UNIVERSITY OF TWENTE.

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FACULTY OF ENGINEERING TECHNOLOGY

MASTER OF SUSTAINABLE ENERGY TECHNOLOGY

Implementation of a BIPV plant at Centro de Tecnologia Informação Renato Archer

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PREFACE

This report is the result of a three month internship that I fulfilled at the Centro de Tecnologia Informação Renato Archer in Campinas, Brazil. It is also a requirement for the internship program of the master of Sustainable Energy Technology at the University of Twente, Enschede. Included are the experiences, roles, responsibilities and obligations during the internship period from the 10th October of 2012 until the 9th of January 2013.

I would like to thank the employees of Centro de Tecnologia da Informação Renato Archer and especially Antonio Luis Pacheco Rotondaro who have made this experience possible and have taken the time to mentor me during my stay at CTI. Without their help and support it would not have been as successful as it has been.

Quirijn van Hengstum

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1. INTRODUCTION

1.1. Towards more solar PV

As the problems with the current fossil fuel based energy supply are becoming increasingly evident, the debate about a transformation towards a more sustainable energy future is on the top of political agendas across the world. J.P. Warren mentioned in his 2007 report, *Power for a Sustainable Future* (Warren, 2007), that the biggest concern with our current fossil based energy supply is its depletion in the near future. Although the world its future fossil fuel supply and demand are estimations based on extrapolating the past completed with rough assumptions, it is quite certain that all the currently used fossil fuels will deplete within the 22nd century (Shafiee & Topal, 2009). And with more and more countries becoming developed, especially large ones such as China and India, the need for energy can increase even faster which will bring the problem of depletion closer to today than tomorrow.

The increase in demand of fossil fuels, combined with the scarcity of these fuels will also result in other problems. One of these is that the fuel prices will rise as a result of limiting resources recovered at more difficult to reach places. A second problem is that of energy security. Most of the fossil fuel reserves are not spread equally over the world. For instance, the oil reserves are largely in hands of just a few countries. This gives a lot of power to a small number of often already politically unstable countries creating an unreliable supply of fuel. With limiting resources and the chance of future conflicts, energy security is a serious concern for the fuel consuming countries. Another problem with using fossil fuel resources is the carbon dioxide emissions and its effect on global warming. During the conversion of fossil fuels into energy a lot of carbon dioxide is emitted. Globally, the burning of fossil fuel has already exceeded the 30 billion metric tons of carbon dioxide emissions in 2010 (International Energy Agency, 2010). Reducing the usage of fossil fuels is thus needed to reduce these emissions and resulting global warming and climate change. Taking all these problems together it becomes apparent that a transformation towards a more sustainable energy supply is needed.

One technology that can play an important role in a renewable energy based future, and will also be the focus of this report, is photovoltaics. In photovoltaics the energy from the sun is converted by a solar cell into a stream of electrons: a current. This type of renewable energy has a number of advantages over the current used fossil fuels. Because the sunlight is available everywhere, countries can be rather independent on each other for electricity and thus fuel security will increase. Another advantage is that carbon dioxide emissions are almost zero. At this moment, carbon dioxide is only emitted during production of the solar wafers as some amount of fossil fuels is still used for this, but during operation the photovoltaics are completely emission free. Next to this, photovoltaics can be used in almost any size, ranging from a few kilowatts up to hundreds of megawatts, making it very suitable for a large range of applications. Although the use of this technology in the world is currently rather small, the International Energy Agency (IEA) also acknowledges these advantages and views solar technology as a very promising technology for the future with an annual growth in global capacity of over 40 percent (International Energy Agency, 2010). Their 2010 roadmap for the photovoltaic technology estimates that photovoltaics will provide 11 percent of the 2050 global electricity production. However, coming to this amount will not be an easy road. The current economy is completely built around fossil fuels. This phenomenon called “carbon lock-in” was first mentioned by Gregory C. Unruh in 2002. In his report he argues that the current fossil fuel based system that is driven by economies of scale prohibits governments and businesses to take decisions that will move them away from fossil fuels and towards renewable solutions (Unruh, 2002). This creates large barriers for these new renewable solutions. The article by Dangerman gives a similar argument using the dynamic lock-in pattern called “Success to the Successful” (Dangerman & Schellnhuber, 2013). In their article they state that there are two systems for the generation of energy: the conventional system based on the fossil fuel technologies that causes problems as global warming and climate change (for instance coal and oil) and the alternative system with technologies that do not cause these problems (for instance wind and solar). The Success to the Successful mechanism argues that resources (money, knowledge and people) are allocated to a system as a reward for past success. The allocation of these resources enables the possibility of new success. This creates a feedback loop as success leads to new success in the future. In the case of these two systems resources allocated to one system cannot go to the other, thus limiting the success of one. If during years of development most resources go to the conventional system it will create path dependence. It creates rigidity and prohibits a change towards a new alternative system. In order to bring down these barriers and create opportunities for the alternative renewable technologies it is therefore very important not to only increase the awareness of these problems, but also to increase research and projects into renewable energy technologies.

1.2. Centro de Tecnologia da Informacão

A Brazilian research institute, Centro de Tecnologia da Informação Renato Archer (CTI), is interested in playing a role in this transformation towards more renewable energy and especially solar energy. CTI is a research unit of the Brazilian Ministry of Science, Technology and Information located in Campinas, Brazil. After founded in 1982 CTI has currently around 300 researchers working in 10 divisions focused in different aspects of information technology. With a wide variety of divisions in electronics, microelectronics, systems, software and IT applications such as robotics and 3D technology, all located at one facility in Campinas and the close link between these divisions and universities, other institutes, commercial organizations there is good network of knowledge and expertise at CTI.

At the facility in Campinas, CTI has reserved a lab for the installment of a plant capable of assembling photovoltaic modules based on crystalline silicon solar cells. The plant should be able to produce 300 KW per year of solar modules of different dimensions and would focus at the “Building Integrated Photovoltaics” or BIPV market. BIPV solar modules are modules that are integrated in the design of the building, thus combining both the structural component and the energy production component of a building. In cooperation with architects and universities, the goal is to disseminate the photovoltaic technology in Brazil acting as a platform for more research and development. Figure 1 shows the plant before the start of the internship. The machines that are already bought by CTI are still packed in the back.

