



## How to make your solar suitcase – 2021 updated version

Introduction: The solar suitcase is one of the four options for a 'message carrier' of the 'scouts go solar' project. It is meant to have a double function: as a mobile source of light and electricity for scout camps in normal times and as emergency unit to provide light and communication in case of disaster. There should be space enough inside the suitcase to transport other items than those related to electricity, i.e. use it as a suitcase...

The suitcase can serve for light (LED lamps), to charge phones or other small electronic devices (via the USB connector), for music and radio (12V or USB), for computing (use a small laptop on the inverter or via a special car adapter for laptops) etc. DO NOT connect any 'heavy load' as a cooler box, fridge, large computer, coffee machine etc.! If you need a fan, connect a 12V fan from an old desktop computer.

**SAVETY FIRST:** Do not build a 12V solar system unless there is an experienced person knowing about electricity and solar power in the group! 12V DC electricity is considered not lethal, but a battery can deliver dangerously high amounts of energy in short time and can be very harmful. Much care must be taken not to create a spark which could set something on fire.

THIS MANUAL CANNOT REPLACE A FULL TEXTBOOK. If you want to learn more about how to install an independent solar home system, I suggest the following book: "A practical guide to solar photovoltaic systems for technicians", Jean-Paul Louineau, ISBN 978 1 85339 659 5.

## 1. Materials list

You need the following materials to build your solar suitcase. Some of them you can find in a car electricity shop, in a hardware store, in a specialised solar shop or in the internet (ebay.com, etc.).

Part	Specification	Comment
Suitcase	Hard shell with wheels, not too small	Option: in industrialized countries easy to find in a 2 <sup>nd</sup> hand shop

Battery	12V sealed ('maintenance free') lead acid battery, 17 – 22 Ah	A larger battery would be useful, but then the suitcase will be <b>very</b> heavy.  Have all elements ready to attach the wires solidly to the battery (nuts and washers, etc.).
Solar panel	'12V solar panel' (i.e. working voltage about 17V), 20W - 40W	Check carefully the size of the panel. It must fit into the suitcase or into its lid (see point 2)
Charge controller	12V charge controller, 6A or more	It must have 6 screw connectors.
Inverter	12V to 115V or 230V model according to the power grid in your country, 100W to 300W	Try to find a small inverter (not more than 300W). Large inverters 'invite' to use too much electricity.  The inverter is optional, you can build a suitcase without it and just use DC current.  If the inverter does not have an interrupter to shut it OFF, you need to buy another interrupter.
3 or 4 LED lamps	12V DC LED lamps and sockets (unless the lamp comes with its cable attached), 3 to 7W each	They can be 12V DC 'light bulbs' with E27 or E17 screw connection or 12V DC 'halogen spot type' or modern LED lamps for cars.
3 or 4 light switches	(Rated at least 1A).	There is no difference between AC and DC switches. You can buy any model.
Wires	see below	
Fuse and fuse holder	DC fuse rated 10A (or 5A)	Best buy a 'in-line' holder for car fuses if you can find that. Car fuses are handy as the replacement fuse can be found everywhere.
Female car cigarette lighter (multi-)socket		Try to find a multi socket in a car accessories shop
12V USB adapter	USB adapter for cigarette lighter socket	You need a special 1A model to charge an iphone.
Attachment	For instance: screws, plywood plate,	

material	cable ties, metal wire, insulating scotch tape...	
Optional: a radio	It must run either on 12V or on a USB connection (5V)	For emergency situations.

Wire size and length		
From .. to	Length	Size (at least <sup>1</sup> ) for copper wires <sup>2</sup>
Solar panel to charge controller	2m (it might come with your solar panel)	2,5 mm <sup>2</sup> or AWG 14
Battery to charge controller	0,5m	4 mm <sup>2</sup> or AWG 12
Charge controller to lamps	3 – 5m per lamp	0,75 mm <sup>2</sup> or AWG 18
Charge controller to inverter and to car cigarette lighter plug	0,5m	4 mm <sup>2</sup> or AWG 12

**Tools:** Different size and type of screw drivers, wire cutter, wire stripper if available, knife or cutter, pliers, power drill, saw, multimeter, soldering iron and tin/lead.

