velcro, but this is another great way to attach flexible solar panels to fabric or another curved surface. Many boats are not flat, so this may prove preferable to mounting on a frame or using Z brackets. Velcro also makes the panels easy to remove or replace when necessary.
- Mounting with a strong adhesive. Many adhesives suitable for use on boats should be sufficient to hold flexible solar panels in place, although you should be aware that some airflow is needed beneath the panels. If you are going to stick them down, ensure there is a little sealant or something in the corners to lift the panels just slightly off the surface that they are stuck to. You should check on the adhesive frequently to ensure it has not become brittle. Replace it if it is showing signs of wear.

Any of these mounting methods should be suitable for use on a boat. It is always a good idea to test and then stress test your solar panels once they are in place to ensure that they will not come loose on a proper boating expedition. Try them out in rougher weather, and then check the adhesion when you next dock. If it is pulling away in any areas, look for alternatives. Many forms of sealant and tape will hold flexible solar panels in place on a boat.

Step Eight: Wire Up Remaining Components. Once your panels are in place, wire them up according to the manufacturer's instructions (and the RV guide above if necessary). You will still need a charge controller, but again, you may not need a battery inverter if you already have one on your boat.

MOUNTING SOLAR PANELS ON A CABIN

Mounting solar panels to a fixed, unmoving structure such as a cabin (or another form of tiny home) is often the best option because you don't need to deal with movement, dampness, salt, etc. However, you still need to set your system up carefully to ensure your panels are mounted securely and withstand strong winds, lightning, and general wear and tear. You also need to think about positioning; getting the panels angled to make the most of the sun is key because your building does not move.

Again, some of the steps will remain the same or be similar to the other two mounting situations.

Step One: Measure Up. You will need to get up onto the roof of your cabin to measure it accurately. Take into account chimneys, aerials, etc.

Step Two: Consider Key Questions. See the RV section for some of the most important questions.

Step Three: Purchase Your Components. The components will be similar to those of the other two systems, but you will need to purchase a battery inverter because your cabin is unlikely to have one of these pre-installed. Make sure you add this to the list.

Step Four: Assess Inevitable Damage. You may be able to access the roof of your cabin without damaging anything, but if the cabin is insulated, you need to think about how to avoid or repair damage to the insulation. If you can, wire up your solar panels before you insulate.

Step Five: Assemble Components And Purchase Extras. Note that you may need to hire scaffolding to install solar panels on a two-story tiny home safely.

Step Six: Test Your Equipment.

Step Seven: Mount Your Panels. Because you are working with a fixed and (usually) more generous space than with an RV or boat, you may find that you have more mounting options. You are also less likely to encounter ridges or curves, although you might still have to deal with chimneys and aerials.

You can pick from various mounting options (I will cover some of them in the following section), but many people use bracket and rail systems. If you have a tiled roof, be aware that you will need to remove the tiles in places to attach the brackets to the rafters.

You will then be attaching a rail to the brackets, which will often run along the length of the roof. If you are only installing one or two panels, it may not cover the whole roof, but it will need to protrude a little beyond the panels so that it supports them fully, even if it contracts in cold weather.

Next, you should bolt the specially designed clips to the edges of the panels, attaching the panel securely to the rail. Make sure that each panel is secure before moving on to the next, and remember that it’s best to have a minimum of two people for this sort of installation, particularly if your cabin is more than one story high.

The cables behind each panel will be attached to the neighboring panels and then fed through a hole in the roof to the interior space, where your charge controller will usually be positioned. The advantage of the bracket and rail system is that it is very easy to remove the panels if they get damaged or need replacing, and it’s also fairly easy to extend it if/when you want to increase your solar power network.

Ensure that any holes are sealed with a waterproof sealant, and all tiles are replaced.

A similar method can be used for a wooden roof, but note that wood can be a trickier material to work with as it is sometimes brittle and at risk of cracking. More fire concerns are associated with using solar panels on wooden roofs, but this should be safe if installed correctly.