Figure 1: The plant at the start of the internship

1.3. Goals of this internship

The main goal for this internship is to be the project leader and to coordinate the setting up of the 300 KW per year producing BIPV plant at CTI. This results in the following targets:

- The complete production process should be defined resulting in a final floor plan of the plant and a list of all needed materials, machines and appliances.
- A sequence of actions should be defined for the process of installing and testing of all the machines and the acquisition of all the needed materials and smaller appliances.
- The washing plant should be tested together with the mechanical arm and a procedure should be created for its operation.
- The solar simulation tunnel should be assembled and tested.
- The lab implementation will be supervised as the project leader.

All tasks will be fulfilled in interaction with the infrastructure team.

1.4. Structure of the report

The following of this report includes eight chapters. The first chapter adresses briefly the principle of photovoltaics and the assembly process from an individual wafer to that of the building integrated photovoltaics. The following chapters reports the work done at CTI. The floorplan is discussed and all the needed machines. The progress made at the washing plant, assembly tables, solar simulation tunnel and all the other machines and appliances is adressed . The report ends with a summary of all the work that is still needed to complete the plant and a conclusion about the internship.

2. BUILDING INTEGRATED PHOTOVOLTAICS

2.1. Photovoltaics

For this internship, I coordinated the setting up of a 300 KW per year plant for the production of building integrated photovoltaic modules. These modules are assembled out of externally bought crystalline silicone wafers. A crystalline silicone or c-si solar cell is typically 16 by 16 cm and 0.3 mm thick and converts solar energy into electricity. Figure 2 shows the working principle of a c-si solar cell.

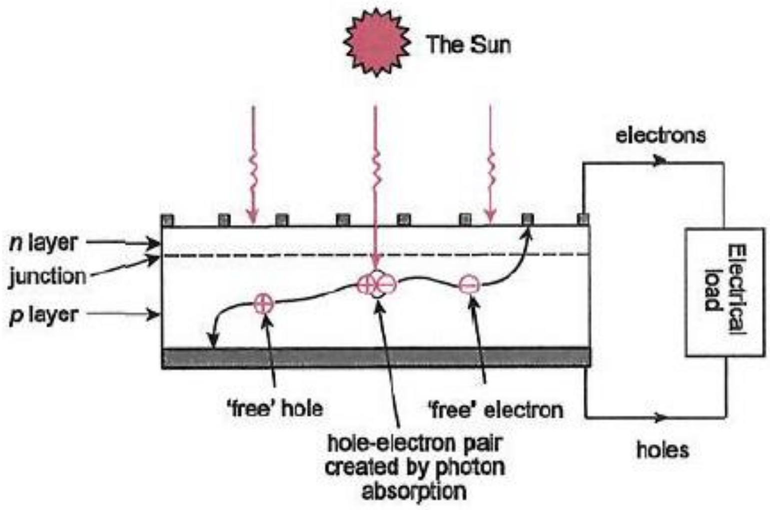


Figure 2: The working principle of a c-si solar cell (Archer & Hill, 2001)

The c-si solar cell consists of two layers of silicon, a n-layer (silicon doped with phosphorus) and a p-layer (silicon doped with boron). The combination of the p-layer and n-layer creates a junction between the two materials. When light enters the solar cell, the photons with an energy higher than the bandgap of the silicon (c-si = 1.14 eV) will promote an electron to jump from the valence band to the conduction band in this silicon layer. This excitation will leave a hole behind in the valence band thereby creating an electron-hole pair. The junction contains a electric field that ensures the electrons to be separated from the holes. The electrons move to the top of the cell and are retrieved by the front grid and the holes move to the bottom where they are captured by the back grid. The photons are now converted by the c-si cell into a stream of electrons and holes in opposite directions creating a direct current from the solar cell and this current can be used to power an electrical load.

2.2. Building integrated Photovoltaics

The focus in this internship is on integrating these crystalline solar cells into the materials that make the exterior of a building. Instead of placing the solar modules on the roof or on a big area of land, they are now integrated into walls, roofs, sunshades and even windows. In this way these building integrated photovoltaic modules combine the functions of electricity generation and construction material. This integration gives some additional benefits to the usage of photovoltaics:

- The most important one is the increase in aesthetics. Were conventional solar panels are not considered to be very attractive, building integrated photovoltaics can be made in almost every form, shape or colour enabling them to become visuallly rather pleasing. As an example using solar modules with different transparencies these BIPV solar modules can now be used as skylight systems in entrance halls, combining beauty with purpose.
- Using building integrated photovoltaics can be a social and political statement from the company as being more environmentally friendly which is becoming an increasingly important aspect of doing business nowadays (Esty & Winston, 2008).
- If it is not about sending out the right image the potential cost reduction is an important benefit of the building integrated photovoltaics as the building materials are now replaced with the modules and no separate construction materials are needed.
- By generating electricty the BIPV modules also reduce the monthly energy bill of the building.

All these advantages together make BIPV potentially a very suitable solution for future energy supply not only for the technology itself but for all solar energy technologies.

In order to create a BIPV module that gives the right current and voltage, the individual solar wafers should be connected to each other and protected from the environment. The assembly process for making the building integrated photovoltaics from the individual solar wafers is as depicted below in Figure 3.

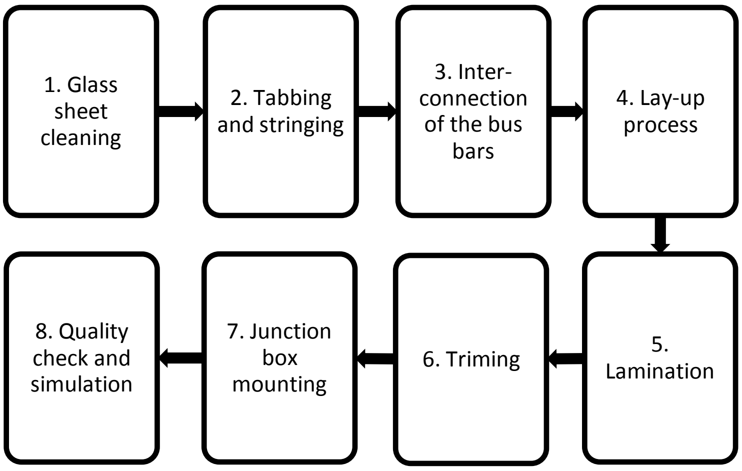


Figure 3: Assembly process for Building Integrated Photovoltaics

The complete process is:

1. **Glass sheet cleaning:** In the first step the front glass sheets are washed in a washing machine until they are clean enough for the lamination process.
2. **Tabbing and stringing:** When the glass sheets are clean the solar wafers should be interconnected in the right order to create the desired voltage and current output using two processes called tabbing and stringing. During the tabbing process the individual wafers are

connected with the cell connector to the sub unit cell as is depicted in Figure 4 with number 1. In the stringing process the tabbed cells are connected to each other in a sub unit string as is depicted with number 2. The current of the string equals that of each individual cell but the voltage is now the voltage of all the wafers in the string added together. This results that the output voltage of a string can be altered by changing the number of solar wafers in that string.

