Handmade Solar (PV)

Making solar power accessible to those who need it most.

DATUM FOUNDATION

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1.0 Overview

The past two years have seen vast growth in installed levels of photovoltaic (PV) solar in the UK. Micro-renewable technology including solar (PV) became financially attractive following the introduction of the *feed in tariff* in April 2010. As a result solar installations are now a common sight in the UK; a journey of just a few miles by car or train will generally bring into view at least one large roof top array.
Solar (PV) may not be considered by some to be as “environmentally sound” an energy source when compared with other renewables. Among the arguments are issues surrounding the chemicals used in production and the large amounts of energy it takes to produce every module. The energy put in can only “payback” following years of use; various studies estimate this to be around 3 years, but this often excludes the embodied energy of the whole system, including inverters.
This manual outlines an additional production method for solar PV that is significantly lower in embodied energy and can save even more energy in broader terms by reusing rejected materials from the mainstream solar industry. Materials that otherwise would be reprocessed at a cost of additional energy input.
The main focus of this manual does not however lie with embodied energy, but that the process outlined is able to be replicated in poorer counties; areas of the world with greater need for cheap forms of renewable energy but where solar (PV) is far too expensive. Affordable Solar (PV) in poorer locations around the world could significantly improve people’s lives. This could be in the form of simple applications such as a solar powered light to enable a child to carry on school work after sunset or enable a nurse, midwife or doctor to see in an emergency.

2.0 Introduction

Solar modules (commonly known as solar panels) are made up of solar <u>cells</u>, each producing approximately 0.5 Volts (V). If you look closely at a module you will see that they are made up of many individual cells, commonly 156 x 156mm. These cells are connected together in series to produce higher voltages. A series circuit means that the 0.5V value of each cell is added each time another is connected to make a string of cells. Grid connected arrays (modules connected together) can reach voltages in excess of 800V. This is still achieved by small 0.5V increases, cell by cell, then module by module.
Solar cells are made up of wafers of silicon that are extremely brittle until laminated together. During production cells can become chipped, cracked or broken and these cells are likely to be rejected by the manufacturer. These damaged cells are still usable; we're going to explain how.

- Power (*Watts*) = Voltage (*Volts*) x Current (*Amps*). Explained below (skip this section if you already understand this).

- <u>Voltage</u> - The <u>potential</u> of energy.

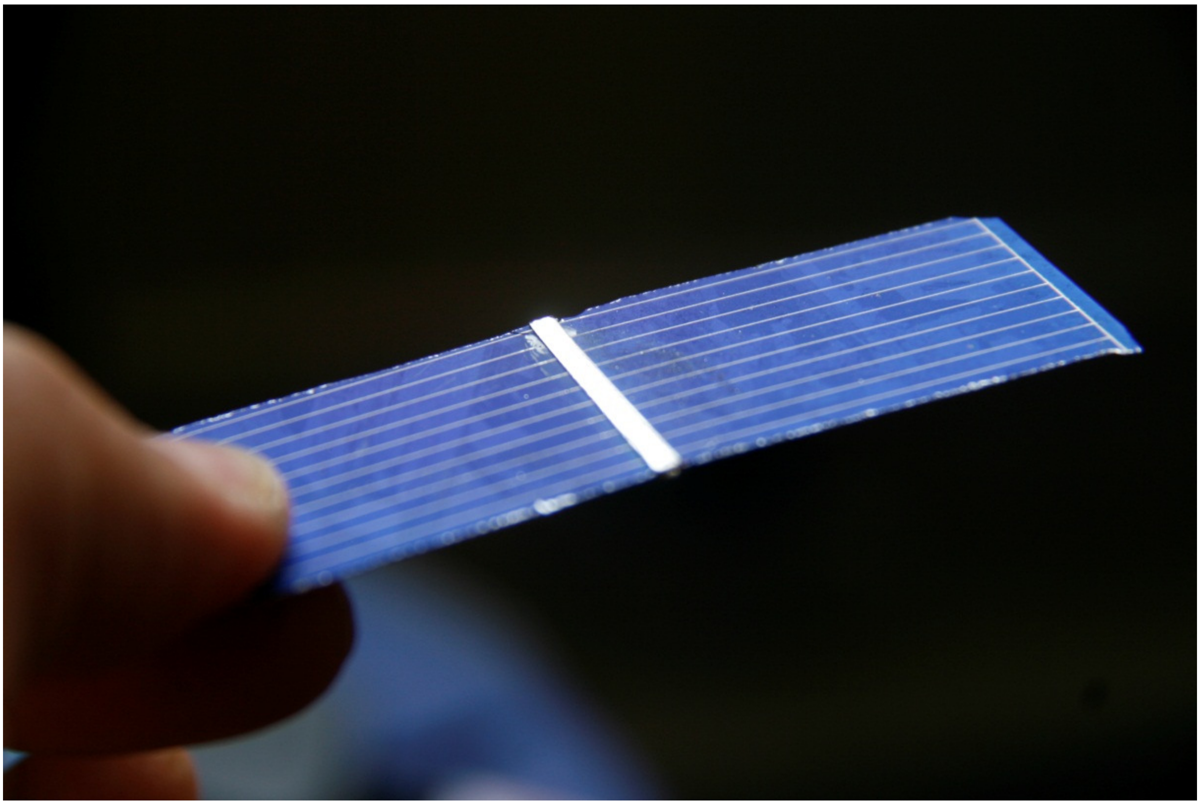
  - It’s a cold winter's evening; imagine the difference in temperature between a warm living room and the street outside. There is potential for energy (heat) to flow if the front door were opened, but the door remains closed, there is no flow of energy, only <u>potential</u>. This is like voltage - the measure of difference.

