Kiwa®

100% Natural

Group

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Project Summary

Project Summary

Introduction

The following report documents the background, design, development, and testing of a solar heating project undertaken by our D-lab team in partnership with the Ecuadorian company, Inaproces. Our report highlights key factors that contributed to our design process including client needs, prior art, and achievability within the project's 10-week timeline.

Today, social and environmental responsibilities are emerging as powerful marketing tools in the developed world. Kiwa, an Ecuadorian vegetable chip brand, created by the Inalproces company, demonstrates commitment to both. The company approached the UC Davis D-lab expressing its interest in expanding the Kiwa brand and exploring solar technologies for dehydrated fruit chip production. Kiwa hopes to reduce the costly energy it consumes in its current frying process and increase the environmentally friendly image of its brand.

Starting in January 2013, D-lab teams worked with Inalproces to research and develop solar systems for dehydrated fruit production. In the spring of 2013, our D-lab team developed a rooftop air preheating unit that utilizes solar energy to increase the temperature of the air entering a gas burning fruit dryer.

Project Goal

Assist Kiwa, a small vegetable chip company in Ecuador, in exploring solar options for expanding their production into fruit drying.

Project Objective

Design and prototype a system that utilizes solar energy as part of a fruit drying process that is both appropriate for Kiwa and the Ecuadorian climate.

Background: Ecuador and Inalproces

Kiwa is located in the province of Calderon, at the north of Quito, Ecuador.

Quito is the capital city of Ecuador. It has an elevation of 9,350 feet (2,800 meters above sea level) and it is located in north-central Ecuador, in the Guayllabamba river basin. With a population of 2,197,698, Quito is the second most populous city in Ecuador.

The city has a Mediterranean climate, with spring-like weather year-round. Quito receives on average 298 sunny days every year. The solar irradiance in Quito is approximately 5-7 kWh/m2/day. For these reasons, solar technology is appropriate for the region.

Inalproces launched Kiwa in 2009. The company produces and exports fried vegetable chips to many international markets, including the United States. Kiwa means "green" in Quechua, a local native language, and the company promotes itself as an environmentally friendly and socially responsible entity. The company sources its raw materials specifically from low-income farmers mostly in the north and central highlands of Ecuador (including, Carchi, Pichincha, Imbabura, Tungurahua, Cotopaxi, Chimborazo, and Bolivar). This commitment to supporting small farmers makes Kiwa an ideal candidate for our D-lab project.

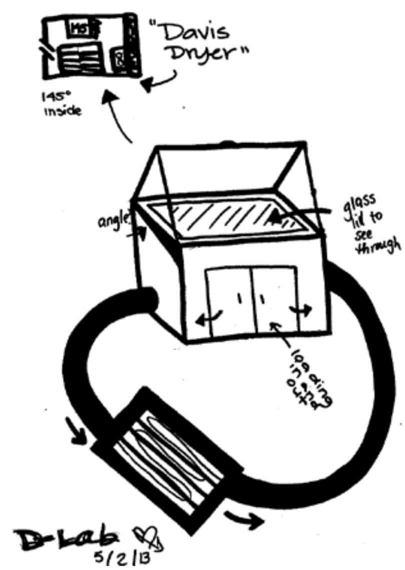
Currently, Kiwa's chip production involves an energy-intensive frying process. Chips a friend in vats of oil that are heated with natural gas. The company then drains, sorts, and packages the chips on site. The costs to heat the oil are high (The company spends about $ 4,000 in propane gas consumption each month), and for this reason Kiwa is interested in exploring solar dehydration to cut costs.

As our D-lab team explored new avenues for production for Kiwa, we took the company's needs and interests into account. The company is interested in utilizing solar energy as a means of reducing costs, producing a quality product, diversifying the brand, and promoting the company's environmentally–friendly image. Kiwa expressed its openness to investigating a variety of approaches to achieving these goals.

Preliminary Design Considerations

Building upon the previous research carried out by the D-Lab team working with Kiwa in the 2013 D-Lab I course, our team explored a variety of articles and books related to solar energy capture and food drying. These sources are listed in the report appendix. Our initial goal was to design and construct a food drying system. Since Kiwa is a mid-sized food processor, we noted the scale of the project and recognized the need to design a system for an industrial entity capable of processing a ton a raw material each day.

Our team examined several food drying systems including direct solar systems, indirect systems, and hybrid systems. In our initial design concept brainstorm, we drew inspiration from rooftop solar pool heaters, greenhouses, and even the Easy-Bake Oven. Many of the preliminary design ideas are recorded in the report's appendix.



After presenting our research to D-Lab reviewers, we met with project mentor, Jim Thompson, and narrowed our focus. The team's first goal was to design a three-part food drying system. This system included a solar rooftop air heater, a dryer, and an air heat exchanger that would utilize exhaust heat to increase the temperature of incoming air. Due to time and expertise constraints, however, the team decided to focus specifically on developing a system to pre-heat the air flowing into a traditional gas- powered dryer. In this way, Kiwa would utilize solar energy to increase the temperature of the air entering the dryer, decreasing the amount of time spent running a gas burner to heat the dryer.

The new focus of the project was proposed to Kiwa and the company expressed positive encouragement.

Design Process

General Considerations

One of our first considerations was to primarily focus on designing a solar collector which would heat the incoming air we fed to the dryer system, rather than focusing on designing the dryer which would be drying the food. This is because there are many solar drying systems already in existence, and Kiwa specifically asked us for a way to incorporate solar into their existing system. Therefore, it was in our best interest to maximize our efficiency by focusing on the collection of solar energy as a way to save energy further along in the process of drying the fruit. We narrowed this down even more by determining that we'd like to focus on a system which would focus primarily on horizontal air movement, which is to say that is would lay flat most, if not all of the time. This decision was due mostly to the fact that Ecuador is on the equator, and thus would get the most sun exposure by laying the solar collector flat (either on the ground or on the roof of the existing factory). We also had to consider designing this prototype with the intent to run tests and experiments on it in order to gauge whether or not we were on the right track with our design meeting the needs of the client. Luckily for us, our client, Kiwa, was very open and supportive about the possibilities, direction, and methods we decided to go in, and they encouraged us to do whatever we thought would be the best design decision.

Metrics

Two major metrics we worked under were to make sure we reached a temperature of 145°F, which is the ideal temperature to of air to dry the fruit, at the ideal temperature at which the enzymes of the fruit break down so as to maintain the freshest color which is a vital component of Kiwa's gourmet market brand image. If we didn't hit this temperature while drying the fruit, it would become brown as it dried and create a less-than-superior product. Additionally, we also measured our progress by our ability to be able to be a part of a system that processes up to 1 ton of fruit chips a day, which will be possible once we find a compatible fruit dryer design to attach to our solar collector.

Assumptions

We had to assume a few things in order to start designing our prototype. Namely, although when one thinks of solar, they often think of photovoltaics, we had to assume that these are not practical for a number of reasons, including maintenance, lifespan, and number one, cost. Photovoltaics are simply too expensive and fragile to be considered a viable option in our prototype design. Therefore we must figure out some alternative way to incorporate solar collection in our design. We also decided to make the assumption that an indoor drying system is a much more industrial system than an outdoor system. This is because our client Kiwa is already a fairly industrialized company and has indoor facilities. The decision to design an indoor rather than an outdoor system was to accommodate for their current needs. Finally, we had to assume that we would be able to attach our design to an existing gas-powered dryer design to ensure for operational reliability and product quality throughout the life of the system.

Pre-Prototypes

Designs

We designed five pre-prototypes to be constructed out of cardboard boxes to test different possible structures of the final prototype. The first pre-prototype was our "control" which we designated as simply an empty cardboard box painted black with the lid shut tight. The next box was the same idea but with a "glass window" we fashioned out of cellophane/saran wrap. Next, we constructed a box with a window just like before but we left this one unpainted. In addition, we constructed another black box with a window as well as including a black metal tube inside, which we deemed the "solar tube" design. Finally,

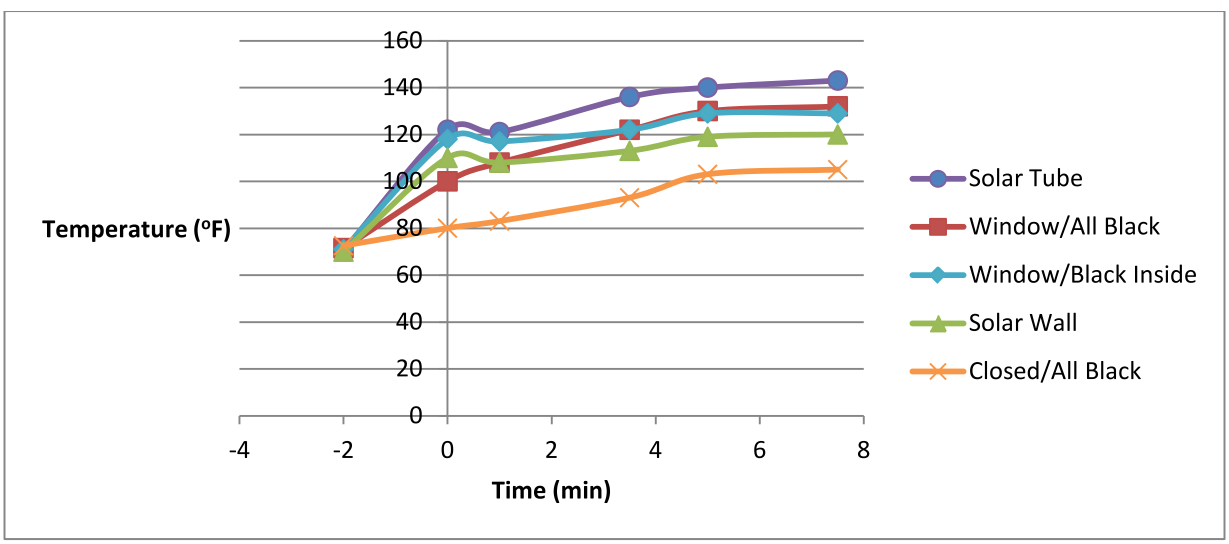
we constructed the “solar wall” design by using perforated tin foil and applying that over the last cardboard box which was also all spray-painted black.

Experiment

To test the pre-prototypes, we took a temperature reading of the stagnant air inside each box using five probe thermometers punctured in the same spot to compare their relative maximum air temperatures. When placed outside towards the sun, we were able to take immediate change in temperature readings.

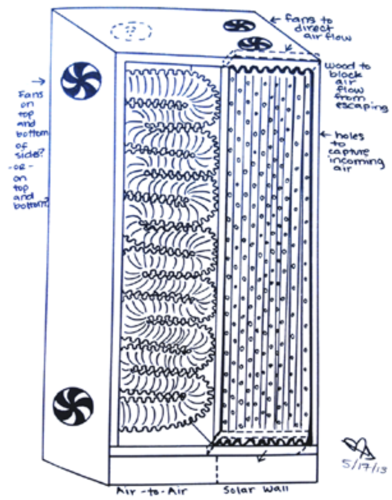
Results

Our results clearly showed that the “solar tube” design outperformed the rest of the pre-prototypes, with the fastest gain in temperature as well as maintaining the highest temperature overall. Additionally, we also collected some surprising data. For instance, we learned that painting the boxes black on the outside verses just black on the inside had no real temperature affect. So when constructing our final prototype we decided to paint both the inside and the outside for more esthetic purposes knowing it wouldn’t lower the temperature significantly. Finally, in viewing our collected data for, we decided to go with the two most promising designs (the “solar tube” and the “solar wall”) because these were the most interesting designs with the most potential, as well as the ability to compare both side by side to see how our design (the “solar tube”) faired with a conventional design already on the market (the “solar wall”). This comparison was sure to give us more data on the performance ability of either design.



Final Prototype

Considerations



For our final prototype, we decided to compare our top pre-prototype design to the solar-wall. Half of it would be a metal tube with plexiglass covering it. Air would flow through the tube, heating up as it passes through. The other half would be a solar wall, a corrugated steel sheet with holes all over. The air would heat up in contact with the steel and be drawn in through the perforations.

Because the pre-prototypes were only tested by heating stagnant air, we worked to include air flow through the final prototype. The design is intended to function horizontally, so natural convections couldn't be used. Rather, two 12V computer fans would power the air flow on each half of the design. A potentiometer (adjustable resistor) would be installed to regulate the voltage to the fans, allowing the fan speed to be controlled.

This prototype would be large and heavy, so mobility would be needed.
A pair of wheels and handles would allow a person to move the prototype by themselves.

Finally, this prototype would need to be designed for experimentation. The area exposed to the sun and the area of the air inlets would be the same for both designs. The fans would be designed to have the same voltage in order to have a similar air flow. To track the temperature of the air flow, 5 probe thermometers would be set up through the prototype: at the inlet, outlet, and middle of the solar tube, and on the outlet and surface of the solar wall.

Construction

To construct the prototype, we used a refurbished metal bookshelf as the enclosing. First the entire bookshelf was painted black. Then the internal space was halved by a divider made from repurposed bookshelves riveted together. Insulation was installed in the divider to reduce the effect of close contact of the two halves. A 3" diameter hole was sawed from both halves on top and on the bottom of the solar tube side of the prototype. That way both halves would have an outlet but the solar tube's inlet would be on the bottom while the solar wall's inlets would be the punched holes.

