INTRODUCING THE MANUFACTURE OF SOLAR OVENS AND PHOTOVOLTAIC MODULES TO A REMOTE VILLAGE IN COLOMBIA

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ABSTRACT

The Nicaraguan Grupo Fenix has been teaching solar oven workshops in Nicaragua and other Latin American countries for more than a decade. Coauthor Nimia Lopez was asked if she would come to Colombia and give a two week hands-on course in the Juaruco village before the next session of the cottage PV module assembly course offered by coauthors Richard Komp and Julian Lustig. Using a variation of the well established solar oven design adjusted for the different materials locally available, Nimia's group constructed four solar ovens of different sizes. The two largest solar ovens were made big enough to receive the 90 cm by 65 cm piece of glass used for the 65 watt PV modules, and the floor of one of the ovens was reinforced to take the extra load of the concrete blocks used as weights in the EVA encapsulation method developed by one of the co-authors, Richard Komp), which requires a heat curing process but costs 1/10 the cost of the two-part silicone it replaces. The encapsulations of two PV modules are reported, with the 65 watt module being the biggest PV module ever encapsulated using a solar oven instead of a commercial laminating machine

1. INTRODUCTION

Back in 1999, the Grupo Fenix and the Programa de Fuentes Alternas de Energia of the Universidad Nacional de Ingenieria in Managua started a program under the tutelage of coauthor Susan Kinne to introduce solar box cookers based on a design promoted by William Lankford into the rural areas of Nicaragua. Over the years, this design has been modified to produce more efficient ovens that are cheaper and easier to build[1]. In the last few years this successful program has expanded to include work introducing these solar cookers to compesinas in other countries. Coauther Nimia Lopez has given solar cooker workshops in Peru, the Dominican Republic and most recently, in Colombia. One of the biggest dangers to the health, and consumer of time of women in developing countries, is cooking with wood. The search for wood also leads to deforestation in these countries and can put the women at risk of attack, and in northern Nicaragua, risk of encountering unremoved landmines.

Fig 1: Nimia Lopez (second from right) and the compesinas with the finished solar ovens in Chupaca, Peru

While over one half of the people living in the rural areas of developing countries have no access to utility grids, Colombia is more advanced as most rural villages in that country have been wired for utility electricity. However, the delivery of electricity is very unreliable and often not available for hours or even days at a time. After hearing a paper by coauthor Richard Komp et al[2] at the ASES conference in Phoenix AZ in 2010, coauthor Julian Lustig invited coauthor Richard Komp to come work with him in his native Colombia to introduce these same cottage industry techniques for the peasants to build and install their own PV systems.

In the first PV module assembly workshop in March of 2011, we used the encapsulation method developed by Marco Antonio Perez[3] using two part liquid silicone as the encapsulant. However, for the second workshop in September 2011, we decided to use the new encapsulation technique we have developed that uses ethylene-vinyl acetate (EVA) instead of the much more expensive liquid silicone[4]. However, this process need a heat curing step where the entire PV module has to be heated to at least 120^{o} C for a minimum of half an hour. Since the location where we will be building the PV modules has no large oven available, we decided to invite Nimia Lopez to Colombia to offer the Grupo Fenix solar oven workshop as part of the program.

2. THE SOLAR OVEN ASSEMBLY WORKSHOP

2.1 Details of the Solar Oven Assembly Process

The basic process for assembling the solar box cookers has been honed over the past 14 years by the Grupo Fenix in Nicaragua and is available in a book published by them in 2004 (revised in 2011)[5]. However, since these solar ovens are assembled in remote locations, we vary the details to make use of what materials are locally available. For example, in the Barranquilla area of Colombia where the workshops were held, no aluminum printing plates were available so Nimia Lopez substituted 3 mm thick compressed hardboard covered with aluminum cooking foil for the printing plates as the inside liner of the ovens when she taught the workshop in the Juaruco Native American village in the hills north of Barranquilla.

Julian Lustig arranged for a neighboring carpenter to rip the proper shapes from local wood and Nimia Lopez taught the village compesinas how to cut these shapes to size and assemble the frame of the solar oven. They covered the outside of the frame with thin galvanized steel sheets and filled the wall and floor cavities with wood shavings as insulation before installing the interior box. Double layers of 4 mm glass were inserted into grooves in the top frame to create a 2 cm dead air space between the layers and the top layer of glass was sealed with transparent silicone caulk. An insulated, hinged top cover/reflector was fastened to the ovens, which were then painted with oil based paint to preserve them. Finally the oven adjustment rods were installed so that the reflectors could be adjusted as the day progressed.

2.2 Using the Finished Solar Ovens

Fig 2: Nimia (center) and Julian (2nd from right) and the campesinos with the solar ovens they built in Colombia.

Nimia Lopez and the compesinos built four solar ovens. Two of these were large ovens with exterior dimensions of 105 cm by75 cm by40 cm high. One had a reinforced oven floor to withstand the pressure of the weighted PV module being heat cured The second big oven was taken by the owner of a beach restaurant on the Caribbean coast near Juaruco and has .become a demonstration of what can be done with solar energy. A third smaller oven is at a second restaurant, while the smallest oven is at Julian's house.

Fig 3: Trying out the new solar cooker at the Caribbean beach restaurant.

