DIY Solar: Phone Chargers

A step by step guide

October 2017 Version 1.2

Contents

Introduction

The Demand Energy Equality project

Demand Energy Equality (DEE) is a UK based community energy project that seeks to empower and power low-income households. We are a group working for systemic change in the way energy is produced, distributed, controlled, delivered and used. These aims are within the context of rising energy inequality (in the UK, at least), rising fuel bills, climate change and the increasing cost of fossil fuel extraction. See our website to find out more about the project.

Through teaching people DIY solar PV skills we also aim to develop their relationship with energy, and enable them to understand it better: where it comes from, how it is used and how it relates to their demand and needs. Ultimately we aim for this to change behaviour, leading to better use of energy and overall reduced demand. Reduced energy use is an unavoidable fact of the relatively near future – far better to prepare now than be surprised later on.

Using this guide

This written guide is for anyone interested in building their own solar phone charger, or learning more about the concepts involved. It assumes no prior knowledge of any kind relevant to building a fully functioning panel. The guide is designed to be used alongside other DIY guides and resources provided by DEE.

The guide starts with a summary of the tools and materials used. This is followed by a description of each of the steps in the process of building a 12W solar phone charger with a laptop carry case. At the end of the guide is an appendix with supplemental detailed information about the tools and materials needed.

For other types of DIY solar panel that can be made, instructables.com is a good place to start looking for alternative designs. DEE (and other organisations) run workshops based on other panel designs – you will find information about the workshops that we are currently running on the DEE website (www.demandenergyequality.org).

You will find the latest version of this guide available to download from the DEE website, as and when this guide is updated, alongside our other guides and resources.

We encourage you to share the skills you learn with others through your own workshops, particularly if you are able to target and work with low-income communities. Please contact us for any support you feel you may need if you plan to do this.

The design

The basic components of the design, and that which makes it economically and practically feasible are the “broken” solar cells. These are cells produced in the industrial manufacture process (mainly in China) that are broken either in transit, or during assembly on arrival. Because they are of no commercial use, these cells can be bought relatively cheaply. Using simple techniques and accessible reused materials DIY solar PV panels become a possibility!

The solar charger this guide describes is a self-contained design, and can be connected directly to USB devices with no additional equipment needed. The solar panel it uses has a 12V output, so can potentially be used to power 12V devices directly with some minor modifications.

This particular guide reflects the latest iteration in the construction of DIY photovoltaic panels as practiced by DEE, but it is likely that it may evolve and expand over time. Because we occasionally introduce new materials and construction methods, the guide may not always be in line with the other DIY resources published by DEE, and may not exactly reflect the content of current workshops. Contact DEE if you need an update on any recent changes.

Disclaimer

This guide is for general guidance only and whilst every effort is made to ensure that the information it contains is correct, it should not be relied upon as accurate. The information / advice contained within this guide is intended for use within the UK only and by persons of no less than 18 years of age. Use this guide at your own risk.

DEE will not accept any liability for any loss, damage, injury or negligence direct or indirect from use of the information / advice contained within this guide.

Before starting

Staying safe

You should be aware of and familiarise yourself with any potential hazards involved in making a solar charger. Ensure you are working in a suitable environment - work indoors on a stable, clear surface, and make sure any trip hazards from trailing cables are cleared away. Have a source of water nearby for the emergency treatment of burns.

Recognise that liquid flux is an irritant so avoid direct contact with your hands when using it and rinse off your hands asap once you're done. If it gets in your eyes or mouth wash it out immediately.

The main sources of danger are the soldering irons (DEE uses 80W irons that get significantly hotter than standard soldering irons).

- handle soldering irons with care, making sure to never touch the hot metal parts.
- do not grab an iron if it is dropped on the floor.
- though the soldering irons have heat resistant cables it is possible to burn through them which would cause an electrical hazard.
- Always place the soldering iron back in the stand when not in use.
- put burns under running cold water for several minutes.

The metal nozzles of heat guns can get very hot, especially on the high setting or with sustained use. They present similar safety issues as soldering irons. While using them, be careful not to point them towards people or anything that would be damaged by heat, and when finished with them always place the heat gun with the nozzle resting on a non-flammable surface (e.g. the tile on a soldering station).

