ABT 289-002: D-LAB II

Spring 2018

Instructor: Kurt Kornbluth

PROJECT SUMMARY REPORT

Solar Powered Ventilation at the Student Farm's Greenhouse

Students: Noah Coleman, Sonia Krishna, Alice Dien

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1. Introduction

1.1. Project and Client Background

Our client is Raoul Adamchak, Market Garden/CSA Coordinator at the UCD Student Farm at the UC Davis Student Farm. As an integral part of the UC Davis food system, the UC Davis Student Farm not only provides certified organic, local produce to Dining Services, the CoHo, and a CSA, but also provides donations to the Pantry, and Fruit and Veggie Up!, programs which serve the members of our campus community who are food insecure. In addition, roughly 500 students come through the Student Farm each year for internships, tours, and through courses. The Market Garden's greenhouse is essential for producing the vegetables grown at the farm, but the current greenhouse fan provides inadequate cooling to the greenhouse. The project seeks to install a solar panel, two DC exhaust fan and two shutters and further involves testing the air flow and temperature changes before and after the installation.

1.2. Project Goal Statement

We are UCD students committed to enhancing the efficiency, food quality, and sustainability of our campus. Currently, the local student farm's fan and cooling system inadequately cools its greenhouse. We will tackle this issue by installing a solar panel, two DC exhaust fans, two shutter, and test the air flow and temperature changes before and after the installation.

This improved cooling system will ensure that the student farm's organic, local produce is fresh for the Dining Services, the CoHo, CSA, the Pantry, and Fruit and Veggie Up! Programs. Furthermore, this will also directly aid the 500 students who come through the Student Farm each year for internships, tours, and through courses.

2. Design Process and Methodology

The most important steps in our design process were the Layout and the solar panel installation.

2.1. Layout

We had to find the layout that would give the better cooling performance. The equipment was: 1 Solar Panel, 2 DC Fans, 2 Shutters, Wiring.

The criteria and metrics were:

Criteria	Qualitative/ Quantitative	Testing Procedure	Target Value	Metric
Installation doesn't inhibit greenhouse activities	Quantitative	Assessing which greenhouse processes might be affected by our cooling system	0	Greenhouse activities affected
Solar Panel Location	Quantitative	Fan performance	40	Voltage

Measuring CFM/Temp Changes	Quantitative	Measuring CFM/Temperature changes	1 air exchange per min / 75-85 ºF	Cubic feet per meter/ Fº Degrees
Location of 2nd Fan to Maximize CFM	Qualitative	Figuring out max point for CFM	Max possible	Cubic feet per meter
Fans must be run after shutters or evaporative coolers open	Qualitative	Timing the shutters so they occur before fan is ran	Fans on before evaporative coolers	Fans on and of

2.2. Solar Panel installation

For the solar panel we had three things to consider in our design: the location in the greenhouse, the angle and how we would mount it.

We made an evaluative matric to stablish the relevance of the design considerations.

The criteria and metrics were:

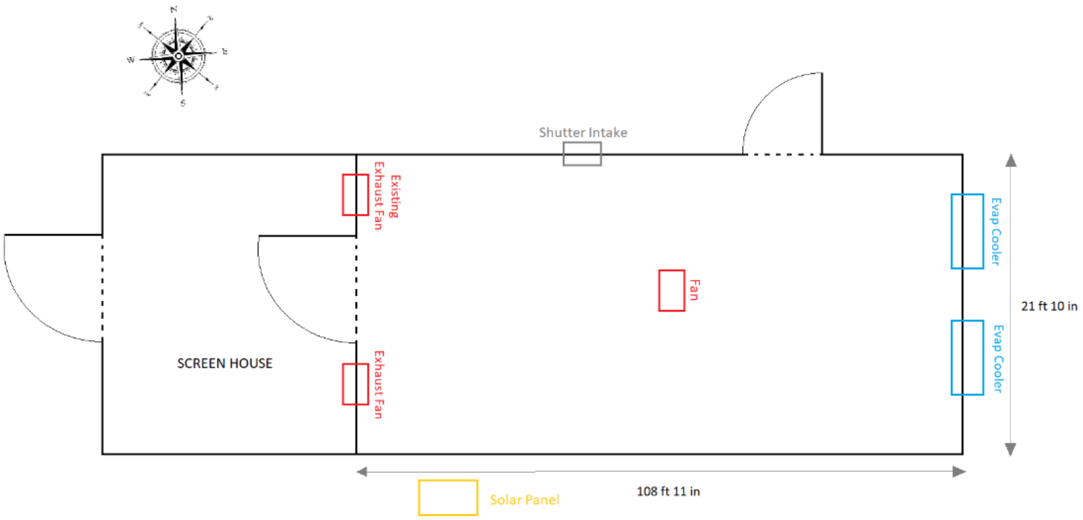
Criteria	Qualitative/ Quantitative	Testing Procedure	Target Value	Metric
Safety for us	Qualitative	We used tools that we were fully trained on. We also didn't use certain solar panel mounts as they would require us to work on the roof more. This would be a hazard.	-	-
Safety for the workers	Qualitative	We ensured the panel was close to the roof to ensure that it didn't hot any farm works or get in the way of truck deliveries.	-	-
Doesn't Inhibit Greenhouse activities	Qualitative	We didn't use pressure sensitive wood for the panel mount as it was toxic for the organic plants growing.	-	-
Sunlight Location	Quantitative	We used a software to determine the correct coordinates (latitude/longitudinal) and algorithm to determine the degree tilt for our panel.	15-18	degrees
Easily Removable	Qualitative	We ensured the components we installed were easily removable incase the greenhouse ever wet through construction.	-	-

