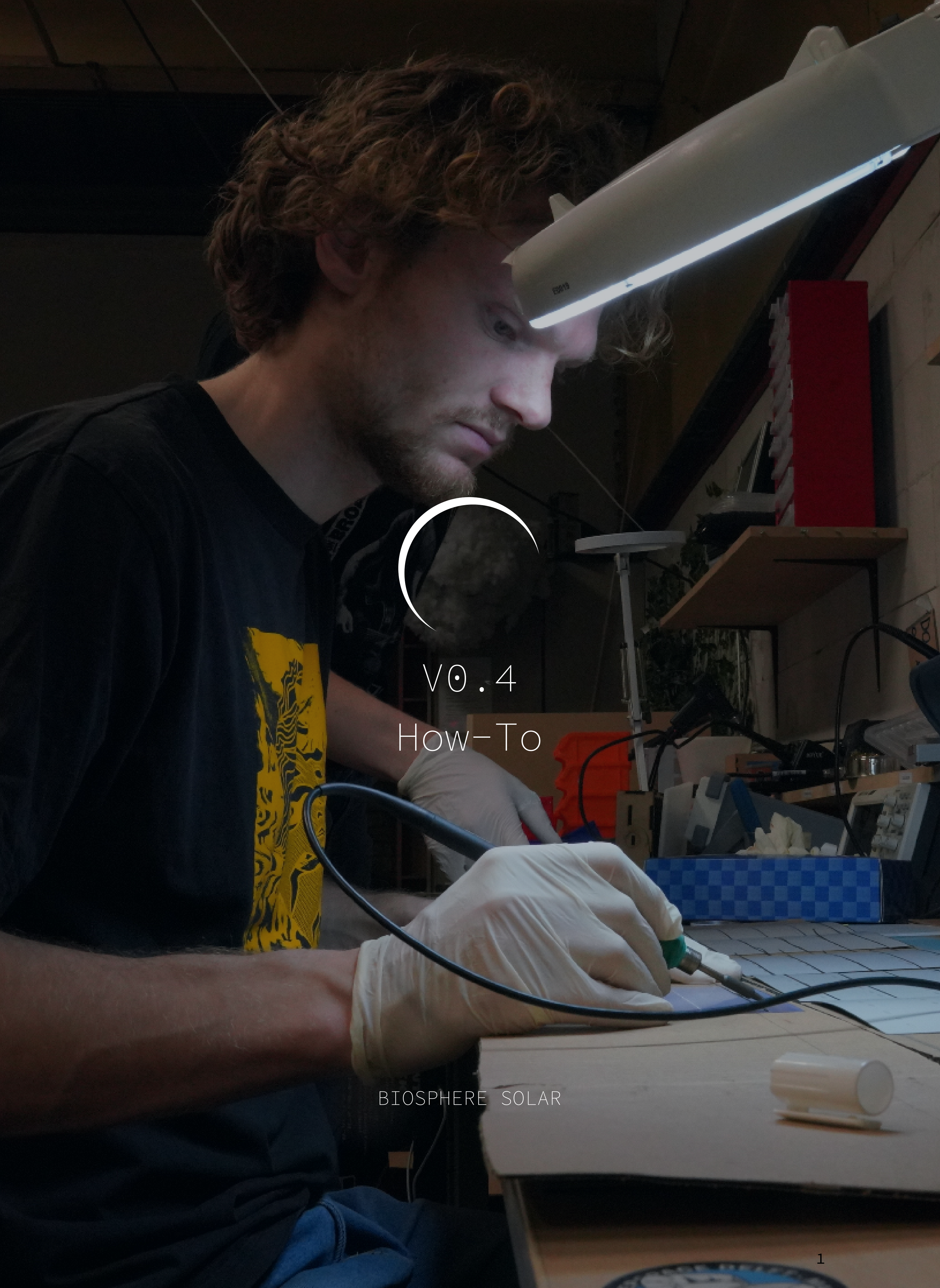

V0.4
How-To

BIOSPHERE SOLAR

INTRODUCTION

Figure 1. Picture of our V0.3 (left) and V0.4 (right) prototypes

Dear reader, welcome to the second **HOW-TO document**, in which we learned from V0.3 to build prototype V0.4. Here, we provide you with all the building blocks of information to allow you to do it yourself! Feel free to give us feedback on this document, or make adjustments/improvements to the design and share them via our discord channel or wikifactory page.