Tools and materials

To complete a solar charger you will need:

- a 40W-80W soldering iron with a flat tip in a soldering stand with a damp sponge
- a flat heatproof surface, e.g. a ceramic tile
- a flux pen – if these are refillable type they will need to be filled with liquid flux
- small wire cutters
- large household scissors
- small nose pliers
- a 2000W heat gun with high and low settings
- a flat head screwdriver
- a utility (Stanley) knife
- a multimeter set to measure DC voltage
- extra solder
- extra EVA
- a hot glue gun (optional)
- a grow lamp (optional, for indoor testing)
- heat-proof gloves (optional)

- a sheet of UV resistant polycarbonate, 330mm x 265mm
- 0.5 Watt PV cells, approx 80mm x 40mm (30 cells should be enough, allowing for breakages)
- approx 3m of 2mm tabbing wire, cut to lengths double the width of a cell
- two sheets of EVA cut slightly larger than the polycarbonate sheet
- a foam carry case for a 15.6" laptop
- two 3A terminal blocks
- two short lengths of flex wire (optional)
- A DC 12v-5v USB voltage converter

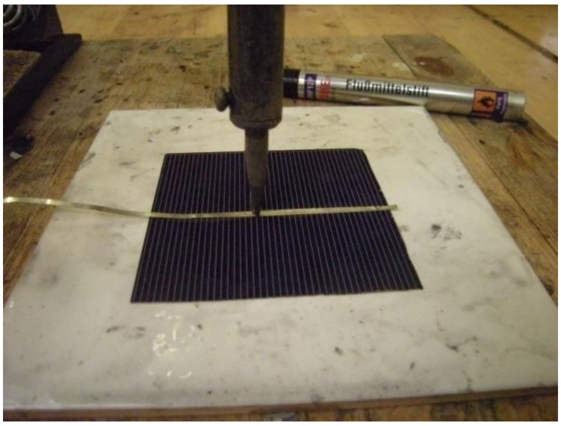
See the Appendix for more info on how to source materials for a DIY solar panel.

How to Solder

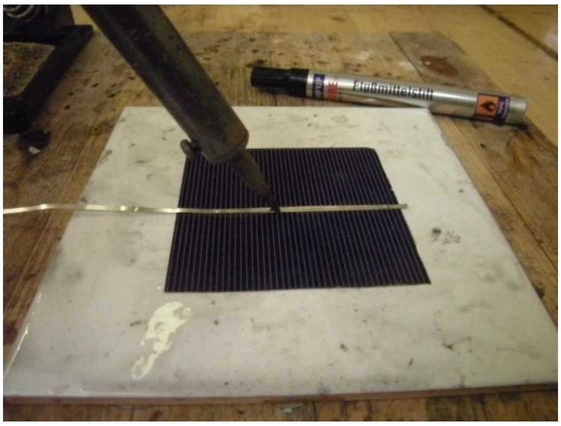
This is the key skill that is needed to join solar cells together. .

Key points for good soldering technique:

- Make sure the tabbing wire is flat and straight – kinks can be smoothed out by drawing the wire between your finger nails.
- Keep surfaces to be joined as free from acidic skin oils as possible by not handling unnecessarily
- Remove dirt and oxidation by applying flux
- Ensure that the surfaces to be joined are heated to a sufficient temperature to allow the solder to flow (which is aided by the flux). This can be achieved by holding the soldering iron on a point to allow heat to build up until you can see the solder melting before wiping the tip slowly along the tabbing wire
- If using a chisel tip, hold the soldering iron vertically so that the flat tip has maximum contact with the tabbing wire (see photo below).
- Slowly draw the soldering iron along the tabbing wire (learning the right speed is a trial and error process). It should be possible to see the solder go shiny as it melts and then forms a wave as the soldering iron is drawn along the tabbing wire.
- Keep the soldering iron tip clean by wiping it on the wet sponge (or rubbing on the emery cloth).



Good technique



Not so good technique

Common soldering errors:

- Forgetting to apply flux
- Not holding the soldering iron long enough on one spot for the tabbing wire and cell below to heat up
- Not holding the soldering iron vertically
- Wiping the soldering iron repeatedly along the tabbing wire (this can remove the solder) – it is better to just do one slow stroke.
- Not cleaning the tip of the soldering iron regularly enough.
- Breaking cells by mishandling them or applying too much force with the soldering iron.
- Tabbing wire running over the edge of the cell

