SMART SOLAR BOX

* Please Remember *

<u>Safety First</u>! Everything you do that is related to your DIY project is at your own risk. Please use safety precautions at all times. If you do not understand something or do not feel comfortable doing something - consult a professional.

Thank you for trusting our product. Because you trust us, I'd like to return the favor by presenting you a fresh new project. I hope this project will mean a lot in terms of mobility, reliability and independence, regarding your energy independence.

Ryan Tanner

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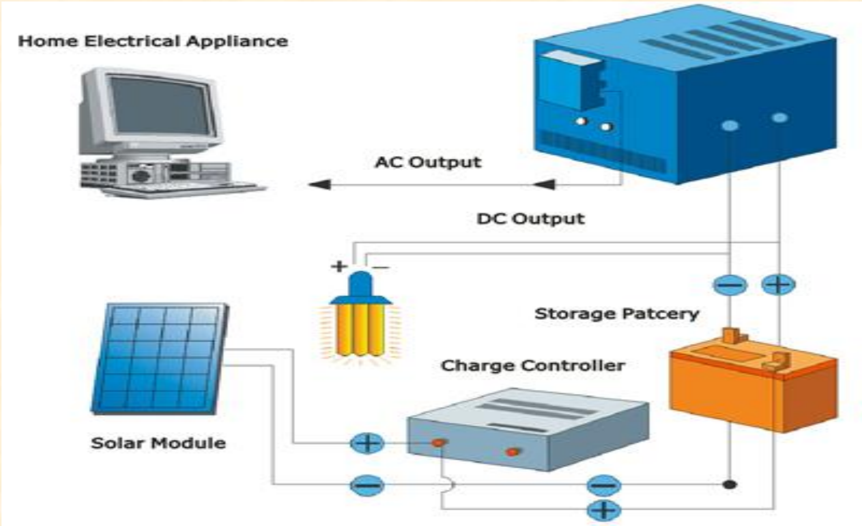
CHAPTER 1. Introduction

a. Basical principal regarding solar energy

There are three main types of solar electric systems: off-grid, grid-tied or grid-tied with battery back-up. Off grid systems typically use batteries as their form of energy storage and have been around for many decades. Grid-tied systems have only gained popularity in recent years, as utility, state and federal incentives have made the solar system much more cost competitive with its dirty rivals: the fossil fuels.

These grid-tied systems use the utility grid (the network of wires and cables that span every city and town in the US) to store their energy, sending excess energy into the grid during the day and pulling from it at night.

Every solar system, no matter which type, will always start at the solar panel. This is where the energy starts, and from there it must enter some conductor to reach its destination. This conductor is typically an insulated copper wire. The amount of energy and the distance of the wire will determine what size wire to use. In an off-grid application, the energy from the sun typically flows through these components:



(general scheme)

From the solar panel the current flows into a charge controller. This unit is in essence a regulator of energy. It is a customizable unit that regulates the flow of energy to the battery and determines how much energy is being pulled from the batteries at nighttime or in cloudy weather. Depending on the size of the solar array you may spend anywhere from under $100 to a couple hundred dollars for your charge controller(s).

Controllers are available in a variety of sizes and appearances.

The batteries are a crucial component of your off-grid system. This is what will be powering your appliances when the sun goes down or behind clouds. Most batteries now are lead-acid batteries, although as more funding is being put into the R &D of batteries the chemistry is constantly evolving and becoming more efficient.

Batteries are also available in unsealed and sealed types. The unsealed types are much more common due to their lower cost. However, they do require weekly maintenance to keep their electrolyte levels above the plates inside the battery. The sealed batteries come at a premium, but do not require the maintenance, since the electrolyte is usually in a gel substance.

For either battery you will want to keep them away from any potential heat or fire sources. A shed or a well vented room in your home will work best. Try to avoid temperature extremes for your battery bank, as this will affect the performance negatively.

The charge controller can be programmed to stop flow from the batteries when they reach a certain depth of discharge (DOD). The DOD is typically no less than 50% of the battery's capacity. The further you discharge a battery on a regular basis the shorter the life span of a battery will be. For solar applications you will want to use deep cycle batteries. Wired together, they form a battery bank.

These may look very similar to car batteries but are only similar in appearance and greatly differ in their requirements. Car batteries are meant to be fully discharged and then rapidly recharged. Solar deep cycle batteries are slowly charged throughout the day and then discharged slowly at night. Their energy input will vary throughout the day and the discharge will be sporadic at night, too.

A car battery used for a solar application would not be expected to last even one year, while a well maintained deep-cycle battery can be expected to last 6 years or more, depending on the depth of discharge level you have set and how often you keep the electrolyte levels maintained.

If you are using just direct current (DC) loads you will not need an inverter and can just charge the loads from the battery, assuming the voltages match up. However, the cost and availability of DC appliances remains an impediment to the solely DC home.

Alternating current (AC) appliances dominate the home appliance landscape and require an inverter to change the DC current from the solar array to AC current for your refrigerator, TV, lights, etc. You should expect to spend around $0.50/watt or more depending on the size of the inverter needed.
Typically, all but the largest residential solar systems will work fine on one inverter.

Inverters, like the charge controllers, will vary in shape and size depending upon the inverter's output rating and manufacturer.
You may be able to save some money on larger systems by purchasing an inverter that has a charge controller inside its circuitry.

Check the spec sheets to determine this. Many of the larger manufacturers of inverters have solar string sizing programs available for free on their website, so you may want to reference this to determine what size inverter to use. The inverter's input voltage window is the main determination to determine how many panels you can wire together in a series string, which is why they are often called string inverters.

You can get by with an inverter that is rated below the name plate rating of the array. For example, a solar array with a name plate rating of 3,300 watts (3.3 kilowatts) will work just fine with a 3,000 Watt inverter, since you will typically lose up to 20% of the output from the panels from many factors. Among them, voltage losses in the wires, panel mismatch, dirt or pollen on the panels and the DC to AC inversion.

