2

Do-It-Yourself
Metal Framed and Encapsulated Solar Panel

~~ NOTICE ~~

Legal Disclaimer

The authors and publishers both disclaim liability regarding any loss or risk incurred as a direct, or indirect, consequence of the application and usage of any of the contents within this Do It Yourself (DIY) instructional material.

Copyright

Power4Patriots.com Terms & Disclaimer

By using, viewing, and interacting with the DIY guide or the Power4Patriots.com website, you agree to all terms of engagement, thus assuming complete responsibility for your own actions. The authors and publishers will not be held liable or claim accountability for any loss or injuries. Use, view, and interact with these resources at your own risk.

All products from Power4Patriots.com and its related companies are strictly for informational purposes only. While all attempts have been made to verify the accuracy of information provided on our website and within the publications, neither the authors nor the publishers are responsible for assuming liability for possible inaccuracies.

The authors and publishers disclaim any responsibility for the inaccuracy of the content, including but not limited to errors or omissions. Loss of property, injury to self or others, and even death could occur as a direct or indirect consequence of the use and application of any content found herein.

Working on home improvement projects and with renewable energy sources is dangerous. Since you are dealing with electricity, high roof tops or towers, and numerous other unknown conditions, seek expert opinions and help where necessary. The authors and publishers assume that, while carrying out your DIY project, you are aware of all the risks and possible damages associated with home improvements and renewable energy.

Check with your town, city, state, province, county or country for applicable laws about home improvements and alterations. Often, it is necessary to obtain local government permits and licenses to prevent legal implications. We also recommend that you call your local electrician, and other professionals, to assist in your DIY projects. Failure to do so could cause injury or death - you are acting at your own risk.

Before performing any home improvement or renewable energy project you should first check with your insurance carrier, homeowners association or any other persons or associations that may need to approve such work. Insurance coverage and premiums may be affected by home alterations and so you need to check with your insurance agent first. All Power4Patriots.com information is intended for adults above the age of 18 years only.

By choosing to use the information made available by Power4Patriots.com or within any of our publications, you agree to indemnify, defend, and hold harmless the authors, publishers, and any other related companies from all claims (whether valid or invalid), judgments, suits, proceedings, losses, damages, and costs or expenses of any nature whatsoever that result from the use or misuse of any information provided.

The information provided may need to be downloaded using third party software, such as Acrobat or Flash Player. It's the user's responsibility to install the software necessary to view such information. Any downloads, whether purchased or given for free from our website, related websites, or hosting systems, are done at the user's own risk. No warranty is given that websites are free of corrupting computer codes, viruses or worms.

If you are a minor, you can use this service only with permission and guidance from your parents or guardians. Children are not eligible to use our services unsupervised. Furthermore, Power4Patriots.com specifically denies access to any individual covered by the Child Online Privacy Act (COPA) of 1998.

Remember...Safety First!

Table of Contents

Section 2

Do-It-Yourself

Metal Framed and Encapsulated Solar Panel

Introduction

As thousands of homeowners are taking the energy crisis into their own hands by building their own solar electric panels there are some choices that must be made before beginning your project. Obviously, with the ability to customize the panel to meet any current or voltage parameters that you may require there is the choice as to what output you will want your panel to have. By wiring the panel with more cells in series, or choosing cells with higher current output, you can build one panel that may match the needs of a wide variety of batteries, water pumps, brushless DC fans, etc.

There are the obvious dimensional choices, too. You can build your panel in any shape or size; whether it is to minimize space of the array, fit strange angles on your roof, or to fit within a frame that you have bought or found to use for your panel. The panels can be built as rectangles, squares, or even triangles to suit your needs. What most people don't know, however, is that there are choices to be made in how you choose to construct the panel, regardless of the panel's output or dimensions. This decision will ultimately determine your panel's effectiveness.

Longevity of the panel and your budget are the two major factors involved in making the decision concerning which construction method to use. The two are, in fact, quite related. By investing in better materials for building the frame of your panel, and by taking the necessary steps to protect the cells from the damaging elements you can build yourself a panel that will last several times as long as a panel built with a minimalistic approach. This will increase your initial investment into your solar panel, but you will get much more power in the long run, at a lower cost per kilowatt hour produced from your panel.

Construction Choices

When you set out to build your solar panel, there are 3 main upgrade choices. Each will give your panel more strength and protection from the elements and each will all add a bit of cost to your initial investment. Each upgrade can be done independently from the other 2 options, so you can choose to add strength and protection for your panel by choosing just one of the upgrades below, or you can opt to make all 3 upgrades for the most professionally built panel possible.

Upgrade Option #1: Building a Metal Frame

Your first option for adding strength and longevity to your solar electric panel involves the construction of the frame. With the "Under $98 Solar Panel" the frame is made with wood. While the wood is sealed with primer and paint, the protection from the elements – mainly rain and sun – is not sufficiently adequate to protect the panel for more than a few years. Insects can also find a home in a wooden frame, further speeding up the decomposition process. In addition to the eventual rotting of the wood, the actual construction process itself creates more spacing for water and insects to get inside the frame, where the cells would then be negatively affected.

By choosing to upgrade to a metal frame, and in our case an aluminum frame, you give the panel extra protection by encasing it inside of a frame which will stand the test of time against the rain and sun. The beauty of aluminum is that is won't rust, making it ideal for the frame of a panel which will be exposed to the rain and placed under as much sun as possible. Not only will using aluminum provide extra protection from the elements and provide better strength overall, but it will provide fewer weak spots in the design of the frame where insects could burrow into and multiply. The beauty of this upgrade is that it will not add too much cost to the panel. Since metal provides more strength than scrap wood pieces, not as much aluminum is needed and no painting needs to be done, keeping the extra money spent very minimal.

Upgrade Option #2: Encapsulating the Cells

With the “Under $98 Solar Panel” the cells are wired together and then attached to a substrate behind them. This is not a bad option; however it leaves the cells exposed to the elements. No matter how hard you try to seal the frame to keep all of the weather elements out, eventually some moisture will get behind the front glass and into your frame and the cells will collect the moisture. Any exposure to the weather elements on the part of the cells will lower the output and degrade the cells faster than they should degrade.

The best way to protect the cells from the elements – and a method that is possible to do in your backyard – is to encapsulate them with a liquid silicone. This liquid silicone, when mixed with its curing agent, hardens into an optically clear rubber-like polymer. This silicone hardens around the cells, completely encapsulating them to the glass and completely protecting them from the elements. While the commercial solar panel manufacturers encapsulate their cells in EVA sheets, the vacuum sealing machines for this method make this unfeasible for your backyard project.

On the other hand, the liquid silicone, produced by Dow Corning under the name “Sylgard 184 Silicone Elastomer Kit” can be bought through one of their distributors and in the quantity necessary to build just one panel. This method will add no more than $40 or $50 to your final costs for the project and is the main factor in increasing your panel’s estimated lifespan from around 5 years up to 25 years or more!

Upgrade Option #3: Using Tempered Glass

By upgrading from regular single pane glass for the front of your panel to tempered glass you add a lot of strength to your panel. Tempered glass is much stronger than regular glass. It can withstand begin hit with hail, flying debris or other objects without the likelihood of breaking as you would find with regular glass. Glass can be tempered by washing it in a chemical bath or by superheating the glass until it is just below its melting point and then uniformly spraying it with cold water. This rapidly cools the outside of the glass while the inside remains hot, creating the tempered structure of the glass.

The major downside of this upgrade is that it can be very costly. Tempered glass cannot be cut once it has been tempered, so you would have to cut the glass to size and then temper it. The problem with this approach is that tempering glass must be left to the professionals, and it can be costly. Unless you plan on placing an order for hundreds of pieces, you may find yourself paying over $100 just for one 2' x 3' piece of glass to be tempered.