One half of the bookshelf had the solar wall covering the inner space.It was fabricated from a sheet of corrugated steel with holes punched buy a screwdriver and a hammer and painted black. This design mimics the solar wall system currently marketed for industry and home use. Each punctured hole is 5x10mm and the team calculated the number of holes necessary to match the area of the air intake hole (3 inch diameter) of the solar tube system. Those calculations are as follows:

Area of 3in (74mm) wide tube = 1/2 π (37mm)^2 = 2149.33 mm^2

Area of perforation = 10mm x 5mm = 50mm^2

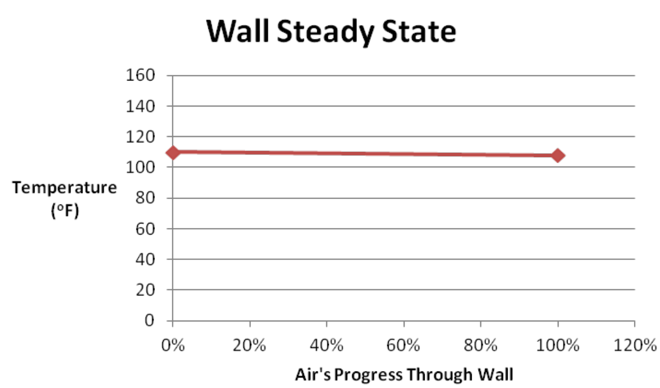
2149.99/50 = 86 puncture holes

Our team made 84 puncture holes, and left the corrugated steel without insulation at the end opposite the fan allow for a small amount of extra air to flow through the system. The sheet of punctured corrugated steel was secured to one side of the refurbished bookshelf using rivets. The gaps left by the ridges in the metal were stuffed with insulation and taped over with aluminum tape on the outlet end of the prototype to reduce the amount of heated air that could escape the system.

The solar tubes were constructed from four 3" diameter 8' long aluminum ducting painted black and connected with aluminum tape. 4"-to-3" pipe reducers were inserted into the cut holes and the solar tube was attached to the inlet and outlet holes of the solar tube half. Two computer fans were inserted into each 4" outlet pipe reducer. Gaps around the fans were filled with scrap insolation. Both fans were connected to the same potentiometer which was connected to a 12V DC converter. This fan arrangement allowed them to be powered by a 120V AC wall outlet, supply the same voltage to both fans, and control the speed of the fans. Finally the solar tube half was covered with plexiglass, everything was riveted together, all the extra air gaps were filled with leftover insulation, and finishing touches were added like paint and a fan control knob.

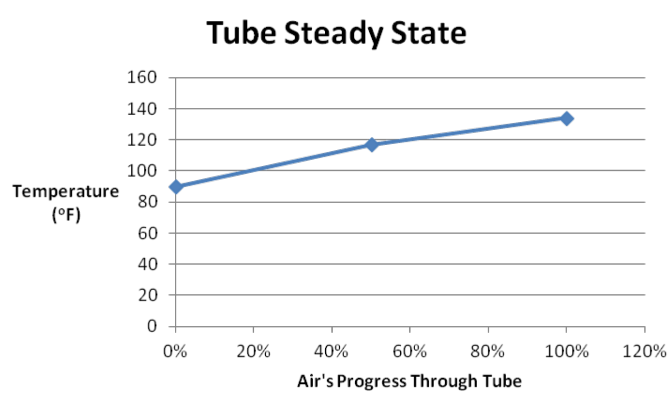
Experiment

To test the final prototype, we recorded temperatures as a function of time in the sun. Five thermometers were set up in key points to see the behavior of the heated air as it flowed through the two designs. The prototype was laid horizontally during a sunny day around noon and was plugged into an extension cord to power the fans. Temperatures were recorded in °F at time intervals for 60 minutes; the time intervals became larger as steady state was reached.



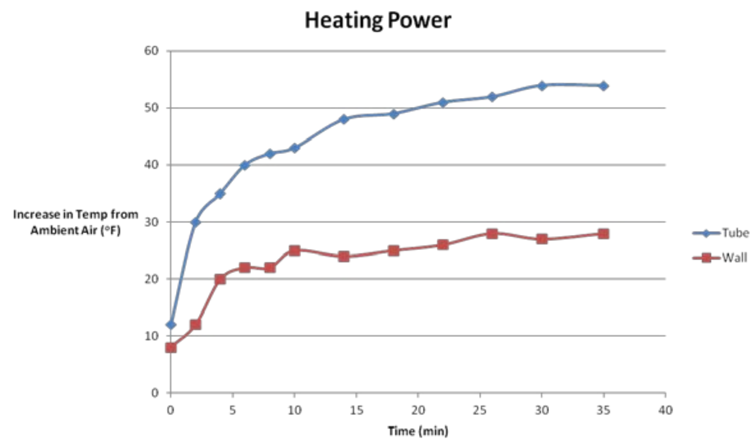
Results

To process the readings, the temperature profile of the design at steady state was used to plot the temperature of the design as a function of distance traveled through the system. In the solar wall design, the wall's temperature marked the beginning of the air flow and the outlet temperature marked the end. The solar tube's inlet, middle, and outlet marked the beginning, middle, and end of the air's path. This gave an idea of how fast the air was heating up and how close the air was to its maximum temperature. As is shown in the graphs, the solar wall's outlet temperature is about the same as the temperature of the wall, indicating that the air is reaching its maximum temperature as this air speed. The solar tube's middle temperature is



approximately the median of the inlet and outlet temperatures. This suggests that the air's temperature hasn't reached its maximum temperature and may get hotter with slower fan speed.

To compare the effectiveness of both designs by their ability to heat up the air, a plot was made graphing each design's increase in air temperature from the ambient 80°F as a function of time in the sun. The results show that the solar wall slowly climbed to an increase of 30°F where the solar tube immediately jumped in temperature and climbed to about an increase of 55°F, about twice the temperature increase of the solar wall.



Unfortunately, when beginning the experiment, the fans didn't work because the potentiometer was failing and beginning to smoke. So the fan speed control had to be bypassed make the fans operational. This means that our data is incomplete because the airflow couldn't be varied. A more complete experiment would test the effect of different airflow speeds on the temperatures throughout the design.

Conclusions

Based on the data that was collected and on the experience of constructing this prototype, some conclusions can be made on what situations are appropriate for each design.

The solar wall is simple but moderately effective. It is easy to assemble, requires little to no maintenance, and is already being used in the industry. This design, though, is only moderately effective at utilizing solar heat; the design's maximum air temperature is limited by the maximum temperature of the metal cooled by the surroundings. This means the solar wall has difficulty reaching temperatures high enough to dry fruit without relying on gas burners.

The solar tube is complex but highly effective. Constructing an enclosing with plexiglass is difficult to set up, susceptible to air leaks, and requires maintenance to clean. On the other hand, it is effective at reaching high temperatures using smaller space than a solar wall. The system is not easily cooled off by the surroundings because the heating elements are inside the insulated enclosing. The air from a solar tube can easily reach the optimum 145°F for drying, allowing the possibility for completely solar operation.

Airflow rates definitely play a role in determining which design is a better solution for KIWA. For example, the solar wall may be able to operate at high flow rate without decreasing the air temperature while the solar tube may be very sensitive to increased air flow. How airflow speeds affect the designs, the airflow desired, and the level of solar dependence desired are unknowns that will affect the final design decisions.

Recommendations for Next Steps

After testing our prototype, our team presented the results to a panel of professors, researchers, and engineers. With their assistance, we identified several areas where the prototype could be improved and new considerations for continuing with the project.

Further Experimentation with Airflow

Our prototype testing only observed each system's performance under one fan speed. Additional testing should be undertaken to discover the effect different fan speeds have of the air temperature reached in the solar tube and solar wall systems. Moreover, the size of air inlets also plays a major role in air resistance and the overall flow of air. Further experiments could be done analyzing the how the area of intake holes impacts the temperature of the air leaving each system. With more research, the ideal fan speeds and intake areas for both systems can be identified.

Cost/Benefit Analysis for Kiwa

Pre-heating incoming air has the potential to save Kiwa money as it expands production into food drying. However, the likely cost-savings need to be calculated in order to establish whether a system similar to our prototype would truly be appropriate for Kiwa. This involves identifying the size and scale that the company needs as well as the amount of energy needed to run such a system. The team should explore factors such as real estate, rooftop area, electricity costs, and natural gas costs. This would go in tandem with determining ideal airflow specifications. With this data, projections about future costs, in terms of construction and energy consumption, can be made to Kiwa.

Identifying Best Materials

Our prototype was constructed from mostly inexpensive materials: a metal bookshelf, corrugated steel, aluminum duct tubing, etc. Additionally, the paint we used may not be appropriate for industrial food standards. More research is necessary to establish from what materials a final solar system ought to be constructed. Considerations include durability, availability, cost, and heat insulating properties. Future work requires a more in-depth examination of prior art as well as looking at international food safety recommendations.

Deliverables

Randall Cass
Shealia Chambers
Christopher Large

Initial Design Brief

What are the project goals? Why?

Our project goals are to create a viable solar drying system to produce dehydrated fruit in the subtropical climate of Ecuador while simultaneously expanding production capacity, lowering energy input costs, and increase product life and quality within consideration of our client, KIWA's ability.

Who is the target market/customer?

Our target market is those companies interested in mid-sized fruit drying processors in extremely sunny regions. Our customer is an international company, KIWA, located in Ecuador that produces and exports fried vegetable chip products internationally; they are looking into switching to dehydrating fruit to expand their product line.

What are the specifications (if any)?

The specifications the client KIWA has given us are:

- Dehydrate Without Oil Fryers
- Utilize Solar Energy
- Function Within Client's Climate
- Improve Cost Effectiveness
- Durable, Long-lasting Construction
- Production Capacity (1 Ton a Day)

What are the benchmarks?

4/23/13	**Initial Design Brief, Considerations Brainstorm, Decision Matrix**
4/25/13	**Design Considerations, Criteria, Metrics, Brainstorming**
4/30/13-5/2/13	**Annotated Bibliography, Proposed Design Concepts, Idea Evaluation, Project Timeline, Budget, Design Reviews #1**
5/23/13	**Prototype Demo #1**
TBA	**Prototype Demo #2**
6/4/13	**Design Reviews #2**
6/10/13	**Executive Summary**

What is the budget?

The budget will be determined after further research and consultation with the client.

What is the timeline?

4/22/13	First Group Meetings
4/23/13	**Initial Design Brief, Considerations Brainstorm, Decision Matrix**
4/24/13	Group Brainstorming Meeting
4/25/13	**Design Considerations, Criteria, Metrics, Brainstorming**
4/26/13	Weekly Friday Meeting Refined Brainstorming Session
4/29/13	Group Meeting Refine Upcoming Deliverables
4/30/13-5/2/13	**Annotated Bibliography, Proposed Design Concepts, Idea Evaluation, Project Timeline, Budget, Design Reviews #1**
5/3/13	Weekly Friday Meeting Meet with Jim Thompson (Mentor) By This Date Decide on Prototype #1 Concept Drafts for Solid Modeling
5/7/13	Open Lab in Shop (Work on Building Prototype #1)
5/9/13	Open Lab in Shop (Work on Building Prototype #1)
5/10/13	Weekly Friday Meeting Test Current Prototype #1 Refine Prototype #1 Designs According to Results
5/14/13	Open Lab in Shop (Work on Building Prototype #1)
5/16/13	Open Lab in Shop (Work on Building Prototype #1)
5/17/13	Weekly Friday Meeting Test Refined Prototype #1/Continue to Refine Prototype #1 As Needed
5/21/13	Open Lab in Shop (Work on Revising/Finalizing Prototype #1) Final Test/Troubleshooting/Revisions of Prototype #1
5/23/13	**Prototype Demo #1**
5/24/13	Weekly Friday Meeting Discuss/Review Prototype Demo #1 Rework Prototype #1 into Prototype #2
5/28/13	Open Lab in Shop (Work on Building Prototype #2)
5/30/13	Open Lab in Shop (Work on Building Prototype #2)
5/31/13	Weekly Friday Meeting Test Current Prototype #2 Refine Prototype #2 As Needed
TBA	**Prototype Demo #2**
6/4/13	**Design Reviews #2**
6/10/13	**Executive Summary**

What are the final deliverables?

Our final deliverables will be a Final Built Prototype, an Executive Summary, and a Recommendation for our client KIWA.

Randall Cass
Shealia Chambers
Christopher Large
04/28/13

Fruit Dryer Project Brainstorm

1. Similar to Subway Bread ovens
2. Utilize fruit brine or desiccant spray as a pre-cook treatment (lemons juice? Salt?)
3. Utilize residual heat from current fryers - additional heat source
4. A tumble cooker like a clothes dryer
5. Easy-Bake Oven type light heating mechanism
6. Collect solar energy from external array without solar panels
7. Heat transfer from radiation
8. Convention and/or conduction
9. Incorporation of solar without being completely dependant (See Green Illusions)
10. Two separate drying systems – one solar and one electric grid based (A Hybrid)
11. Leaning toward indirect solar rather than direct solar – for a large industrial system
12. Use of copper to conduct heat as well as naturally antibacterial
13. Use glass, or recycled glass, to make a window to monitor the cooking process
14. Include thermometer to assist in quality control
15. Make prototype modular so it can be duplicated as the company expands
16. Vacuum-Seal the machine to maintain freshness
17. Use Vacuum to wick away moisture
18. Use oil that has been degraded from frying chips as fuel or in heating pipe
19. Use air vents for airflow, and also keep out dust and bugs
20. Blanching before drying to improve quality
21. Interchangeable parts – things you can buy at the hardware store (Cradle to Cradle)
22. Open-Source blueprints
23. Preserving the Kiwa mission of sustainability, healthy snacks, colorful, etc.