Building the panel

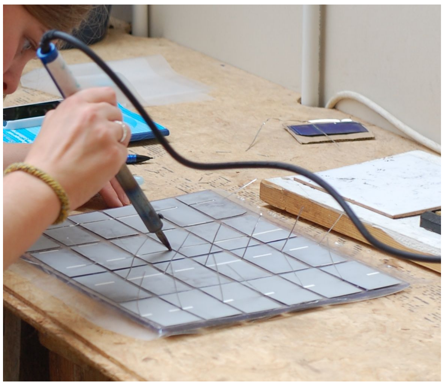
Summary of the construction process

Step 1: Solder tabbing wire to the top of cells

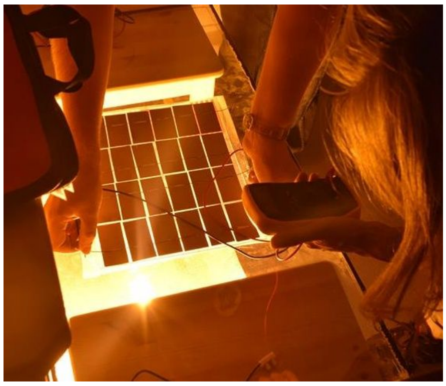
Step 2: Lay EVA on polycarbonate sheet and arrange cells face down

Step 3: Apply enough heat to EVA to stick cells down

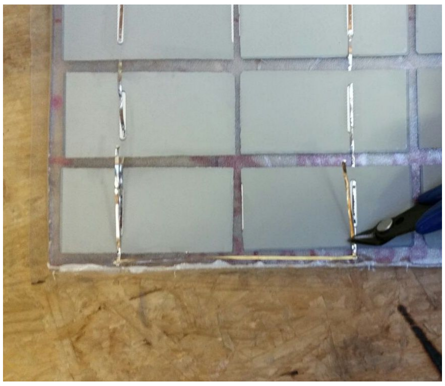
Step 4a: Tim tabbing wire tails



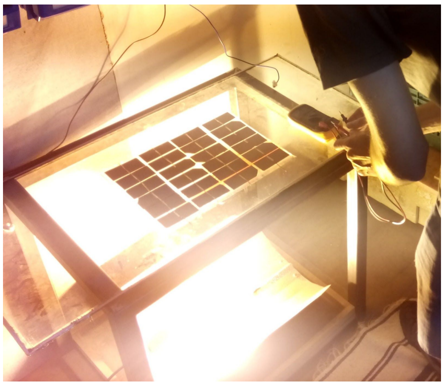
Step 4b: Solder tabbing wire tails to the backs of cells



Step 4c: Test the voltage on each row and correct errors



Step 5a: Connect each row of cells together (cross-tabbing)



Step 5b: Test voltage and current of whole panel

Step 6: Encapsulate cells with second sheet of EVA

Step 7: Bind solar panel to laptop carry case

Step 8: Attach USB voltage converter

Completed solar charger

Step 1: Soldering tabbing wire to the top of the cells

You will need to become confident at soldering and build up a stock of cells with tabbing wire on one side. Half of the tabbing wire should be soldered to the front of the cell, with the other half forming a 'tail' running off the cell. You will need 24 of these to create a 12v panel.

Additional spare cells can be soldered to replace possible breakages, to save time later.

Tips

- avoid soldering too close to the edge of the cell - loose solder on the edge of a cell can cause it to short circuit.
- Putting too much pressure on the cells can cause them to crack.
- If cell contacts are off-centre, make sure that the tabbing wire on all cells lines up when it comes to connecting them in columns.

Step 2: Preparing the polycarbonate and placing the cells

Place one sheet of EVA on the polycarbonate (remove any protective film first). Arrange the tabbed cells face down on the panel in 4 columns of 6 cells, with the tails bent so that they point slightly up. There should be a clearly visible gap between each cell (~2mm) and a gap at the top and bottom of each column (~5-10mm). It can be useful to have a grid drawn out on a sheet of paper to aid the correct arrangement of the cells. The direction of cells in each column should alternate, so that they can be connected in series to create a continuous string (or "snake").

You may need to cut/trim sheets of EVA to use – they should be slightly larger than the polycarbonate sheets, with a margin of around 5mm on each edge.

The tabbing wire tails from each cell will need to line up with the conductive contacts on the back of the next cell – some cells have their conductive strips off-set to one side, so make sure all the cells in a row all have their tails and conductive contacts in alignment.

Tips

- avoid shorting the circuit by not having cells touching each other.
- Check that columns of cells are running in opposite directions – failure to do so can waste a lot of time and materials.
- Check that contact points for soldering tabbing wire tails are all lined up properly.
- Check each cell for cracks or poor soldering before placing it.