If you plan on placing your solar panel in an area where falling branches or debris are unlikely to land on your panel, and you plan on taking your panel inside or covering it when a hail storm looms then you should be just fine with regular glass. The tempered, low iron glass used by the commercial solar panel manufacturers is just too costly for a small-scale backyard project. The big manufacturers place orders for thousands of tempered glass pieces at a time, which is why they can even afford to temper their glass to begin with. If you are just looking to build a few small panels and you cannot find any flat tempered glass that would work for you then go ahead and use single pane glass and simply place your panel in a location where it is less likely to break. For the sake of this guide, we will be building a panel that uses the single pane glass, but does include the metal frame and encapsulated cells upgrades.

Sourcing Your Materials

Once you have determined the method for constructing your panel, you will need to go ahead and begin to source the location for these parts. While the majority of the materials needed for building your aluminum framed and encapsulated solar cell panel can be found at your local hardware store, some important materials, such as the solar cells and encapsulate must be ordered through distributors or from online vendors. The chart below lists the materials needed for constructing the panel, what you should expect to pay, and where to source these materials.

Metal Framed / Encapsulated 65 Watt Solar Panel

Part	Price	Source
Tabbed Solar Cells	$72	www.ShopDIYEnergy.com
Encapsulate	$35	Dow Corning
Glass Cover	$17	Hardware Store
Aluminum Angle	$7	Hardware Store
Aluminum Channel	$14	Hardware Store
Metal Corner Braces	$4	Hardware Store
Blocking Diode	$1	www.ShopDIYEnergy.com
Rivets	$3	Hardware Store
Solder	$2	Hardware Store
Flux Pen	$8	www.ShopDIYEnergy.com
Bond Paper	$1	Craft Store
Plastic Back Sheet	$2	Hardware Store
Junction Box	$4	Hardware Store
Terminal Strip	$2	Hardware Store
Plastics Glue	$1	Hardware Store
Silicon II Sealant*	$2	Hardware Store
TOTAL:	$175	
(*note that some prices reflect not using the entire amount of the materials – example: the Silicone II Sealant was $6/tube yet only 1/3 is needed = $2/panel)		

It is important to note that the prices listed above are only to be used as a reference since both costs and availability of materials can vary with time. However, with the right ideas and a little hunting you can certainly get what you need for under $200. Consider how many panels you are preparing to build, too, as the price per item – such as the solar cell – can drop when you order larger quantities. One panel will need 36 cells, but you should consider buying a few more as they are very breakable. If you plan on building 3 panels you will have more purchasing power and could get a better price for buying 3 times as many cells at once.

Another way to save money on the solar cells is to buy them untabbed. It will require more time to solder on the tabs yourself, and you may break a few more solar cells in the process, but the savings can justify this. The cost of the extra tab ribbon needed (figure one foot per cell) is marginal and will not offset the savings from buying untabbed cells.

A big reason that DIY solar panels have been gaining popularity in recent times is the availability of traditionally hard-to-find materials on the web. In the past, the majority of the population did not have access to solar cells or hard-to-find electronic components. However, with the rise of online vendors and auction sites like eBay everyone with a valid shipping address can buy whatever materials they need to build a solar panel that rivals any commercial solar panel in performance and durability. That said, anything you can source locally should be sourced locally to avoid any shipping costs. You may think you are getting a great price on a deep cycle battery online, but when adding shipping costs to a heavy battery it may become more expensive than to buy it locally despite whatever deal you may think you are getting.

If you don't need to build your panel right away, you may want to begin doing research online for the best prices for the solar cells. Many of the "buy it now" options ensure the quickest transaction on the online auction sites such as eBay, yet many times you end up paying retail. Try searching for cells or other materials early on in the process and bid on the item for a lower cost. While you may not win the item for the low price you seek if you have time to do this on several items you should end up saving yourself some money.

Buying broken or blemished cells may save you considerable money, too, but make sure that you are buying cells you can work with. Blemished cells many times will have the same output as non-blemished cells just with minor aesthetic issues. If you buy chipped or cracked cells you will want to make sure that the remaining pieces are large enough to work with. If you open the box and find only tiny little pieces you will have nothing to work with. For the purpose of this guide we will be using 3” x 6” solar cells without and cracks or chips, but if you find a good deal on cells with tiny chips or cracks they will work. Just remember, the current output is directly proportional to the size of the solar cell, so if the chip or crack is too large then your cell’s output will be lower than the rest and will bring down the power output of the entire panel.

In any case, don’t attempt to buy solar cells from a vendor that does not offer shipping insurance – especially if they are selling chipped cells which can break further on transport quite easily. The cells are very fragile, so you want to ensure that if you open your package of cells and most of them are broken you can get your money back.

Solar Panel Construction

Currently, the limiting factor for widespread adoption of solar is the initial cost of the completed solar system. While a typical solar system will consist of many components, the solar panels often comprise more than 50% of the entire cost. This accounts for thousands of dollars even in the smallest of residential cases. Solar panels, when made yourself can be done for a fraction of the cost of what is available commercially and can ultimately save you a lot of money, whether you opt for building a small 65 watt solar system or for wiring several panels together and creating a larger system. Even with no experience and limited access to tools anyone can learn how to build a fully functional PV panel and can begin producing energy from the sun in just a few hours. For the purpose of this DIY panel we will be dealing with crystalline cells and the following is a basic guideline in what steps to take, which methods to employ and which tools to use to build your own metal framed and encapsulated solar cells panel.

Tools and Materials

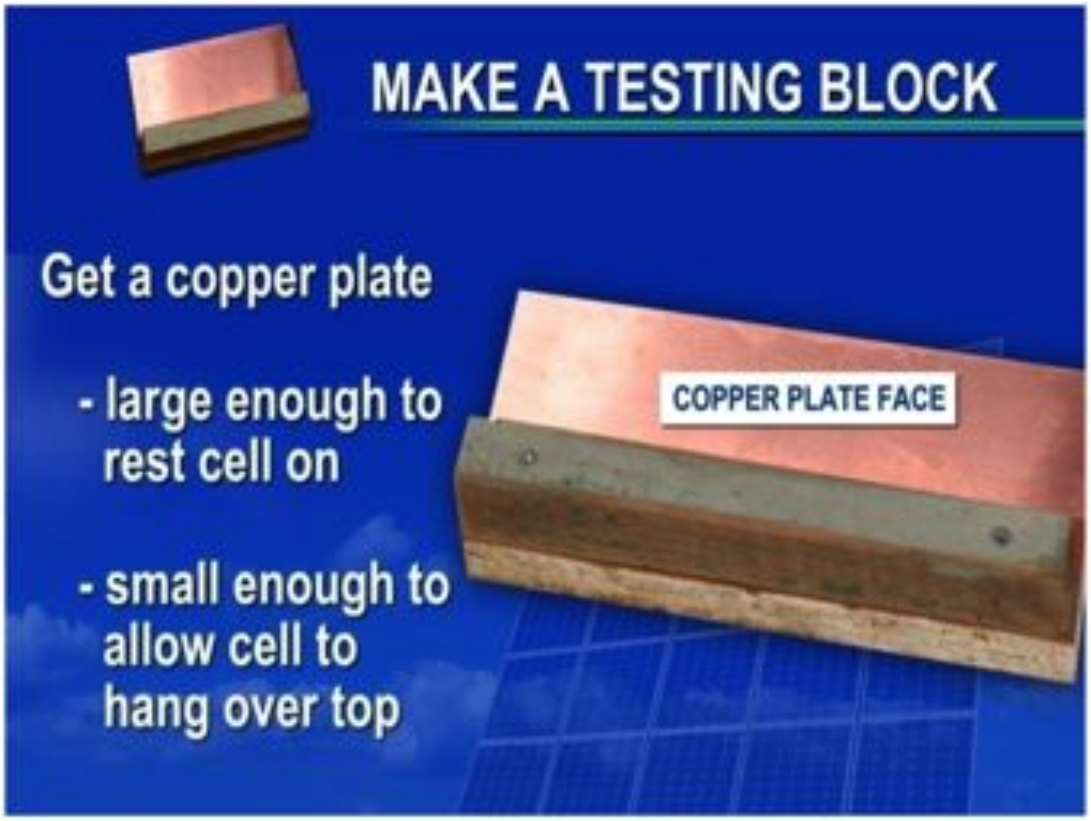
As stated before, most of the following tools and materials can be sourced locally. The rest can be found online and through national distributors than ship via USPS, FedEx or UPS.