Meeting Minutes

D-Lab II
Team Fruit Dryer

1. ***Monday; 4/22/2013; 10am-12pm, 4pm-7pm***
   a) Wrote design brief
   b) Discussed design considerations
   c) Created first decision matrix

2. ***Friday; 4/26/2013; 5pm-6:30pm***
   a) Design brainstorming discussion
   b) Wrote 20 design ideas

3. ***Monday; 4/29/2013; 9am-11:30am, 4:30pm-7:30pm***
   a) Prepared for design discussion presentation
   b) Created brochure and visual aids for presentation

4. ***Thursday; 5/2/2013; 4pm-5pm***
   a) Met with Jim Tomson
   b) Decided to use solar to pre-heat incoming air
   c) Use a heat exchanger between hot exiting air and cool incoming air
   d) Base model on Community Dehydrator
   e) Use propane as secondary heat source

5. ***Friday; 5/3/2013; 4:30-5:30***
   a) Discuss design details
   b) List possible parts and materials
   c) Assign price scouting of materials

Annotated Bibliography

D-Lab II Kiwa Team

Ashby, M. F. (2009). *Materials and the Environment: Eco-Informed Material Choice.* Burlington, MA: Elsevier Ltd.

This is a book that focuses on the eco-impact of material choices. It also gives good guidelines for green engineering in general. This will help our design to work toward the sustainability we wish to attain.

Ashby, M. F. (2011). *Materials Selection in Mechanical Design.* Burlington, MA: Elsevier Ltd.

This book is a great resource for chosing appropriate materials for the prototype. It has sections that screen materials based on their yield strength, stiffness, density, and even cost. This will help make an efficient prototype without limiting our options to just mild steel and wood.

Baron, Jeff. "IIP Digital | U.S. Department of State." *Ecuadorian Firm Cooks a Gourmet Snack for U.S. Market*. IIP Digital, 25 Nov. 2011. Web. 30 Apr. 2013.

This online article focuses on the KIWA brand's market strategy of focusing primarily on the export market, with the goal of 50% export to the United States. It interviews the general manager of Inalproces, Martín Acosta, who was also one of our contacts for this project. This article emphasizes the company's professionalism as well as ingenious strategy to cater toward the foreign gourmet market, "The 5 or 10 percent that can buy good stuff," according to Acosta, which increases product quality rather than cutting costs.

Bainbridge, D. A., & Haggard, K. (2011). *Passive Solar Architecture: Heating, Cooling, Ventilation, Daylight and More Natural Flows.* United States: Chelsea Green Publishing Company.

This book has some details on passive flow, air flow driven by thermal risers instead of mechanical fans. It goes over the basics of designing passive heating and passive cooling flows and has some example setup and considerations. This book focuses on the architectural applications, but I feel this will be useful for planning the ventilation of our final design.

Dong, Allen. "Farm-Scale Food Dehydrator." *UC Davis Agricultural Sustainability Institute.* (2009). Web. 17 Apr. 2013.

This short article offers background and schematics on a food dryer developed by UC Davis extension service in 1943. The "Community Food Dryer" is a farm-scale food dehydrating model that utilizes a space heater and a fan to circulate hot air in the dehydration chamber. Although this model is not solar, a panel could power it. Most importantly, it is simply designed and a good example of prior art.

A. Esper, W. Mühlbauer. "Solar drying - an effective means of food preservation." *Renewable Energy*. 15.1–15.4. Sept.–Dec. (1998): 95-100. ETDEWEB. Web. 28 Apr. 2013.

This article focuses on the mitigation of post-harvest loses in developing regions of the world and on utilizing dehydrated foods as a means of achieving food security. While the focus of the article is on less industrialized processes, it provides context for solar dehydration systems and their impact on resource-poor areas. Moreover, it highlights issues related to post-harvest loss.

Janjai, Serm. "A Greenhouse Type Solar Dryer for Small-scale Dried Food Industries: Development and Dissemination." *International Journal of Energy and Environment* 3.3 (2012): 383-98. *ETDWEB*. Web. 11 Feb. 2013.

This author offers an intensive review of solar drying technology through greenhouses, specifically with small-scale industry in developing countries in mind. The author explains the appropriateness of the greenhouse for the size of small developing businesses. A benefit of this type of system is the amount of fruit that can be dried at once. A drawback is the price of materials to construct it and its reliance on an additional "burner" to help regulate temperature. For KIWA, however, this system could be promising.

Leon, M Agustus, S. Kumar, and S.C. Bhattacharya. "A Comprehensive Procedure for Performance Evaluation of Solar Food Dryers." *Renewable and Sustainable Energy Review* 6.4 (2002): 367-93. *ETDEWEB*. Web. 11 Feb. 2013.

This article offers a detailed explanation of the differences between different food dryers that are widely used today. This includes direct, indirect, mixed, forced circulation, cabinet, and tunnel systems. It also proposes its own metrics for testing their effectiveness: time, density, product flavor, etc. With its in depth evaluations of existing systems, we will have a better idea of what type of system to suggest to KIWA – the benefits and the drawbacks.

***Mommy Brain Reports: Big Boss Oil-less Fryer*. (n.d.). Retrieved from Youtube: http://www.youtube.com/watch?v=_HQbzjv6KBo**

This video reviews an "oil-less fryer" I saw at a grocery store. It turns out to just be an easy-bake oven with a fan in it. The primary heat sorce is the heat-lamp and the secondary source is from the driven convection.

Murthy, M.V. Ramana. "A Review of New Technologies, Models and Experimental Investigations of Solar Driers." *Renewable and Sustainable Energy Reviews* 13.4 (2009): 835-44. *ETDEWEB*. Web. 11 Feb. 2013.

In this article, the authors discuss the costs and benefits associated with cabinet, greenhouse, and forced convection systems. It also places an emphasis on making these systems available to businesses in developing countries. They explain an "Evaporative Capacity" concept that is related to each system's ability to efficiently dry a given fruit, vegetable, or grain in a given climate. They conclude that the type of product being dried should be the driver in choosing a system. This article should help us identify when system is better for KIWA's specific needs.

Ramlow, B., & Nusz, B. (2010). *Solar Water Heating: A Comprehensive Guide to Solar Water and Space Heating Systems.* Canada: New Society Publishers.

This book is dense with details concerning heat exchangers involving solar-to-thermal energy collection. It describes many systems that harness thermal energy from the sun with "solar thermal panels" and use that energy to heat the indoor air. Although this book is meant for architectural purposes, this could be an innovative way of harnessing the power of the sun to heat the fruit dryer.

Additional Sources:

http://www.kiwalife.com

This is the website of our client. Here we find an abundance of information, not only on the company's products, but also their mission and branding that will be important to consider as we design a prototype.

http://www.cona.at/index.php?id=17&L=2

CONA is an Austrian nonprofit that connects developing regions with sustainable technologies. We are using their case study in Guatemala as an example since its situation is comparable to that of KIWA.

"Technical manual on small-scale processing of fruits and vegetables." FAO Regional Office for Latin America and the Caribbean. http://www.fao.org/docrep/x0209e/x0209e06.htm

This FAO handbook will offer additional insight on drying methods and requirements of different fruits and vegetables.

Concentrated Solar Drying Final Report, D–Lab II, Spring 2010

Caitlin Flint, Simon Li, and Daniel Schmidt

This is a project that was carried by D-Lab students in 2010 in which they researched solar dehydration models for a Nicaraguan community. Though their project is on a different scale, their methods and models offer us a template for our research.

Visuals

Fruit Dryer
Prototype Team

Randall Cass
Shealia Chambers
Christopher Large

D-Lab Design Review
April 30, 2013

Kiwa
100% Natural

Fruit Dryer
Prototype Team

Quito, **Ecuador**

Fruit Dryer Prototype Progress

Randall Cass
Shealia Chambers
Christopher Large

D-Lab Design Review

April 30, 2013

Fruit Dryer Prototype Progress

CLIENT BACKGROUND

The Fruit Dryer team for D-Lab two has spent several weeks exploring fruit dehydration systems appropriate for the Kiwa Chips brand in Quito, Ecuador. Already a producer and exporter of fried vegetable and plantain chips, Kiwa is interested in expanding and producing fruit chips as well. The Kiwa brand is known for its commitment to social responsibility through buying raw materials from local small farmers. The company hopes to demonstrate its commitment to environmental sustainability with solar production.

TEAM BACKGROUND

The UC Davis D-Lab has worked in partnership with Inalproces, the company that owns Kiwa, since January 2013. Our current team members have backgrounds in design, mechanical engineering, and international development. This is an especially exciting project to work on since one of our team members has the opportunity to visit the company in Ecuador this August and present them with our findings.

CLIENT STATS

COMPANY: INALPROCES

BRAND: KIWA® BRAND CHIPS

LOCATION: QUITO, ECUADOR

CLIMATE: MEDITERRANEAN

ELEVATION: 9,350 FT

SOLAR IRRADIANCE: HIGH

DID YOU KNOW?

KIWA comes from "qiwa" which means "green" in Quechua.

PROJECT GOALS

- Build An Oil-Free Fruit Chip Dryer
- Take Advantage of Abundant Sun
- Produce A Quality Chip Product

TARGET MARKET/CUSTOMER

The target market for the prototype will be mid-sized commercial fruit chip producers interested in environmentally friendly production practices.

SPECIFICATIONS

- Dehydrate Without Oil Fryers
- Utilize Solar Energy
- Function Within Client's Climate
- Improve Cost Effectiveness
- Durable, Long-Lasting Construction
- Production Capacity (1 Ton a Day)

PROPOSED DESIGN DIRECTIONS

We want to make our design as industrialized as possible. Former D-Lab groups who designed solar dryers focused on direct solar heating, resulting in low-tech, low-capacity, and long-processing-time fruit chips. We want our prototype to work efficiently, durably, and with a high yield. Additionally, we are working toward innovative, novel approaches not seen in other common solar dryers. Some of the directions our design team wishes to explore include:

- Solar-to-Thermal Energy Collection
- Indoor Functionality
- Solar and Secondary Energy Hybrid
- Pre- and Post-Drying Processing

FOR MORE INFORMATION

http://www.kiwalife.com/

https://www.facebook.com/KIWALIFE

Prior Art

DIRECT DRYER

Green houses make excellent solar dryers. The fruit chips are exposed directly to the sun's rays. As the chips dry, the moist air is wafted away by natural air flows; hot air rises out of the top and cooler, dry air is replaced from the bottom.

INDIRECT DRYER

In architecture, solar thermal panels are a creative way to capture the sun's energy and direct it to warm the air where it's needed. If this technology is applied to fruit chip dehydration, it allows an indoor dryer to be solar powered without using photovoltaic solar panels.

HYBRID DRYER

When the sun doesn't shine, back-up systems are a must. Ovens like the "Easy Bake" oven use heat lamps powered by grid electricity to bake food. This method of heating does not require burning fuel, making it a good secondary heat source when solar power is unavailable.

Fruit Dryer Prototype Progress

Randall Cass
Shealia Chambers
Christopher Large

Who Is KIWA?

Who Are We?

What Are Our Goals?

Who’s The Target Market?

What’s The Specs?

What's Been Done?

What's Our Direction?

Questions?

Kiwa
100% Natural

Solar Powered Air Pre-Heater

Randall Cass
Shealia Chambers
Christopher Large

Project Description

Our Goal

- Assist Kiwa, a small vegetable chip company in Ecuador, in exploring solar options for expanding their production into fruit drying.

Our Objective

- Design and prototype a system that utilizes solar energy as part of a fruit drying process that is both appropriate for Kiwa and the Ecuadorian climate.

Client Background

About KIWA

- Kiwa is a socially minded company that produces and sells fried vegetable chips to international clients.

- The company seeks to expand production into dehydrated fruit chips produced using solar energy.