- <u>Current</u>.

- When opened your front door size will dictate how much energy will leave your warm room. Relating this to broken solar cells would be to imagine your door to be half the size. The temperatures inside and out are the same, so the potential remains the same (voltage). A door half the size would only have room for half the amount of heat loss to pass through the reduced gap. This is where the reduction in power comes from a reduction in flow (current) not voltage. It is still equally as chilly outside, you just have a smaller door!

The cell is still able to produce electrical energy no matter how chipped, cracked or broken it may be. A solar cell broken in half will still produce the same voltage as it did when it was whole. However the power it produces will be reduced by half, this is as a result of the reduction in the current produced by the cell. Hopefully the example above has helped you to understand how if you didn't already know.
(This manual is not intended to fully cover the theory. You do not have to understand the relationship between power, voltage and current to continue and make a panel.)

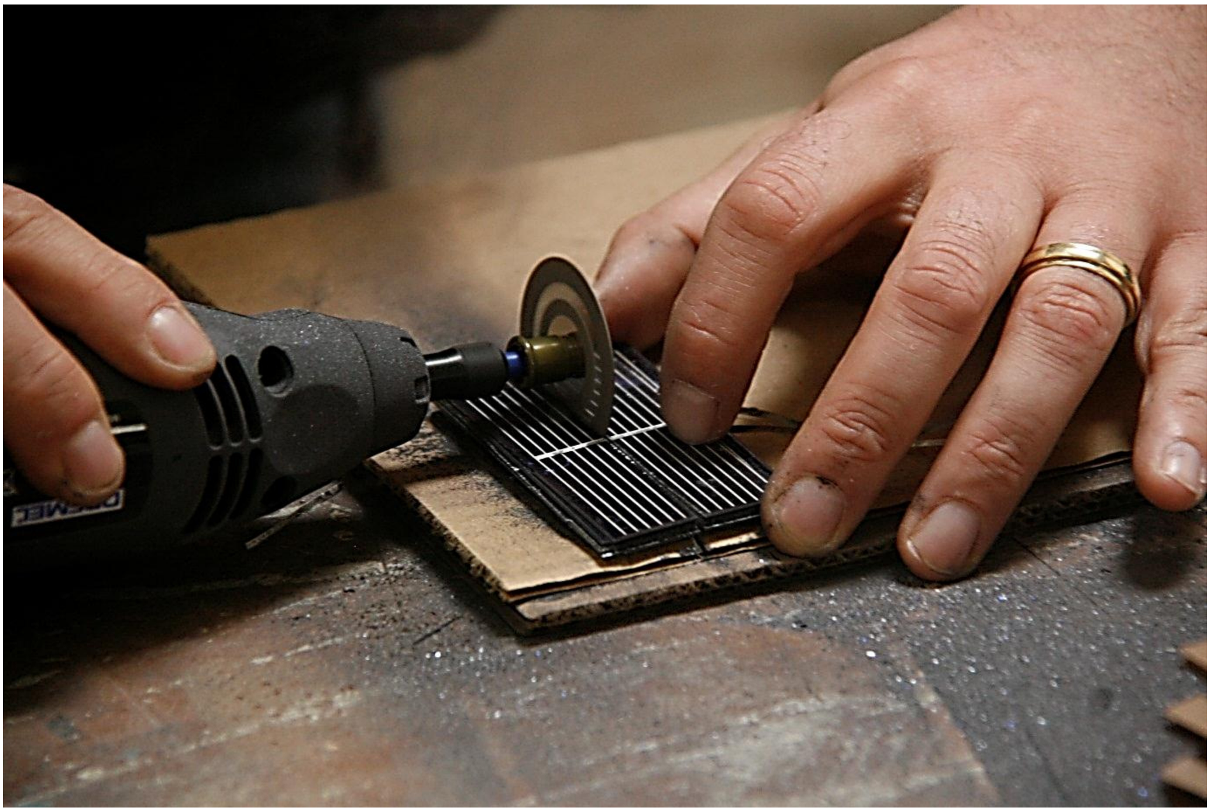
3.0 Handmade Solar PV



Soldering solar cells by hand is a fairly straight forward process and with some practice you will be able to achieve the same finish as a factory-produced module. The only real difference between factory and hand is laminating/sealing the module.
Laminating is the most important part of the whole process; this gives the panel its longevity. The handmade panel may be cheaper to produce - however the investment in time and effort could easily be negated by a poor seal resulting in the ingress of moisture. Ingress of moisture could lead to the eventual failure of the module. Factory modules are guaranteed for 20-25 years, handmade panels should be built with the same intention.
In this manual we have used a method for laminating devised by Dr. Richard Komp and his associates for use in developing countries. It uses a 2-part silicon elastomer to create a

layer of clear silicon either side of the cells. This also bonds the glass and backing sheet together. This process was created with the intention of using the minimum amount of the expensive silicon elastomer. This part of the process still accounts for over half the overall cost of a handmade module, even when used sparingly.