3. Results and Discussion

3.1. Layout

We decided to install one exhaust fan at the end of the greenhouse and one in the middle. The middle-fan provides air circulation, improving the airflow throughout the greenhouse. The exhaust fan increases the airflow and the amount of air pulled out of the greenhouse, helping to achieve the target value of 1 air exchange/min.

The solar panel will be mounted in the south side of the greenhouse where the sun shine is available most of the day time throughout the year.



3.2. Fan and Shutter Installation


Picture 1


Picture 2


Picture 3

Picture 1: Middle-fan installed.

Picture 2: Front view of the greenhouse. In the left there is the existing exhaust fan and in the upper-right the shutter and the new exhaust fan installed behind it.

Picture 3: Exhaust fan installed.

3.3. Wiring


Picture 1


Picture 2


Picture 3

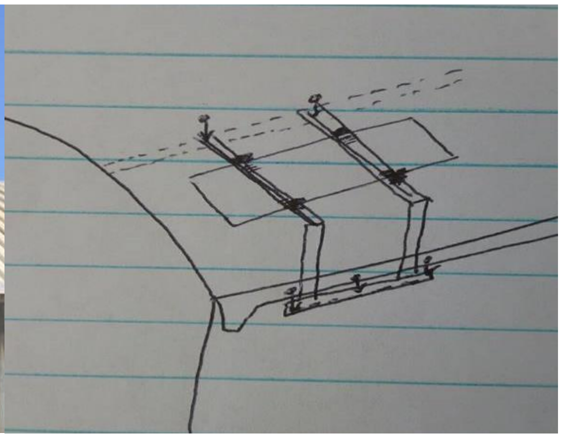
Picture 1: A Metal reducer is connected to the fan wires to the breaker box wires. We used heat shrink and electrical tape to cover our electrical connections in the end. We also used zip ties to hold all the wires along the greenhouse.

Picture 2: Manual switch.

Picture 3: The positive wires from the fans and the panel are connecting at the top and bottom of the breaker box. The negative wires from all of the components are connected to ensure there is voltage change to control the on and off switch.

3.4. Solar Panel


Picture 1


Picture 2

In the gutter there is a piece of Unistrut bolted down. More Unistrut is welded into that bar vertically. Two longer pieces of Unistrut are welded to those two legs and are bolted into one of the Cross beams of the greenhouse. The solar panel is clamped on with the L brackets from the top and the bottom.

Picture 1: Solar panel mounted on the roof.

Picture 2: Solar panel design sketch.

4. **Recommendations**

Recommendations for operating the system:

- Ensure fan is on during the day and off during the night. There is no charging system to power it during the night.

- If any wiring alterations need to be done, be sure to cover the solar panel up.

Recommendations for future improvements of the installation:

- Do temperature tests and calculate the air exchange per minute in the greenhouse. *See A.10: Deliverable 11: Test chart.*

- Install the second shutter in the North side of the greenhouse. This way there would be more air coming in from the outside and it will increase the airflow and cooling capacity of the greenhouse. Keep in mind that the shutter should be mounted with a screen to avoid pests coming inside the greenhouse.

- Install a battery to stock the energy provided by the solar panel. This way the temperature could be regulate at any time of the day and the fans would always run at their maximum level of power.

- Install timers or thermostats connected to the fan's switch, so they could turn on or off automatically when needed.

- Design a system to easily get the shutter open and closed.

5. **Conclusions**

In our project the design process was about deciding the optimal layout to achieve our client requirements and brainstorm how to build the equipment he purchased to the existent structure of the greenhouse. On the one hand, that made the initial brainstorming process easier because our project is not about prototyping, we already had the equipment we needed to install. But on the other hand, we found a lot of design considerations that nobody thought before buying the material as for example bugs or how to work with the greenhouse glazing material.

We spent many hours doing the installation and ended running out of time. The wiring was done yesterday and we now our installation works but didn't have time to test it with our chart.

We have learned a lot doing this project, we have become familiar with the tools and learned how to deal with a hands-on project and an in-site client. All in all we are very satisfied with our work.

Appendix

A.1. Contact Information

- Group members information

Member	Phone number	Email address
Sonia Krishna	(510)-789-3211	srkrishna@ucdavis.edu
Alice Dien	(530)-204-8783	adien@ucdavis.edu
Noah Coleman	(859)-979-1934	necoleman@ucdavis.edu

- Local partner name and contact

Partner	Phone number	Email address
Raoul Adamchak Market Garden/CSA Coordinator, Student Farm, Agricultural Sustainability Institute	-	rwadamchak@ucdavis.edu

- Local mentor

Partner	Phone number	Email address
Kurt Kornbluth	-	kkorn@ucdavis.edu
Peter Nasielski	-	pnasielski@ucdavis.edu

A.2. Deliverable 2: Initial Design Brief

To better understand the project, answer the following questions:

- **Who is the client and what is their business?**

Rodney (Raoul) Adamchack, the Market Garden/CSA Coordinator at the UCD Student Farm, Agricultural Sustainability Institute.

