GNG1103/2101

Design Project User Manual

“THE COTTAGE” GREENHOUSE

Submitted by:

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Abstract

The purpose of this user manual is to be able to teach the user how to assemble and how to operate the product. This can be achieved since this manual includes instructions regarding the construction of the final prototype, including all the research, steps and work that has been completed on the final prototype of “The Cottage” Greenhouse to aid the user in using the product effectively. The manual also documents the list of materials used and the total cost estimate to give the user an idea as to what is required to build this product.

***NOTE:*** *This project was in development during the COVID-19 outbreak. Therefore, it is for this unfortunate reason that the project was not able to be completed. Nevertheless, this user manual will still be fully elaborate in describing the product, and the process needed to build this product.*

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List of Acronyms

|  |  |
| --- | --- |
| **Acronym** | **Definition** |
| HPS | Hydroponic System |
| COVID-19 | Coronavirus disease |
|  |  |
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# 

# Introduction

This manual will be modeled on the design thinking process and examining how it was implemented in the real-life application when working with a client, Monique Manatch, to construct a greenhouse for the Algonquin community at Lac Barrière. Firstly, it is important to empathize with the client through an interview to be able to interpret their answers into specific needs and a condensed summary of the problem, also called the problem statement. Then, using online products that are suitable for the client based on the information gathered from the interviews, it is possible to ideate different possible designs, and finalize on a conceptual design by benchmarking the different designs. After a conceptual design has been made, multiple prototypes must be made to be able to be presented to the client in order to continuously receive feedback on how to improve the product. Section 2 will talk the process as to how the prototypes were made into the final product. All the other elements of the design process will be included in Appendix II.

## THE PROBLEM AND WHY IT IS IMPORTANT

The problem is relevant since this product is being made to facilitate the lives for the inhabitants of an aboriginal community of approximately 50 people who live at an abandoned airport strip in Le Domaine on Barrière Lake. The community lacks access to new materials to construct new houses, resulting in 8-15 people living in one house. The community also has no electricity or running water, and the nearest freshwater stream is highly polluted. It was also mentioned that the generator is maxed out, meaning that there is no room for expansion. Therefore, this product will help improve the lives of the inhabitants, while also taking into consideration the circumstances to prevent being inconvenient in any way.

* 1. **THE FUNDAMENTAL NEEDS OF THE USER**

The user requires this product to allow the community at Lac Barrière to harvest crops for the duration of three seasons using a 6ft x 6ft x 6ft greenhouse that is equipped with an HPS and solar panels. This product must also take into consideration issues regarding accessibility, pests, and structural endurance against the climate conditions.

* 1. **WHAT DIFFERENTIATES OUR PRODUCT FROM OTHERS**

The Cottage Greenhouse differentiates from other products since it is personalized precisely to the needs of the client. This was accomplished by working very closely with the client to brainstorm ideas, to develop prototypes, and eventually, to build a final product. In addition, our greenhouse planned on utilizing insulation on as much surface as possible to ensure that the water tank, located inside the greenhouse, and the food being harvested do not freeze under colder temperatures. Our product also includes measures to be able to use the product safely against the pandemic during the time of the construction phase of the product, COVID-19.

* 1. **THE MAIN FUNCTION OF THE PRODUCT**

The main function of the product is to work effectively with the HPS installed inside, while also providing the plants inside the greenhouse to get as much sunlight as possible. This will allow for the product to be able to provide families in the aboriginal community at Lac Barrière a new source of food.

# How the Prototype is Made

## 

## PROTOTYPE I – Hardware

The greenhouse project is unable to have separate prototypes solely for testing purposes, since the greenhouse itself requires an immense amount of time and materials to build, it is not practical for our circumstance. However, this prototype is made to include as many features as possible as a demonstration to the client as to what is being included in the final product. It is more convenient for the client to see this type of prototype without having to go to the lab itself to get a good idea as to what the product is going to look like. It also allows for modifications to be made easily, especially since the material used is very inexpensive. The testing required for this product can only be done on the final product itself, which will be talked about in greater profundity in the *“Testing”* section.

# 



### PROJECT PLAN

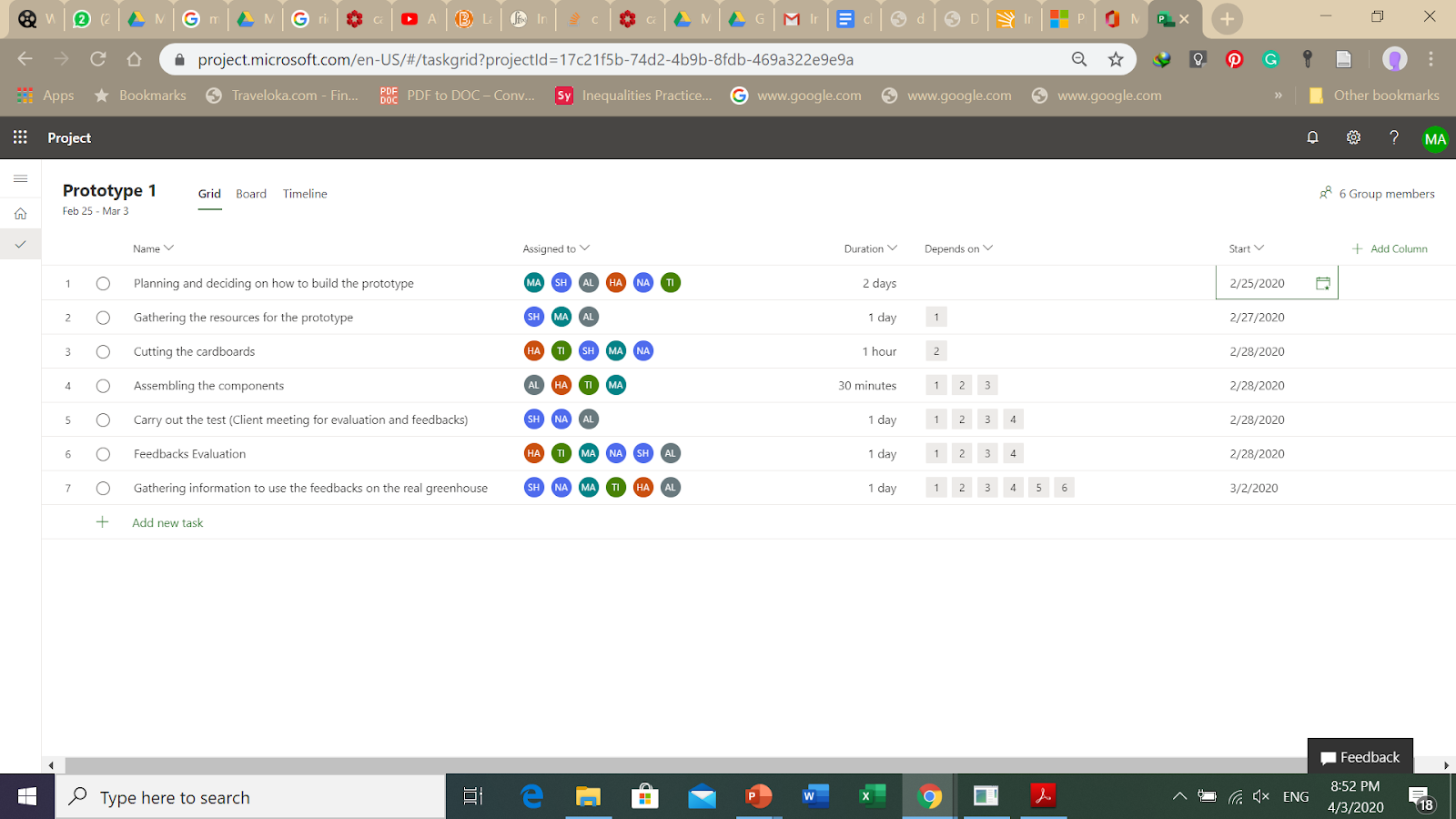


Figure 1: Project Plan for Prototype I (Tasks)

