# Final Report

## Small Solar Cooker Subteam

### Description of Problem

Currently, the only solar ovens available to the solar oven team at Cornell are exactly the same as those used in Nicaragua. These ovens work well and are invaluable for tests aimed to improve the efficiency and effectiveness of the Nicaraguan ovens. However, these ovens only work under the solar oven team's overhead lighting array in a laboratory setting. In order to demonstrate the usefulness of solar ovens without using artificial lighting, the team decided to design an oven compatible with the Ithaca climate and location. The new oven was to be scaled down in order to transport more easily and the window was angled to allow maximum solar gain, sized to be carried by one person and fit through a doorway, and constructed of locally available materials.

A side project that was undertaken at the beginning of the semester: the development of a new method for propping the lids (which act as reflectors to increase the incident radiation into the oven) open on the ovens in Nicaragua. Some of the Nicaraguan women affiliated with an organization dedicated to the promotion and production of solar cooking devices called Grupo Fenix had asked for several years for help in the design of prop rods. These rods would be able to prop the lids stably and securely during wind and that could be infinitely adjusted, as opposed to the one-sided flimsy wood board design with a series of drilled holes that act as settings (which operates as the current design).

### Methods

The design of the small solar oven was based on the team's existing Nicaraguan oven designs and on another small oven previously built by the solar oven team, which is frequently used by Professor Francis Vanek. The new design for the small solar ovens incorporated the best elements of each of these ovens, eliminated elements that do not work well, and created solutions to produce an elegant and functional design.

The first step of the design process was to design the frame of the oven. This included determining the angle of the glass window. Research suggested that a solar collector (in our case, the glass surface) should be angled off from horizontal by a value approximately equal to its latitude. Ithaca sits at a latitude of 42°26' North. The team decided to modify this value and use an angle of 45° two reasons: first, a 45° angle simplifies the design and improves constructability, and second, 45° allows us to capture more solar energy in the fall and winter when the sun does not rise as high.

The team then determined dimensions for an oven that one person can carry, while accommodating three pots. Professor Vanek's oven proved useful for this task, as it can hold three pots and be transported by one person. The interior of the oven was sized such that a small pot could be pushed to the front of the oven and not be impeded by the angled glass cover. A design was produced in AutoCAD to which the team referred throughout construction (Figure 1).