- **What is the Project Goal Statement? This speaks to the need your design addresses. It should be concise (1 or 2 sentences).**

Enhance the cooling capacity of the Student Farm Market Garden greenhouse by installing a shutter intake as well as a solar powered exhaust fan with a solar photovoltaic array. Furthermore, we seek to test the effect of the added exhaust fan both in terms of airflow in Cubic Feet/Minute (CFM) and temperature gradients inside and outside the greenhouse before and after the installation.

- **What are the specific project goals? Why?**

Installation/Monitoring & Evaluation

1. Install shutter intake with thermostat and motor (E. end of Greenhouse).

2. Mount Solar array and install exhaust fan with wiring (W. end of Greenhouse).

3. Design and implement a methodology to Monitor CFM and temperature changes due to new installation.

Public education/outreach/awareness

1. Video installation process/create accessible educational video demonstrating the purpose and outcomes of the installation (45sec-1min final product).

2. Document Greenhouse Gas emissions from fan of comparable size.

3. Submit final report.

- **Who is the target market/customer?**

UCD Student Farm, Campus students, Campus programs, Dining Commons, Greenhouses that could benefit from solar energy.

- **Any known benchmarks?**

Medium Hoppy Solar Fan example: http://snapfans.com/additional-information/example-photos/ (snap fans).

- **What is the approximate budget?**

2 Univent Automatic Vent and Window Opener $47 each from:

http://www.johnnyseeds.com/tools-supplies/greenhouse-and-tunnel-supplies/univent-automatic-vent-and-window-opener-9034.html?cgid=greenhouse-and-tunnel-supplies#start=1

- **What is the approximate timeline?**

See Gantt Chart in *A.3. Gantt Chart*.

- **What are the final deliverables?**

1. Video.

2. Installation of solar array, exhaust fan, and shutters.

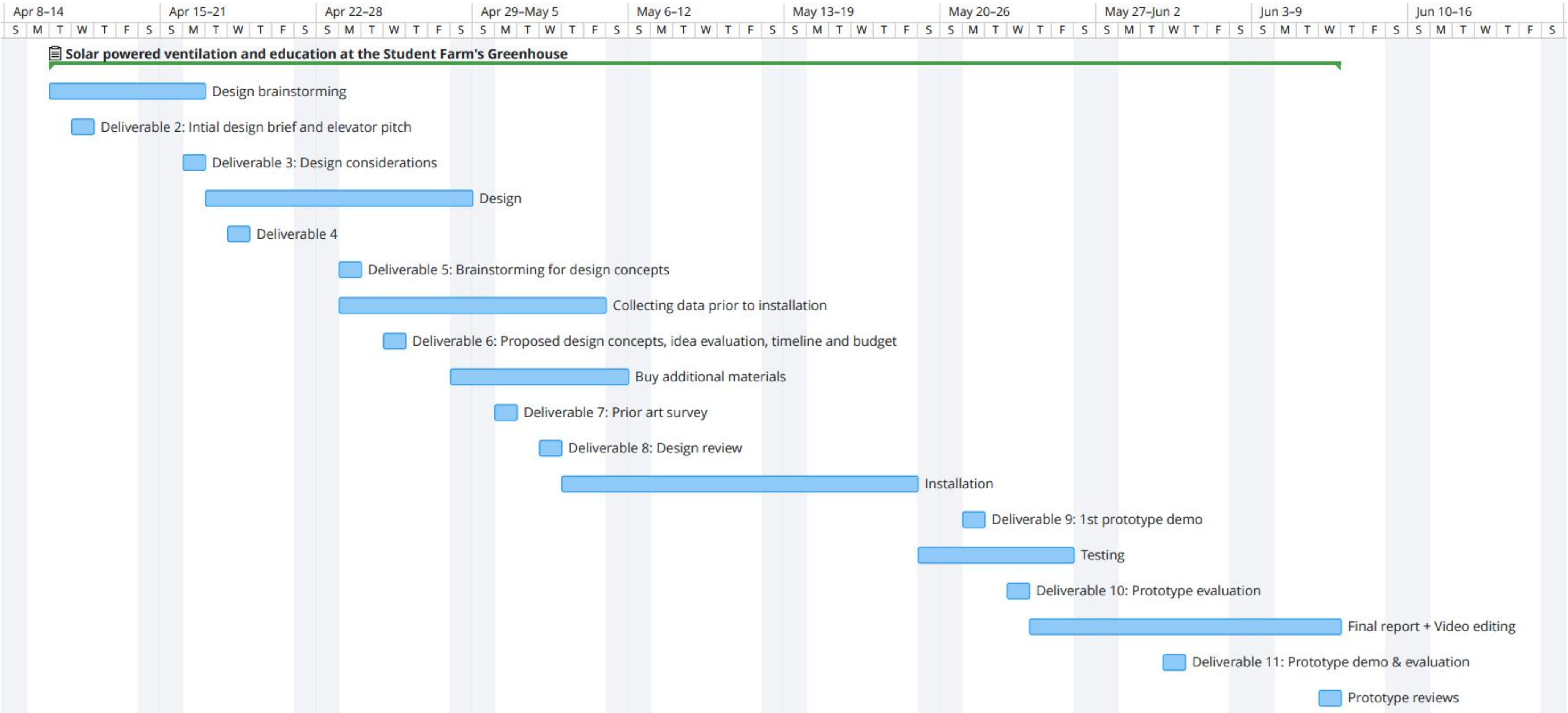
3. Methodology to monitor CFM and temperature change.