Design Brief

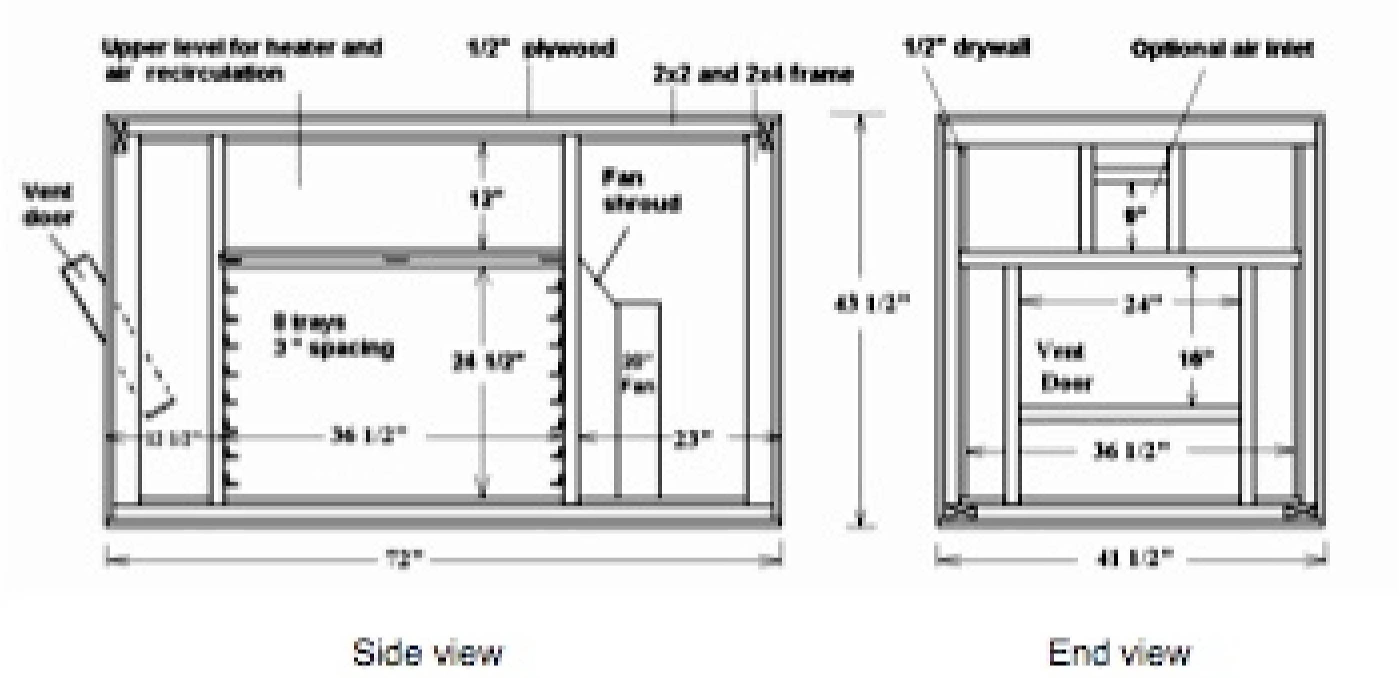
Problem Statement

How can solar power be introduced in an industrial fruit drying system that is both appropriate for KIWA and the Ecuadorian climate?

Design Brief

Solutions – Original Focus

What system could use solar energy to dry fruit chips?



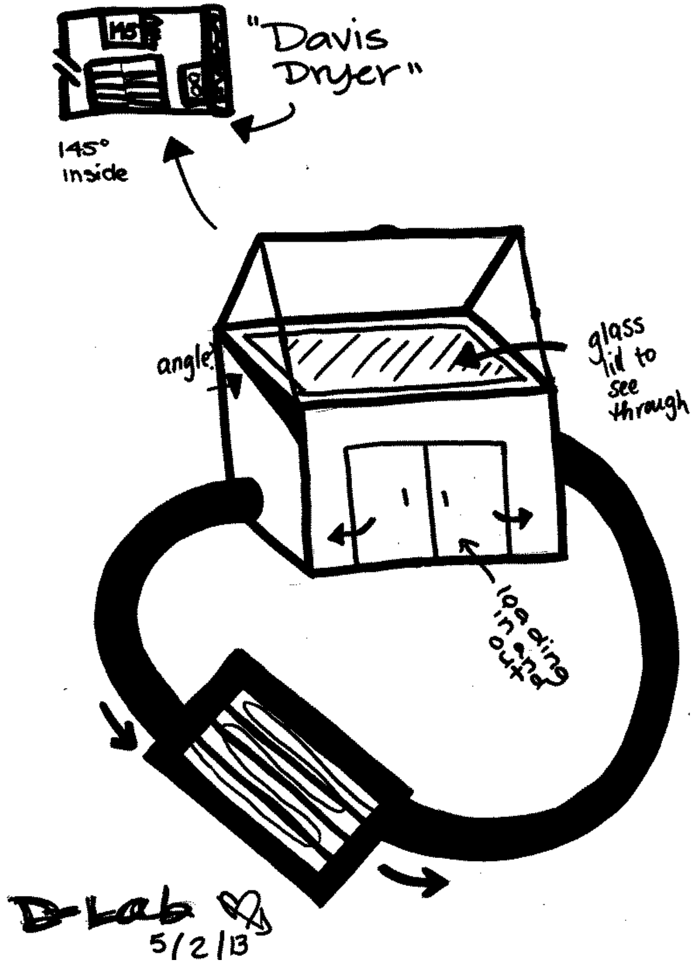
Design Brief

Solutions – Original Focus

We explored building a 3 component system:

- Solar Air Heater
- Indoor Dryer
- Inlet/Outlet

  Air Heat Exchanger



Design Brief

Solutions – New Focus

How can we preheat air using solar power to reduce fuel reliance in a gas powered dehydrating system?

Design Process

Considerations

- Focus on heating air rather than drying food
- Systems with horizontal air movement
- Design with intent to test/experiment
- Client very open about possibilities/direction/method

Design Process

Metrics

- Reaching temperature of 145^{o}F
- Part of system that processes 1 ton of fruit chips a day

Assumptions

- Photovoltaic not practical
- Indoor drying system is more industrial than outdoor
- Attach to an existing Gas-Powered Dryer for operational reliability and product quality.

Design Process

Pre-Prototype Test

Tested 5 small scale variations of solar heaters:

1. Closed/All Black
2. Window/All Black
3. Window/Black Inside Only
4. Solar Wall/All Black
5. Window with Tube/ Black Inside Only

Design Process

Pre-Prototype Test

All were built from same-sized cardboard boxes:

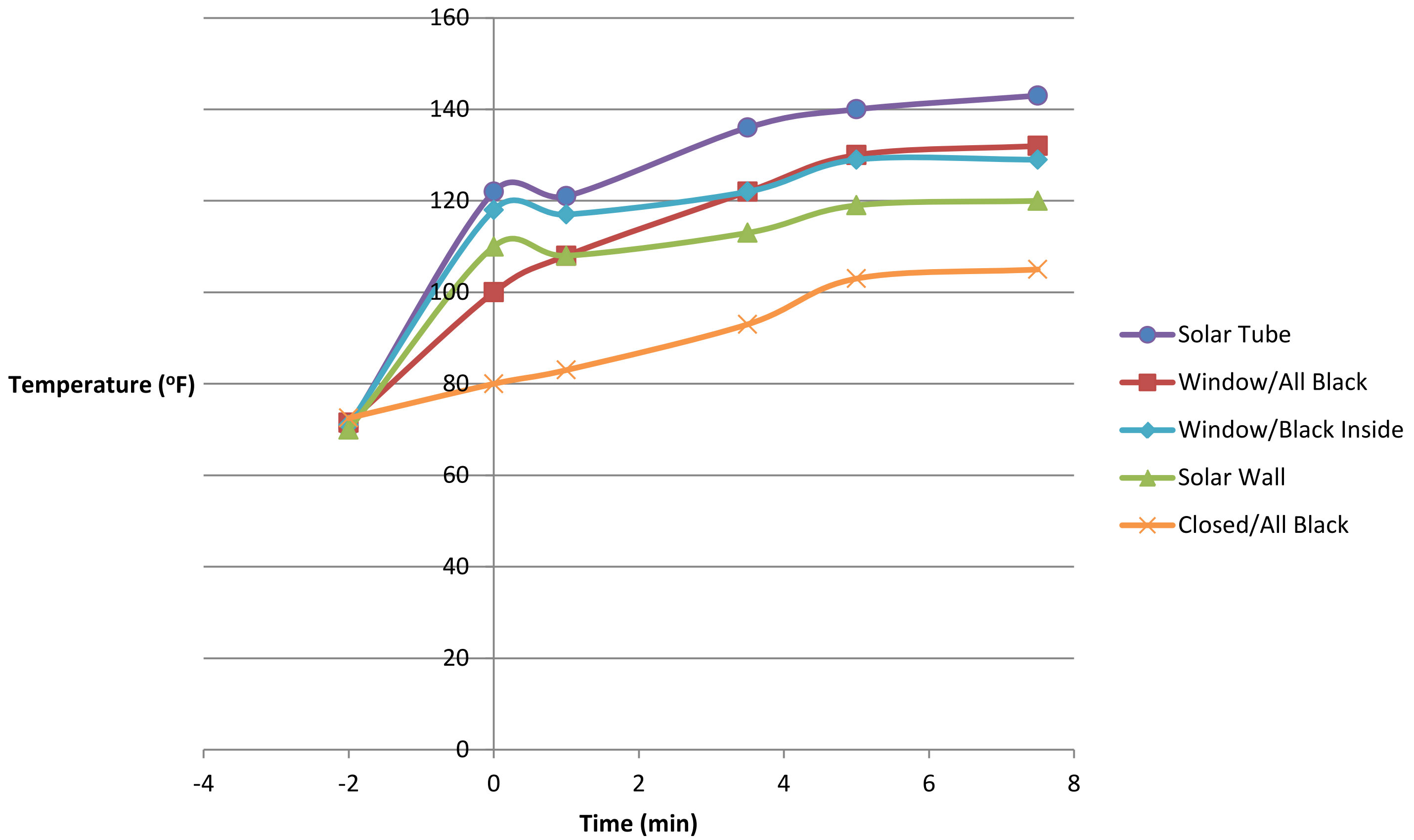
Design Process

Pre-Prototype Test – Experiment

- Oriented to face the sun at the same angle
- Temperature measured at the same spot using one probe thermometer in each design

Design Process

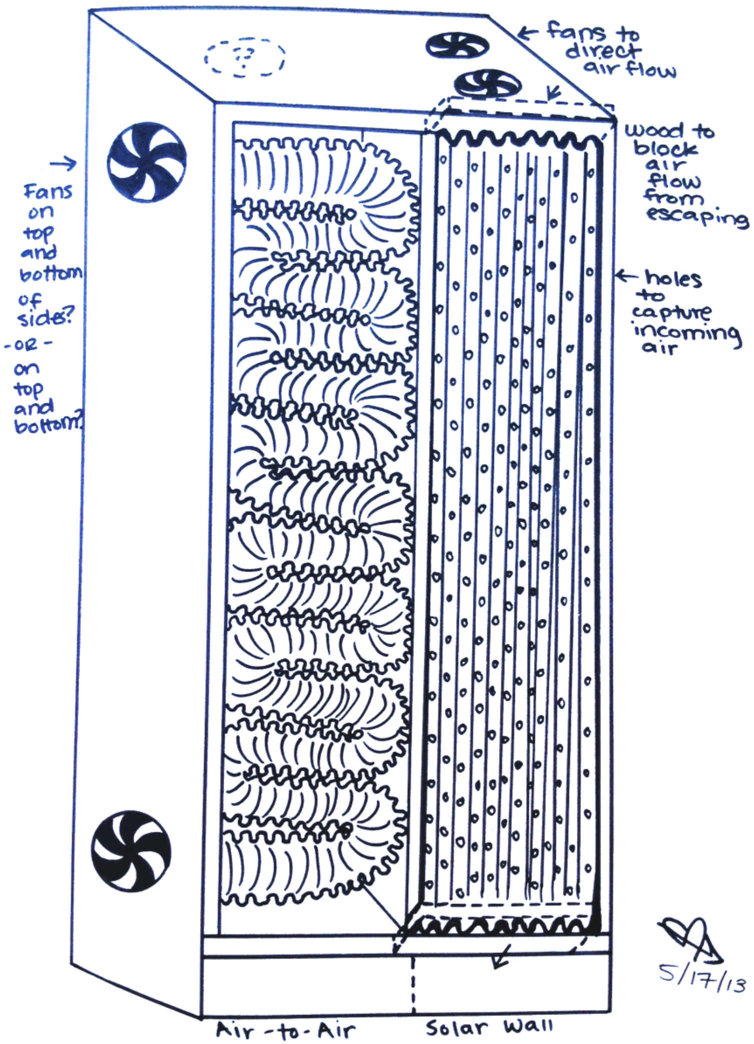
Pre-Prototype Test - Results



Design Process

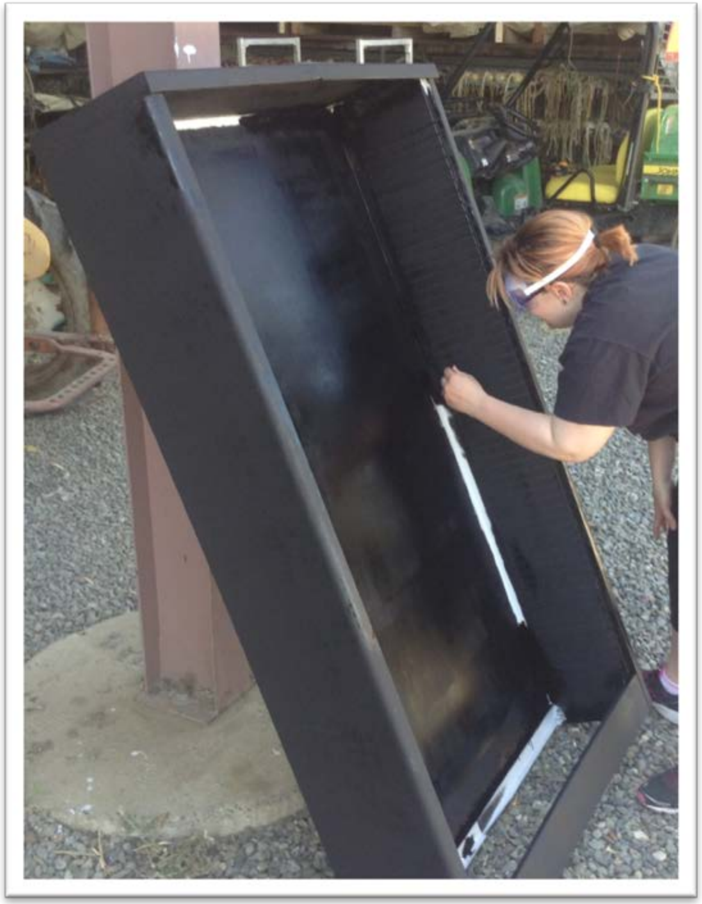
Final Prototype –
Design Considerations

- Compare Solar Wall and Solar Tube
- Introduce Air Flow
- Design for Mobility
- Design for Experimentation