## 2. Work on the suitcase and the optional a base plate

All elements must be solidly fixed to the suitcase. It is helpful to prepare a plywood base plate of about 40cm x 40cm (check the inner size of your suitcase) and attach battery, charge controller, switches etc. to the base plate first and later on screw the plate to the suitcase.

It is up to you if some elements like the power plugs or even the light switches should be accessible even if the suitcase is closed. In that case you must prepare openings (drill, jigsaw, handsaw, ..) and attach the female connectors etc. directly to the suitcase. You might even foresee a window to check the state of the charge controller.

You have two options for the solar panel:

- You can integrate the solar panel into the lid of the suitcase (cutting a large opening) or screw it solidly to the lid. This looks nice, but your panel might break during transport in a bus or air plane.

<sup>1</sup> If you buy wires in American size (AWG) be aware that the **lower** the number, the **better** is the wire. i.e. AWG12 has a higher diameter than AWG 14!

<sup>2</sup> Choose a slightly higher diameter for aluminium or steel wires.

- You can leave the solar panel free or prepare a way to temporarily fix it to the lid (with magnets or velcro tape for instance). For transport, the solar panel travels **inside** the suitcase.



*This suitcase has one large opening to integrate the solar panel into the lid and other openings for the 12V DC and 230V AC female connectors.*

You should also foresee a protected place in the suitcase to store the lamps and their cables as well as other small devices like phone chargers, etc.

### 3. Placement of the elements and electrical connection

We are preparing a small 'classical' 12V independent solar home system. Find a place for all elements either on the base plate or inside the suitcase. Try to place the battery near the bottom side of the suitcase towards the wheels (it is the heaviest element and should be near the wheels for easy transport).



<i>All elements attached to the base plate which will be screwed into the suitcase.</i>	<i>A suitcase where battery, charge controller, etc. are all separately attached to the suitcase. (The connection to the battery is only temporary.)</i>
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It's a good idea to leave some space on the plate for a transparent folder where you keep all manuals and a spare fuse easily available.

As soon as all elements have found their place, cut wires to the corresponding length, not forgetting to use the thickest one from the charge controller to the battery, to the inverter and to the female connectors. The wires to each lamp can be thinner.

While working, always make sure that open wire endings cannot touch each other. If at some stage you have 'hot'<sup>3</sup> stripped wire endings (electricity can come both from the battery and from the solar panel!), cover them with scotch tape until you use them.

If available, use red wire for plus connections, black for minus. If you have other couples of colour, use the lighter colour for plus and the darker for minus. 'Strip' the end of the wires using a wire stripper, a knife, scissors, etc.

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<sup>3</sup> i.e. under voltage.

The following schema shows the electrical connection:



Step-by-step connecting instructions:

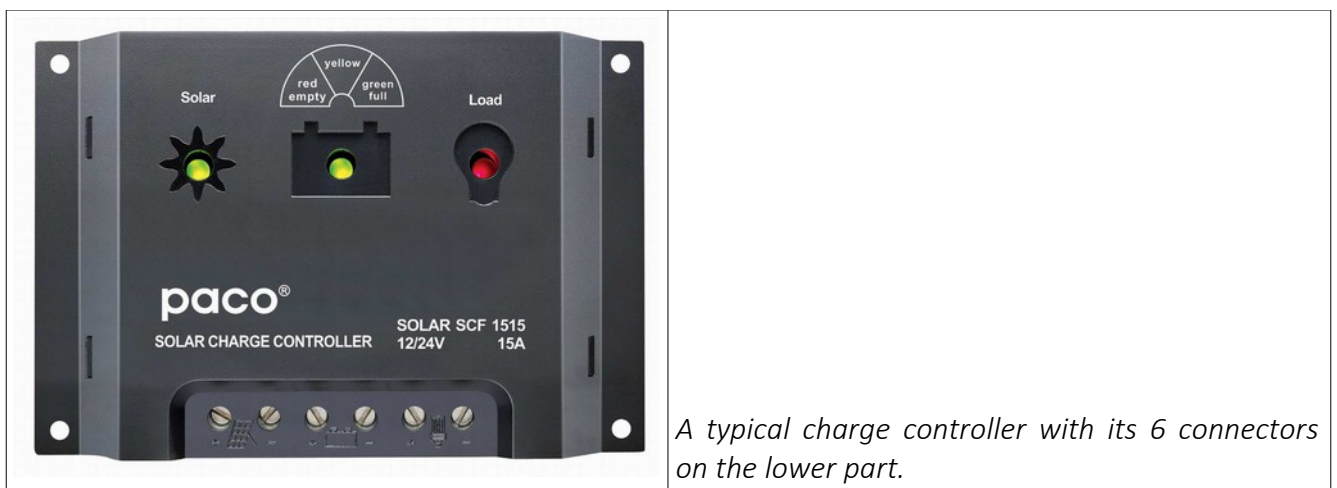
- THE VERY FIRST THING is to attach the fuse holder into the wire coming from the battery's plus pole. DO NOT INSERT the fuse yet. Attach the plus and minus wire solidly to the battery (using nuts and washers or special connectors). Do not use 'alligator clip style connectors'!
- Attach the wires coming from the battery to the charge controller at the screw connectors with the 'battery' symbol. (Connect battery *plus* to the *plus* symbol of the charge controller).
- Keep the solar panel face down on the table to not produce electricity yet. Attach the solar panel to the screw connectors at the charge controller with the 'solar panel' symbol.
- Insert the fuse into the fuse holder at the plus pole of the battery. Check if the charge controller indicates the charge of battery<sup>4</sup>.
- Put the solar panel into the sun or strong light and check if the 'charge' LED<sup>5</sup> lights.
- If anything feels wrong, go to section 5, 'tips to find errors'.
- Disconnect the solar panel or put it face down on the table.
- Unplug the main fuse again.

4 Some charge controllers only light a LED if the voltage is too low, but nothing if it is OK. Check the manual of your model.

5 If your charge controller has such a LED...



- Prepare wires from the charge controller to the inverter, to the lamps (passing through an interrupter) and to the female cigarette lighter connectors. All these wires must fit into the connectors (plus and minus) at the charge controller with the 'lamp' symbol.
- It is very probable that they do not fit all together into the connector, so you might have to solder connect all pluses and all minuses separately and prepare one plus and one minus wire which connect the connection point to the charge controller. You might use screw terminal wire connectors instead of soldering if you find them.
- If the inverter does not have its own interrupter to shut it OFF, you need to insert another interrupter into its plus connection from the charge controller. The inverter should only be switched ON if you really need it; it loses too much electricity in its stand-by position.
- If all wires are connected, review all connections again. Isn't there any inversion of plus and minus?
- Replace the main fuse and reconnect the solar panel or lift it from the table and put it into the sun.
- Check all lamps and the inverter if they function well. In case of problems, refer to section 5.
- Secure the connections of the battery with insulating scotch tape so that no blank metal is visible any more. Otherwise any metal object like a screwdriver in your suitcase can induce a spark and set the suitcase on fire!
- Prepare a manual for your suitcase and keep it with the corresponding manuals of each device in a transparent folder which you attach inside the suitcase.
- Try out your suitcase in open and closed position. Is it comfortable to use? Is there a way for the cables of the panel and the lamps to 'leave' the closed suitcase without being pinched? Cut more openings if needed.



#### 4. Storage and use of the solar suitcase

While storing the suitcase, keep everything connected with the fuse in its holder. The solar panel should be at a well lit place near the window (Best: in direct sunlight until the battery is full, then in strong indirect sunlight to keep it charged). In that case, it is always ready to use when you need it! The battery will not overload, it is protected by the charge controller. If panel and suitcase are separated, keep the panel in the sun and the suitcase in the shade (the hotter the battery gets, the

lower is its lifetime). Avoid storing it in a freezing place either. Keep the suitcase slightly open to vent it and keep everything in a well vented room<sup>6</sup>.

