DO IT YOURSELF

GREEN POWER HOME

SOLAR SYSTEM

GO GREEN, SAVE MONEY, TIME AND THE PLANET;
INSTALL YOUR OWN HOME SOLAR SYSTEM

BOB HOPKINS

DO-IT-YOURSELF GREEN POWER HOME SOLAR SYSTEM

GO GREEN, SAVE MONEY, TIME AND, THE PLANET,
INSTALL YOUR OWN HOME SOLAR SYSTEM

BOB HOPKINS

CONTENTS

FREE GIFT

Bob has a gift for you, his Solar Payback Period Worksheet. You can it get by going to this website:

bob-hopkins.com

INTRODUCTION

“For they have sown the wind, and they shall reap the whirlwind.”

— HOSEA 8:7

Did you know that in 2020 alone, the average American household consumed over 10,000 kiloWatts of electricity? Collectively, we consumed 3,802 Terawatt-hours of electricity (Energy Information Administration, 2021). This is a staggering amount of electricity, more than a ninefold increase from the nation's electricity in the 1960s. It is not our electricity consumption that makes us responsible for the damage to the planet; rather, it is the way we produce most of this electricity.

The reason is that the major sources of energy meeting our electrical power needs pollute the environment. When a source of energy, such as coal, is burnt during the power

generation process, a lot of carbon dioxide is released into the atmosphere. Carbon dioxide, and some other gasses, form a blanket around the earth, resulting in increased surface temperatures and, more importantly, climate change. Sadly, most of the electricity produced in America is derived from non-clean sources of energy.

This doesn't mean that power generation is solely responsible for the levels of pollution reported by scientists. Among the polluting activities are transportation and manufacturing, but electricity generation is statistically the largest contributor to the pollution we are witnessing right now.

Despite several pleas from environmentalists, people remain ignorant or find it difficult to make the necessary changes. Sir Isaac Newton's third law of motion states that "action and reaction are equal and opposite." Based on this law that many consider a universal law, I think it returns the favor of whatever we do to the planet. Of course, what happens and how it happens is more complex than this. Still, I am using this law to illustrate the concept to individuals who may wonder why it is important to shift to solar or other alternative forms of energy. Nature will always fight back for as long as we continue to pollute the earth.

Most people ask themselves what can be done to stop this, and you probably have asked the same question too. One answer is that changing the way electricity is generated is important.

The philosophy behind this book is that if our collective consumption has resulted in the pollution of the air, then collective intervention can help restore balance to the earth. This is a sentiment that many people share, but the uncertainty surrounding the complexity of DIY installations

and the cost has led most people to fail to take action. Some do not feel confident that they can safely build their home solar system. This is understandable. Knowing what must be done is only half the job. I have had the privilege of learning about this in college, but you probably do not know where to begin if you are like most people. The cost of a professional installation of an alternative energy solution like solar is too expensive for it to be economical for the average person, despite the tax rebates. People also ask how a solar installation can be done cheaper. If you have asked yourself these questions, then the lessons contained in this book will be invaluable to you.

These lessons are based on my two decades of experience as a practicing engineer and thorough research. I have spent most of these years renovating my own homes and helping people become energy independent and efficient in their homes as an independent contractor. I am a practical and skilled individual, and my dirty clothes show it. Sadly, photographic proof of this cannot be published in this book, but I take it upon myself to make sure my houses are in tip-top shape and function efficiently for the good of my family and the community. If these are your values, too, then you will find the experience more rewarding beyond the savings to your pocket.

I have used my expertise to renovate countless homes and have been actively involved in installing solar panels on newly built homes in California. I know that anyone can benefit from my technical knowledge and professional experience to help other people and the environment because this is something I am passionate about and the motivation for writing this book. I will teach you how to properly design and configure your systems to meet domestic and small business power needs. You will learn

how to save money and the planet without wasting time and valuable resources.

A PEEK INTO OUR JOURNEY

This is a future-oriented book. Its goal is to give you all the information needed to install a home solar system. In it, we will consider the potential problems that you may encounter shortly. Cybersecurity is one potential threat that most home solar system installers fail to consider. It is important that we start our discussion with the basics of solar energy and why you should consider it before designing and installing your system. The idea is to equip you with the fundamentals. Perhaps you will be inspired to consider investing your time installing home solar systems for your family or friends. Available financial options are also discussed because the goal is to make some solar systems accessible to everyone. These discussions will be done in the first two chapters of the book. The subsequent chapters will teach you the factors you must consider when choosing your system components and for your system to perform optimally, as well as the options available to you based on whether you want to have a grid-connected system or an off-grid setup.

This, and other preferences, will determine the components you need to purchase and the skill level required to do a good job. Finally, we will demonstrate two sample projects to meet the energy needs of different homes. In between, we will talk about safety, cost-cutting tips, and regulations that you may need to follow, depending on your state and local authority. The content will include some brands to illustrate how you can use the manufacturer’s specifications when designing your project because you will do the same when you purchase your components. This

does not mean that the brands are endorsed in this book, and neither do I receive any commission from brands used to demonstrate the sample projects. Most of the top brands have been identified through research, although I will throw in some brands based on my personal experience with them.

The last thing you need to note is that we will only talk about solar electrical power in this book. Capturing thermal or heat energy from the sun requires different equipment.

Now, without further ado, join me in this journey where we talk about how to go green and save green using solar energy.

1

WHY HOME SOLAR

By now, you must already have an idea of why we must stop relying on electricity from fossil-fuel-fired power plants. Back in the day, alternative energy was unaffordable, and it made no financial sense for an individual to invest in solar energy. Now, advances in technology and manufacturing methods have made it

cheaper, and the incentives from the government add to the savings that a homeowner can realize. People are often surprised when I tell them that installing solar power in their homes is financially and environmentally sustainable over time. Home solar power's environmental and economic benefits are the two main reasons to choose DIY solar power. This is why more than two million homeowners already have a solar system installed on their properties. Millions more are expected to install solar power on their homes by 2025 (EFS Energy, 2020). So, the big question is, how does installing solar power in your home help the environment?

Shifting to solar power and alternative energy, in general, reduces greenhouse gas (GHG) emissions into the atmosphere. Over 80% of the GHG emissions are from the combined burning of fossil fuels, and unfortunately, we still rely on these fuels to meet our energy needs (Environmental Protection Agency, 2021). Fossil fuels include coal, natural gas, and petroleum. In my opinion, anything that is burned to liberate energy is bad news. Over 60% of utility-generated power in the US is produced from fossil fuels, with natural gas and coal having the largest share, accounting for 40.5% and 19%, respectively (Energy Information Administration, 2021).

HOW DOES SOLAR HELP THE ENVIRONMENT?

There is no difference in the carbon emission savings between a professional and a DIY installation, so most people who can do so prefer DIY installations. To put the environmental impact of adopting alternative energy into perspective, research shows that over 0.8 pounds (lbs) of CO2 emissions are eliminated for every one kiloWatt-hour (kWh) of energy derived from alternative sources (Energy

Information Administration, 2020). If you consume electricity like the typical American household, you will save 80,000 lbs of greenhouse gasses from polluting the environment. Over a year, this translates to a reduction equivalent to what a small car would emit as greenhouse gasses. Knowing the amount of greenhouse gasses prevented from entering the atmosphere always gives my environmentally conscious clients something of which to be proud.

ALTERNATIVE ENERGY OPTIONS

You probably wonder why I have chosen to talk about solar power and other alternative forms of energy that can help reduce CO2 emissions. Indeed, some people opt for wind and micro-hydroelectric power because they also produce clean energy. The main difference is that, unlike solar

power, which works using light energy, the two sources use kinetic energy to transform natural resources to drive a turbine. Micro-hydroelectric systems require moving water to move the turbine, while wind power systems need moving wind to generate electricity. Each energy source has its pros and cons, and solar is not an exception. Still, the idea is that collectively, we can positively impact the climate by adopting renewable energy into our lifestyle.

In my opinion, home solar is a better solution compared to the other forms of alternative energy options currently available on the market because it is more reliable. Since the sun is the energy source, you can always count on it to be available most days of the year. In the US, the average peak sun hours range between three and five hours per day, which is more than enough for a properly sized system to provide power to the home. You have a guarantee that electricity will always be available when needed. This does not mean that the system will only produce electricity for this period, but the sun-peak hours are when the solar panels generate maximum power.

On the contrary, if you want to adopt wind energy, you may not enjoy the same reliability because wind patterns are erratic throughout the world. Some areas are perfect for wind power generation, while others do not experience favorable wind conditions needed to turn the turbines fast enough. In the case of micro-hydropower, there needs to be water flowing from either a stream or river, and not many people have access to water bodies of this type close to their properties. Pumped Storage Hydropower (PSH) is an option for people bent on hydropower despite the absence of a flowing water body. However, this is a costly solution, and it’s not worth exploring save for large-scale power generation.

Pros of Home Solar Systems

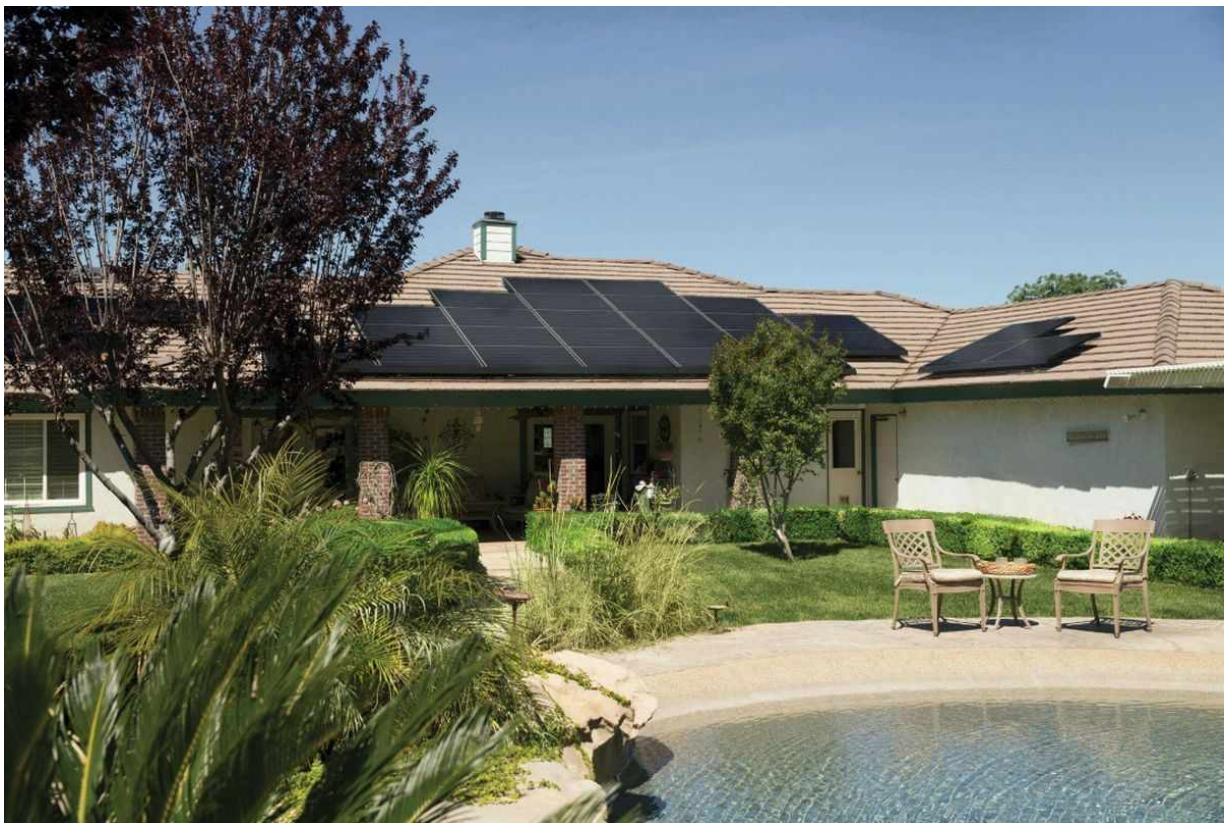
Longevity: You can expect your home solar system to last over three decades if quality system components are used. This is usually when mortgages mature, and studies show that installing solar panels leads to increased property values. According to reports from the real estate giant Zillow, the actual appreciation is around four percent, but some estimates put this figure higher (Sanchez, 2019).

Simple to install: Solar is the easiest to install of the three alternative energy options. If you want to install wind power, you might find it difficult to do it DIY because the equipment is bulky. Micro-hydro electricity has less bulky equipment, but you need a large body of flowing water near your property for it to work.

Little Maintenance: Solar installations are cheaper to maintain because the system has few moving parts. This makes the other two forms of clean energy, wind and micro-hydroelectric, more expensive in the long run. If the generator on a wind turbine breaks down, a professional repair is required. A solar panel that breaks will only need to be replaced. You can easily do this yourself, and it is as easy as assembling Lego blocks. To keep a home solar power system operating efficiently, ensure the modules remain clean and the connections secure. You can easily track the power generated by the system and compare this output to the manufacturer's rating to determine if there is degradation.

Savings on electricity costs: Another reason to go for solar is that a home solar installation will save you money spent on electricity bills. In the US, an average home spends around $118 per month on electricity, and since 1990, the average retail price has been steadily increasing, peaking at $0.107 per kW-hr in 2020 (Alves, 2021). If you have a solar system, you need to pay electricity bills to the power utility company. Sometimes, the utility company may

pay you money for the electricity you feed into the grid if you have a system capable of feeding power back to the grid. Potential savings can be as high as $20,000 over two decades, and this figure can increase significantly (O'Keefe, 2021). Of course, there is a payback period on the investment. In an example project, I will teach you how to calculate your payback period later in this book.



Cons of Home Solar Systems

Not every system is perfect. Power generated from utility companies is great because it is standard, not prone to fluctuations, and does not need huge investment from individuals within the grid infrastructure. But its downsides are the greenhouse gas emissions and the rising costs of electricity, as we have previously mentioned. On the other hand, a home solar system fixes the CO2 emissions problem

and absolves the homeowner from rising electricity prices, but there is a catch to realizing these benefits.

Large physical footprint: In the US, an average home requires a system capable of producing at least 10 kW at any given time. Suppose you want to run demanding appliances such as dishwashers, swimming pool pumps, and air conditioners. In that case, your system needs to produce at least three times the rated power draw indicated by the manufacturer of the appliances. This translates to a large installation to run these appliances from a home solar system. In my experience, it is not feasible to run thermal appliances such as a hot plate stove on a small system because the power demands will increase the cycle of the system, reducing battery life for independent off-grid systems. If you have limited space on your roof, it may be difficult to meet all your energy needs from a home solar system.

High initial and replacement costs: Solar is still expensive, despite manufacturers' attempts to decrease costs. If you have space, then the other con will be the initial upfront investment. More panels and batteries mean a large initial cost. When the system reaches end-of-life, the cost to replace it is on the homeowner. In contrast, the replacement cost is the service provider's responsibility for a power utility company. The good news is that most homeowners' insurance policies cover solar home systems, and it is possible to get full replacement coverage when you need to replace the system due to age or damage.

Of course, this means that the insurance premiums will go up, and you can expect to pay an additional amount if the addition of solar panels changes your coverage limit. For example, if you install a system that requires you to increase the dwelling limit by $50,000, then the average increase in the annual insurance premium can be around a

couple of hundred dollars (Martin, 2021). This is a good deal because your annual savings will likely cover this premium. However, when you shop for insurance, keep in mind that not all policies cover damage from events such as damage from hail. You must discuss your options with your insurance provider to know the type of coverage.

The system can be complex: Grid-tie systems can be beyond the expertise of a DIYer. Besides the amount of paperwork involved, the law in some jurisdictions does not allow unlicensed individuals to touch anything related to the grid connection. If you want to benefit from selling a portion of the power produced, in those jurisdictions you need a professional to install it for you.

Loss of performance: Solar panels gradually lose their power output over time. On average, between one and two percent can be lost per year. The reason is the effect of temperature on the solar cells leads to damage. This damage is irreversible but not significant. Quality solar panels only lose one percent of their rated output annually.

DIY Installation vs. Professional Installation

DIY installations are great if done correctly. You will save money. On average, homeowners pay around $25,000, while the costs can get up to $32,611 to install a home solar system (O'Keefe, 2021). Usually, the labor charges make up a considerable portion of costs. If the installer does not charge labor directly, in most cases, there is a markup on the system components to compensate for this. The standard practice is that a supplier has in-house professionals who can install your property. Sometimes, it is also possible to purchase the system components and have an independent professional install them at an additional cost. In terms of costs, there isn't much difference between an installation performed by a supplier

or an independent professional. These costs can be avoided if you install the system yourself, and up to 10% can be saved if you install the system yourself before the tax incentives are added.

Doing this, however, can be a difficult and dangerous undertaking for an unskilled DIYer, especially if the home keeps its grid connection. Some local authorities even prohibit non-licensed persons from making connections to the main panel box, and licensed electricians must perform the installation for the system to be certified. If done incorrectly, the consequences can include damage to the power utility's infrastructure and the possibility of an electrical fire on the connections. DIY installations must be limited to connections that do not interact with power from the grid. You will need to check the rules in your state regarding DIY home solar installation. This is very important because hefty fines can be imposed. Most local authorities issue what is known as "permission-to-operate," and they may need to see the installer's license. Call your local authority to check if DIY installations are allowed in your area.

To satisfy the needs of the DIY soul where the regulations prohibit, some manufacturers provide kits that are easier to install for off-grid connections or smaller power requirements for applications that are not linked to the grid, such as lighting for an additional shed. These are readily available on Amazon, Home Depot, or directly from the manufacturer's website. Reputable manufacturers include Grape Solar and Renogy. You can easily purchase an 800 Watt system for less than $1,300, translating to just under $1.75 per kWh (EnergySage, 2021). The kits are suitable to charge appliances and provide lighting but fall short of the general needs of an average home.

You may also encounter restrictions from homeowners associations (HOAs) if you live in a planned unit development (PUD). HOAs banned solar panels in recent years before the enacted solar access laws. However, the associations still have a say regarding the installation itself as long as operational and cost efficiency are not compromised. This means that an HOA can decide to restrict DIY solar installations, and in this case, you will likely have to opt for a professional installation despite your skill levels.

On the other hand, professional installations are more expensive, but they also offer benefits for grid-tie systems that require net metering. Permission to turn on is a breeze, and most of the paperwork is filed on your behalf to get the final sign-off from the utility company.

WAYS TO HAVE A HOME SOLAR SYSTEM

One of the top questions I also get is, "how can I afford to install a home solar system?" Similar to buying a car, there are several ways through which a homeowner can have a home solar system. At the moment, there are three options you can use to finance a home solar system. Most people prefer to pay cash for their system to own it from the get-go. This is known as a cash purchase, and its main advantage is that a homeowner can maximize their savings. By owning the home solar system entirely, you would have paid for your electrical needs years in advance, cushioning you from increases in electricity rates. Additionally, the tax incentives and rebates will put more money back into your pocket. The obvious con is that you will have to pay through the teeth in one go for the home solar system.

Alternatively, a solar loan can finance a home solar system. This option also makes you eligible to receive rebates and

incentives from the state or federal government. There are no initial costs, and the monthly payments are also lower than what most people pay towards their monthly electric bills. After the loan has been fully paid off, you will start to enjoy free electricity from your investment. Traditional credit institutions can provide solar loans. Suppose you are keeping your connection to the utility company in states that do not allow you to go completely off-grid. In that case, a participating utility company can pay a certain amount towards the loan when you pay your electricity bill. You can also find a lender dedicated to solar loans. Currently, SoFi is the best lender for large loan amounts, while Light Stream is regarded as the best company for quick funding.

Solar leases and power purchase agreements (PPAs) are another way to have solar at home. However, they are becoming less popular because solar systems are more affordable today than when solar technology was in its infancy. These two options are third-party ownership options or TPOs, and today, most offers feature a locked rate throughout the lease period. I'm not too fond of the idea of leasing, but it is up to you to weigh the options to determine the correct approach to suit your needs.

Other Ways to Afford a Home Solar System

If you live in an eligible state in the US, you might be able to benefit from low-income solar incentive programs. Rebates and tax incentives already lower the cost of installing a home solar system, but many people still find the cost unaffordable. Many programs consider low-income households as families that earn 80% and below the arena median income (AMI). California, Colorado, Hawaii, Illinois, and Massachusetts are examples of states that offer these programs. The offerings are state-specific, but some include reducing solar loan principal by a third, reducing loan interest rates, or subsidizing solar panel installation

for low-income single-family homes. Sadly, California's SASH program expired at the end of 2021, but you can contact the authorities in this and other states to know the specific low-income solar programs available.

Owning vs. Leasing Home Solar Equipment

If you choose to lease a solar installation, it is not possible to do it DIY because the company you are leasing it from needs to guarantee the performance and longevity of the system. In most cases, the third party is responsible for installing and monitoring the system and performing regular inspections to ensure that the system continues to function properly. The major advantage of having a home solar system using this route is that there are no upfront costs involved, and you can start saving on your monthly electric bill right away. While the annual electrical bill you pay to the equipment owner still increases, the general trend is that this increase is half of the amount by which utility companies raise their rates.

You can either purchase the system or return it at the end of the lease agreement. The leases are also 100% transferable, meaning if you decide to sell the home, the new owner can continue with the lease if they like. There is a catch to purchasing the system if you are in a lease contract, and you must lease the system for at least five years before buying it. You will also be ineligible for tax benefits that an outright owner of a home solar system enjoys during the lease period.

Other than this, there are no other benefits to having a solar home system that is leased. The property value of your home will not appreciate when a leased system is installed because it is not considered a permanent part of the home. Despite the 100% transferability of the system,

when a home is appraised, the solar system is excluded from determining the property value.

BEST STATES FOR SOLAR POWER

You might be curious to know if your property is located in a state where you enjoy the maximum benefits resulting from installing solar at home. In the 2020 Solar Power Rocks (SPR) report, New York, Rhode Island, Massachusetts, Maryland, and New Jersey were identified as the top five states across the US for homeowners to install solar power. Of course, solar power works everywhere, but the report's findings include other factors such as state laws, rebates, geographical properties, availability of low-income solar programs, net metering policies, and current electricity prices to rank the states. If your property is not located in these five states, this does not mean you should worry. Many other states are actively promoting solar energy, and states like California already have legislation in place compelling builders to install solar on newly constructed homes.

In the next chapter, we will get into the inner workings of solar power so that you can understand how the technology works to make your skills better when installing the system DIY.