Disconnect switches are often times built into the inverters, but many municipalities require a separate disconnect switch for either the DC side or the AC side, or both. If you are planning on getting your system inspected by a licensed inspector or are going to connect your system to the grid check with your local laws to determine which disconnects you will need to install. The National Electrical Code (NEC) book, too, has set laws on mounting the equipment, such as how high off the ground, distance from batteries and other components, etc.

Disconnect switches, depending on how many strings of panels you are creating may need to have an integrated fuse. These disconnects can be purchased at a local electrical supply or hardware store.

If you are constructing a small array, you may get away with just one battery, a small charge controller and a low wattage inverter, like the kind you can plug into your car adaptor. You can plug many AC electronics or even appliances directly into the inverter, so long as the inverter is rated to handle the load requirements.

For larger systems, you should opt to run the inverter AC wires directly into your homes breaker panel with breaker slots allotted for the inverter. A master electrician's services should be sought for this step.

To make sure your breaker panel can handle the backfed current take the busbar rating found on the inside cover, multiply it by 1.2 and then subtract your main breaker size. The max continuous output current of the inverter multiplied by 1.25 (depending on which NEC Code year you reference) must be below this number.

For example, a 200 A breaker panel (standard in most new construction) with a 200 A main breaker will allow for 40 A to be backfed (200 x 1.2 – 200 = 40 A). You can typically fit up to about 7000 watts on a 200 A breaker panel since the max continuous output of a 7,000 Watt inverter is usually close to 32 A. The max continuous output of the inverter is found in the spec sheet or by contacting the manufacturer.

Grid-tied systems substitute the utility grid for the batteries. Most homes that are connected to the grid opt for this service. If going this route, you will want your utility provider to install a net meter for you.
This meter records the flow of electricity in both directions, essentially crediting your account for sending excess electricity into the grid.

When the sun is out and your panels are producing more electricity than your home needs, your meter will spin backwards. When the sun goes down and the lights come on you begin to pull electricity from the grid and your meter spins forwards again. Most states have now adopted net metering for renewable energy systems. If you don't get a net meter your old meter may actually charge you for energy consumed and energy produced!

It is important to note that when you lose power from the grid, you won't be able to use the power from your solar array. This is a safety feature built into the inverters so that if you have a utility lineman working on the power lines in your front yard they can be confident there is no current in the lines. If your array were in the backyard feeding the grid and he was working in the front he would run the chance of having a bad electric shock.

A small percentage of homeowners opt for a grid-tied solar system with battery backup. This is more common in places with an unreliable utility connection like very remote areas or places with inclimate weather. Aside from the extra maintenance and introducing more toxic chemicals into your home and the environment, you could pay up to 50% more on the total cost of an installed system by adding battery backup. There are inverters out there that have grid-tied/battery backup capabilities, but you may need two inverters for this option.

Having a crucial load subpanel is a good option for when the power goes down and you are drawing from the batteries. This isolates some of your electric loads on a separate breaker panel so that you won't pull down the battery's storage too fast by running unnecessary loads.

b. General technical regards

The sun's rays are comprised of many tiny photons of light. These photons, while technically without matter, do possess energy. These little balls of energy multiplied many times over strike the surface of the solar panel and cause the necessary commotion to knock the electron free in the solar cell.

Solar cells are typically made up of high grade silicon as the semiconductor, but this alone is not sufficient to create an efficient enough solar cell. However, if a doping agent is introduced, commonly boron and phosphorus, it causes an unbalanced chemical structure, with a surplus of electrons in the silicon-phosphorus layer on the front surface of the cells.

This creates a negative charge and is referred to as the N-layer. Boron is often added to the back layer of the cells, creating a silicon-boron mixture that has a positive charge and can easily accept extra electrons, often referred to as the P-layer.

In between the two is a positive/negative junction, or P/N junction. This middle junction between the other two layers has a neutral charge and will only allow the flow of electrons in one direction; from the P-layer to the N-layer.

Inherently, electrons like to move from negative to positive charges, and the only pathway for the electrons to return to the P-layer from the N-layer is through the conductor, which offers them very little resistance and allows them to flow out of the surface of the solar cell.

It then returns to the solar cell through the completed circuit into the Player.

By taking this flow of electrons, or electricity, and attaching a load to its circuit you make the electrons do work and have usable, renewable energy.

When each photon hits the cell it carries enough energy from the sun with it to excite one electron in the cell into the movement that creates the electricity. That is where the importance of the sun comes in.

Without an outside energy source, the circuit would not flow.

However, when there is enough sunlight, the electrons from the P-layer leave their unbalanced atom and leave holes behind, which are easily filled by new electrons returning from their work in the circuit. This process happens until the sun sets for the day and they lay in wait for a new day.

A blocking diode on the positive lead prevents any current from the cells at night and draining the batteries. You can wire the solar cells together to form a solar panel. When solar panels are wired together they form a solar array.

Of the three, monocrystalline cells are the most efficient, while polycrystalline cells are a close second.

Amorphous cells, while considerably less efficient tend to cost only a fraction of what the crystalline cells do. The crystalline cells comprise the panels that are typically used in residential installation. Because they are so much more efficient that the amorphous cells you do not need as much roof or ground space to provide enough energy to offset a typical home's usage.

However, due to amorphous panels' low costs they tend to be preferred for many commercial applications, since space is not an issue in many cases.

When you know both the voltage and amperage of a solar cell you can multiply them together to find its rating in watts. Completed solar panels are rated in watts, so it's important to understand this formula.

Knowing just two parts of the formula, you can also derive the third component. For example, understanding the basic formula V (volts) x A (amps) = W (watts) allows us to derive the amps from a 100 Watt 18 Volt panel.

V x A = W or W/V=A

100w / 18v = 5.55 amps that the panel will deliver

Once you know the voltage and amperage of your solar cells you can begin to wire them together to form the solar panel.