We are currently developing an alternative method using the same materials to laminate a panel as in the factory process; however the 2-part silicon remains better suited to small production numbers. The following is a guide to producing a handmade module.

3.1 Sort and cut cells



Sort your broken cells into similar shapes, then cut the pile (8-12 cells). This not only saves time but appears to lead to fewer breakages during cutting. Cells are best cut in a stack of approximately 10 in number.

i. Place your stack of approximately 10 cells on thick cardboard >10mm. The cardboard dampens vibration during cutting (you may also wish to do this on a wooden board to protect to the table you are cutting on).
ii. Grip the stack of cells, but note the position of your fingers and the direction cutting is required. Make sure the two do not coincide at any point along entire cut! Prepare your body position so you do not move your grip on the cells throughout the process. The intention is to only move your body and not your fingers as you cut through the stack in one movement.
iii. Using a rotary tool (Dremel) and a diamond cutting disc; sink the disc into the card approx. 4-5mm just in front of the stack of cells.
iv. Keeping the disc embedded in the cardboard move horizontally through the stack of cells. This is best done on a lower speed setting

and with slow movements. If there is any doubt over your finger position lift the disc up and switch off. To resume, switch back on, sink back into your last position and carry on with the cut.

This process should be carried out by a competent person. Suitable gloves should also be worn (not pictured).

3.2 Clean and test

A soft damp cloth can be used to lightly wipe dust free from the cell following the cutting process. Moisture should be seen to evaporate from the cell almost immediately. If this does not happen the cloth is too moist.
Using a multimeter measuring DC volts touch the black lead on the front of the cell and the red one on the reverse. If daylight is still able to hit the front of the cell then the multimeter should give a reading. If doing this test inside the value of the reading is not important, only the noticeable increase from 0V when the multimeter probes touch the cell.
If carrying out testing outside expect a reading upwards of 0.5 volts, though this may be lower in low light levels.

3.3 Cut tabs

It is best to cut all the tabbing ribbon you require before you start soldering. There should be enough for one ribbon to every cell though a few extra may be a good idea. Cut lengths of ribbon 1.75 times the length of the cells you are using.