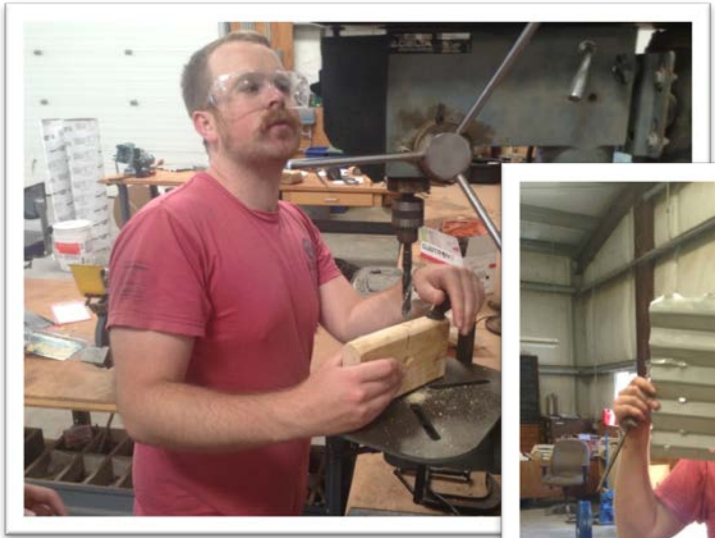
Design Process

Construction – Pre-painting Entire Unit



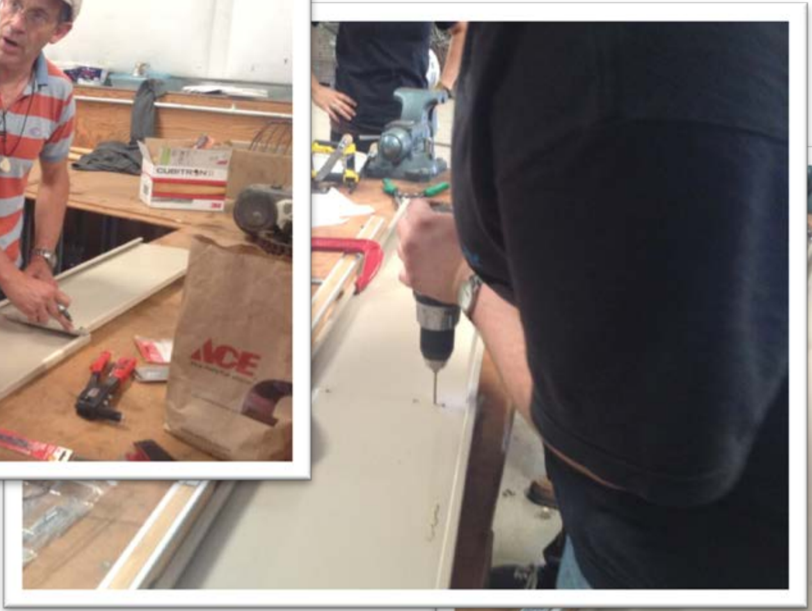
Design Process

Construction – Punched Holes in Corrugated Steal



Design Process

Construction – Cutting/Riveting Shelves Together



Design Process

Construction – Installing Handles and Wheels

Design Process

Construction – Riveting Divider/Adding Insulation

Design Process

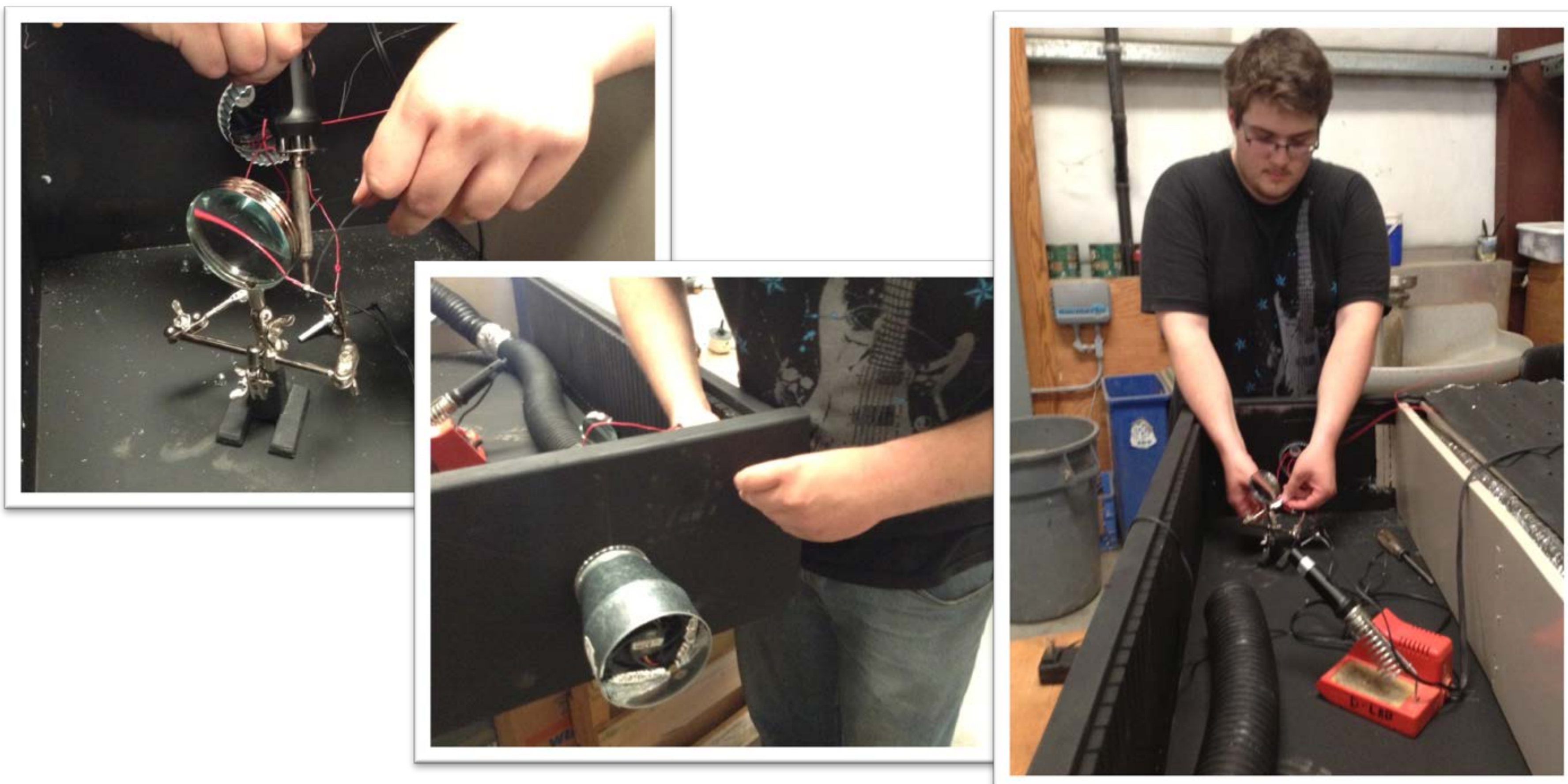
Construction – Cutting Plexiglass/Corrugated Steal