2

BEFORE YOU GET STARTED

“Safety first is safety always.”

— CHARLES M. HAYES

Power generated using solar panels is regulated because it is dangerous if handled and installed incorrectly. This is why some guidelines and standards are enforced to ensure the safety of installations. It may not seem necessary because, indeed, small solar panels are used for charging small devices that many people are used to and do not find potentially harmful. Panels used to produce electrical power sufficient for a home are a different ball game. Combined, they produce enough electricity that can lead to death if not handled correctly.

The starting point to familiarize yourself with the requirements is the *Standards and Requirements for Solar Equipment, Installation, and Licensing and Certification* to ensure your safety. Although this text is a guide for project managers in States and local governments, you will need to know the standard to which your installation will be measured if you decide to install the system yourself.

Safety precautions must be taken when working on the roof and wiring the installation inside the attic. Personal protective clothing and equipment such as glasses and gloves are mandatory to prevent injuries. You need to determine the load-bearing properties of the roof and if the final installation maintains the required fire rating. The National Electric Code is another resource worth looking at for you to gain a deeper understanding of what the inspections look at before the final sign-off is issued. Before I teach you how to get started with mounting panels on the roof, we need to discuss the safety precautions necessary when working on the system.

WORKING ON YOUR PROJECT

The dangers you are exposed to when dealing with electricity and general solar panel installations are

different at each stage of the installation process. Solar panels are heavy objects that carry live currents when exposed to the sun. When mounting the panels on the roof, the risk of falling is more than the risk of electrocution, while there is a higher risk of being electrocuted when wiring the system. This is why many rules and regulations govern electrical and general installations. The National Electric Code (NEC) is a standard that regulates electrical installations, including solar systems. In this section, we shall cover the basic safety procedures you must pay attention to at each stage of the installation process.

In most cases, electrical safety will become a concern when conducting repairs or wiring the system to the distribution board. The first safety concern is when handling solar panels after unboxing. Some panels come with wires extending from the modules. Avoid touching the wires with your bare hands, and make sure the wires themselves are not bare. If the wires touch, a short-circuit will develop, which may shock the handler and, at times, damage the panel. Wear gloves designed for electrical work to act as an insulator. Electrocution and arc flash explosions are the leading hazard that installers are exposed to, and you must be aware of the potential hazards.

General Safety Precautions

Never work on a hot circuit when wiring the system: The initial power supply to a circuit is provided via hot wire. It is responsible for carrying current from the source to the outlet and always carries electricity. It is unsafe to touch this wire while it is receiving power**.** This wire always carries electricity from a source, and if a solar combiner is used, it will be a single conductor that feeds current to the circuit. There is a risk of electrocution if you work on a hot circuit. You can avoid working on a hot circuit by mounting

the panels on the roof first, then connecting to the power source once the panels are fixed to the mounting rack.

Have an assistant when installing the panels: Solar panels are heavy. The average weight for a 300 W solar panel is 40 lbs (Solect Energy, 2021). You will need to bring the panels to the top, and to do this; the panels need to be secured by safety belts and guided up the roof with at least one receiver ready to place the panels on the racks. If you cannot find an assistant, it is possible to haul the panels up by yourself. You will need to be more careful and bring each panel up one at a time until you are done. This is labor-intensive, so I recommend taking breaks if you are not in shape.

Building your solar panel lift is a good idea to boost your confidence in DIY installations by adding complexity into the mix. They are pretty easy to build, and the one I made nine years ago still works fine. There are plans available on the internet to build your solar panel lift safely. This is a good idea if you have more than one home and plan on installing solar panels on all your properties.

Use the correct tools for the job: Ladders are needed to go up and down the roof, and you will also need an impact drill, multimeter, and wire strippers as part of your toolkit. In our examples, we will detail the basic tools and materials you need to safely complete a project in addition to the top essential tools that you need to have in your arsenal.

ESSENTIAL TOOLS YOU NEED

Chances are, you are not a handyman and have never operated a tool in your life. If so, then you will have to buy the tools outlined below. Before using any tool, carefully read the operating manual and follow the instructions to

avoid injury. Always wear safety gloves, boots, and a hard-hat to avoid injury if anything goes wrong.

Digital multimeter: You need ways to measure the amount of current and voltage flowing through each panel when doing the installation. Other professionals even use the multimeter to do a continuity test to check if a solar panel is working properly. A basic digital multimeter can easily test most system components, including the main panel breakers. They are not expensive and can easily be found at a local hardware store.

Wirecutter and stripper: This tool is important when wiring the panels once they are on the roof and during any other wirings. The tool is to expose the bare conductor by stripping away the insulation. Identify the thickness of the wires or cables you will strip, and use this information to buy the correct tool from your local hardware store. Alternatively, you can always buy a set and have everything you may need ready on hand.

Tape measure: Probably, you have this already lying around your home. You need a tape measure to determine the distance between the two mounting holes on each side of a solar panel. This is important when marking the holes on the roof to drill holes that are perfectly aligned for securing the mounting racks to the roof.

Screwdrivers: The panels are secured in place on the racks using screws, and to do this, a screwdriver is needed. Purchase a set of star and flat screwdrivers to use the appropriate tool. Likely you will not know the screws used to fasten the panels to the roof until after you have opened the package containing the mounting rack package.

Conduit Bender: You may sometimes need to make odd angles when installing the conduit to protect electrical wiring. EMT conduit is a commonly used material used for

this purpose, and a conduit bender will make it easy to bend the pipe to fit the profile.

Portable drill: Battery-operated drills are handy when drilling holes for the mounting racks. Since they do not need to be connected to AC power, they are safer to use because of the absence of electrical cords that could trip you during the installation process. Choose a drill tip appropriate for the roof installed on your home. This is not rocket science. You can easily do this by letting your hardware know the type of roof you have; they will supply you with the appropriate drill tip for the job.

Caulk Gun: After the holes have been drilled and the mounting rack has been attached to the roof, it is important to seal the holes to avoid rain from leaking into your attic or ceiling.

Hack saw: If you are into aesthetics, you may need to purchase a hacksaw to cut off excess material after the panels have been secured to the roof. You will also need this tool to cut off any conduits and thin metal pieces for a neater installation.

Ladder: You need a ladder to climb up the roof and haul the solar panels. Although it is obvious that working at a height requires the assistance of a ladder, many people forget this until they are about to get onto the roof. If you do not own a ladder, ask a neighbor for one instead of attempting to use questionable tools such as a table to try and make your way up the roof. Thinking you can wing it is dangerous. I still have the X-ray scan of my broken hand after I fell using makeshift “ladders” many years ago.

Flat pry-bar: Most roof types have shingles where you can slide the flashing under when installing the roof rack. A pry-bar can help you lift the shingles right where you install the mounts. This makes it easy to slide the flashing in,

allowing you to fasten the screw mounts to the roof to add the rails.

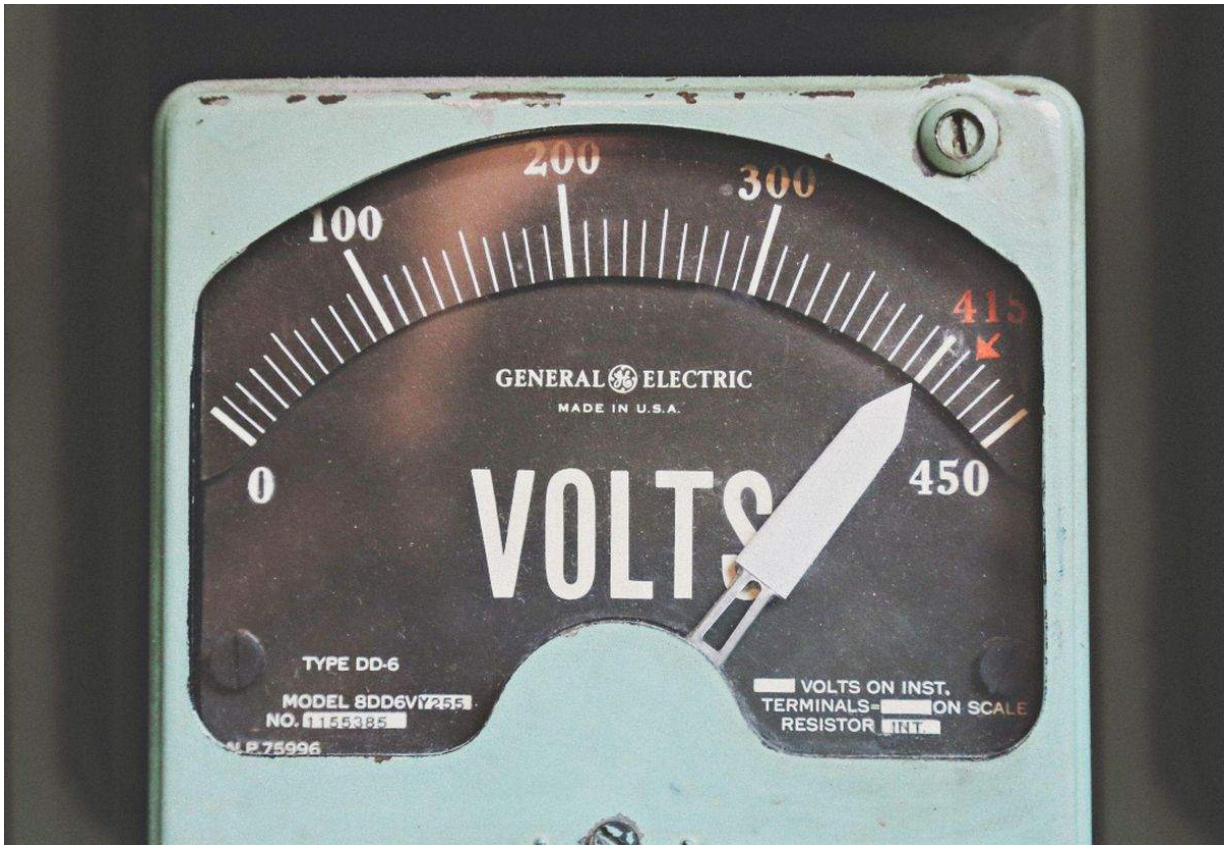
Roofing harness safety kit: This is a must-have safety kit. Many designs are available, and you can easily source them from your local hardware store or buy them online from Amazon, The Home Depot, or eBay. Find a kit with a body harness and a single-leg shock-absorbing lanyard for better protection.

You will need to have other tools and materials handy such as a utility knife and insulation tape. It is a good idea to have a safety bag and harness to place all your tools to climb the ladder safely.

SYSTEM OVERVIEW

Once you have your tools and safety equipment, you are ready to begin installing panels on your roof DIY. The question now is, “where do you begin?” If you are unfamiliar with home solar systems, you might be thinking, “how does the system work?” This is a common question, and most of my clients ask me this almost every time I conduct the initial visit. Journey mapping is important for you to know what to do and to identify where you might have gone wrong if your system does not work correctly when you turn it on for the first time. We have already mentioned the term “solar panel” numerous times in this book. This is just one component of a home solar system. The system consists of several components, which we shall briefly describe.

Definition of Terms



Alternating current (AC): An electrical current that changes direction at a specific frequency. In the US, the standard is 60 cycles per second. You must select an inverter that can simulate this form of electricity for your electrical appliances to work correctly.

Ampere-hour (amp-hour or Ah): The term measures battery capacity, and it refers to how much current a battery can discharge in one hour.

Direct current (DC): A form of electrical current that does not change direction. Solar Panels produce Direct current.

Power: The product of a system's voltage and current. It is measured in Watts.

Solar panels: This is the heart of every home solar system. It is responsible for capturing light energy from the sun and converting it into electrical energy. Without it, there is no home solar system. There are many types of solar panels, but the working principle is the same. In the next chapter, you will learn more about the various types of solar panels and choose the best type for your budget, roof size, and application.

Solar panel wiring: Also known as stringing, solar panel wiring refers to connecting different panels to make what is known as a solar array. If the solar panels are connected, the connected set is called a string. You'll often hear professionals mention that they are "stringing" the panels, meaning they're connecting them. Installers can choose to string the system in parallel or series. Panels connected in series result in a system voltage equal to the sum of the voltage produced by all the panels in the system, while the current remains the same. If the panels are connected in parallel, the system voltage remains equivalent to the voltage produced by a single panel. In contrast, the system current is the sum of the current produced by each panel in the system. Before deciding how to string your panels, you need to know the specifications of the inverter you intend to purchase.

Solar combiner: Once the panels have been strung together, a combiner can feed the generated power to the inverter for the produced electricity to be transferred from the array to the inverter or charge controller. The original function of the combiner was to reduce the number of strings, leading to reduced power losses. If a combiner is used, only one positive conductor and one negative conductor carry electricity from the solar panels to the inverter or charge controller. Additionally, labor and material costs are reduced if a solar combiner is part of the

home solar system. An unintentional result of the combiner box is added safety. The combiner box houses circuit breakers, which work as overcurrent protectors. The circuit breakers can also function as DC disconnect switches. Surge protectors can be added to the combiner to protect the system from lightning.

Inverter: Solar panels produce electricity as DC. An inverter is necessary to convert this form of electricity into AC so that your dishwasher, air conditioning unit, and any other appliances require AC power to function. There are many types of inverters; some lack a charge controller, while the hybrid versions have a charge controller. Charge controllers are required if the system needs to rely on a battery backup to avoid overcharging or undercharging the batteries.

Solar System Disconnect: This component functions as a bridge between the inverter and the home AC power system. If there is a need to shut off the solar power from getting into the home, for example, in the case of a fire, the solar disconnect switch is used to quickly turn off AC electrical power produced by the inverter.

Surge Suppression: Over-voltages and lightning can potentially damage a solar system. The arrays and inverter face the greatest risk of damage, and for this reason, surge protection devices (SPDs) are installed to protect the system’s critical circuits from damage. Lightning-induced failure can include loss of power if an inverter is damaged or reduced power in the case of damage to the array.

Grounding: The grounding aims to add protection to the solar system from lightning. The system is electrically connected to the earth using a copper wire to absorb excess energy to avoid damaging the equipment or home occupants. The common grounding technique uses

grounding rods to create a path of least resistance for the current to dissipate into the ground safely. Small solar systems can be safely grounded using copper grounding rods with ½ inch minimum diameter and minimum 12 AWG wiring. The ground rod is connected to the frame of the solar panels, the outer frame of the inverter, and the ground bar of the AC wiring. There are additional methods to achieve grounding, but grounding rods are the most common for home solar systems.

AC Wiring: If you are not living off-grid, then AC wiring is simply a matter of connecting the AC output of the inverter to the main panel box or service. If your home is off-grid and newly built, chances are it has no wiring, and this means that you will need to start by wiring the entire home and to install a new main panel box. This is not a DIY job, and you will need to hire a licensed electrician in such cases.

System-Level Basics

Now that you know the components integral to a home solar system, the next stage is to familiarize yourself with the basics of electricity regarding how electrical appliances draw power from a solar system.

I am sure you have come across the term “rated power” when purchasing electrical appliances. Power is the product of the voltage and current required by an electrical appliance. Let’s take an example of an LED light bulb. If the bulb is designed to work with power supplied by the utility company at 110 Volts (V), and the rating is 10W, the current draw is 0.09 amps (A), discounting losses. Power generated by solar behaves differently from power generated by utility companies. The main component for generating power from the sun are photovoltaic arrays, commonly known as solar panels or modules. Light energy

from the sun contains particles known as photons, and these knock off electrons from atoms of the semiconductors that are part of the solar panel structure. Electricity is the flow of electrons, and this flow of electrons generates electricity from the panels. Power is generated from the solar panels as direct current (DC), and an inverter is necessary to convert this form of electricity into alternating current (AC). Most appliances work with AC, which is the power that all utility companies generate.

DC differs from AC because the polarity is fixed, and the system voltage rarely goes past 48V. Using the previous example of a light bulb, if the system voltage is 48V and the bulb is rated at 10W, the current draw becomes 0.21 A. Already, you can see that the current flowing through the bulb and the electrical wire supplying the electricity to the bulb is over twice the current flowing in the same bulb if it is designed to operate with AC. The general rule is that the higher the system voltage, the lower the current flowing, translating to lower heat losses because current flow generates heat. This has implications on the type of wiring required for a home solar system. Manufacturers have recently introduced appliances, including LED lights and irons that work with DC. This eliminates the need for an inverter in some applications.

Types of Home Solar Systems

One of the hardest decisions that a homeowner needs to make is to choose the right system that will give them the best value for money, given their circumstances. The two major options are grid-connected solar panels and off-grid home solar systems. Both have pros and cons, and the state laws sometimes limit you to grid-connected solar panels, especially if you live in an area where a connection to the power utility grid exists.

Grid-connected home solar systems: Also known as a "grid-tie system," this option offers a homeowner better efficiency rates, net metering as well as lower cost of installation. Batteries are not required for this home solar system, leading to a cheaper installation cost. The net metering option provides the opportunity to sell excess electricity adding to the financial incentive for installing a home solar system. This is particularly beneficial when your utility company offers the same rate for the electricity you produce to the power you feed back into the grid.

The grid functions as a virtual battery, where the efficiency benefits come into play. Some losses occur if you store your electricity in backup batteries because batteries at most are only 90% efficient at storing electricity. The grid loses 7% of the electricity generated to transmission losses. In case of your home solar system fails, you have the option of relying on electricity generated by the utility company until your system is fixed.

For grid-connected home systems to work, a grid-tie inverter is required. Often equipped with a power meter, the inverter synchronizes the frequency of the electricity fed into the system to match the power utility's frequency of 60 Hertz (Hz). The output voltage is set slightly higher so that excess energy can flow back into the grid based on the difference in potential. The power meter is usually free, although this can differ among utility companies. To help you choose, you can input your zip code into an online calculator to determine the savings you can realize from a grid-connected home solar system. Solar Reviews provides a handy calculator, but you can choose any calculator that you find to determine this.

Off-grid home solar systems: You will need batteries to store electricity, meaning your overall system efficiency will be lower than a grid-connected home system. It costs more

to install this type of home solar because of the additional cost of the battery. The major advantage is self-sufficiency, and this is also a cheaper option if you live in a remote area and your property is located more than 100 yards away from the grid. The cost to install a transmission line stands at an average of $11,000 per mile if your property is located in an urban area and can easily exceed eight times this amount if you live in a rural area.

Hybrid home solar systems: This system combines the other two home solar systems. They are cheaper than off-grid systems and hold smart grid capabilities. They offer a homeowner the opportunity to earn even more from their investment and do this in two ways. You can easily program them to kick in when the utility company charges higher rates. You can also store your electricity and sell it to the grid when at peak periods, meaning the utility company will pay you more per unit of electricity supplied.

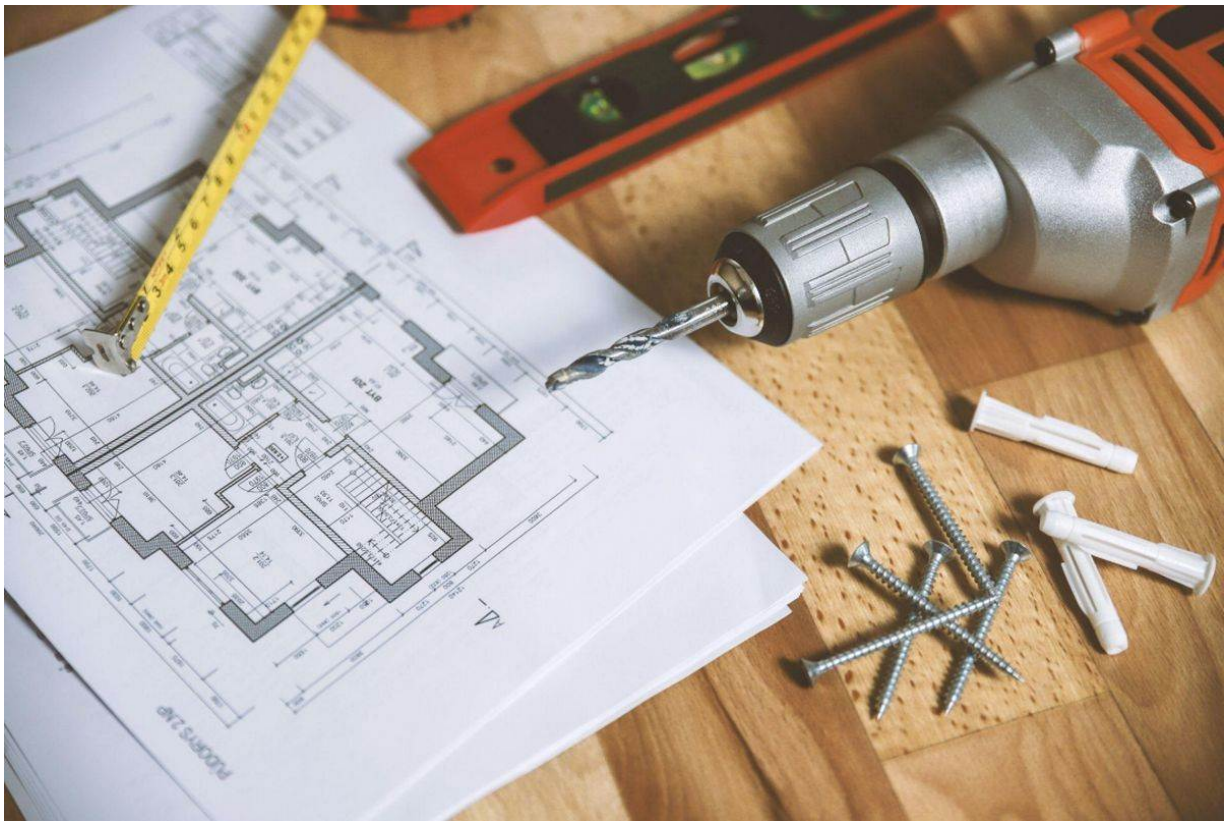
In the next chapter, we will discuss designing your home solar system and the factors you need to consider when determining your needs. You can choose any of the systems described above, but the material we shall discuss applies to either of the three.

3

SOLAR SYSTEM DESIGN

Before you start designing the system for your home, the first step is to check the regulations in your area. The laws governing alternative energy are not uniform throughout the country. Some states allow people to completely disconnect from the grid, while others require you to remain tethered to the grid network. The good news is that the climate issue forces many municipalities to relax the laws, with some even offering rebates for solar installations. Once you have ascertained the regulations regarding your intended installation, you can design the system. Things will be a little technical on this part of the book, but you will learn how to size the system to meet your daily needs.