3.4 Solder tabs

A soldering iron able to reach high temperatures is required to solder the ribbon to the solar cells. Most 'off-the-shelf' soldering irons available in DIY/hardware stores will not be suitable. The soldering iron should be at least 60 watts or able to be set at 450+℃. A bevelled soldering tip of about 3mm is also preferable.

i. Place your pre-cut ribbon and on a solid (impermeable) surface and apply flux to one side of the ribbon. Use the same area on the surface to apply flux and after a few applications the excess left behind will start give a light coating on the underside of the ribbon as well. Applying flux to the ribbon rather than the solar cell gives a better finish and ensures excess flux is not left on the solar cell.
ii. Clean the soldering tip and apply a small amount of silver solder. Place the end of the ribbon **2-3mm from the end** of the cell, starting at this point move the soldering tip slowly down the ribbon. Apply a light pressure so that the ribbon is in contact with the cell. Don't expect the ribbon to be fixed in place immediately your iron moves on, but as you move further from that point it will cool sufficiently and will then become so.
iii. Carry on down the ribbon after the end solar cell to the end. This allows the last part where contact is made between the cell and ribbon to cool before pressure is removed as you lift off with the soldering iron.
iv. A light pull on the tab will ensure it has been soldered correctly

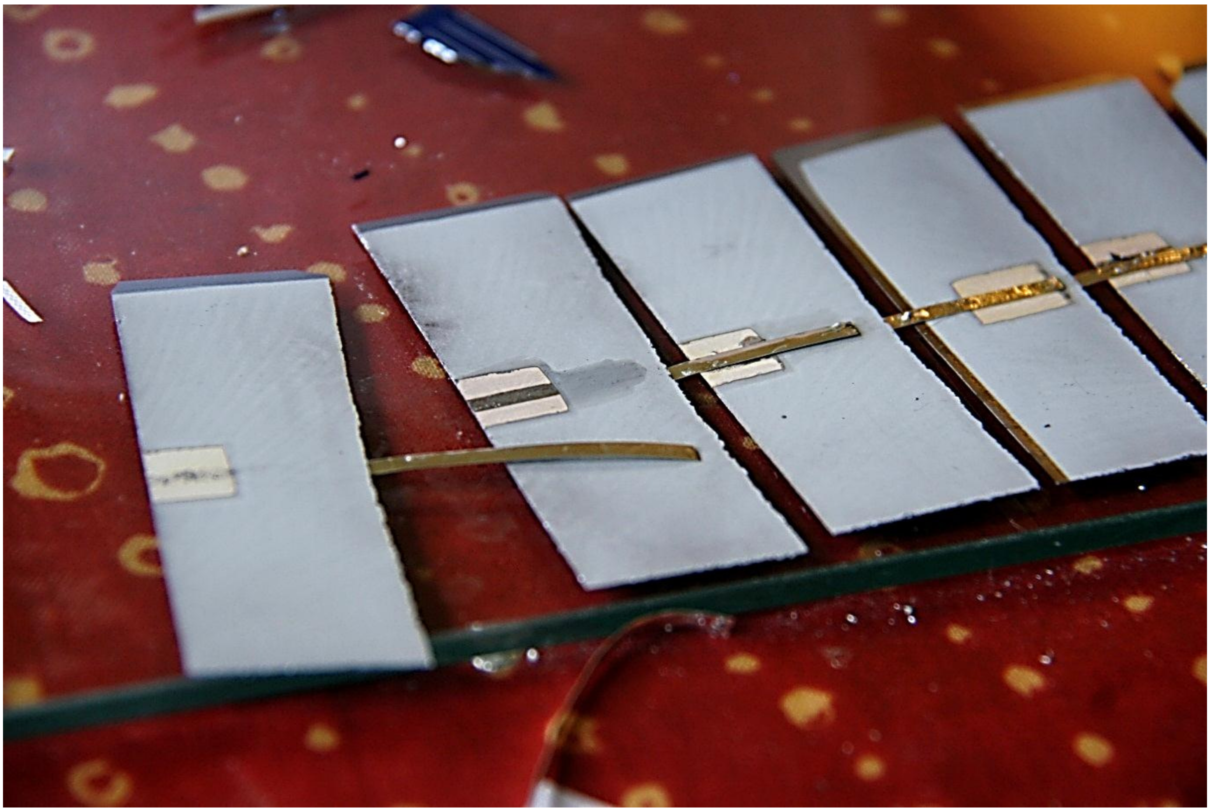
3.5 Short string and test

i. Decide on your cell layout. An example would be using an A4 sized piece of glass and cells measuring 50x50mm - then you can have five horizontal rows of three cells. Maybe cut out pieces of paper the same size as your cells and arrange them on your glass. Pack the cells tightly together with the minimum gap for your ability level, aim for 1 or 2mm gaps as you progress. The cells must not touch.

ii. Create a string of cells. To do this you must solder the 'tail' of one cell to the underside of another, obviously keeping the same orientation. Add flux to the underside silver contact of the cell. As your iron moves slowly over the ribbon and silver contact the solder will melt and create a connection. Keep moving at the same speed until you reach the end of the ribbon, even over the areas of cell where there is no silver contact.

iii. String cells by the lowest number. For example with our A4 panel we could produce three strings of five cells or five strings of three cells. Always try and use the lower number as they are easier to handle. Creating five strings of three cells is preferable for our example.