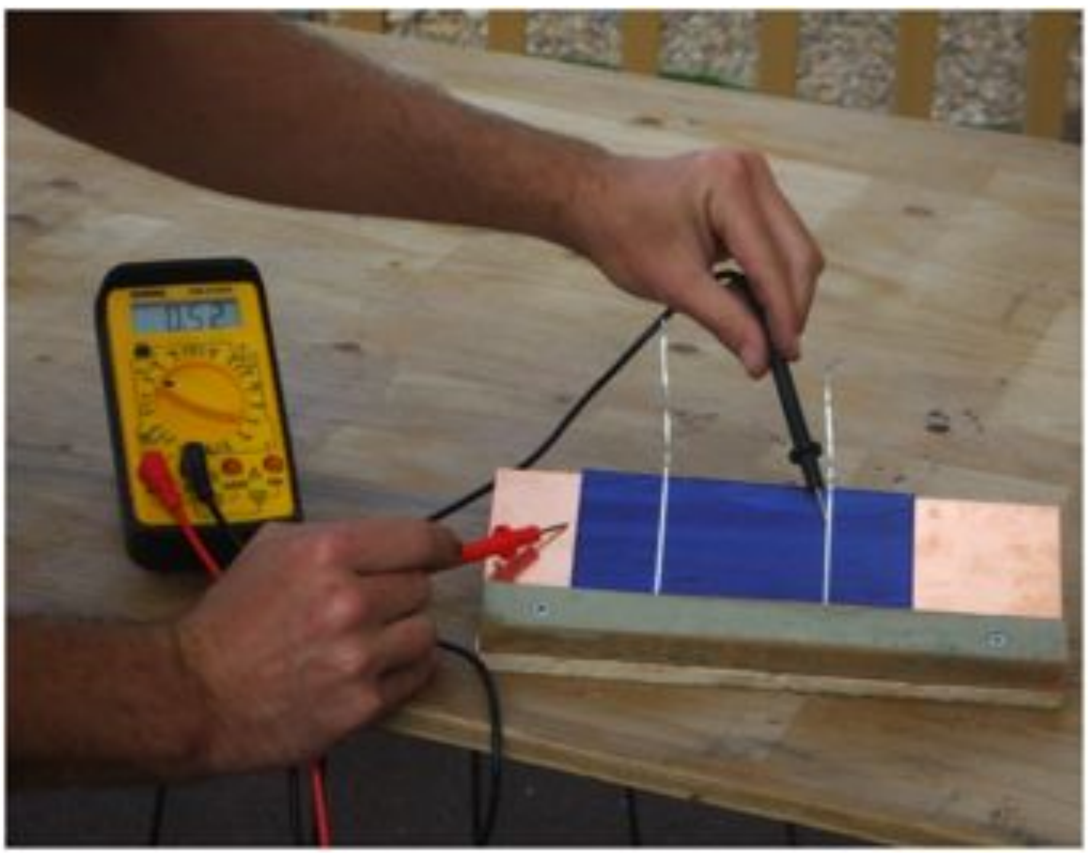
Solar cells and tabbing wire	Hacksaw
Bus wire	Metal File
Encapsulate	Vacuum Hand Pump
Respirator	Rivet Gun and Rivets
Eye Protection	Clamps
Multimeter	Clear glass panel cover
Aluminum Channel and Angle	Latex Gloves
Metal Corner Angles	Flux Pen
Solder Gun and Solder Caulk	Miter Box
Gun and Silicone Caulk	Carpenter's Square

STEP #1: Obtain Solar Cells

Solar cells are measured by their power in watts. To obtain a cell's wattage you must first know how many volts, represented by V, and amps, represented by A, the cell has. Amps are commonly measured in current, represented by I. To determine its watts, represented by W, you multiply the volts by the amps. This formula can be expressed as V x A = W. If the voltage and amperage are unknown, you can measure it with a multimeter that will take both current readings up to at least 10 amps and voltage reading of up to 600 volts.

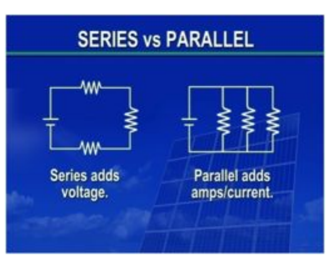
Take your measurements in full, constant sun. You can hold the cell perpendicular to the sun and contact the multimeter's negative and positive probes to the negative and positive electrodes on the cell. You may opt to construct a solar tester using a highly conductive backing, such as a copper plate. This will provide a steady place to rest the cells for measurement and will only require you to touch the positive probe from the multimeter to the metal backing instead of the cell itself.


MAKE A TESTING BLOCK
Get a copper plate
- large enough to rest cell on
- small enough to allow cell to hang over top
COPPER PLATE FACE



A solar cell will have a voltage right around 0.5 volts, but may read upwards of .6 volts in direct sun. Its current reading will vary dependant in its size. For example, a 3’ x 6” solar cell may read .5 volts and 4 amps under full sun. If you were to cut that cell up into four equal pieces, you will have four cells that each still read .5 volts, but now each one has just 1 amp. Be very careful in your handling and measuring of the cells, as they are extremely thin and very fragile. Measure all of your cells to make sure that you are only going to be using the best cells for your solar panel. Less desirable cells should be put aside with the broken cells for future projects that don’t require very much power. This is an important step, especially if buying blemished, broken or used cells off of the internet since if just one cell has a low current rating it will bring down the current of the rest of the cells it is wired in series with. Remember, when wiring in series the voltages add, but the current remains the same, and will only be as strong as its weakest link. Measuring the current is more important than measuring the voltage, since each cell will be close to .5 volts even with blemishes or chips.