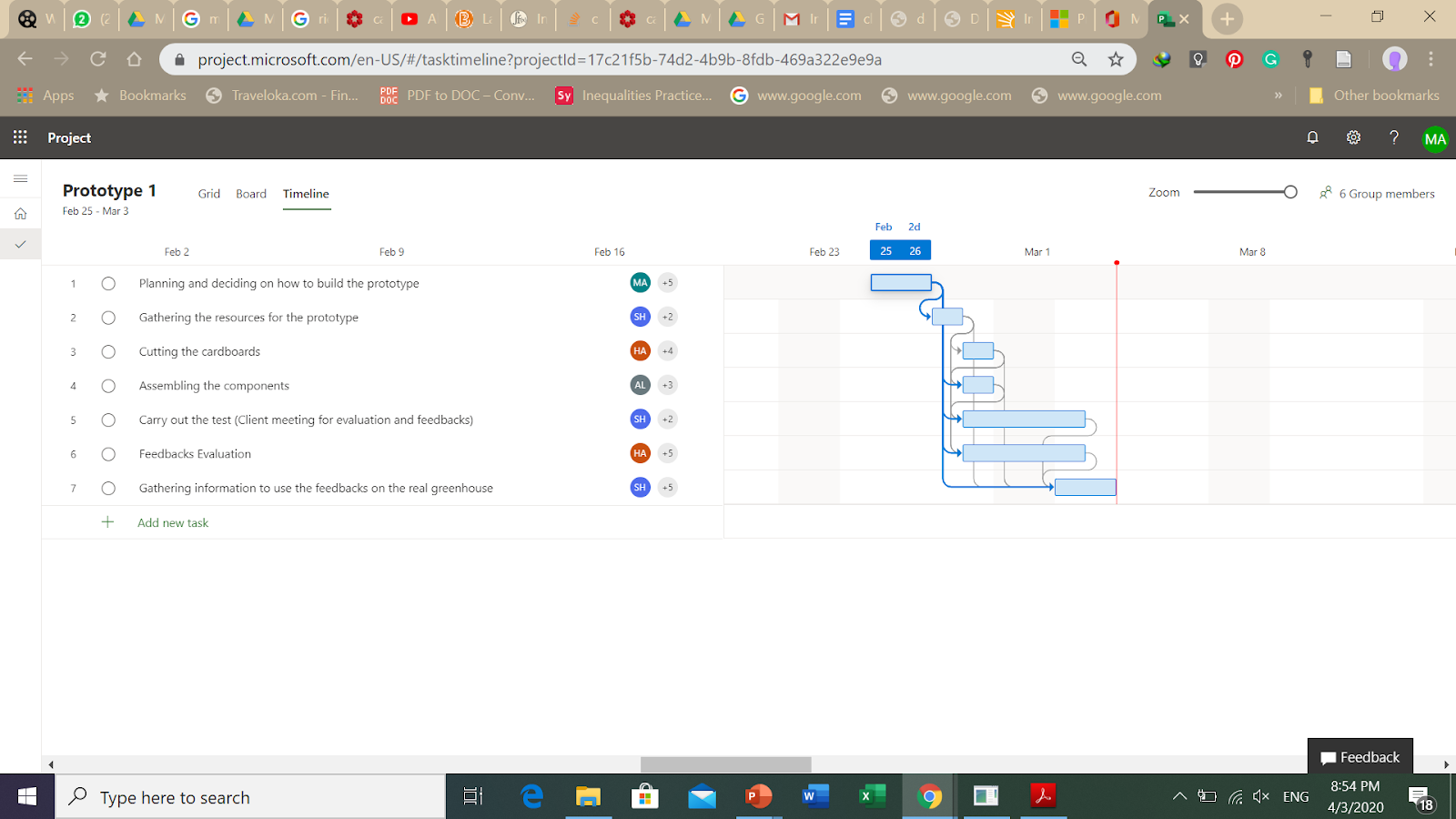


Figure 2: Project Plan for Prototype I (Gantt Chart)

### IMAGES OF PROTOTYPE

|  |  |
| --- | --- |
| **Figure 3: Angled View of Prototype I** | **Figure 4: Side View of Prototype I** |

This prototype was made without any measurements, and used materials that were very inexpensive materials, typically found around the typical household, since the purpose of this prototype is simply to give the client a general idea as to what to expect in terms of features while also being a physical model, which should allow for the client to be able to provide sufficient feedback from this prototype.

|  |  |  |
| --- | --- | --- |
| **Materials** | **Cost** | **Source** |
| Masking tape | free | Team members personal belongings |
| Hot glue gun | free | Team members personal belongings |
| Box | free | Recycled material |
| Cardboard | free | Recycled material |
| Scissors | free | Team members personal belongings |
| Knife cutter | free | Recycled material |
| Cellophane tape | free | Team members personal belongings |
| Straw | free | Recycled material |
| Plastic wrap | free | Team members personal belongings |

Table 1: Materials used for Prototype I

### CLIENT FEEDBACK

Based on the first prototype, the client suggested reconsidering the location of the water collecting tank from being outside to being inside, since it will provide the tank with proper protection against exterior elements and animals, while also avoiding it from being damaged under colder temperatures when the water inside expands when turning into ice. The client also suggested having the tank elevated to use gravity as a natural pump. Finally, as a non-functional requirement, the exterior colour should be the colour that absorbs the most heat, thus black, and the interior should be the clients favourite colour, thus green.