PREPARING YOUR PROJECT



Suppose you decide to employ the services of a professional to install the system for you. In that case, you will not have to worry about the initial assessment and permit applications necessary to install the system. Most companies are familiar with the system and handle all the paperwork for you. The report from the assessment is used to determine the ability of the roof to support the dead weight that solar panels introduce, as well as the structure's resilience. For DIY installations, you will need to do this yourself.

DIY Site and Condition Assessment

Besides checking the roof's condition, your panels need to be oriented correctly for them to receive maximum sunlight. A south-facing roof proves solar panels with maximum exposure to the sun in the northern hemisphere. A mobile compass can be used to determine the orientation

of the roof. The location of choice must also be close to the utility connection to reduce labor and material costs if you are not going completely off-grid. You can reach out to installers to help you with this, even if you do not plan on having the system professionally installed. They can do this in-person or virtually with drones or using satellite imaging.

Inspect the attic to determine if the trusses are free from rot and for you to make a detailed wiring plan for the home if your home is off-grid. The NEC regulates the routing of the electrical cables, and part of the regulation is that lugs must secure electrical cables on the structural part of the roofing timber. Throughout this book, I will constantly remind you of the regulations because it is counterproductive and a waste of money to install a system that will not pass.

Check for shading from trees, other buildings, and communication antennas outside the home. If your roof accumulates snow during winter, you may need to think about how you will clean the panels and consider brands that stand up to high snow loading conditions so that your solar panels will not break under the weight of heavy snow.

Determining Your Needs

There are two ways to calculate how “big” your system should be. The easiest way is to look at your energy bill and check the monthly or annual usage reported on the statements. Usually, the bill shows the kWh that a household consumes in a month. Divide this number by 30 days and multiply by a factor of two to compensate for the months that more power is consumed. If you have statements that cover the entire year, take the highest consumption and use this figure in your calculations.

Alternatively, you can manually compute the daily requirements using an online calculator. Gone are the days when one had to check the power rating of the appliances to work out the power draw. Most online calculators have a list of appliances with average power consumption already factored in. All you need to do is input the number of hours you expect to use the device or appliance. The calculator will automatically add each electrical appliance selected based on the usage and display the total daily power requirements. Some calculators apply a factor to account for differences between brands, but you must be sure. Otherwise, you risk under designing the system. One of the best calculators is found on Unbound Solar's website. This is in no way an endorsement of the company's products. I find it convenient because it is one of the few calculators that allow users to enter their zip code to determine the peak-sun hours of the location. You can find other calculators by simply searching online. We will use a similar calculator to determine system requirements in our examples.

Once you have determined the requirements, it is time to go shopping. I always advise my clients to shop for products physically from hardware stores, but purchasing online is an option if it is not possible. The reason is some parts can be faulty, and having the product tested in-store guarantees that your purchase is in good working order. In addition to this, reputable suppliers have in-house experts that can help you choose reliable brands and choose the correct gauge of the electrical cable based on the system current.

SOLAR PANELS AND MOUNTING PART ONE

There is no home solar system to talk about if there are no solar panels. Other system components can be negotiated, and the system will still work. Without solar panels, there is no home solar. You have several things to think about when choosing the right solar panels. Do you have a large roof or value efficiency over cost? These are some of the questions you need to be asking yourself to make better decisions when choosing the appropriate solar panel size and type.

SOLAR PANEL SIZES

The power generated by an individual solar panel of the same type is proportional to the size of the panel. The standard sizes start from 100 W and go up to 500 W. The latter is a recent development in the market, and Trina Solar is one of the few companies that manufacture panels of this size. If you target a 20 kW system and plan to install a system based on 200 W panels, you need at least 100 panels. That is a lot of panels to install on a residential roof. On the other hand, a similarly sized system based on 500 W solar panels will require 40 panels installed on the roof. Based on the manufacturer’s technical datasheet, a 500 W panel will cover 26 sq ft on a residential roof, placing 66.4 lbs on the structure.

CONVENTIONAL SOLAR PANEL OPTIONS

Before you head to the nearest supplier, the type of solar panel you buy must also be factored into the design process. Conventional solar panels feature a rectangular module with a metallic border to keep the panes rigid. Four

main types of solar market are currently available for purchase, specifically thin-film panels, monocrystalline, polycrystalline, and Passive Emitter and Rear Contact (PERC). The main difference is the quality of silicon used to manufacture the cells. Monocrystalline panels are manufactured using pure silicon crystals, and these panels can be easily identified because of their distinctive dark color. They are the most efficient panel type and last longer than the other types, but this comes at a cost because of the higher purity of the silicon used. Much of the silicon is wasted during the manufacturing process, which adds to the overall cost.

On the other hand, polycrystalline solar panel cells are leftover silicon from monocrystalline panels. The silicon is melted and molded into squares, leading to little waste during the manufacturing process. You can easily identify the panels from the distinctive shape of the cells. Polycrystalline panels are cheaper to purchase, but they are less efficient than monocrystalline panels and do not tolerate heat well. If you live in a hot climate, avoid this panel type because the energy conversion reduces with higher temperatures.

PERC panels are the most effective type of solar panels that feature a passivation layer on the back surface of the cells. The layer functions to increase the amount of radiation absorbed by reflecting light into the cells. This allows light waves with longer wavelengths to be absorbed, leading to better energy conversion. Another advantage is that more energy can be harvested from this panel for the same physical footprint than the other three types of solar panels. Only the additional materials increase the overall cost of the panel, but the average cost per kWh is lower because of the higher efficiency. If you have limited space

or worry about placing heavy loads on your roof, consider purchasing PERC panels.

Finally, thin-film solar panels are the least effective panels among the four types. They are flexible and commonly made from various materials such as copper indium gallium selenide (CIGS) and cadmium telluride. Thin-film panels are not suitable for generating electricity for a home because of their low efficiency and the absence of rigid backing to properly mount the panels outdoors. In many cases, they also lack the metallic frame characteristic of conventional solar panels.

According to McBride (2021), electricity generated using PERC solar panels costs between $0.32 and $0.65 per Watt, while electricity generated monocrystalline and polycrystalline panels cost around $1.50 and $1.00 per Watt, respectively. These costs do not include installation, labor, and other overhead costs, but the general rule is that electricity generated using PERC panels is cheaper.

SOLAR SHINGLES AND SOLAR TILES

Tiles are usually multilayer thin panels integrated with thin-film monocrystalline or polycrystalline solar cells. On the other hand, most shingles feature just monocrystalline cells, and some can be embedded with the existing shingles. These solar panels are all about aesthetics and are a favorite among homeowners looking to upgrade their roof. Classified as building-integrated photovoltaics, they are built to suit roofs that are not suitable for supporting heavy loads, and surprisingly, they last longer than conventional shingles. If you are familiar with the Tesla Solar Roof, you must know what solar tiles and shingles look like. Their small form factor means that each shingle produces between 50 and 100 W (Solar Metric 2021).

Ideally, you want to choose solar shingles when your home is being built or if the roof is to be replaced. Tesla's solar roofs are a bit pricey, so unless you need a completely new roof, their solar shingles are not the best solution, and you will need to look at alternative manufacturers.

Generally, it costs $44,000 to install a Tesla solar roof for a 2,000 sq ft home against an average of $10,000 for conventional roofing. You can consider brands like Certain Teed, Luma Solar, Exasun X-Tile, RS Energy, and SunTegra. Products from Luma Solar will cost you around $4 per Watt, while products from SunTegra Tile range from $3.80 to $4.25 per Watt. This is an affordable option if you factor in the higher than average cost of Tesla's complementing roof shingles as part of the solar roof package. One downside to solar shingles and tiles is that they need to be installed by a professional, taking the DIY experience away from you. In addition, the cost per Watt is higher than electricity generated using conventional solar panel options.

BI-FACIAL SOLAR PANELS

This is the future solar panel, and many homeowners are expected to realize at least 40% more power delivered from the same physical footprint with bi-facial solar panels. Featuring a photovoltaic surface on both sides of the panels, most bi-facial panels available are monocrystalline, although polycrystalline panels are also being produced. The operating principle is that the top solar panel absorbs sunlight like a conventional solar panel, while the bottom surface absorbs light reflected from the ground. This light is known as albedo light, and if you want to maximize the absorption of this light, then it is a good idea to paint your

roof white or silver. White surfaces can reflect as much as 80% of albedo light.

The question is, should you choose bi-facial solar panels for your DIY project? This depends on your budget, the available space, and the surrounding environment. There are several homes where I have installed bi-facial solar panels, and the system works perfectly. The decision to install this type of panel was made because the roof had insufficient space to accommodate panels that could meet the electricity required to power the home properly. If you think that bi-facial panels are the right option for you, stick around for the detailed project that we will discuss towards the end of this book. For now, here is a checklist that can help you decide if this type of solar panel. At least two answers should be yes to the checklist questions below.

- Does it snow over the greater part of the year on my property?
- Am I comfortable with mounting my solar system on the ground?
- Does my property have awnings, or am I comfortable adding them around the home or above the windows in the future?
- Am I comfortable painting my roof silver or white to get better albedo light?
- Do I have a pergola of any size on my property, or am I willing to build one for my solar panels?
- Do I have a sandy location on my property, or am I willing to create a mini beach if I do not have one?

FACTORS TO CONSIDER WHEN CHOOSING SOLAR PANELS

Size and condition, and type of your roof: On average, the size of a residential building has a roof covering 1,700

sq ft. Large residential properties can easily reach 3,000 sq ft, so when choosing the type of solar panel, consider if the size of your roof can accommodate the power requirements. If you want to install a 20 kW system using 500 W panels, the roof must be 1,100 sq ft. Divide the area of the individual panel into the total exposed roof area to get the number of panels that your roof can accommodate.

Regarding the roof's condition, check for structural issues to determine if the roof can support the weight of the panels and the mounting racks. In a 20 kW system that uses 500 W panels, the total weight supported by the roof is 2,656 lbs. This weight is evenly distributed, resulting in a distributed load of 2.5 lbs per sq ft. If you are not sure that your roof can adequately support the structural loads, consider hiring a professional to conduct the initial site visit.

Knowing your roof will also determine the type of racking system you need to purchase for mounting your solar panels. Asphalt, tile, and metal roofs have different properties, and this means that you must buy a roof rack that is perfect for the material used to construct your roof.

Potential shading: If trees or tall buildings surround your property, your panels will experience shading due to obstructions. This will reduce the power output from the entire system if the cells are blocked from receiving sunlight. Contrary to what many people expect, shading 1/36 cells in a 36 solar cell panel can reduce the power output by as much as 75% (Brown, 2021). The next section will selectively discuss how inspectors check the system for regulatory and safety compliance for permission to operate.

Brand reputation: Not all brands are equal. I recommend choosing reputable brands with a long history and national or international presence. If the panels do not perform as

expected, you can easily get them replaced under warranty as long as the panels were not damaged during or after installation**.** Trusted sellers such as The Home Depot are good sources because they carry reputable brands. You can also purchase the panels from the manufacturer directly or through their stocking partners. Check for warranty periods, manufacturing standards, and manufacturer guaranteed reliability. Generally, you want your panels to last at least 25 years, or you will not get a good return on your investment. In winter, panels are exposed to harsh conditions such as snow, and you will need panels with good snow loading and wind loading properties.

SOLAR PANEL OPTIMIZERS

Optimizer modules are optional, but they perform a very important function to improve the efficiency of a solar panel. The working principle is that it tracks the Maximum Power Point (MPP) of each solar panel to maintain a fixed voltage of the entire string. They are designed to correct any mismatches in power generation which could arise from shading or manufacturing tolerances. Almost all panels are compatible with optimizers, including bifacial solar panels. On average, DC optimizers can add three percent to an individual solar panel’s efficiency. If you have ten solar panels installed on your roof, this can easily translate to 20% increased efficiency if your optimizer is configured correctly.

SolarEdge is considered the leading brand when it comes to optimizers. Offering a guarantee of system protection from arc faults, the devices are designed to offer “touch-safe” protection levels when the grid or inverter shuts down. The modules are designed to withstand extreme environmental conditions. The latest is the S-Series power

optimizer that is expected to hit the market starting in 2022. You can easily upgrade the optimizer's performance through firmware updates provided by the manufacturer. Other leading brands include SMA, Delta, and FIMER.

TOP SIX SOLAR PANEL BRANDS FOR HOME SOLAR

Three criteria are often used to rank solar panels. Third parties often consider efficiency, temperature coefficient, and warranty to decide which brands offer value for money to the end-user. SunPower is considered the best brand for efficiency, with a panel efficiency rating of 22.8%, followed by LG with panel efficiencies of up to 22%. REC, CSUN, and Panasonic follow the two leading brands. These brands have panels with efficiencies of almost 22% and utilize monocrystalline cells (EnergySage, 2022).

The temperature coefficient of a solar panel indicates how high temperatures affect a solar panel's ability to produce electricity. Panasonic, REC, and Solartech Universal lead the pack, with a temperature coefficient of -0.26, SunSpark Technology and SunPower with coefficients of -0.28 and -0.29, respectively. This coefficient is an important parameter in your system design because the optimum temperature for a solar panel is 25 degrees C. If the temperature rises to 30 degrees C for a panel with a coefficient of -0.30, the efficiency of this panel reduces by 1.5%. If your system is designed without an allowance for temperature losses, this has implications, leading to insufficient electricity for your home.

Regarding warranty offered by manufacturing companies, all leading companies offer 25-year warranties against the industry standard of 10 years. This advantage guarantees the homeowner that their panels will not fail before the payback period is reached. Apart from the brands

mentioned above, Silfab, Solaria, Q Cells, and Mission Solar provide extended warranties for home solar panels. You can follow the example projects to get the full perspective of installing a home solar system when we get to the example projects. We will consider the appropriate brands based on climate. The rule of thumb is that high-efficiency brands, such as LG and SunPower, are great for shaded and wet climates, while high-temperature coefficient brands, like Panasonic and REC, will perform better in warm and dry climates.

SOLAR PANELS AND MOUNTING PART TWO

This is the part to which DIYers look forward. One of those stages during the installation process is challenging yet fulfilling. Other than the differences in efficiency and output between different types of solar panels, panels of the same type have different sizes for different power output. These differences determine the amount of electricity that a single panel produces. It is important that, when purchasing solar panels, all the panels in the system should have the same current and voltage output to avoid mismatches when stringing. Ideally, choose the same brand of solar panels for your installation.

Doing this will help your system deliver consistent power and performance.

Usually, your solar panels will be mounted on rails. Check with the manufacturer of your solar panels to determine which mounting system works for you. Mountings are often rated to comply with national engineering standards to meet wind and snow loading requirements. You will only need your solar panels and the mounting in addition to the tools to successfully install the panels on the roof. Before you get started, gather your tools and supplies in one place, preferably close to where you climb the ladder. Check the area to determine if obstacles can make you trip while carrying heavy loads.

TYPES OF MOUNTINGS FOR HOME SOLAR PANELS.

Standard rails: This system makes the rows of solar panels on pitched roofs easy to mount. Both portrait and landscape configurations can be easily adopted, and each panel is secured to two rails using clamps, while the rails are secured to the roof using bolts or clamps depending on the type of roof. Flashings are installed around each anchor point to create a seal that prevents water from getting into the attic. The standard railing system is good for asphalt and tile roofs.

Rail-less mountings: This type of mounting considers the frame of the solar panels as the rails, and the panels are attached to the roof using nuts and bolts that go directly into the roof’s structure. The system reduces installation time, and the absence of the rails reduces the shipping costs, resulting in a cheaper installation. Rail-less systems require the same number of holes to be drilled into the roof because each panel must be anchored at the corners. The major advantage of this system is that the panels can be

arranged in any orientation, making it a good choice for non-conventional roofs.

Shared-rail mountings: Another quick install solution, shared-rail mounting systems feature two rows of panels, with the middle rail removed. Essentially, this reduces just the material because two panels share the middle member of the system, leading to a cheaper mounting system than the standard railing system.

Ballasted and non-penetrating mountings: This mounting type is increasing in popularity for sloped roofs. They are designed to distribute the weight of the panels throughout the roof structure, preventing localized dead loads that can add extra stress to older roofs. There is no roof penetration, as seen with other mounting systems. The only downside is that additional ballasts made from concrete might be needed to hold the entire system in place.

Ground solar panel mounting: Sometimes, your solar array will not fit on the roof if your installation is large. You can mount the solar panels on the ground using a racking system mounted on poles. I have seen some innovative homeowners build pergolas and carports that use solar panels as the roofing structure. You can buy the mounting poles or make them yourself.

In addition to these mountings, there are options for flat roofs that are slightly different from the mountings used to hold panels on traditional sloped roofs. Usually, these mountings are used on large industrial buildings with a concrete top to allow bolting with the appropriate adjustment to the elevation for the optimum angle for the panels to absorb sunlight.

Top Mounting Kit Brands

- **Iron Ridge XR100:** I have used the Iron Ridge XR100 racking system with flashings. I find it one of the easiest solar panel mounting systems, and it is fully compliant with all building codes endorsed by all states across the US. The system is suitable for pitched roofs, flat roofs, and ground-based solar arrays. This is a highly recommended mounting kit by professionals in the industry. You can get them in different sizes and configurations, and the variants are XR10 and XR100.
- **Everest's CrossRail 44-X and K2 Single Tool System:** I am conflicted between Everest's CrossRail 44-X and K2 Single Tool System for the second spot. Everest's kit features the ability to withstand winds up to 200 miles per hour and 100 lbs per sq ft of snow loading and rail wire management.
- **KB Racking ReziRack 2.0:** The KB Racking ReziRack 2.0 is best for rapid installation without sacrificing rigid mountings. Its selling point is the ability to be used as a shared-rail system and a full rail system.
- **QuickBOLT QB2:** QuickBOLT QB2 is another brand that offers fast installation and a lean array. The system only has three components, and this is why it takes just under 30 seconds to install. Its L-Foot and Dual-drive shoulder screw compresses the micro flashing to eliminate water leaks into the attic.
- **MageBracket F:** The MageBracket F is a simple and low-cost mounting bracket ideal for standing seam metal roofs.
- **S5 PV Kit:** The S5 PV Kit is also a very good mounting system, perfect for mounting on a metal roof if the roof has built-in rails.

Suppose you want to buy any of these products. In that case, you can easily order them directly from the manufacturer or buy from online stores like Amazon or specialty solar shops like Solar Electric Supply.

INSTALLING PANELS ON AN ASPHALT OR A TILE ROOF

According to the National Association of Home Builders (NAHB), asphalt roofs are the most common roofing material in the US. For this reason, we will extensively detail how to mount your solar panels on the asphalt roof. The mounting process is similar to installing solar mountings on a tile roof. Roofs older than five years must have a professional inspection to get a thorough evaluation

of the roof's condition. Generally, they last around 20 years, so it is a good idea to have their condition assessed to prevent your roof from failing while your panels are still in pristine condition. Before you start, note that you must avoid scratching the surface of the solar panels at all costs. You can either lift the solar panels to the roof while still in the box or cover the panels with a cloth to prevent scratching the surface. Hold them securely to prevent them from falling. In all my experience, I have never seen a solar panel that survives falling from a height and continues to function properly. Below is the step-by-step process for installing solar panels on an asphalt or a tile roof.

Materials you will need:

- Fall protection kit
- Solar panel mounting rail kit (e.g. Iron Ridge XR100)
- Hacksaw or small angle grinder
- Essential tools kit (from Chapter 2)

Step One: Drill the Holes

Read the instruction manual that comes with your solar panel mounting kit. This example will illustrate how to mount solar panels using the IronRidge mounting kit. You can purchase any mounting kit you can find and make sure it is a standard system that uses flashings because they are better suited for mounting on asphalt roofs.

Measure the distance between the mounting holes of the solar panels you have. The holes are located at the back of the solar panel and are designed to secure the panel to the mountings. After this, you must determine where your roof's trusses are located, keeping in mind that some building codes and local authorities require a distance of at least three feet between the edge of the solar panels and

the edge of the roof. Start by measuring three feet from the roof's edge, and look for the truss location beyond this distance.

Drill a small pilot hole beside the truss on which you want to start anchoring your panels. This hole is intended for the bottom left hole of the solar panel. You can leave the drill bit inside the hole so that it can serve as your marker when you get inside the attic to determine the location of the hole versus the anchoring truss. It may be easier to find the truss by looking for nails on the fascia board to give you an indication of where the truss might be.

Get into the attic to locate the position of the pilot hole you just drilled. Measure from the center of the drill bit you left in the hole to the edge of the truss. Return to the top of the roof and transfer the hole using the distance you just measured from the hole to the edge of the truss, plus half the thickness of the trusses on your roof. The goal here is to drill a hole for the bolt that will anchor the panel you are installing first, exactly at the center of the face of the truss. In most cases, the thickness of the truss is one and a half inches thick. Later, this hole will be sealed using an appropriate sealer for asphalt roofs. You may need to repeat this step until you get it right, especially if you do not have standard trusses installed on your home.

Measure a straight vertical line going towards the top of the roof and put a mark to match the distance between the two mounting holes on the left-hand side of the panel. For instance, if the distance between the mounting hole at the back of the solar panel is 40 inches, you will need to mark a hole 40 inches vertically, away from the initial anchoring hole you drilled previously. This is a rough mark for where the second hole will be.

After this, measure the distance between the initial anchoring hole (located in the middle of the truss) and the edge of the roof. Using your chalk block, draw a line that meets the rough mark you made above, and drill a hole at the crossing point. The idea is to have a perfectly square installation. You can use a square tool if you think you will not eyeball the holes correctly. The two holes you just drilled will serve as a reference point for the other holes. It is better to transfer all the holes using the measurements of your solar panels and only drill once you have made sure that everything lines perfectly.

Step Two: Mount the Flashings and Rails

Materials you will need:

- Chalk block
- Silicon caulking gun
- Small ratchet and socket set
- Flat pry bar
- Flash foot two flashings
- Flash foot two lag bolts
- Flash foot two caps

Using the pry bar, carefully lift the shingles where the holes are located, and check for any nails on the truss that can interfere with the flashing. Do not damage the shingles while doing this. Slide the flashing into the opening you made using the pry bar, and center it on the hole. You need to insert the lag bolts and tighten them to secure them in place. Do not over-tighten to prevent breaking the bolt. Place the flash foot caps over the flashing, and twist it to lock it in place in the right orientation. Do this for all the flashings to match the number of holes.