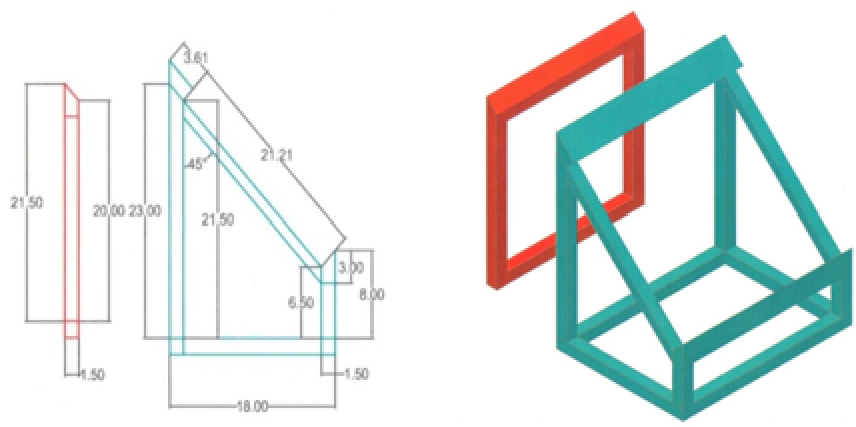


*Figure 1: AutoCAD drawings of the Frame*

After the dimensions for the oven were determined and the frame was designed, the team needed to determine the essential materials used in the oven. Since this oven will only be used in Ithaca, the team decided to ignore the limitations on materials to those only available in Nicaragua. Materials were chosen that are readily available locally, rather than imitating the materials used in Nicaraguan ovens
The team used 2x4 lumber that was split in half lengthwise to construct the oven's frame. This lumber is easy to come across locally, and happened to be stocked in surplus in the lab. The framing was all connected with coated wood screws available in any hardware store. Fiberglass insulation was used in the cavities of the oven because of its good insulation properties, its compatibility with high temperatures, and its local availability. The inside of the oven is covered with a thin fiberboard which offers some insulating properties as well as structural support for the thin, reflective, metal film attached to the inside of the oven. The team had originally decided to use aluminum sheeting to line the interior of the oven, but a roll of the film was presented to the team and we decided that it would most likely perform better. Double pane glass is used for the oven cover to maximize heat gains and provide better thermal resistance. The small solar oven is depicted in Figure 2 during and after construction.

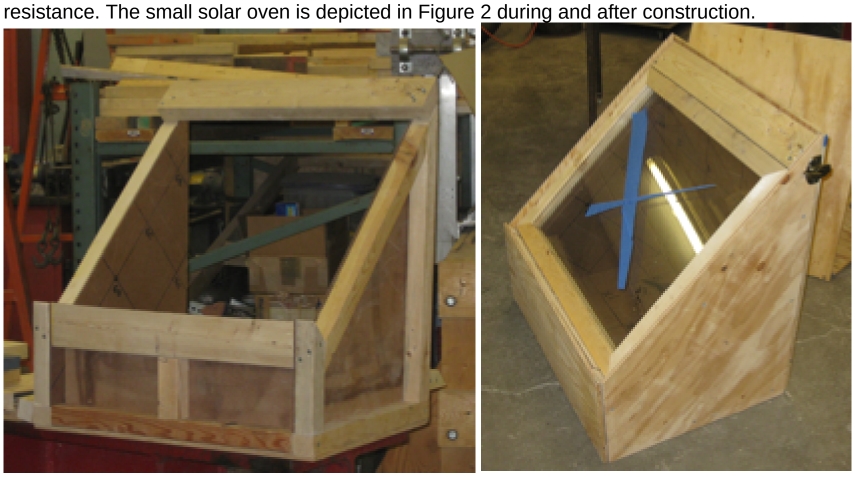

*Figure 2: Oven Frame during Construction and Completed Oven*

In addition to designing and building the small solar oven, the team was also working to develop a new design for the prop rods on the ovens currently used in Nicaragua. The current prop rod design consists of a single wooden bar with holes so that the user can select the height and angle of the solar oven's lid. The method for determining a new prop rod design mainly consisted of discussion. There were a variety of factors to consider when designing a new prop rod. Such factors included availability of materials, ease of construction and retrofitting and if the new design would have any impact on how Nicaraguan women used the oven. The final design selected was based off of a prop rod design used on one of the power tools in the Winter Lab (Figure 3).

_Figure 3: Prop Rod_

## Results and Discussion

This semester, the small solar oven team set about designing and building two smaller box ovens. We set a tentative schedule as a group, as to when we thought we'd finish each phase of our project, and began work. Looking back at our progress throughout the semester, our team was able to successfully follow our schedule upon completion of each milestone, except for a few instances. The design process took a little longer than expected, but producing a well-thought design before beginning construction proved to be very beneficial down the road, as we did not encounter any major setbacks, or unforeseeable factors. Since we were confident of our design, to make up for the extra time added to the design process, we were able to use the services of a few interested ESW chapter students, who were keen on helping us out. We were able to give them clear instructions on various tasks, while we continued construction and this reduced construction time noticeably. At the end of the semester, we successfully completed one of the ovens, while the other is nearly complete. The second oven will be completed during study week, or by the students in the ESW chapter as the oven is being built for their use.