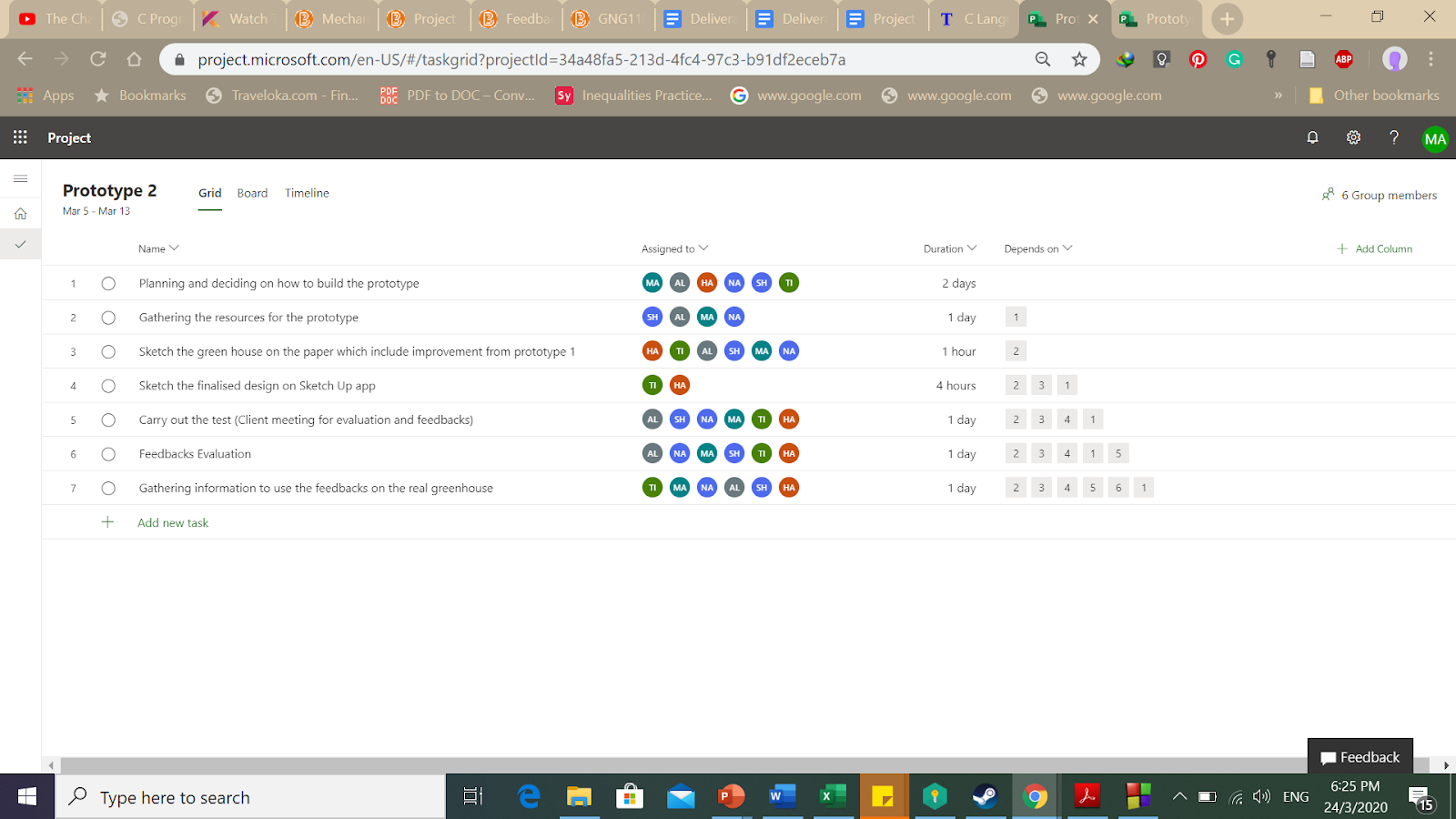
* 1. **PROTOTYPE II - Software**

The type of prototype used for this deliverable was a qualitative prototype. This type of prototype was used over a quantitative prototype since the size of the greenhouse is simply too big to recreate and test different designs when it comes to different tests that must be conducted on the greenhouse. Making a full-scale prototype is unreasonable for this type of project. It is for this reason we decided to choose a qualitative prototype using a software called SketchUp. Although we cannot analyze its metric performance, it is still the best option as it is easier for the client to gage the user experience by seeing the layout and all the included features, thus making it easier for the client to give feedback on what to include, what not to include, and what to modify.