The railings will sit on the flash foot two caps. Make sure you place them with the "hardware" side facing down so that the wires and other components are not visible once the whole system has been installed. You do not need to tighten the bolts on the railings until you have made sure the railing is properly aligned and adjusted to suit the roof's profile. Ensure that your rails are cut to length before mounting them on the flashings. Check your dimensions before cutting because there is no going back once you cut. Finally, install the end-caps that come with the railings. They are unnecessary, but you won't have anything to do with them if they are not fitted. Install the wire management clips. Normally you need three clips per solar panel. These are easy to slide onto the rail and are fully adjustable.

Step Three: Install Microinverters and Optimizers (Optional)

If you choose to have a system that incorporates microinverters and DC optimizers, these are installed on the rails, preferably on the top rails. This step is optional because you will not need to install micro-inverters if you are using a string inverter. To install an optimizer, use the wire management clips to hold and manage the optimizer's cable. Insert the optimizer on the rail slot, and twist the bolt provided by your supplier to lock the optimizer in place. You will notice a notch that indicates if the optimizer is locked in place. The general rule is that when the optimizer is locked in place, it must intersect the direction of the rail slots. If your rail runs horizontally, you must lock your optimizer in the vertical position.

Step Four: Install the Grounding

The IronRidge system includes a grounding bolt for each solar array. There is a slot for it on the rails, and the bolt is

attached to a copper wire which then grounds the system via a grounding rod already installed on your property. You will only need one grounding bolt per array because all the components of the mounting kit are connected. This eliminates the need to ground each panel and is probably the greatest advantage of the brand's mounting kit.

Step Five: Mount the Solar Panels

Take your solar panel and place it over the cable management clips. Lay it flush against the rails. Position the panel so that the mounting holes are aligned with the rail's mounting channel. In the box of your mounting kit, you will find T-bolts and clamps that you can use to fix the solar panels to the rails. The clamps must go to the lower end of the solar panels. They function to prevent over-tightening while holding the solar panels in place. If you over-tighten the solar panel, you will risk damaging the top glass of the panels. Refer to the installation manual provided by your supplier to get a pictorial illustration of how the T-bolts and mounting clamps are inserted. Mount the solar panels with the longer side running vertically to the roof's pitch.

MOUNTING SOLAR PANELS ON METAL ROOFS

Metal roofs are also very common in the US. They are generally regarded as the best type of roof to install solar panels, and bi-facial solar panels will perform better when the metal roof surface is reflective. Before you begin the installation process, you will need a few tools and materials. Also, it would help if you took care to lift your panels to the roof carefully to avoid scratching their top face. And again, do not drop them.

There are two different ways to mount solar panels on metal roofs using Rails and clamps or z-brackets. Below are the steps for both ways of mounting.

Standard Rail Mounting

Materials you will need:

- Fall protection kit
- Solar panel mounting rail kit (e.g. Iron Ridge XR100)
- Hacksaw or small angle grinder
- Essential tools kit (from Chapter 2)

Step One: Drill the Holes

Read the instruction manual that comes with your solar panel mounting kit. This example will illustrate how to mount solar panels using the IronRidge mounting kit. You can purchase any mounting kit you can find and make sure it is a standard system that uses flashings because they are better suited for mounting on asphalt roofs.

Measure the distance between the mounting holes of the solar panels you have. The holes are located at the back of the solar panel and are designed to secure the panel to the mountings. After this, you must determine where your roof's trusses are located, keeping in mind that some building codes and local authorities require a distance of at least three feet between the edge of the solar panels and the edge of the roof. Start by measuring three feet from the roof's edge, and look for the truss location beyond this distance.

Drill a small pilot hole beside the truss on which you want to start anchoring your panels. This hole is intended for the bottom left hole of the solar panel. You can leave the drill bit inside the hole so that it can serve as your marker when

you get inside the attic to determine the location of the hole versus the anchoring truss. It may be easier to find the truss by looking for nails on the fascia board to give you an indication of where the truss might be.

Get into the attic to locate the position of the pilot hole you just drilled. Measure from the center of the drill bit you left in the hole to the edge of the truss. Return to the top of the roof and transfer the hole using the distance you just measured from the hole to the edge of the truss, plus half the thickness of the trusses on your roof. The goal here is to drill a hole for the bolt that will anchor the panel you are installing first, exactly at the center of the face of the truss. In most cases, the thickness of the truss is one and a half inches thick. Later, this hole will be sealed using an appropriate sealer for asphalt roofs. You may need to repeat this step until you get it right, especially if you do not have standard trusses installed on your home.

Measure a straight vertical line going towards the top of the roof and put a mark to match the distance between the two mounting holes on the left-hand side of the panel. For instance, if the distance between the mounting hole at the back of the solar panel is 40 inches, you will need to mark a hole 40 inches vertically, away from the initial anchoring hole you drilled previously. This is a rough mark for where the second hole will be.

After this, measure the distance between the initial anchoring hole (located in the middle of the truss) and the edge of the roof. Using your chalk block, draw a line that meets the rough mark you made above, and drill a hole at the crossing point. The idea is to have a perfectly square installation. If you cannot eyeball the holes correctly, you can use a square tool. The two holes you just drilled will serve as a reference point for the other holes. It is better to transfer all the holes using the measurements of your solar

panels and only drill once you have made sure that everything lines perfectly.

Step Two: Mount the Flashings and Rails

Materials you will need:

- Chalk block
- Silicon caulking gun
- Small ratchet and socket set
- Flat pry bar
- Flash foot two flashings
- Flash foot two lag bolts
- Flash foot two caps

Using the pry bar, metal roof panel where the holes are located, and check for any nails on the truss that can interfere with the flashing. Do not damage the roof panel while doing this. Slide the flashing into the opening you made using the pry bar, and center it on the hole. You need to insert the lag bolts and tighten them to secure them in place. Do not over-tighten to prevent breaking the bolt. Place the flash foot caps over the flashing, and twist it to lock it in place in the right orientation. Do this for all the flashings to match the number of holes.

The railings will sit on the flash foot two caps. Make sure you place them with the "hardware" side facing down so that the wires and other components are not visible once the whole system has been installed. You do not need to tighten the bolts on the railings until you have made sure the railing is properly aligned and adjusted to suit the roof's profile. Ensure that your rails are cut to length before mounting them on the flashings. Check your dimensions before cutting because there is no going back once you cut. Finally, install the end-caps that come with

the railings. They are unnecessary, but you won't have anything to do with them if they are not fitted. Install the wire management clips. Normally you need three clips per solar panel. These are easy to slide onto the rail and are fully adjustable.

Step Three: Install Microinverters and Optimizers (Optional)

If you choose to have a system that incorporates microinverters and DC optimizers, these are installed on the rails, preferably on the top rails. This step is optional because you will not need to install micro-inverters but instead use a string inverter. To install an optimizer, use the wire management clips to hold and manage the optimizer's cable. Insert the optimizer on the rail slot, and twist the bolt provided by your supplier to lock the optimizer in place. You will notice a notch that indicates if the optimizer is locked in place. The general rule is that when the optimizer is locked in place, it must intersect the direction of the rail slots. If your rail runs horizontally, you must lock your optimizer in the vertical position.

Step Four: Install the Grounding

The IronRidge system includes a grounding bolt for each solar array. There is a slot for it on the rails, and the bolt is attached to a copper wire which then grounds the system via a grounding rod already installed on your property. You will only need one grounding bolt per array because all the components of the mounting kit are connected. This eliminates the need to ground each panel and is probably the greatest advantage of the brand's mounting kit.

Step Five: Mount the Solar Panels

Take your solar panel and place it over the cable management clips. Lay it flush against the rails. Position

the panel so that the mounting holes are aligned with the rail's mounting channel. In the box of your mounting kit, you will find T-bolts and clamps that you can use to fix the solar panels to the rails. The clamps must go to the lower end of the solar panels. They function to prevent over-tightening while holding the solar panels in place. If you over-tighten the solar panel, you will risk damaging the top glass of the panels. Refer to the installation manual provided by your supplier to get a pictorial illustration of how the T-bolts and mounting clamps are inserted. Mount the solar panels with the longer side running vertically to the roof's pitch.

Things you must consider regarding the size of the roof. The number of panels you plan on installing must allow for a correction gap or module inter-row spacing. If you don't leave this gap, it won't be easy to maintain the solar panels when needed.

RAIL-LESS MOUNTING

The best mounting kit for a metal roof is arguably the S5 PV Kit. It is a rail-less attachment kit, and according to the manufacturer, it can save up to 35% on material cost and installation time.

Step One: Install the Mounting Clamps

Locate the positions where you want to mount the clamps. It is advisable to mount the clamps on the seams on metal roofing sheets. You must avoid drilling holes on the sheet base to prevent water from getting into your attic, which could end up damaging your roof. Measure and mark where you will be mounting your clamps starting with the end clamps. Attach a string on these two clamps to ensure the middle clamps are in a straight line. Use a permanent

marker or a sharpie to make your markings visible. Using your portable drill, drive the screws to fasten your clamps on the marked areas. An alternative is to utilize the existing roofing screw holes to avoid drilling more holes into the roofing sheets. Finally, screw in your edge grabs and secure them without tightening.

Step Two: Mount the Panels

Mount your first solar panel and tighten your edge grabs onto the panel edges. The first panel can work as a jig and base for the other solar panels. After this, install clamps on the other side of the first panel, maintaining the same seams on the other side. Attach the edge grabs to the new clamps and leave them loose to make room for the second top panel. The second panel must be mounted onto the loosened edge grabs of the second panel and secured on the other side by installing another set of clamps, and edge grabs to the other side of the solar panel. Repeat this process until you finish installing all the panels on the same side. The purpose of leaving the edge grabs loosened is to make it easier for the installer to align the other solar panels before tightening them smoothly. Finally, align all other solar panels to match the jig panel. Follow through tightening all the remaining edge grabs for a tight and secure installation. Repeat this process if another row is needed starting from the bottom panel. Ensure that your clamps have rubber seals for airtight connections during the installation. In the case of small visible spaces around the screw holes, seal these spaces with silicon to prevent rainwater from leaking under the roof.

Pros of Installing Solar Panels on a Metal Roof

Durability: Recent studies indicate that a metal roof

can have a lifespan of up to 60 years, which will save you a significant amount of money in the long run when it comes to roofing replacements and solar panel reinstallation. These roofs do not need to be replaced as often as asphalt roofs. Suppose your home solar system is designed to last longer than your asphalt roof. You will need to replace the roof first. I am sure you do not want to install solar panels only to take them down and do the installation all over again.

High wind resilience: Metal roofs have since become known for their resilience to high winds. This is only possible if the installation is done correctly to exploit the metal roof's structural strength fully. You must get a mounting unit with a similar wind loading rating to the panels. In most cases, the mountings are made from similar materials to a metal roof, meaning you can have uniform

snow and wind loading conditions. Asphalt and tile roofs normally have lower wind loading properties than the metal mountings installed on the solar panels.

HOW TO STRING SOLAR PANELS

Tools required:

Wire stripper and Crimping Tool

MC4 connectors and MC4 Tool

You will use MC4 connectors to string solar panels. The purpose of stringing is to reduce the number of wires feeding power into the solar combiner to make managing wiring easier. Take your wire stripper and remove one inch of insulation from one end of the connecting cable. The MC4 connector kit comes with a hollow contact tube, termed the “female positive contact.” After striping the end of the connecting electrical cable, insert the exposed copper wire into the contact. Crimp using the crimping tool to bond the copper wire to the contact. Pull the contact to make sure that the connection is tight. Slide the connector body over the contact and press firmly for a tight fit.

Finally, tighten the connector body and repeat the process for the other end of the connecting cable.

You can connect several panels, and generally, three panels can be joined together properly using MC4 connectors. If you plan on building a big array, the MC4 connectors are just an intermediate step, and the electricity they supply will be fed into the solar combiner.

6

SOLAR COMBINER

Chapter 2 mentioned that a combiner box is a useful part of a solar home system. Although it is an optional component in a three or four-string system, if a combiner is installed, it combines the outputs into one common output, transmitted by a current-carrying conductor. The conductor carrying this output connects to the inverter, and the result is consolidated power, which helps reduce power losses. The ideal combiner must be easy to install, eliminating the

need for a professional. Most combiners meant for DIY applications feature plug-and-play installation capabilities, and you have many choices when it comes to solar combiners. Your selection must be guided by maximum open-circuit voltage, maximum short-circuit current per string, and polarity protection.

TYPES OF SOLAR COMBINERS

Despite other ways of combining multiple strings from the solar array, like MC4 wire adapters, which do not provide safety for the solar system, the combiner box is the safest and most convenient unit to narrow the number of strings from the array. There are different types of solar combiners, and these differences are determined by the combiner's function in the solar system. Below is a list of the two main types of solar combiners and their respective functions.

Standard Combiner: The function of this type of combiner is to combine the several DC power input strings into a single output source which then goes into the inverter, or in some cases, a solar charge controller.

Disconnect Combiner: The sole purpose of this type of combiner is for safety. The disconnect combiner box allows the user to switch off the system at a single control point in an emergency, protecting the system from avoidable post-emergency damages.

CHOOSING A COMBINER

The next step would be to consider when choosing the suitable combiner for your solar system. Several factors would affect the type of combiner you need for your system

and the relation of the combiner to the other component in the system. Other important factors that must be considered are the combiner's maximum open-circuit voltage, short circuit per string, input and output fuse holder type, monitoring capabilities, maximum PV array connections, and the maximum input current of PV array, etc.

Combiner boxes usually come in metallic, outdoor enclosures and nonmetallic enclosures. The most popular combiner boxes in the US would be the Midnite solar combiner series and the eco-combiners, which are arguably the best in the market. Weather is another factor that can affect the type of combiner one needs, for it influences the design of the combiner enclosure. The number of strings to be combined can also be a factor to be considered when choosing a combiner, for it also affects the size of the combiner unit. Combiner boxes may differ in rating, so choosing a combination with the correct rating (e.g. voltage and current) is wise. Other components are also needed for the unit to function (e.g. circuit breakers and overcurrent protection fuses).

In some cases, larger arrays may require an extra set of combiners called re-combiners that feed into another combiner called a sub combiner. You will not need this for a home solar system unless you plan on living off-grid and intend to use solar power to meet your irrigation needs.

Mounting Your Combiner

The following are the steps to install a solar combiner box successfully:

Remove the conduit knockouts: A new solar combiner box usually has conduit knockouts placed to keep the combiner interior airtight. The first step of the combiner mounting process would be to remove the conduit

knockouts using a sharp/flat tool, preferably a flat head screwdriver with the aid of a hammer.

Choose the mounting area: The next step is to find a suitable flat surface to mount the combiner box and mount the combiner in the area. Your mounting area must not be in an area of continuous water flow and must not be exposed to extreme temperatures. Prepare to mount the combiner box at the back of the solar array for ground-mounted panels or the mounting rail on the roof. Drill holes on the chosen suitable area and secure the combiner box with the screws through the mounting slots on the combiner. You must not drill any holes on the combiner box for any other openings because this might expose the components inside the combiner to harsh exterior conditions. Ensure there is at least one inch on each side of the combiner box for proper heat dissipation, and there is also enough space for the combiner cover to open or close freely.

Install the grounding wire: Installation of an external ground wire is the next step of the mounting process, that is, if the combiner box requires this external ground wire. The ground/earth wire is attached to the ground bolt, which is usually close to where other strings enter and leave the combiner box. Unscrew the nut on the ground bolt just enough to make room for the ground wire to be placed between the wire slots in the middle of the ground bolt. When the wire is safely inside the slot, secure the wire by tightening the nut and ensuring the ground wire is secured properly.

Opening the combiner box: A screwdriver is the only tool required in this step. Unscrew the screws on the combiner cover and the transparent cover inside the combiner box.

Attach the conduit onto the conduit hub: The attachment of the conduit and conduit hub is the next step of the installation. The first step is to attach the conduit to the conduit hub. The assembled unit secures the hub to the knockout holes in the combiner box. Note that you must use conduit hubs approved by the local authority. To reduce system losses, the idea is to terminate the string wires close to the panels. After you have mounted the combiner box, you proceed with wiring the solar combiner box.

Wiring the Solar Combiner

The wiring stage is the last in installing the solar combiner and is also the most crucial stage. It requires great attention to detail to make sure installations meet the required guidelines stated by your regulatory board. Bad wiring connections may cause great damage to the whole system, and the surroundings can be at risk from electrical disasters. In the worst cases, reports of combiner boxes catching fire are common. So, at this stage, expert assistance might be required to inspect the combiner wiring before connecting the solar power either to the load or to the grid to avoid potential hazards. If it is a DIY installation, at least basic knowledge of electrical wiring would be needed.

In preparation for the wiring, the process makes sure all the required components are in place, including circuit breakers, ground terminal strips, lightning arrestors, and disconnectors. There are also complete ready-made combiner boxes on the market which can be a more friendly option for a DIY installation but can be a bit pricier than building up your combiner with components readily available at hardware stores.

The first step in building your combiner box is matching the number of strings from the solar array with the circuit

breaker so that each array is connected to its circuit breaker. This helps in the maintenance of the system, especially when there is a need to isolate or disconnect an array. Attach the circuit breakers to the breaker rail inside the combiner. Run your strings from the solar panels through the conduit into the combiner and cut off the excess length from the strings to avoid congesting the combiner box. It is advisable to mark the strings, both positives and negatives, with an electrical tape of different colors to avoid mixing up strings.

Strip the string ends to the desired sizes avoiding leaving unwanted bare wires. Attach the negative strings from the array to the negative busbar in the combiner with the aid of a screwdriver which loosens and tightens screws that hold the wires in their slots. The PV negative output string will also be attached to the negative busbar. Attach the positive strings to the bottom of the circuit breakers and overcurrent protection and make sure they are tightly fit to avoid free play.

On top of these circuit breakers, slot in the metal tab, which combines the positive outputs. There is also a lug on the metal tab, which will be the origination point of the combined positive output. Connect the equipment grounding strings from the solar panels to the grounding busbar. If it is a ground-mounted system, you connect your ground wire on the grounding bus bar and run the cable to your dc ground for earthing as per NEC standard.

You can also add extras to the wiring pool. A surge protector would be a good add-on to protect the system from lightning strikes. The surge protector beam goes through one of the knock-offs in the combiner frame, with the surge strings going in first. The surge protector has three wires and is wired by connecting the negative wire of the surge protector to the negative bus bar. The positive

wire of the protector is connected to the lug on the metal plate connecting the positive strings at the breaker area. Lastly, the surge protector ground wire is connected to the grounding busbar. At this point, one would safely say the combiner box wiring would be complete.

One thing to be mindful of is that solar combiner boxes come in slightly different designs, which vary from company to company, so do not be surprised if you do not find the components described where you would expect them to be. The manual or installation guide will be very handy in helping you to familiarize yourself with the combiner components.

Being a crucial component in the solar system, the combiner box requires routine maintenance, and below are some useful tips you might consider to keep your combiner in good shape. Regularly check for dirt building up inside the combiner and if dirt is present. Switch off the system by opening the disconnecting switch, carefully remove the fuses and avoid being shocked by the charged fuses. Vacuum out the dirt using a non-conductive machine. Check for any signs of moisture inside the combiner to ensure that the combiner seals are still in good working condition.

7

THE INVERTER

DC-AC power conversion is possible because an inverter can rapidly switch the DC power direction. This simulates the AC that power utilities generate. Some panels have micro-inverters integrated when they are manufactured. Power generated by each panel is converted

into AC at the source. This has many advantages over a string or central inverter system. You can extract more power from the panel because the maximum available power produced by a panel is fed into the system. If shading is a problem, panels will naturally produce different amounts of power, and a microinverter will deliver the maximum power available from the panel. DC solar optimizers also come with a built-in microinverter. You will need to check with your supplier if this is the case, and if so, you may not need to buy a separate inverter because the optimizers will perform this function at the panel level.

In a string system, the inverter feeds power into the system based on the output of the least producing unit. You can easily identify a panel not operating properly based on the individual power output. Some homeowners also prefer micro-inverters because the power transmitted by each panel never exceeds 220VAC, unlike a string system where the voltage is the sum of the voltage produced by every panel connected in series. The downside is that panels fitted with micro-inverters cost more than ordinary panels. The micro-inverters can act as tiny lightning rods that can conduct lighting to the system during thunderstorms.

Despite the improvements in reliability, most professionals, including myself, remain skeptical about this. The ability to monitor individual panel performance is not readily available to the end-user but rather the installer. If you want the ability to monitor individual panel performance, a separate monitoring system is required, which will add to the final installation cost. Choose panels with micro-inverters only if you anticipate shading problems from permanent buildings or trees that you have no control over. On the other hand, String inverters are simpler and easier to replace if they are faulty. You will have to sacrifice maximum power extraction for reliability and cost.

Besides just converting the power generated by solar panels into AC, most hybrid inverters nowadays come equipped with a charge controller. The controller is responsible for ensuring that if batteries are part of the system, they are properly charged. Overcharging and undercharging the battery damages the battery, resulting in degraded performance. Often, the batteries will not last as designed by the manufacturer when this happens. I have mentioned that you can directly use power from the panels if you have DC appliances or devices that work with both forms of electricity. There is a catch, however. The electricity produced by solar panels fluctuates throughout the day, and without an inverter, this electricity will be fed to the loads with no regulation. This can lead to either underpowered or overpowered appliances, damaging the appliance.

TOP FIVE INVERTER BRANDS

Choosing the best inverter brand is quite difficult because different people have different needs regarding their expectations from an inverter. People living off-grid will need inverters that are non-hybrid because a separate charge controller is necessary to charge the battery more efficiently, and an uninterrupted power supply (UPS) is not necessary. Off-grid homes are better off utilizing non-hybrid inverters because they are cheaper to purchase and less complicated to install. Below, I have detailed the leading inverter brands for both on-grid and off-grid home solar systems.

Fronius Primo 6.0: This is arguably the best solar inverter on the market currently. The manufacturer features an 8.2 kW power output with a built-in cooling system that guarantees reliability. Inverters generate heat,

and cooling can become an issue in hot climates. When supporting heavy loads, you do not want an inverter that burns out from thermal stress. Of course, 6 kW might be a little less than what a typical home needs to meet all of its electricity requirements. Still, this hybrid inverter works well when it works alongside electricity provided by the utility company. Other features include a maximum input voltage of 600 W, wireless monitoring, smart grid readiness, and data logging to the manufacturer's cloud service. You may not use all these features, but it is good to know that your inverter is primed for the future when smart grids become more common. Its revenue-grade metering is optional, and you will need to purchase this feature at an additional cost.

