Deliverable K-User Manual

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Abstract

This report is used to outline the process by which we constructed our greenhouse. It also explains how we went about making the greenhouse and all the steps we took to create our final product. This includes identifying the needs of our client, design concepts, materials used and cost as well as a detailed description of the building process with its associated challenges. Included are also user guidelines.

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List of Acronyms

Table 1. Acronyms used throughout User Manual meanings

Acronym	Definition
OSB	Oriented strand board
PCT	PolyCyclohexylenedimethylene Terephthalate
VIBE	The motto of the project

1 Introduction

At a fundamental level, every single person has a very specific set of needs to survive. The fundamental needs would be food, water, and shelter. Unfortunately, not everyone has access to these important needs at any given time. Without these essentials, one cannot survive. Even in developed countries such as Canada, there are some communities that don't have the ability to secure a source of food, one of the fundamental needs, which is a big problem. One such community is the Algonquins of Barriere Lake community. They do not have access to food all year round due to environmental issues and they need a system that will help provide them with food. For this project we were tasked with designing a system that would be able to help this community by giving them something that would supply them with food. We ultimately went with a greenhouse system that would allow them to grow food year round. Our design is specifically catered to our client's needs and allows for year round crop growth along with other added features like rodent protection and power generation just to name a few. Through working with the client, we were able to generate ideas, create and test our designs to manufacture the best possible greenhouse for their needs. These needs include a transportable, weather-resistant greenhouse that can feed up to five people while needing minimal maintenance, being self-powered, and automatically watered. The greenhouse should be low-cost while remaining easy to use. In this report, we will outline in great detail our designs, design process, prototypes, construction process, and our next steps for future improvements.

2 Need Identification and Product Specification Process

Problem Statement

Our client requires a transportable, weather-resistant greenhouse that can feed up to five people while needing minimal maintenance, being self-powered, and automatically watered. The greenhouse should be low-cost while remaining easy to use.

Needs Identification

Table 2. Client needs

Needs	Weight (out of 5)
Water collection and reuse	5
Electricity generation	5
Durable to extreme weather conditions (ice, rain, cold)	4
Heat generation for cold months	3
Grow plants to feed up to 5 adults	5
Should not be harmful to wildlife	2
Protection from wildlife	4
Cost should be under 500 $	2
Must withstand weight of snow	4
Transportable	4
Minimal labour and low-cost maintenance	3
Educational for youth in the community	1

Benchmarking

Table 3. Table of Benchmarking

Requirements	Sunshine Mt. Hood Garden House - Single Door	Palram Hybrid Lean-to-Grow House	Palram Glory Heavy Duty Greenhouse
Picture			
Cost ($)	1319.00	938.00	2775.00
Base size (ft)	6 x 4	8 x 4	8 x 12
Water collection	None	Gutters	Gutters
Durable to all weather conditions	Yes (wood frame w/ polycarbonate walls)	Yes (aluminium frame w/ polycarbonate walls)	Yes (aluminum frame w/ polycarbonate walls)
Minimal labour and low-cost maintenance	Yes	No	No
Not harmful to wildlife	Yes	Yes	Yes
Electricity Generation	No	No	No
Heat Generation	No	No	No

Target Specifications

Functional requirements

Table 4. Identified Functional Requirements

Design specs	Weight (1-5)	Value	Verification method
Water collection and reuse	5	Yes	Analysis, test
Electricity generation	5	100 W	Analysis
Heat generation for cold months	3	10-30 ℃	Test
Grow plants to feed up to 5 adults	5	5kg/week	Test

Table 5. Identified Constraints

Design specs	Weight (1-5)	Value	Verification method
Cost	2	< 500$	Analysis
Must withstand weight of snow	4	> 20kg/m^2	Analysis
Transportable ● Weight ● Size	4	Yes ● < 100kg ● < 32 ft^2	Analysis
Minimal labour	3	< 1 hour / week	Test
Should not be harmful to wildlife	2	< 2 cabbage dead	Analysis
Durable to extreme weather conditions (ice, rain, cold)	4	Yes	Test