Step 3: Heating the EVA to stick the cells

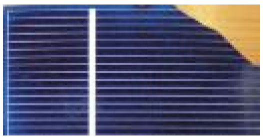
This step involves sticking cells to the sheet of polycarbonate using heated EVA. Use the low setting on your heat gun to apply heat to the cells and the EVA. As they heat the EVA should turn transparent and become tacky. If the EVA is creased or folded, it may be necessary to carefully apply a little pressure to the edges of each cell as they heat up to make sure they are stuck flat on the polycarbonate. Once the heat is removed, the EVA will cool and cells will remain bonded. It's not necessary to apply a lot of heat at this stage – just enough to fix the cells in place to allow the tabbing wire tails to be soldered. Give the tail of each cell a slight wiggle to check it is fixed in place.

Tips

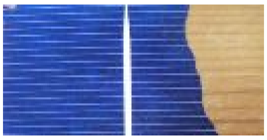
- If cells crack after they've been stuck down, you will need to use the heat gun to loosen the EVA bond before you can remove the broken cell. If the cell is removed while the EVA is cool, it will fragment into lots of tiny pieces which are time-consuming to remove.
- The easiest way to remove a broken cell is to use a thin blade to carefully lift the cell off once the EVA is hot.
- Once a cell has been removed, you may need to use an extra patch of EVA to fill any holes – it's useful to have some spare EVA offcuts to hand for this purpose.

- Overheating can cause cells to be overly stuck down and then difficult to remove later

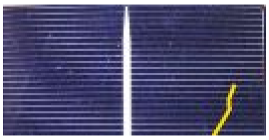
A note on cracks
Everyone who builds solar panels breaks cells at some point and this is a guide to whether to replace cells that get cracked. Early in the construction process before cells are stuck down and connected together you can afford to be fairly conservative and to discard most cells that get cracked. But once they are connected together it is a time consuming job to strip off the tabbing wire and to remove the cell. This a quick visual guide to help you decide whether to replace a cracked cell.



Less than 10% broken off – **OK**

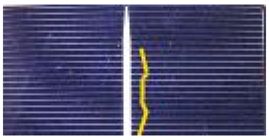


More than 10% broken off - **REPLACE**

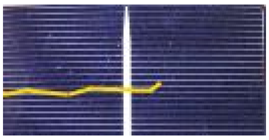


Minor crack away from conductor strip – **OK**

Minor horizontal crack - **OK**



Long crack parallel to conductor strip – if the crack propagates half the cell would be lost - **REPLACE**



Long crack across conductor strip – this is **OK** providing there is tabbing wire across the crack on both sides (it effectively becomes a parallel connection) but check for shorting

Step 4: Tabbing the other side of the cells

Once the tabbed cells are stuck to the polycarbonate the tails can be soldered onto the backs of adjacent cells to connect them in series. You should now trim any excess tabbing wire on each tail using small wire cutters - any wire that extends beyond the contact on the back of the adjacent cell isn't needed. Solder each tabbing wire tail to the back of the next cell, using a similar technique as on the front of the cell. Since the tabbing wire tails will try to spring up when being soldered, you can use the tip of a pair of scissors or some other heat-proof implement to the hold them in place while they are being soldered. Leave the tails coming off the end of each row, and cells at the other end of each row will need an extra strip of tabbing wire soldered to their backs.

Tips

- Avoid shorting the circuit by not soldering too close to the edge of the cell, and avoid putting too much pressure on the cells as they are likely to crack.
- If cells crack at this stage, they will need to be de-soldered from adjacent cells before they can be removed from the EVA as above.
- Check tabbing wire tails are firmly soldered to the back of cells by using a fingernail to try to lift them. Any loose connections that are not spotted at this stage are likely to fail when the cells are encapsulated.
- Using a multimeter and a light source to test each row of cells before moving on to the next stage can allow you to spot and fix problems early.
- GO SLOWLY as breakages now are very hard to fix

Testing the panel

Testing is best done in bright sunshine outside but in some circumstances it can be carried out over a high wattage grow lamp placed under a glass-topped table.