SolarEdge HD Wave Single Phase Inverter: The runner-up for this home solar system component features an internal arc fault circuit interrupter. This means that the inverter protects itself from short circuits and complies with the NEC's requirement of rapid shutdown capabilities. It also includes DC optimizers that help monitor the power produced by the solar panels. The power output ranges from 2.5 kW to 10 kW, making it ideal for residential solar applications. An integrated Ethernet port allows a monitoring system to be easily connected to check individual-level panel performance. Probably the best feature of this inverter model is its efficiency. The inverter uses digital processing technologies that result in 99% efficiency in converting DC electricity to AC. It is also very light, making it one of the easiest inverters for a DIYer to install.

SMA Sunny Boy Grid Tie Inverter: This is the inverter for you if you think about selling your excess power to the utility company. The manufacturer has been in the business for many years, and its model has been proven to be

reliable by many installers and customers who use this device. They are predominantly used as string inverters, and the maximum rating is around 7.5 kW. The average input voltage also stands at 600 V, with a standard output of 110/220 V AC.

Growatt SPF5000ES: This is the king of hybrid inverters. It contains the solar charge controller and AC charger, and it costs less than $1,000. Its AC charging capabilities mean you can use power from the utility company to charge your batteries if you have them installed. Ordinarily, you can charge batteries at 80A. The power output is rated at 5 kW, and you can set the inverter to deliver either 110 V or 220V as a single-phase output. The downside is needing a transformer if you want a split-phase power supply. Power input is rated at 450 V, slightly lower than the above brands.

Schneider Conext XW Pro: Featuring an output of 6.8 kW, this inverter is great for off-grid applications. Although it doesn’t work for grid-tie systems, I rank this inverter highly because it can be stacked with other inverters of the same model to increase its output power to just over 100 kW and can be arranged in groups of three to provide three-phase power. If you have a off-grid home business that demands three-phase power, you can use these inverters to supply all the electricity you need with little difficulty.

8

THE BATTERY BANK

You need to store the power produced by the panels during the day for use when the sun sets or in overcast weather if you are not on a grid-tie system, making batteries optional. Batteries are useful for this and are

mainly used in an off-grid setup where power from the utility company is not available. Several batteries are available on the market, but deep cycle batteries are the best for home solar projects. Avoid using batteries designed for vehicles because they are not deep cycle batteries. Instead, they are designed to deliver a large but unsustained burst of current needed to start automotive engines. On the other hand, deep cycle batteries provide current consistently, making them ideal for use in solar systems.

There are two leading types of deep cycle batteries. Lithium-ion batteries are the most efficient on the market currently. With depths of discharge (DOD) that average 80%, most people prefer them over lead-acid batteries despite the higher cost. Lead-acid batteries have an average DOD of 50%, meaning you can only use half the battery's rated capacity. As an illustration, if you have a lithium-ion battery with a capacity of 100 ampere-hours (Ah), the usable capacity is 80 Ah. After this, the battery will run out and need to be recharged. If the battery is a lead-acid battery, only 50 Ah is available before the battery runs out. This means that more lead-acid batteries are required for the same power output. You will understand the terms I just mentioned later on when we get to system design.

Batteries are designed to have a life cycle, usually determined by the charge cycle. You can easily relate to this if you own a smartphone. Over time, you notice that the battery will not hold up as when the device was new. iPhones especially have a battery count that lets the user know how many times the battery has been fully charged and discharged. Choosing lithium-ion batteries is one of the best decisions you can make because the DOD specifications mean your charge cycles will be less than

lead-acid and gel batteries. They will last longer before they need to be replaced.

In my experience, the greatest advantage that lithium-ion batteries have over lead-acid batteries is their efficiency. It is rare for a lead-acid battery to have efficiencies greater than 85%. If your panels deliver 100 W to the batteries, you will only get a maximum of 85 W from lead-acid batteries, while you can extract as much as 95 W from lithium-ion batteries from the same panel. This higher efficiency characteristic of lithium-ion batteries also means the batteries charge faster, so if the peak-sun hours in your area are below average, you must seriously consider purchasing this type of battery despite the cost. It is not uncommon for a lead-acid battery of the same capacity to take twice as long to charge. I do not advise anyone to consider lead-acid batteries based on these considerations. It is an old technology, and throughout this book, only lithium-ion batteries are considered batteries.

TOP BATTERY BRANDS

The general estimates are that solar batteries in the US cost around $700 for every kWh installed (Svarc, 2021). You will find that there are high-end models and lower-end models based on each brand's offerings. Remember that batteries are critical to meeting your electricity requirements, especially off-grid. Do not go cheap on this part, and look for manufacturers that offer long battery life and warranty. Below is a list of the top reputable brands. I have also included a few unknown brands that are highly ranked, feature good build quality, and are affordable. You can consider this brand if you are on a tight budget.

Powerwall: These batteries are manufactured by Tesla Motors specifically for home solar applications. The

production house is located in Nevada, USA, meaning you can easily source the batteries within the US and also get them replaced if they fail for some reason. The manufacturer offers a 10-year warranty because the batteries are based on lithium-ion technology, which explains the longevity. The batteries have a high lifespan, affordable. They feature an easy installation of an integrated battery inverter with smart-connect features that allow you to receive alerts if the environmental conditions are not perfect for normal or optimum operation. The batteries are sold as a package and can deliver at least 5.8 kW of continuous on-grid power and a peak of 10 kW for off-grid solar installations. You can expect to pay around $11,000, which is not bad for a battery of this quality. If you like smart installations that are child-friendly, the Powerwall is one of the best solutions for you. The major con is that these batteries are not available for individual purchase, and the company requires you to install the Tesla home solar system if you want a powerwall in your home.

Generac PWRcell: Generac has over 60 years of experience in the backup power industry and is located in Waukesha, Wisconsin. It is one of the most scalable, flexible, and powerful batteries on the market for home solar energy systems. The major selling point is that the battery is compatible with most installations for any climate because it features its Standard Outdoor Rated Battery Cabinet (SORBC). It has up to 9 kW of continuous backup power, and half of this is the standard operating output if the battery is connected to solar panels. It features a load protection system with cohesive load management, and this is why the manufacturer offers a 10-year warranty on the batteries. Configuration is easy, making it a flexible solution to suit most lifestyles. You can expect to pay around $20,000 for a basic model. There are

a lot of battery modules on offer. A single PWRcell inverter can allow the connection of multiple PWRcell battery cabinets. The PWRcell inverter load will be up to 36 kWh of storage capacity and 11kW of continuous backup power.

Sonnen ECO: The product is sold as a package consisting of 2.5 kWh modules and features high depths of discharge of around 90%. While the capacity of the base model is lower than what its rivals offer, the brand's pricing point is reasonable at $6,100 without installation. Another advantage is that you are not tied to an ecosystem if you purchase this battery. The company allows individual purchases through its website or official distributors. It provides links to professional installers for homeowners who may not be up to the task of a DIY installation. Homeowners can invest in these smaller solar batteries as per their needs in their homes. The battery capacity range is between 5kWh to a maximum of 10 kWh, and you can get at least 10,000 cycles from the battery. If you are based in Utah, you can benefit from the Utah Wattsmart Battery program that Sonnen supports to get additional incentives for your home solar system.

LG RESU: This model is a coupled DC battery perfectly compatible with hybrid inverters for both grid-connected and off-grid home solar installations. These batteries come in various sizes starting from 6.5 kWh to 16 kWh. The DoD for these batteries is 90% with a warranty of 10 years and up to 4000 cycles of life. This is a mid-range battery with a starting price of $6000, although higher capacity models can get up to $8,000 excluding installation. If you decide on this model, choose the 9.6 kWh battery because it provides the optimum solution for daily use. The modular design of this model enables easier transportation, handling, installation, and remote battery monitoring with real-time battery status monitoring and early diagnosis. This means

that you can easily identify any performance issues before they cause permanent damage to the battery.

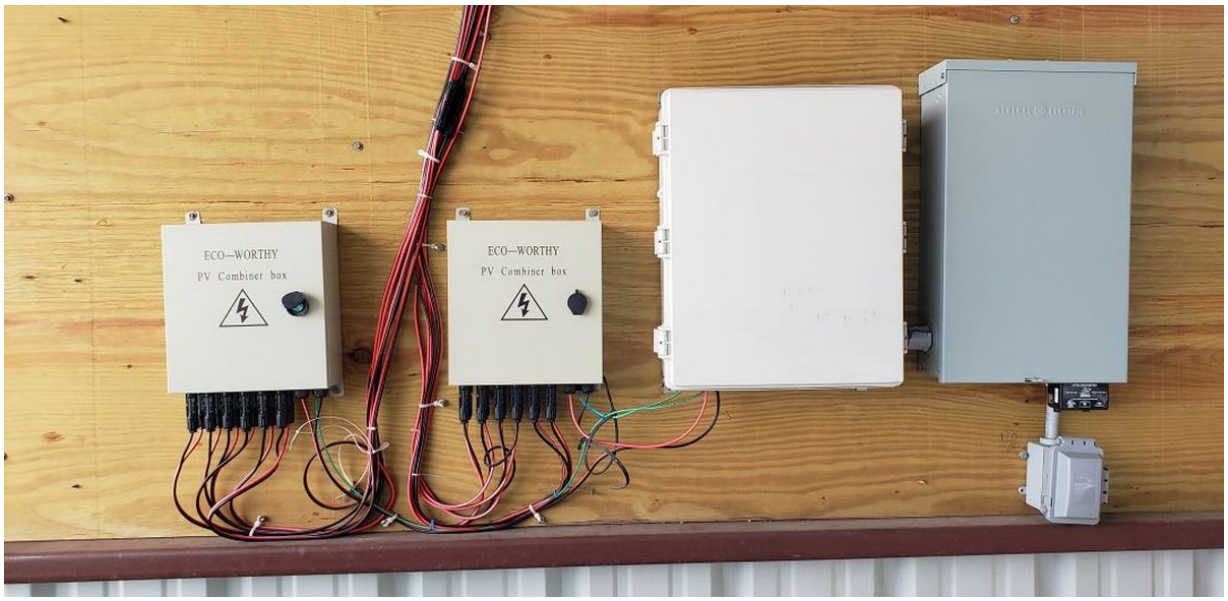
Best unpopular brands: SOK manufactures good quality lithium-ion batteries that are reasonably priced. The company’s 12V 100 Ah batteries cost around $600, meaning for this price, each battery will give you around 1 kWh after factoring in system losses. You can also get a 206 Ah battery for just over $1,000 from the same manufacturer. The battery cycles are rated at a maximum of 8,000, and the warranty is seven years, which is slightly lower than the other brands described above, but this is a fair compromise for the price. There are many reviews for this battery, and most professional installers agree that this battery gives the best value for money if you can get your hands on it. Due to very high demand, most suppliers struggle to meet customer orders. You can purchase this battery from the Current Connected website, and the products are available on pre-order only.

LOCAL PANEL BOX (JUNCTION BOX)

The Local Panel Box is an optional part of a Home Solar System. You could choose to connect your inverter directly to your Solar Disconnect Switch. But depending on your project details (Number and Location of Inverters, Location of Solar Disconnect Switch, Location of Main Power Panel), you may choose to add a local AC Power Panel to combine the AC Power from your inverters before sending it along to your Solar Disconnect Switch. This Panel Box can be a standard outdoor panel, so nothing unique or hard to find is needed if you choose to use one.

Mounting the Local Panel Box

Mount your Local Panel Box close to your Inverters. Open the Panel Box, and use screws appropriate for the purpose. Deck Screws into a sturdy Plywood board on which you have also mounted your Solar Combiners, and your Inverters will do the job easily and securely.



Wiring the Local Panel Box

You can connect the Inverters to the Local Panel Box using Insulated Copper wires rated for the Voltage (220) and Current produced by your inverter. Later in this book we will have two examples, one with a 8 kW Inverter and another with a 1 kW Inverter.

The 8 kW inverter will produce up to 36 Amps at 220 Volts. The Electrical Wire Tables show that for Power Transmission, for 37 Amps you need a 6 Gauge wire. You will strip the ends of the 6 Gauge wire and connect it to the output terminals of the inverter. Then the wire is routed thru Electrical Metal Tubing (EMT) conduit to the Panel Box. You will have mounted a 50 Amp rated double pole circuit breaker in the Panel Box. Strip the other end of the wires and Connect Line 1 and Line 2 to the circuit breaker. Your main breaker for the Panel Box may be rated at 50 to 200 Amps, and you will use a larger gauge insulated copper cable to go from the main breaker to your Solar Disconnect Switch.

The 1 kW Inverter will produce less than 5 Amps at 220 Volts. The Electrical Wire Tables show that for Power Transmission, a 12 Gauge wire is rated at 9.3 Amps which is more than adequate to support 5 Amps. Since the 1 kW Inverter will use a standard AC Power Cord. The output end of the cord will plug into a standard AC wall outlet. The AC wall outlet is mounted in a wall box inside the box in which the inverter is mounted. A small EMT conduit is connected from the Inverter Box to the Local Panel Box. You strip the 12 Gauge insulated copper wires on one end and connect them to the AC Wall Outlet repurposed to Line 1, Line 2, and Ground. You run these wires are from the Inverter Box thru the conduit into the Local Panel Box. You mount a 10 Amp double pole circuit breaker in the Local Panel Box. Then you strip the other ends of the wires, and connect Line 1 and Line 2 to the circuit breaker and Ground to the Ground Bar.

10

AC AND DC DISCONNECTS

Local regulations and building codes require AC, and DC disconnects to be installed as part of a home solar system. The purpose of a DC disconnect is to regulate the flow of DC electricity by preventing power generated by the solar panels from reaching the inverter when required. It is installed between the solar panel array and the inverter, although it can also be built into the Solar Combiner. A well-installed DC disconnect provides an easy and efficient way to switch off the solar systems as required by the regulations for providing safe methods of isolating the solar panels and the inverter. If your inverter does not have a built-in DC disconnect switch, you must follow the DC disconnect's installation manual to mount and wire the unit correctly.

On the other hand, an AC disconnect switch is installed after the inverter. It is used to protect the home in an emergency, such as a fire, and must be mounted near the electricity meter from the utility company outside the home. Firefighters and other emergency personnel need to quickly identify this disconnect switch if an emergency occurs. The two types of disconnects are part of the balance of system components. It also protects Power Company Linemen. If your inverter's grid-tie function fails

during a daylight power failure, the Solar Disconnect switch removes AC power from the grid and, more importantly, from the 220 Vac side of your Line Transformer. That Line Transformer could operate “backward” and feed multiple thousands of volts back out onto the supposedly “dead” power lines. Then the dead object could be your friendly local Lineman. Bad Day at the Office. So, provide a Solar Disconnect Switch and when requested by the power company, open the switch and save a life. (And a nasty lawsuit).

WHY ARE AC AND DC DISCONNECT SWITCHES IMPORTANT?

You don’t have an option for installing the disconnect switches. The law requires it, and that on its own makes them an important part of the home solar system. Your installation will not get permission to operate if the inspector cannot locate the solar disconnect switches. If you check with the 2020 NEC code, Article 690.13, more details about this regulation will be found. The main reasons that the disconnects are required are:

1. If a fire breaks out on your property, the AC disconnect switch is turned off to reduce the spread of fire and prevent the electrocution of the first responders or occupants of the home.
2. During severe weather, such as tornadoes, hurricanes, or electrical storms, a homeowner can reduce the likelihood of their wiring and inverter becoming damaged by flipping the DC disconnect switch.
3. If a flood occurs, both disconnects must be turned off so that there is no power in any part of the system.

4. Sometimes repairs need to be done on your electrical equipment, lines, or transformers. Contractors need to disconnect the power supply so that they can work safely when doing repairs.

How to Choose and Size Your AC and DC Disconnects

You find that disconnects come in different sizes, starting from 30 A to 800 A, and you will need to choose the appropriate size based on your solar system. The power output of your system must guide you by factoring in the system voltage, the rated insulation voltage, circuit load, breaker sizes, and cable sizes. The disconnect box can be equipped with early-break auxiliary contacts that can be used to signal the inverter's logic, stop the modulation, and bring the solid-state switched to a blocking state when opening the disconnect. Below is an explanation of a few parameters considered when selecting a disconnect switch.

Rated insulation voltage: The rated insulation voltage describes the isolation capabilities of a disconnect switch. The parameters of the rated insulation voltage are the dielectric strength which is the distance between the internal conductor of the switch, various insulation materials used to make the device, and the atmospheric environment where the device is installed.

Operational current and voltage: The voltage and the rated operational current value must match or exceed those from your solar array for DC Disconnect, and from your inverter for the AC Solar Disconnect.

Unlike solar panels, batteries, and inverters that have dominant players in the market, most disconnect products are generic, and I have rarely encountered problems with generic solar disconnects. The products are easily available online. If you want a quality product, checking out product

reviews is a great way to know that the product you are buying will work properly and last long.

How to Wire the DC Disconnect

All electrical installations must be done according to regulations available so that your home system conforms to the NEC and building codes standards. This installation is one of the critical things that the inspector looks at before final sign-off. The disconnect is installed between the solar combiner and the inverter. If you look at your DC disconnect, you will notice that there are hole templates on the DC disconnect used to make entry holes in the enclosure of the DC Disconnect. It is good to mount the disconnect box first before wiring the box. Read the instruction manual carefully and identify the components that come with the package.

Step one: Drill the holes for the DC disconnect wire glands into the din rail enclosure that comes with your disconnect box using a step drill tip. Install the wire glands onto the disconnect box. Normally the box has two glands, and you can use one for the incoming wires supplying power to the box and the other for the wires that supply electricity to the inverter. Offset the wire gland if you want to install a charge controller or additional breakers inside the box. You will only need a charge controller if your inverter does not have a built-in controller and install batteries as part of the system. The DC Disconnect is slid into the place on the lower right of the backplate. The left and right tabs are put on the front of the backplate, while the center tab goes behind it.

Step two: Attach the disconnect box to the backer board using screws. Truss head screws are great for this. Make sure that each box corner is attached to the backer board. Proper alignment is achieved by leaving the screws loose

for the time being, while tightening will be executed in a later step. Proper grounding is achieved when the teeth of the lock washers face the tab, not the screw.

Step three: Install the wire duct. This is an optional step, but it will make your installation look professional. Wire ducts are just a piece of plastic conduit with small ‘fingers’ on the sides. They are designed to pass wires through, and the slots allow the wires to easily ‘leave’ the channel and attach to the components. It includes a snap-on lid that keeps all of your cables neatly organized, concealed from view, and gives the wire a layer of physical protection. It can be attached to the backer board using truss head screws. You must have your inverter already mounted on the wall by hanging it by the two tabs located at the top of the inverter’s backplate. You must not set the full weight of the inverter on top of the DC disconnect, so precautions must be taken when you are setting the inverter in place.

Step four: The grounding screw and lock washer are inserted on the bottom of the inverter and tightened to a torque. The DC disconnect is held against the bottom of the inverter, and mounting screws are tightened to a torque. Remove the cover of the inverter as illustrated in the instruction manual. You must take care to avoid damaging any components. Attach the grommets supplied with the DC disconnect into the two openings located at the bottom of the inverter’s cover. The grommets are meant to provide a tight seal to prevent dust and moisture from getting in. They also add insulation in case the insulation of the electrical cable gets damaged. You want to protect the inverter’s metal body from contact with a bare current-carrying wire.

It is convenient to insert the wires carrying DC power into the left grommet on most inverters. The red wire is connected to the terminal block marked positive (+), and

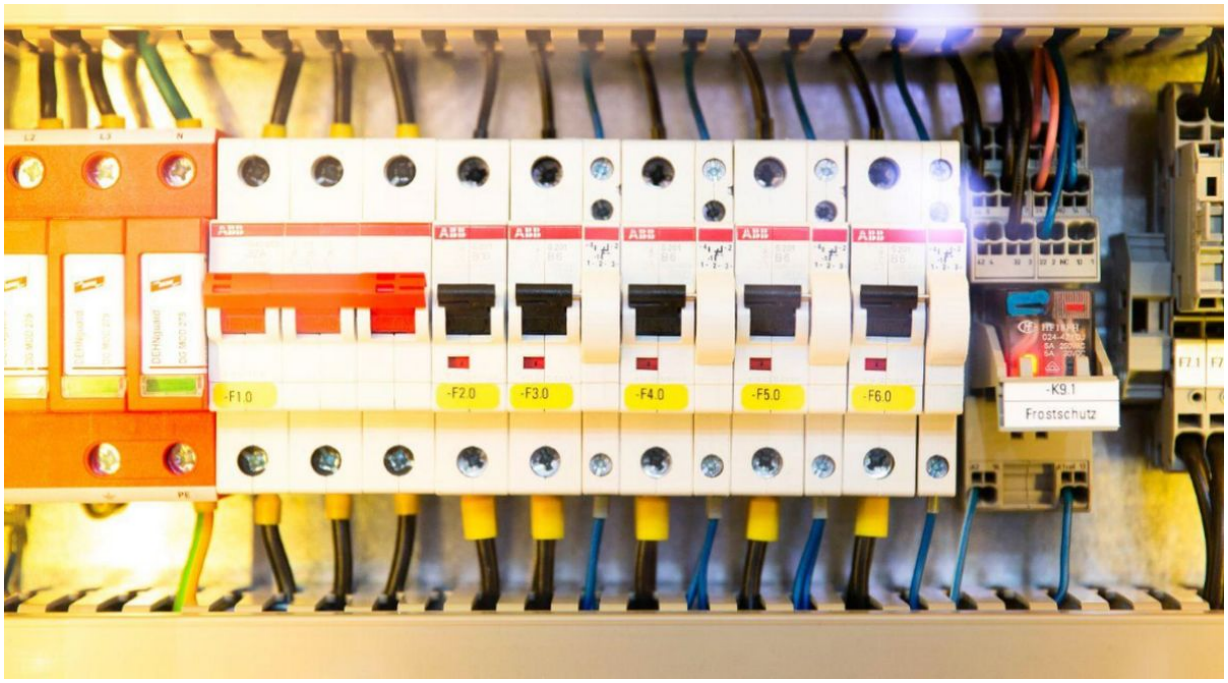
the black wire to the terminal block marked negative (-). The grounding conductor is marked according to the manufacturing standard. You may find this terminal marked GND or represented by an earth sign that is frequent on most AC appliances' plug tops.