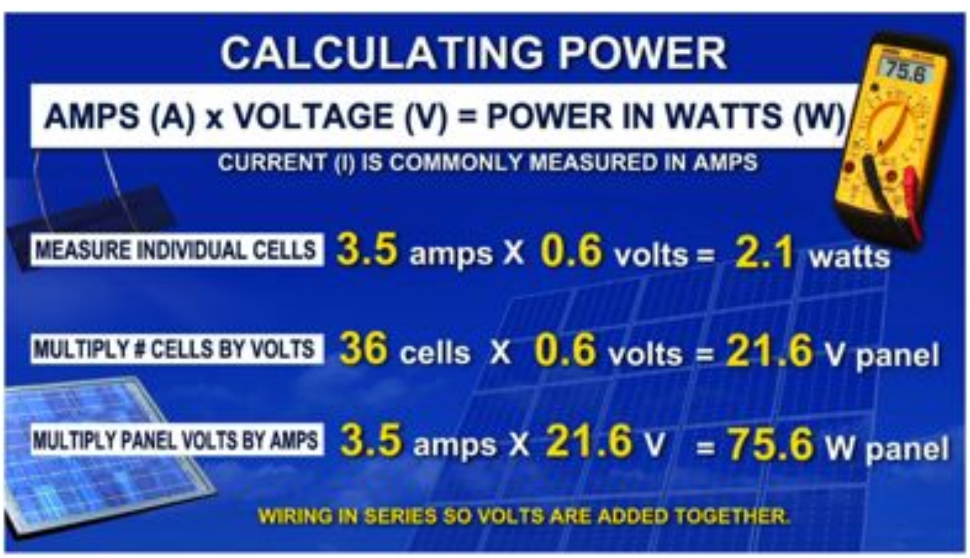
Going back to the previous example with the 3” x 6” cell cut into four pieces we will now see just how customizable a solar panel can be. The solar cell started with a rating of 0.5 volts at 4 amps. By cutting it into quarters we have 4 cells of .5 volts and 1 amp. Now, if we were to wire these cells together in series we will have a string of cells with 2 volts (.5 volts x 4) and 1 amp. If we were to wire these cells together in parallel, we would have a string of cells with .5 volts and 4 amps. All of this can be done with just one cell. The same concept applies to wiring panels together.



STEP #2: Determine Your Desired Panel Output

If you are trying to charge a 12 volt battery it is advisable that you build a 16-18 volt panel. To build an 18 V panel (as we are to do) you need 36 cells in series. This is determined because 36 cells wired in series at .5 V each will give us 18 V (36 cells x 0.5V = 18V). Again, you may have cells that have a higher voltage than 0.5, but building a panel with 36 cells is still good practice.

The current rating of the panel will be the same as the rating of just one solar cell, in this case 3.5 amps, assuming they are all wired in series. If you desire higher amperage you can wire two strings of 36 cells together in parallel to double the amperage in a given panel to have an 18V and 7A panel, or you can simply wire two 18v and 3.5A panels together in parallel to achieve the same purpose. Keep in mind size and weight limitations, not to mention breakability when determining the power output of your panel. Building a large panel with a glass frame may increase the likelihood that the glass may get cracked in the future.



See
www.power4patriots.com/shop

STEP #3: Determine the Panel Dimensions

This is done by some simple math. First, take the dimensions of your individual solar cells, in our case 3” x 6”. There are two main panels layouts that you may wish to work with. The first and the one we will outline are 4 rows of 9 cells wired together. The other option is to use 3 rows of 12 cells, as illustrated below on the right.

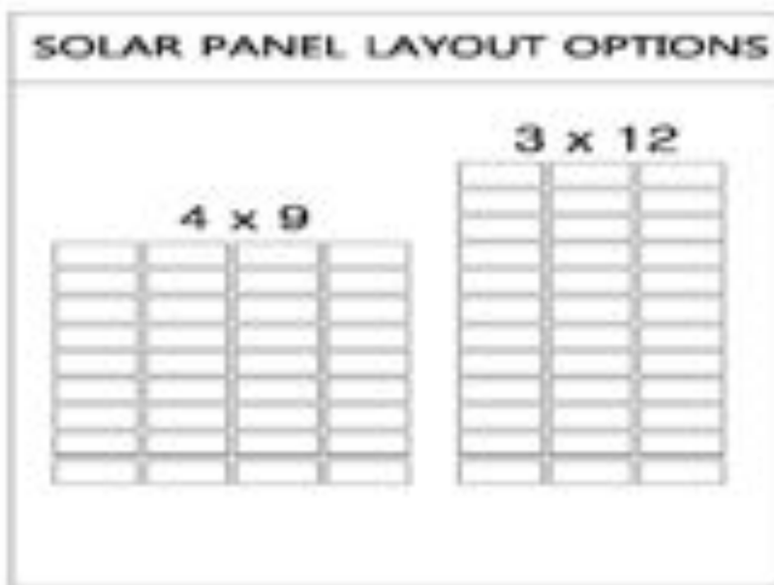


Figure 1

Working with the example of the 4 rows of 9 cells, we need to determine the width and length of the panel. If each cell is 3” x 6” and there are 4 cells wide we will need at least 24” (6” x 4 = 24”). Typically you will want to allow at least 1⁄4” in between the rows, so add 3⁄4” to the width (1⁄4” x 3 = 3⁄4”). Then add an inch on the right and left sides and you are left with 24 3⁄4”. We’ll round this up to 25”. Do the same math to determine the height. (9 cells high x 3” each) + (8 spaces in between the cells X 1⁄4”) + (3” – allow more spaces along the tops and bottoms of the panel for wiring the individual strings of cells together) = 32”. That leaves us with 25” x 32”. This is the dimension necessary for the inside of the metal frame.

It is important to note that this is the minimum size for your panel. If you find a precut piece of tempered glass or a metal frame that is a little larger than the dimensions given that you can work with it, just add more spaces in between the cells or along the edges. The important part is that you provide enough space within the inner dimensions of the panel frame for all of the cells. Perform the same calculations for a panel comprised of 3 rows of 12 cells but make adjustments as necessary.

Step #4: Build the Frame

For building the metal frame aluminum is the best choice. One, it holds up very well against the weather elements and is very rust resistant. Second, it is lightweight and easy to work with. All this comes at a very competitive cost. For a 65 watt panel you will need about 10 feet of Aluminum stock C-channel. The actual measurements are 1" x 9/16" x 1/16". This can be found at any local hardware store and should cost less than $15 for the entire length. While at the hardware store, you should also pick up the aluminum angle. You will need about 8 feet of the angle stock at 1⁄2" x 1⁄2" x 1/16". This aluminum angle will be used later.

Measure out the aluminum channel to fit outside of the solar cells. Take your measurements from earlier from the inside of the metal frame and then add the depth of the aluminum channel. This will give you your outside dimensions of the panel. For this guide we built the outside dimensions at 26" x 33". Measure out 2 pieces at 26" and 2 at 33".

Use a miter box to make perfect 45 ° angles on each C-channel. Make sure you make the cuts so that all four pieces when lined up will create a rectangle with the C-channel facing the inside of the panel.

The corners will be held together with rivets and metal angles pieces. Use a small piece of wood with holes drilled into it as a template for drilling into the aluminum. This will ensure that the corners are riveted together nice and tightly, will line the holes in the aluminum to the holes in the metal angles and will save you time for lining up the other 3 corners.

Use a carpenter's square to line up the two sides of the frame you are going to join to make sure they form a perfect 90° angle. If the angle is too far off then the frame will not be a rectangle and your last corner will end up off. Once you have lined up the pieces of the first corner then proceed to rivet the aluminum C-channel to the metal angles. This will join the frame pieces together and will add the strength from the metal angles.

It is important to make sure that you only attach 3 of the sides together before sliding the glass inside. If you attach all four sides together you won't be able to fit the glass inside the closed off channel. It is also important to know that if you do make any mistakes in the rivets placements you can remove the rivets with a drill. Simply use a small drill bit and drill into the center of the exposed rivet. This will allow you to pop off the rivets and realign before proceeding with the rest of the panel construction.

If you have cut the angles with a miter box and they still don't seem to align correctly when lined up with the carpenter's square then use a metal file and file it down to match correctly. Once you do have two frame pieces that line up well mark the inside of the channels so that you can remember to match those two up later. Take your time with this step, as the strength of the panel depends on good, tight rivet connections and flush angles.

STEP #5: Cut the Glass Pane for the Panel

The most important part of this step is to remember to wear protective gloves and eye wear. Cut glass can be extremely sharp, and when the glass breaks extremely small shards of glass can become airborne. If cannot find a piece glass that matches your need requirements, and you don't want to pay extra to have someone else cut the glass for you, it can be done right at home and is quite easy.