Step Eight: Wire Up Inside. Once the panels are in place and secure, you can connect the wires to two DC isolators and then, to the charge controller and inverter. According to the manufacturer's instructions, these should be wired up and fixed firmly to a wall in an accessible but out-of-the-way spot. You will only need to get to your inverter if something goes wrong or requires maintenance.

CONNECTION METHODS FOR MOUNTING SOLAR PANELS

As you have already noticed, there are many different ways solar panels can be mounted. I have explored quite a few above to offer you as many options as possible, but here are some of the commonest methods you might want to try. Because there are so many different circumstances in which solar panels can be installed, it's a good idea to understand as many mounting systems as possible so that you can choose the one that is the most suitable for your setup.

Above Roof For Tile/Slate Roofs: This is often inexpensive if your tiny home has a tile or slate roof, and it is also efficient because it allows for airflow (which helps keep the panels cool); This is the method described above, in which tiles are removed to allow brackets and rails to be attached to the roof. The panels are then clamped to the rails, and the tiles are put back. This method is great for traditional housing on pitched rooftops.

In Roof Solar Panels: This system is usually only suitable if you are redoing the roof from scratch; if you are, it is possible to build the panels directly into the roof; This has some cost savings because it reduces the amount of roofing material that you will need. However, it does not allow the panels to cool as efficiently, and it may mean you struggle when the panels need replacing unless you can get some with identical dimensions.

Solar PV Roofs: You can turn your entire roof into a giant solar panel if you purchase panels that have been designed for this. These are flat and can look attractive, but you will probably only find them useful if you build a cabin or tiny home from scratch. They are unlikely to work well on boats or RVs, as the roofs tend to be part of the vehicle's fabric already. You can also buy tiles/slates that will allow you to tile your roof with solar panels.

Z Brackets: If you want just to install a few panels, you may find that the rail system is overkill, and in that case, you could consider using Z Brackets. These are often suitable for boats, RVs, and tiny homes, and they can be effortless to fit. However, they will need the holes to be sealed, or they may compromise your roof.

Adhesive/Velcro: In some situations, Velcro and/or a strong adhesive will be sufficient for attaching small panels. This is usually only the case for systems that are lower down, as, on a house, solar panels will experience significantly more uplift (where the wind rushes under the panel and attempts to lift it away from the roof). It is not advisable to glue down solar panels (huge ones) to the roof of a house; you should mount them properly with metal brackets. If you use adhesive or Velcro, you need to stress test the system and ensure it is sufficiently strong, even in poor weather, and keep your panels securely attached.

Standing Seam For Metal Roofs: This generally involves clamping a U-clamp onto the raised seam and then attaching solar racking to it to mount the panels on. The advantage of this is that there is no need to drill into the roof. If you have a corrugated metal roof, you can similarly avoid much drilling by installing specially designed brackets over the corrugations.

SUMMARY

In this chapter, we've covered:

- A simple method for attaching solar panels to your RV roof
- The possible methods for attaching solar panels to your boat
- The commonest method for attaching solar panels to a standard rooftop of a cabin or tiny home

- Depending on your circumstances, some other attachment methods may prove viable in certain situations.

In the next chapter, I will look at some of the issues that you may encounter as you swap to off-grid solar power and how you can overcome these problems. It isn't always straightforward to make the switch, and you're bound to find you run into the odd hiccup along the way – but hopefully, I can talk you around or through some of these to make the experience the best it can be.

7

THE CHALLENGES OF SOLAR POWER

“It's really kind of cool to have solar panels on your roof.”

— BILL GATES

Solar power might be one of the “cool kid” things to do, and there are certainly very major benefits that you are probably aware of – but it is not without its faults, especially when you are building your system from scratch. In this chapter, I will run through some of the challenges you may encounter and how you can troubleshoot these issues to optimize your system.

Technical faults with solar panels are surprisingly rare if installed correctly, but many people experience both major and minor issues with their panels. Quick resolutions – or prevention – should get you back up and running as soon as possible, ensuring you get the most from your panels.