The solar cells are wired together with conductors, commonly tab ribbon. This allows us to take the single solar cell and pair it with similar cells to create a solar panel with customizable power outputs.

So, let's start to see how you can make this at home with a very decent budget and effort. This device is a solar charger but it can be also a small solar generator; in order to make it a power solar plant you can scale it up to your requirements

First, let's see what we need in order to complete this project.

CHAPTER 2. Tools and components

a. Tools

Pliers

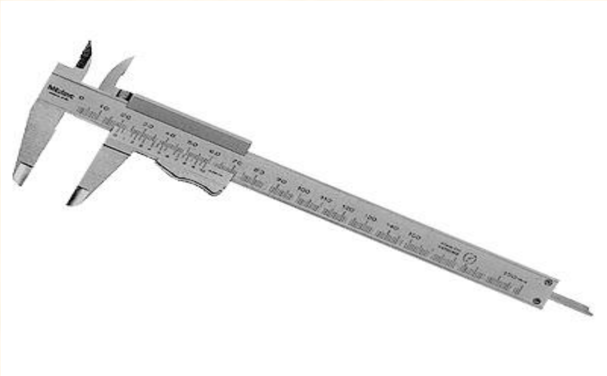
Cable Cutter (Pliers);

Flat and Cross Screwdriver;

Cable Crimper Pliers;

Decorticator pliers;

Box Cutter Knife;



Sliding Measuring Callipers;

Fixed Wrenches;

Plastic Cable Ties;

Hand Drill

Drill Bits;

Multimeter (Amp\Voltage Measuring Device).

b. Components (electronic parts needed)

Solar Panel Cable Coupling;

Power Inverter 12V – 110V (220V) at 800W;

Solar charger controler;

Electrical cables for wiring (red and black) ᶲ1.5-2mm– 3.5 ft (10 m);

Metallic Coupling for Solar Panel Fixing – you can choose from a large variety

Screws, Washers and Nuts ᶲ6, 2.4 inches, 1.6 inches and 1 inch long;

Connectors;

On/Off Switch;

 or 

Socket for 110V or 220V;

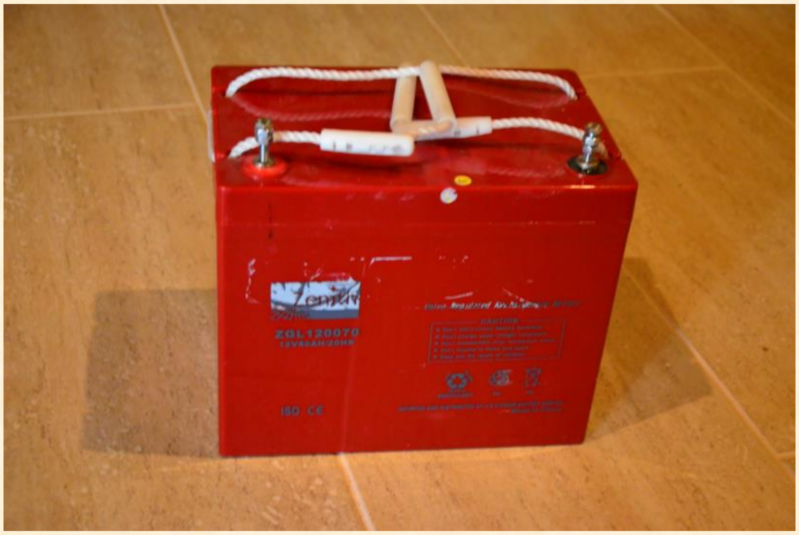
Car Lighter Socket 12V;

USB Socket;

2 x Threaded Metal Rods;

Tripod for Solar Panel Support;

2 x 40 / 50W Solar Panels;



2 Smaller sized car batteries or a Big One;

1 Toolbox inside which we'll assemble the Power Bank for better maneuverability and ergonomics;

For testing the Device we'll use: 2 Halogen x 10W bulbs, 2 x 10W bulbs, 8 x 100W bulbs connected in parallel. Also, we'll use a cell phone and other household devices.

Next you'll see the step-by-step assembly process, and we'll do a final recap at the end of the video.