At Biosphere Solar, with our team, global community, and your help, we are bringing circularity and fairness to the solar industry and market. An overview of the Biosphere Solar projects - including documentation - can be found on our Wikifactory page. There we invite anyone to join the development of the design and production line. For more information on our mission and values, see our **Read-Me document.**

IMPORTANT INFO

Let's briefly go over some important information you might need to make this panel yourself.

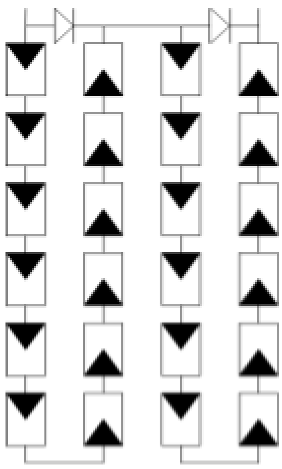

Figure 2. Circuit diagram of a 24-cell solar panel

First, keep in mind that building PV modules by hand can be difficult and tedious. It requires practice and it is normally not done by hand. Because we aim to bring a disruptive new panel design to market, and we like a challenge, building prototype panels is at the core of what we do.

So in case you are looking to build a solar system with pre manufactured panels, this document will also be useful. This is because for this prototype, we had to build the balance of system (BoS) ourselves as well (see Figure 1 where you can see our very first system).

Second, know that in a solar panel, cells are usually connected in series, creating high voltage and manageable currents. A 24-cell solar panel would typically have the circuit diagram that you see in Figure 2, with 4 **'strings'** of 6 cells; note that 60 or 72 cell configurations are much more common in the solar industry, but we are using a small size to iterate the prototype more quickly. In addition, bypass diodes can be included between the strings to prevent shading losses.

Third, the interdigitated back contact (IBC) cells used in this prototype are one of the newest technologies available. The main advantage of these cells for DIY solar panel building is the incredible ease with which they are tabbed together. Tabbing the cells is normally the most time-consuming task with conventional front-to-back contact cells. Another advantage is the higher efficiency (~25% in MPPT STC conditions). The disadvantage is of course the price, which is about double that of conventional cells.

Figure 3. Our social media expert soldering IBC cells.

Fourth, know that the cells will be encapsulated as an edge sealed glass-glass module, meaning there is glass both on the front and the back of the module, with a rubber edge seal. To make the module disassemblable, we do not use (EVA) lamination! This means: no glue on the cells. The illustration in Figure 4 shows the difference between a conventional module stack and Biosphere Solar's design. To create adequate space between the front- and back- glass we use spacers, which are placed at the corner of each cell. The cells are held in place by rubber strips, which are placed at the back of the cells.

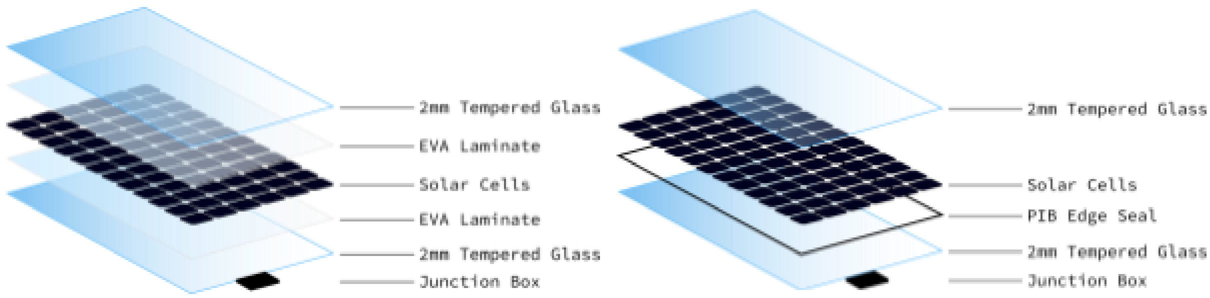

Figure 4. Left: Conventional module design; Right: Biosphere Solar module design

These are the important disclaimers. It might be a lot to take in, but when you start going through the step-by-step process, it will all become clear.

In the building of this prototype, there are a few main points that went well for us and some things that we still have to improve. We'll mention these here because although they are specific to us, some of the points could also help you in your process.