Step five: Insert the AC wires into the right grommet. Connections of the black, red, and white wire vary with the design and regulations available. The earth-ground conductor does not need to be connected to the terminal in the inverter, and the outer casing facilitates the grounding of the inverter. After all the wires have been placed where they are supposed to go, tighten each screw that secures an electrical wire. Be careful to overtighten. Normally, you will "feel" that the electrical contact is tight enough to prevent it from loosening during normal operation. The inverter is usually a fixed device, and therefore, there is little that can cause the connection to loosen. The danger of loose connections is arcing and sparks, so it is important to ensure that the contacts are properly secured.

Step six: The AC and DC field wiring are connected to their respective disconnect switches. The most terminal block is where the earth ground connects on the right. This is a simple process that does not need much explanation. After the connections are complete, replace the cover of the DC and AC disconnect switches.

11

WIRING



Wiring is the last stage of the solar installation process. At this point, the goal is to bring the AC power from the inverter to the home's AC service panel or main panel box. The box is sometimes called the distribution box and houses all the breakers that receive power from the electric utility company. This service panel is the main distribution panel, acting as an AC electricity receiver to distribute the power to your home's branch circuits (lights, electrical

sockets) to power your appliances. Its main components are the panel door, protective cover with openings for circuit breaker switches, and circuit breakers. The wires are hidden behind the breakers to avoid contact with hot circuits. Circuit breakers for the subsidiary circuits and the main breaker are connected to the service drop feeder supplying the power either from the grid or a backup power source.

The service panel has additional circuit breaker spaces for possible expansion in most cases. You will also find bus bars inside the main panel box. This is a metallic strip used for local high current electricity distribution. If your home is off-grid, newly built, and has not had its wiring, then you will need to wire the house to bring lighting and power sockets where they are needed. Sadly, I cannot cover this in this book, and chances are, in your state, a licensed electrician is needed to wire a home according to the building codes and the NEC standards.

AC WIRING TO THE HOME AC SYSTEM

On this part of your home solar installation, I have to re-emphasize that you need to observe safety. Start by checking all your backup power source connections, beginning from the solar panels down to the output strings on your inverter, to ensure the connection is secure before connecting the outputs from the inverter to the service or main panel box. Check that the main breaker in this panel is off, and test that there is no electricity being distributed. If there are any other existing power feeders apart from the utility, switch them off using its circuit breaker. The main breaker normally has a “twin switch” situated at the top center inside the service panel for the utility feeder. It can also be identified by its thick wires coming in and out of the

circuit breaker. The wires are the thickest among the ones passing through the other breakers.

Use your digital multimeter to do a power test by selecting the appropriate function based on the instruction manual. Here you will be wiring the AC system from the solar disconnect switch, and this means that you will be installing the wiring that transmits power from the inverter to the AC main panel. Once you are certain that the entire system is off, wiring can be done. Now that the safety issues are out of the way let the fun begin.

Step one: Check that all power sources are off again, then open the service panel breaker cover with a screwdriver and identify the circuits you want to use to distribute solar power in the home.

Step two: Find a circuit breaker to use for the solar input. It will be spare a two pole breaker rated to receive the power from your inverter.

Step three: Connect wiring to the inverter outputs. Make sure your inverter is compatible with service panel circuit breaker connections. To determine the installation's wire size, use a wire sizing chart to pick the correct wire size. These are not difficult to find. Search online, and you will get a suitable chart to use that determines the correct electrical cable gauge for the voltage and current to be transmitted.

Step four:

1. Test the busbar with the multimeter to check if there is any voltage reading.
2. If there is a voltage reading, **stop** the installation and check if the main breaker is still switched off,

and if the voltage reading keeps showing up, contact an electrician.
3. Once you are certain that there is no voltage reading, continue with the wiring process.

Step five:

1. Strip off the insulation from the wire ends, which run from the inverter to the breaker using a wire stripper.
2. Connect the neutral wire and ground wire to the grounding busbar on the service panel and connect the hot wires to the selected breaker.
3. Secure the circuit breaker.

Step six: Once all the inside connections have been made, place the circuit breaker cover, turn on the main breaker and the inverter, and test the system. If everything goes well, you should expect to see signs of life in your system. The power for your home will now be coming from your solar system.

12

PERMISSION TO OPERATE

You will need permission to operate the system, although this can be an exception if you install the system off-grid. In the United States, permission to operate is usually obtained from a local authority. A utility company representative must be present to determine if your system does not pose a risk to the utility company’s infrastructure

for grid-connected systems. This process can take between one and two months; therefore, you need to be patient while waiting to get your system approved. Both the local authority and a utility company representative must give the green light for the system to operate as a grid-connected system. If you live where building codes are enforced, the building inspector normally performs an inspection first and issues a report. This report is then included in the paperwork forwarded to the power utility company.

You need to be mindful of the following aspects that inspectors might look at before operating your system.

Quality inspection: Your solar system's energy passes through one or two inspections from the local authorities to make sure it meets the required standards or codes. An inspector from the authority will visit your home to conduct the system inspection. The waiting period for the inspector is usually a couple of weeks, but this varies depending on the assigned inspector's schedule.

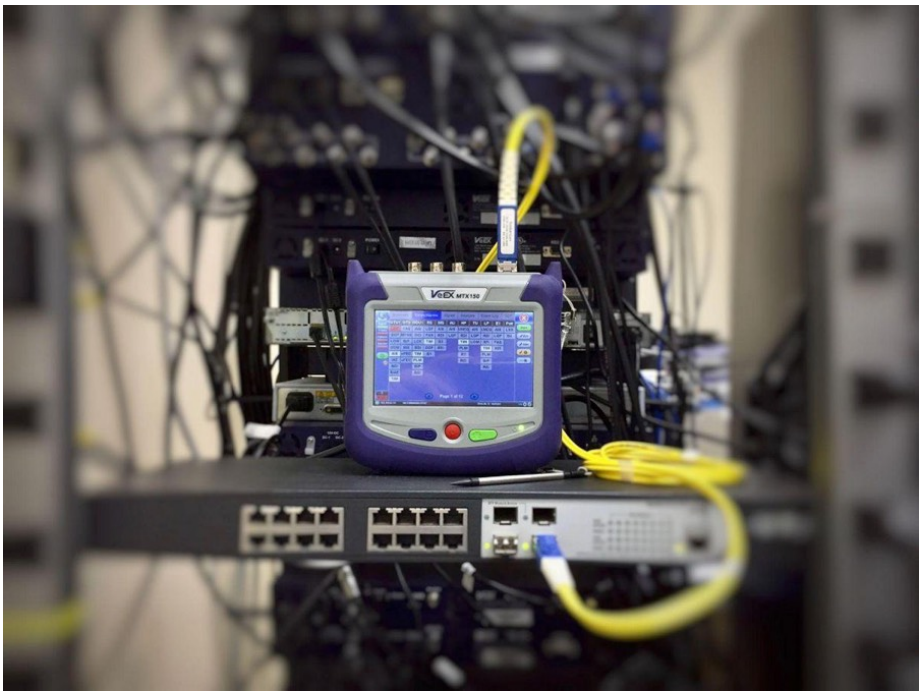
Proper labeling: The system components must be properly labeled and marked, especially the AC and DC disconnect switches. In the event of an emergency, it is important for firefighters and other first responders to quickly determine which switch to turn off so that they can perform their rescue mission in the least possible time.

Meter replacement: If you are planning on having a net metering unit installed, the utility company will follow up the inspection process with installing a new meter, or they may decide to reprogram your existing meter if possible. If you are lucky, you can get a new meter on the same day that the inspector deems that your installation meets the requirements.

There are many other things at which inspectors look. Most of the issues we have already covered. If you go through the inspection checklist designed for one and two-family dwellings, you will find that all the holes you have drilled when mounting your solar panels are checked to determine if they are properly sealed. Grid-connected systems must be marked “utility interactive,” and the inverter output breaker must be located at the opposite end of the bus from the utility power supply. There are over 100 items on the checklist, and you will do yourself a favor if you look at them before starting your installation. If the inspector finds errors within the solar system, alterations may need to be made to make your system compliant with the standards. You will have to schedule another inspection, and likely you will have to pay for it. If your system passes the inspection, it can be immediately turned on, and you start to enjoy the fruits of your labor as soon as the inspector leaves your property.

13

MAINTAINING AND MONITORING YOUR HOME SOLAR SYSTEM



Technical and performance issues are not uncommon, and you can easily detect problems using either the information displayed by the inverter or a solar monitor. Depending on the solar monitor you choose to install, you can either “see” how your system is performing or remotely adjust your consumption to keep your electricity usage in check during periods of high demand. Some monitoring systems send alerts to your mobile device if drastic

changes in energy production are identified. Here is a breakdown of what you can expect a high-quality solar monitoring system to do for you.

Production level monitoring: This is the first monitoring level. Your monitoring device will tell you how much electricity your solar panels are producing at any given time. This information is represented digitally, and you can use an app that comes with your monitoring device to display the production readings. You also have plenty of devices to choose from, and the prices begin from $20 to over $300. Sense Energy Monitor is one of the leading brands that are easy to install. It takes less than an hour to install the device, but there are concerns that it does not always give accurate readings. SolarEdge also manufactures high-quality solar monitors with fault detection. You must purchase the SolarEdge inverter to use this system because the monitoring system is integrated into the inverter.

Consumption monitoring: You can also monitor how much electricity you are using, and over time, your device will learn which appliances are consuming the most electricity. This will give you control over which appliances to run at a specific time of the day. Ordinarily, you will want to run appliances that demand more electricity during the peak sun-hours period so that you can give your panels enough time to charge the batteries if they are installed.

Bill comparison: This is a great feature if you sell power to the utility company. You can easily compare how much you are paying for your electricity against how much the utility company pays you for the power you export to them. You can also get daily estimates of what you expect to pay for the power you use from the utility company. This feature is handy and works well to see if you are saving money through your solar system.

TROUBLESHOOTING

The two common problems that a home solar system can often encounter are zero power output (no power) or high-voltage and low-voltage issues. The starting point when you encounter either of these issues is the instruction manual that comes with your inverter. Most digital inverters have a display screen that shows error codes. If you cannot determine the cause of the problem, you can take the following actions to fix the problem.

Zero power output: A frequent problem when a home solar system has been operating for some time. It is caused by either a faulty inverter or charge controller. There is also a probability that one of the panels could have failed. If your solar panels are connected in series, a failure of one of the solar panels introduces an open circuit. To fix the system, check each component using a multimeter. You will need to select your multimeter for a current / voltage test. Zero Volts or Zero Amps from the array points to a bad panel.

High power output: Sometimes, the system can provide too much electricity that can cause damage to the appliances. In most cases, this means that the voltage regulator located inside your inverter is no longer working properly. Inverters are supposed to shut down if conditions of over-voltage are detected.

Low power output: This occurs when a solar system is not delivering adequate power for which it is rated. Solving this problem is more involved than fixing a no power problem. Some factors that cause a lower power problem are:

- **Shading:** This is the major common cause of low voltage. A regular survey of the installation site is recommended to ensure that there are no trees around, which will be a shadow on any day of the day. The shadow will impede sunlight from directly hitting the solar panels. The lifespan of the solar panel is high, while trees grow over time. The canopy of trees varies with the type of tree and the magnitude of the shade it provides.
- **Temperature:** Voltage drop increases with a temperature rise. High temperatures cause the system to produce a lower power output. Adding more modules in the series will eliminate this problem because you will increase the system voltage. Make sure that there is sufficient air circulation under the panels and around the inverter. Do not block any openings on the inverter.
- **Bad Connection:** Check for a bad or loose connection. A multimeter is used to check voltage levels at various points to determine where the low voltage is initiated. Poor wiring is the most common cause of this problem. It is recommended to engage qualified personnel to re-do the wiring and installation.
- **Solar panel defects:** Despite the life expectancy of a solar panel, failure is not uncommon. Product recalls are frequent, and this is why you must choose a reputable brand. If you buy cheap products, chances are you won’t be informed of a defect, and usually, there is no warranty, or it is voided if you install the system yourself. You can check your panels for the following during troubleshooting.
- **Battery not adequately charged:** This is common in off-grid installations, particularly if the system runs for a while. If poor quality batteries are used,

the battery cycles cannot be guaranteed, and the battery will lose its ability to hold a charge very quickly. In this case, check that the battery is holding charge correctly by using your multimeter. Each battery must record a voltage greater than 12.6 V. If you notice your batteries are below 12 V after charging them, then it is probably time to replace the batteries. Sometimes, the charge controller could be faulty as well. You will need to get your inverter checked by the manufacturer if the inverter has a built-in charge controller.

Hotspots

When micro-cracks appear in the cells, a hotspot occurs. This will result in a series of resistance of the solar cells in a panel that could have increased over time. The overall result is a lower voltage in the panel, and the overall voltage of the solar array will be brought down.

Faulty Panel Junction Box

A junction box exposed to moisture might cause an increase in resistance. This is why you must ensure a tight seal when you install the local junction box behind the solar panel. There must be no air gaps, and you must let the adhesive fully cure before mounting the panels on the roof.

Delamination

When the bond between the plastics at the back of the panel and the top glass separates, the condition is known as delamination. The naked eye can easily observe this problem, and moisture can penetrate the electrical circuit of the panel, which might create a current or short leak if there is delamination.

Other Troubleshooting Solutions

Check the breaker switches: Zero-power can occur if surges, glitches, and overloads trip switches. This prevents solar electricity from either charging batteries or distributing power to the main panel box. If you flip the switch on and off and nothing happens, continuity test, and if nothing happens, your breaker might be faulty.

Check for obstructions on the solar panels: Unexpected shading can come from recent tree foliage, accumulated dust, debris, and pollen that can build over time. Consider installing a pet guard to prevent mice, birds, and rodents from making a home out of your solar panels.

Check your solar monitor: Data from your solar monitor will give you a good picture of what is happening to your system. The good thing is that the data logging shows you the system's historical performance, and you can always trace back to the point in time when the system began to lose its performance.

TAKING CARE OF YOUR SYSTEM

Although solar panels do not require maintenance like other power generation devices, you may need to maintain them from time to time. Physical inspections must be done regularly to identify anything that could interfere with how your system operates. Here are some of the activities you can do to take better care of your home solar system.

- Remove and constantly trim any trees or vegetation that can introduce shed to your panels. You may not have tall trees on your property, but your neighbor might. Consider talking to them about the options regarding how to prevent your solar panels from becoming shaded. If birds frequent your property, check the panels for bird droppings and clean

appropriately using a lint-free cloth that does not scratch the glass surface. Cleaning agents can cause abrasion and make the panels opaque, and scratches can scatter the light, preventing it from effectively reaching the cells. You must use only water to clean the surface of your panels.

- Do not use alternative light sources to make your panels produce electricity. Light from fires and torches can potentially damage your solar panels, voiding your warranty and setting you back thousands of dollars. Make sure only direct sunlight falls on your array.
- Keep dust away from your inverter. Dust is a good conductor of electricity, and if dust enters your inverter through the cooling system, the internals of your inverter may short-circuit, resulting in either a fire or an electrical explosion. In addition to this, your inverter must not get into contact with water. Not only will your system get damaged, but you also risk electrocution and damage to your electrical appliances if moisture gets inside the inverter.
- If batteries are installed as part of your system, do not place the batteries directly onto the floor. If you do this, the cells of your batteries can get damaged because of the floor temperature and lack of ventilation.

TOP MISTAKES THAT PEOPLE MAKE WHEN INSTALLING A HOME SOLAR SYSTEM

Poorly sizing the system: Solar users, in most cases, end up on the wrong side of their expectations because of wrongly sizing their systems. Grid-tied users usually over-project their savings and do not consider what their solar system produces compared to their usage. In off-grid

installations, solar system users can be blacked out. Commonly, off-grid users usually don't factor in the production changes caused by seasons (e.g., during winter, solar panels tend to produce less energy because of limited sun hours). Perform your calculations thoroughly, and factor in seasonal changes before installation can efficiently help you decide on your system's sizing.

Poor foresight: Solar users usually make their solar system decisions based on their current expectations. Customers may only look at their current load and side-line room for expansion. A solar system is a long-term investment; long-term factors should also be considered when choosing the right system for you and your family. Another thing to factor in is the loss in performance over time. Solar panels lose about one percent of their output per year, depending on the brand's quality. You must take this into account. Oversizing your system slightly is the way to compensate for the losses in solar panel output.

Improperly mounting solar panels on the roof: Mounting solar panels requires precision. If your panels are not properly oriented or in perfect alignment, they will be exposed to the sun differently, resulting in a different production at the individual panel level. Solar optimizers can help correct this problem, but they can only work with what they have been given. You need to avoid power mismatches as much as possible. Avoid installing solar panels of the same array in a different place. I know some people prefer to install connected strings on either side of the roof, hoping they will take advantage of the sun's movement. This is a bad idea, especially if the panels are connected in series. Your system performance will be based on the panels generating the least electricity. If you want to take advantage of the sun's position throughout the day, installing a ground-based system that utilizes solar trackers

is better. They are quite expensive, but you can easily double your peak-sun hours by installing solar trackers.

Focusing on the cost of installation: Most owners fall into the trap of choosing the cheapest option for their solar system investment to shorten their return-on-investment period. You might find that the cheaper options in solar supplies may not be as effective as expected. Another con of buying cheap products is that the costs incurred in maintaining these products will increase the return-on-investment period and, at the same time, compromise the process of energy production. Never compromise on the quality of your solar system.

Not installing a monitoring system: The ethernet port on the inverter is there for a reason. I do not consider this a mistake by the DIYer because professionals do not often discuss solar monitoring. If you want your home solar to continue giving its peak performance over its lifetime, you must install a monitoring system.

FUTURE THREATS TO YOUR HOME SOLAR SYSTEM

With remote monitoring via the ethernet communication ports that most inverters now have, your home solar system is vulnerable to cybercrime. The industry is moving towards smart-grids, and your connected home can serve as an entry point for malicious activity. Think about the ransomware attacks that became a big story in 2021. In a ransomware attack, a hacker can prevent you from accessing electricity from your home system. Or they can subtly do this by either manipulating your solar monitor or stealing part of your electricity. This has happened before on a larger scale, and in recent years, there have been attacks on national infrastructure, leading to blackouts in some communities. Denial-of-service, or DDoS attacks, can

occur if a hacker penetrates your home network and gains access and control of your inverter. You need to be aware of system vulnerabilities, and these vulnerabilities can be easily fixed if you keep up-to-date with the software updates from your equipment manufacturer. If you are not a technically inclined individual, relying on the security patches from your supplier is the simplest way to guard yourself against cyber-crime. You must also make sure your home network is secure to prevent system intrusions that might be difficult to detect.

BONUS TIPS

Find a friendly licensed electrician: If you install your system DIY, mistakes are bound to happen. Before you call the inspectors for your permission to operate, ask an electrician to do a preliminary inspection for you. Doing this will help you reduce the chances that your system will be deemed unsafe. Likely you will pay a small fee to the licensed electrician so that they can determine if everything was done correctly.

Consider a professional initial site visit: It will be difficult for you to comprehensively assess the condition of your roof on your own and provide an engineering report that may be needed when you file your application to get permission to operate. The engineering report will also help you choose the appropriate racking system and give you quantitative evidence that your roof can support the full weight of the solar panels that you plan to install.

File your application early: Filing your application early will avoid delays in getting your approval. It is now possible to file these applications online, and you will get an appointment date from the local authority regarding when

the inspector will visit your premises. This can take anywhere between 30 and 45 days.

Buy all your components from the same supplier: You want to ensure that all your components are compatible with each other. Instead of stressing yourself going through the technical spec sheets, buying your supplies from one vendor will give you access to knowledgeable people who can recommend the best products in their store.

14

EXAMPLE PROJECT - GRAND FORKS

We have discussed your options regarding solar panels, batteries, and inverters throughout this book. We have also talked about installing solar panels on the roof wiring the solar combiner and the AC systems, among other things you need to do when installing your home solar system. This chapter will demonstrate an example project to give you a better perspective of what you need to do when designing and installing your home system. This project will be a case of a home located in a cold climate. A home located in Grand Forks, North Dakota, will be our case for a home located in a cold climate, and the system design is focused on low-cost without sacrificing system quality.

For this reason, a mix of popular brands and unknown brands will be used as the components for the system. Cold climates generally have fewer sun hours than warm climates, so choosing Grand Forks city for this example. If you live in a warm climate, you can easily use this example to start and complete your home solar system installation.

DESIGN CONSIDERATIONS

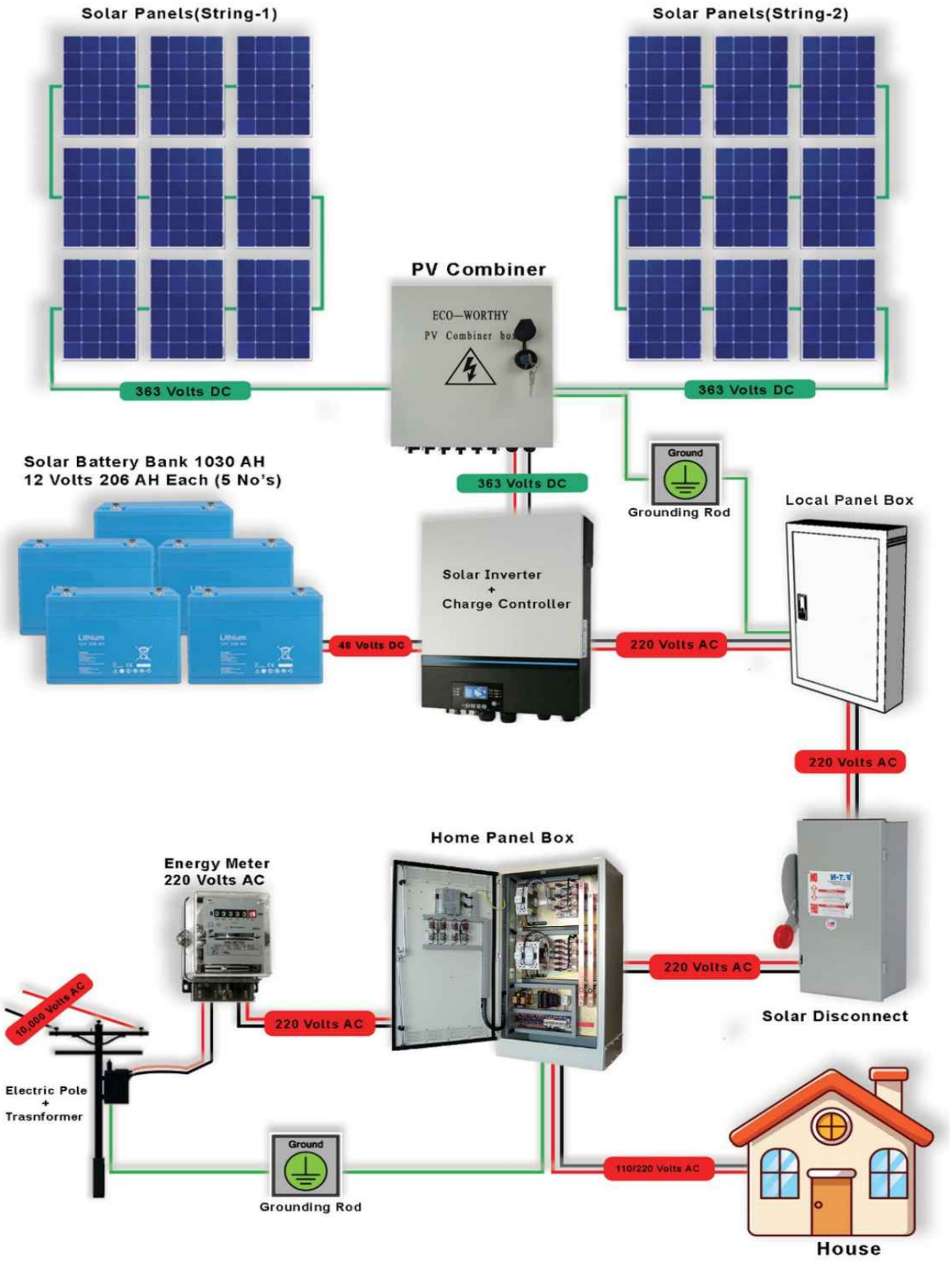
Operating temperature: The minimum average temperature in Grand Forks is negative 3.1 degrees F.