Use a multimeter set to measure DC voltage, on the 20V setting. With the solar panel pointing towards the light source, touch the probes on the multimeter to the tabbing wire coming off each end of a column to measure the voltage it is generating. Each column of 6 cells should measure around 3 volts. If you are measuring less than that, it may be because there is not enough light for testing, or that one or more cells is short circuited. Touch the probes to the tabbing wire running either side of a cell to measure the voltage of each individual cell - if any of those is reading 0 volts, it is short circuited. If the entire column is reading 0 volts, there is a bad connection - go over each soldered contact on each cell to make sure the connections are good, and test again.

You can also use the multimeter to check the polarity of each column - touching the positive probe to the positive side of the column and the negative probe to the negative side of the column will give a positive result - reversing the probes will give a negative result.

Step 5: Cross tabbing

Use a piece of tabbing wire to connect each row. To keep the cross tabbing secure, but also allow access to it in the event of a problem, the cross-tabbing should run between columns either just inside or just outside of the polycarbonate.

Trim the tabbing wire tails on the end of the columns to be connected, then create a small hook into which the tabbing wire for the cross-tabbing can be inserted. Crimp the hook together firmly around the cross-tabbing, then solder the tabbing wires together at the crimped joint.

Once the columns have been connected, you should have a continuous chain of cells, with two free lengths of tabbing wire remaining at each end. These are the terminal wires, and should be left extending out from the polycarbonate sheet. One is the positive terminal, and the other is the negative.

Optional - you can also solder short (~5cm) lengths of flex wire to the positive and negative terminals of the panel.

Tips

- Make sure not to connect the tops and bottoms of two rows together to create a loop.
- Use the end of a pair of scissors under the cross tabbing joints when soldering to provide a firm base and avoid melting the polycarbonate.
- Make sure to test the output of the whole panel before moving on to the next stage (see Testing the panel above). You should get a reading of around 12 volts.

Step 6: Encapsulation

Use a second sheet of trimmed EVA, placed over the backs of the cells to encapsulate the panel. Encapsulation seals the cells from air and water intrusion, and prevents failure due to galvanic corrosion. Use the heat gun on a high setting to seal the cells and tabbing wires – it usually takes around 5 mins to get the EVA up to the right temperature, by which point it will look clear and glossy, and will be very sticky to touch. You should be prepared to move **immediately** on to Step 7 once this is completed.

Tips

- All cells should be totally encapsulated – make sure there are no edges sticking out.
- The application of heat at this stage may break poorly soldered connections as the metal expands – this can cause the panel to perform poorly, or even break it entirely. It's very important to ensure all soldered joints are good before this stage.
- When using the high heat setting, ensure that the heat gun is constantly moving to avoid creating a hot spot and warping the polycarbonate.
- The colder the environment you're working in, the longer it will take to heat up the EVA, so if you're working in a cold space, add more time for this step.

Step 7: Bonding the panel into the neoprene case

At this point, the panel can be bonded into the neoprene carry case. This step usually follows directly on from the previous step. Use the heat gun on a high setting until the EVA is very hot, then quickly place the panel face up into one side of the neoprene case with the terminal wires aligned at the hinge of the case, fold the other side of the case over it, and apply sustained even pressure to it from above. The goal is to allow the hot, semi-liquid EVA on the back of the panel to soak into the foam of the case before it cools. The hot EVA will take a few minutes to completely cool, so pressure will need to be applied until it has solidified enough to create a firm bond. You may find that the corners of the panel don't completely bind to the laptop case – you can reapply heat to the corners of the panel and bind them to the case separately, or use a hot glue gun to reinforce the corners.

Tips

- It takes quite a bit of patience to get an effective bond, the more time spent getting the EVA hot and then waiting for it to cool, the better. If the bond doesn't take first time, you can re-heat the EVA and try again.
- Make sure that you have everything laid out with enough room to lay the panel into the laptop case quickly, before it starts to cool down.
- It's best to arrange the panel with the terminal wires at the hinge of the case.

Step 8: Attach USB DC-DC voltage converter

When bonding the panel to the carry case, make sure that the two terminal wires remain clear and extend from the panel at the hinge of the case. Use a small terminal block on each wire coming from the panel to connect to a USB DC-DC voltage converter, which steps the 12V output of the panel down to 5V for charging USB devices. Apply hot glue to the terminal blocks to fix them next to the edge of the polycarbonate sheet at the hinge of the case. Connect the red wire on the converter to the positive terminal, and the black wire to the negative terminal. The positive terminal will be the tabbing wire running from the back of a cell, and the negative terminal will be running from the front of a cell. If you're not sure which is which, use a multimeter to check.