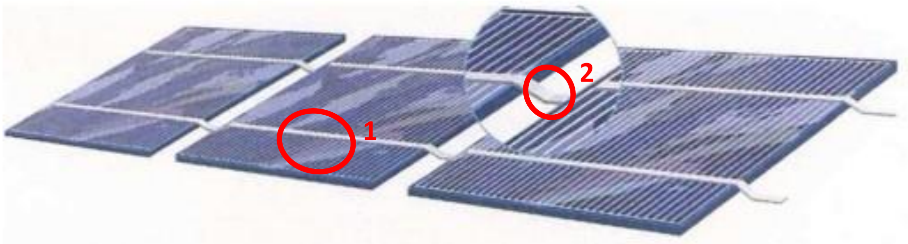


Figure 4: The tabbing and stringing of a solar wafer (PV Modules and Other Components_Basics_Knowledge_Powerway, Your Professional Solar Farm Builder)

3. **Interconnection of the bus bars:** To connect all the strings of solar wafers with each other, the junction box and the bypass diodes (if there is shade on the solar cell, the bypass diode prohibits the current to be different in the series connected cells as differences in current can damage the string) a bus bar is needed. In this step the bus bars are soldered together and to the strings.
4. **Lay-up process:** The cells and bus bars are now ready for the assembly process of the module. This assembly process is called the lay-up process. For the front commonly a sheet of glass is used for its strength and transparency. The strings of connected solar cells are sandwiched by two layers of encapsulation foil, most often ethylene vinyl acetate or EVA. These layers of encapsulation foil will melt in the lamination process surrounding the wafers and ensuring an airtight sealing of the modules. These layers are put on the glass sheet. The back sheet is then added to complete the module. Tedlar is most used as back sheet but if the back should be transparent also glass is suitable. The final module as shown in Figure 5 can now enter the lamination process.

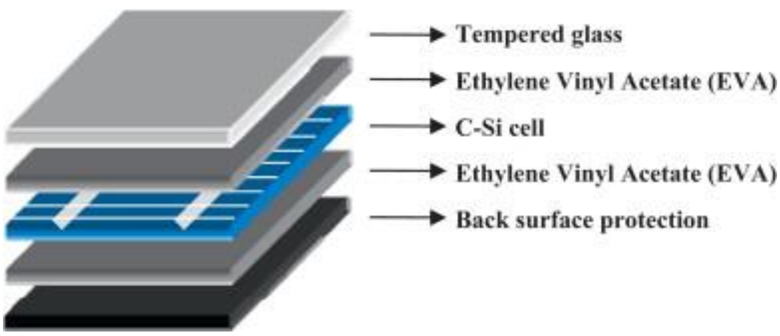


Figure 5: The different layers of the BIPV module (Kim & Lee, 2012)

5. **Lamination:** In the lamination step the layers stacked in the previous steps are processed to one unit, the solar module. During lamination the air in the module is removed and pressure is added on both sides of the module. The module is heated which melts the encapsulation foil that now covers the wafers and protects the cells.
6. **Trimming:** After the laminator all overlapping encapsulation foil and back sheet material is removed in the process called trimming.
7. **Junction box mounting:** In the final step the junction box is mounted to the solar module and the BIPV module is finished.
8. **Quality check and simulation:** To ensure a good quality, the modules undergo a number of quality tests in different simulated situations.

After all these steps the building integrated photovoltaics are now ready for usage as a construction material and for the generation of electricity of a building.

3. THE FLOOR PLAN

3.1. The machines needed

All the steps mentioned in the previous chapter which are needed to transform the individual solar cell wafers into the final assembled modules should be fulfilled in the plant itself. For this a number of machines and appliances should be acquired. The German solar energy consultancy company Sunnyside Up Solar provided their expertise on solar panel assembly lines by giving a production manual for the whole process and advice on which machines and tools to buy. With their help, the following machines were bought:

- A stringer (soldadora) to tab the individual wafers and string them together into rows of stringed solar cells.
- A washing plant (washadora) to clean the glass sheets. To ensure that the module glasses are clean enough for the lamination process the sheets will go trough the washing plant twice.
- A mechanical arm to move the glass sheets and the laminated modules around the plant as they are too heavy for manual lifting. Rails will be used to move the mechanical arm across the plant.
- A cutting table (cortadora de folhas) will be designed and installed to cut the EVA foils and backing sheets in the required dimensions.
- Four time of the laminator. The third table is used to take the laminated module out of the laminator and the last table (montagem de módulos) will be used as the place to mount the junction box to the module.
- A laminator (laminadora assembly tables to fulfill the assembly process of the modules. Two tables (mesa de montagem) needed before the lamination process will operate as the lay up tables. As the lamination process itself takes 20 minutes and the lay up will take much longer this will increase the operating) to laminate the different sheets together in one module.
- For quality testing and simulation, a solar simulation tunnel (simulador solar) will be installed which by using a flashing light and measuring tools will be able to do different tests with the modules.

3.2. The final floor plan

To create the final floor plan for the photovoltaics lab, the following restrictions should be taken into account. The washing plant releases some moiture in the air during operation. It is important that the solar wafers and other layers of the BIPV module before lamination are kept away from any moisture as much as possible. Moisture can create not only damage the layers but can also create leaks during the lamination process. Therefore the washing plant should be placed away from the stringer and the lay up tables. As the moisture is not a problem any more for the laminated modules the junction box mounting and the solar simulation tunnel can be placed near the washing plant. This results in the washing plant placed on one side of the plant and the stringer and lay up tables on the other side. The second consideration of the floorplan is that there should be enough space for the final modules to be placed in the solar simulation tunnel using the arm. These modules enter the simulation tunnel from the side. Therefore, the only possible location for the tunnel is in the right center of the plant. Taken these two considerations into account, the floor plan in Figure 6 below is the most suitable for this plant.