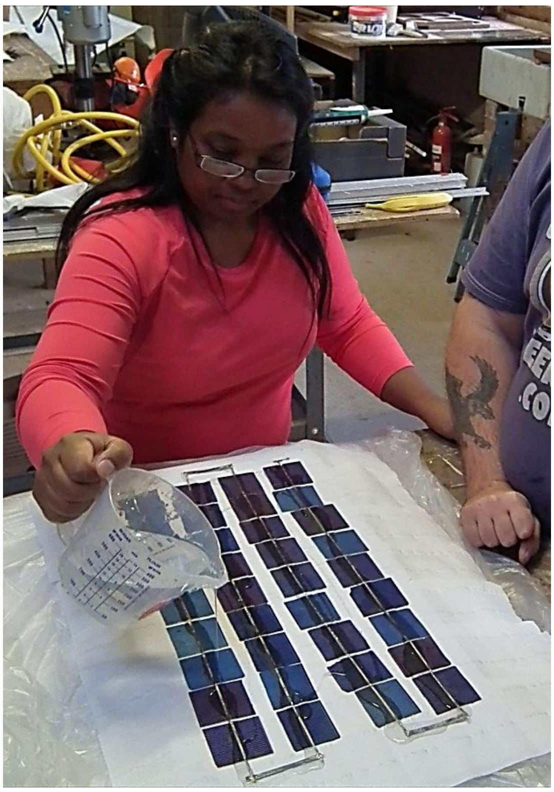
iv. Once you have completed a string test in a similar way as before, expect a higher reading in line with the number of cells in your string. Our strings of three should read >1.5V outside, but again if measuring inside look for the noticeable change from 0V, but now three times greater than before.



3.6 String panel and Encapsulate

The photo below shows four strings of nine cells. However, the recommended way to do this is nine strings of four cells. As can be seen, each string is connected to the next string by a link. If the tabbing ribbon leaves the top of the last cell in the string it still needs to be connected to the bottom of the first cell in the next string. The next string is a continuation of the previous string but only physically in a different direction.

i. Lay all four strings face up on your sheet of glass, don’t worry - the glass does not need to be cleaned at this stage. Ensure that when all four strings are connected in this way the cells are still alternate - the top connection on one cell must contact the bottom on the next cell.



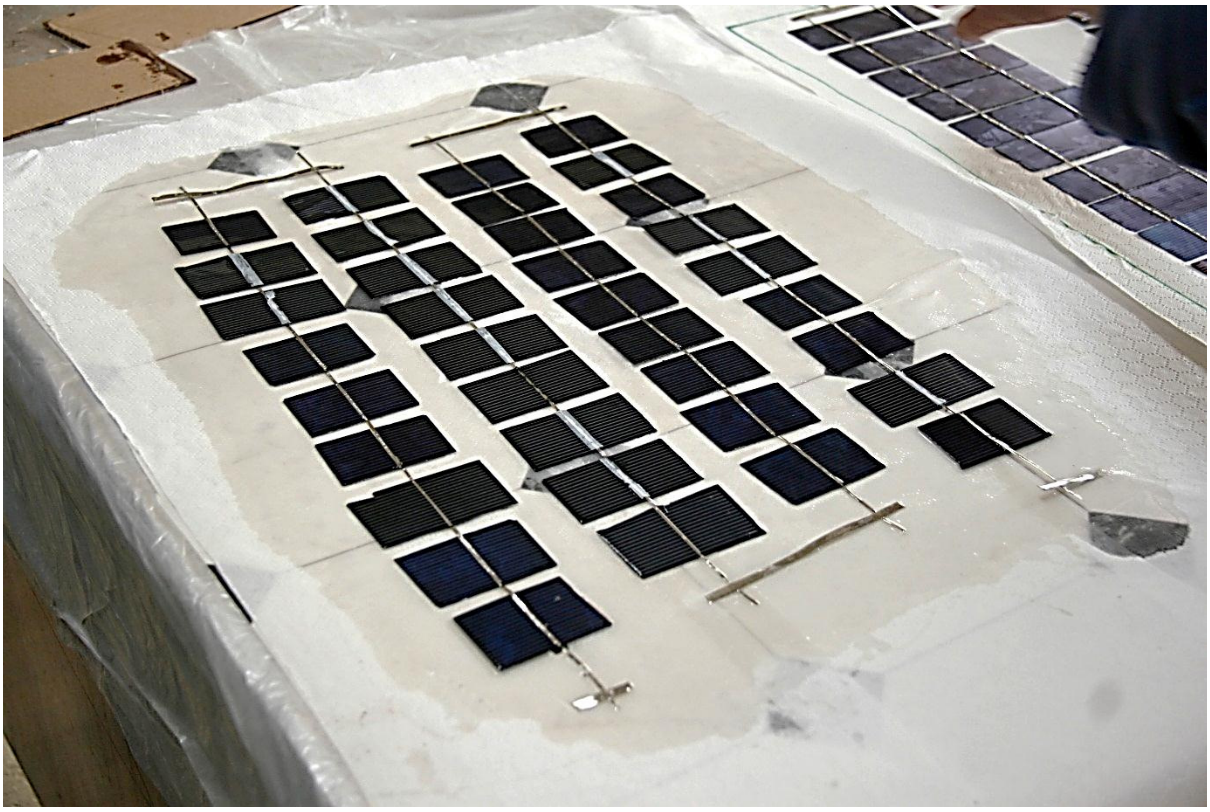
ii. The first and last cell in the entire circuit requires a ribbon if it does not already have one. This will be our positive and negative connection and will poke through the back of the panel.