Glass cutting kits can be bought at your local hardware store for just a few dollars. With a very straight edge you will want to score the glass along the line that you want to cut the glass. Tap underneath the glass to ensure the score line penetrates the width of the glass. Hold the glass over a very straight edge, line up the score with the edge of the table and apply even pressure to the part of the glass that is hanging off the table.

If the line has been scored adequately the glass will break smoothly along the line. This may require some practice, so I would recommend getting some smaller pieces of glass to test your technique. Also, be sure that the dimensions of the cut glass is made to fit within the inside dimensions of the aluminum frame. Since the aluminum channels are 1/16" deep, the two channels on either side of the frame will combine for a 1/8" total. If you measure the frame from the outside and cut the glass to match you will cut your glass 1/8" to wide and 1/8" too long. Account for the added depth of the aluminum channel and your glass will slide into the frame smoothly.

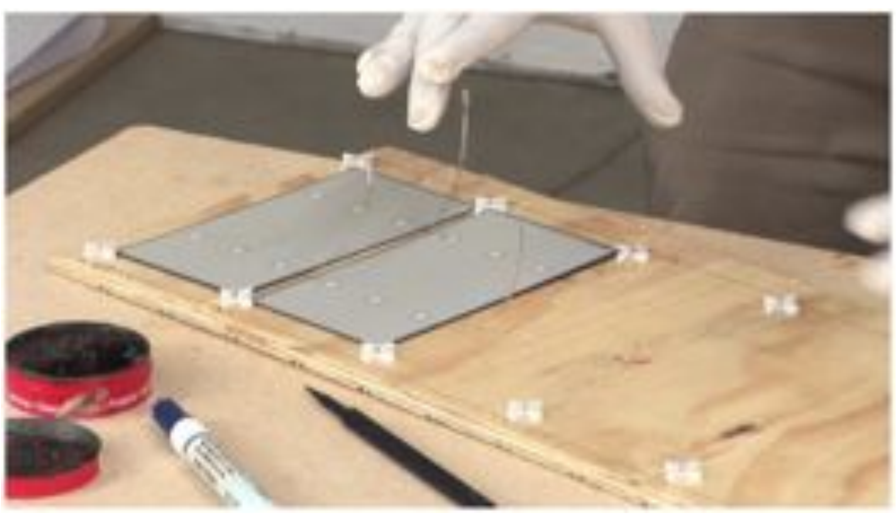
After you have cut the glass and before you have slid it into its frame place a bead of caulk around the inside channel of the frame. Make this bead along the inside of the front edge of the panel. This will give a better seal between the glass and the frame to protect from any water entering the frame of the panel from the front glass.

Slide the glass into the frame very carefully and with gloves. Once the glass is all the way inside the frame and contact has been made between the caulk bead and the glass on all 3 sides attach the final side. Rivet the corners like before and make sure the angles are square. This is where you will be able to tell just how square you got the other 3 corners. Don't forget to put the bead of caulk on the last side before riveting it into place.

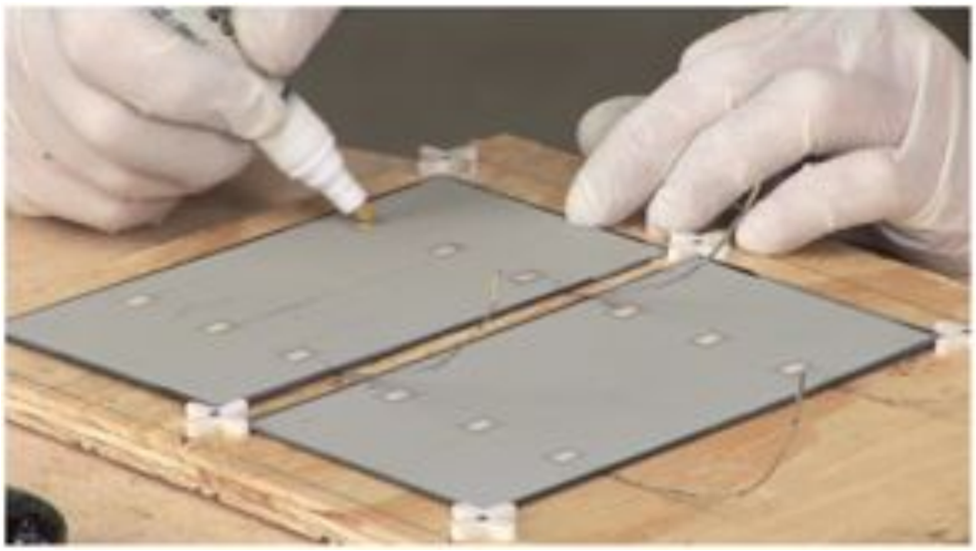
STEP #6: Solder Cells Together

If you have pre-tabbed cells (the ones with the thin tab ribbon coming off of the face) you will only have to solder the cells together at the back, or negative side. If untabbed, apply solder to the tab ribbon and connect the tab ribbon to the front bus bars that run from the bottom of the cell all the way to the top of the cell on the negative side. You will have to do this twice for each 3" x 6" cell as you will have two bus bar strips. Allow enough tab ribbon lead to come off of the cell to attach it to the back side of the next cell in series, roughly twice the height of your cell.

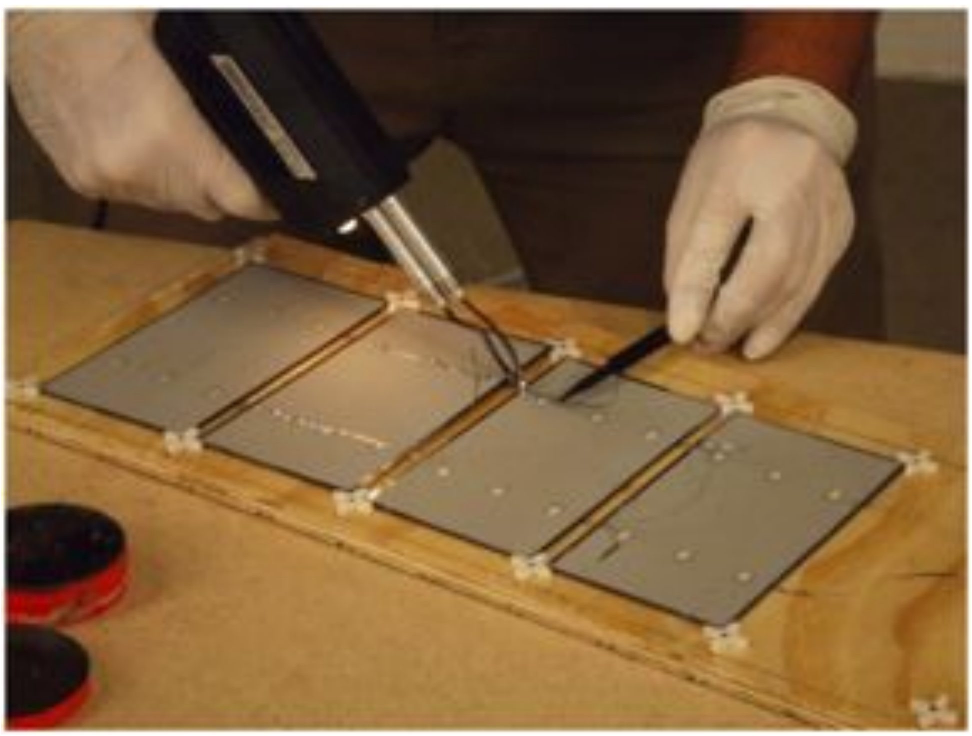
Once you have 36 cells with tab ribbon coming off the face of the cell you will want to begin soldering the cells together in series. A good trick here is to build a template for the cells so that the solar cells are evenly spaced apart and when you are soldering they will not move very much. A template can be made with tile spacers attached to a piece of plywood. Measure carefully and attach a tile spacer in the spacing between each solar cell.