Based on the temperature coefficient of bi-facial solar panels, a home solar system based on bi-facial solar panels is the best solution because this type of solar panel outperforms the monocrystalline single face solar panel in colder temperatures. It is recommended to connect the solar panels in series for cold climates. However, most inverters are limited to 600 V DC input, meaning the solar panels need to be split into two arrays.

Average household electricity consumption: In this example, we will use the national average consumption of 10,500 kWh per year. This translates to an average of 30 kWh per day. It is good to oversize the system to account for conversion losses at the inverter. The standard practice is to add 25% to the daily consumption. In this case, we could say that a typical home in Grand Forks consumes an average of 37.5 kWh per day.

Sun-peak hours: Grand Forks has 4.52 sun-peak hours.

SYSTEM DESIGN


Solar Panels(String-1)
Solar Panels(String-2)
PV Combiner
ECO—WORTHY
PV Combiner box
363 Volts DC
363 Volts DC
363 Volts DC
Ground
Grounding Rod
Solar Battery Bank 1030 AH
12 Volts 206 AH Each (5 No's)
Solar Inverter
+
Charge Controller
48 Volts DC
220 Volts AC
Local Panel Box
220 Volts AC
Home Panel Box
Energy Meter
220 Volts AC
10,000 Volts AC
220 Volts AC
220 Volts AC
Solar Disconnect
Electric Pole
+
Trasnformer
Ground
Grounding Rod
110/220 Volts AC
House

Sizing and stringing the solar panels: To adequately provide an average home with electricity with the smallest physical footprint, we need the maximum available rating for a bifacial solar panel. The largest available bifacial panel is a 450 W solar panel, translating to 18 solar panels for the system. In this example, we will use the Blue Sun Mono panels with a total surface area of 23.5 sq ft. A total of 450 sq ft rooftop area is required, and the panels will exert a total of 2.4 lbs per sq ft. You will need to determine if the solar panels can be supported your roof. The rated maximum output voltage is 40.4 V per panel.

Splitting the 18 modules into two arrays results in a maximum operating DC voltage of 363.6 V. The total output of the solar panels is 8.1 kW. The solar panel's cost is $157.50 bringing the total cost to $2,826 without shipping.

To reduce the number of wires transmitting electricity into the combiner box, the panels are stringed into groups of three using the MC4 connectors. This results in six inputs feeding into the combiner box. If the panels are not supplied with MC4 connectors, these will need to be purchased separately. They are inexpensive, and you can ask your solar panel supplier to include them.

Choosing the mounting: The Iron Ridge mounting has been selected for this project. The steps described earlier in the book can be followed to install the mounting. Each kit costs $60, and to mount 18 panels you need 18 kits. The total cost is $1,080. The roof can be painted underneath the panels using reflective paint. There is no need to paint the entire roof, and the panels themselves will hide the reflective color. Around five gallons are required to paint 450 sq ft with durable reflective elastomeric paint. The

estimated cost is $150 if the paint is purchased from Home Depot.

Choosing the combiner box: The system's maximum operating current is 22 A. Therefore, the standard 63 A combiner box is sufficient for this system. For this project, the Eco-worth combiner box is a good choice, and the cost is $200, including shipping from Amazon.

Choosing the inverter: The inverter must have an output lower than the rated output of the solar panels. This means that the inverter output must be less than 8.1 kW. For our example, we will choose the SMA's Sunny Boy central inverter because it is known to work well with bifacial solar panels. A maximum of 600 V DC can be fed into the inverter. If batteries are installed as part of the system, the inverter has a built-in charge controller, and a separate controller is not needed. The solar panel configuration described above is within the design specifications of the inverter. The model costs $2,000 from Sunwatts plus an additional $175 shipping.

Selecting the electrical wire gauge: At 363.6 V, the maximum system current is 11.1 A per string. A 10 AWG wire is sufficient to transmit power from the combiner box to the inverter based on the wire gauge charts. You will need two wires, one for the negative and one for the positive terminal. These two terminals will connect directly to the input of the inverter.

Selecting the batteries: The SOK 206 Ah battery provides the best value for money. A 48 V system is regarded as the most efficient setup for home solar. This means that you will need to connect four batteries in series to obtain a 48V battery module. The daily power requirement is 37.5 kWh per day. Since batteries are rated in Ah, we need to divide this figure by the system voltage.

The calculation yields 781 Ah. It is necessary to multiply this by the charge efficiency, which stands at 90%, and a 90% depth of discharge typical for lithium-ion batteries. The required battery capacity is 964 Ah. Since each batteries provides 206 Ah, five battery modules are needed for this installation. Five modules times four batteries per module equals Twenty batteries. The total cost of the batteries is $5,500.

AC and DC disconnect switches: These components can be purchased for as low as $15, although higher quality products start from $114. For this project, both disconnects are required, and the total cost is around $228. The components can be bought online from Amazon or Harbor Freight, and local hardware stores also stock AC and DC disconnect switches.

Once your components are in place. You can follow the steps described in the previous chapters to mount your solar panels, connect the disconnect switches, and wire the combiner box. Additional electrical cables are needed to transmit electricity to the AC main panel box from the inverter. The length of the cables depends on the distance between the inverter and the main panel box. Finally, the monitoring system can be installed, and the installation turned on after the permission to operate has been issued.

Overall project cost: Adding the total material costs, you can expect to spend just over $11,000. It is always good to add 20% for unexpected costs such as filing paperwork and inspection fees. In total, an 8 kW system using bifacial solar panels can be installed for under $15,000.

This is a far cry from the average cost of professionally installing a home solar system. Of course, the work is hard, but you will save a lot of money and gain new skills by going the DIY route. Research shows that installing a home

solar system on your own will save at least 10 % of the total cost. Still, most surveys and calculations do not factor in the savings a homeowner makes by purchasing their components. Professional installers make a profit on the components raising the total cost of a professional installation.

Payback Period:

System Costs	Grand Forks	Dallas
Cost Per Panel	157.5	89
Number of Panels	18	10
Cost of Panels	2835	890
Mounting Kit Cost Each	60	5
Mounting Kits Cost	1080	50
Cost of Combiner	200	374
Cost of Inverter	2175	280
Cost per battery	1100	0
Number of Batteries	20	0
Cost of Batteries	22000	0
Cost of Solar Disconnect	66	33
Cost of Panel Box	150	120
Cost of Wiring	200	50
Cost of System	28706	1797
Cost of Electricity per KWH	0.1196	0.1196
Electricity Use Per Month KWH	937	150
Cost of Electricty Dollars per Month	112.07	17.94
Number of Months needed to equal cost	256.15	100.17
Number of Months per year	12	12
Payback Period - Years	21.35	8.35

15

EXAMPLE PROJECT – DALLAS 1KW

There are many ways to install a DIY Solar System. This example shows that you can get started with DIY Home Solar fairly inexpensively. This project will be a case of a home located in a hot climate. A home located in Dallas, Texas, will be our case for a home located in a hot climate, and the system design is focused on low cost and expandability. For this reason, a mix of popular brands and unknown brands will be used as the components for the system. Hot climates generally have abundant sun hours compared to cold climates, which is why we chose Dallas for this example. If you live in a warm climate, you can easily use this example to start and complete your home solar system installation.

DESIGN CONSIDERATIONS

Operating temperature: The average temperatures in Dallas are 46 degrees F in January and 78 degrees F in July. Low-cost solar panels for this area output 12 to 36 volts and 100 Watts.

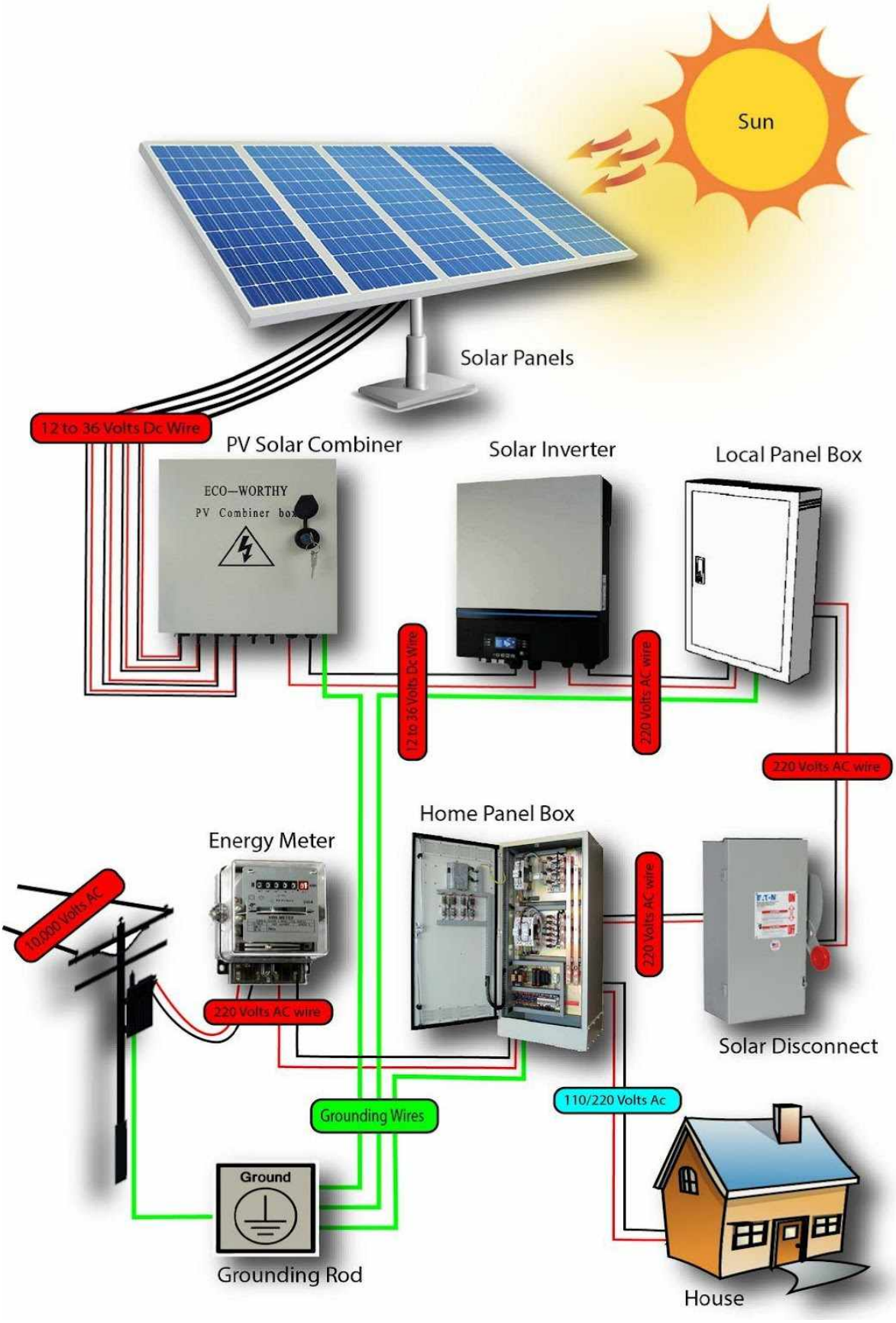
Average household electricity consumption: In this example, we will use the national average consumption of 10,500 kWh per year. This translates to an average of 30

kWh per day. It is good to oversize the system to account for conversion losses at the inverter. The standard practice is to add 25% to the daily consumption. In this case, we could say that a typical home in Dallas uses an average of 39.7 kWh per day.

Sun-peak hours: Dallas has 5.4 sun-peak hours on a fixed panel.

SYSTEM DESIGN

This diagram shows a basic Home Solar System.

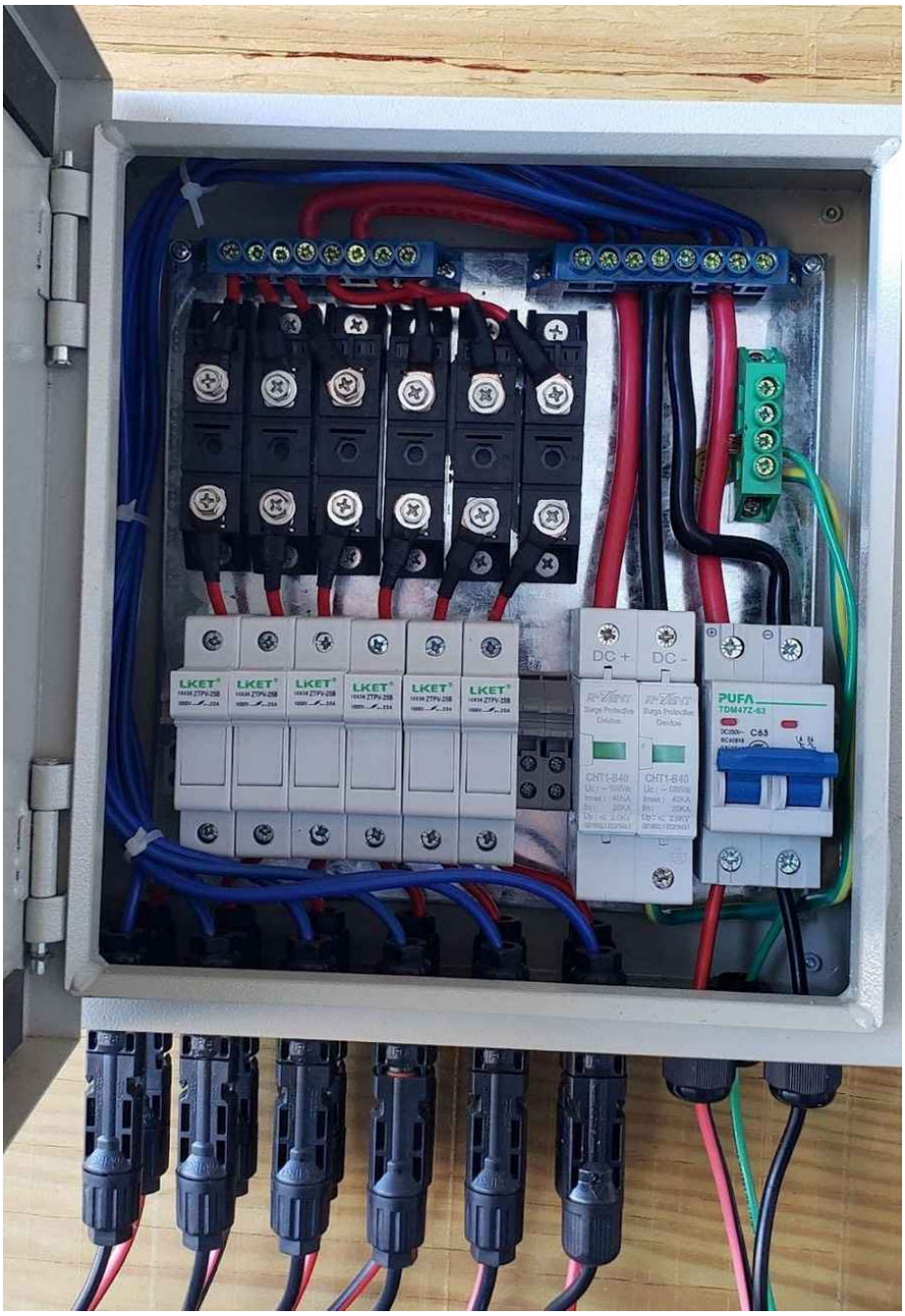

Sun
Solar Panels
12 to 36 Volts Dc Wire
PV Solar Combiner
ECO—WORTHY
PV Combiner box
Solar Inverter
Local Panel Box
12 to 36 Volts Dc Wire
220 Volts AC wire
220 Volts AC wire
Home Panel Box
Energy Meter
10,000 Volts AC
220 Volts AC wire
220 Volts AC wire
Solar Disconnect
110/220 Volts Ac
Grounding Wires
Ground
Grounding Rod
House

Sizing and stringing the solar panels: To provide 1 kW of power, we will use ten each 100 Watt panels. Each panel will occupy 12 square feet with room around the panel for mounting. A total of 120 sq ft rooftop area is required, and the panels weigh 19 pounds and will exert a total of 1.6 lbs per sq ft. You will need to determine if your roof can support the solar panels. The rated maximum output voltage is 24 V per panel, with 12 V being nominal.

The total output of the solar panels is 1 kW, and the cost of the solar panels is $87.99 bringing the total cost to $879.9 without sales tax.

The wires transmitting electricity into the combiner box are connected with MC4 connectors. Each panel produces 100 Watts, and at 12 Volts, that is 8.3 Amps maximum. The wire tables for power transmission show that 12 AWG wires are the right size. Six inputs feed into one combiner box with two each input combiners, and four feed the other combiner box. The panels and the combiner boxes use MC4 connectors, and these will need to be purchased separately. They are inexpensive and can also be purchased from Amazon.

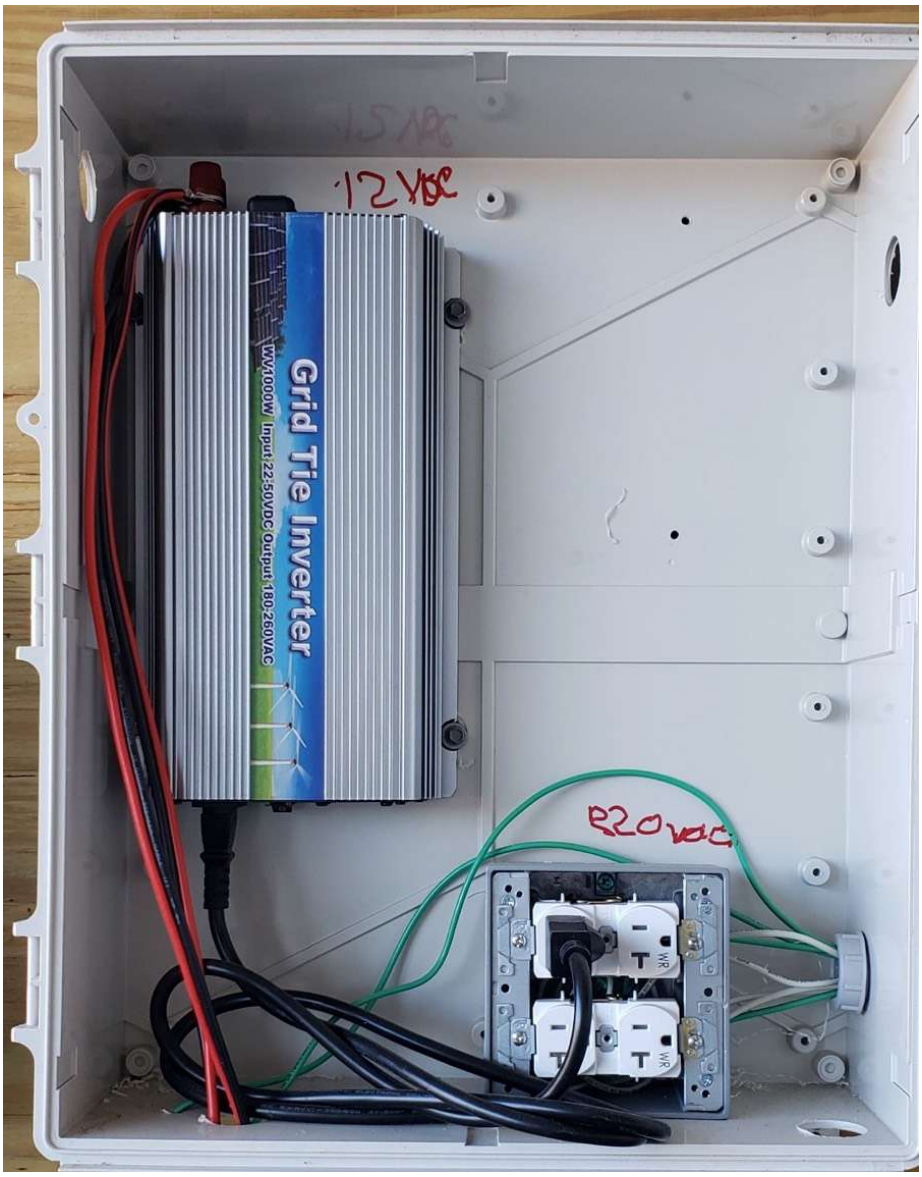
Choosing the mounting: Z brackets from Amazon are chosen for the mountings. The panels are mounted on a metal roof for a carport and are quite stable.



Choosing the combiner box: The system's maximum operating current is 41 A. Therefore, the standard 63 A combiner box is sufficient for this system. For this project, the Eco-worth combiner box is a good choice, and the cost is less than $200, including shipping from Amazon. We will

need two combiners with six channels each to connect ten panels.

Choosing the inverter: The inverter must be of similar power to the planned array, in this case, 1000 Watts. A Meshbeam Grid Tie 1000 Watt Inverter from Amzaon lists for $280.