What went well:

1. Having a good functioning soldering station with a flat tip that works properly for soldering tabbing wires.
2. Taking enough breaks in-between soldering the cells.

What needs to be improved:

1. The soldering should be practised on old or broken cells first.
2. Buy enough extra solar cells, because the cells break easily (especially if you are not used to handling them).
3. Pre-cut the tabbing wires at exactly the right size.
4. Use a fresh Flux pen to solder better.
5. String the cells on cardboard jigs with markings to indicate the correct spacing between cells.
6. Do not use FBC cells as they are very tedious to solder, back contact cells are much easier
7. Thinner glass since it saves weight, material, costs and increases efficiency. Downside is lower rigidity.

With these things in mind, let's jump into the build! This documentation starts with a bill of materials and a list of tools needed, after that the steps of the build will be outlined, and the document will close with sharing instructions. Good luck!

TOOLS NEEDED

In the following table all the tools we used, how critical they are and what they are used for is described.

Tool	Critical?	Notes
Soldering Station	Critical	Used to solder the tabbing wires onto the solar cells and bus-bar wires.
Wire Clippers	Critical	To cut the busbar wire to the right lengths.
Multimeter	Critical	To ensure the cells are well connected and current can pass through. One that can measure not only voltage but also current, up to at least 10A, is highly recommended for later testing.
Soldering Fume Extractor	Interchangable	The fumes released from soldering are toxic, make sure to extract or filter them in some way.
Clamps	Interchangable	For encapsulation, we used special clamps. These worked very well, although weighing down the solar panel is also a viable option.
Flat soldering tip	Interchangable	Although having a flat soldering tip makes it (much) easier, it is possible to do with alternative tips
3D printer	Interchangable	To print the spacers at a high precision. Alternatively, using a (laser) cutter and cutting spacers out of the wanted material is an option.
Scissors	Interchangable	To cut the PIB sealant and rubber strips it is very useful to have a good pair of scissors.
Small flathead Screwdriver	Optional	To hold the end of the tabbing wire as you solder it.
Tweezers	Optional	Also to help hold the tabbing wire and spacers as you place them.
Sewing Machine	Optional	To sew the oxygen absorber and desiccant sachets which are used to keep an inert atmosphere in the solar panel. Hand sewing is also an option.
Calipers	Optional	To measure the thickness of various components.
Jigs	Optional	Cardboard sheets at the length of one string,

Tool	Critical?	Notes
		with markings indicating correct cell spacing

MATERIALS NEEDED

In the following table the materials we used, how critical they are and what they are used for is described.

Material	Critical?	Notes
Glue	Critical	Used to stick the spacers and desiccant/oxygen absorbers on glass. The glue must allow polymer-glass bonding and be temperature resistant.
Latex Gloves	Critical	To ensure you never touch the cells with your finger: this will result in rapid degradation.
3M masks	Critical	To ensure you don't breathe in the toxic fumes.
Flux (pen)	Critical	Although you could use solder wire throughout, flux pen is crucial if you want to keep the tabbed wire from becoming thick with solder. Also, having a flux pen will also make applying the flux and the experience of soldering as a whole much easier.
Dog Bone Connectors	Critical	Needed to tab the cells together. These were hard to find online, try using 'ibc cell dog bone connectors' in your search
Bus bar wire	Critical	Used to connect each 'string' of cells, and to connect the junction box.
Tempered Glass (4mm)	Critical	Used as a front and back-sheet. Tempered to ensure resistance to heat, shocks, and scratches.
Solar cells (mono-Si IBC)	Critical	The basis of a solar panel! Needed to convert your light to electricity. Make sure to over-order as they are very fragile and some will break.
PIB/Butyl tape	Critical	To create an edge-seal and prevent moisture and air ingress which would cause rapid degradation of cells.
Oxygen Absorber	Critical	Iron flakes, small grains
Desiccant	Critical	In powder form