Project Goal Statement Elevator Pitch

Refine your project statement into a speech that you can give in under a minute that briefly and in the most engaging way possible covers: Who Are You? What is the Problem or Need? Who are you addressing it for? Why is it important?

We are UCD students committed to enhancing the efficiency, food quality, and sustainability of our campus. Currently on our campus, the local student farm's fan inadequately cools its green house. We will tackle this issue by installing a solar panel, battery, DC exhaust fan, shutter, and test the air flow and temperature changes before and after the installation. This improved cooling system will ensure that the student farm's organic, local produce is fresh for the Dining Services, the CoHo, CSA, the Pantry, and Fruit and Veggie Up! Programs. Furthermore, this will also directly aid the 500 students who come through the Student Farm each year for internships, tours, and through courses.

A.3. Gantt Chart



A.4. Deliverable 3: Expanding the Design Brief and Brainstorm Project Considerations

To expand the design brief, answer the following questions:

- **Who is the client? Who are you designing the technology for?**

Rodney (Raoul) Adamchack, the Market Garden/CSA Coordinator at the UCD Student Farm, Agricultural Sustainability Institute.

We are designing the technology for the Market Garden branch of the Student Farm.

- **Who is the target customer? Who will actually be using the device? Be specific.**

Farm managers both Rodney Adamchack and the lead student farmers since primarily these stakeholders operate in and walk students through the processes of seeding flats, growing microgreens, and taking care of seedlings.

- **What are the specifications if any given for the technology?**

The installation should not interfere with the greenhouse activities. Also, the solar panel should be installed in a place where it cannot be broken by trucks or students and would be easy to take out if they need to replace the glazing material of the greenhouse.

- **What are the technical, social, environmental, and financial considerations?**

a. Technical

Ideal greenhouse temperatures for this structure are between 75-85 degrees Fahrenheit and solar panels must be oriented in a southerly direction. For the Installation process, we will need adequate training on:

1. Sawzall/angle grinder (for cutting into the corrugated plastic).

2. Drills/Bandsaw/circular saw to prep wood or aluminum for framing the shutters/fans.

b. Social

The greenhouse is a hub of student involvement. We must make sure the technology we use best benefits the students and the produce.

c. Environmental

We must make sure our solar system is practical for all weather and environmental changes as the green house is outside.

The greenhouse grows organic food, so the used materials must respect the laws for organic spaces.

d. Financial

The Green house is proposed by the student farm, so we must ensure that it is financially efficient.

- **What are other existing designs?**

Medium Hoppy Solar Fan example: http://snapfans.com/additional-information/example-photos/ (snap fans).

- **What will a successful design do?**

A successful design will provide increased cooling/ventilation and decreased temperatures within the greenhouse.

- **What is the timeline?**

See Gantt chart in page number 7.

- **What is the project budget? What is the cost and quantity of products needed?**

2 Univent Automatic Vent and Window Opener $47 each from:

http://www.johnnyseeds.com/tools-supplies/greenhouse-and-tunnel-supplies/univent-automatic-vent-and-window-opener-9034.html?cgid=greenhouse-and-tunnel-supplies#start=1

- **What is the end deliverable?**

1. Video.

2. Installation of solar array, exhaust fan, and shutters.

3. Methodology to monitor CFM and temperature change.

- **What skills and information will you need to design a successful product?**

For the Installation process, we will need adequate training on:

- Sawzall (for cutting into the corrugated plastic).
- Jigsaw.
- Bandsaw/circular saw.

And we will need information about:

- CFM/optimal temperature information.
- Wiring/DC source information.
- Solar Panel Optimal Location information.
- Air flow information (shutter and fan timing) so the air cycles.

Based on your answers to these questions brainstorm design considerations and write down 10 to 20 of them.

1. Space to work is limited at the East end of the greenhouse.

2. Passive air vent in west end should maximize air intake and not obstruct equipment outside.

3. Second fan should be placed to maximize CFM output from the greenhouse.

4. If fans are running before shutters are open, a vacuum can be created which further prevents the air cycling.

5. Solar panels may need infrequent cleaning and should be installed in a way which allows for this to be done safely.

6. Installation process should be completed in a way which does not inhibit ongoing greenhouse activities.

7. The final design should only act as a cooling system and not affect any of the other circuitry or infrastructure of the green house.