Design Process

Construction – Cutting Holes for Inlet/Outlets

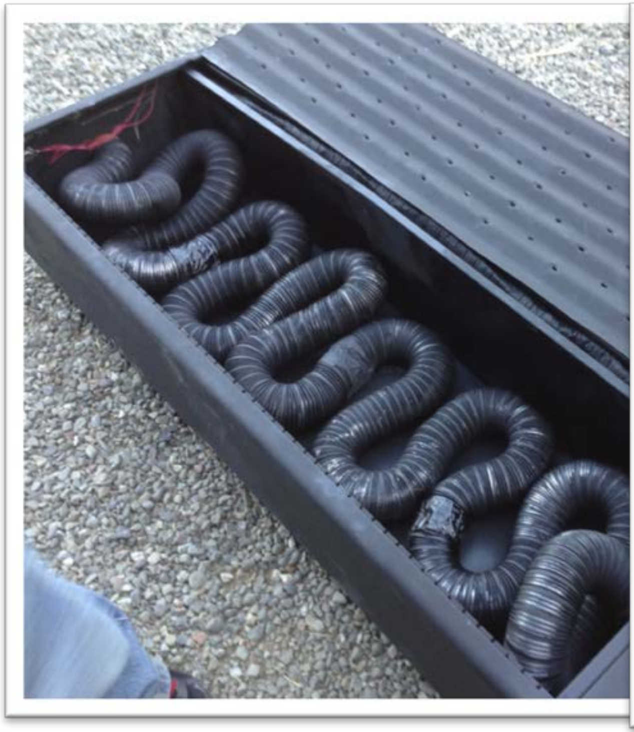
Design Process

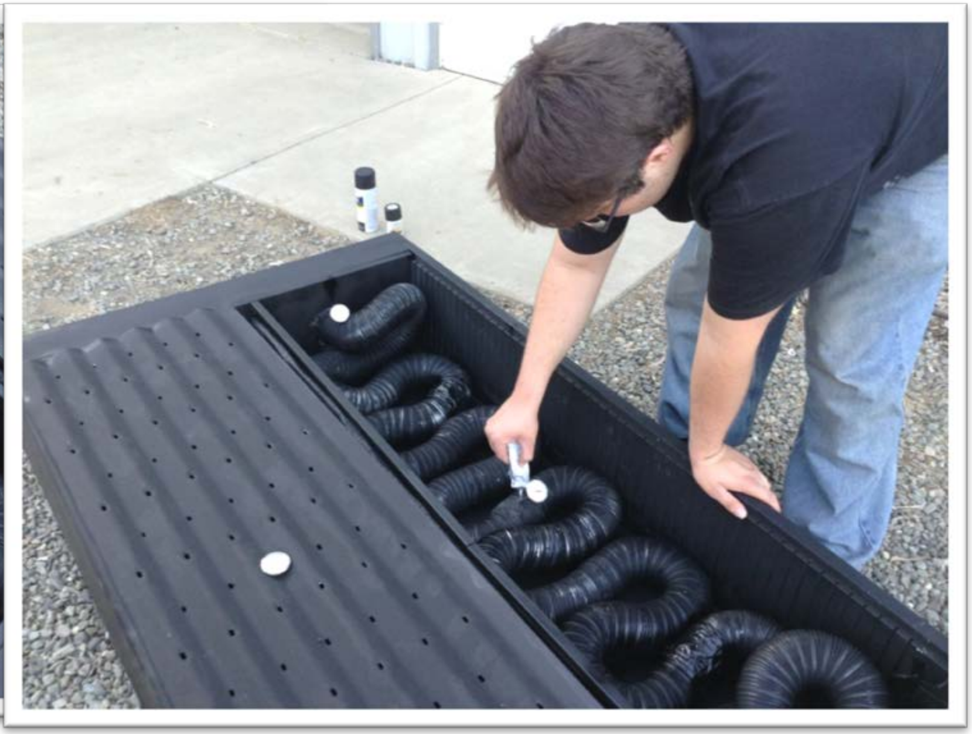
Construction – Wiring/Installing Fans



Design Process

Construction – Installing Tubes/Thermometers





Design Process

Construction – Installing Plexiglass/Corrugated Steal

Design Process

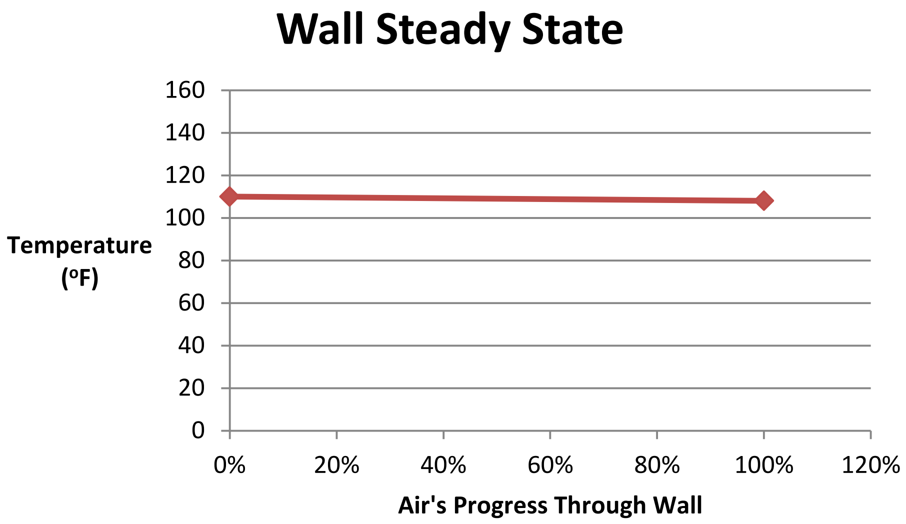
Construction – Finishing Touches

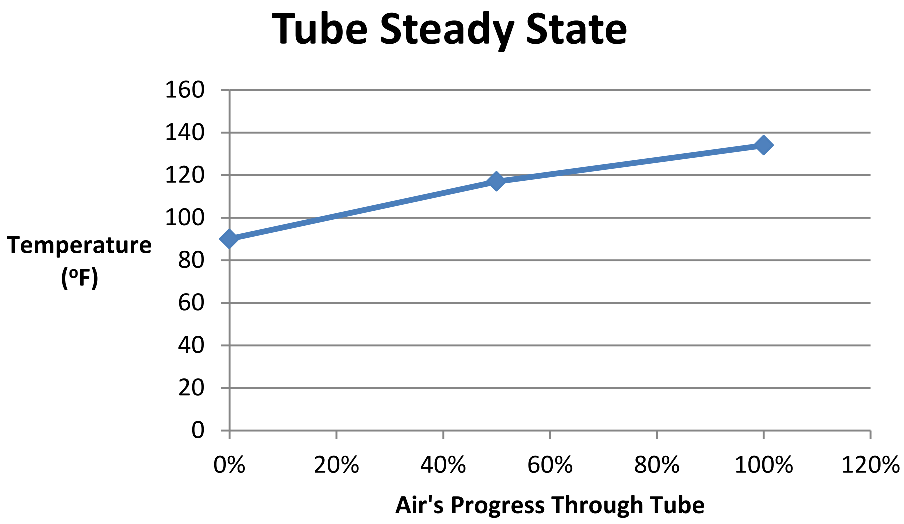
Design Process

Prototype Testing

Design Process

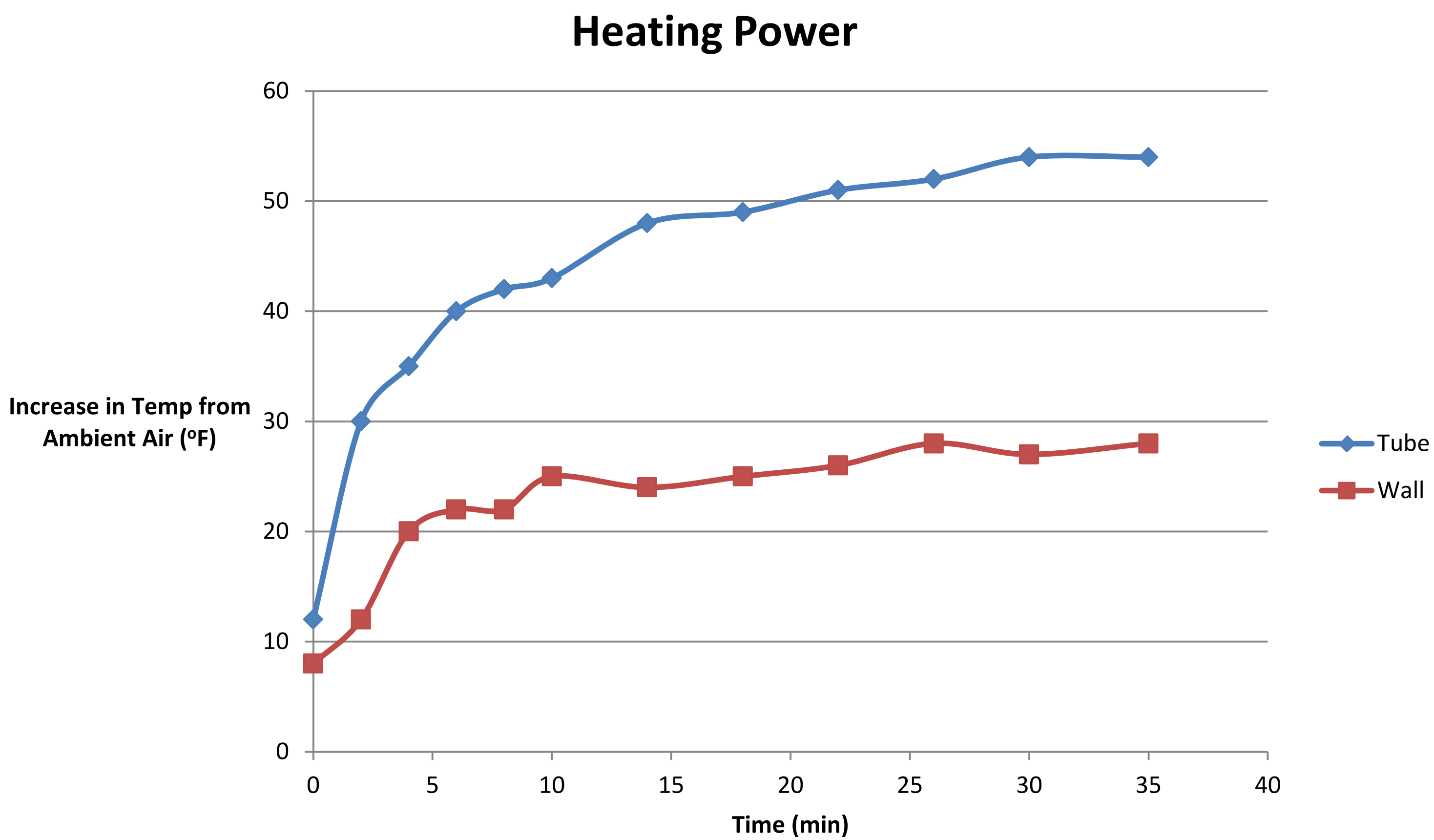
Results





Design Process

Results



Evaluation

Solar Wall

Pros

- Simple Setup
- Low Maintenance
- Low Cost
- Already in Use

Cons

- Moderate Heating Power
- Low Solar Efficiency

Evaluation

Solar Tube

Pros

- High Heating Power
- High Solar Efficiency

Cons

- Complex Setup
- More Maintenance
- Moderate Cost

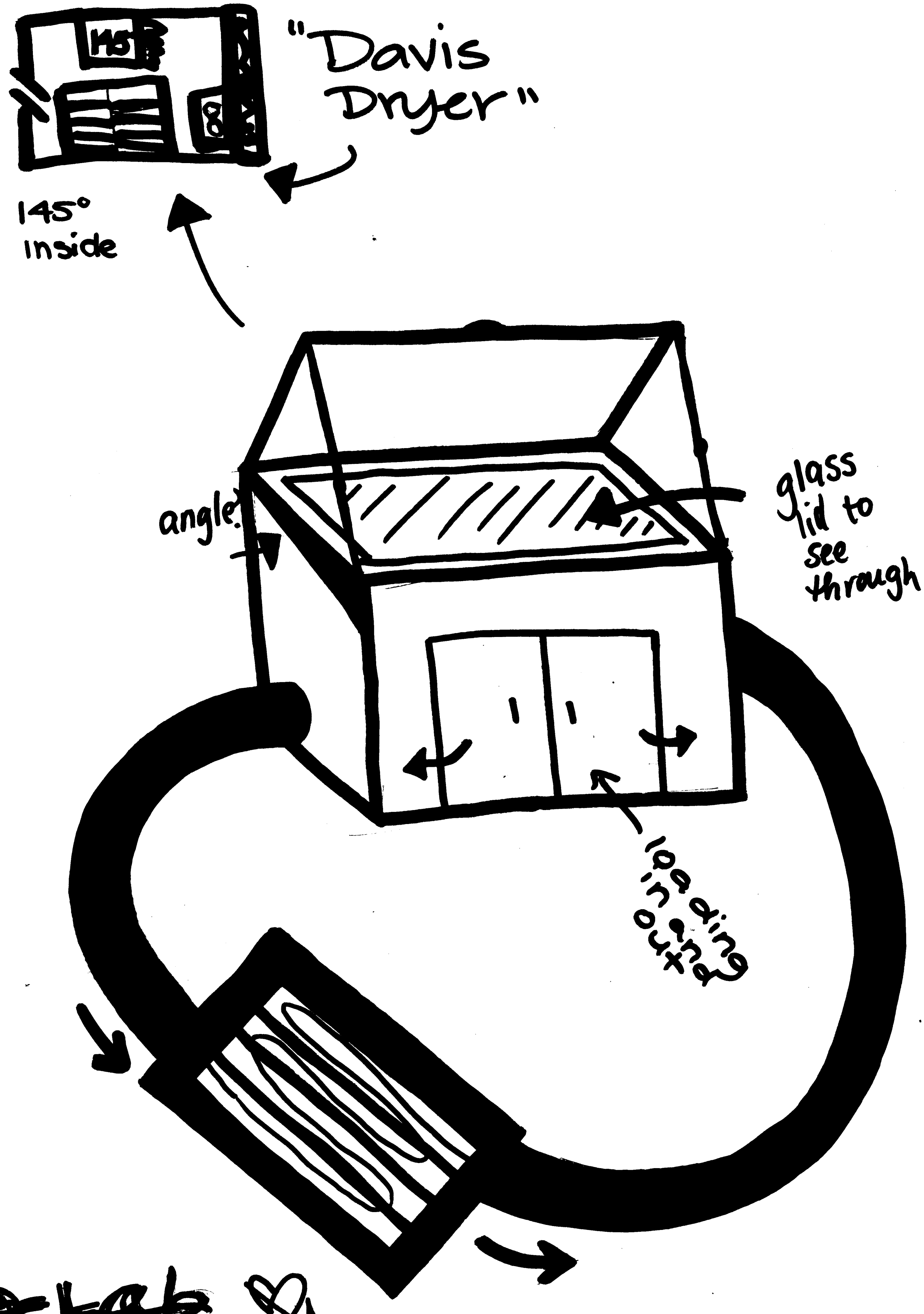
Evaluation

Recommendations

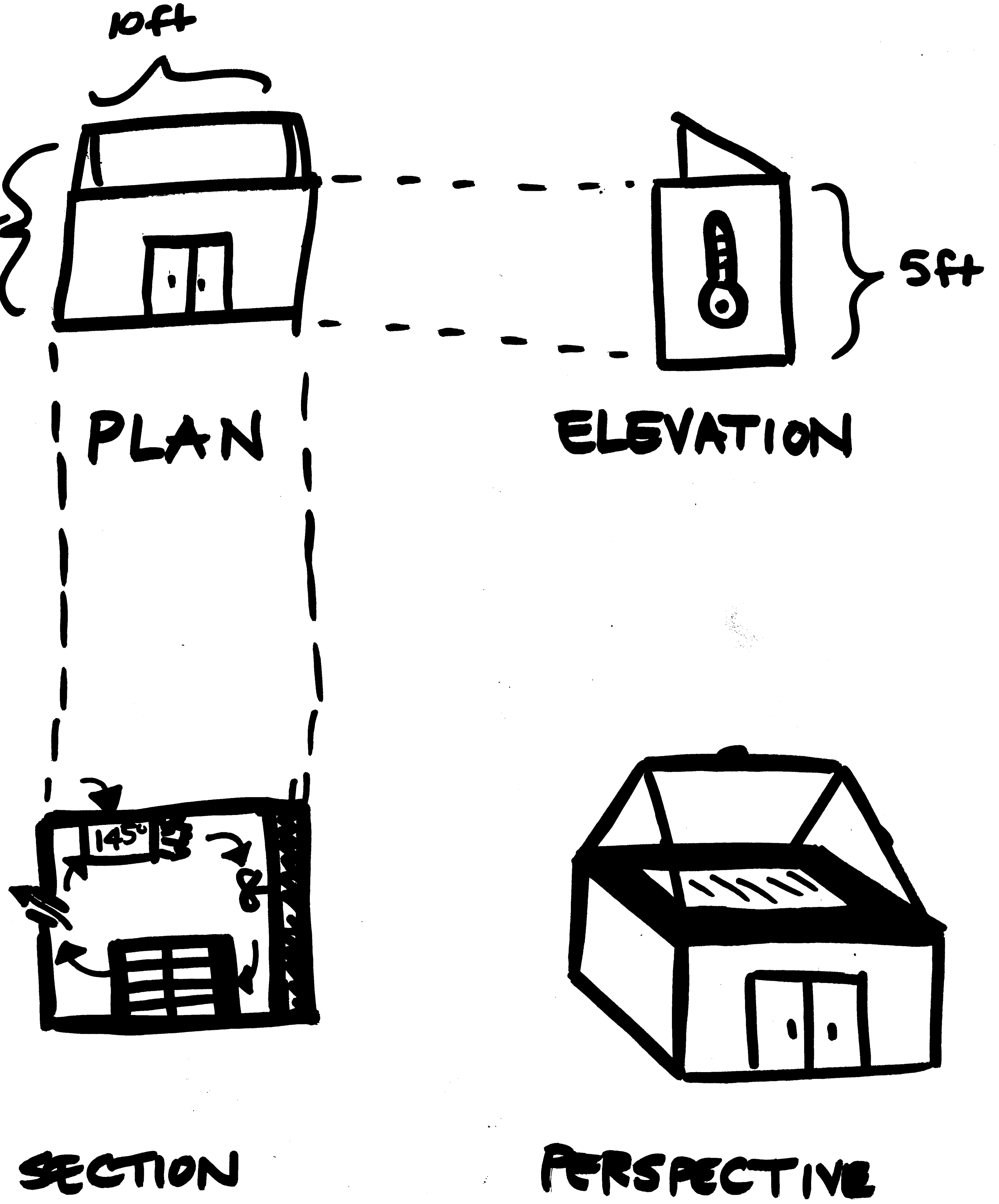
- Further exploring airflow (fan speed)
- Effect of variable airflow (wind)
- Possibilities of other heat convectors that operate with Plexiglass casing

Future Work

- Figure out compatible dryers
- Making it work for Kiwa – food safety, specific fruits, etc.