Nobody wants to be without their solar panels. Still, those who depend upon them in an off-grid setup are hit even harder by issues, so it’s important to spend a bit of time familiarizing yourself with what can go wrong and how to avoid it or fix it swiftly.

ISSUE ONE: ANIMAL INVASIONS

A surprising but common issue is animals taking up residence in your solar panel setup. This usually occurs in solar panel setups on fixed abodes, not mobile ones, but it is not unheard of for animals to nest among solar panels even when they have only been in place for a short period. This is particularly true if you have parked in an area with a lot of wildlife accustomed to human presence.

The commonest creature to find making a home for itself among your solar panels is birds. Because solar panels need to be slightly spaced out to allow heat dissipation, birds often build nests between the panels, where a narrow channel is perfect for nesting in. While this might sound cute, it can cause quite a few issues, and it isn't something that you should encourage.

Firstly, it often creates a lot of noise, especially if the birds successfully hatch and rear chicks. In a tiny home, you may sleep close to the roof, and this can be very frustrating if it prevents you from getting proper rest. Since many birds take weeks to hatch and fledge, it's also not a short term issue.

Furthermore, the nest and/or the birds could cause damage to the panels, especially if they climb on them or try to get underneath them. They may scratch the panels and get them dirty, which will reduce their efficiency, especially over a long time.

Additionally, if you are in a mobile home, you may not want to disturb the birds when the time comes to move again, and this presents a moral dilemma that is best avoided if possible. You don't want to be stuck on a campsite for longer than planned because you have a nest full of baby birds on your roof, and you feel responsible for their well-being.

Birds aren't the only issue, either. Other animals such as rodents could also use the panels for nesting, presenting even more serious problems. They might damage the wiring or chew their way into your home – both of which need to be avoided if possible. Squirrels and rats are unwelcome in most houses because they can be so destructive and may spread disease, so it's important to take action to protect your panels, your home, and your health.

The solution: Fortunately, there are a few things that you can do to prevent this. Installing coiled wire or mesh between the panels or blocking off access to the channels with plastic strips should stop the birds from building

nests there and prevent access for all but the most determined rodents. Some rodents may still chew their way into the space if they can smell food or are desperate, but the wire, in particular, should deter them.

If you end up with animals among your solar panels, it's a good idea to call a company to deal with them. This may not be an urgent issue, as most animals are unlikely to do severe damage in a short time, but you should still get professional help to remove them if possible. Acting promptly, especially for birds, may help the wildlife out because they will put less energy into building nests and laying eggs if they are removed quickly, rather than being allowed to start on a home before being disturbed.

If you have nesting birds on your roof, make sure you look into the legalities of moving them. Many species are protected by law, so prevention is much better than cure in this scenario.

ISSUE TWO: THE SOLAR INVERTER

According to Which, more than one in ten solar panel owners experience issues with their inverters.[1] Of course, this is a UK stat, but it's likely to apply similarly in the United States, and it highlights just how tricky this particular bit of equipment can be to make the most of.

Unfortunately, the solar inverter is also crucial for keeping your system operating correctly. Without it, you won't be able to use your solar panels for anything but direct current. Quite a few things can go wrong with a solar inverter, but it's important to note that some solar inverters don't last very well.

Because most solar panels have such long lifespans (20+ years), many people automatically assume that a solar inverter will do the same – but in fact, most solar inverters only manage between 5-15 years. That is a pretty significant difference.

A high-quality solar inverter should last for longer than a cheap one, but even so, it is unlikely that an inverter will last for as long as a solar panel will. Although inverters can be expensive to replace, you should recognize this likely cost and prepare for it. Check what warranty the manufacturer

offers before purchasing anything, and always make sure that it isn’t still covered before you purchase a new unit. It’s a good idea to set funds aside for replacing your inverter.

If your inverter is still working but is displaying an error message, refer to the manual for guidance on what’s wrong and how to fix it. You should check the fuses and ensure that breakers are not getting tripped. If they are, you will need to start testing various parts of the system to try and detect any faults that may have developed.