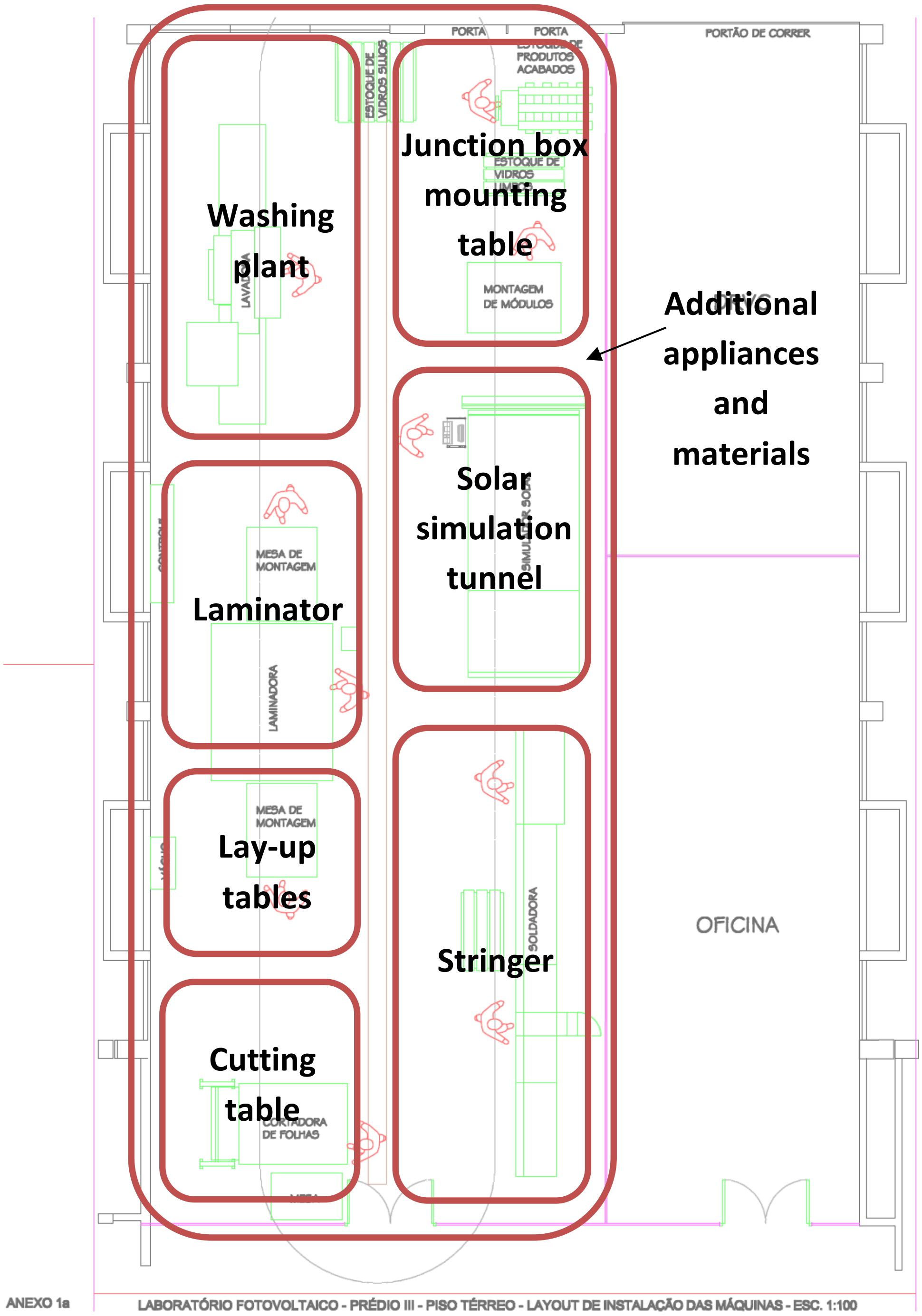


Figure 6: The floor plan of the plant at CTI

One goal for the internship was to coordinate the installation of all the large machines in the photovoltaics plant meaning the solar simulation tunnel, the washing plant, the mechanical arm, the stringer and the laminator. As these machines are rather complex, external specialists were hired to execute the assembling process. For the stringer and laminator, it was unfortunately not possible to acquire the right visa in time for the engineers to come to CTI during the internship period and no progress is done on these machines so far.

The next chapters present the installment and testing of the washing plant and mechanical arm, the installment of the solar simulation tunnel, the design of the lay up tables and gives a list of all the smaller appliances and materials needed.

4. WASHING PLANT

4.1. The washing plant

In the building integrated photovoltaics lab, the glass sheets needed for the solar modules are cleaned in a washing plant. Although the externally bought sheets are already rather clean, any dirt on the side of the glass facing the solar wafers should be removed. This dirt can not only reduce the transparency but can also create leaks in the module during the lamination process. Moisture entering these leaks can damage the solar wafers in the final module.

The washing plant at CTI was already installed before the start of this internship. The Brazilian company Agmaq supplied the plant. Agmaq is one of the biggest companies in Latin America specialized in fabricating machines for sheet glass, with a wide range of products for handling glass the company is very capable of delivering a washing plant that would suit the need for the photovoltaics plant. One of the goals of the internship was to test the installed washing plant together with the mechanical arm and create a procedure for their operation. Due to the absence of the person in charge of operating the washing plant it was not possible to use the plant and therefore write the final procedure for cleaning the glasses. Below I describe a draft procedure which can be adjusted when the plant is in process.

4.2. Draft procedure for cleaning glass

Figure 7 shows the washing plant. The unwashed glasses enter on the right side of the machine where they go through the cleaning process. The cleaning process inside the washing plant consists of a rotating wraparound and water jets for cleaning (no soap is used) followed by forced air drying to dry the glass sheets. On the left side, the clean glasses come out of the machine and with the use of the yellow fluorescent lights the inspection of these glasses can be executed. The glasses will then go through the washing plant for a second time to ensure the side facing the solar wafers will be clean enough.