Concerning the small ovens, the semester proved to be a success. Our team worked through the design and build process without leaving out important details of the oven's design. The team had spoken with Professor Vanek, who has been using a small solar oven for a few years, before the start of the design process. We discussed ways in which the oven could be improved, and were able to incorporate all of these suggestions into our design to produce a cooker that is both more comfortable to use and more robust. Such suggestions included a better system to secure the oven door. Originally, a bungee cord had been used to close the door; this did not allow for a very tight fit and was somewhat dangerous. Also, the oven was made slightly taller to accommodate larger pots and the glass cover was made removable. We were able to keep a good balance of staying with a proven design, while making changes to improve performance and intuitiveness in the design.
The primary objectives of the small solar oven team were to design and construct a solar oven that is smaller than the conventional design that could work in Ithaca, which were achieved. Underlying these goals was the pursuit of promoting solar oven technology in the Cornell and Ithaca communities. Due to the interest in alternative energy of the populace in Ithaca, it seemed only fitting to translate the technology of solar cooking from ovens designed to work in Nicaragua to ones that would work in Ithaca. If anything, raising awareness in the Cornell community was definitely achieved through conversation regarding the project between the team members and their friends and acquaintances. This project even attracted younger prospective engineers, who volunteered their time to aid in construction; this further suggests that the project was indeed successful.

With regards to the prop rod project, the team developed a simple design using materials present in the lab. A 3/8-inch diameter steel rod fitted with a brass tee to be attached to an oven that was threaded for a bolt to screw in and apply pressure on the rod to hold it in place. The team is confident that the new prop rod will solve the problem of the tops coming loose, but time constraints prevented the group from conducting tests to evaluate their performance.

## Criteria Review

### Technical

The technical criteria for the construction of the small solar oven were relatively straightforward. First, the oven needed to be small enough so that one person could easily carry and transport the oven. Current designs used in Nicaragua are large, bulky, heavy and impossible to be carried by one person. The new oven is much smaller in size and can easily be carried by one person. Though the size was significantly decreased, the oven is still large enough to fit three medium sized pots comfortably in the oven. Additionally, the oven design was altered to accommodate for the solar elevation in Ithaca. The glass window in Nicaraguan ovens is flat, but the oven designed for Ithaca had to be tilted in order to maximize sun exposure. Construction of the oven was completed, however a set of reflector panels has not yet been constructed. Therefore, we have not tested the oven to see what temperature it can reach. However, since the design was closely based off of Professor Vanek's fully functional oven, we are extremely confident that with the addition of reflector panels, the oven will reach high temperatures necessary for cooking. Materials used for constructing the oven were mostly available in the Winter Lab and similar to those used in construction of the Nicaraguan ovens. Though the materials the team used were not exactly what is used in Nicaraguan ovens, they are not drastically different and will give people a good representative of the materials a Nicaraguan oven is made of. Overall, the technical criteria proposed at the beginning of the project were fully maintained.

Though the prop rod project was not mentioned in the original proposal, there are also applicable criteria for this project. The prop rod design needed to be easy to use and robust, considering current designs were not holding up in heavy winds. Though we have not devised a way to test the current design, the team believes that it will hold up better than the wooden prop rods since it is made of metal. An additional benefit to the new prop rod design is that there aren't discreet places that the prop rod must be at (the old design consisted of a series of holes in a wooden rod), but rather the user can slide the metal rod along the hydraulic fitting to get the desired height of the oven lid.

### Social

The social characteristics of this project vary slightly from those of the other solar oven subteams. While we are all working towards the same cause- providing an inexpensive way for women in Nicaragua to prepare food, the small solar oven team is more concerned with outreach rather than improving the design of the ovens used in Nicaragua. The construction of the small solar oven will enable us to effectively demonstrate how solar ovens work and how well they work in Ithaca. Because the design was altered for the Ithaca solar elevation, the demonstration will be more meaningful because the oven will be able to reach higher temperatures and not require artificial lighting. Promoting the solar oven project will help the team get recruits and also make the general public more aware of the cause. Promotion of solar ovens may even convince people to get their own solar oven to use instead of traditional ovens. This helps promote the use of green energy in Ithaca.

