Design Criteria

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Abstract

This document defines a list of prioritized design criteria and does technical and user benchmarking. In addition, based on the design criteria target specifications are identified. The document builds on the needs of the client identified in the Needs Identification deliverable. The main purpose of this document is to outline the requirements and limitations for designing the hydroponic system.

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Prioritized Design Criteria

Based on the list of needs identified the deliverable "Needs Identification" the design criteria have been broken into three categories of functional requirements, non-functional requirements, and constraints.

Functional Requirements

Below is the list of function requirement for the design criteria of the hydroponic system.

- Must be capable of growing a variety of plants

The system must be able to accommodate the different sizes and shapes of different plants. Specifically, it must accommodate different root lengths, so that each plant is in contact with the water, and it must accommodate the size of each plant by having a range of different basket sizes to transplant the plants into (e.g. one for lettuce, one for herbs, etc.).

- Must be able to automatically control the system's temperature

The system must control the temperature of the water to prevent harming the roots of the plants. The water must be cooled down or heated to a optimal temperature.

- Capable of testing and adding nutrients to nutrient solution.

The system must test the water regularly for pH levels and electrical conductivity. Based on the results, the system must automatically add nutrients to maintain the proper growing solution.

- Must have good lighting

The walls of the greenhouse must be transparent allowing a good portion of daylight shine through. A grow light system should be considered for locations with little sunlight and for potential rainy days.

Non-Functional Requirements

Below is the list of non-function requirement for the design criteria of the hydroponic system.

- The hydroponic system must be reliable

The system should be durable and able to support the client's desired number of plants throughout the entire growing season. The system should be constructed of relatively strong material, that will not rot or fail over multiple growing seasons. It must also be constructed with materials that will not leech harmful chemicals into the water.

- The system must rely on only natural means to grow food (no chemical fertilizer)

The hydroponic system must be designed to use only naturally occurring substances to provide nutrients to the plants. Commercial organic fertilizers are available, but will not be able to provide all the nutrients the plants need, specifically nitrogen and calcium. If the client wants to only use organic fertilisers, the client may provide these necessary nutrients in the form of compost supplied by the greenhouse's users.

- The system should be easy to transport to the setup location

The system should be relatively compact and should be designed with attention to how the process of transporting the individual parts will be completed. Specifically, the system should be broken into many simple individual parts, such as straight pieces of lumber/ pvc, rectangular containers, and flexible piping. Awkwardly shaped components should be redesigned for easier packaging and transport of the product. Similarly, the assembly process of our product should be simple.

- The system should be easy to assemble

Our product should be easy for a non- professional to assemble, and it should not take an extended period of time to assemble. As much of the product as possible should be preassembled before we ship it to the user, so as not to inconvenience them. All parts that the user must assemble themself should be simple for the user to put together while following our manual.

- The water in the reservoir should be easy to replace

The water in the reservoir of the hydroponic system must be replaced by new water once a week. This process should be easier for the user to complete. A drain system and a method to easily replace the drained water should be in place.

- The system should be scalable

To allow for further expansion, this system should be designed in a way makes it easy to add on to the system.

Constraints

Below is the list of constraints for the design criteria of the hydroponic system.

- The system should require minimal electricity.

The hydroponic system should be compatible with a wind or solar power generating system included in the greenhouse design.

- ❖ The system should be able to function efficiently with limited space

The user may only have limited space to put the hydroponic system. Therefore, the system should be as compact as possible, without sacrificing functionality. Additionally, the system should be efficient in its use of growing space, maximizing the number of plants that can be grown within the given area.

- ❖ The system should be user friendly

The user may not be experienced at running a hydroponic system. Therefore, the system should be easy to understand and have user friendly features.