Figure 7: Washing plant

Because the glass sheets are too heavy and delicate for manual handling a mechanical arm is installed in the lab. This arm can pick up and move the glass sheets from the glass storages to and from the washing plant. The mechanical arm will also be used to move the final laminated modules around the plant. Figures 8, 9 and 10 show the compressed air line, the rails for moving and the mechanical arm.

Figure 8: the air line for the arm

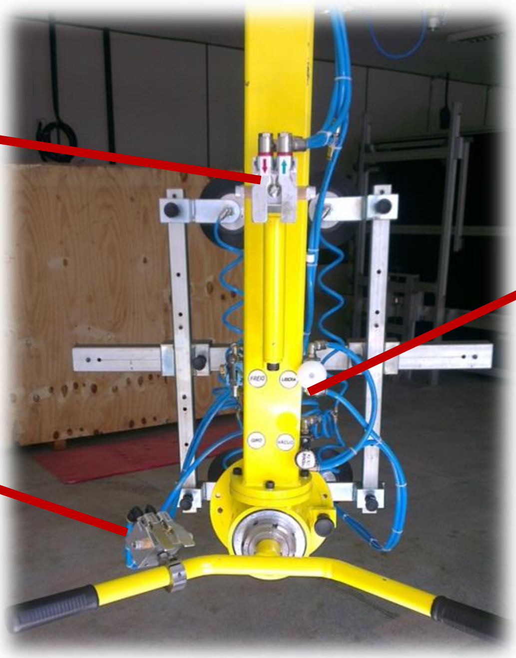
Figure 9: the rails for the arm

Figure 10: the mechanical arm

The operation of the mechanical arm itself is depicted below.

Buttons to move the arm up and down

Buttons to tilt the suction pads forwards (desce) and backwards (sobe)



Front of the mechanical arm with the buttons for its operation

Fredo = to release the break on the arm and enable the arm to move to the left and right
Giro = to release the break on the handle to rotate the handle vertically
Vacuo = to create a vacuum on the suction pads
Libora = to release the vacuum on the suction pads by pressing air out of the pads.

The mechanism to adjust the location of the suction pads both horizontally and vertically for modules of different sizes

Side view of the mechanical arm with the suction pads in a slight forward tilted position

The front of a suction pad

The procedure for cleaning the glasses is as follows:

1. Figure 11 shows the mechanical arm put in position in front of the storage of dirty glasses using the up/down and desce/sobe buttons.

Figure 11: the mechanical arm put in position in front of the storage of dirty glasses using the up/down and desce/sobe buttons

2. By using vacuo a vacuum is created and the glass will stick to the suction pads as is depicted in Figure 12. The glass can now be lifted and moved around the plant.

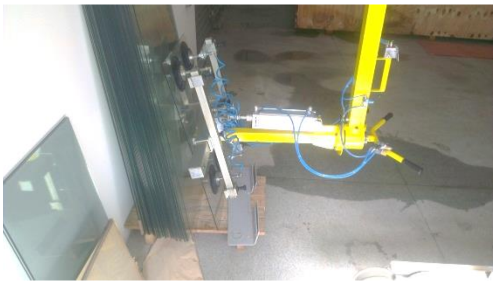


Figure 12: A vacuum created by the mechanical arm allows movement of the glass sheets

3. The arm is put into place for the inlet of the washing plant using the up/down and desce/sobe buttons. When the arm is in place the vacuo is pushed to stop the vacuum and libora to push some air through the suction pads to release the glass sheet onto the belt of the washing plant. The mechanical arm can now be removed from the washing plant and used to take a new “dirty” sheet out of the glass storage

Figure 13: The glass sheet before releasing it on the washing plant

Figure 14: The glass sheet on the belt of the washing plant

4. The glass sheets enter the washing process. When the sheet leaves the washing plant, the mechanical arm takes the sheet and puts it in the washing plant again using the same procedure as for the dirty sheets. In this way, the glass sheets go through the washing plant twice to ensure they are clean enough.
5. Next, the glass sheet is taken with the mechanical arm to the storage for clean sheets. Care should be taken to ensure that the clean side of the glass is not contaminated with any possible dirt.
6. When the suction pads are dirty, they are cleaned to ensure there is a good vacuum with the sheets.

When the washing plant is in operation, a final procedure for operating the plant in combination with the mechanical arm can be written with the use of this draft procedure.

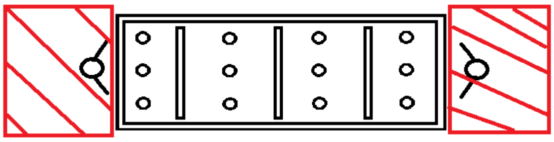
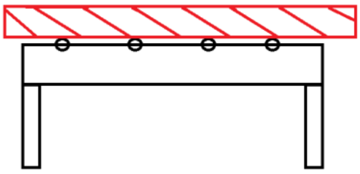
4. LAY-UP AND JUNCTION BOX TABLES

4.1. Specifications of the tables

In the photovoltaic lab, we use four assembly tables. Two of these tables will be used for the laying up process, one will be to take the modules out of the laminator and one will be used for the junction box mounting. For these tables, we have put a list of specifications together. In principal, all the tables are the same except that for the lay up tables, it is necessary to have light underneath the table top for inspection of the wafers and the soldering. Table 1 gives the list of these specifications.

Table 1

Assembling tables	
Amount	• 4 tables
Sizing	• Length = 2.50 m • Width = 1.55 m (equals width of entrance laminator) • “Working” height = 1.00 m • Height when supported by the ball casters = 1,137 m (equals height of laminator)
Additional requirements	• Transparent table top (for instance tempered glass) • Light source underneath table top for inspection of cracks and tear (interference with the light should be reduced to a minimum) • Height of the table is adjustable • Ball casters (spheres) to heighten the module and enables the movement into and out of the laminator (movement in both x and y direction) • The ball casters should be able to withstand the temperature of the laminator • Wheels under the table with breaks • Easy connection to the compressed air line • Two soldering stations per table at opposite places (for instance lower left side of the table and upper right side)

	• Ability to store small equipment (scissors, tape, gloves, tweezers, wire cutting pliers, clamps, caliper, ruler, a folder meter, a multi meter and a magnifying glass) • Equipment cannot be stored in the red areas because this will be the connection point where the table will be placed when the modules ‘ enter or leave the laminator  • Equipment cannot be stored in the red area because this will limit the movement of the modules 

For the design and manufacturing of the assembly tables CTI found the company Agmaq willing to fulfill this as they already have solutions for the glass industry and with installing the washing plant CTI had already positive experience with Agmaq. One of Agmaqs products is a table for handling, drilling and cutting glass sheets as is shown in Figure 15 below.