The solution: If your inverter needs replacing, you will have to buy a new one and wire it in. It is worth investing in a good inverter despite the upfront costs because this increases its chances of lasting well.

However, if your inverter displays an error, you will need to check the manual for information about what is going wrong. If the fuses keep blowing or other errors occur, make sure you test the system or get an engineer to inspect the system and diagnose the fault. Although this will cost you, it could also save you a lot of time, because it won’t always be easy to tell what’s going wrong.

ISSUE THREE: CORRODED WIRING

Like all parts of your system, the wiring is subject to failure. You should regularly check on your wiring, especially outside the home, because this is more likely to corrode. It’s essential to look out for loose connections when you do this general maintenance check, too. Try to do this every few months, or more frequently if you live in a very wet environment.

If you live on a boat, make sure that you increase your wiring checks' frequency and build this into your general “boat maintenance” routine. Any exposed wiring will corrode much more quickly than in a dry environment with constantly damp air.

Any corrosion issues should be dealt with promptly, as they could break your system, cause fire hazards, and reduce the conductivity. This decreases the efficiency of the solar panel, meaning that you are generating less

energy overall, even if the panels are still working. A lot of corrosion could have a significant impact on the system.

The solution: Make sure that wires are sealed in a waterproof casing. This is particularly important for wires outside of the home, but it should be done for all wiring. If you live on a boat, you need to be even more careful to look out for corrosion, both on wires and contacts. This will ensure that you can fix issues promptly and keep your solar panels at maximum efficiency. It is also important for maintaining safety.

Promptly replace any wires that have corroded, and turn the system off until you have done so, especially if the corrosion is bad. While it is unlikely to cause safety issues, it’s still better not to use corroded wiring.

ISSUE FOUR: CORRODED SOLAR PANELS

Solar panels can get corroded, too, although this will usually only occur if the panel gets damaged in some way. If something falls onto a panel, breaking the seal, water can start to seep in and corrode the components inside.

As with other corrosion, this can reduce the efficiency and may, in some cases, be dangerous. It is, unfortunately, also very difficult to fix.

The solution: This problem can usually be solved by replacing the solar panel. If you notice that your solar panels have been damaged by a falling branch or something similar, it is important to do a thorough inspection and take action if you find any sign of damage. If you have an off-grid system, you may depend on a constant flow of power, and a corroded panel could leave you in a difficult situation.

Some people claim that you can repair solar panels by sealing the crack, but this is not likely to work very well in most instances and will still result in reduced performance. A PV solar panel needs to be completely sealed to operate efficiently, so be cautious of attempting this. Most sealants will turn foggy or discolor in the sunlight that solar panels are constantly exposed to, which will reduce the panel's effectiveness over time.

If you are going to try to repair a solar panel, make sure you get the inside of it as dry as possible before sealing over the crack with your chosen material. This will reduce the risk of corrosion, but if it has already begun, it may not solve the problem.

A broken panel will need to be replaced. You may be able to patch it up temporarily, but at-home repairs are not likely to work for long. At present, there is no dedicated material for mending a damaged solar panel – especially once it has begun to rust internally.

ISSUE FIVE: DIRTY SOLAR PANELS

This might not sound like a very serious problem, but it can be a surprisingly big issue. Dirt and debris getting built up on the panel can dramatically reduce how much sunlight hits the solar cells, and this will reduce how much energy they generate for you every day.

If you live somewhere near a tree and the leaves blow onto the panel, or there is a lot of air pollution, or birds commonly perch on the panels, you may find that they quite quickly accumulate a film of dirt and leaves. A little dirt should not noticeably affect your panels, but if a panel gets very dirty (for example, from bird droppings or leaf litter), you will need to address this issue.

Similarly, if you are operating a boat with solar panels and are frequently out at sea, the panels will likely collect a misting of salt over a few months. This will also decrease the efficiency and reduce the amount of electricity your panels produce each day.