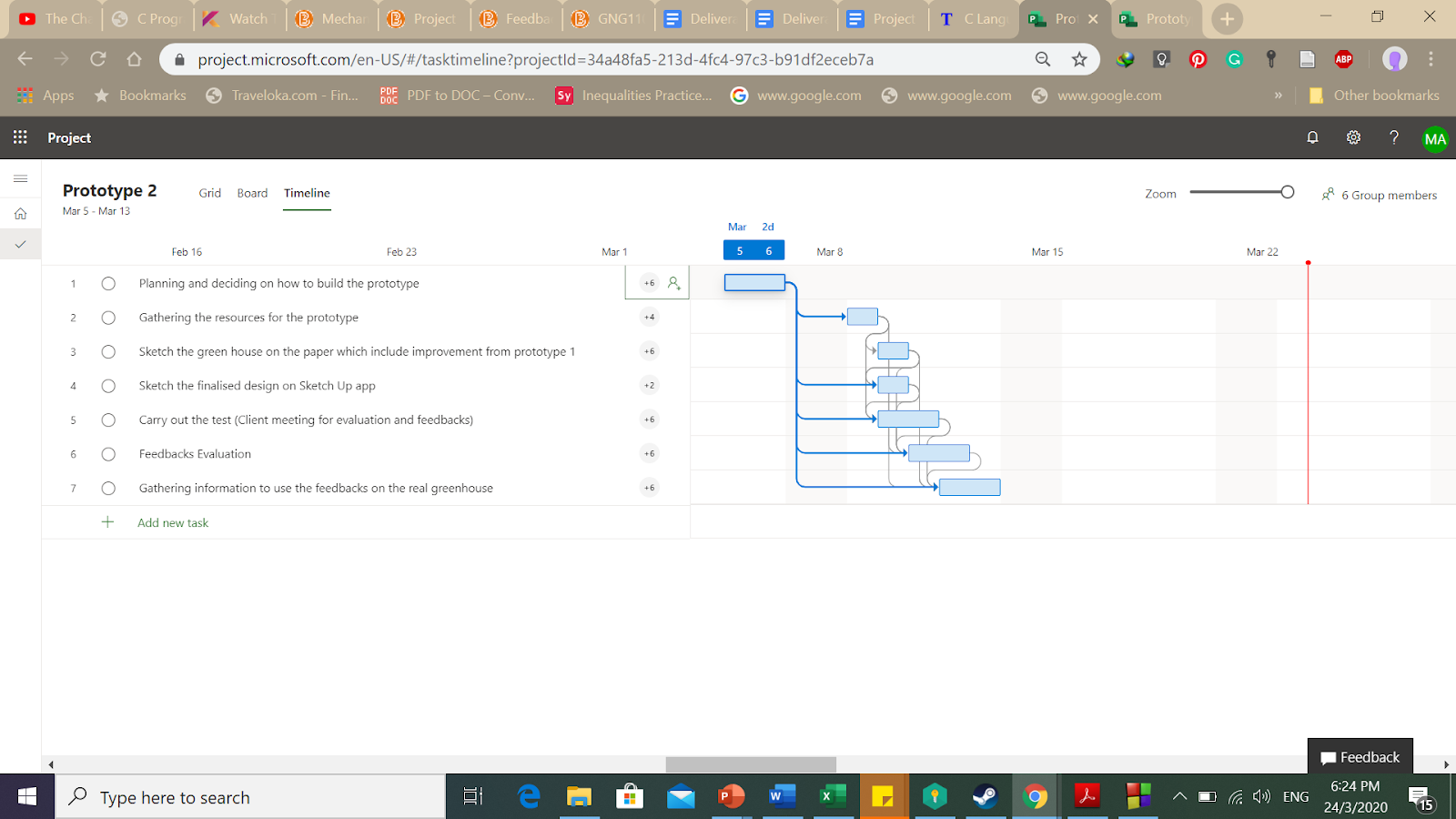


### PROJECT PLAN

**Figure 5: Project Plan for Prototype II (Tasks)**

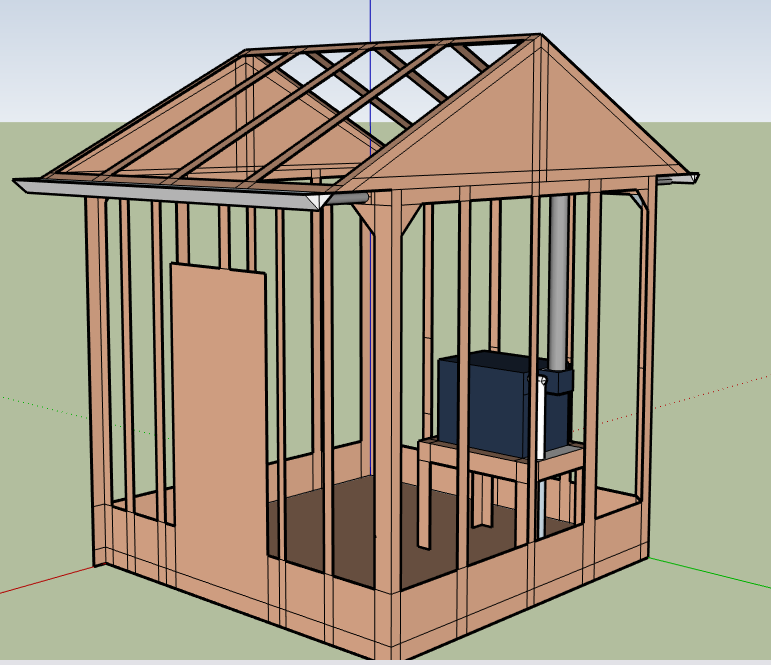


**Figure 6: Project Plan for Prototype II (Gantt Chart)**



### IMAGE OF PROTOTYPE

**Figure 7: Image of Prototype II**



### CLIENT FEEDBACK

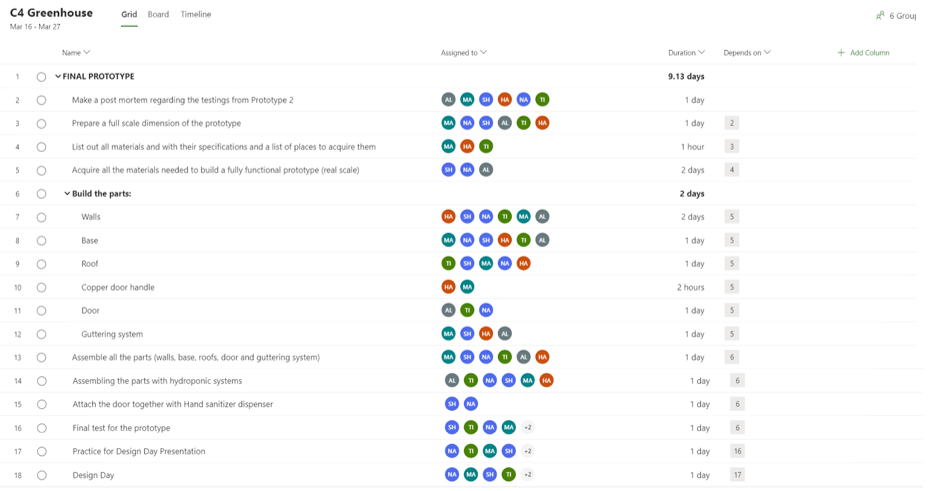
Unfortunately, the client could not provide any feedback due to the unforeseen circumstances regarding the Coronavirus. However, it can predicted that the client would have a positive response to the changes we implemented into our new prototype, since we were able to accommodate for all of the clients suggestions, with the only exception being the interior colour not being green since that colour was not available to us. Otherwise, all the suggestions were implemented appropriately: the water tank was moved to inside the greenhouse as requested by our customer; the piping system is complete from the gutter system to the water tank; and plywood was added as reinforcement to the bottom base of the greenhouse to combat rodents from entering while also gaining better stability. By following this predicted feedback and considering the current circumstances, the idea arose to improve the model and to develop a final prototype adapting to the current situation to be able to be prepared should this situation occur once again. For the next prototype, more features will be presented along with improvements to the features currently in this prototype.

* 1. **PROTOTYPE III - Hardware**

The current state of the prototype is partially complete during the time of writing this user manual. A lot of the necessary tasks have been completed; however, there is still a considerable amount of work left to do in order to consider this a complete product. For example, as can be seen in the pictures below, the structure of the greenhouse has been completed, as well as most of the painting required to make the product aesthetically pleasing. Although the structure requires the most amount of work to complete and is part of a large majority of the work needed to be complete, there are still many elements needed to be completed.

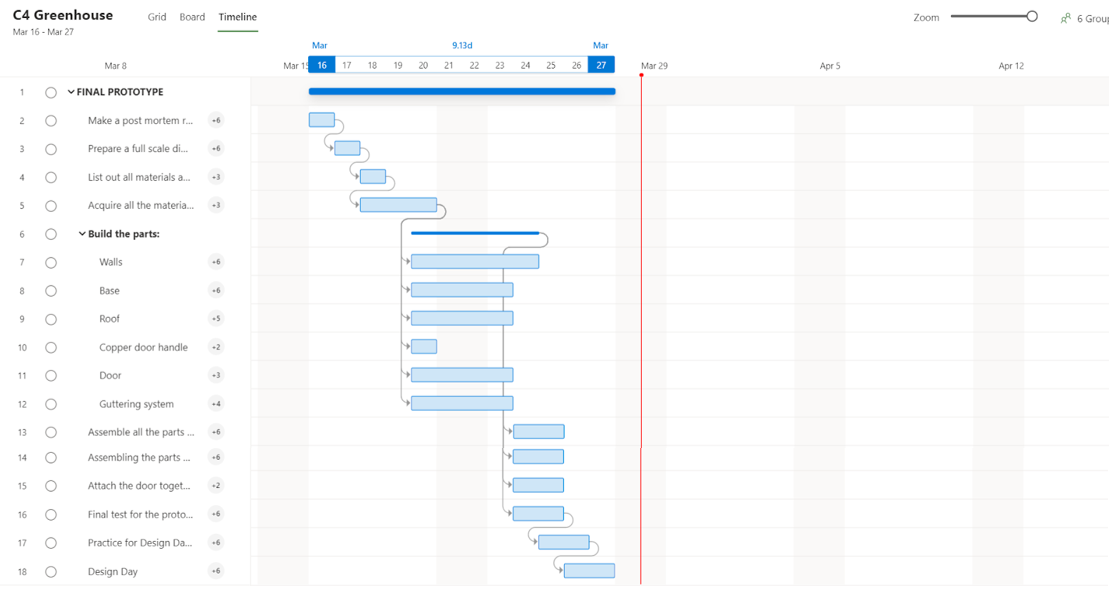


### PROJECT PLAN



**Figure 8: Project Plan for Prototype III (Tasks)**

**Figure 9: Project Plan for Prototype III (Gantt Chart)**



### IMAGES OF PROTOTYPE III

|  |  |
| --- | --- |
| **Figure 10: Front View of Prototype III Structure** | **Figure 11: Side View of Prototype III Structure** |
| **Figure 12: Front View of Prototype III Painted** | **Figure 13: Side View of Prototype III Painted** |
| **Figure 14: Bottom View of Roof Structure** | **Figure 15: Another Angle of Roof Structure** |
| **Figure 16: Another Angle of Roof Structure** | **Figure 17: Another Angle of Roof Structure** |
| **Figure 18: View of Floor Painted Blue** | |
| **Figure 19: Isometric View of Final Product (3D Render)** | **Figure 20: Another angle of Final Product (3D Render)** |

### 

### EXPECTED CLIENT FEEDBACK

The client’s feedback is expected to be very satisfied and content with the final product. The product implements both the client’s initial needs, as well as all their suggestions from the client meetings. For example, the client was impressed with the prototype presented. They did, however, give some suggestions to ameliorate the design. The main suggestion was to reconsider locating the water tank inside the greenhouse instead of outside since it will keep the tank safe from any pests or animals, while also preventing it from breaking in lower temperatures when the water inside expands as it becomes ice. The client also suggested using more inexpensive materials, and to paint the exterior black, since it is the most heat-absorbing colour, and to paint the interior green, since it is the client’s favourite colour. All of these suggestions were implemented, with the exception of painting the interior green as that colour was not available. Instead, blue paint was used, which is also an acceptable colour according to the client. Otherwise, everything wanted from the client was implemented, while also taking into consideration the implementation of hygienic resources for the current COVID-19 situation, ultimately creating the best product possible for the client.

### Bill of Material

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Bill of Material** | | | | |
|  | **Item Description** | **Quantity** | **Unit Price** | **Total Amount** |
| 1 | Spruce wood (2” x 4”) for structure | 30 | $3.22 | $96.60 |
| 2 | Spruce wood (2” x 3”) for structure | 4 | $1.64 | $6.56 |
| 3 | Plywood for floor | 4 | $4.87 | $19.48 |
| 4 | Fasteners (nails, screws, etc.) | 1 | $15.00 | $15.00 |
| 5 | Vinyl for walls | 6 | $3.00 | $18.00 |
| 6 | Corrugated acrylic for roof | 3 | $24.00 | $72.00 |
| 7 | Waterproof caulking [5] | 1 | $2.49 | $2.49 |
| 8 | Insulation [6] | 5 | $10.20 | $51.00 |
| 9 | PVC pipe for water pipe [7] | 1 | $17.99 | $17.99 |
| 10 | PVC pipe elbow [8] | 2 | $3.19 | $6.38 |
| 11 | Aluminium gutters [9] | 3 | $16.99 | $50.97 |
| 12 | Door | 1 | $30.00 | $30.00 |
| 13 | Paint | 2 | $10.00 | $20.00 |
| **Subtotal:** | | | | $406.47 |
| **Total with Tax:** | | | | $459.31 |
| **Budget remaining:** | | | | $40.69 |