Table 6. Identified Non- Functional Requirements

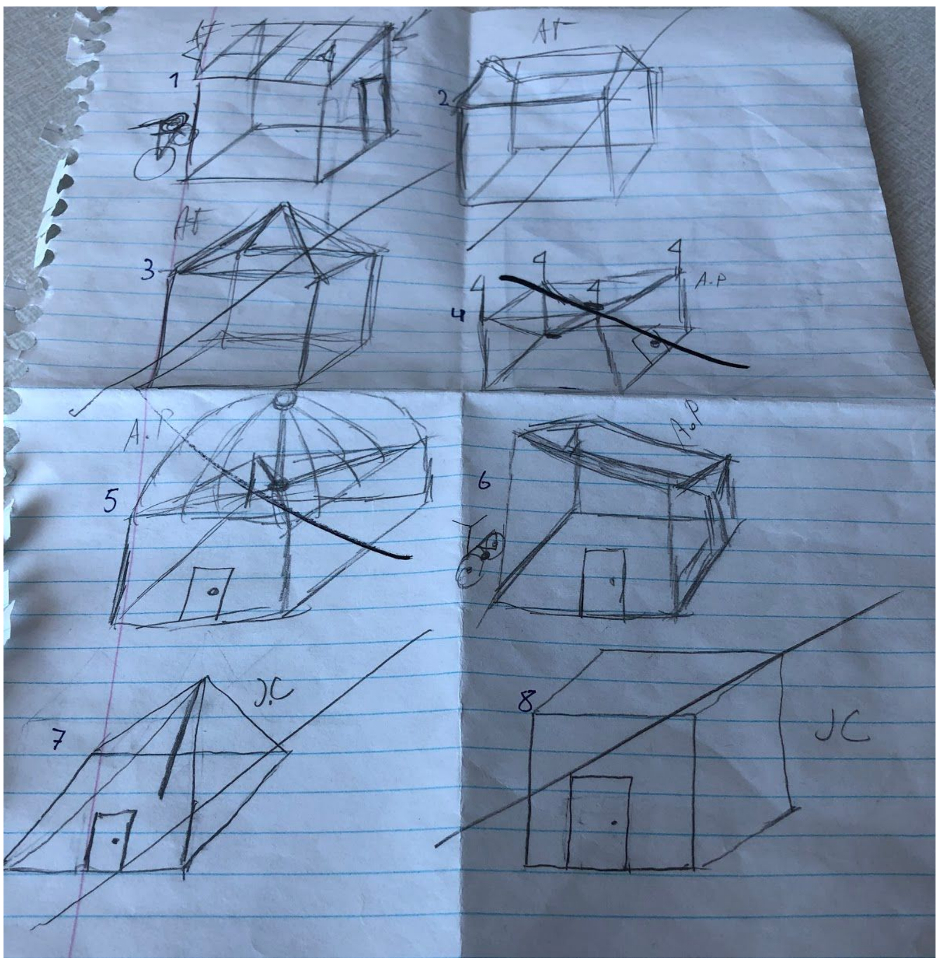
Design specs	Weight (1-5)	Value	Verification method
Educational for youth in the community	1	Yes	Test
Aesthetics	1	Yes	Test
Protection from wildlife	4	Yes	Test

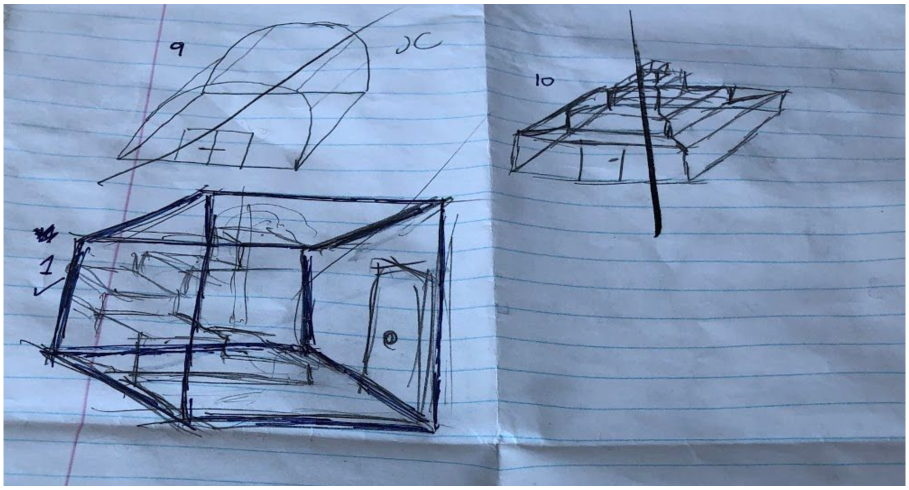
Our thorough benchmarking has allowed us to establish guidelines for each design specification. We provided metrics for those specifications that required them, while others are qualitative and therefore could not be valued with metrics.

3 Conceptual Designs

Brainstorming Results

Figure 1. Ten Potential Design Ideas





1) A 6x6 box with a slanted roof for water collection.
2) A 6x6 base that leads to a triangular shaped roof similar to a house.
3) A 6x6 box with a pyramid on top.
4) A 6x6 castle shaped box with a concave roof for collecting water.
5) A 6x6 box shape with a dome roof
6) A 6x6 box with a slanted roof for water collection.
7) A 6x6 base with a tent shape enclosure
8) A 6x6 cube
9) A 6x6 base with a cylindrical farm shed enclosure.
10) A 6x6 square base pyramid with gutters at each level

Analysis

<u>Greenhouse with Slanted Roof and Bike</u>

This greenhouse sits on a 6’ X 6’ base and will include three walls that are 6’ x 6’, the fourth wall being 6’ x 8’, and the door being around 2’6” x 6’8”. The plastic roof will be slanted so rain and snow can be collected in the gutters and stored. This idea is reasonably compact and portable, but also very useful because the water collection will be maximized. Although the recollection will be maximized with only one gutter collecting all the water, this also can lead to some problems. One problem is that since only one gutter is being used, heavy rainfall and precipitation can cause an overflow, and especially with snow, the gutter could fall and be a danger to anybody nearby. Additionally, snow can fall off the other side and block the door, or fall onto someone else, which could be another safety hazard. The following images are of dimensions for this greenhouse.