"Davis Dryer"
145
145° inside
angle?
glass lid to see through
loading in and out
D-Lab
5/2/13

D-Lab Design Multi-View :)



5/2/13

D-Lab

THINGS TO DO/TALK ABOUT:

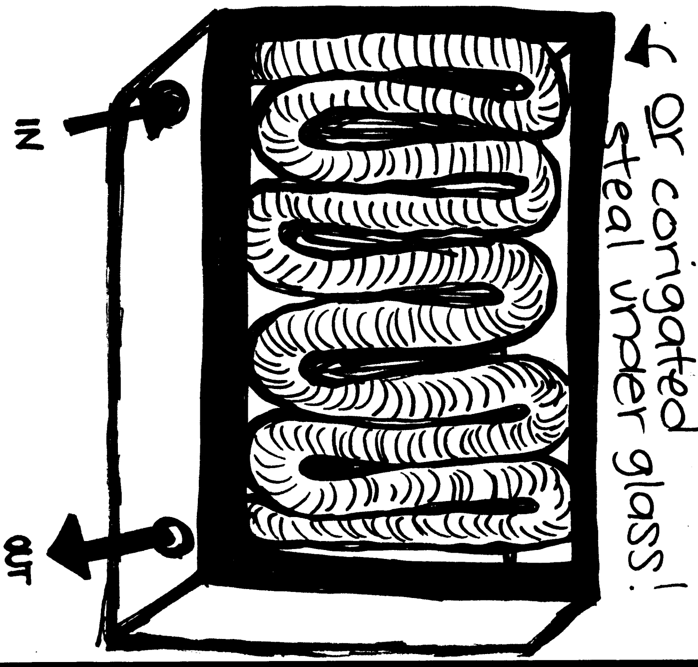
1. Finish solid models of pre-prototypes
2. Use mcmaster.com to price materials
3. Start designing solid model of prototype
4. Download scale versions of materials (fan/burner)
5. Search for filing cabnets/racks on craigslist/other
6. Ask Kurt for Mentoring/Advise/etc.
7. Finish solid model prototype! :)
8. List of materials for purchase/sourcing!
9. Purchase materials tomorrow! :o

QUESTIONS:

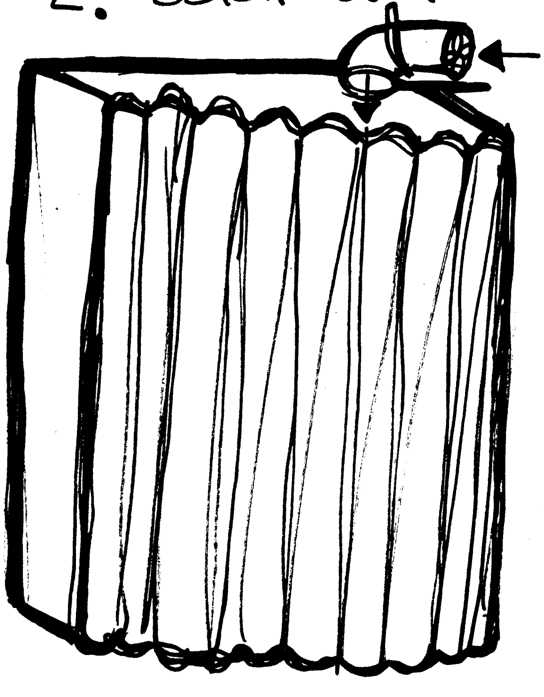
1. Should we focus on developing solar heating design more than dehydrator design?
2. What types of materials do you suggest we use?
3. How can we incorporate the fan?
4. How can we incorporate the burner??
5. How many weeks until Design Review??! :o

2nd Phase Prototypes:

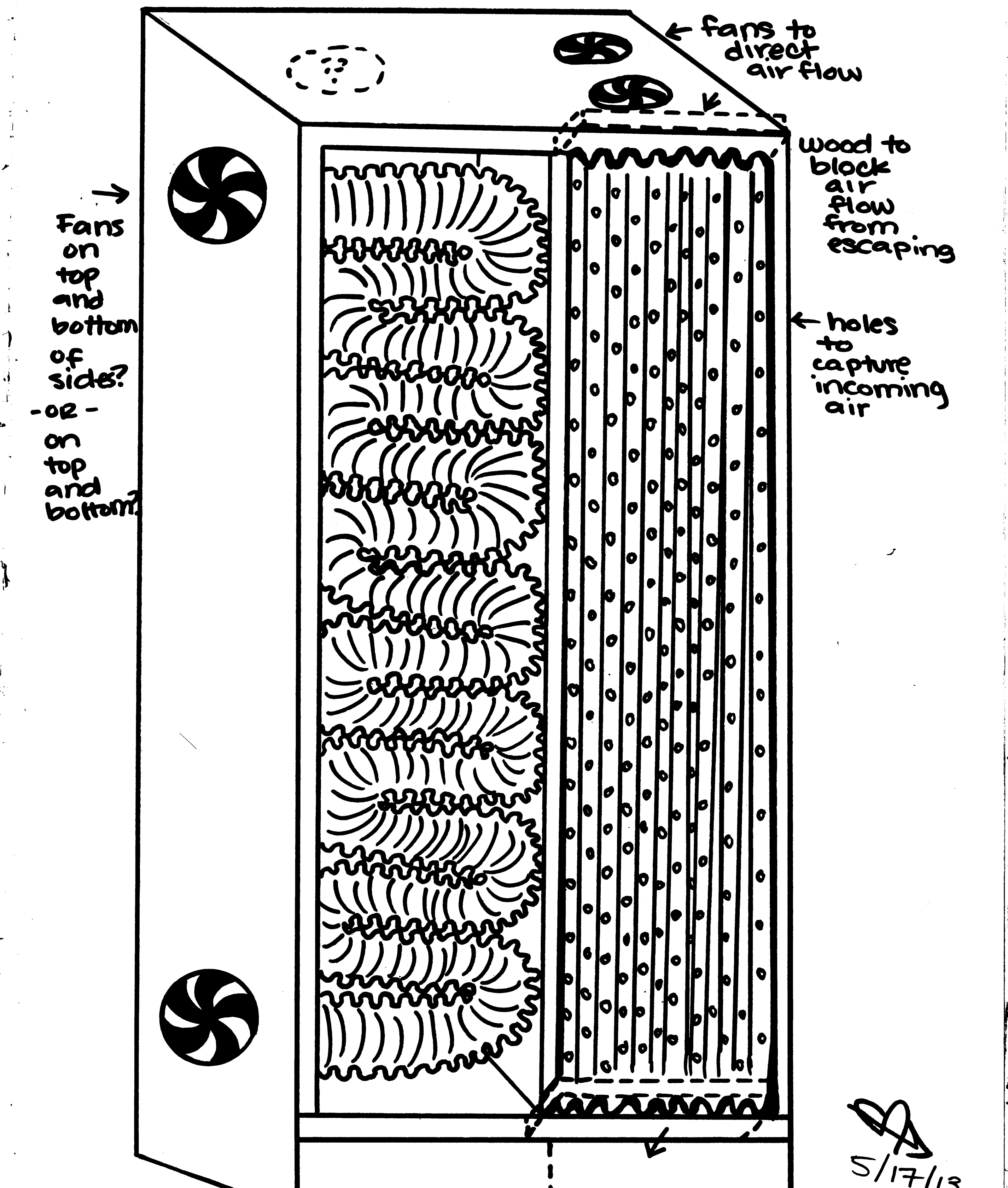
1. Air-to-Air Tube Solar



2. Solar Wall



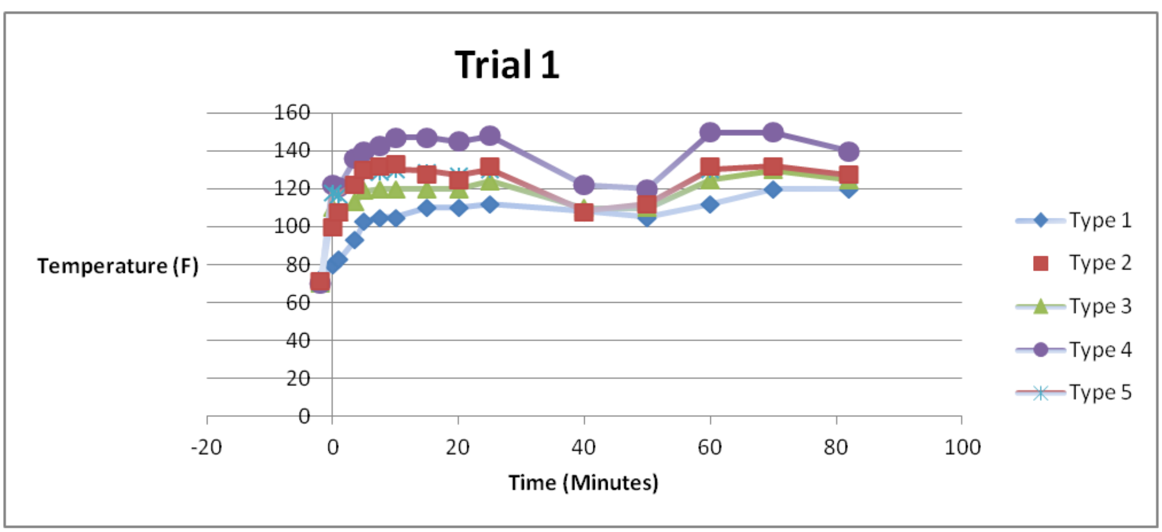
5/17/13


fans to direct air flow
wood to block air flow from escaping
holes to capture incoming air
Fans on top and bottom of sides? -or- on top and bottom?
Air-to-Air
Solar Wall
5/17/13

Experimental Data

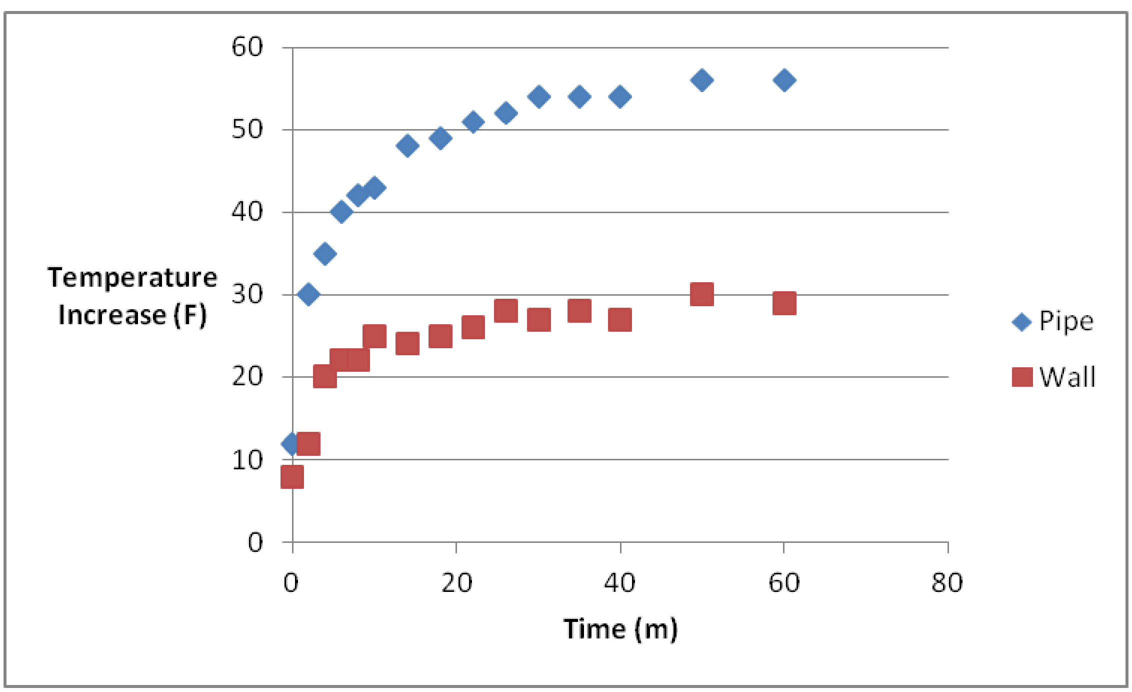
Pre-Prototype Trial

Box Type	All Black	Window	Extra		Time in Minutes	
A	y	n	n		Temperature in F	
B	y	y	n			
C	y	n	Al Wall			
D	n	y	Tube			
E	n	y	n			
	Box Type					
Time	A	B	C	D	E	
-2	72.5	71.5	70	70.5	71	
0	80	100	110	122	118	
1	83	108	108	121	117	
3.5	93	122	113	136	122	
5	103	130	119	140	129	
7.5	105	132	120	143	129	
10	105	133	120	147	130	
15	110	128	120	147	129	
20	110	125	120	145	127	
25	112	132	124	148	130	
40	108	108	110	122	108	
50	105	112	110	120	112	
60	112	132	125	150	130	
70	120	132	130	150	132	
82	120	128	125	140	127	



Final Prototype

Air's Progress	0%	50%	100%	0%	100%			
	T1	T2	T3	T4	T5		Delta(T)	
Indoor	79	80	81	83	79		(Estimating 80deg Ambient)	
Time (m)							Pipe	Wall
0	80	90	92	85	88		12	8
2	82	100	110	91	92		30	12
4	84	105	115	100	100		35	20
6	86	108	120	102	102		40	22
8	87	110	122	106	102		42	22
10	86	110	123	106	105		43	25
14	83	110	128	106	104		48	24
18	86	112	129	106	105		49	25
22	87	113	131	109	106		51	26
26	88	116	132	109	108		52	28
30	89	117	134	110	107		54	27
35	90	117	134	110	108		54	28
40	90	117	134	109	107		54	27
50	90	118	136	112	110		56	30
60	90	118	136	112	109		56	29



Contacts

Contacts

Team Members

Randall Cass
Masters Student, International Agricultural Development

rpcass@ucdavis.edu

Shealia Chambers
Undergraduate Student, Design

smchambers@ucdavis.edu

Christopher Large
Undergraduate Student, Mechanical Engineering

cmlarge@ucdavis.edu

Client Contacts

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Founder and CEO of KIWA, Ecuador

martin@inalproces.com

Johanna Angulo

I&D Assistant and Project Leader, KIWA, Ecuador

Investigacion@inalproces.com

Project Mentors

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Founding Director of the Program for International Energy Technologies/D-Lab, UC Davis

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marco.pritoni@gmail.com

Jim Thompson
Agricultural Engineering Cooperative Extension Specialist, UC Davis

jfthompson@ucdavis.edu

UCDAVIS Randall Cass <rpcass@ucdavis.edu>

Continuing the D-Lab project

6 messages

Randall Cass <rpcass@ucdavis.edu> Mon, Apr 22, 2013 at 3:27 PM
To: Investigación y Desarrollo <investigacion@inalproces.com>

Hi Johanna,

I hope this email finds you well.