Table 2: Bill of Material without COVID-19 Measures

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Bill of Material** | | | | |
|  | **Item Description** | **Quantity** | **Unit Price** | **Total Amount** |
| 1 | Spruce wood (2” x 4”)  for structure | 30 | $3.22 | $96.60 |
| 2 | Spruce wood (2” x 3”)  for structure | 4 | $1.64 | $6.56 |
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| 4 | Fasteners (nails, screws, etc.) | 1 | $15.00 | $15.00 |
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| 8 | Insulation[6] | 5 | $10.20 | $51.00 |
| 9 | PVC pipe for water pipe[7] | 1 | $17.99 | $17.99 |
| 10 | PVC pipe elbow[8] | 2 | $3.19 | $6.38 |
| 11 | Aluminium gutters [9] | 3 | $16.99 | $50.97 |
| 12 | Door | 1 | $30.00 | $30.00 |
| 13 | Paint | 2 | $10.00 | $20.00 |
| 14 | Copper Door Handle [10] | 1 | $15.87 | $15.87 |
| 15 | Hand Sanitizer Dispenser [11] | 1 | $32.69 | $32.69 |
| 16 | Energizer "C" 1.5V 4-Pack Batteries for Dispenser [12] | 3 | $8.99 | $26.97 |
| **Subtotal:** | | | | $482.00 |
| **Total with Tax:** | | | | $544.66 |
| **Budget remaining:** | | | | $-44.66 |

Table 3: Bill of Material with COVID-19 Measures

### Equipment list

|  |  |
| --- | --- |
| **Walls** | **Base** |
| * Miter saw * Nail Gun * Nails for Nail Gun * 6 × Vinyl (54” × 6”) * 4 × Spruce wood (2” × 4” × 72”) * 4 × Spruce wood (2” × 4” × 70”) * 16 × Spruce wood (2” × 4” × 69”) * 4 × Spruce wood (2” × 4” × 72”) | * Drill * 2” Screws * Nail Gun * Nails for Nail Gun * Miter saw * Jigsaw * 4 × Spruce wood (2” × 4” × 72”) * 3 × Spruce wood (2” × 4” × 70”) * 3 × OSB (24” × 72” × ½”) |
| **Roof** | **Door** |
| * Drill * 2” Screws * Miter saw * 3 × Corrugated Acrylic (26” × 96”) * 1 × Spruce wood (2” × 4” × 72”) * 8 × Spruce wood (2” × 3” × 48”) * 2 × Spruce wood (2” × 3” × 24”) * 4 × Steel Plates * 3 × Corrugated Acrylic (26” × 96”) | * Drill * 9 × 2” Screws * 3 × Door Hinges * 1 × Wooden Door (2” × 3” × 24”) |

Table 4: Equipment List

# How to Use the Prototype



## Explain in detail the functions of the prototype and how it works

Features, Function and Capabilities:

* Serve the purpose of storing a hydroponics system, thus enabling to grow crops for the owners.
* Transparent walls and roof to allow maximum light to pass through the greenhouse
* Equipped with a water guttering system and a water tank. It can help harvest the rainwater and store it.
* A hand sanitizer dispenser is installed inside the greenhouse to help improve the hygiene of the user.
* Self powered, installed with solar panels that can be used to power up the pumping system of the HPS.
* Copper doorknob to prevent microorganisms or bacteria lives at the doorknob and prevent transmission of bacteria onto the owners
  1. **Explain how the user safely operates the prototype.**

Safety guidelines:

* Always wear safety boots and goggles during the construction.
* Follow any instructions given by the professor and TA during the lab session.
* Use high risks tools properly by following the safety steps provided during the first lab session by the professor.
* Ask permission before using any extra tools that requires extra safety measures.
* Be fully aware of the lab’s layout in case of emergency
* Use tools responsibly to avoid injuries.
* If an instrument or piece of equipment fails during use, or isn't operating properly, report the issue to a technician right away. Never try to repair an equipment problem on your own.
* Use a safety helmet in the designated spot of the lab if required.

Precautions and health issues:

Throughout the tests conducted, the greenhouse was found to be not associated with any health issues. The height inside the greenhouse is approximately 6ft height so most of the users can stand comfortably without the need of watching out your head. Prevent spraying pesticide inside the greenhouse because it could accumulate inside it as it is sealed. Make sure the pesticide sprayed only at the outside of the greenhouse. The rainwater collected is not safe for direct drinking and the water should be filtered first before consuming it.

* 1. **Explain how the user installs the prototype to use (if applicable).**

### Walls

Using two 4”x2”x72” as the top beams and four 3”x2”x69” as the inner posts, the frame of a wall is constructed. The side walls need to use two 4”x2”x70” and four 3”x2”x69” to make a slightly shorter wall. The process is repeated to get four wall frames. In order to combine it properly we need two walls with the length of 72” and two walls with the length of 70”.  The walls are then reinforced with two more 3”x2”x69” woods placed parallel in the frame to make the wall stronger. The four walls are then combined with the base using nails and screws to put it in place.

### Base

To construct the base, make a frame that is 72”x72” using 4 4”x2”x72” pieces fixed together with nails at each joint to produce a rectangular frame. To reinforce the frame, add the remaining 4”x2”x70” pieces parallel with the 72” length of the frame, each 16” apart starting 16” to the right of the left edge of the frame. Once the frame is completed, nail the OSB to the top face to finish the base.

### Roof

To make the diagonal beams, cut the ends off of 8 of 2”x3”x48” spruce wood at an angle of 32°. Then, attach both 2”x3”x24” spruce wood vertically using screws on top of both door side and the back side of the greenhouse. Then, connect the start and the end of the  2”x3”x72” spruce wood to the both vertical 2”x3”x24” spruce wood. Finally, connect the cut side of 2”x3”x48” spruce wood to the 2’’ x 3’’ x 72’’ spruce wood. There will be 4 2”x3”x48” spruce wood for each side of right and left. The distance between each 2”x3”x48” spruce wood is 18”. Lastly, reinforce it by connecting the 2”x3”x48” spruce woods that lie on the wall frame using a steel connector. Finally, attach the acrylic roof onto the roof frame and screw it in place.

### Door

A 72”x24” door was used. It will be necessary to measure the height of the door and cut off the excess height of 6” since the height of doorframe is 66”. Then, using screws, attach 1 hinge at the top, 1 hinge at the middle, and 1 hinge at the bottom of the door, to be able to attach it to the doorframe using more screws.

# How to Maintain the Prototype

Make sure the gutter system is free from debris, dried leaves or anything that can block the water flow. The roof must always be clear from anything that can block the sunlight from reaching the plants. This can be achieved simply by checking the greenhouse monthly. During winter or off season, it is suggested to move the greenhouse away from open places that can cause snow to pile up and damage the gutter system. Since the greenhouse is modular therefore this task can be done easily during the end of fall. Other than that, do regular check upon the greenhouse’s woods from any pests such as termites that can weaken its structure. The owner should also look up for any leaks or cuts that might be caused by the debris or branches. The greenhouse should have no leak to ensure the insulation of the greenhouse is in a good state.

# Conclusions et Recommendations for Future Work

A few lessons have been learned throughout this project. First of all, it is important to have good communication. Communication is an essential tool to give out ideas, instruction and solving conflicts. Ideas should be generated during the brainstorming session of initial design to solve the problem. However, with the lack of communication, these ideas may not be generated. For example, all team members are scared to speak out their ideas because they thought they were crazy ideas or just waiting for others to give ideas. The meeting will not become successful and will cause time to be wasted. It is also important to be proactive on the project throughout the entirety of the project, since it is important to maintain a fair amount of workload for all members of the group.

In the future, it would be ideal to install a snow melting device that can help produce fresh, filtered water to the community. This device can be made using a heater and a filtration system. First, it will melt the snow, and then undergo a filtration process. This water can be used for the HPS, and it can also be used for drinking purposes. Initially, the client liked the idea of having a snow melting mechanism in the greenhouse. However, due to a lack of budget and the lack of time, it could not be implemented.

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APPENDICES

APPENDIX I: Design Files

For design files, visit: “<https://makerepo.com/npare083/gng1103-c4-the-cottage-greenhouse>”

APPENDIX II: Other Appendices

Empathize

CLIENT STATEMENT

On January 22, 2020, a client named Monique Manatch discussed the issue in the Algonquin of Barriere Park. An aborginal community of approximately 50 people live at an abandoned airport strip in Le Domaine off of Barriere Lake, 4-5 people per family. The community lacks access to new materials to construct new houses, resulting in 8-15 people living in one house. It was observed that there was no electricity or running water, but there is a freshwater stream nearby. The area has a flat stable ground with lots of sand. It was mentioned that the generator is maxed out which required us to find another way to generate power. However, there were problems with the farm due to animals such as mice, bugs, and squirrels eating the crops. Also, these farm beds will not be usable during winter as the temperature drops to as low as -35°C. There are large amounts of snow drops at the location and strong winds over the trees. The University of Ottawa has agreed to assist the community with a budget of $500 for construction and $100 for a HPS.