Selecting the electrical wire gauge: At 24 V, the maximum current for six panels is 25 Amps. Based on the

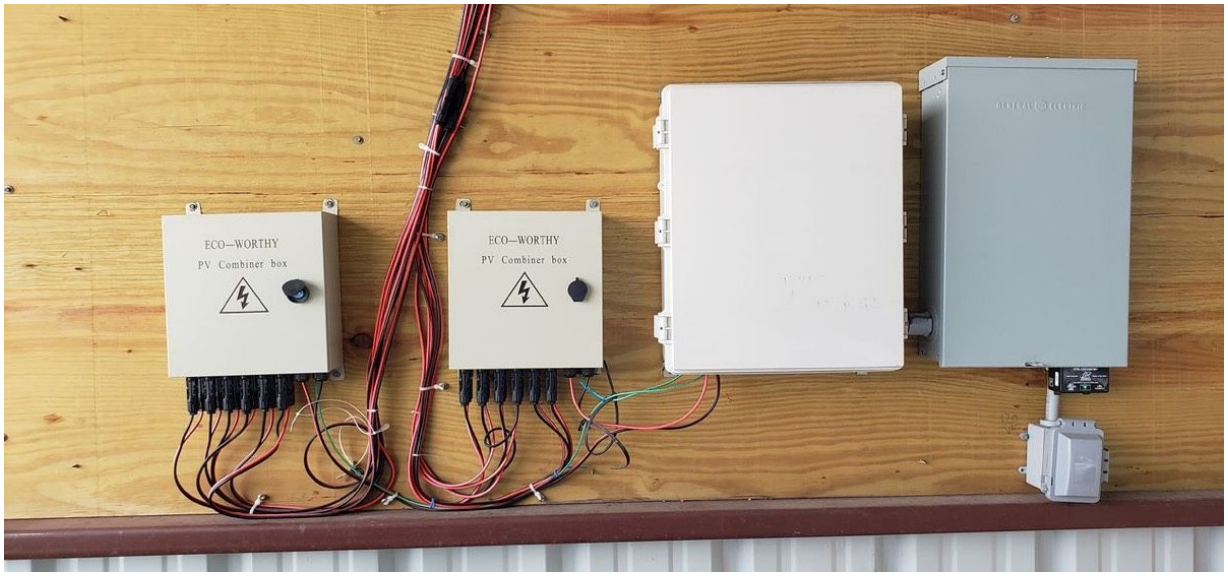
wire gauge chassis wiring charts, a 12 AWG wire is sufficient to transmit power from the combiner box to the inverter. You will need two wires, one for the negative and one for the positive terminal. These two terminals will connect directly to the input of the inverter.

Solar disconnect switch: These components can be purchased for as low as $15, although higher quality products start from $36. The disconnect switch can be bought online from Amazon or Harbor Freight, and local hardware stores also stock AC disconnect switches. You must place a Solar Disconnect sign near your Solar Disconnect Switch.

Once your components are in place. You can follow the steps described in the previous chapters to mount your solar panels, connect the disconnect switches, and wire the combiner box. Additional electrical cables are needed to transmit electricity to the AC main panel box from the inverter. The length of the cables depends on the distance between the inverter and the main panel box. Finally, the

installation can be turned on after the permission to operate has been issued.

Overall project cost: Adding the total material costs, you can expect to spend just over $2,000. It is always good to add 20% for unexpected costs such as filing for paperwork and inspection fees. In total, a 1 kW system using 100 Watt solar panels can be installed for under $2,400.



FAQS

In addition to the questions I have mentioned earlier in this book, there are countless other questions that a homeowner like you often asks me. This section will try to answer the most frequent questions that I receive.

What are the benefits of a home solar system?

Investing in a home solar system is the best financial decision you can make. Gone are the days when home solar was just a cliche that only the rich could afford. Technology has made home solar systems more affordable, and the tax rebates and the federal incentives give you money back towards your investments. You can save big and not pay for electricity again after your payback period.

On what items do I get a tax incentive?

Generally, you will get a rebate on the labor charges and the equipment costs. Rebates and incentives vary depending on in which state you live. You might have to visit your local authority to enquire about the available benefits. The anticipated rebate would be the federal investment tax credit (ITC). ITCs allow you to deduct 26% of your total solar investment from taxes. ITC's are currently likely to last until 2024 unless congress changes this law.

Some studies say that solar is bad for the environment. Is this true?

Indeed there is research to support this. Arguments against solar energy are that metal and other minerals are mined to manufacture the solar panels. This involves the emission of carbon dioxide into the environment and environmental degradation. Other than this, when solar panels reach their end of life, they need to be discarded, and most people do not know what to do with old solar panels. In my opinion, this argument doesn't hold. Suppose coal or other fossil fuels are being used to generate electricity. In that case, the same problem exists, compounded by the release of pollutants into the atmosphere when fossil fuels are burnt to liberate energy. From my perspective, solar energy solves the second part of the problem. There are also recycling plants being built to deal with the components that reach their end-of-life. Based on these two reasons, solar energy does more for the environment than other sources of electricity.

What impact does solar energy have on the environment?

Solar energy is a renewable source of energy that cuts down the pollution mostly caused by non-renewable sources (e.g., coal and nuclear).

Can one go completely off-grid and meet all of their electricity requirements with solar panels?

The answer to this question will be a big yes, although to achieve the off-grid goal, your solar system has to be hooked up with a battery bank to store energy generated by the solar panels during sun hours. In addition to this, you will need to design a system that lasts for several days because sometimes it can be overcast depending on the weather. There is a term known as days of autonomy that must be factored in. The general rule is to design a system with three days of autonomy. This means that your battery bank must be designed to last three times longer than a system designed to last for a day.

Do solar panels produce energy when there is no sunlight?

Solar panels depend on sunlight to produce energy. The greater the intensity, the greater the amount of electricity produced. Little electricity is generated with cloud cover, and no electricity is generated during night hours. You will need either a battery or a grid connection to meet your electrical needs at night. For this reason, solar panels feature a diode contained in the local panel box to prevent electricity from flowing from the batteries to the solar panels at night.

Does installing solar mean I won’t be affected by blackouts?

Solar systems with battery banks can run in a blackout because the electricity is stored locally on-site. Grid-tied systems without battery banks also switch off during a blackout because the electricity is stored in the main electricity grid and accounted for via net metering. If your area is prone to natural disasters leading to frequent

blackouts, then you must seriously consider including a battery bank as part of your home solar system.

What is net metering in solar systems?

This is a system put in place by your utility company to credit you for the excess energy produced by your solar system, which is fed into the local grid. A two-way meter measures the electricity you use from the utility company and the electricity you produce. If your utility company has the same rate for both consumption and supply, you will only pay for the difference between the readings of the two meters if you are a net consumer.

How do I know exactly how much I need for my home?

Solar system size is mainly determined by the amount of load they are required to feed. It is advisable to check your energy usage records to determine how much energy you consume in your home. Your electricity bill is the only thing you need to determine your consumption. The rule of thumb is to average your monthly electricity consumption over one year to get a full picture of how much electricity you use in a day. In the rare event that your utility company does not provide your consumption information, then you will need to manually compute the power consumption of the devices you use. This is a complicated process, but online calculators can help you determine how much you need.

How do I know if my roof is compatible with solar panel mounting?

This is a common question. I know some people have flat roofs, while other people have roofs that have a high pitch. Your roof pitch should be between 7 to 12 inches to accommodate the required 30-degree angle of the panel. If your roof is flat, you can add an angled mounting system to

give your panels the optimum pitch for absorbing sunlight. Other than this, you still need to consider the age of the roof, the material, and the structural integrity. Alternatively, you can mount your panels on the ground if you have space within your property. You will still get the same benefits, including tax rebates and incentives from your state and the federal government. Remember that in the northern hemisphere, your panels must face the true south to optimize the amount of daily sun-peak hours and to always avoid shaded areas.

I want to install a home solar system with net-metering DIY; how can I go about this?

This is a tough one. Most utility companies do not want people touching anything related to the grid. At best, you can wire the system to the AC main panel and use your home solar system instead of power from the utility company. Consider finding a professional installer willing to work with you on the complicated parts that require a licensed individual's skills and experience.

CONCLUSION

There is no doubt that a home solar system is a great investment for your property. The benefits are clear, and the installation is not difficult even for a novice DIY. You now know the system components needed for the system to work correctly. The system's performance largely depends on the solar panels because this component is responsible for generating electricity. The sizing and performance of the other components are hinged on the panels'

performance, and they must be correctly sized to deliver the power you need for your home. The starting point is your average monthly consumption which you can easily get from your utility bill. In my opinion, this is probably the most reliable method to determine how much electricity you need daily. Designing your system without determining your needs is not very useful and is similar to putting the cart before the horse.

Devices like solar optimizers are great optional add-ons that can greatly improve the power output of your solar panels. Not only do they regulate the electricity delivered to the inverter via the solar combiner, but they also help to protect the system from arc faults and other electrical problems that your system can encounter. You can live without solar optimizers, which is why they have not been included in the example projects illustrated in the previous examples.

On the other hand, inverters are a must-have component required if you want to run your traditional electrical appliances. It is important to choose your inverter carefully and consider whether you want a grid-connected or independent system. These two options decide whether you can choose a hybrid inverter or an off-grid inverter. In the case of the former, your inverter must simulate the electricity provided by the utility company, albeit at a slightly higher voltage, to allow net metering when you want to export power to the grid.

Once you have your system installed, remember to install devices to monitor your system. This is something that most people forget, yet it is one of the most important indicators of really saving money. Its function is just like the fuel or battery gauge on your car informing you how much mileage you still have. I do not think anyone would go onto the highway without knowing how much gas they

have in the tank. Likewise, your solar monitoring system should be kept in perfect working order to tell how much power you are producing and how much you are consuming. Regularly inspecting your system to check for fallen debris on solar panels will keep your panels producing close to their rated power for quite some time. You will also need to ensure that all the other components remain free from dust and moisture and all the other causes of poor performance discussed in this book.

Finally, always remember to take safety precautions when working on your system. Electricity is dangerous, and any mishaps can lead to death. I have to re-emphasize that you must not work on a hot wire regardless of whether the power is coming from the solar panels or the utility company. You must also ensure that you are following safe working practices when installing the solar panels on the roof and always wear your safety gear during the entire installation process. Also, always read the instruction manuals with all your components, including the mounting racks. I know they might be a little detailed and confusing, but taking the time to understand how the manufacturer designed the products to be used will save you a lot of time and money. Remember to never turn your system on without permission from the local authority and the utility company. Doing so will land you in big trouble.

Now that we have reached the end of our discussion on installing your home solar system, you are ready to install the system. You have seen how investing in solar energy can save you a lot of money over time, especially if you use quality components that last when building your system. Besides your pocket, the environment is probably the biggest beneficiary if we all do our part. Solar energy promises to reduce the amount of CO2 and greenhouse gas

emissions, and future generations will thank us for preserving the planet for them.

There is no need to delay, especially with inflation causing prices to sky-rocket. Chances are electricity prices will continue to rise. The time to invest in solar energy and save money is now. In fact, with the available financial options, community programs, and low-income incentives, there is no reason why anyone should not have a solar system installed. This book has equipped you with all the tools you need to complete a DIY home solar system. Millions of people have already committed to installing home solar systems. By waiting, soon you will just be buying electricity from other people if they export it to the grid. The famous old Latin saying goes, “fortune favors the bold.” I wish you success in your noble quest to go green and save green.

PLEASE LEAVE A REVIEW

If you think that the lessons you have been equipped with within this book have adequately informed you on installing your home solar system, consider leaving a review on Amazon. This will help others wanting to install their own Home Solar systems. Spread the word and help others safely install Home Solar systems of their own.

REFERENCES

Alves, B. (July 5, 2021). Electricity retail prices in the U.S. 1990-2020. Statista.https://www.statista.com/statistics/183700/us-average-retail-electricity-price-since-1990/

Brown, C. (March 7, 2021). Shading losses in PV systems, and techniques to mitigate them. Aurora. https://www.aurorasolar.com/blog/shading-losses-for-pv-systems-and-techniques-to-mitigate-them/

Carbone, S. (September 23, 2021). Your guide to HOAs & solar panels: % Tips to get approval. Aurora Solar. https://www.aurorasolar.com/blog/how-to-get-hoa-solar-approval-tips-for-success/#:~:text=Solar%20access%20laws%20prevent%20HOAs,less%20effective%20or%20more%20expensive.

Chapple, K. (February 19, 2021). 10 Essential tools for DIY solar installation. Unbound Solar. https://unboundsolar.com/blog/10-essential-tools-for-diy-solar-installation

Connected Current. (2021). SOK battery: 100-206 Ah 12 V battery. https://www.currentconnected.com/product/sok/?fbclid=IwAR2pMfAK98kbgoNmqTpY3K2W6QHuNGRj62gtpyBdR7GYDUjm2LsniUZPoHo

Deep Cycle Battery. (n.d.). How to maintain batteries. The basics on batteries. https://deepcyclebatterystore.com/how-to-maintain-batteries/

EFS Energy. (July 01, 2020). How many solar panels are needed to run a house? (The answer will surprise you!). https://efsenergy.com/how-many-solar-panels-are-needed-to-run-a-house/

Energy Information Administration. (October 17, 2021). How much electricity does an American home use?

Energy Information Administration. (2020). How much carbon dioxide is produced per kilowatthour of U.S. electricity generation? https://www.eia.gov/tools/faqs/faq.php?id=74&t=11

EnergySage. (2021). 500-watt panels: a technology update not to miss. https://news.energysage.com/technology-update-500-watt-solar-panels/

EnergySage. (2021). DIY solar panels: can you install solar panels yourself? https://news.energysage.com/diy-solar-panels-pros-and-cons/

Environmental Protection Agency (2021). Sources of Greenhouse Gas Emissions. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

Hays, C. M. (n.d.). Safety first is safety always. AZ Quotes. https://www.azquotes.com/quote/586167

Hosea. (750-722 BC). KJV For they have sown the wind, and they shall reap the whirlwind. Hosea 8:7

House Logic. (n.d.). Roofing: A guide to the options. https://www.houselogic.com/organize-maintain/home-maintenance-tips/roofing-guide-options/

McBride, A. (January 15, 2021). Comprehensive guide to solar panel types. Aurora. https://www.aurorasolar.com/blog/solar-panel-types-guide/

McCloy, J. (July 29, 2019). 5 Best solar panel monitoring systems in 2021. GreenCoast. https://greencoast.org/solar-panel-monitoring-systems/

Office of Energy Efficiency and Renewable Energy. (2021). Solar energy glossary. https://www.energy.gov/eere/solar/solar-energy-glossary

O'Keefe, C. (January 15, 2021). How much do solar panels cost? Home Advisor. https://www.homeadvisor.com/cost/heating-and-cooling/install-solar-panels/

Ritchie, C. (December 10, 2021). Best solar battery 2021. Which is right for your home? Save On Energy. https://www.saveonenergy.com/solar-energy/best-solar-battery/

Rooij, D. (n.d.). PV Junction box: purpose and connection. Sinovoltaics. https://sinovoltaics.com/learning-center/materials/pv-junction-box-purpose-and-connection/

Rooij, D. (n.d.). Solar lightning protection: PV system grounding and lightning protection Sinovoltaics. https://sinovoltaics.com/learning-center/system-design/solar-lightning-protection-grounding-lightning-protection-solar-systems/

Sanchez, V. (October 5, 2021). Solar power can boost your home's value — especially in these 10 states. CNBC. https://www.cnbc.com/2019/10/05/solar-power-can-boost-a-homes-value-in-these-10-states-the-most.html

Solar Harmonics. (2021). What does a power optimizer do? https://www.solarharmonics.com/solar-inverters-are-solar-optimizers-worth-it/

Solar Metric (2021). Are solar shingles worth it? 2021. https://solarmetric.com/learn/are-solar-shingles-worth-it/

Solar Reviews. (November 3, 2020). Low-income solar incentives in the US. https://www.solarreviews.com/blog/free-solar-panels-for-low-income-families

Sonnen. (2021). Battery technology. https://sonnenusa.com/en/eco/

Sunpower. (n.d.). How many solar panels do you need: panel size and output factors. https://us.sunpower.com/how-many-solar-panels-do-you-need-panel-size-and-output-factors

Svarc, J. (April 22, 2021). Tesla Powerwall 2 vs LG RESU vs Sonnen Eco vs BYD. Clean Energy Reviews. https://www.cleanenergyreviews.info/blog/powerwall-vs-lg-chem-vs-sonnen-vs-byd

Svarc, J. (November 8, 2021). Home solar battery systems-comparison and costs. https://www.cleanenergyreviews.info/blog/home-solar-battery-systems

Tesla. (2021). Powerwall. https://www.tesla.com/powerwall

Unbound Solar. (n.d.). Off-grid solar system sizing calculator. https://unboundsolar.com/solar-information/offgrid-calculator

Unbound Solar. (July 8, 2020). Solar panel installation: How to install step by step. https://unboundsolar.com/blog/step-by-step-diy-solar-installation

Ustun, T. S. (2019, November). Cybersecurity vulnerabilities of smart inverters and their impacts on power system operation. In 2019 International Conference on Power Electronics, Control and Automation (ICPECA) (pp. 1-4). IEEE.

Zipp, K. (October 9, 2018). Lightning and overvoltages: Why solar systems need surge protection. Solar Power World. https://www.solarpowerworldonline.com/2018/10/lightning-and-overvoltages-why-solar-systems-need-surge-protection/

IMAGE REFERENCES

80cho8. (January 6, 2018). [Danger warning sign]. Pixabay. https://pixabay.com/zh/users/8ocho8-7613390/

CHAIYARAT. (February 5, 2022). MC4 connector solar panel on white background. Shutterstock. https://www.shutterstock.com/image-photo/mc4-connector-solar-panel-on-white-1653024976

EAKNARIN JITONG. (February 5, 2022). Crimp tool , Crimp tool for solar cell module work. Shutterstock. https://www.shutterstock.com/image-photo/crimp-tool-solar-cell-module-work-431196547

EHStockphoto. (February 5, 2022). Woman's Hand Pulling Electrical Plugs on White. Shutterstock. https://www.shutterstock.com/image-photo/womans-hand-pulling-electrical-plugs-on-495568408

Halliwell, H. (November 23, 2017). Close-up photo of batteries. Pexels. https://www.pexels.com/photo/close-up-photo-of-batteries-698485/

Ildefonso, P. (June 13, 2018). [Electrical monitoring system]. Unsplash. https://unsplash.com/photos/DX9X0g0Cg88

JE Shoots. (January 29, 2018). Floor plan on table. Pexels. pexels.com/photo/floor-plan-on-table-834892/

Kelley, T. (March 15, 2016). [Voltmeter]. Unsplash. https://unsplash.com/photos/xVptEZzgVfo

Kindel Media. (June 25, 2021). Female engineer looking up. Pexels. https://www.pexels.com/photo/female-engineer-looking-up-8486918/

Kindel Media. (October 12, 2021). Man wearing safety glasses and gloves holding solar panels on the roof. Pexels. https://www.pexels.com/photo/man-wearing-safety-glasses-and-gloves-holding-solar-panels-on-the-roof-9875411/

Kryukov, V. (January 14, 2019). Three white and brown smoke. Unsplash. https://unsplash.com/photos/zc9sCp1sc

Los Muertos Crew. (July 21, 2021). [Solar panels installation]. Pexels. https://www.pexels.com/photo/person-s-hand-on-top-of-solar-panel-8853511/

Los Muertos Crew. (July 21, 2021). Solar technician installing solar panel. Pexels. https://www.pexels.com/photo/solar-technician-installing-solar-panel-8853503/

Nilov, M. (June 29, 2021). Person holding blue and green globe Pexels. https://www.pexels.com/photo/healthy-nature-man-person-8542357/

Mead, W. (December 01, 2020). Man installing solar panels. Pexels. https://www.pexels.com/photo/man-installing-solar-panels-6040783/

Pixabay. (December 22, 2016). Light bulb. Pexels. https://www.pexels.com/photo/bright-bulb-close-up-conceptual-269318/

Pixabay. (June 05, 2017). Solar panels on snow with windmill under clear day sky. Pexels. https://www.pexels.com/photo/alternative-alternative-energy-clouds-eco-energy-433308/

Pixabay. (March 20, 2017). Question mark on chalk board. Pexels. https://www.pexels.com/photo/question-mark-on-chalk-board-356079/

RoschetzkyIstockPhoto. (July 30, 2021). Tesla Home Battery Powerwall. Istock https://www.istockphoto.com/photo/tesla-home-battery-powerwall-gm1329792536-413411749?clarity=false

Rukawajung. (March 28, 2021). MC4 socket connector of solar cell panel. Istock

https://www.istockphoto.com/photo/mc4-socket-connector-of-solar-cell-panel-gm1309212814-399000662?clarity=false

sahibzadaibi. (January 19, 2022). solar energy system illustration for a book cover. Fivrr.https://www.fiverr.com/v4/users/mattvea/orders/FO11219B5B987/delivery

sahibzadaibi. (February 13, 2022). Solar Energy system Design. https://www.fiverr.com/v4/users/mattvea/orders/FO416DFA25586?source=orders_navigator

Sikkema, K. (January 7, 2021). Hand plugging a white cord into an outlet. Unsplash. https://unsplash.com/photos/vT9zeLCOpps

Spiske, M. (December 13, 2018). [Electrical breaker switches]. Unsplash. https://unsplash.com/photos/kK7uPfb2YWU

tew65. (February 5, 2022). MC4 connector set for Solar Array shutterstock. www.shutterstock.com/image-photo/mc4-connector-set-solar-array-1919785115

Tung, H. (February 5, 2022). Computer three prong power plug, shutterstock. https://www.shutterstock.com/image-photo/computer-three-prong-power-plug-298095938

Vea, M (January 24 2022). Solar System Components, Solar System Several Private Photos

Vector 8 DIY. (June 3, 2019). [Solar panel energy photovoltaic]. Pixabay. https://pixabay.com/zh/photos/solar-panel-energy-photovoltaic-4249315/

Vivint Solar. (August 26, 2019). Black solar panels on brown roof. Pexels. https://www.pexels.com/photo/black-solar-panels-on-brown-roof-2850347/

WooHoo Production. (February 5, 2022). Crimping tool (Actually Wirestripper) shutterstock. https://www.shutterstock.com/image-photo/crimping-tool-187333802

Again, to get Bob’s Solar Payback Period Worksheet go to:
www.bob-hopkins.com