Design Criteria and Target Specifications

Introduction:

The following document identifies the design criteria required to meet our previously outlined list of design needs. We also explore comparable products on the market, isolating features that we could implement in our own design to meet our specified needs. We then convert these features into a set of specific design criteria for our model, while reflecting on our first client meet and the strategies we implemented in the Empathize stage.

Functional and Non-Functional Requirements:

Functional	Non-Functional
- Safe and sanitary (e.g. stagnant water draining system) - Increased heat levels during winter - Low-tech (only moving part is blower fan) - Sustainable power source for blower fan	- Sustainable materials - Renewable power source - Lower monthly energy costs - Withstand 35-40 years of use - Quiet fan system - Odorless air - Easy to maintain

Design Criteria:

	Needs	Design Criteria
1	The product needs to be environmentally friendly with zero emissions, as it is intended to function as a sustainable heating and cooling alternative.	**SUSTAINABLE MATERIALS** -Materials used must be sustainable
2	The power source to supply electricity to the thermostat and sump pump systems should be renewable.	**SUSTAINABLE POWER** -Electricity sources must be renewable (e.g. geothermal, solar)
3	The product should be low-tech and inexpensive.	**COST** -System should be low-cost -Should lower users' monthly costs by 40%-50%
4	The system should be designed to withstand 35 – 40 years of use.	**DURABLE MATERIALS** -Won't corrode -Won't degrade quickly
5	The system needs to be easy to maintain.	**MINIMAL MOVING PARTS** -Minimal user input -User friendly design

6	The stabilized air entering the house should not pose any health threats to the users. All stagnant water must be collected and removed, and the air must be filtered.	**SAFE, CLEAN** -Stagnant water removal -Airtight pipes -Air intake pipe must have filter
7	The design needs to be compact and easily installable in an average townhouse yard. The mechanism should not span as large an area as the current GCHE does.	**AREA** -Takes up a small amount of space -Pipe network must be tightly wound
8	The heating system should be able to achieve higher temperatures in the winter. The current model reaches temperatures of 15°C during winter; future models should boost it to 20°C.	**ENHANCED PERFORMANCE** -Intake and outtake pipe must be insulated to maintain heat -Must have fan -Must reach 20°C
9	The air entering the building should be odorless as to not cause discomfort to users. This can be ensured with airtight pipes and proper use of sealants to close the main box.	**ODORLESS** -Properly-sealed pipes and filters must be implemented to prevent odor
10	The fan system should be quiet and non-disruptive to the user.	**SOUND** -Fan should produce minimal noise

Constraints:

Arguably one of the most important aspects of our design is the source of energy we will use to power our system. It is crucial that our source of electricity is renewable and green as to minimize our ecological footprint.

Another key criterion that we cannot overlook is the ability to maintain heat in the pipes for a longer period and circulate enough air throughout the house to raise the temperature. The pipes must be tightly wound inside the box, but we must also ensure that they offer the air enough exposure to the warmth conducted into the box.

Our project comprises of several carefully tuned and well fitted subsystems that will constantly interact with each other to heat or cool the user's building. To ensure that only fresh and clean air enters the system and later into the building, we must outfit our air intake pipe with a filter that will ensure excellent air quality. The interior mechanisms will also have to be carefully adjusted and installed correctly. The motors and fans must be oiled and fastened properly so that they create the least amount of disturbance as possible. We must also strive to create the most intuitive and user-friendly design that will help the user easily operate the system.

The use of proper and cost-effective materials is imperative for this project. We must use sustainable materials that leave a negligeable or nonexistent ecological footprint. Furthermore, the materials must be durable and long-lasting as our system must last several decades. The materials that we will utilize cannot corrode, deform or degrade and must be ethically sourced. We will need insulative as well as conductive materials to build a functioning model.

Once the proper materials have been chosen, our group will also have to decide on the most appropriate sealants and sealing techniques that will be used to assemble the prototype. We cannot allow any underground air, water, or other unwanted elements to penetrate our system, so it is crucial that every crevice is well sealed. Additionally, we must also evaluate the layout of the system and how it will connect to the user's building as well as how much space the system will take up on the user's land.

Technical Benchmarking:

The following features are ranked from most to least optimal, through a green-yellow-red scale, respectively. The third model, the "AirEase A97USMV Series," is a gas furnace that we included to compare the sustainable and unsustainable models of this product.