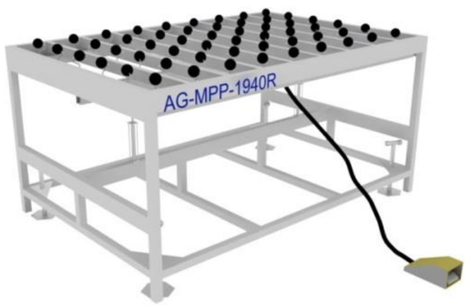


Figure 15: reference table Agmaq

Figure 16: commonly used design for an assembly table (Solar Module Production Line)

As this table is already used for similar applications and manufactured by Agmaq it would be the easiest to use this as a basis for the assembly tables and put through some adjustments to make it suitable for this specific purpose. Therefore, a table commonly used in other solar module product lines depicted in Figure 16 is combined with the table from Agmaq.

4.2. Draft design of the tables

To speed up the process and create a better picture of the demands a draft design is made using the design program Solid Works. Figure 17 shows the table in the assembly position. The ball casters are at their lower position and the different sheets rest secure on the transparent table top. On the right in Figure 18, the ball casters are heightened and the assembled module rests on the rolling balls. The module can now be moved in all directions and can be put in and taken out of the laminator.

Figure 17: The table in "working" position

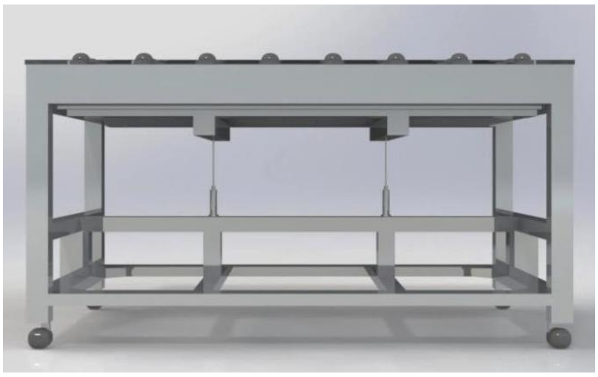


Figure 18: The table in upward position

Figures 19 and 20 shows the design from different positions with the transparent top and the lamps between the ball casters needed for lighting of the sheets.

Figure 19: The table showing the glass top

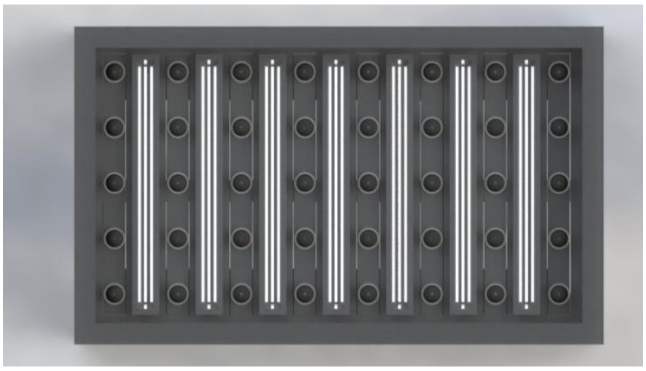


Figure 20: Top view of the table showing the lamps

Figure 21 and 22 show the ball casters in their downward and upward position.

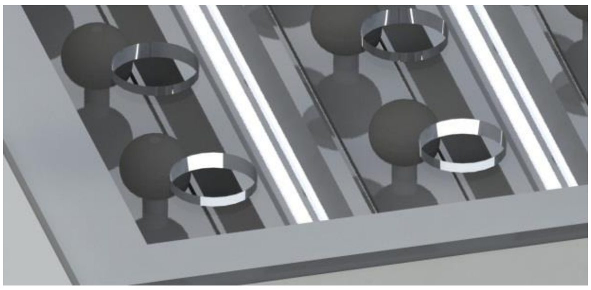


Figure 21: the ball casters in downward position

Figure 22: the ball casters in upward position

I discussed the list of specifications and draft design in a meeting with Agmaq. In order to fulfill this part of the photovoltaics plant, Agmaq should be contacted to discuss about the progress and to get a timeframe for the design process and a quotation.

5. SOLAR SIMULATION TUNNEL

In the photovoltaics lab, I set up at CTI a solar simulation tunnel to enable CTI to do research with the assembled solar modules and to test their quality. The tunnel, as can be seen in Figure 23, is a large box with in the front a module holder to hold the laminated BIPV modules. The module holder can be adjusted to fit different sizes of solar panels.

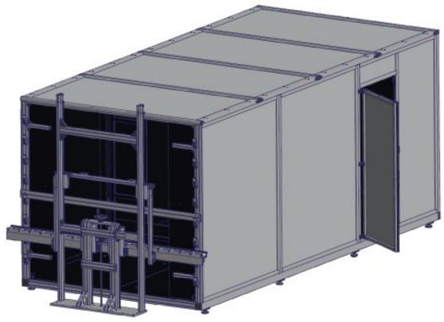


Figure 23: The solar simulation tunnel

The tunnel is painted black inside and is constructed in such a way that no light from the outside can enter the tunnel. On the back there is a flasher that gives light flashes at a predetermined rate. The light will go from the back to the front were it reaches the solar panel. Because the tunnel is covered in black paint all around, reflection in the tunnel is minimized and the light falling on the solar panel is almost all direct light from the flasher. A door near the back of the tunnel enables the engineers to do maintenance on the tunnel and the flasher. The solar panel put in front is connected to a computer that will read and analyse the data from the panel. The simulation software on the computer and the data from the panel are used for research and quality testing of the panels.