Tips

- Check that the red wire of the DC converter is connected to the positive terminal from the panel, and the black wire to the negative.
- Test the output of the panel by connecting a USB device to ensure that it charges.

Appendix: Sourcing materials (and possible alternatives)

Solar cells

DEE uses reclaimed 6” square cells that are cut down into regular 1/8th size pieces prior to the workshop. This removes damaged sections of the cells and makes it easier to construct a panel of modest size with a sufficient charging voltage.

DEE can supply cells already cut to these sizes on request, but you can cut your own using a rotary tool (Dremel) with a fine diamond-tipped cutting disk. It works best if built into a jig to make a mini-table saw, that allows you to cut stacks of a dozen cells at a time. The cutting process creates a lot of dust, debris and noise, so goggles, ear protectors, and a dust mask are essential. Contact us if you'd like more details on how to do this.

DEE has 1kW boxes of undamaged 6” x 6” Grade A cells for sale, and can cut them into halves, quarters or eighths as required. Contact us at info@dee.org.uk with any requests.

You can also find cells of various sizes and specifications being sold on eBay, which can be useful for smaller projects.

Polycarbonate

DEE uses 330mm x 265mm sheets of 4mm thick polycarbonate as the protective front of the solar panel. Polycarbonate is a tough, transparent plastic, that can be made UV resistant, meaning it can be left outside in sunlight for years without degrading. Polycarbonate usually comes in large sheets that will need to be cut to the size you want, but you can order polycarbonate pre-cut to a pre-determined size from a website such as https://www.cutplasticsheeting.co.uk/ if needed.

To cut polycarbonate, it's best to use a table saw, but a powerful jig saw or angle grinder with an appropriate blade or cutting disk will also do the job. As for any type of cutting work, goggles are essential.

When ordering polycarbonate, ensure that it's UV resistant. Other types of clear plastic such as acrylic or polystyrene are not UV resistant, meaning they will discolour if left in sunlight for too long, so are unsuitable for use in solar panels.

Glass can be used, but cutting it to the size for this design is difficult, and the EVA doesn't bind as firmly. For alternative designs for larger panels using reclaimed glass windows, see previous versions of DEE workshop guides.

EVA

Ethylene Vinyl Acetate (EVA) is used to encapsulate the cells to make them weatherproof and to bind the cells to the polycarbonate sheet and into the neoprene case. It's used for the same purpose in commercially made panels. EVA comes in rolls as a translucent film, but when heated it becomes clear and transparent.

DEE uses EVA sheets cut from 1m wide rolls, that we can cut to whatever size is needed for our panels.

It's not the sort of thing that is commonly available to buy, but it is possible to find smaller quantities of solar EVA film on eBay.

You can also use a specialist two-part epoxy such as Qsil to encapsulate solar cells, but it wouldn't be suitable for this design. For alternative designs for larger panels using Qsil as an encapsulant, see previous versions of DEE workshop guides.

Tabbing wire

Tabbing wire is thin, flat conductive wire that is coated in a layer of solder.

DEE has several long reels of 2mm tabbing wire that we use for our workshops, and we can supply it in various lengths.

Tabbing wire can be ordered on eBay and several other websites in large and small quantities.

Flux pens

Flux is used to clean the surface of the metallic contacts of solar cells and to help the molten solder flow into the microscopic crevices of the material being soldered onto to create a strong bond.

DEE uses liquid flux, applied with refillable watercolour brush pens.

For small solar panel soldering jobs, you can can also use a disposable flux pen. These are readily available on ebay.

DC converters

The DC voltage converter is used to step down the incoming voltage from the solar panel to a stable 5v voltage for a USB output.

The DC converters DEE use are enclosed buck converters that are reasonably cheap, efficient, sturdy and waterproof, but there are plenty of other options available that do a similar job. E.g. you could wire in a cigarette lighter socket and use a plug-in USB charger... this would allow you to use the solar panel to supply power to other 12V devices that use a cigarette lighter plug. You could also use an LM7805 voltage regulator, but it would need a decent heat sink to be used with a 12V supply for any length of time.

These are all readily available from eBay and other online shops.

USB Battery packs

DEE recommends using a USB battery pack with a solar charger make best use of it. Having a battery pack gives you the option to store energy that you can use to recharge your devices at night, instead of only using the solar power to charge devices directly when the sun is out.

In good sunlight, a 12W solar charger should be able to charge up a mobile phone or a 2000mAh battery pack in 2 hours. Bigger USB battery packs are available if you are looking for more storage.