CHAPTER 3. Building Smart Solar Box

a. Assembling solar panels

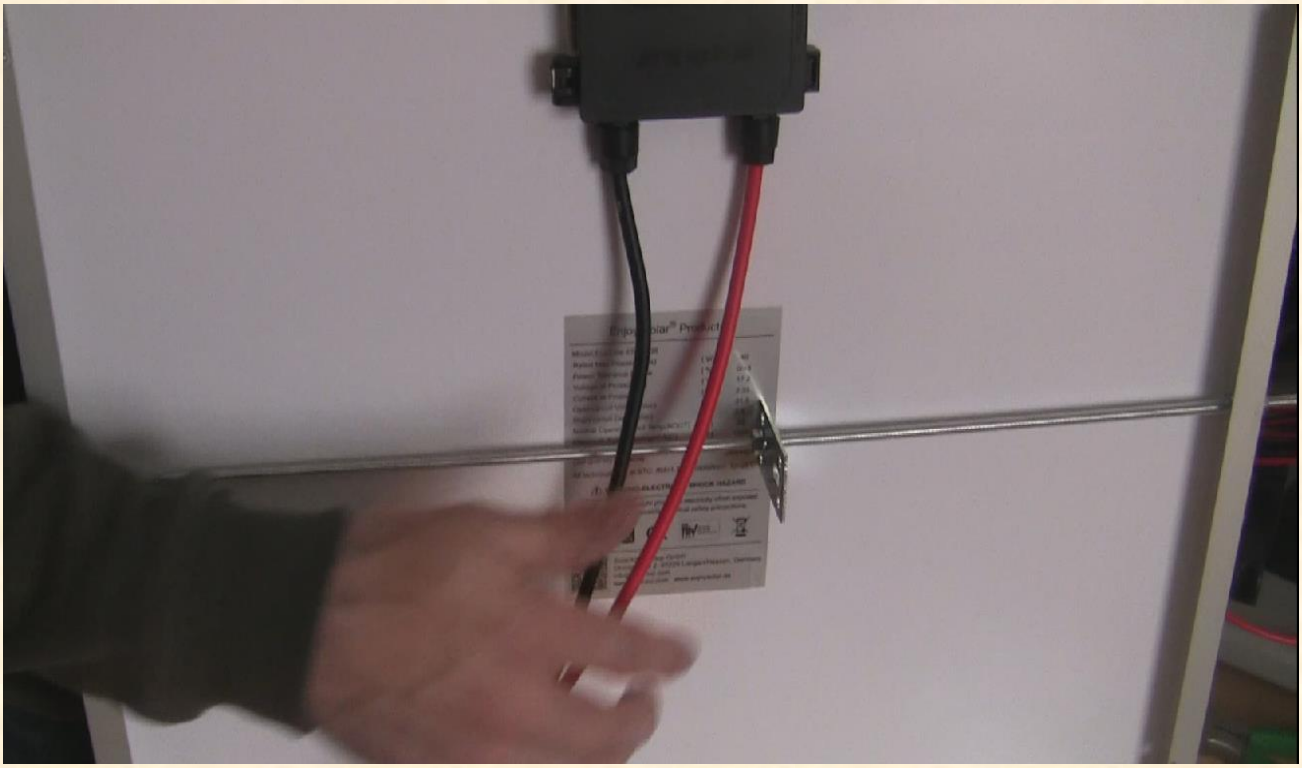
We'll use a normal but robust tripod (normally used for spotlights and other devices). According to the desired size of the device, you can choose bigger and more durable tripods in order to sustain the solar panels for the exposure period.

You'll need a permanent marker and a measuring tape with which we'll find and note the middle of the aluminum frame that holds the 2 solar panels. Please pay attention when drilling the hole in the middle of the frame, so the threaded rod won't touch the surface of the solar panel. The drilling must be done carefully to avoid damaging the solar panel; in the video we used an aluminum frame which is easy to drill into, but be careful not to puncture the solar panel. After drilling you can smooth out the edges of the hole to remove all the debris.

We'll repeat the procedure for the second solar panel, making sure we follow the same drilling pattern (the cables must be on the same side).

We'll mount a washer and a nut at one end of the threaded rod, and then we'll tight it in place with another nut, so the other end of the rod will sustain the solar panel. We'll add on the middle of the pipe another nut that will stiffen the tripod connection of the metallic frame you can see in the video. Depending on the size, you can center or skew to one side the metallic coupling, so at the end the tripod will be balanced, and the solar panels firmly in place. Make sure you don't over-tense the solar panel frame and avoid any contact between metal objects and the solar panel. If contact is made, the solar panel might crack.

At the end of this step the panel should look like this:



Repeat the procedure for the second solar panel.

All the settings, tuning and coupling will be performed after placing the panels on the tripod, for better balancing. Also, make sure the connections on the solar panels are not obstructed, tangled or deteriorated in any way during the assembling procedure.

The excess tops of the threaded rods can be cut off for better ergonomics.

The tripod we're using is normally used for spot lights. We'll attach some metallic connectors / couplers using which we'll attach the solar panels in the final stage. The mobility options it's yours... and any coupling device of the two panels is ok, as long as it can hold the weight during charge times.

We'll use an 1 inch screw for fixing just like you see in the video. A helping hand when doing this is always welcome. It will be easier when setting up the solar panel on the final position. We'll tighten the screws, making sure we don't touch the solar panel.

At the end, the two solar panels will look just like you see in the video, with the cables left hanging for the following connection.

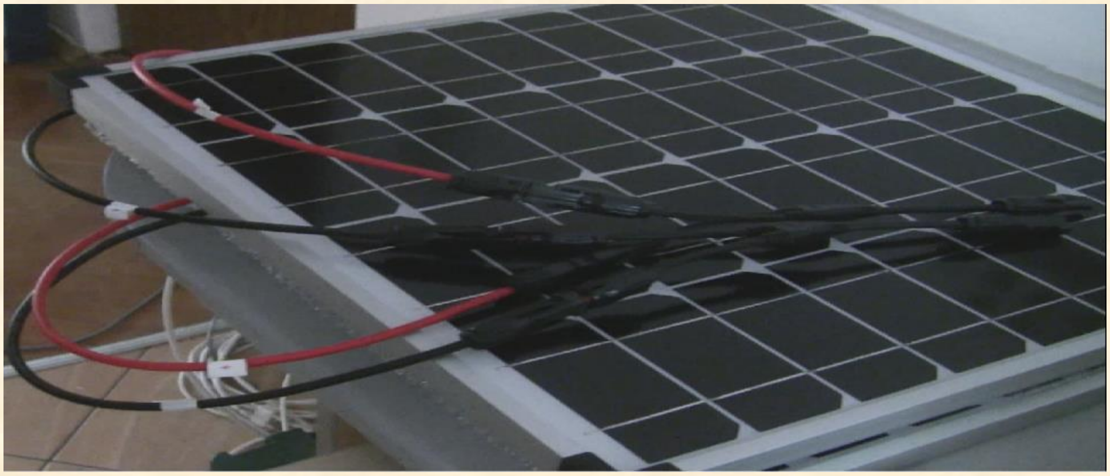
Next, you'll see how to connect the 2 solar panels and how to use the couplings mentioned in the first chapter.

The solar panels we used (for which you have the technical specs) are already semi-wired; if you buy them without connectors, the manufacturer's diy kit should include all the wires and connectors needed. As you can see, the red wire is on positive and the black one is on negative. I recommend using red-black color coded wires, at a length suitable for your needs.