Originally CTI would hire an external workforce to assemble the tunnel, but as this would take too long and the other machines had severe delays, the assembly process became part of my internship. I carried out the assembly process together with another Dutch internshipper at CTI. Figure 24 and Figure 25 show the location and available materials at the beginning of the internship.

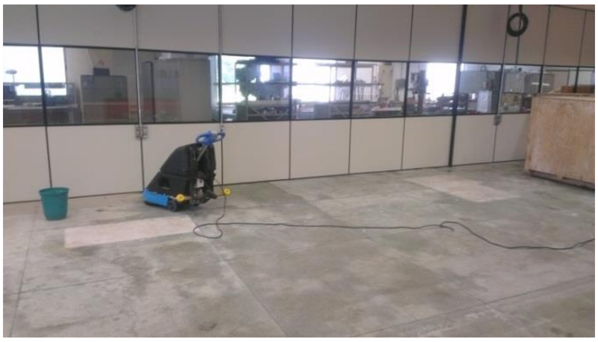


Figure 24: the location of the simulation tunnel

Figure 25: the materials for the simulation tunnel

Unfortunately the instruction manual that was delivered with the materials was very bad; a significant amount of critical instructions were not given or were very unclear. Most of the assembly process is therefore done on a basis of trial and error which took a vast amount of time as the methods for connecting pieces together were very different from those commonly used in the Netherlands. Figure 26 shows the ground structure.

Figure 26: The ground structure of the tunnel

Figure 27 shows the black painted floor and side panels on the ground structure. Two plates are put in the tunnel to focus the light from the flasher on the module. One of these plates is depicted in figure 28.

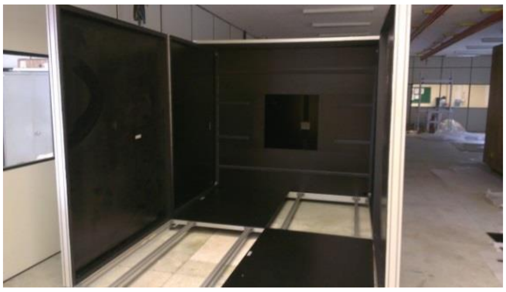


Figure 27: The simulation tunnel in progress

Figure 28: One of the black plates

The assembled solar simulation tunnel is depicted in Figure 29 and Figure 30 below. The module holder is also put in front of the tunnel. The tunnel could not be finished completely during the internship. The module holder need to be mounted to the ground and the flasher should be installed in the back by a specialist. The computer with the simulation software should be installed in front of the simulation tunnel near the wall. When everything is installed the first tests with the assembled modules can be executed.

Figure 29: the assembled simulation tunnel

Figure 30: the side of the assembled tunnel

6. ADDITIONAL MATERIALS AND APPLIANCES

Next to the machines discussed above there are a number of other “small” appliances and materials needed for this plant to produce the 300 KW per year of building integrated photovoltaics. The list is compiled with the use of a production manual given by the consultancy company Sunnyside UPp and by looking at comparable production lines. The list is added to this report in Appendix A and is given to a colleague to find the suitable suppliers.

7. WORK TO BE DONE

During the three month internship all the work that could have been done on the BIPV lab is fulfilled. There is however still a lot of work before the plant can produce the BIPV modules. This is largely cost by external factors. Below is for each part of the plant a short description of the work that is still needed.

Washing plant and arm: The washing plant and mechanical arm are installed but they need to be tested in order to make from the draft procedure a final procedure for cleaning the glass sheets. The storages for the dirty and clean glasses need to be designed and bought externally. It should be considered in the designing process that it should be easy for the mechanical arm to take the glass sheets from the "dirty" glass storage and put them after the cleaning process in the "clean" glass storage easily. Because only one side of the glass is cleaned in the washing plant the storage should be designed that the glasses do not make contact with each other.

Laminator: There has not been any progress so far on the laminator due to visa problems of the specialists. When the laminator is assembled first testing can be done on the speed and settings of the laminator.

Lay up tables: A list of specifications and a draft design is made for the 4 assembly tables that are needed in the photovoltaics plant at CTI. These are sent to Agmaq to make a final design and quotation and start the manufacturing process. When the tables are manufactured the testing in combination with the laminator can be fulfilled.

Solar simulation tunnel: The solar simulation tunnel is almost completely assembled but there are some minor things that need to be done. The module holder in the front of the tunnel should be mounted to the floor. In the back the flasher and the normal maintenance light should be mounted by the specialist. The computer with all the right software should be installed in front of the tunnel next to the module holder. After this the first testing with the tunnel can be done.

Stringer: Due to visa problems the stringer is not assembled yet. These visas should be acquired as soon as possible so that the stringer can be assembled and tested.

Additional appliances and materials: The list of needed materials and appliances is put together. For all these materials at least three suitable suppliers should be found. When the quotations are approved by the financial department the materials can be bought and put in the photovoltaics plant at CTI.

When all the machines, materials and small appliances are bought and installed the final workflow can be set up. This means getting the right time frame for each step in the assembly process and the right connections between the different steps. After this the first employees can be trained to fulfil these steps and get the plant up and running.

8. CONCLUSIONS

Using renewable energy as a source for our future energy demand is becoming increasingly popular. Of those green solutions photovoltaics is a very promising technology. CTI in Brazil wants to take part in this by starting a 300 KW per year producing building integrated photovoltaics plant at their research facility. During this internship a big step towards realizing that plant is made. The final floor plan is made taking into account some of the restrictions of the various machines. The washing plant and mechanical arm are installed and a draft procedure for handling the glass is put together. The solar simulation tunnel is almost completely assembled and the specifications for the different lay-up and junction box mounting tables are put together. A draft design for the tables is send to a potential supplier. All the other needed materials and appliances are put together in a list to enable to find the right suppliers.

There is however still a lot of work that needs to be done before the plant can start its operation. Largely due to bureaucracy and external factors not all of the goals of this internship have been reached. The laminator and stringer are not yet assembled due to visa problems of the externally hired specialists. The installation of the mechanical arm took almost a month which could have been done in three or four days because mistakes were made during the drilling process. The washing plant could not be tested due to vacation of the person in charge of its operation. All this made that roughly only 30 per cent of the total project is done in the internship period and a lot of time was spent waiting. This was very unfortunate as it would have been a great experience to see the plant up and running. However when the rest of the machines are assembled and all the materials and appliances are bought a final process scheme can be set up and a workforce can be trained to operate the plant. Than the plant can start producing the 300 KW/year building integrated photovoltaics and act as a good push in the right direction for the transformation towards a more sustainable energy based future in Brazil.