NEEDS IDENTIFICATION

|  |  |  |  |
| --- | --- | --- | --- |
| **Questions** | **Customer Statements** | **Interpreted Needs** | **Importance (1-5)** |
| **Who is the client and who is the user?** | Customer: Monique Manatch  Users: Algonquins from Barrière Park | Easy to set up, easy to maintain, and is modular for high portability | 5 |
| **What is the problem?** | No drinkable water due to polluted river | Produce a reliable source of food for the community | 3 |
| **What are the intended uses for the greenhouses?** | To grow crop that can be harvested quickly and staple food | Supply hardy crops such as potatoes or green vegetables | 5 |
| **What is the intended goal for the use of greenhouses?** | Can feed family for at least a week throughout the 3 seasons (summer, spring, fall) | Provide a food source yearly for 3 seasons (summer, spring, fall) | 5 |
| **What is the source of electricity available in the village?** | Generator using diesel, propane | Self-sufficient or self-powered | 4 |
| **What can this greenhouse also do?** | Help to filter the polluted water and collect the rainwater | Can act as a water filtration system | 3 |
| **What can the greenhouse do during winter season?** | Temperature gets to as low as -35°C. The depth of snow is approx.  20-30 cm. | Melt snow as a water supply during winter | 1 |
| **Is there any pests threat?** | There are animals such as raccoons, squirrels, deer, etc. | Prevents pests and animals | 4 |
| **Can the greenhouse withstand the rain?** | There would be rain from time to time. | Must be waterproof | 5 |
| **Will the greenhouse create any hazards for community members?** | There are children around playing in the area. | Child friendly | 2 |

Table 5: Needs Identification

Define

PROBLEM STATEMENT

Based on the first interview and the needs identification table above, the problem can be summarized within the following sentence: *“To allow the community at Lac Barrière to harvest crops for three seasons, a 6ft x 6ft x 6ft greenhouse, equipped with a HPS and solar panels, must be built, while considering issues involving accessibility, pests, and structural endurance against climate conditions.”*

DESIGN CRITERIA

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Design Specifications** | **Relation (=,<, or >)** | **Value** | **Units** | **Verification method** |
| **1** | Hydroponics system | = | Yes | N/A | Test |
| **2** | Shields from pests | = | Yes | N/A | Test |
| **3** | Provide viable food supply for different seasons (Summer, Spring, Fall) | = | Yes | N/A | Test |
| **4** | Portable/Modular | = | Yes | N/A | Test |
| **5** | Self-sustained | = | Yes | N/A | Test |
| **6** | Good light transparency | = | Yes | N/A | Test |
| **7** | Provide suitable temperature for plants | = | 80-85 degrees | Fahrenheit | Test using thermometer |
| **8** | Ventilation | = | Yes | N/A | Test |
| **9** | Humidity (for plants) | = | 50-70% | Grams of water vapor per cubic meter volume of air | Test using hydrometer |

Table 6: Functional Requirements

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Design Specifications** | **Relation (=,<, or >)** | **Value** | **Units** | **Verification method** |
| **1** | Dimension | = | 6 by 6 | feets | Measuring tape |
| **2** | Cost | < | 500 | Canadian dollars | Estimate, Final check |
| **3** | Weight support | < | 250 | Kilogram | Analysis |
| **4** | Operating conditions: Temperature | = | -10 to 25 degrees | Celcius | Test |
| **5** | Operating conditions: Weather during Summer, Spring, Fall seasons | = | Yes | N/A | Test |

Table 7: Constraints

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Design Specifications** | **Relation (=,<, or >)** | **Value** | **Units** | **Verification method** |
| **1** | Aesthetics | = | Yes | N/A | Survey |
| **2** | Safety: Child friendly | = | Yes | N/A | Test |
| **3** | Product life | > | 5 | years | Test |
| **4** | UV resistance | = | Yes | N/A | Test |
| **5** | Corrosion resistance | = | Yes | N/A | Test |

Table 8: Non-Functional Requirements

Ideate

REAL PRODUCT BENCHMARKING

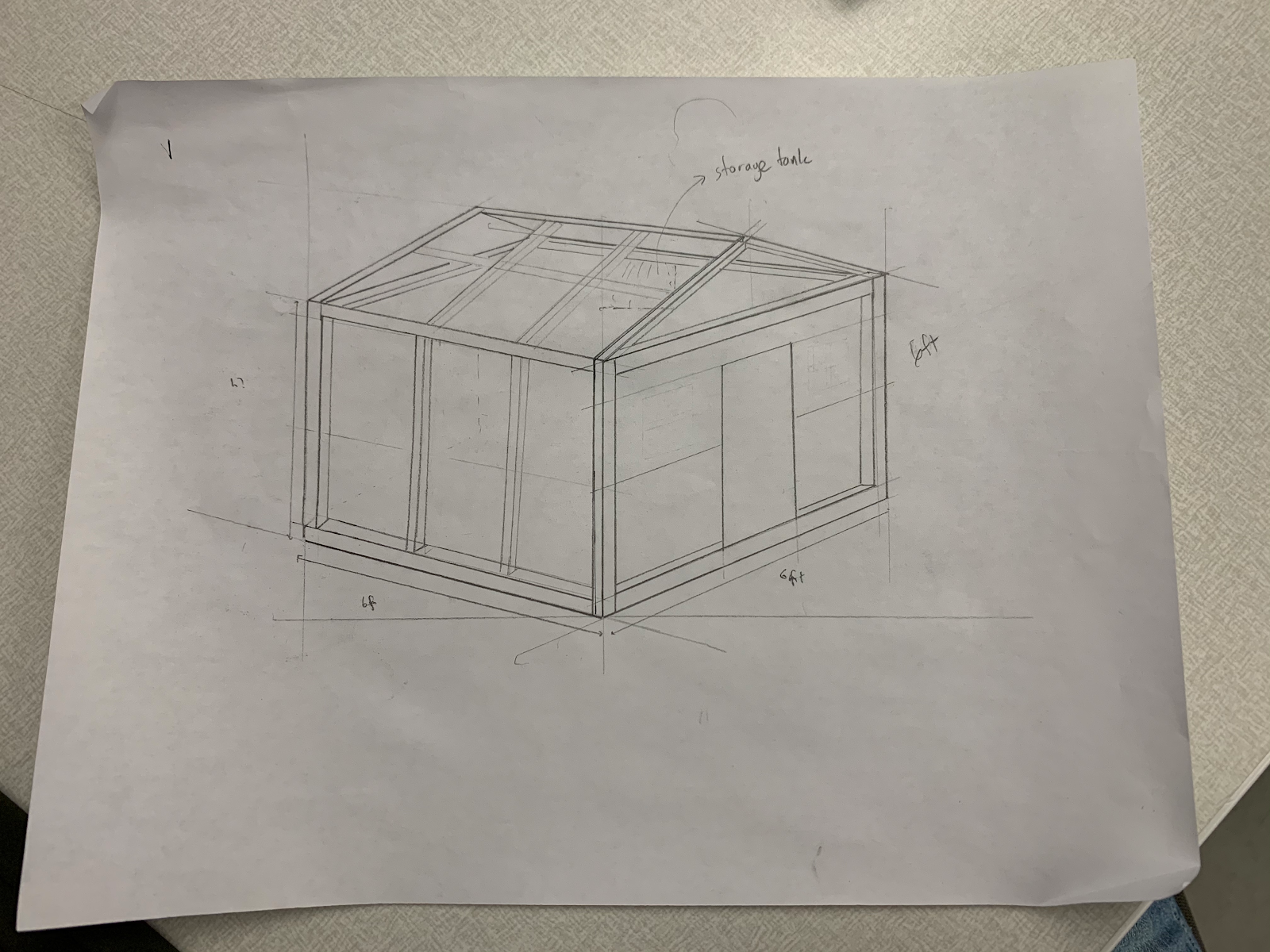
In order to gather ideas for the conceptual design, three real-life products, either from Amazon Inc. and The Home Depot, were compared to determine which one was best suited for our needs so that the highest-scoring product will be the basis of the design. In this case, the ShelterLogic GrowIT Backyard Greenhouse[1], the Outsunny Walk-in Garden Greenhouse[2], and the Palram Nature Series Mythos Hobby Greenhouse[3] were being compared. The benchmarking was done using a 3-point scale for the compatibility aspect, and a 5-point scale for the importance aspect. The final score is determined by the sum of the compatibility scores multiplied by the importance scores for each aspect of the greenhouse.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Aspects of greenhouse | Importance weight | ShelterLogic GrowIT Backyard Greenhouse | Outsunny Walk-in Garden Greenhouse | Palram Nature Series Mythos Hobby Greenhouse |
| Dimensions | 1 | 3 | 3 | 3 |
| Cost | 5 | 3 | 3 | 1 |
| Material | 4 | 1 | 3 | 3 |
| Ventilation | 3 | 2 | 3 | 3 |
| Rain collecting system | 3 | 1 | 3 | 3 |
| Waterproof | 5 | 3 | 3 | 3 |
| Water filtration system | 3 | 2 | 2 | 2 |
| Animal proof | 3 | 1 | 3 | 3 |
| Easy to assemble | 5 | 3 | 3 | 3 |
| Total | | 70 | 93 | 83 |