Since the women from Nicaragua put in a specific request for the team to address the prop rod problem, there aren't any concerns as to whether the new design will be accepted among users of the oven. The design change will be welcomed, as it solved a problem with the current ovens.

### Economic

In our proposal, we planned to use mostly materials available locally in Nicaragua so that our demonstration oven would accurately represent ovens used in Nicaragua. However, we did not limit ourselves to using only materials used in Nicaraguan ovens. We constructed the frame and siding using wood, as Nicaraguan ovens are constructed. Fiberglass was more readily available and is a better insulation material than wood chips, which are traditionally used in Nicaraguan ovens, so the team opted to use fiberglass instead. Additionally, reflective sheeting was used for the reflective inside. It was readily available in the lab and did not need to be purchased; therefore it was a cheaper option than sheet metal. Overall, since the team was able to utilize many materials available in the Winter Lab, the cost of construction of the oven was extremely low, which upheld the original criteria outlined in the beginning of the semester.
Additionally, the prop rod also needed to be made of cheap, locally available materials. Hydraulic fittings and metal rods are inexpensive and thus fill the economic criteria for this section of the project. Also, because the new design is more robust, prop rods will not have to be replaced as often, thus saving money for the Nicaraguan women using the ovens.

### Environmental

The primary focus of the solar oven project has been to minimize energy consumption. By using the sun's energy to cook food, we directly reduce the amount of nonrenewable energy (specifically wood) that Nicaraguan women use to cook. The small solar oven's purpose is to help promote the project so that we can optimize designs and make solar ovens more available to Nicaraguan women. Additionally, we wanted to make the oven as robust as possible so that it has a long lifetime, without overdesigning the oven. The longer the lifetime of the ovens, the less often they must be replaced and less resources will be used in construction of the ovens. The team believes that the design for the small solar oven is robust enough to have a lifetime of at least five years. Designs were based off of a small solar oven that has been in use for five years. Improvements on the old oven's design should increase the lifetime of the new small solar oven.

### Recommendations for Future Teams

This semester, the small solar oven team had planned to construct two fully functional solar ovens to be used for demonstration purposes in Ithaca. Due to time constraints, the team was not able to complete these tasks. Future teams should finish the construction of the second small solar oven. Additionally, a reflector panel system must be designed in order to maximize the oven's sun exposure to reach desired temperatures. This system can be based off of the reflector panels currently used with Professor Vanek's oven, adjusted to improve ease of constructability and oven temperature. Additionally, future teams should work towards developing an experiment to test the robust-ness of the new prop rod designs and perhaps taking them to Nicaragua on the spring break trip to retrofit current ovens with the new prop rod.

### Conclusion

Overall, the small solar oven team had a very productive semester. Our original goals were to design a solution to the prop rod problem and design and build a small solar oven for demonstration purposes in Ithaca. We devised several feasible new prop rod designs, all which would be easily integrated into the current Nicaraguan solar oven design. Additionally, ovens already in use would be easily retrofitted to incorporate the new designs. We were not able to come up with a way to test these designs, so we do not know how well they work, but the team is confident that the new prop rods are much more robust than the previous prop rods.

The majority of the semester focused on the design and construction of the small solar oven. The team was fortunate enough to have an oven to base designs off of, but we still had to consider how the frame would fit together, the best way to assemble the oven, and how to construct the oven to maximize insulation.

In estimating the timeline for completion of the project, the team underestimated how long construction of the small solar oven would take. Most team members were inexperienced with construction and had minimal knowledge to estimate how long the project would take. Additionally, we were not able to test the effectiveness of the prop rod designs because work in the latter half of the semester was heavily focused on completing construction of the oven. Fortunately, the solar oven project is an ongoing one, so the Spring 2011 team will be able to complete the work that time constraints prevented us from finishing.