Material	Critical?	Notes
Junction Box	Critical	To connect the leads of the solar panel to MC4 connectors & electrical wiring. Minimum of 2 bypass diodes.
Heat shrink tubing	Interchangable	To insulate the leads from the solar panel. Using insulating tape or other tubing is also possible.
Cloth	Interchangable	To make the oxygen absorber and desiccant sachets. Can also be interchanged with other materials
3D filament	Interchangable	If you use a 3D printer to make the spacers, you will need 3D filament to print them.
EPDM Tape	Interchangable	A soft rubber tape with an adhesive on one side and a thickness of 1-2mm. Used as 'shock-block'
Solder Wire	Optional	For soldering the dog bone connectors
Glass cleaner	Optional	To clean the glass prior to placing the cells and prior to closing the module
Glass cleaning cloth	Optional	To ensure the glass does not have any markings from the glass cleaner

HOW TO

In this section, we will provide you with a step-by-step description on how to make V.0.4 of Biosphere Solar's module. If you recreate this, make changes, or have questions, please refer to the *questions and hacks* section below.

Also, to make the building a smoother process, here is a checklist you can use to keep track of what step you are on. They are structured in the same order as the descriptions you will find below.

- [ ] Print the spacers
- [ ] Sew and store desiccant/oxygen absorbers
- [ ] Prepare the tabbing wires
    - [ ] Measure the correct lengths
    - [ ] Stretch the tabbing wire
    - [ ] Cut the tabbing wire
- [ ] Solder tabbing wire onto front of cells
    - [ ] Check soldering is intact
- [ ] Solder tabbing wire onto back of cells
    - [ ] Check soldering is intact
    - [ ] Test with multimeter
- [ ] Clean glass using glass-cleaner
- [ ] Apply EPDM tape
- [ ] Place strings onto the glass
    - [ ] Check that they are placed correctly in terms of front to back contacts between strings
- [ ] Glue spacers between cells
- [ ] Glue desiccants/oxygen absorbers to sides
- [ ] Cut bus-bars
- [ ] Fold leads so they come out of the panel
- [ ] Solder tabbing wire to bus-bars
    - [ ] Test with multimeter
- [ ] Place the PIB edge-seal
- [ ] Clean the front glass sheet using glass cleaner
- [ ] Place the glass front sheet on top
- [ ] Press the module
- [ ] Celebrate having made your first very own solar panel!

STEP 0: MODULE SIZING

The process described in this document can be applied for varying module sizes. You are therefore free to choose the size, but for prototyping purposes somewhere between 4x3 and 7x5 (cells per stringxstrings) cells is suitable. For the width of the glass, take: width = cell width*number of strings + cell spacing*(number of strings + 1) + edge seal spacing*2. For the length of the glass, replace ‘number of strings’ with ‘number of cells per string’, add 14 mm of space for the busbar at the top and 7mm for the busbar at the bottom. We used 5x5 inch (125x125mm) cells, 25mm cell spacing, 15mm edge seal spacing (recommended), and a 6x4 cell configuration. Our cell spacing is fairly high in order to facilitate plant growth under the panels.

A last thing to consider is that one bypass diode per two strings is recommended, and that the strings should not be longer than 8. This prevents shading from having a significant impact on the performance.

STEP 1: MAKE THE SPACERS

We **3D-printed** the spacers at a thickness of 2mm. Thicker is not recommended, as it will require a lot of layers of butyl. The spacers can be made with other materials and in any colour. White is best for efficiency as it reflects light. The shape of the spacers depends on the cell corners. Make spacers that fit in the space between the corners of the cells, considering the cell spacing and an error margin. *Keep in mind that your strings will not align perfectly or, even worse, your cell spacing within the string will not be equal everywhere either. Therefore, spacers for each cell corner, or at least for the corners of* separate *strings is desirable.* Figure 5 shows some options.