Very Important! Wiring connection on the solar panel will be done in parallel! Even if you have more than 2 panels, the principle is the same.

Note that the connections are simple (mom-dad), avoiding undesired errors. For the positive line (connector + / red wire), we'll use at one end a mom connector in which we'll connect the red cable on the interior pin. Decorticate the end of the wire and then tighten it to ensure the correct connection to the metallic pin. Insert the tightening sleeve and then the coupling and tighten the lot. You'll see that it is light weight and strong.

Repeat the same procedure for the negative side of the circuit (connector - / black wire).



The coupling connection it's done as you see it in the picture above: the positive terminals in the positive coupling, and the negative in the negative coupling. In case you opt for a 4 panel system (or more), you'll have a splitter with 4 red wire entries on a positive connector and 4 black wire entries on a negative connector. The working principle is that you'll have X positive entries connected to a single positive base, and X negative entries, connected to a single negative base.

The other ends of the wires will be connected to a solar charge controller as you'll later see in the video.

b. Preparing the BOX

We'll use a plastic tough toolbox, on which we'll mount a normal socket (110V), a car lighter socket (12V), an on/off switch and an USB socket. Inside the box we'll have the charge controller, the power inverter, the battery and the excess cable.

So let's get to preparing the box for all the sockets, and afterwards we'll connect all the components for the final demonstration.

We'll first mount the socket for the 110V devices. **I'll mention here, that the combined power consumption of the devices you plan on using cannot exceed the nominal output power of the inverter**.

We'll use a drill or a box cutter knife to make a hole in the lid of the box. After drilling, clean the edges of the hole for debris, and position the socket. We'll hold it in place using two small screws, but only after connecting the wiring.

We'll repeat the procedure for all the other elements we'll place on the lid: On/Off switch, 12V car lighter socket, USB socket. That will be done after drilling each hole using the plastic/metallic O-rings.

Once the box is ready, we'll go on to the next step, in which you'll see how to make all the connections inside the box (it should look like this):

c. Wiring process

First thing … we put the battery in the box, setting it on the final position. After that we'll put the Power Inverter inside, and finally the charge controller.

The first step is connecting the battery. Use the connectors for the bases just like you see in the video. The red Connectors will go on the positive (+) base, and the blue connectors (in our case) will go on the negative (-) base and to the black connectors on the solar panels.

To determine the necessary length of the cables for connecting each socket, measure enough so you won't have a tensed wire circuit if the lid is open. Measure the distances for all the connections on the lid. Cut at the desired length 4 (in our case) pairs of wires. One for each connection... coupled with the same type of connector (red for the positive base and blue for the negative wires). The coupling is done by tightening the connectors on the cables.

After finishing the necessary wiring for the sockets, we'll measure the cable we need for the connection between the battery and the inverter and between the charge controller and the battery, following the same working principle: the cables must not be tensed so none of the connections will break.

For a better stiffening of the inverter we'll use a piece of Styrofoam, to make sure that it will stand still in the box without any space to move around. We'll also choose the final position of the charge controller, making sure that the connection side is up for easy access.

Now we'll connect the inverter (red to red and black to black) to the battery. Do the direct connection just like you see in the video. Next we'll connect the inverter to the socket. For that we'll take a cable from a plug. One end will be for the socket bases. We'll also need the on/off switch for controlling the socket power on the socket. The other 12V sockets will be permanently powered. If needed, you can mount another switch for those too. But because of the low voltage, we don't think that's necessary.

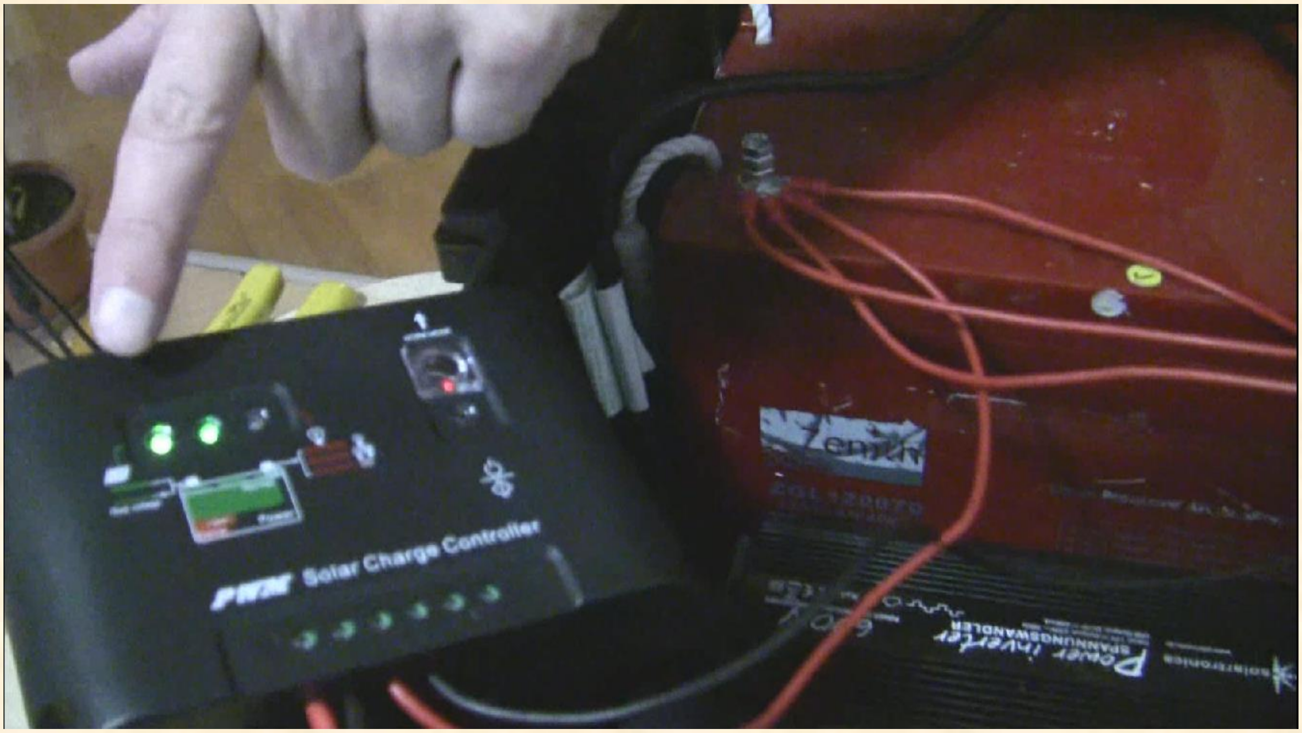
In the video you'll see that there are three wires coming out the plug: yellow (grounding), brown (faze), blue (null). In our case we'll cancel the grounding part.