Lay each cell in place to begin connecting them in series. Each cell will be laying face down with the tab ribbon leads coming off in the same direction. Apply a little bit of flux to all six exposed electrode rectangles on the back of each cell with your flux pen. This will help draw the solder onto the cell and will make a stronger solder joint.

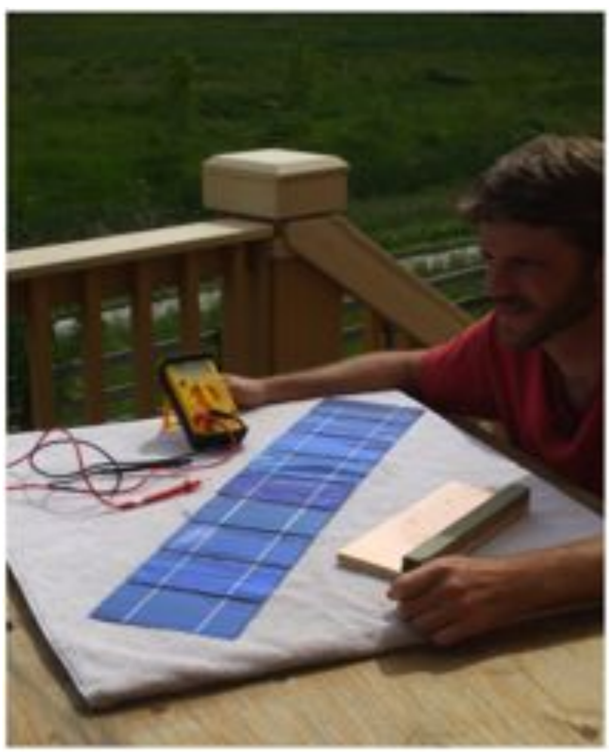


Once the cells have been fluxed take your solder gun and apply a little bit of solder to each tab ribbon. This will save you time when connecting the tab ribbon to the back of the next cell. Use a solder pen (seen in black in the picture below) or similar object to keep the tab ribbons in place and apply a press the ribbon down onto each exposed electrode that you have pre fluxed. Do this along each string of cells until you have connected each string of cells in series.



Once each string is completed, cut a strip of tab ribbon to attach to the back of the first cell in each string. This will ensure that you have tab ribbon leads coming off each string. You will need tab ribbon leads on both ends of the strings to connect each string together with bus ribbon when on the glass.

When all of your strings are wired together go test them in the sun to ensure the series connections were done properly. If there is a problem in one of the strings this is your best chance to isolate it and fix the issue before the cells and all connected on the panel and the encapsulate has been poured.



STEP #7: Pour Encapsulate

Take out the Sylgard 184 Silicone Elastomer Base and its Curing Agent. You will want a clean container to mix the two chemicals together and something to stir it with. A Food Saver jar works especially well since it can be capped with a hand pump attached to it to vacuum the air bubbles out of the mixture.

The 0.5 kg kits are the perfect amount for one panel, although with some practice you can get by with using only 90-95% of the kit per panel. Take the entire contents of the Curing Agent and slowly pour it into the container with the Elastomer Base. It is very important that you completely mix the two together so that the curing process is even throughout the panel. Using your stirring rod and mix the contents for about 5 minutes or so. The mixture should bubble as the mixing is done.

Once the encapsulate has been mixed you will have a few hours before the solution starts to harden, so you can take your time and do it correctly here. The bubbles that emerge in the mixture will eventually be transferred to the panel and become bubbles on the face of the glass if they are not removed. By vacuum sealing the jar with the mixed encapsulate inside you pull the air out of the container and the air bubbles will naturally draw out of the mixture. The container should ideally be vacuumed 29 Mercury (Hg) of pressure, if possible, to remove all of the air bubbles from the mixture. If you cannot achieve 29 Hg of pressure in the container and some bubbles remain you will have the opportunity mitigate the bubble factor later on.

Take the frame with the glass attached inside and lay it on a perfectly flat table. Make sure it is completely flat, for if it at a slight angle your cells will end up all on one side of the glass. You may want to place a piece of plastic underneath the glass to protect the table, as some of the encapsulate may leak out during the curing process. Pour a little bit of the encapsulate over the glass. The cells will then be placed on top of this encapsulate. Only use a little, however, as you will want to save most of the encapsulate for pouring over the cells once they are on the glass.

STEP #8: Lay Strings of Cells on Glass

Take each string a place it down on top of the glass. The encapsulate you have already poured will help keep the cells in place while you do the final soldering. Make sure to lay each string so that are in opposite directions from each other. In other words, if the first string has the positive leads coming off the top then lay the next string so that the negative leads come off the top. This will allow you to wire each string together in series with the bus ribbon. Remember, the tab ribbon coming off the backs of the cells are the positive leads, and the tab ribbon coming off the front of the cells is the negative leads.

Wire the strings together with bus ribbon to ensure you have a completed series connection throughout all 36 cells. You will also want to wire bus ribbon from the two "home runs" to the center-top of the panel. The home runs are the two tab ribbon leads that come off either end of the completed string. They will be in the top left and top right of the panel if you are working with a 4 row by 9 cell configuration.

Solder the bus ribbon on to connect each string to each other and then solder enough bus ribbon to the two home runs to allow you to pull the bus ribbon through the bond paper and plastic back sheets and into the junction box that will be connected later on. An extra 6 inches from the top corner of the panel will work. Be careful soldering on top of the glass, as too much direct heat on the heat may crack or discolor the face of the panel. Placing a thin piece of cardboard under the bus and tab ribbon before soldering can help prevent this situation from happening.

Once all 36 cells are completely wired together in series and the home runs have been made place another bead of caulk around the perimeter of the cells and just under the lip of the c-channel. This will prevent the encapsulate from oozing out the sides of the panel. It will also keep more of the encapsulate in the middle of the frame where the cells are so that complete encapsulation will occur.

Pour the rest of the encapsulate over the backs of the solar cells. Go slow and make sure to pour encapsulate over the entire panel. The encapsulate will settle and seep under the faces of the cells to encapsulate them to the glass. Try not to pour encapsulate around the entire perimeter of any given cell, as this will trap the air under the cell and cause a big air bubble to form. Again, this can be mitigated later on, but it is best to avoid making this mistake.

Next, place the bond paper on the encapsulate. This bond paper will absorb some of the encapsulate and become attached to the cells. This provides some strength to the encapsulation of the cells, as the fibers in the bond paper harden in the mixture to add rigidity. Place a weight over the back of the panel so that the cells are lightly pressed against the glass nice and flat. Carpet matting or newspaper under a piece of plywood cut to size would work.

You will want enough pressure to flatten the cells, but not too much to break the cells. This is where good, flat solder joints will help out. If your soldering on the faces of the cells was sloppy it could make the cells harder to lay flat on the glass and cause more air bubbles to form. Once all of the encapsulate has been poured and the bond paper has been placed on top, let sit for a few hours before checking back on it.

STEP #9: Lay Back Sheet & Attach Angle Aluminum

After a few hours go back to check on the panel. At this point you should be able to tilt the panel up to see how the face of the panel looks. Some air bubbles will be present, but let them stay for now. Take the plastic back sheet that is cut to fit on the inside of the frame. Cut in about 1" from each corner so that the plastic can fit nicely on the inside of the c-channels. Cut a hole in the bond paper and feed the bus wires hoe ones through it. Cut a hole in the plastic back sheet where the home runs where come through and feed them through.