Figure 2. Dimensions of Selected Design

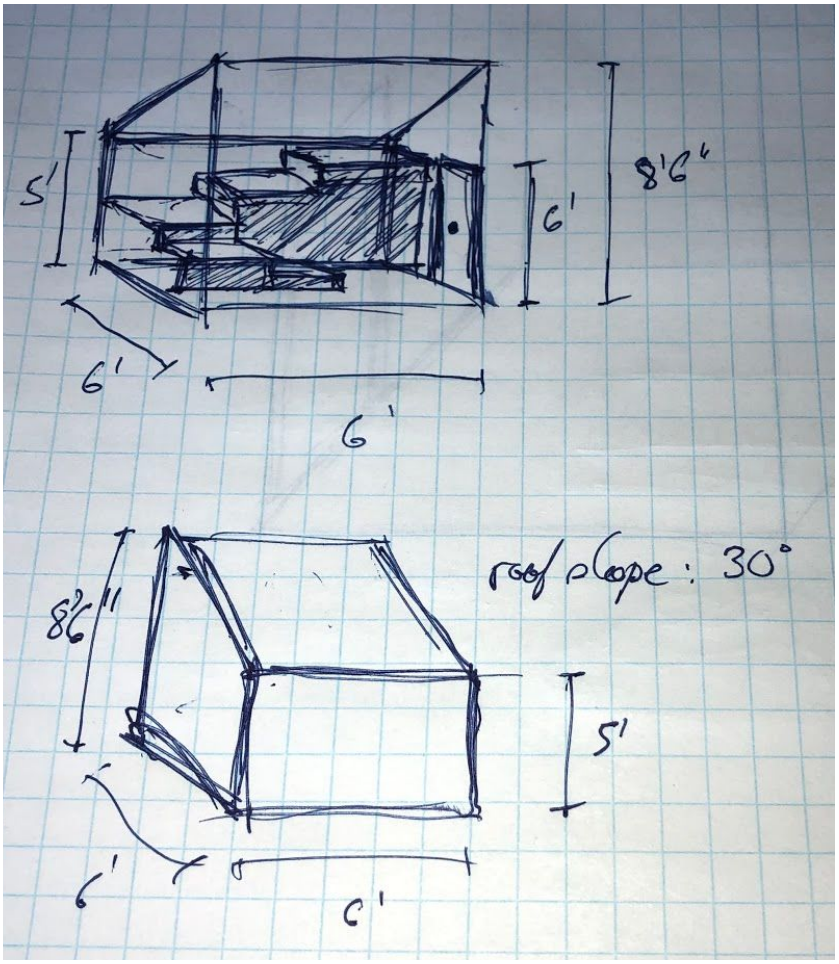
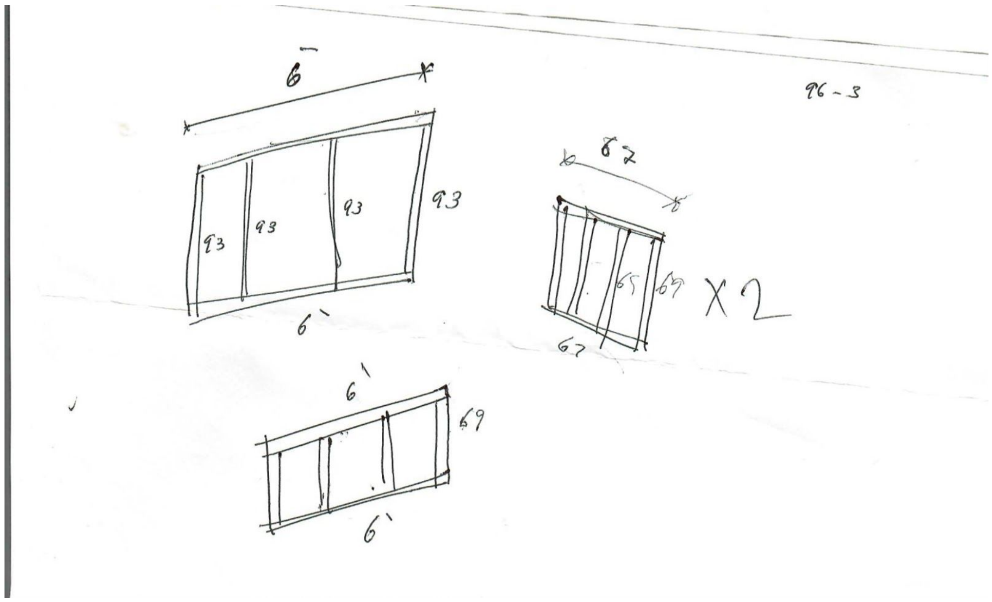


Figure 3. Dimensions of each wall and support



<u>Castle Greenhouse with Inverted Roof and Flags</u>

This greenhouse design uses an intricate design with a complex roofing system that is designed to collect water in the center of the roof and feed directly to the hydroponic unit. Collecting the water in the center of the roof would eliminate the need to use any gutter. However, one flaw with this design is in the winter the snow would build up on the roof, as it would have nowhere to run off, possibly causing damage to the structure. One possible solution developed that could eliminate that possibility is adding a structural support at each edge of the roof at the vertex of the roof but testing would need to be done to confirm that it would eliminate the problem. Another possible flaw could be if the roof holds water on the same spot for a prolonged period of time it is very likely the roof could develop a leak and the wood could be damaged. This greenhouse will sit on 6'x 6' base and would have four walls supporting the structure that would measure 6'x 8' along the sides, with the roof coming down at 6' at the center and 6'x 8' along the front and back, with a door that measures 6' tall at the front. The following image is of dimensions for this greenhouse.