3. BUILDING PHOTOVOLTAIC MODULES

3.1 Encapsulating the PV Modules

The Juaruco villagers had continued to assemble the PV modules after the first workshop in March, so they were very familiar with the techniques of sorting, cutting and soldering the Evergreen Solar cells into the sets of strings needed to assemble he modules. Coauthor Hugo Gonzalez joined Julian Lustig and Richard Komp to first assemble a 32 watt PV module, using the 150mm x 80 mm Evergreen solar cells cut in half for 75mm x80mm pieces. Using the technique described in an earlier paper[4], we placed the 4 mm thick front glass sheet on a black painted sheet of galvanized sheet metal and laid one sheet of STR Photocap 15295 EVA film on the glass. We had cut the EVA sheet exactly the same size as the glass. We then laid the six strings of six PV cells each on the EVA sheet and soldered the strings together in series, being careful to use a small piece of wood under the ribbon joints while soldering so not to heat the EVA prematurely. When the entire array was soldered and tested, we then laid a second sheet of EVA on the array of PV cells and laid the clear poly-vinyl-chloride (PVC) back sheet on top of the EVA sandwich and covered it with a second sheet of glass. The PVC back sheet was 2 cm larger in both dimensions than the 55 cm x 55cm square glass sheets so that any EVA squeezing out from the sandwich during the encapsulation would not glue the second glass sheet to the sandwich since the purpose of the second glass is simply to spread the weight of the two concrete blocks smoothly across the entire sandwich during the lamination process.

We then carefully placed the finished sandwich into the large solar oven and after putting a scrap piece of cardboard on top of the top glass sheet, we placed two concrete blocks on the finished pile. We then closed the oven door and adjusted the oven to receive the maximum sunlight and sart the laminating process. Since some clouds partially blocked the sun at times, this heat curing step took over 3 hours, but when the oven thermometer read 120°C for 30 minutes, we closed the oven reflector/lid and let the entire oven slowly cool. An hour later, we opened the oven, removed the concrete blocks and retrieved the finished laminated module, which worked perfectly, with a V_{oc} of 20.3 volts and a I_{sc} of 1.72 amps, under what we estimated as about a 800 W/m^2 sun intensity. We trimmed off the excess PVC back sheet and framed the module with 3 cm tall by 1 cm leg C channel aluminum extrusions.

3.2 The Large 65 watt Lamination

Two days later, we prepared and encapsulated a 65 watt PV module using 36 of the full size Evergreen Solar cells. The process was the same as for the smaller module with the only difference being that we had to readjust the door on the front of the oven to fit the big module into place properly since the 90 cm x 60 cm glass sheet was slightly larger than Nimia Lopez had anticipated when she made the door. We also used a second black sheet of galvanized steel on top of the sandwich instead of the cardboard for this experiment

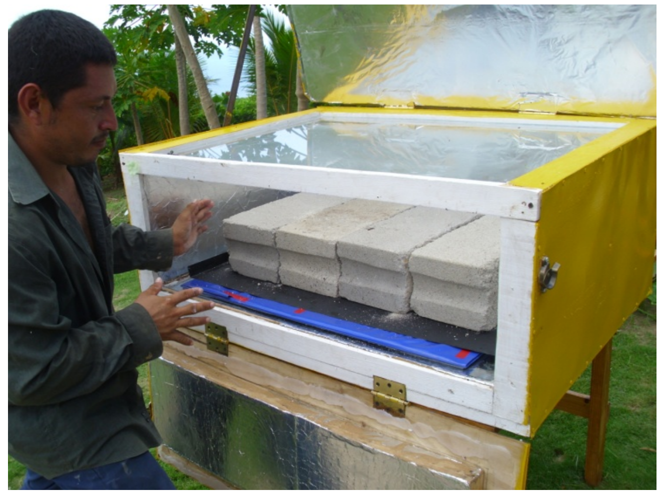

Fig 4: Coauthor HugoGonzalez adjusting the PV module

With the bigger load in the oven and more partly cloudy skies, it took over 4 hours for the oven to get to the proper laminating temperature so we left the lamination in the oven overnight. The final result when we unpacked he oven the next morning was a perfectly laminated 65 watt module. The V_{oc} was 20.8 volts and the I_{sc} was 3.7 amps in the morning sun Again we had to estimate the sunlight intensity, which was similar to that when we tested the first PV module.

Fig 5: Richard Komp and Hugo Gonzalez showing the first full size 65 watt PV module made using this new lamination method.

4. <u>FUTURE WORK</u>

One of the problems that came up when Nimia Lopez gave the solar cooker workshop in Peru was the weight of the solar ovens. Women had come from five different villages up in the Andes and women from two of the villages had no way to get the ovens back to their remote villages. Nimia and Richard Komp have designed a light weight portable solar oven that folds down to a packet that is easily carried by one person (on on the back of a llama) for use in remote locations. When Richard had a group of nomads make solar ovens in Agadez, Niger West Africa, the same problem occurred so we will also introduce the new oven there. With some funding from the Whole World Botanicals Company, Nimia has started building the first prototype of this oven.


Fig 6: The partly completed portable solar cooker being made in Nicaragua. It will fold down to a packet about 15 cm tall.

5. <u>CONCLUSIONS</u>

It is very difficult to introduce solar ovens to rural communities in the developing world. The social process is far more important than the technology, although the technology has to work superbly well to have any success at all. Since Nimia Lopez is a compesina who can relatewith the women she is working with, she has considerably more success in this important endeavor of bringing this firewood and smoke-free method of cooking to these remote locations.

The success in using these same solar ovens as the heat source for laminating PV modules using EVA is important since the EVA is only 1/10th the cost of the room temperature curing silicone the EVA replaces. This will make it possible for people to use this cottage industry method to build their own PV modules and compete with the new lower prices of commercial PV modules from developing countries. This work will continue the work that we have been undertaking in many parts of the developing world to not only bring affordable electric power to these rural areas, but to do so in a way that supports the economy of the area and creates local jobs[5].

6. <u>REFERENCES</u>

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