8. Solar Panels location should be installed to capture the most sunlight.

9. Must adhere to different specs for AC and DC sources.

10. Must come up with a way to measure temperature and CFM that's easy for maintenance of student farm workers.

A.5. Deliverable 4: Specific Design criteria, and metrics

- **Has your project goal statement statement changed since learning more information? Update if needed.**

  Not update needed.

- **What are the important design considerations? Narrow down to 5 from the previous deliverable and refine them into criteria (see table below!)**
  - Location of Solar Panels.
  - Measuring the CFM/Temperature Changes.
  - Location of 2nd Fan to maximize CFM.
  - If fans are running before shutters are open, a vacuum can be created which further prevents the air cycling.
  - Installation process should be completed in a way which does not inhibit ongoing greenhouse activities.

- **How you will evaluate and test the design? Will these be qualitative or quantitative?**
- **What are the metrics (the unit of measurement)?**
- **What are the target values for each metric and in what are the units?**
- **Make a Testing Table with this information**

Criteria for the Layout and installation:

Criteria	Qualitative/ Quantitative	Testing Procedure	Target Value	Metric
Installation doesn't inhibit greenhouse activities	Quantitative	Assessing which greenhouse processes might be affected by our cooling system	0	Greenhouse activities affected
Solar Panel Location	Quantitative	Fan performance	40	Voltage
Measuring CFM/Temp Changes	Quantitative	Measuring CFM/Temperature changes	1 air exchange per min / 75-85 ºF	Cubic feet per meter/ Fº Degrees
Location of 2nd Fan to Maximize CFM	Qualitative	Figuring out max point for CFM	Max possible	Cubic feet per meter
Fans must be run after shutters or evaporative coolers open	Qualitative	Timing the shutters so they occur before fan is ran	Fans on before evaporative coolers	Fans on and of

Criteria for the solar panel installation (added later):

Criteria	Qualitative/ Quantitative	Testing Procedure	Target Value	Metric
Safety for us	Qualitative	We used tools that we were fully trained on. We also didn't use certain solar panel mounts as they would require us to work on the roof more. This would be a hazard.	-	-
Safety for the workers	Qualitative	We ensured the panel was close to the roof to ensure that it didn't hot any farm works or get in the way of truck deliveries.	-	-
Doesn't Inhibit Greenhouse activities	Qualitative	We didn't use pressure sensitive wood for the panel mount as it was toxic for the organic plants growing.	-	-
Sunlight Location	Quantitative	We used a software to determine the correct coordinates (latitude/longitudinal) and algorithm to determine the degree tilt for our panel.	15-18	degrees
Easily Removable	Qualitative	We ensured the components we installed were easily removable incase the greenhouse ever wet through construction.	-	-

A.6. Deliverable 5: Brainstorming for design concepts.

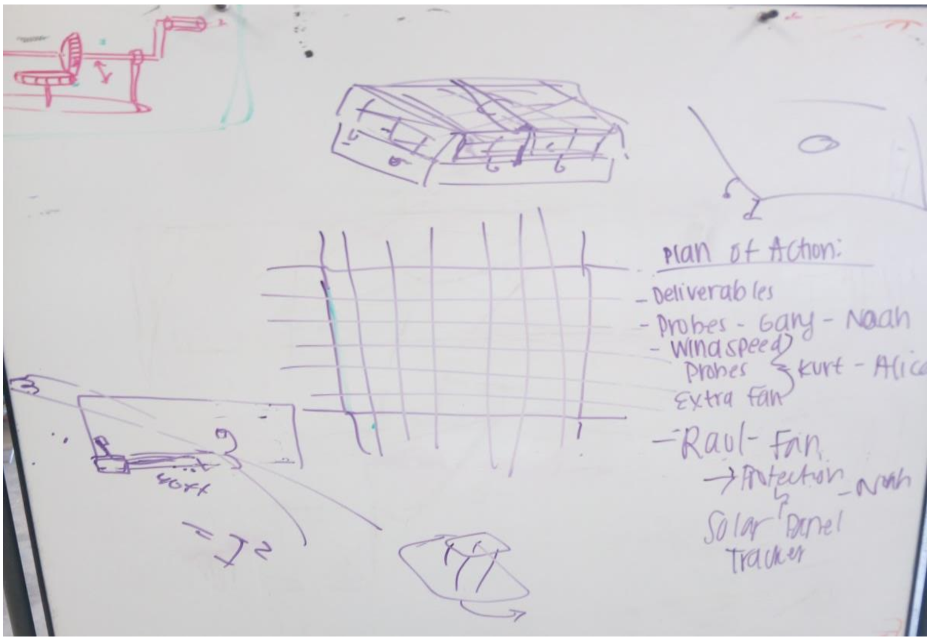
- **Revise your statement based on any new information**

Good day, my name is ___, I'm ___ and I'm ____.