Figure 4. Castle Greenhouse with Inverted Roof

Chosen Design

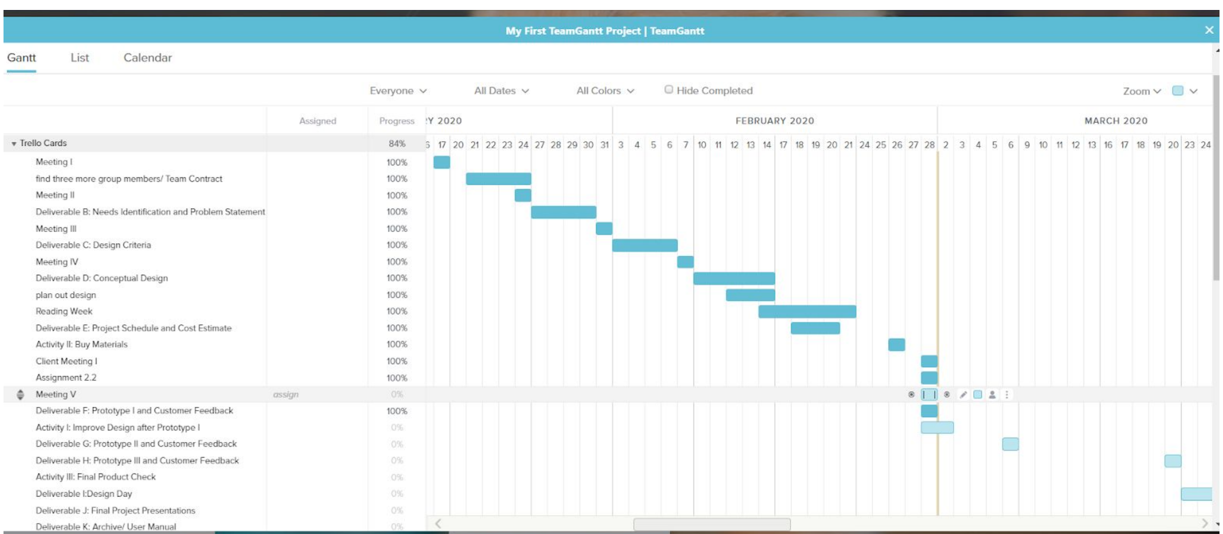
In the end, our group decided to go with the greenhouse design that had the slanted roof for water collection. We chose to go with this design for a number of reasons, mainly because of its simplistic design, structural integrity and the ease of construction. Going forward ,we will be in close contact with our hydroponics team to further our design and continue the construction. The selected design includes plans for cascading plant platforms to be used by the hydroponic system, but this can be modified to suit the exact specifications of the hydroponic design.

4 Project Plan, Execution, Tracking & Bill of Materials

List of tasks

1. Discuss with the hydroponic team and decide the base size, 30 mins, Joshua.
2. Select a roof shape from brainstorming ideas, 1 hr, all members.
3. Determine what kinds of materials we need to use for building the greenhouse, 20 mins, all members.
4. Build the 6 x 6 base, 2 hrs, all members.
5. Build the walls, 2 hrs, all members.
6. Nail the walls and base together, 1 hrs, all members.
7. Nail the roof, 1.5 hrs, all members.
8. Build a frame to support the hydroponic system, 3 hrs, all members.

Figure 5. Team Gantt Chart



Project risks and associated contingency plans

1. Hydroponic system not fitting properly inside the greenhouse

We could communicate to the hydroponics team the dimensions of the greenhouse to avoid any problems of the system not fitting within the greenhouse. If the system is created and still does

not fit within the greenhouse, we could modify the dimensions/shape of the hydroponics system to make it fit properly within the greenhouse.

2. Structural integrity of the greenhouse

Extra supports can be added to the structure where they are needed to make sure the structural integrity of the greenhouse is suitable for the conditions it will be placed under.

3. Weather-proofing

Making sure the vinyl has no punctures in it to prevent water from entering and making sure the roof is properly sealed to make sure no water can enter between the panels of the roof.