iii. Another check is that the tabbing ribbon on top of the cell is not in contact with the ribbon passing underneath it. This should not be possible if the 2-3mm gap was left when the ribbon was soldered in place as described in previous sections.

iv. Prepare your encapsulating area. It is best to use a completely flat surface - a wooden board for example. We will need plastic sheeting at every point during this process - eg dustbin bags or polythene dust sheet. Cover the base with a layer of polythene - the two part silicon does not stick to polythene.

v. Lay your vinyl flooring as the next layer and cover with kitchen roll. Leave a 50mm border in addition to your glass size in both these materials.

vi. Lay your solar cells as the next layer (face up). It is best to bring the glass carrying the cells into place just above the position required and carefully slide them off. It is not very easy to move the strings any distance once resting on the kitchen towel. Alternatively, you may wish to solder your strings on top of the kitchen towel rather than lay them out on the glass; this is a better option if only making one panel at a time. If you choose to do this you will need to protect the kitchen towel from the soldering.



vii. Make holes through the kitchen towel and vinyl in line with the ribbon used as the positive and negative connection (the first and last cells). Thread the ribbons through so that they are between the paper and vinyl.

viii. Mix the two-part silicon. Do this slowly, to cause as few air bubbles as possible. Leave to rest for 10 mins to remove excess air.

ix. Pour the mixture to achieve an even spread - a small bead up and down each cell, between the gap and around the sides. Smooth the silicon first over the surface of the cells and then between the gaps. Aim to have covered the same area as the glass, but be careful not to have large amounts towards the edges. As pressure is applied the silicon will migrate towards the edges so try to keep the concentration slightly higher in the middle but still covering the whole surface.

x. Leave for 10mins exposed so that air bubbles can easily dissipate.

xi. Gently lay the cleaned glass over the area. Once in place press down evenly and cover with polythene.

xii. Add another flat surface to cover the whole area. The same material as the base is preferable. Slowly increase the weight on top of the pile, the heavier the weight the better for removing air, but the greater the risk of developing a crack if there is any uneven solder. Depending on how even you feel your soldering is, try weighting your pile from 20kgs upwards.

3.7 Remove wrapping and uncover results

Curing time is dependent on temperature. On a summer night you may find your panels are cured by morning. Even in a warm room it is best to leave them longer to be on the safe side. After a few days remove all wrapping and weights.
Your panel should be air-free and stiff. Trim the border.

3.8 Frame and seal

You don't need to follow a specific method when it comes to framing. We need to add strength and rigidity to the glass. An aluminium frame would do this and look more like a factory-made panel. However any material that adds strength and rigidity, and that can be easily replaced if required can be considered - including wood.
You can explore different kinds of framing to find what works best for you.
If using a silicone sealant during framing ensure the complete cure of the two-part silicone first, as it is likely that they won't be compatible during the curing stage.