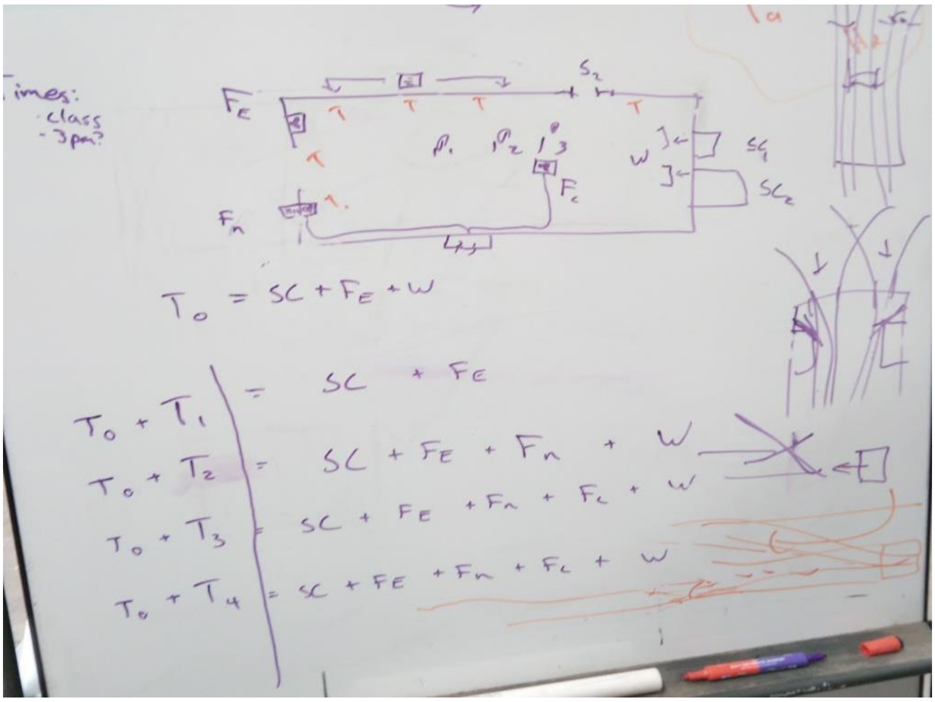
The UC Davis Student Farm contributes to the sustainability of the UCD food system by providing certified organic, local produce to students through several outlets including Dining Services, the CoHo, a CSA, and donations to the Pantry, and Fruit and Veggie Up! In addition, roughly 500 students come through the Student Farm each year for internships, tours, and through courses. The greenhouse is essential for producing the vegetables grown at the farm, but the current greenhouse fan, used to maintain an optimal growing climate, is inadequate to cool the greenhouse. We are tackling this issue by reexamining the cooling system within the greenhouse and by designing, building, and testing a solar powered installation to enhance greenhouse cooling capacity. This will be done in place of installing another grid-based fan. Doing so will improve the sustainability of the Student Farm, reduce grid energy use through the implementation of renewable energy technologies, and provide an opportunity to educate students about sustainable energy and agriculture.

- **Brainstorm at least 20 design ideas. Write them down and sketch**

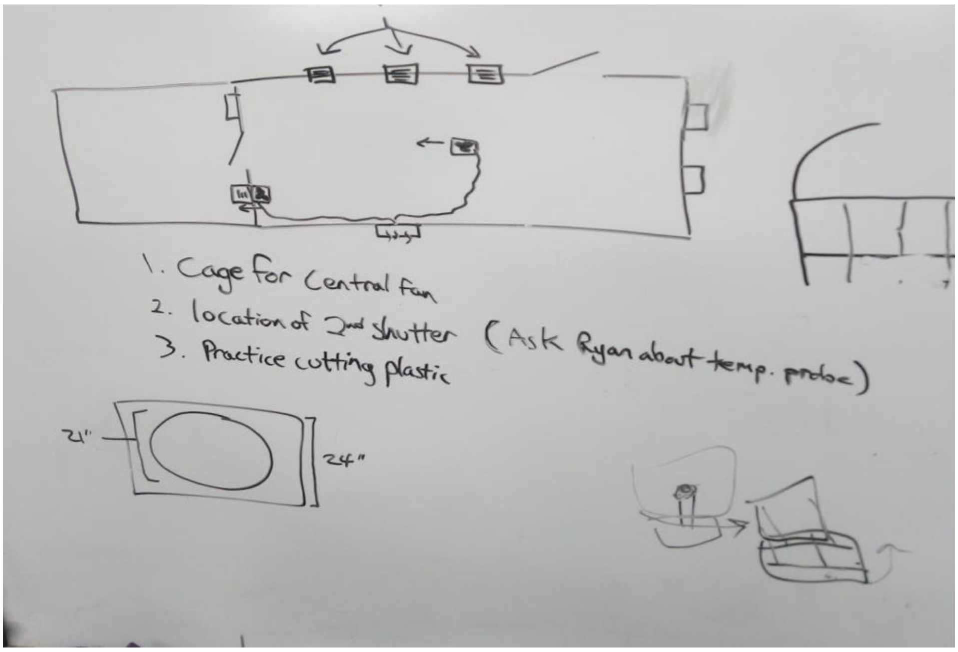
An important design idea is that of purchasing large-holed hardware cloth which will protect the fans from being damaged by outside intrusions. The hardware cloth could be bent and screwed directly into the fan's frame which would provide a light and effective protective covering.