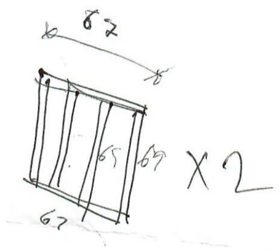
Estimate cost of components and materials

Table 7. List of the costs associated to each material

Product	Use	Amount	Cost ($)
OSB	Base	432 (in^2)	10.74
Spruce Wood (2x3)	Building Structure	30 Boards	65.70
Spruce Wood (2x4)	Base Structure	6 Boards	17.94
Clear PCT Vinyl	Walls	1872 (in^2)	21.00
Corrugated Plastic	Roof	504 (in^2)	105.73
Door	Entrance	30x80	41.99
Screws and Nails	Fasteners	Approx. 50	10.00
Gutter	Water Collection	8 ft	8.49
Wire Mesh	Rodent Protection	288 (in^2)	57.00
			338.59

5 Analysis

Side Walls (6x6)

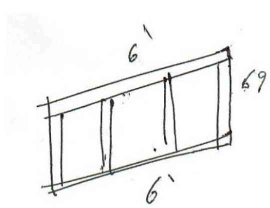


The sides wall has a 2x3 board along the top and bottom that is cut to 6ft long to match the width of the base. To do this the board is cut from the original 8ft board to 6ft (96-24)=72). The vertical boards between the top and bottom boards are cut to 69’’ to get the required 6ft as the actual width of a 2x3 is 1.5x2.5, therefore we would need to do the following equation: 96 - (24+(1.5x2)).

Table 8. How side walls were constructed

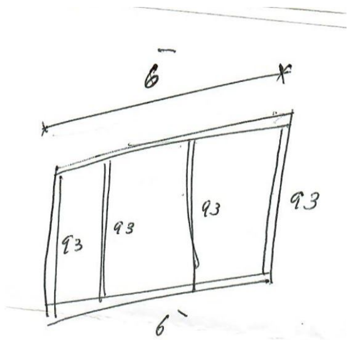
Part	Use	Amount	Length Needed (in)	Function
2x3	Vertical Beam	4	69	96 - 24+(1.5x2)
2x3	Horizontal beam	2	67	96 - 24+(2.5x2)

Back Wall (6x6 w/ door)



The front wall has a 2x3 board along the top and bottom that is cut to 6ft long to match the width of the base. To do this the board is cut from the original 8ft board to 6ft (96-24=72). The vertical boards between the top and bottom boards are cut to 69’’ to get the required 6ft as the actual width of a 2x3 is 1.5x3.5, therefore we would need to do the following equation: 96 - (24+ (1.5x2)).

Front Wall (6x8)



The back wall has a 2x3 board along the top and bottom that is cut to 6ft long to match the width of the base. To do this the board is cut from the original 8ft board to 6ft (96-24=72). The vertical boards between the top and bottom are cut to 93'' to get the required 8ft as the actual width of a 2x3 is 1.5x3.5, therefore we would need to do the following equation: 96 - (1.5x2).

Roof (7x6)

The roof rests on the front and rear walls, composed of 4 2x3 planks 7' in length that serve as a base for the roof. To do this the board is cut from the original 8ft board to 84 inches (96-12=84). The 4 planks would then be secured to the slanted roof with screws evenly spaced apart along the 6'. To do this we measured 2' from the middle of the outside planks, which would be lined up with the sides of the structure, to the middle of the interior planks. From here, we would measure the length in between each plank and cut another 2 pieces of wood that we would put in to stabilize the roof. To do this we measured the distance in between the planks and cut 2 pieces of 2x3 to put inside as support.

Base (6x6)

The base was the first component to be constructed, using 2x4's. Two 72" planks that were placed at the front and back, cut from 8' boards while four 69" (72" - 2 x 1.5") boards ran perpendicular to these planks, from front to back. Once this frame was built, OSB was nailed to the top and runs from side to side, perpendicular to the planks within the base for added support.

6 Prototyping, Testing and Customer Validation

Prototype Objective

The critical objective of our prototype is to communicate our design and allow us to create a proof of concept that we can use as a reference when constructing our main model. The prototype is a cheap and more comprehensive design to help us visualise the general proportions of the design while also saving us money in the process. The prototype will also give us an idea of the structural integrity of our design. The prototype is successful if it helps us conceptualize and model our chosen design.