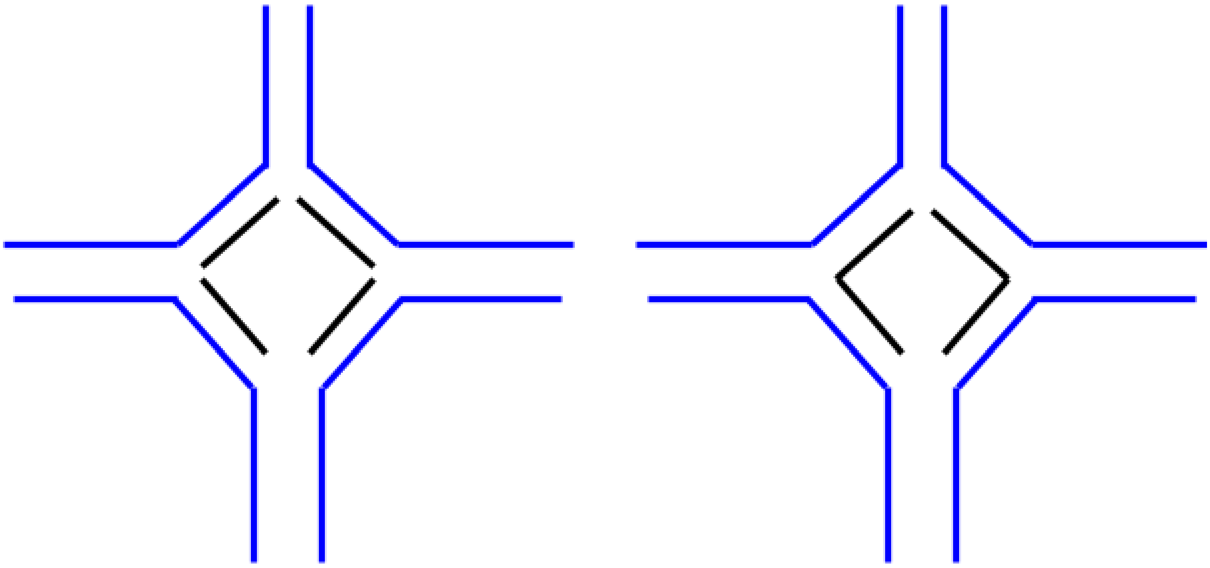

Figure 5: Two options for spacers. The left option leaves more room for error, but is more tedious to place.

Figure 5 shows the different types of spacers we made for the different parts of the panel.

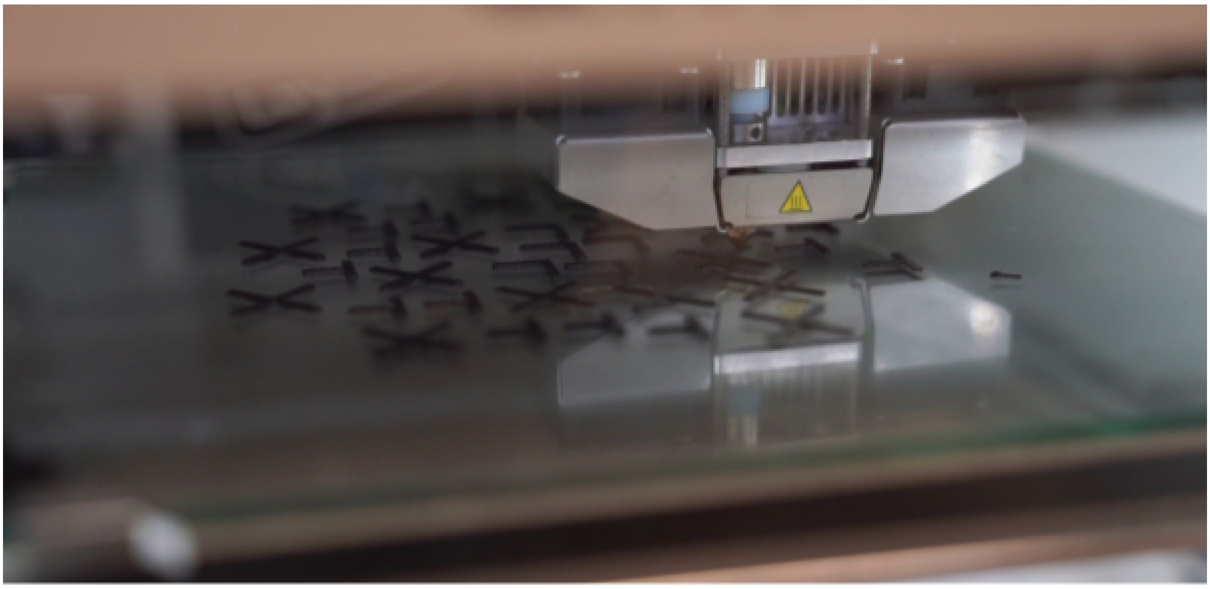

Figure 5. 3D printing of spacers

STEP 2: PREPARE ABSORBERS

To take moisture and oxygen out of the inner module atmosphere we use desiccants and oxygen absorbers.