Before feeding the bus ribbon home runs all the way through the plastic back sheet put some silicone caulk on the back of the bond paper to help seal the plastic back sheet to the bond paper. Some tackiness will still be present in the encapsulate, so not too much silicone will be needed. Make sure to leave a little bit of caulk in the tube for the junction box.

Lay the plastic back sheet down on the cells and feed the bus ribbon home runs through the hole you have cut. Make sure that the plastic is completely flat against the cells and bond paper, but be careful not to apply too much pressure to the back of the cells so that none get broke. If a cell were to break at this point it would be very hard to remedy.

Once the plastic back sheet is in place it is time to attach the aluminum angle. The aluminum angle will fit inside the c-channel and keep the glass from moving. It will also keep the plastic back sheet in place and add further protection from the elements. This will be done by rivets, as well.

Take the cut aluminum angle and drill two holes into each one. Lay them in place inside the channel where they will be and mark a hole on the c-channel. Drill these second holes and put the aluminum angle back in place to make sure the holes line up. If all the holes line up then go ahead and rivet the aluminum angle to the channel. Make sure that the angle is flush to the glass and provides some pressure downward onto the glass to keep it in place. Placing a block inside the channel with the angle will help keep pressure while you rivet. As with the other rivets you have made, if you place a little caulk in the hole before sliding the rivet in place it will provide a better water seal.

STEP #10: Add Junction Box

The bus ribbon home runs will need a way to pass their current onto wires suitable for outdoor exposure. This is best done with a terminal strip attached within a junction box. You can source the terminal strips and junction boxes from your local electric suppliers or you could opt for something called a project box available at RadioShack. In any case you will want an enclosure that has a fairly low profile and will provide some protection from the elements.

If you drill two small holes in the ends of the bus ribbon you can them feed the tiny set screws in the terminal strips though them and screw the bus ribbons down to either side of the terminal strip. Take outdoor rated wire that is also rated for the current it will carrying for the distance given and attach that to the other end of the terminal strips so that the current form the negative and positive bus ribbons will pass into the two wires. Mark each wire positive or negative and feed it through the hole in the junction box before making the connection.

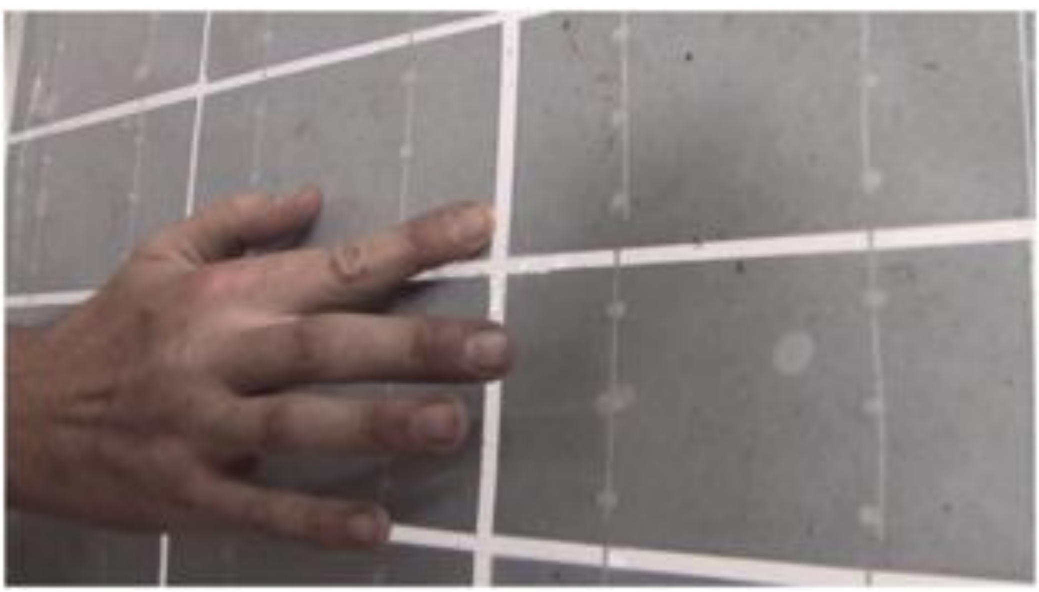
Glue down the junction box to the plastic back sheet so that it will stay in place. Use the glue liberally. If the wires leading from the panels at any time get pulled you will want to the junction box to stay in place. Once the connections have been made place the cover on the junction box. Apply a thin bead of caulk around the outside of the junction box to provide a good seal against the elements. If any water were to get behind the junction box it could find its way through the hole that was cut for the bus ribbon and into the panel.

If you choose to include a blocking diode in your solar panel you can wire it in parallel on the positive lead coming from the panel. If you plan on using a charge controller, however, you may not need a blocking diode, as the charge controller is set up to prevent reverse flow from the batteries into the solar panels at night.

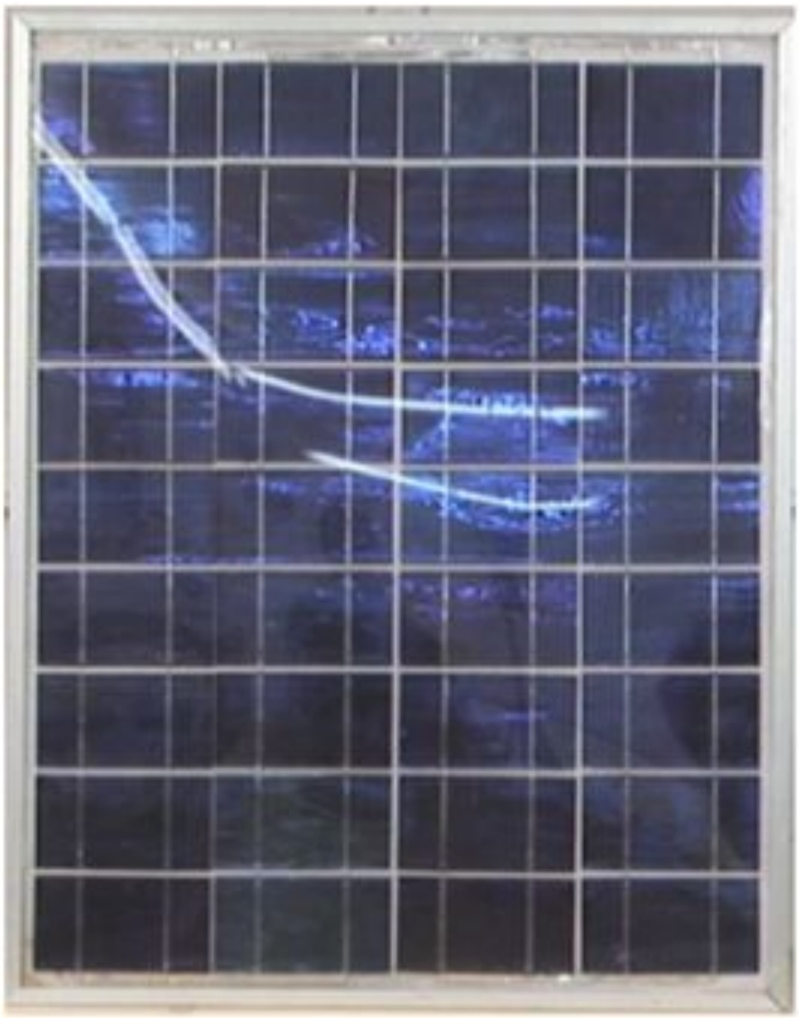
STEP #11: Remove Air Bubbles and Test in the Sun

At this point you now have almost everything in place and can concentrate on the air bubbles. Take the panel and tilt it on its side. Look over the face of the panel for any air bubbles that may have formed during the curing process. Since the encapsulate has not fully set up it should still be possible to apply a lit bit of pressure to the back of the solar panel and 'push' the bubbles away from the faces of the cells and into the gaps in between where they can exit through the back of the panel.