Next in line is the on/off switch. This will close/open the inverter, powering up the socket. So, the positive base of the inverter will go on the positive base of the switch, and the other base of the switch will go to the battery. As you can see, we're using both cable of the same color (red).

Next is the charge controller and its connection (at one end to the solar panels, and at the other end to the battery).

THE IMPORTANT RULE HERE IS TO CONNECT THE CONTROLLER TO THE BATTERY FIRST AND THEN THE PANELS TO THE CONTROLLER. In our case we have icons on the controller that help in the process in an intuitive way: near the panel icon we have the positive and the negative coupling in which we'll connect the solar panels (red wire to positive + and black wire to negative -); the next two couplings are for the battery connection. For that we'll measure 2 wires (one red and one black). After inserting the decorticated ends in the controller, tighten the screws making sure it's a strong connection.

We'll connect on each battery base the cables with the specified colors. On the positive base we'll connect all the cables (from the controller, switch - inverter and 12V sockets). In the same way we'll connect the negative bases and cables (controller, inverter and the two 12V sockets). You probably noticed that the battery charge is already crating sparks. Make sure all the socket bases are connected before you connect them to the battery base. And as you can see, the controller is already powering up.



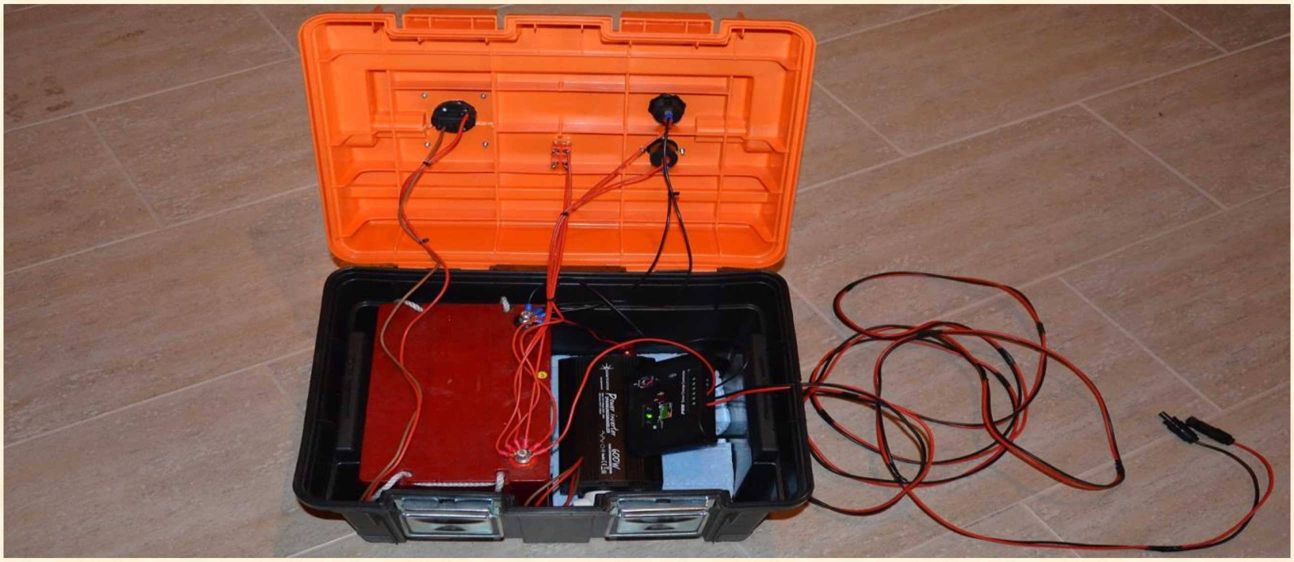
d. Recap – short review of the process

Let's recap. From the solar panels we have to outputs (negative to negative and positive to positive). These will connect to the controller, which will be connected to the battery bases. The green LEDs show that the panels are already charging. The inverter is also connected to the battery through an on/off switch on the positive side, and the negative coupling is connected directly to the battery. The 110V (220V) socket is connected through a plug to the inverter, and the 12V sockets go directly to the battery, following the polarities (red to red and black to black).

Next step is beautifying the system (tracing and setting in place the wiring and the components so it will prevent damaging the connections). We'll use plastic cable ties, Styrofoam as a space filler and we'll make sure that everything is firmly set in place before testing the device.