The solution: Cleaning the solar panels is usually fairly straightforward, although it can be more challenging to do safely if you have a two-story home. You may need to hire a company or at least some scaffolding to get the panels clean successfully.

Otherwise, simply get to the same height as the panels and clean them using soap, water, and a soft cloth. Do not use harsh chemicals or heavily abrasive materials on your panels, as you may scratch them or damage their coating;

soap and water should do the trick in most cases. Use an eco-friendly soap if possible to reduce the risk of damage to the environment.

If you are struggling to remove dried-on bird droppings or something similar, try leaving a wet cloth on the mess to help it soften, and then have another go at cleaning it later. I've found that being allowed to "soak" in this way helps to loosen almost all the dirt that might get onto solar panels.

Regularly cleaning your solar panels should make them easier to clean, whereas if you allow a thick coat of dirt to build upon them, they are likely to prove more challenging. It's a good idea to clean them with soap and water at least once a year, or more often if you live in a heavily polluted area. Remove debris such as leaf litter with a long brush as necessary.

ISSUE SIX: CRACKED SOLAR PANELS

Sometimes, your solar panels will develop cracks after they have been installed. Interestingly, this is often due to micro-cracks, which would have been present before you installed the panels but are not visible. These tend to occur during transportation, so choose a reputable shipping company for transporting your panels to you – or consider collecting them in person if you can use them so that you can minimize the risk of knocks occurring. Solar panels are unfortunately quite delicate, and it's effortless for them to get damaged in transit.

You may occasionally be able to see these cracks if you inspect the panels very closely before installation, but unfortunately, they are usually invisible. As time passes, they are likely to grow larger, and eventually, they will start to impact your solar panels' ability to generate power. When they are tiny, the impact will be exceedingly small, but as they get bigger, you might start to notice a drop in the efficiency of your panels.

It is somewhat unusual for panels to get damaged once installed as they are, in general, safe from sharp impacts that could harm them. However, falling branches, a thrown stone, balls, and other flying objects might cause a crack that was not there before installation.

The solution: Unfortunately, there is not much you can do about this sort of thing. You will simply have to replace the panel. The one upside to this is that the impact from most cracks will not be huge, so you do not need to rush to replace a panel before you can afford it.

ISSUE SIX: HOT SPOTS

I mentioned earlier how heat can be problematic for solar panels and losing efficiency when kept in warm environments. That's why hot spots are another important thing to look out for when it comes to maintaining your solar panels properly. A hot spot is an area on a solar panel overloaded. It becomes much warmer than the other parts of the panel while operating.

There are a variety of causes of hot spots, but you must do your best to mitigate all of them, both when installing and when maintaining your solar panels. Hot spots could reduce the lifespan of a solar panel and may also reduce its performance day today. They can cause short circuits and damage and need to be prevented or fixed if they occur.

Some of the common causes for hot spots include connections that have been badly soldered, debris buildup in areas of the panel, or structural defects. Partial shading can also be a problem to watch out for.

The solution: Sometimes, you will need a professional to work out that a hot spot even exists, but there are a few things that you can do yourself to reduce the risk of them occurring and fix them quickly if they do appear. The first of these is to make sure that you have soldered all connections thoroughly. Routinely check on connections and ensure that all are still firmly attached.

Secondly, keep your panels clean and free from debris, and where possible, remove items that shade the panels. This may not always be viable, but if not, consider repositioning a panel that gets heavy shade in one area consistently. This will help ensure that all solar cells within the panel generate electricity and spread evenly throughout the panel.

If you have fixed a hot spot, but the panel is still not performing as it should, you may need to consider replacing it. Hot spots can do severe

damage to solar panels, and once this has happened, there is little that you can do to solve the issue.

ISSUE SEVEN: INCORRECTLY ESTIMATING THE AMOUNT OF POWER NEEDED

This is a much bigger issue if you operate in an off-grid setup because it matters how much power you generate. If you have the grid's security behind you, it might be annoying not to generate sufficient power from your solar panels. Still, it is unlikely to have a considerable impact on your daily life – although you will have higher power bills as a result.