We used cloth to make sachets 1 cm wide and 2 cm long. Each sachet contained about 3 grams of desiccant and oxygen absorber. In total we made 3 sachets per module, but **we recommend making 4**. Take care that the sachets are not thicker than the spacers. For this version, the thickness was 1.4 mm. Callipers can be used to measure this.

Store the sachets in an **airtight container** to prevent them from saturating before use.

STEP 3: STRING THE CELLS

Before you get started, here are some tips to help the soldering go smoother:

- Use a flat tip on the soldering iron
- Clean the soldering iron often
- Watch this video for a clear instruction to soldering IBC cells
- Set the soldering station at about 350-450 °C (you might want to experiment with the temperature to check what works best with your soldering machine)

And finally: make sure to wear latex gloves when handling the cells, as fingerprints will stay on them.

Since the video demonstrates the process clearly, we only provide some troubleshooting tips.

1. Sloppy soldering can lead to a short circuit. In the following image, several examples are shown. For it to become a short circuit, a blob of solder has to be covering multiple horizontal fingers. If it's just a few traces, like in the middle image, it will be fine.

2. If your dog bone is not aligned neatly, use a screwdriver while heating the solder to wedge the contact.
3. Regularly check with the voltage of your string with a voltmeter. If the voltage is lower than cell voltage*number of cells, you have probably reversed some of the cells.

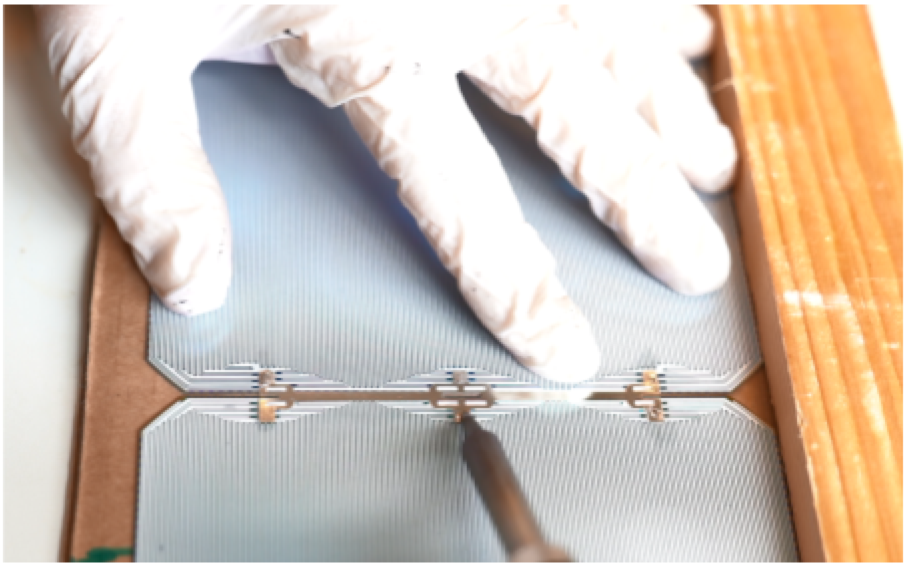

Figure 7. Perine soldering the dog-bone connectors

STEP 4: CONNECT THE STRINGS

Now we connect the strings. To keep the cells in place and provide some cushioning, EPDMP tape was used. Two strips were cut for each string. First, clean the glass!! After measuring out the placement of the cells, they were then placed on the glass where the cells would be placed.

Then, we placed the cells and cut busbar strips so that they could be placed like Figure 8. Measure the voltage to see if the cell strings are placed correctly. Positive voltage means the red point is the positive side, negative means the red point is the negative side.

The bends in some of the busbars were made by folding the busbars where needed. The busbar going out of the panel, attached to the top middle connection was needed for our double bypass diode junction box.