Table 1 Design Criteria

Functional Requirements	Non- Functional Requirements	Constraints
Variety of Plants	Reliable	Power Source
Temperature Control	Natural Fertilizer	Limited Space
Control Nutrient Solution	Ease of Transport	User friendly
Lighting	Ease of Assembly	
	Replace water in reservoir easily	
	Scalable	

Technical Benchmarking

The technical benchmarking is based off three popular hydroponics. The specifications relate to the design criteria in order that we can evaluate the capabilities and limitations of current models.

The hydroponics are ranked with respect to the importance of the specifications. The colors indicate the effectiveness of the systems 1 red, 2 yellow, and 3 green. This determines the overall rank of the systems.

Table 2 Technical Benchmarking

Hydroponics / Specifications	Importance Weight	Wally-32	Tobato 5	Nutraponics Hydroponics Growing System
Company		Planta Greenhouse	Planta Greenhouse	Nutrabinns
System type		Nutrient film technique	Deep water culture	Nutrient film technique
Material	5	BPA-free, food-grade plastic	food-grade polypropylene	Acrylonitrile Butadiene Styrene
Shape	3	Trough (wall)	Rectangle	Cylindrical
Dimensions	4	67x61x4 in	24x20x41 in	27x27x17in
Weight	3	Unspecified	29.7 lb	32 lb
Cost	3	$766 CAD	$825 CAD	$1,541 CAD
Number of plants	4	32	5	80
System control	5	Compensation float for automatic water filling	Fills the water reservoir when levels drop.	User has control of air humidity, amount of water supply, spray timings and energy used
Grow Lights	3	Yes	20 Watts LED	Yes
Scalable	3	No	No	Yes
Grow height (inch)	5	12	Able to handle large plants.	14 to 16
Backup Power	4	No	No	No
Temperature	3	No	No	No
Natural Fertilizer	3	No	No	No
Rank		93	93	94

User Benchmarking

The following user benchmarking data has been collected from multiple reviews of popular hydroponic models, experienced hydroponic users, and hydroponic reports/articles. The goal of this benchmarking is to identify the most reliable and sustainable hydronic system based on user experiences and efficiency.

The systems are ranked by the categories importance. The colors indicate the effectiveness of the systems 1 red, 2 yellow, and 3 green. This is how the overall rank of the systems are evaluated.

Table 3 User Benchmarking

Hydroponics System Types / Capabilities	Importance Weight	Deep water culture (DWC)	Nutrient film technique (NFT)	Aeroponics
Irrigation system	5	Plants roots have steady access to water.	Common for the vertical tower systems to have dry spots preventing proper growth.	Common for systems to have inadequate water pressure.
Maintenance	3	Have to change the water in the reservoir once a week.	Easy to access for cleaning and inspecting roots.	Highly automated easy access to roots but requires to be monitored.
Growing Space	4	Limited growing space.	Vertical models allow for maximum space usage.	Vertical models allow for maximum space usage.
Reliability	4	Only, fails if the air pump stops running.	Clogged the channels, pump failure (constantly running), and fluctuating pH levels.	Spray nozzles can become easily clogged with mineral deposits. Pressure system failure. Highly sensitive system.
Water efficiency	3	40% less water than traditional growing	75% less water than traditional growing	95% less water than traditional growing
Root disturbance	5	The design of the system requires the user to disturb the roots system to change the water.	Some root disturbance is required when root block the flow of water.	Minimal root disturbance.
Yield	5	Grows faster than traditional farming but slower the NFT and aeroponics.	High yields of food	One of the fastest ways to grow food.
Skill	3	Easy to set up and monitor.	Need to constantly monitor flow of water notice roots blockage or nutrient depletion.	Requires a comprehensive understanding of the technical aspects of the system.
Rank		62	68	74

Target Specifications

Using the design criteria, the following target specifications are determined.