The image below articulates different modes which we will be testing to ascertain optimal design SC- Swamp Coolers, W-Wood, Fe-Fan Existing, Fn-Fan New, Fc-Fan Central. In the orange at the top right, we have indicated that we will need to gatter data on baseline factors to assess the utility of our measurements. These baseline factors include: Time of day, Cloudiness, Temperature outside, Relative Humidity, and wind speed.

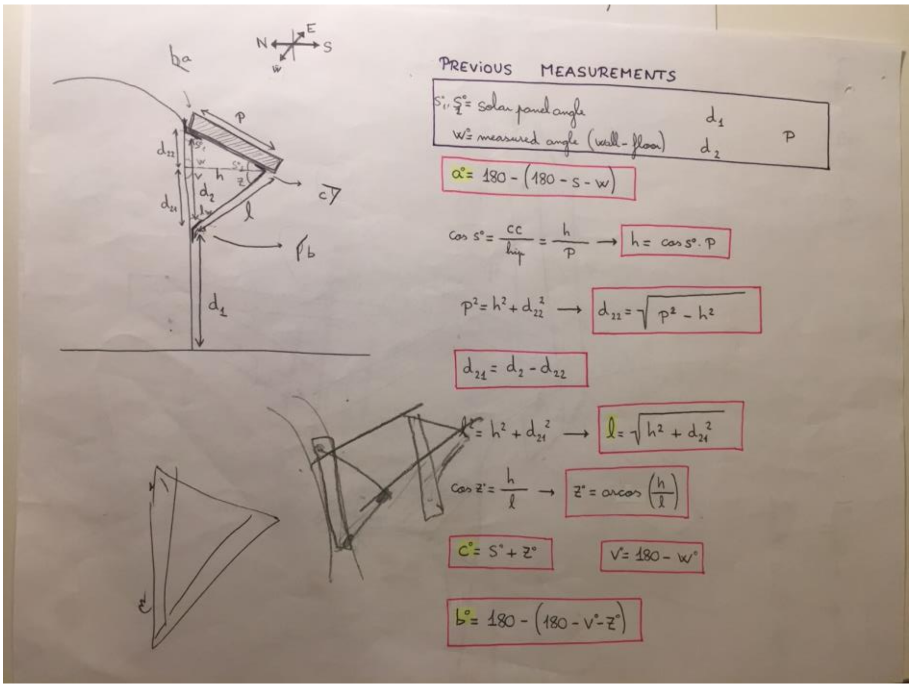


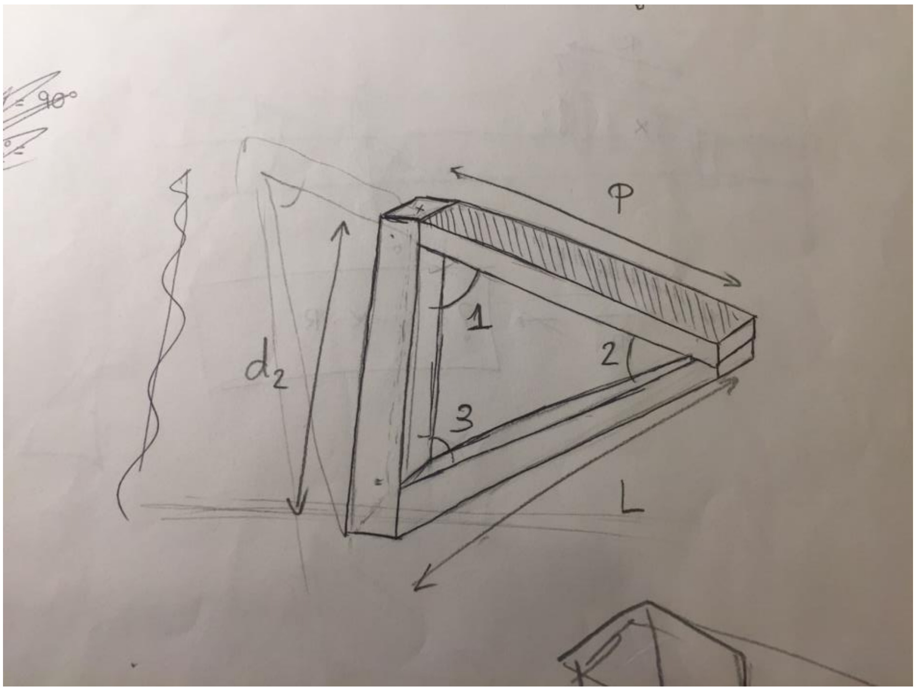
The image below describes the general layout of our greenhouse for this project and indicates that there is still some gaps in data which would determine where the optimum location to install the passive intake shutter will be. The location of the solar panels is to be midway between the two fans, outside the greenhouse and at waist height.