Prototype Images

Figure 6. Different views of Prototype I

Figure 6.1. Side View

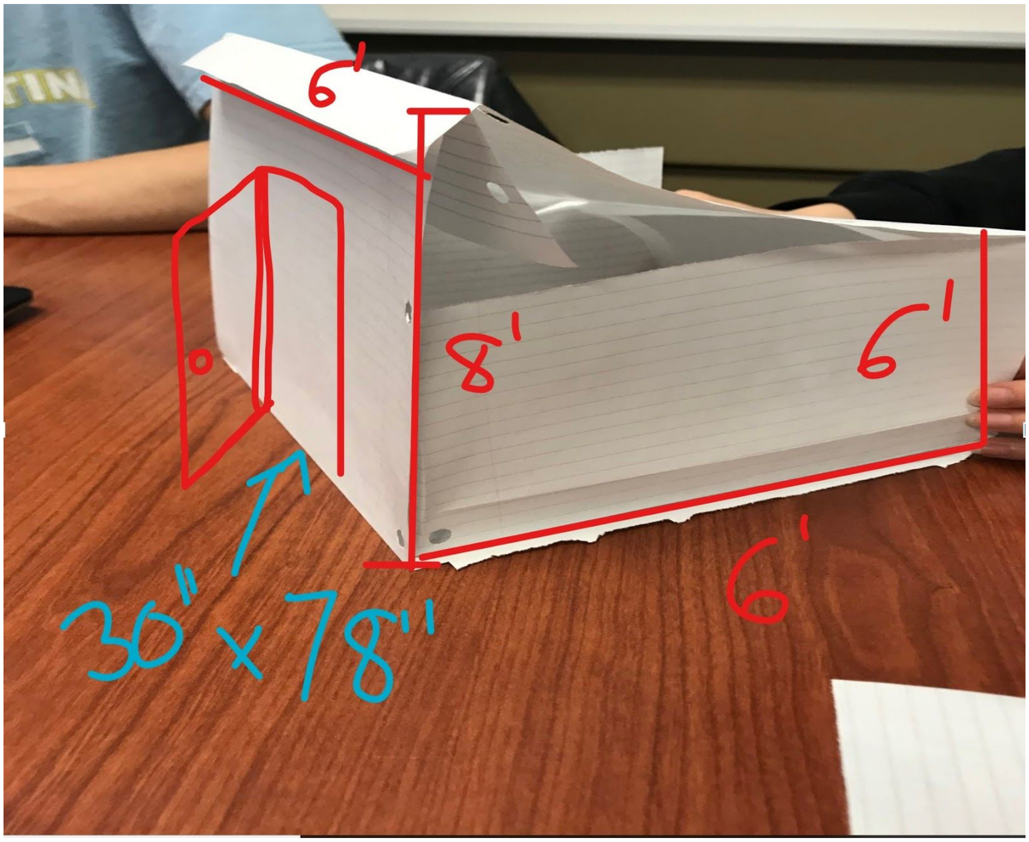


Figure 6.2. Top view

Prototyping Process

In order to build the physical model, lined paper was carefully selected for its availability and inexpensiveness. These qualities make it easy to reproduce. The lined paper was cut into proportional shapes and put together using staples to mimic the behaviour of screws holding the walls in place. The roof was simply placed on top, as this is the concept we'd like to apply during the construction of the greenhouse. Testing consisted of blowing on the roof, mirroring the effects of wind on the structure. The walls deformed considerably but stayed in place due to the staples, the roof effectively being swept away. This suggests that the roof will have to be bolted or screwed into the walls for structural integrity.

Client Feedback

The client was quite pleased with our design during a meeting held on February 28th. However, there was a point of concern. She was mainly concerned with pests and infestation and wanted us to implement a system to help reduce infestation and ward off pests. We proposed an 18 inch wall at the base of the greenhouse constructed with OSB to minimize cost and defend against rodents clawing at the vinyl. In addition, culking at the joints will be used to fill gaps. These suggestions were well received and this feedback will help us improve our design and allow us to get a better understanding of the client's vision for the product. This feedback was obtained through images of our existing full-size greenhouse.

Prototype Objective

The objective of this second prototype is to effectively communicate our design modifications following feedback from the first prototype. Having obtained feedback on this second model, we aim to apply the suggestions to our final design, especially with regards to critical animal and weather proofing strategies. The size and materials used to build this prototype will help us minimize costs while accurately representing a potential final design. The change in materials for the prototype reflects the poor physical properties of paper and the more robust materials used in the final design.

Prototype Images

I. SolidWorks Model

Figure 7. Different views of Solidworks Greenhouse

Figure 7.1. Isometric view

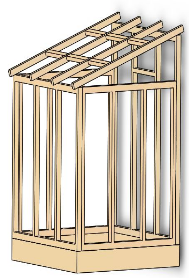


Figure 7.2. Back view

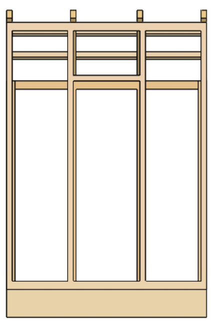


Figure 7.3. Front View

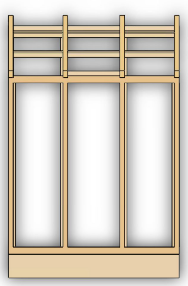


Figure 7.4. Side view

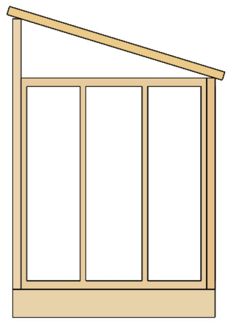
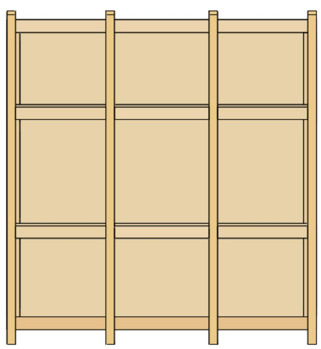


Figure 7.5. Top view



II. Cardboard Model

Figure 8: Different Views of Prototype II

Figure 8.1 Side View

Figure 8.2. Front View

Figure 8.3 Top View

Prototyping Process

In order to build the physical model, cardboard was carefully selected for its availability and inexpensiveness as well as ease of construction. These qualities make it easy to reproduce. The cardboard was cut into proportional shapes and put together using tape and glue where nails would be placed to mimic the behaviour of screws and nails holding the supports in place. The roof was taped to the top, as opposed to the previous prototype, in order to ensure strong winds and impacts could be withstood. This makes it a high fidelity design. Elements such as the doorway were drawn, as well as concrete blocks we believe would be effective against rodents and small animals. Testing consisted of using a strong fan, mirroring the effects of wind on the structure. A second prototype was also built, and these were thrown at each other to test for impact resistance.