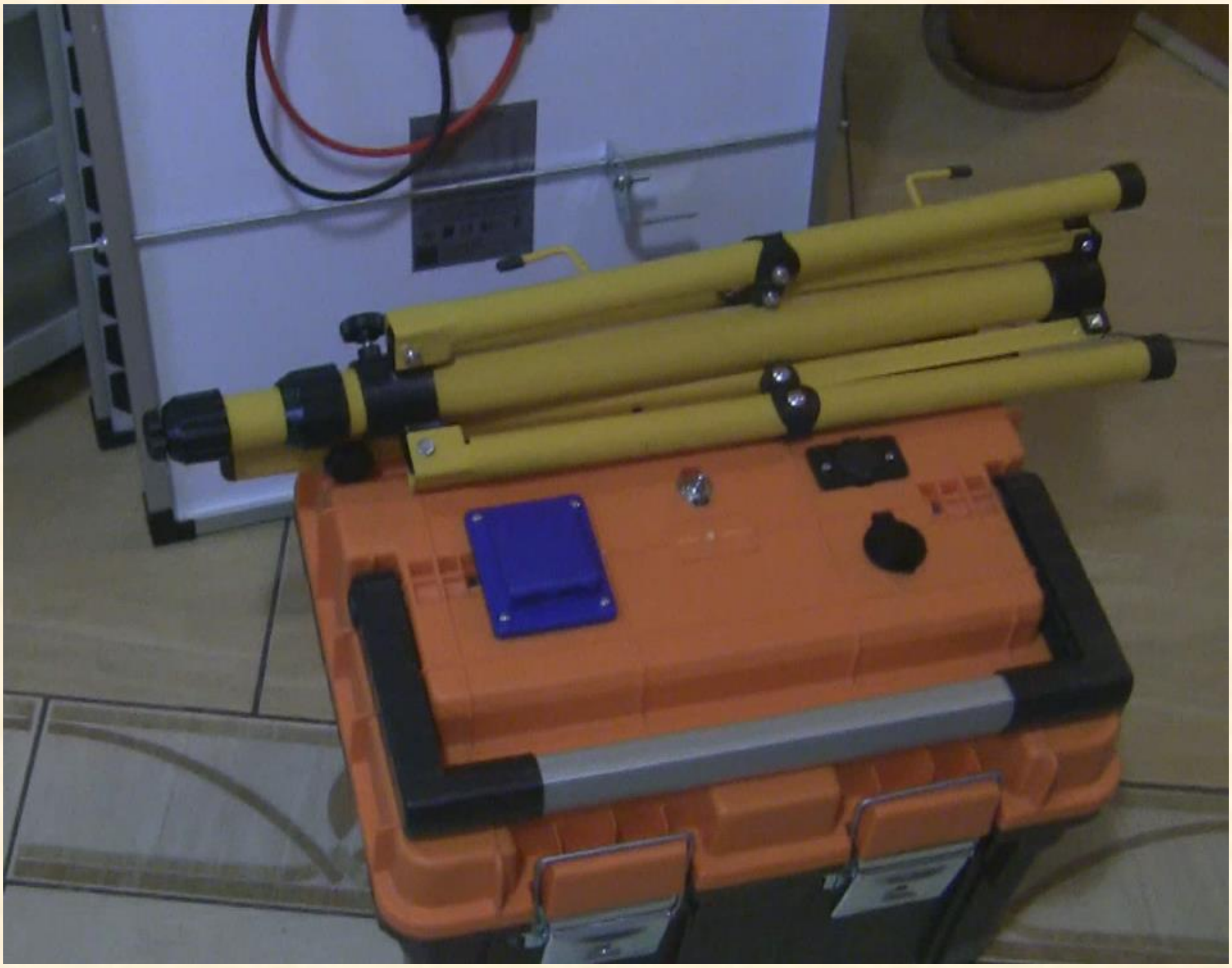
WARNING! This is a powered up device. To avoid electrocution close the circuit from the switch or do this operation before connecting the battery bases!

This is how the device looks in the final stage after all the cables and components have been set in place:



CHAPTER 4. Testing the device

This is how the system looks: box, panels, tripod and wiring.



Inside the box we have:

- A battery for storing energy from the solar panels

- An inverter for transforming 12V into 110V (220V)

- A charge controller which controls the flow of electricity from the solar panels to the battery.

The working principle is the following *(see page 4 – general scheme)*:

From the solar panels, the electricity is transferred through the charge controller to the battery. From there it leaves to the consumer interface (in our case towards the inverter which lifts from 12V to 110V or 220V socket, and to the 12V sockets - car lighter and USB).

We chose to use a toolbox for the power bank for mobility. You can roll the cable from the panels, disconnect the panels, fold the tripod and you're ready to go. Any isolated destination is now connected to your own personal power grid.

We chose to hook our panels to the tripod at this angle, so it will allow maximum solar energy absorption.

For testing we used a phone for the USB charge, a light bulb array connected in parallel, 100W each for the 110/220V socket and two halogen 10W light bulbs for the car lighter socket.

We'll connect first the box to the panels, and then plug in the different consumers.