The amount of available electricity is very limited. Reduce your consumption to the minimum. Turn lamps and any other electrical device off as soon as you do not need them. Do use the inverter only sparsely and avoid any device that uses more than 30W or use it only for a very short time. Turn off the inverter as soon as you don't need it any more. Use a small modern laptop only.

Always keep the solar panel in the sun at days of use of the suitcase. In a typical configuration of 30W panel and 20 Ah battery you get roughly the following values if your panel stays in the sun all day:

- 30 Wh production in winter day in Europe
- up to 200 Wh production in a sunny summer day in Europe
- 120 – 150 Wh production in an average day in the tropics
- Your battery can store about **200** - 300 **Wh**, i.e. it charges completely in about 2 – 3 days in the tropics.

**Per hour and per item**, your appliances use roughly:

- LED lamp 3 to 7 Wh
- phone charger 5 Wh
- radio 5 Wh
- modern small laptop 15 – 20 Wh (more while recharging its own battery)
- small music amplifying loudspeakers 5 Wh
- any device with USB connector 5 Wh (example: handheld video projector with double USB connector = 10 Wh)
- Loss of inverter 5 Wh

Just add the Wh of all devices you use and divide your available 200 Wh of electricity by this number to know the running time of your suitcase from a completely full battery to a completely empty battery. Example: Laptop, loss of inverter, 2 lamps, radio, 1 phone charging = 40Wh per hour → 200 Wh = 5 hours of use.

## 5. Tips to find errors

- If in doubt about which 'hot' wire (from the panel, from the battery, etc.) is plus and which is minus, check it with your multimeter: Use it in its 'voltage' position. Connect by chance one of the wires with the red tip of your multimeter, the other one with the black tip. If the multimeter indicates a positive reading, you have found positive = red and negative = black. If your reading is negative (" -12,3V") invert your tips and you'll have found the answer.
- If your lamps (etc.) do not work, check the following:
  - Is the battery empty and the charge controller switched your devices off?

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<sup>6</sup> In the unlikely case of a ill-functioning charge controller the battery might overload and produce hydrogen.



- Is the fuse of the charge controller or your main fuse near the battery broken or not in its place?
- Is a connection loose?
- Is your device (lamp, etc.) defective?
- Did you invert positive and negative?
- (Be aware: a DC light bulb has a plus and a minus connection! Normally the tip of the socket should be on plus, the side with the thread on minus.)
- (Most 'tip' connectors similar to audio jacks have plus on the tip and minus on the side.)
- To check the state of charge of your battery manually, measure its voltage with a multimeter. Less than 11,5 to 11,8V = 'empty'<sup>7</sup>, more than 13,5V = 'completely full', 12V-13V = partly full.
- To check 'what your charge controller is doing': Measure the voltage of the panel (by touching the screw heads of the corresponding connectors with the tips of your multimeter). Do the same for the battery voltage. If the two voltages are similar (less than 1V difference) → the panel is charging the battery. If the panel has a much higher voltage than the battery → they are disconnected. The reason for the latter might be:
  - The battery is completely full, the charge controller disconnected the panel.
  - A fuse inside the charge controller is broken.
  - The charge controller has decided that your battery is 'dead' (for instance if its voltage is lower than 9V, etc.) and refuses to charge it.
  - A connection inside the charge controller is destroyed.
  - The charge controller has a bad day... in that case disconnect all wires, wait 10 minutes and reconnect them. It might change its mind...
- The right order to connect a charge controller is: 1. battery 2. panel 3. appliances. Disconnect in the reverse order.



*Black parts inside the charge controller → something did 'burn'*

## 6. Pictures

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<sup>7</sup> In principle, the battery is not empty. But a battery should not be run down completely to give it a long lifetime. Therefore, the charge controller stops your appliances at about this range of voltage.



*Suitcase ready to use!*



*Easy transport.*



*Scouts setting up their suitcase.*



*Suitcase in progress in Brazil.*



*Suitcase serving as phone charging station.*