Table 9: Benchmarking of Real Products

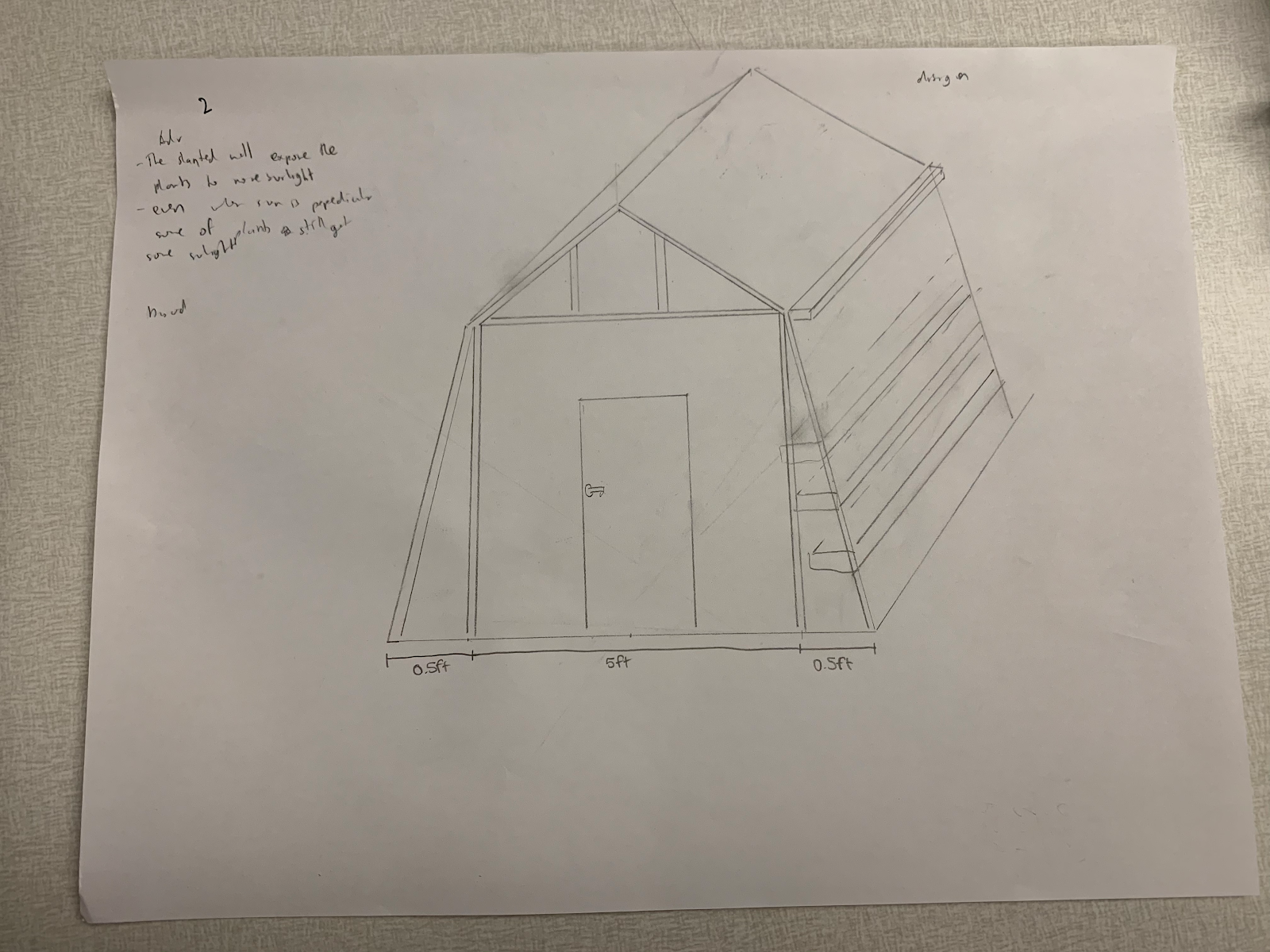
CONCEPT GENERATION

For the concept generation, each member of the team was required to make 3 designs of a greenhouse, thus having 18 designs to choose from. Then, from those 18 designs, the team was required to reduce the amount options to the best three. Once the group chose the top three designs, benchmarking was performed, similar to the benchmarking done for the three real products, to determine the best design. The following are the top three designs that were chosen.