I am writing to keep in contact with you and to let you know that we are excited to continue working with KIWA over the next three months on the solar cooker project in D-lab. We now have a new team, but I will still be working on the project and I will be the main contact person if you have any questions.

Unfortunately, we did not receive the grant we applied for to carry out a project with you in Ecuador (it was very competitive this year) - but I will be in Ecuador this summer on a different project, and I hope to visit Inalproces and maybe we can plan to do some sort of research and development. We can talk about this as our project progresses.

The new team has a few questions for you as we get started:

1. The fruits you want to process are mango, banana, naranjilla, and tomate de arbol? I ask because Tom Stein, a member of D-lab, mentioned that you may be interested in Plantains and coconut.

2. Have you changed locations yet? and if so, do you have enough of space available for a large solar cooker installation? We would be interested to learn more about the amount of space you have.

Thanks again for all your help. We will be in touch soon.

Have a nice day,

Randall Cass

Investigacion y Desarrollo <investigacion@inalproces.com> Mon, Apr 22, 2013 at 4:02 PM
To: Randall Cass <rpcass@ucdavis.edu>
Cc: Martin Acosta <martin_acosta@hotmail.com>

Hello Randall,

Thanks for the information, we are very pleased to be working with you over the next three months.

It´s a shame we didn't get the grant. However, it´s good to know you'll be here this summer, you are more than welcome to come visit us and help us with some research and development work.

About your questions:

1. Yes, we want to process mango, banana, naranjilla, coconut and tree tomato. I´m not sure about plantain, we should leave that for the future, we want to focus on fruit dehydration first.

2. Unfortunately we had some trouble and we are looking for another place to move in. So we still don´t

know how big the new place will be. I´ll talk to the person in charge of the new company´s location, and I'll give you an update as soon as possible.

Have a great evening!

If you have any questions, please let me know.

Best,

Johanna.

De: Randall Cass [mailto:rpcass@ucdavis.edu]
Enviado el: lunes, 22 de abril de 2013 05:28 p. m.
Para: Investigación y Desarrollo
Asunto: Continuing the D-Lab project

[Quoted text hidden]

Randall Cass <rpcass@ucdavis.edu> Fri, Apr 26, 2013 at 6:02 PM
To: Investigacion y Desarrollo <investigacion@inalproces.com>

Hi Johanna,

I hope this finds you well. I just wanted to check in with you again. We've been working on the project and we will be presenting our ideas for the course next week.

We have a few questions:

1. We are under the impression you are interested in exploring multiple types of solar energy - solar/electric hybrids, indirect/indoor systems, etc - not just solar panels. Is that correct?

2. Would you be interesting in exploring utilizing oil waste from the frying process as a fuel source? What do you do with the oil waste?

3. Are you interested in a multi-step system - for example, dehydrating fruit and then quick-frying it? That is something we could explore.

We just want to make sure we are exploring options you are interested in.

Thanks!

Randall

Mail Delivery Subsystem <mailer-daemon@googlemail.com> Fri, Apr 26, 2013 at 6:02 PM
To: rpcass@ucdavis.edu

Delivery to the following recipient failed permanently:

investigacion@inalproces.com

Technical details of permanent failure:
DNS Error: DNS server returned answer with no data

----- Original message -----

X-Google-DKIM-Signature: v=1; a=rsa-sha256; c=relaxed/relaxed;
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h=mime-version:x-received:in-reply-to:references:date:message-id
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X-Received: by 10.220.244.137 with SMTP id lq9mr30250864vcb.13.1367024541241;
Fri, 26 Apr 2013 18:02:21 -0700 (PDT)
Received: by 10.52.35.137 with HTTP; Fri, 26 Apr 2013 18:02:21 -0700 (PDT)
In-Reply-To: <007c01ce3fad$6a770480$3f650d80$@inalproces.com>
References: <CAHsGWHRJb6ygQQkoga2T+5Dd=1QDrPMQenPGfr+GkdBLhn3pcA@mail.gmail.com>
<007c01ce3fad$6a770480$3f650d80$@inalproces.com>
Date: Fri, 26 Apr 2013 18:02:21 -0700
Message-ID: <CAHsGWHS88qqkUo7KxG=1XUz3-=1ZPH7w0a+21F0ypnL5r-ZLGg@mail.gmail.com>
Subject: Re: Continuing the D-Lab project
From: Randall Cass <rpcass@ucdavis.edu>
To: Investigacion y Desarrollo <investigacion@inalproces.com>
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Jh1BU/xfRXatF9M98Nn+q
[Quoted text hidden]

Randall Cass <rpcass@ucdavis.edu> Mon, Apr 29, 2013 at 9:31 AM
To: Investigacion y Desarrollo <investigacion@inalproces.com>

Hi Johanna,

I hope this finds you well. I just wanted to check in with you again. We've been working on the project and we will be presenting our ideas for the course next week.

We have a few questions:

1. We are under the impression you are interested in exploring multiple types of solar energy - solar/electric hybrids, indirect/indoor systems, etc - not just solar panels. Is that correct?

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3. Are you interested in a multi-step system - for example, dehydrating fruit and then quick-frying it? That is something we could explore.

We just want to make sure we are exploring options you are interested in.

Thanks!
[Quoted text hidden]

---

investigacion@inalproces.com <investigacion@inalproces.com> Mon, Apr 29, 2013 at 6:46 PM
To: rpcass@ucdavis.edu
Cc: martin_acosta@hotmail.com

Hello Randall,

I惴 glad to hear from you again! about ypur questions:

1. Actually we are very open-minded about the drying system, what we need at the end of the day is to develop a technology that allows us to have a high quality product with a competitive price. We want to use as much solar energy as possible, of course, but if we can find a combined technology that can give us better results in terms of quality and finance, it would be great!

2. At the moment we don惕 have a big amount of oil waste because we have a periodical filling system that is monitored by quality control, so when they determine that the oil is no longer suitable for frying, the oil is sent to an environmental office. So, I don惕 think the amount of oil waste we have now will be enough to serve as a fuel source.

3. I was doing some research on the multi-step systems to dry and then quickly fry, I read that it has great results specially on fruits, so we could explore that option as well.

Do you have any update about the KIWA report? is it still under revisions?

Please Randall let me know if there is anything else I can help you with.
Have a nice day!

Regards,

Johanna.

De: Randall Cass [mailto:rpcass@ucdavis.edu]
Enviado el: lunes, 29 de abril de 2013 11:31 a. m.
Para: Investigacion y Desarrollo
Asunto: Re: Continuing the D-Lab project

Hi Johanna,
[Quoted text hidden]

UCDAVIS

Randall Cass <rpcass@ucdavis.edu>

SUMMER VISIT TO ECUADOR

5 messages

Investigacion y Desarrollo <investigacion@inalproces.com> Mon, May 6, 2013 at 2:46 PM
To: Randall Cass <rpcass@ucdavis.edu>
Cc: Martin Acosta <martin_acosta@hotmail.com>

Dear Randall,

I hope this finds you well,

I am writing find out about your visit to Ecuador during the summer, as I told you before we are looking forward to your visit. Any help you can give us will be very helpful.

Do you know the dates you'll be here and how long will you stay?

We will really appreciate if you could spend some days in our company, please let me know if this is possible so we can make some arrangements.

Have a nice day!

Best,

Johanna Angulo

Research & Development

INALPROCES-KIWA

Tel: 2824589

Cel: 0999016598

Skype: investigacion.inalproces

Randall Cass <rpcass@ucdavis.edu> Wed, May 8, 2013 at 9:43 PM
To: Investigacion y Desarrollo <investigacion@inalproces.com>
Cc: Martin Acosta <martin_acosta@hotmail.com>

Hi Johanna and Martin,

I hope this finds you well. I am very excited to visit Ecuador and I hope that my visit may be of assistance to the company.

Right now, it looks like I will be in Ecuador from July 28 through August 24. But I have to confirm this with my project coordinators and buy the tickets. I will need to work on my project at least 3 weeks, maybe more. I will let you know when I will be available to meet after I discuss it with the project coordinators. I should know by next week.

I'm really looking forward to it, and I'm enjoying the work we are getting done building a prototype right now.

Johanna, I have a question for you - the prototype we are currently planning on building utilizes a direct solar heater as well as a heat exchanger mechanism to heat air, but it will be a hybrid system that also uses a gas or electric heater. Basically, the solar heat minimizes the how much gas is used by making it very very efficient. Does that sound like something you would be interested in? I can send some drawings if you would like.

My question is about gas and electricity prices in Quito - Do you have a preference for one type? And do you know where I can find prices for gas and electricity in Quito?

Thanks for all your help. I'm looking forward to my visit.

Best,

Randall
[Quoted text hidden]

Martin Acosta <martin_acosta@hotmail.com> Thu, May 9, 2013 at 6:35 AM
To: Randall Cass <rpcass@ucdavis.edu>, Investigacion y Desarrollo <investigacion@inalproces.com>

hi Randall,

I think gas will be cheaper as it is subsidized by the government.

Johanna, please get those costs details from Rafael and Nelson,
M

Date: Wed, 8 May 2013 21:43:05 -0700
Subject: Re: SUMMER VISIT TO ECUADOR
From: rpcass@ucdavis.edu
To: investigacion@inalproces.com
CC: martin_acosta@hotmail.com
[Quoted text hidden]

Investigacion y Desarrollo <investigacion@inalproces.com> Thu, May 9, 2013 at 9:21 AM
To: Randall Cass <rpcass@ucdavis.edu>
Cc: Martin Acosta <martin_acosta@hotmail.com>

Hello Randall,

I'm so glad to hear that your visit will be very soon!!

About your question: I really believe that a hybrid system will work for us, if you have drawings please send them to me. I checked our monthly energy payments and I found that each kWh costs 0.080 cents, we consumed 1720 kWh last month and the payment was $134.88. Anyways, I found some information in the Ecuadorian Electric Company webpage. Here is the link if you´d like to see the file http://www.eeq.com.ec/upload/pliegos/20130425075436.pdf , but it´s in Spanish. Basically is says that if you consume less than 300kWh per month the rate is 0,052 cents per kWh, but if the consumption is more than 300kWh, the rate is 0.084 cents per kWh.

When it comes to gas each kilogram costs between 0.86-0.89 cents.

I hope this information will be useful. Let me know if you have any doubts.

I have a question for you, We were wondering about how the drier will work when it´s not sunny at all for a long time, is there any mechanism to save the solar energy to have continuous production when it´s raining all day for example? Or when this happens should we use gas only?

Have a nice day!

Johanna.

De: Martin Acosta [mailto:martin_acosta@hotmail.com]
Enviado el: jueves, 9 de mayo de 2013 08:35 a. m.
Para: Randall Cass; Investigacion y Desarrollo
Asunto: RE: SUMMER VISIT TO ECUADOR

[Quoted text hidden]

Martin Acosta <martin_acosta@hotmail.com> Thu, May 9, 2013 at 9:34 AM
To: Investigacion y Desarrollo <investigacion@inalproces.com>, Randall Cass <rpcass@ucdavis.edu>, "Kurt Kornbluth [" <kkorn@ucdavis.edu>

hi Randall,

this company is doing solar dehydration already: Biolcom, check out their page,

http://www.biolcom.com/i_index.htm

the owner is a Swiss guy who is a friend of mine, I only found out last week that he has solar dehydration which he says is a problem because his system is not hybrid... so if he has no sun for 3 days then all fresh fruits get rotten. He mainly does golden berries and bananas, I have tried both of them and they are good...

The company is based in Pifo, only 30 minutes away from our current production plant, and 5 minutes away from the new airport.

Best regards,
Martin

From: investigacion@inalproces.com
To: rpcass@ucdavis.edu
CC: martin_acosta@hotmail.com
Subject: RE: SUMMER VISIT TO ECUADOR
Date: Thu, 9 May 2013 11:21:54 -0500
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