Testing and Feedback

The second prototype did much better facing strong wind simulation, as no deformation was noted and the roof did not slide, anchored to the structure with tape and glue. We believe this also provided torsion resistance for the walls. In the impact resistance test, neither model suffered any damage, which suggests our full-scale greenhouse, using even more rigid materials and connections such as wood, nails and screws, will be resistant to important impacts. Our client was in favour of using cement as a rodent-proofing strategy, however any barrier can only be effective up to a certain height, after which the vinyl must be clear to let sunlight in. Any barrier will therefore only be effective against small rodents, and must be difficult to climb.

7 Final Solution

Our final product is a greenhouse composed of a 6x6 base followed by 3 6x6 walls and a 6x8 wall with a slanted roof. The base and all 4 walls with 6 planks to give each section rigidity with the exception being the base, which also had 4 extra OSB planks fastened on top. Each Wall is wrapped in layers of vinyl to maximize sunlight. The taller wall has a 30’’x80’’ door in the middle with 3 large windows made of corrugated to again allow for maximum sunlight and access to the inside. In addition to the large wall, the back wall has a gutter that would allow for water collection and storage Each wall also has 4 extra triangular supports made of OSB, located at the top and the bottom corners,used to further increase the stability of the greenhouse. The walls also have 2 braces,located at each top corner, strengthening the connection to the roof. The roof of the greenhouse is made up of 4 separate planks with another 4 supports planks on the outsides. The roof is also covered in corrugated plastic, giving it the ability to stand up to most weather conditions while also allowing for water collection and sunlight. Another feature of the greenhouse is a mesh that goes around the base that serves as rodent proofing. The last not worthy feature is the solar system. Solar panels will be placed on the sides of the greenhouse that would be used to continuously power the hydroponic unit on the inside. The results gathered from our test would indicate that our greenhouse is very stable. It can withstand almost anything the weather can throw at it while also allowing for all the necessary sunlight. Our tests also indicate that our greenhouses sub functions are all functioning as intended. No rodent can get in ,water collection is seamless with no leaks in storage and the solar system is self sufficient, allowing for constant power to the hydroponic unit. In short, our greenhouse is the complete package and more, able to do its job regardless of the scenario.

8 Conclusions and Recommendations for Future Work

Next Steps

While our team came very close to completing the project, due to the outbreak of the coronavirus pandemic, the greenhouse's construction could not be completed. What follows is a list of steps needed to be taken in order to complete the greenhouse.

-Stay in touch with the hydroponics team while awaiting further instructions from university administration regarding access to school laboratories.

-Once it is safe to access relevant facilities, schedule a time for team members to complete the remaining tasks.

-Replace the frame around the door, originally removed to allow the door to fit (See figure below).

Figure 9: Greenhouse with door frame completed

-Finish stapling the vinyl sheets to the exterior of the greenhouse, including the openings in the door.

-Screw the corrugated clear plastic to the roof, weather-proofing the structure.

-Complete the water collection system.

-Screw gutters to the top of the rear wall.

-Feed the gutters through a cut-out in the rear vinyl sheet while sealing it with duct tape, the spout terminating in the reservoir inside the greenhouse.

-Cut a hole into the top of the reservoir with a pipe leading outside the greenhouse to avoid spillage and to empty excess water outside the greenhouse.

-Screw a wire mesh to the outside of the pipe to ensure no rodents can use it as an entry point.

-Wrap wire mesh around the base of the greenhouse, preventing small rodents from clawing at the vinyl and breaking in.

-Help the hydroponic team with their construction process wherever needed.
Deliver the completed greenhouse to the client.

Conclusion

In conclusion, our design for our greenhouse and the whole process went smoothly and our client really enjoyed what was going to be our final product. For our design we started off really simple and ended up sticking to the simple design as we thought it was the optimal option. For the prototyping process, we went with a 3 prototype plan due to time constraints, among other factors.They were mainly used to give us an idea of what we were thinking at the time and help us with the proof of concept. Our construction process was pretty seamless, everything went very well and was going very smoothly until the emergence of COVID-19 resulting in a global pandemic hit us and shut us down. As far as next steps for our greenhouse, everything highlighted above will be taken into consideration to help us improve for our next projects in the future.