Work as fast as possible here, since the cells can still shift and become uncentered on your panel. Apply some light pressure – just enough to move the bubbles, but not too much to crack any cells. This may take a bit of practice, but if everything was done correctly you should not have too many bubbles to deal with.



Once you have gotten all of the bubbles out let your finished panel let it sit overnight. The curing process depends on the temperatures, but at a room temperature of around 77° it should be able to fully cure in 2 days. At the very least, let it sit overnight so that they cells are firmly encapsulated to the glass and won't move within the frame if the panel is to be moved. After the encapsulate has completely cured you are finished.



Now that you panel is complete its time to test it out! Going out into full sun, take your panel and orient it so that it is as perpendicular to the sun's rays as possible. This will give you the highest readings and, thus, the biggest sense of accomplishment. Take your multimeter and attach the negative lead to the negative homerun and the same with the positive lead. Take the voltage and current readings. You should see at least 18 volts from your 36 cells, although it is quite possible that you will see a little more. As the cells heat up in the solar panel throughout the day under the sun you can expect to see the voltage drop.

Next, change the setting on the multimeter to get the current reading. You should see a current reading similar to what each individual cell was rated at. Multiply your voltage rating by your current rating and you have your panel's power in watts. Now you're done and can congratulate yourself on producing your own clean electricity for years to come right in your backyard!

Analyzing your Solar Investment

By looking at the overall energy production of the solar panel versus the initial cost you get a much better picture as to the savings that this panel will give you. Take, for instance, a 65 watt panel that you built for $90 that produces roughly 66 kilowatt hours (kWh) per year. This panel, built as inexpensively as possible may last for just 5 years, at which point it will have produced 330 kWhs over its lifetime. A similar panel, rated at the same 65 watts, but built for about $180 will give you the same daily output as the $90 panel – assuming it is mounted in the same location, but will last much longer due to superior construction methods. This panel, being built to withstand the weather elements, could give you 25 years or more of operation. Over its 25 year effective lifespan, this $180 panel will have given you about 1,650 kWh. To best compare the two take the initial investment and divide it by the power production over its estimated lifespan to determine the price per kWh.

The $90 panel, which would produce about 330 kWhs, would give you a price per kWh of about $0.27/kWh ($90/330kWh). The $180 panel, built with better materials and methods, would produce about 1,650 kWhs in its effective lifespan would give you a price per watt of about $0.11/kWh. When comparing the two, you see that while the $90 panel requires a smaller initial investment, your actual price per kWh is much higher, and after a few years you will have to build another one. The $180 panel, at just $0.11/kWh is actually cheaper than grid power in most of the country and will last 25 years before needing to be replaced. Throw in the federal tax credit of 30% and you can see why so many people like yourself are choosing to harness the sun to produce their own electricity.

To further analyze your solar investment and find the number of peak sun hours at your site, go to http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/sum2/state.html. Peak sun hours are calculated as when the sun's energy is 1,000 watts per meter2 for one hour. This number varies greatly over the United States and the world, so pick the location nearest to you for the most accurate estimate.

For example, a fully constructed panel that will output 65 watts for 5.5 peak sun hours a day will produce an average of 358 watt hours a day (65 x 5.5). Annually, this panel will ideally output 130,670 watt hours, or 131 kilowatt hours (kWh) a year of DC power. Since you could lose up to 20% of the power through wire losses, dust, inverter efficiencies and battery recharging, you can assume that you will produce about 105 kWhs of usable AC power in one year.

Depending on what you are charged from your local utility determines your payback time for your solar system. If you pay $0.15/kWh, for example, your system will save you $15.75 annually (105 kWh x $0.15/kWh = $15.75). Take the total investment into your solar panel, say $180 and divide it by the annual savings to see its payback time. For a $180 panel saving $15.75/year your payback time would be about 11.5 years. This payback time will increase when you add the other costs associated with a solar system, namely the deep cycle battery, inverter and charge controller. This is only an estimate, as panels degrade with time (typically around 0.5% or more annually even for the commercially made ones) and the cost of a kWh produced from traditional fossil fuels is only going to rise. Also, if you pay more than $0.15/kWh your payback time will decrease and inversely, if your site has less than 5.5 peak sun hours a day your payback time may increase.

If you are providing usable power for a location that would not have power otherwise, then these numbers are useless and the panel's investment is seen instantly! Also important to note that every kWh your panel produces that prevents you from buying a kWh produced through the traditional, dirty, methods is getting us one step closer to a clean environment.

Another simple way to determine the output of your panel is to go to http://rredc.nrel.gov/solar/codes_algs/PVWATTS/version1/ and pick the location closest to you. You system size may be smaller than the program will allow, but you can sidestep this issue by getting the results for a 1 kW array and then multiplying this by your actual system size's percentage of 1 kW. To figure out what a 65 watt would then output you merely multiply the estimated number for the 1,000 watt system by 0.065 (65 watts); a 230 watt array's production could be found by multiplying the results by .23.

Weighing the Pro's and Con's

There are instances when building your panel with the minimalistic approach may best match your needs. If you are working on an extreme budget you may want to consider building the most basic of panels with the least out of pocket. While the panel will not last as long, it will provide reliable power for the short term. This could allow you to match your short term power needs while you save more money for a stronger panel. Likewise, if your needs for power are only short term, and for whatever reason you do not need the panel afterwards, then you may want to opt for the cheaper panel, too.

If you are planning on building several panels and want to use the first one as practice for your soldering, then you may want to just build a cheaper panel that can still provide some power when completed. You can wire this panel with the other sturdier panels, but after a few years the cheaper panel will start to lose power and may pull down the power output of the entire system. A close eye is needed to watch for any degradation in your "practice" panel so that all of the more professionally built panels will produce to their full potential for their entire lifetime. If just one panel in a solar array is underperforming it will pull down the output of the entire string.

While there are instances where it may make sense to save money up front and build yourself the most basic of solar panels you must carefully weigh the pros and cons. You need to consider whether saving some time and money up front is worth building a panel that will only last for a fraction of the time that a more sturdy and professional panel will last –and for less than $100 more in most cases. Even for the cheaper option, if you are already investing $100 into the construction of your panel, it may make sense to invest a little more and build a panel that will last several decades. And even if your power needs are temporary and you don't know what to do with the panel afterwards you shouldn't have a hard time finding a happy recipient for your perfectly good solar equipment once you are done with everything.

Conclusion

We all face choices on a daily basis, and building a solar panel is no different. After carefully weighing the pros and cons of the various construction methods, the choice must be made as to how to build your panel and what materials to use. These choices will determine your bottom line and how much time is invested in your project, but will ultimately dictate the longevity of your panel. In any case, though, the right choice has been made to produce your electricity from the sun.

Solar provides the most reliable access to renewable energy, and it can now be done right in your backyard for less than a few hundred dollars. The methods contained within this guide are tried and true, although in such a dynamic industry as solar energy, staying current of the newest trends will keep you one step ahead of the game. While little to no electrical experience is required to build your own solar panel you can expect there to be a little learning curve. The cells are very fragile and can break under even the slightest of pressure.

It is paramount to keep in mind, however, that practice makes perfect and once the panel is complete you will be able to enjoy access to the sun's energy for years to come. The solar industry, although still in its early years, has found itself in a position where not only is it a much cleaner alternative to its conventional fuel source counterparts, but it is now rapidly becoming the cheapest option. Harnessing the sun is easier than ever before, and as Edison said, "I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait till oil and coal run out before we tackle that."