Table 4 Target Specifications

	Design Specifications	Relation (=, < or >)	Value	Units	Verification Method
Functional Requirements					
1	Pumping system	=	yes	N/A	Test
2	Ability to recover, reuse, and regulate nutrient solution	=	yes	N/A	Test
3	Lighting system	=	yes	N/A	Test
4	Structural stability	=	yes	N/A	Test
5	Water temperature control	=	20 to 25	˚C	Test
6	Water pH control	=	6 to 7.5	N/A	Test
7	Number of plants	>	20	plants/m^2	Analysis
8	Water flow sensor	=	2 to 6	L/min	Test
9	Water addition and drainage system	=	yes	N/A	Test
10	Ability to grow and harvest	=	yes	N/A	Test
Constraints					
1	Weight	<	80	kg	Analysis
2	Height	<	2	m	Analysis
3	Cost	<	500	$/unit	Estimate, final check
4	Volume: transported	<	6	m^3/unit	Analysis
5	Surface area: deployed	<	10	m^2/unit	Analysis
6	Limitations of plant types	=	yes	N/A	Test
7	Availability of power supply	=	yes	N/A	Analysis
Non-Functional Requirements					
1	Reliability	=	yes	N/A	Test
2	Product life	>	10	years	Test
3	Aesthetics	=	yes	N/A	Test
4	Corrosion and UV resistance	=	yes	N/A	Test
5	Safety: minimal pinch points	=	yes	N/A	Test
6	Harvest yield and consistency	>	30	$kg.m^{-2}$	Analysis, final test
7	Water efficiency	<	7	L/ m^2/day	Analysis, final test
8	Scalability	=	yes	N/A	Analysis
9	Minimal maintenance	=	yes	N/A	Test

Reflection

To conclude, our hydroponic design has been impacted immensely by the meeting with our client, specifically concerning the criteria and specifications. We have formulated a list of priorities in our design. Within that list, we have finalized that the most important criteria are for the hydroponic to be durable, capable of growing a large variety of plants, have automatic temperature control, and be user friendly.

With additional research, we have updated new needs that differ from the deliverable B assignment. We have chosen that the vertical model would be ideal, due to the fact that it allows for maximum space usage. The aeroponic system would be a great choice since it uses 95% less water than traditional growing and has the lowest root disturbances. When it comes to changes, we have decided that we will no longer focus on the entire greenhouse itself but focus on the portion that is based on the hydroponic system. As a result, we did not go through with our idea of an igloo shape greenhouse or making the external greenhouse expendable. As well, the shapes for our design would be trough, rectangle, or cylindrical.

Based on Muslim Majeed's instructions we have removed the limitations of no electrical components. A non-functional requirement that has stayed consistent with the last assignment would be that our product would need to be easily transportable. Overall, the needs identified in deliverable B have been used in creating the design criteria.

Resources

Technical benchmarking:

Wally-32

https://plantagreenhouses.com/products/wally-32

Tobato-5

https://plantagreenhouses.ca/products/tobato-5-dutch-bucket-hydroponic-growing-system?c=ca

Nutraponics Hydroponics Growing System

https://www.amazon.ca/Hydroponics-Growing-Vertical-Automated-Aeroponics/dp/B08XM3XTRF/ref=cm_cr_arp_d_product_top?ie=UTF8

User benchmarking:

NASA aeroponic report

https://spinoff.nasa.gov/Spinoff2006/er_2.html
NFT system problem

https://scienceinhydroponics.com/2021/04/why-nft-is-the-best-hydroponic-system-beginners-shouldavoid.html#:~:text=However%2C%20for%20the%20small%20grower,easier%20and%20more%20reliable%20alternative.

Aeroponic

http://vertiponic.com/aeroponics-in-practice/

DWC amazon reviews

https://www.amazon.ca/VEVOR-DWC-System-Hydroponics-Vegetables/product-reviews/B09R1P9GV2/ref=cm_cr_dp_d_show_all_btm?ie=UTF8&reviewerType=all_reviews

Hydroponics comparison

https://www.geturbanleaf.com/blogs/grow-tests/hydroponics-comparison

Hydroponic Systems

https://www.nosoilsolutions.com/6-different-types-hydroponic-systems/