9 Bibliography

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APPENDICES

APPENDIX I: User Manual

I. Collect Needed Materials

1. Start by gathering the tools required to assemble the greenhouse. These include:
    - ➢ A drill
    - ➢ A ladder
    - ➢ A hammer or nail gun
    - ➢ A heavy duty stapler
    - ➢ A exacto knife
    - ➢ A measuring tape
    - ➢ 100 count box of nails
    - ➢ 100 count box of screws

2. You should first collect the materials that are needed to create the greenhouse. These include:
    - ➢ 30 - 2x3 Spruce Wood boards

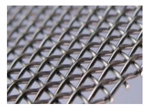
    - ➢ 6 - 2x4 Spruce wood boards

    - ➢ 1 - 30x80 door

    - ➢ 8ft of gutter

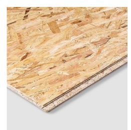
 

- 288 in^2 of wire mesh



- 504 in^2 of corrugated plastic roof panels

- 432 in^2 of OSB



- 1872 in^2 of clear PCT vinyl

II. Assembly Process

1. Build the base 6’ x 6’ base

- Cut two 2x4’ planks to 72” and place at the front and back, 6’ apart.
- Cut four 2x4’ planks to 69” to connect the front and back boards, interspaced by 24” and nail the frame in place.
- Once this frame is built, nail OSB to the top, running it from side to side, perpendicular to the planks within the base for added support.

2. Build the 6’ x 6’ side walls

- Cut two 2x3’s to 67” which will run along the top and bottom - the width for the front and rear walls will account for the remaining five inches.

- ➢ Cut four boards to 69” as boards are 1.5” thick, so the horizontal boards will fill the remaining three inches.
- ➢ Place these boards perpendicular to the horizontal boards, nailing them at 24” intervals.

3. Build the 8’ x 6’ front wall
   - ➢ Cut two 2x3’s to 72” which will run along the top and bottom.
   - ➢ Cut four boards to 93” as boards are 1.5” thick, so the horizontal boards will fill the remaining three inches.
   - ➢ Nail the boards at 21” intervals on the side, leaving exactly 30” for a door in the center.
   - ➢ Double the door frame by adding two 93” boards on either side of the center boards, and add a 30” wide door header 80” from the bottom.

4. Build the 6’ x 6’ rear wall.
   - ➢ The same process as the side walls should be applied, replacing the 67” horizontal boards with 72” boards.

5. Fit the walls to the base
   - ➢ Place the frame for each wall to ensure they fit properly on the base.
   - ➢ Using a drill, screw each wall into the frame for the base, using 12 screws at regular intervals per wall.
   - ➢ The walls should be drilled into each other, using 8 screws at regular intervals per corner.
   - ➢ Due to inevitable instability, use triangular OSB bracing at each corner (four per wall) to solidify the greenhouse.

6. Build the 7’ x 6’ roof structure
   - ➢ Cut four 2x3’s to 84” which will run from front to back.
   - ➢ Space these boards 24” apart, resting them at the top of the front and rear walls.
   - ➢ Screw these boards in place using metal braces to connect them to the walls.

7. Applying the vinyl

- ➢ Take the vinyl and wrap it around the outside of the greenhouse, making sure that it reaches the roof.
- ➢ Staple the vinyl to the greenhouse frame, making sure that the vinyl is tight around the whole greenhouse.
- ➢ If the vinyl is over the roof just cut where needed.
- ➢ If the vinyl is in parts, apply each part along the outside and stretch it so it reaches the furthest most beam on the greenhouse.
- ➢ Staple each end to the beam and between, making sure the vinyl is tight against the frame.
- ➢ Repeat until the whole greenhouse is covered.

8. Adding the corrugated plastic to the roof
    - ➢ Take a roofing tile and lay it along one side of the roof.
    - ➢ Take the drill and screw the roofing tile into the beams in the roof.
    - ➢ Take a second roofing tile and lay it slightly over the edge of the last tile and screw it into the roof.
    - ➢ Repeat until the whole roof is covered.

9. Hanging the door
    - ➢ On the front wall there is a gap between the two beams that will accommodate a door.
    - ➢ Hold the door between the gap, making sure it isn't sitting on the group and push the hinges against the frame.
    - ➢ Take the drill and screw the hinges onto the frame
    - ➢ Open and close the door to make sure it functions properly.

III. Maintenance

1. To keep the greenhouse working at its highest potential the following should be done:
    - ➢ Replace any PCT vinyl that may be damaged
    - ➢ Repair the roof if a leak occurs
    - ➢ Replace the nutrients in the water regularly (see hydroponic system user manual)

IV. Functions and Capabilities

1. Protection against rodents

2. Water collection
3. Plant growing
4. Self-sufficient solar system

V. Safety Guidelines

1. Structure is flammable, keep fires a minimum of 10 meters away.
2. No climbing the structure as this could damage it
3. Toxic if ingested

APPENDIX II: Design Files

MakerRepo: https://makerepo.com/Adrian/gng1103d3vibemachines

Solidworks Diagrams: GNG1103_SolidWorks.zip

APPENDIX III:

Figure 10. Photo of Aleks, Tracy and Adrian (left to right) working on greenhouse with Dr. Jamal

Figure 11. Image of Carter and Joshua working on greenhouse