Green=3, yellow=2, red=1

Specifications	Importance (Weight)	Model #1: Trilogy 45 Q-mode	Model #2: WaterFurnace - 7 series	Model #3: AirEase A97USMV Series, modern gas furnace
Company		Climate Master	Waterfurnace	AirEase
Sustainable materials	5	No, but long lasting	Yes, sheet metal with coat paint	Stainless steel heat exchange technology
Sustainable power	5	Yes, 45 EER (Energy Efficiency Ratio)	Yes, 41 EER	No, natural gas combustion - produces CO_2 (EER of 0.97)
Cost	5	$20,000 + $46/mo	$5,700-$8100 plus monthly rebates due to cheaper energy	$5000-$7000 plus a double (or more) the monthly fees
Durable materials	3	Yes (20-25 years of use)	Rust and salt proof sheet metal	Decently durable - estimated lifetime of 15-17 years
Minimal moving parts	4	Yes, but very complicated inner workings	Yes, but inner maintenance will require a specialist	Yes
Cleaning/ filtering	5	System flushing requires cleaning	Flush cycle, filter	Manually, $50-$300 per appointment

		agents - air filter 0.457m² (MERV11 Throwaway)		
Surface area	5	Vertical up-flow air coil: 28 x 20 inches. Horizontal coil: 18 x 31 inches	0.57 m^2	N/A
Insulation/ fan	4	23cm x 18cm blower, 373 Watts	N/A	N/A
Features	3	iGate connection means system can be controlled from most computers and smartphones	Swing out panel for easy control	20% more efficient than average gas furnace
Total		**71**	**80**	**78**

Technical Specifications:

The * icon indicates standards our prototype should be able to achieve.

	Specifications	Relation (=, <, >)	Value	Units	Verification Method
	FUNCTIONAL				
1	Can reach desired temperature *	=	15°C - 20°C	Celsius	Test
2	Keep temperature steady *	=	Temperature does not vary	Celsius	Test
3	Minimal maintenance	=	Yes	N/A	Material used and number of moving parts
4	Durable materials	=	Yes	N/A	Test (aging chamber)
5	Cleaning/ filtering	≤	AQI index level of 50	N/A	AQI test
6	Insulation/ fan	=	Yes	N/A	Ability to reach and maintain desired temperature, responds to temperature change
	CONSTRAINTS				
7	Cost (prototype)*	≤	100	$	Bill of materials
8	Surface area*	=	Size of given area	Square ft	Measuring
9	Weather conditions*	=	Area of construction	Celsius or Fahrenheit, various means	Weather reports
10	Dimensions	≤	4 ft x 2.5ft x 2.5 ft	Feet	Measurements
	NON-FUNCTIONAL				
11	Product life	>	10 years	Years	Test

12	Reliability	=	Yes	N/A	Test
13	Aesthetics	=	Yes	N/A	Test
14	Sustainable materials	=	EPP certified	EPP certification	Analysis and research
15	Sustainable power	≥	12	EER	Analysis and test
16	Noise	<	30	Decibels	Analysis and test

Reflection:

The first client meeting allowed us to identify and prioritize our client's needs by giving us an opportunity to talk to the client first-hand and gauge his answers to our questions. After examining our client's case individually, our group then met to discuss the aspects of the case and develop a list of questions for our client. We generated questions targeted to give us information about our design; for example, we asked about the sustainability of materials, future of the product, and the shortcomings of the product's current design. These questions allowed us to identify fundamental criteria: what the product should do, what it should be made of, and how it should operate in the future.

After extracting a list of needs from our client's presentation and responses, we were able to determine their importance. When examining the meeting notes and re-watching the recording, we pinpointed topics that the client discussed repeatedly, and inferred that these needs were of critical importance. For example, the client touched on the aspect of sustainability numerous times throughout the meeting, which we translated into being a critical need. Naturally, some needs were prioritized over others and ranked accordingly. Some low-priority needs included quietness of the fan system and a product lifespan of 35-40 years. As a group, we decided that our design would still serve its intended purpose if critical needs like sustainability and compactness were prioritized over such minor needs. As of now, no needs have changed from our initial assessment; however, once we begin the design process, we will have the opportunity to clarify any new ambiguities at our second client meeting and reevaluate accordingly.

Conclusion:

In summary, our team has interpreted our clients and users' needs and formulated relevant design criteria. We also developed a solid benchmark by looking at customer and user reviews of similar products and ranking the associated features by importance. Furthermore, we established critical technical specifications that our future prototype will have to adhere to, and we reflected upon our client's presentation and responses, which proved to be very useful when refining design criteria. The information contained within this document will serve as the basis for prototype designing and will guide us in the completion of future deliverables. Our research has broadened our horizons in the scope of this project and will no doubt serve as a useful baseline. We are confident that the technical specifications outlined above, as well as the client's statements and our benchmarks, will help us generate conceptual designs, subsystems, and functional solutions.

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