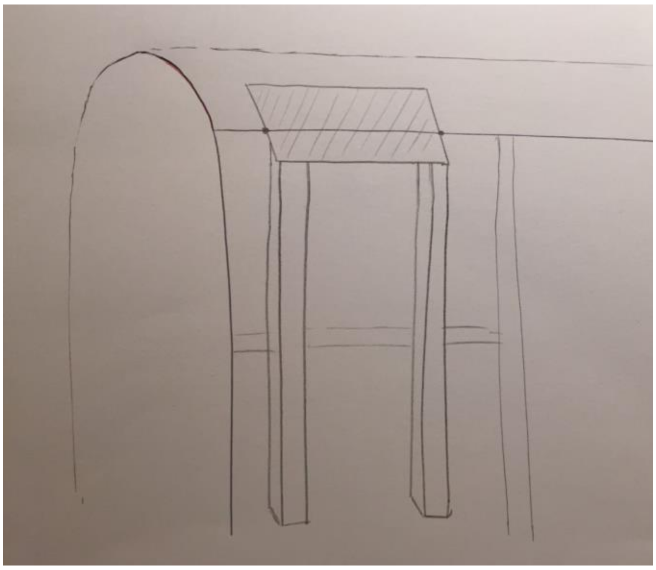
Design for the solar panel

First, we made a design where the solar panel was installed in the side of the greenhouse. The idea was to build a triangle frame to have the solar panel angled 15º south. We ended not using this design because there where issues with trucks coming the way and safety issues for students and greenhouse workers. In addition, it was not a good design to be removed easily in case of greenhouse glazing replacement.



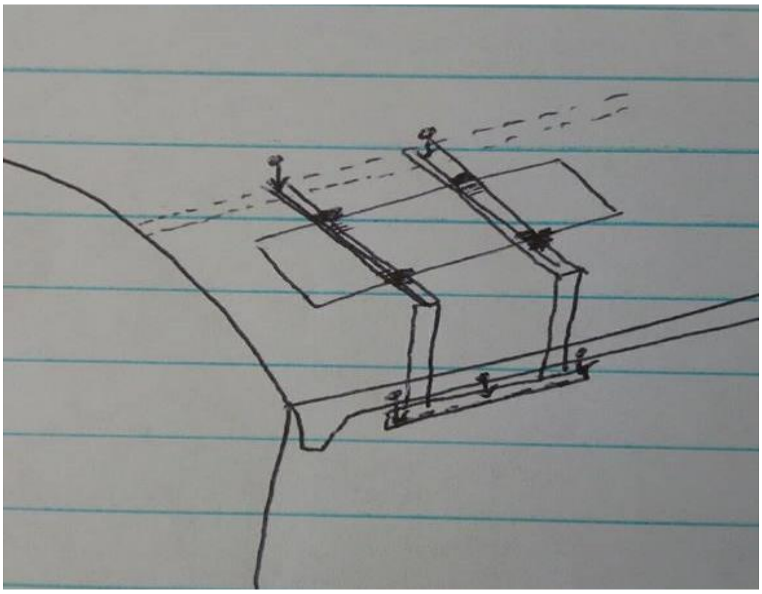


In the second design, the solar panel was screwed in both, the greenhouse structure and two wood sticks. Our client was not satisfied with this design and the treatment the wood had was not compatible with organic agriculture.



The design we selected is shown in the following picture. It was easier to build and don't have to be removed to change the glazing material.

In the gutter there is a piece of Unistrut bolted down. More Unistrut is welded into that bar vertically. Two longer pieces of Unistrut are welded to those two legs and are bolted into one of the Cross beams of the greenhouse. The solar panel is clamped on with the L brackets from the top and the bottom.



A.9. Deliverable 10: Prototype Evaluation

With your group, evaluate/test your prototype based on your design criteria, using the table you created for testing.

Answer the following:

- **Does your prototype work?**
  We are finishing the installation, then we will proceed to the wiring and turn on the installation to see if the fans work.
- **How do you know?**
  We are moving forward on the installation. The amount of work is higher than expected and we don't have the installation wired yet.
- **What could be done to improve it?**
- **What will you do to modify it?**
- **Does it satisfy your Project Goal Statement?**
  For what we did so far, yes.
- **Does it meet the client's needs?**
  For what we did so far, yes.

A.10. Deliverable 11: 2nd Prototype Demo & Evaluation

Demonstrate and evaluate your second prototype or the improvements and changes you made on your first. Again, use your Testing Table.

We created a testing chart for our installation but didn't have time to test it.

DAY 1									
Time	State	T1 (ºK)	T2 (ºK)	T3 (ºK)	Outside T (ºK)	Speed Exhaust fan 1 (m/s)	Speed Exhaust fan 2 (m/s)	Speed Middle fan (m/s)	Volume air extracted* (m^3/s)
10 AM	0								
	1								
12 PM	0								
	1								
3 PM	0								
	1								
6 PM	0								
	1								
DAY 2									
Time	State	T1 (ºK)	T2 (ºK)	T3 (ºK)	Outside T (ºK)	Speed Exhaust fan 1 (m/s)	Speed Exhaust fan 2 (m/s)	Speed Middle fan (m/s)	Volume air extracted* (m^3/s)
10 AM	0								
	1								
12 PM	0								
	1								
3 PM	0								
	1								
6 PM	0								
	1								

*For state 0 calculated as: Air flow fan 1 (m/s) * Area fan 1 (m^2)

For state 1 calculated as: Air flow fan 1 (m/s) * Area fan 1 (m^2) + Air flow fan 2 (m/s) * Area fan 2 (m^2

A.11. Pictures

Pictures are sent in a different document.