However, if you are operating off the grid, you have no backup if you need more power than you are generating. You are entirely dependent on your equipment and what it can create, and if you end up draining your batteries, you could find yourself without heat, light, and your cell phone at a very inopportune moment. If you are a long way from civilization, this becomes even more of an issue.

This is a common problem for people who rush into creating a solar setup experience, and it’s usually a result of not factoring in all the equipment you will be using. If you don’t count your fridge, laptop, air conditioning, or other major power drains, you may find your system is seriously under-equipped to meet your needs.

The solution: Fortunately, there are a couple of things that you can do about this problem, and these are best done in advance before you set the system up. It is sometimes possible to rectify issues with underpowered systems later, but it’s much better to plan first, even if you have calculated your power consumption accurately.

Before you decide what you need for your solar panel system, take some time to think about and list all of the equipment you use. You may find that it helps to do this over a few days or even weeks, writing down every electric device you utilize in that timespan. Think about different times of the year, too. *Do you have a plug-in heater for the winter? Will you have air conditioning running in the summer?* Get input from family or friends, and list everything that you can.

Once you have this list, add up all the power consumption and a safety margin. This covers devices you haven't thought of, instances in which you may use more power, etc. If a friend wants to charge their cell phone at your house, you don't want to find this throws your whole calculation out, so create a good safety margin of 25% or more.

Given your space and budget, this should give you a good idea of how much power you need to generate and how viable this is.

Secondly, think about making your system scalable. Wherever possible, purchase components that will allow you to upgrade and expand when necessary. Many solar systems are modular, meaning that you can add extra batteries, panels, etc., as you need to in the future. If you build a system with scaling it up in mind, you could save yourself considerable costs if you need to expand later.

Remember, it is always better to have a little more than a little less. You don't want to end up fumbling around in the dark in the middle of winter because you have miscalculated, and there are likely to be a few things you have not thought of during your calculation. Over-build and ensure there is scope to expand, and your system will hold up well.

ISSUE EIGHT: PID

You may have come across the term Potential Induced Degradation while looking at information about solar panels. This is an issue that can occur over the lifetime of your solar panel system.

Although you will have earthed your solar panels, you can run into this issue if there is a mismatch between your earthing and the amount of voltage generated by the solar panels. You may encounter some partial voltage discharge in the main circuit when this occurs.

This can lead to a loss in performance, and it can also damage the lifespan of your solar panels – obviously something that owners want to avoid. In some cases, the stray currents will damage your solar panels so much that you see a power loss as high as 30%. This will have a massive impact on your system.

It is worth noting that this issue is even more likely to occur in systems that are not earthed, so it provides another good incentive for properly earthing your solar system. It is both safer and protects your equipment.

Heat and humidity can also cause PID, and it is widespread, although not every solar module will encounter this issue. PID is not something that you will be able to detect visually, and it's quite a big issue for many solar systems. Because unavoidable environmental factors can cause it, it's challenging to prevent it.

The solution: In some cases, PID can be reduced if you can ground the negative DC pole in your inverter. Not all inverters allow for this, and you may need to get a specialist to do it, but it is one option for reducing or negating PID.

Another solution is to buy an "anti-PID box." This will need to be built into your system between the strings and the inverter, and it reverses the effects of PID (although if the effects have been long term, the damage will remain).

Alternatively, if you wish to prevent PID from occurring at all, you may wish to purchase solar panels that have been specifically designed to minimize the risk. These are available but are likely to cost more. Some frameless PV modules are at less risk of PID, but they cost extra and are heavier than standard panels.

High-quality panels are more likely to resist PID, so if you can budget for a more expensive panel, you may find it worth doing so. It is also worth discussing the PID resistance with the manufacturers and asking how their panels fare and what they do about this. Unfortunately, PID is a pretty complicated issue, and as yet, there are no simple solutions – although improvements are being made.