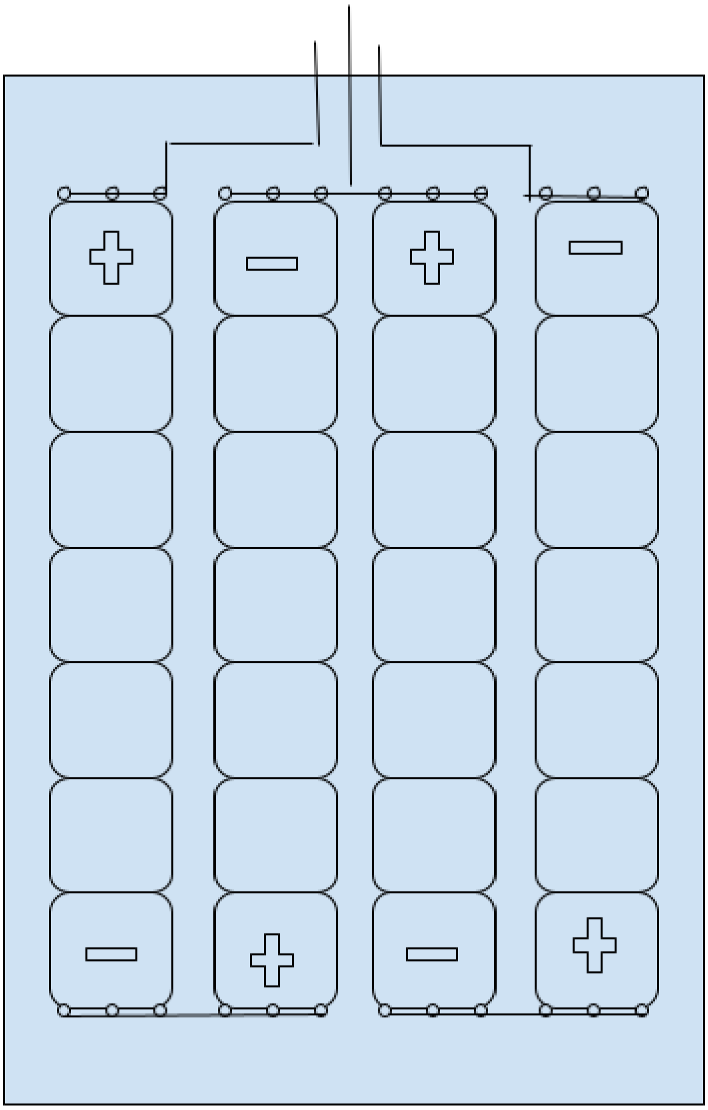

Figure 8. Schematic representation of the string placement

What worked best for us is to solder the busbar under the dog bone connections, for easier pressing.

STEP 5: CLOSE THE MODULE

We placed a ±1cm wide, 2-3mm thick layer of sealant rubber around the edge of the glass. We had a 3x1mm butyl tape so we applied multiple layers to get to the desired thickness and width. Rule of thumb: layers of butyl / spacer thickness > 2.4. You can see us laying out the butyl tape in Figure 9. The butyl tape also adheres the front, and back glass, creating a sturdy assembly.

Figure 9. Application of the butyl tape around the edge of the panel

Finally, glue the oxygen and moisture absorbers to the glass in the leftover space between the cells and the edge seal. From this point on, make sure to close the module rather quickly to prevent the absorbers from saturating.

Clean the front glass with window cleaner and dry it. Place the bottom side of the pressure clamps underneath the module (see video). Then place it with the clean side down onto the module assembly, making sure the front glass is aligned with the back glass before it hits the rubber. It works if someone is standing high above the module and can instruct the two people placing the module. This video will give an idea of how we clamped the module after placement.

Next, apply the silicone caulk around the edge of the module to protect the butyl tape from degradation.

STEP 6: PLACE THE JUNCTION BOX

The leads sticking out of the module at the top should be covered with heat shrink tubing. With a multimeter, you can measure which are the positive and negative terminals. Junction boxes usually have the leads entering them from the back. For our prototype, we adapted our junction box by cutting small slits so the leads could enter from the side rather than from the back. Connect the leads to the terminals of the junction box. Finally, glue the junction box onto the back glass with butyl, apply pressure with glue clamps or pressure clamp and seal it with silicone.

Well done! You built your own PV module 😎

Figure 10. Picture of the junction box we used.

QUESTIONS & HACKS

Do you have any questions? Ask away via discord in our #burning-questions or #general channel. Did you try out our design and find ways to improve it? Share any hacks and improvements on our wikifactory forum in a file called [Name of your changes]_BioSol_V.0.3_HOWTO.

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