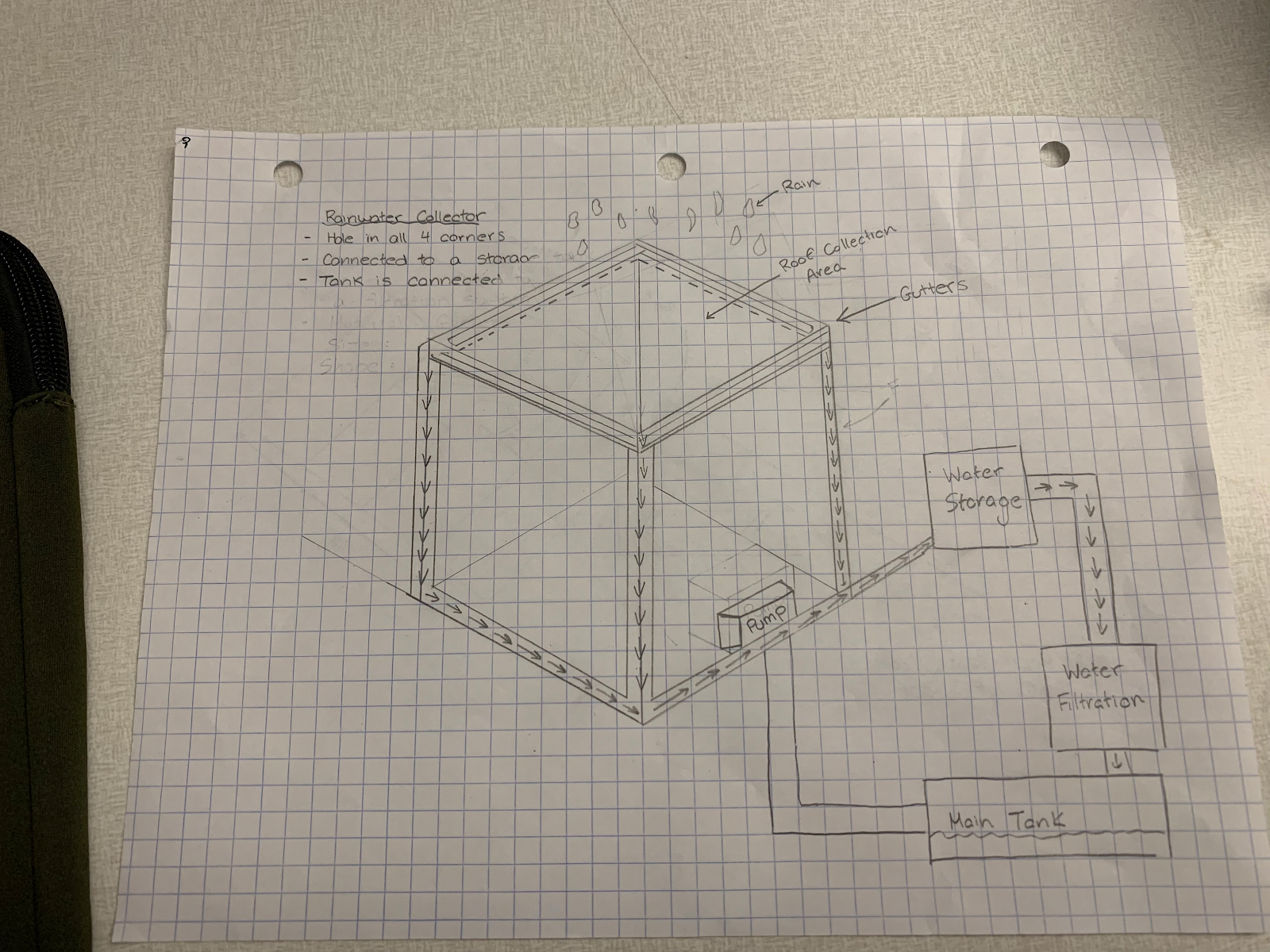


**Figure 21: The Cottage**

**Figure 22: The Camper**



**Figure 23: The Cubical**



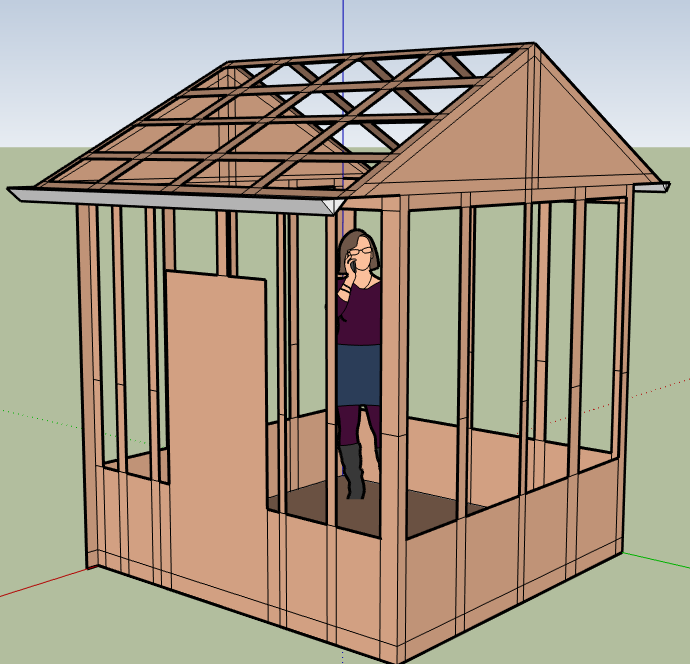
Concept Benchmarking

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Aspects of greenhouse** | | **Importance** | **The Cottage** | **The Campers** | **The Cubical** |
| **Functional Requirements** | | |  | | |
| **1** | Hydroponics system | 5 | Yes | Yes | Yes |
| **2** | Shields from pests | 3 | Yes | Yes | No |
| **3** | Works for 3 seasons | 5 | Yes | Yes | Yes |
| **4** | Portable/Modular | 3 | Yes | Yes | Yes |
| **5** | Self-sustainability | 4 | High | Moderate | High |
| **6** | Light transparency | 5 | Yes | Yes | Yes |
| **7** | Suitable temperature for plants (Insulation) | 4 | Yes | Yes | Yes |
| **8** | Ventilation | 3 | Yes | No | Yes |
| **9** | Humidity (for plants) | 3 | Yes | No | Yes |
| **Constraints** | | |  | | |
| **1** | Dimension (ft) | 1 | 6 x 6 x 4 | 6 x 6 x 6 | 6 x 6 x 6 |
| **2** | Cost ($) | 5 | ≅ $500 | ≅ $3500 | ≅ $600 |
| **3** | Weight support | 2 | Amazing | Low | Good |
| **4** | Resistance against cold temperatures | 5 | Yes | Yes | Yes |
| **5** | Operating conditions during Summer, Spring and Fall | 5 | Yes | Yes | Yes |
| **Non-functional requirements** | | |  | | |
| **1** | Aesthetics | 1 | Yes | No | Yes |
| **2** | Child friendly | 3 | Yes | Yes | Yes |
| **3** | Product life | 4 | <5 years | <4 years | >5 years |
| **4** | UV Resistance | 2 | Yes | Yes | Yes |
| **5** | Corrosion resistance | 1 | Yes | No | Yes |
| **Total** | | | 180 | 144 | 173 |

Table 10: Benchmarking for Possible Concepts

CONCEPTUAL DESIGN

After analyzing all the concepts and analyzing the advantages and disadvantages, “The Cottage” design has been decided as the base design of the project as it scores the highest points in the benchmarking process. As each member presented their own ideas, creating multiple options and designs to choose from, it was decided to combine the most effective part of the design from each member’s design. As the top three designs were analyzed in detail using the design criteria, a final design was developed. Our final design will have a structure made from wood, since it is cheap yet durable; therefore, it will save a lot of the budget for premium wall and roof materials. Furthermore, there will be insulation in the floors. This will provide a maximum amount of sunlight in the greenhouse, while also containing the optimal amount of insulation for colder temperatures. Finally the base will be made out of plywood with wooden support beams underneath and the door will be made out of wood as well. Therefore, this system led to conclude that “The Cottage” satisfies the best functional requirements amongst the other three designs. The 3D render below is the conceptual design made using SketchUp.



**Figure 24: Conceptual Design**

Testing

For the testing of the product, there are a series of tests that can be performed to evaluate the performance of our prototype: its ability to collect rainwater, its ability to keep out animals and pests, its ability to be easily assembled and disassembled, its ability to resist exterior elements, and its ability to work well with the HPS. All these tests require physical testing, instead of measurements, analysis and calculations. Should the COVID-19 virus not have prevented ceased the progress on the greenhouse, the following tests would have been performed:

1. Testing the greenhouse’s ability to collect rainwater simply requires observing how well the water collecting system collects water. This test is very simple, as water needs to be poured on the roof, and then observe whether the troughs are able to collect all the water, without it overflowing. Then, based on the results, modifications can be made to the troughs to compensate for excess water.
2. Testing the product’s ability to keep out animals and pests requires a thorough physical inspection of the greenhouse to ensure that there are no cracks, crevices or holes in the product, thus preventing any areas where small pests and rodents can enter. To ensure that kids are not able to enter the greenhouse, there will be a lock on the door requiring a key or a code to enter, thus keeping all children around the greenhouse safe.
3. Testing the product’s ability to be easily assembled and disassembled requires for the greenhouse to be disassembled when it is completely done being built. If it is difficult to disassemble, then the use of nails over screws should be reconsidered, since screws are used for areas that do not have to be permanently in place, while nails are permanent. It is important to ensure that whichever spots have screws are in easy to reach locations.
4. Testing the product’s ability to resist exterior elements can be performed simply using water from a water hose to spray water at the greenhouse at different angles. Then, if any water leakage is observed through the panels or walls, then sealant can be applied to prevent further water leakage, while also keeping in mind that the greenhouse still needs to be easy to disassemble. A strength test can also be performed to check whether it can hold the weight of a large amount of snow. In this case, 3 adults, weighing approximately 400lbs total, did pull ups [13] on the structure to determine if it can hold the weight of those 3 people, as well as whether it sways from the movement. If it did not, then the product passes the test.
5. Testing the greenhouse’s ability to work well with the HPS necessitates for working in cooperation with the hydroponic team. This would involve setting up the HPS in the greenhouse and installing the water tank to determine whether the system can work as intended and whether it is able to be used in its full potential. It is possible to pour water onto the roof and see how the water is directed into the greenhouse and into the HPS without encountering any problems.