SUMMARY

In this chapter, we've covered:

- Some of the foremost problems that solar power systems suffer from over their lifespans
- Why this option may be worse if you depend on an off-grid system rather than being connected to the grid
- What you can do to prevent or solve these issues when they occur, so your system runs smoothly as much as possible

CONCLUSION

> *“We are star stuff harvesting sunlight.”*
>
> — CARL SAGAN

In this book, I’ve covered the foundations of how solar power works and how solar panels harvest energy from sunlight and convert it into electricity for our homes. I’ve talked about the differences between off-grid and on-grid solar setups, how to build a simple off-grid solar power system, and what the phases of installation will include.

We then looked in a bit more detail at the differences between power and energy to create a foundation from which to work through the rest of the book. Following that, we moved on to the basics of solar power and then delved into the equipment you will need and how to select the correct components to set up an efficient and functional solar power system.

I talked about the different kinds of batteries and how to choose the correct one depending on your setup and requirements. This section covered the differences between lithium-ion batteries, flooded lead-acid batteries, sealed lead-acid batteries, and nickel-cadmium batteries, suitable for various situations. With a little information about the environmental impact and the advantages and drawbacks of each, this has hopefully helped you establish which you could use in your solar setup.

We moved on to one of the most imperative sections next – selecting the correct kind of solar panel. Here, I offered information about the pros and cons of each and also took a brief look at the environmental impact of manufacturing the panels. I compared monocrystalline, polycrystalline, and thin-film solar panels and briefly discussed the situations in which each one might be the preferable choice. All of these have viable applications, even though thin-film is lagging in terms of its efficiency ratings.

After that, we delved into some of the other major components of a solar-powered system and how to choose cables, inverters, and controllers that are suitable for your system. This chapter also covered fuses and offered information on grounding a system to maximize its safety and limit the risk of lightning damage.

Following this, I talked about the various situations in which a person might be mounting solar panels on their roof and covered detailed instructions for mounting solar panels on RVs, boats, and cabins/tiny homes. I also looked at some of the things that you should do before installing them, such as measuring your space correctly and testing all the components of the system.

In the final chapter, we looked at some of the pitfalls that solar panel owners might experience, and I discussed how you could resolve these or even totally avoid them. Hopefully, this will give you a better experience with your solar panels, both now and for years to come, maximizing the efficiency of your system. By keeping your panels clean, looking out for damage, and replacing components when they wear out or run into issues, you can ensure that you are generating enough power to keep your off-grid home functioning fully.

This book should have given you everything you need to set up a solar panel system that is efficient and safe and maintain it in the future. Every one of these systems is different. The more unique and unusual your off-grid setup is, the more complicated you might find the installation process – but the principles offered here should apply to almost every situation.

Hopefully, they will guide you through the process and answer most – or all – of your questions about solar power.

Solar energy is an astounding resource.

Many people are astonished by how long it has taken humanity to start utilizing the power that this unique technology gives us access to. Instead of depending upon a renewable, free source that is available across the globe, we have focused upon non-renewable, unclean energy sources that have to be transported thousands of miles and are not available to anyone who isn't connected to the main system. This has left people tied to civilization or sacrificing the necessities of modern life – but fortunately, that's all changing, and solar power is becoming mainstream.

Getting off the grid is enormously freeing, will save you money, and is a step in the right direction for tackling climate change. It is probably one of the biggest things that individuals can do to help the planet and decrease their carbon footprints.

Solar power allows you to reduce your dependency on big energy companies and non-renewable resources, cuts your costs, and frees you to travel anywhere you want to go, so there's no reason to wait. It's also a valuable backup if you are off adventuring, even if you don't plan to use much electricity. Having a solar-powered system set up could save your life in a tight spot.

If you're ready to get started, I'd recommend you sit down and make a list of the appliances you use so you can begin calculating how much power you would need a solar system to generate and what sort of setup you would like to create.

Now that you have all the information you need, there's no reason to wait because solar panels are better than they have ever been, and most of the world is moving in this direction.

Let's bring the ingenuity of humankind to light and create our power from nothing but the sun!

THANK YOU

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