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APPENDIX A: LIST OF NEEDED MATERIALS

Number of modules =	100
Assembly per day	20

#	Material/Appliance	Used in	Amount		Additional information
1	6" Dummy cell / 2 busbar 220µ	testing in stringer/laminator	400	#	mechanical OK with printed busbars, potential suppliers are neo solar and motech
2	6" Dummy cell / 3 busbar 180µ	testing in stringer/laminator	400	#	mechanical OK with printed busbars, potential suppliers are neo solar and motech
3	6" Good cell / 3 busbar 180µ	complete process	4000	#	16-18% efficiency, mono or polycrystalline, potential suppliers are neo solar and motech
4	Ribbons	complete process	2	rolls	1,8mm x 0,15 mm, HKVT 1.8x0,15, potential suppliers are schlenk and broker
5			2	rolls	1,8mm x 0,20 mm, HKVT 1.8x0,20, potential suppliers are schlenk and broker
6	Busbars	stringer			5mm x 0,5 mm, HKVB 5x0,5, enough for 4000 cells potential suppliers are schlenk and bruker
7	Glass	complete process	100	#	Albarino_AR_4 mm_1648_996, Can find this locally
8	EVA	cutting table/laminator	4	rolls	100 m * maximum width, evasky, potential suppliers are STC and Bridgestone
9	Backsheet	cutting table/laminator	2	rolls	100 m * maximum width, ICOSOLAR AAASS3554_BLACK, potential supplier is isovoltaic
10	Junction Box & Cabling	junction box mounting	100	#	1740699-6 with SL1110 diodes, potential supplier is Tyco
11	JBOX Fixation	junction box mounting	10	kg	PV 804 Black, potential supplier is DowCorning
12	Soldering Wire	stringer	2	kg	Stannol_S-Sn 60 Pb 40, potential supplier is Prodelec
13	Laminator resistant tape	assembly table	200	m	Scotch 3M 8306, potential supplier is 3M
14	Flux	stringer	10	l	Kester_952S, potential supplier is Isotope electronics
15	Set of Label				6150 Tevus 2621 PS, potential supplier is BsB Bentlage
16	Methylated spirit	washing plant	5	l	for cleaning the arm
17	Isopropyl alcohol	complete process	5	l	used in a mixture with water for glass cleaning
18	Scissors or cutters	assembly tables, junction box mounting, cutting table	6	#	4 for the assembly tables, 1 for the junction box mounting, 1 for the cutting table
19	Wire cutting pliers	stringer, assembly tables, junction box mountign	6	#	4 for the assembly tables, 1 for the junction box mounting, 1 for the stringer
20	Knife	assembly tables, junction box mounting, stringer	6	#	4 for the assembly tables, 1 for the junction box mounting, 1 for the stringer
21	Tweezers with teflon tip	assembly tables, junction box mounting, stringer	6	#	4 for the assembly tables, 1 for the junction box mounting, 1 for the stringer

22	Fuzz-free nylon gloves	assembly tables	100	pair	
23	Slip-proof and cut resistant gloves or cloths	washing plant	3	pair	for washing plant
24	Heat resistant gloves	laminator	3	pair	handling after lamination
25	Fuzz free cloth	complete process	100	#	
26	Protection gloves	junction box mounting	3	pair	
27	Face masks	assembly tables	50	#	
28	Hairnets	complete process	100	#	
29	Eye protection glasses	junction box mounting	2	#	
30	Cut resistant forearm protection	junction box mounting	4	#	
31	Leather skirting as body cut protection	junction box mounting	2	#	
32	Clamps	assembly tables/flasher tunnel	12	#	8 for the assembly tables, 4 for the flasher tunnel
33	Calliper	assembly tables/flasher tunnel	5	#	4 for the assembly tables, 1 for the flasher tunnel
34	Ruler	assembly tables/flasher tunnel	5	#	4 for the assembly tables, 1 for the flasher tunnel
35	Folding meter;tape measure	assembly tables/flasher tunnel/stringer	6	#	4 for the assembly tables, 1 for the flasher tunnel, 1 for the stringer
36	Disposal bin	assembly tables/cutting table/junction box mounting, stringer	5	#	2 for the assembly tables, 1 for the cutting table, 1 for the junction box mounting, 1 for the stringer
37	Digital multimeter	assembly tables/junction box mounting	3	#	2 for the assembly tables and 1 for the junction box mounting
38	Magnifying glass	assembly tables/flasher tunnel	5	#	4 for the assembly tables and 1 for the flasher
39	Thermometer for contact free temperature measurement of photovoltaic module	flasher tunnel	1	#	
40	Soldering station with soldering tips	assembly tables/junction box mounting	5	#	4 for the assembly tables and 1 for the junction box mounting
41	Soldering	assembly tables/junction box mounting			amount determined with the supplier
42	Sealant gun (pneumatic or manual)	junction box mounting	1	#	
43	Sunshine resistant sealant (silicone)	junction box mounting	10	L	1 tube = 0,30 liter, assumption is about 3 per tube = 0,10 liter per junction box (0,05 L for sealant layer + 0,05 L for filling of sealant box)
44	Isolation material for wiring	junction box mounting	25	m	4 wires * 6cm/wire is around 25 cm per junction box
45	Screw driver	junction box mounting	1	#	Crosshead
46	Trolley for pre laminated and laminated modules	laminator	1	#	
47	Storage place for junction boxes	junction box mounting	1	#	
48	Wooden pallet for storage	junction box mounting/after process	15	#	assumption that 200 modules can be stored
49	Stacking corners to provide stability for the stacked modules and prevent scratches	junction box mounting	800	#	assumption that 200 modules can be stored
50	Stretch foil + device for unrolling of the stretch foil	storage	300	m	
51	Storage dirty glasses	washing plant	1	#	ability to store 50 glasses
52	Storage clean glasses	washing plant	1	#	ability to store 50 glasses
53	Storage EVA foils	cutting table	Integrated in design		
54	Storage backsheets	cutting table	Integrated in design		
55	metal container	outside of the lab	1	#	