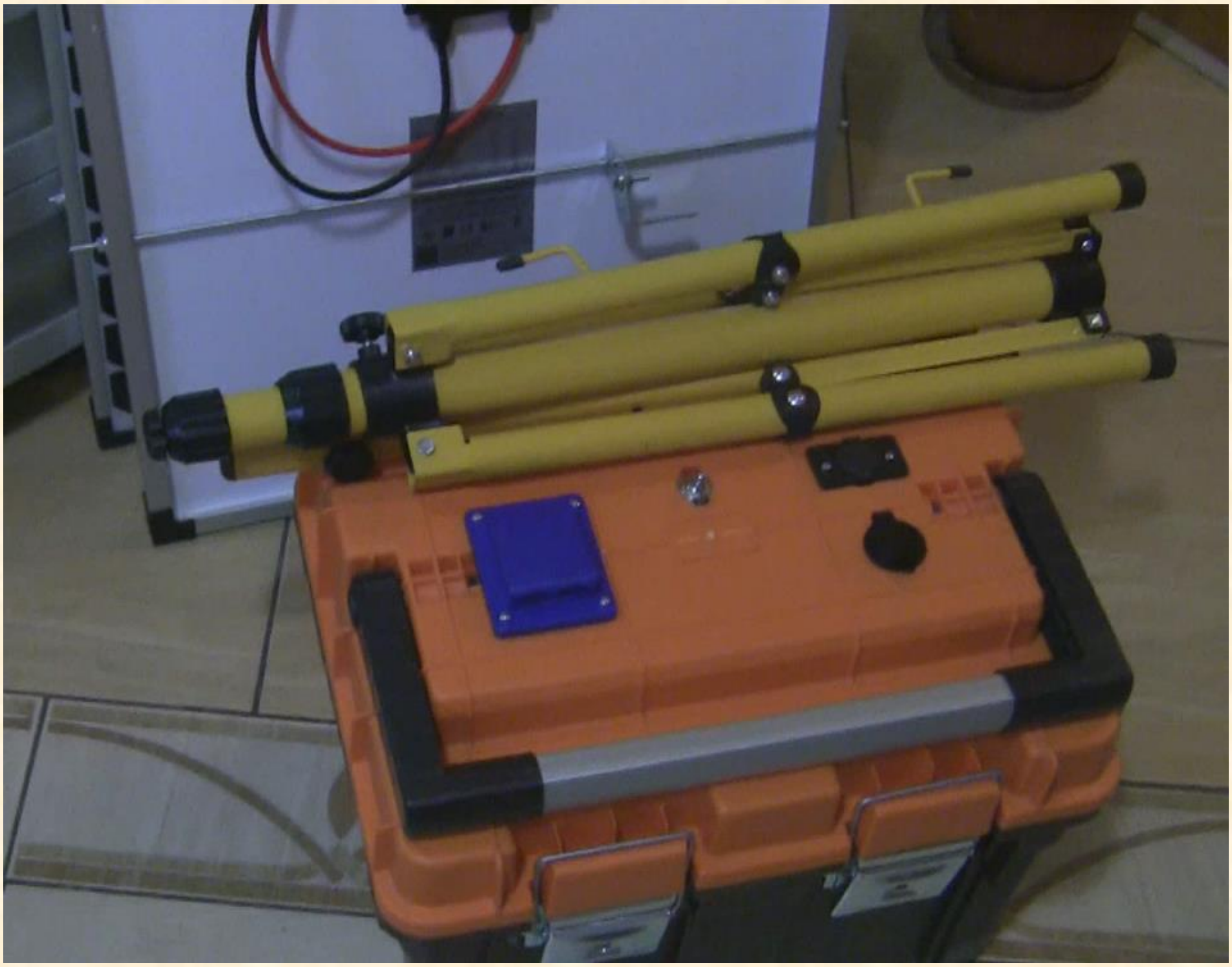
The first ones are the 110V light bulbs. We'll add the 10W halogen light bulbs and finally the phone for the USB test.

Because the battery is already almost fully charged, you can see we already have autonomy for all the tested devices

Depending on the type of solar panel and battery you choose to go with, charge time is between 4-6 hours, and it lasts depending on what you choose to plug in... How many and how much power they need to function in parameters? For the 100W light bulbs you can exceed 12 hours using 4 simultaneously.

You can plug in more powerful appliances (in our case no more powerful than 800W).

Here is how the system looks at the end of our step-by-step vide guide:



All the modules have been disconnected from one another and can easily fit any trunk. And you only need a couple of minutes to put them back together.

We hope you'll enjoy this device for a long time, and you're welcome to take part in our next project as well.

CHAPTER 5. List of places where you can by components

Here is the list where you can find the most important components for this project:

For Solar Panel Battery Charging Controller Regulator

a. Ebay.com >> Click Here << (identical with the one used in our videos)
b. Ani.SolarShop >> Click Here <<
c. Mlsolar.com >> Click Here <<
d. Ebay.com >> Click Here << (if you want to upgrade your system)

For Battery (AGM 80A – the one we used). Here are similar items with similar characteristics:

a. Solarpanelstore.com >>Click Here <<
b. Wholesalesolar.com >> Click Here <<
c. Amazon.com >> Click Here <<
d. Acosolar.com >> Click Here <<

For Solar Panels:

a. Mlsolar.com >> Click Here <<
b. Ebay.com >> Click Here << (a good option wich doesn't require any tripod or sustaining system)
c. Solarpanelstore.com >> Click Here <<
d. Solarxxl.com >> Click Here << (for Europe clients) or >This Version <
e. Enjoy-solar.de >> Click Here << (a good kit)
f. Acosolar.com >> Click Here <<

For Invertor 110/220-12v:

a. Amazon.com >> Click Here << (a double sized version from one used in the videos).
b. Eco-worthy.com >> Click Here <<

c. Ebay.com >> Click Here << (for upgrades)
d. Solarxxl.com >> Click Here << (identical with the one we used)

For 110/220v Panel Mounting Socket:

a. Alliedelec.com >> Click Here <<
b. Aliexpress.com >> Click Here <<

For 12V Auto Socket

a. Amazon.com >> Click Here << or >> This Version <<

For USB Socket:

a. Amazon.com >> Click Here <<

For ON/OFF switch:

a. Amazon.com >>Click Here <<

For Terminal Connectors (on the cables):

a. Eco-worthy.com >> Click Here <<

For Panel connectivity:

a. Solarpanelstore.com >> Click Here << (female) or >> Click Here << (male)
b. Ani.solar Shop >> Click Here <<

For tripod sustaining panels:

a. Dynamitetoolco.com >>Click Here <<
b. 12voltsplus.com >> Click Here << (identical with the one in the videos)

For our Australian custormes we can recomand you this site:

https://www.solaronline.com.au/

For all the other components, we recomand you General / Local Shops.

In order to cut your acquisition bill we recomand you to follow this steps:

- Decide the scale of your system according to your needs;
- See if you can find items like batteries, invertors cables on General Shops or even second hand shops. If you buy anything from a second hand shop, make sure that you receive what you asked for and also a test for the device would spare you for further problems.
- Follow our video guides as much as you need in order to complete your device.

Thank you for your time and trust. If you have questions, we'll be more than happy to answer them on the support address, and will reply as fast as possible.

Ryan Tanner

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