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Objective:

Define a list of prioritized design criteria, do technical benchmarking and determine target specifications which can be used in the development of your final solution.

List of Needs:

User Needs	Ranking (1-5)	Design Criteria	Target Specifications
Functional needs			
<ul style="list-style-type: none"> The heat exchanger must be able to heat a home during the winter and cool a home during the summer. 	5	Degrees above ground temperature (*C) Degrees below ground temperature (*C) Additional power needed to raise temperature (watts)	Must be able to maintain temperature from 20-23*C To concentrate geothermal heat, must generate around 200watts an hour (including for blower fan) (https://www.geoexchange.org/forum/threads/how-much-generation-do-i-actually-need-to-run-my-wf-5-series.5797/)
<ul style="list-style-type: none"> Needs to mitigate the increased humidity in the pipes. 	4	Sump pump Size of sump pump for amount of humidity	Include sump pump 1/3 HP sump pump should be sufficient (https://www.sumpumpsdirect.com/stories/104-How-To-Pick-The-Perfect-Submersible-Sump-Pump.html#:~:text=For%20most%20average%2D-sized%20homes,3%20)

			feet%20and%2025%20feet.)
<ul style="list-style-type: none"> Needs a sustainable source of energy, (i.e solar panel? Wind power?). 	5	Amount of wind in area Amount of sun in area Amount of power required (watts)	Powered by solar panel or small wind turbine To power fan, must generate minimum 90W/hr (https://ecocostsavings.com/cost-to-run-box-fan/)
<ul style="list-style-type: none"> The switch between "summer" and "winter" mode should be automatic. The switch between renewable/ battery power to 120VAC should be automatic. Automatic valve closing to a closed loop system when outside air temp < earth temp Automatic valve opening to an open loop system when outside air temp > earth temp 	3	Design of the chamber Thermostat on outside Thermostat on inside	Detect external temperature change and switch mode automatically Automatic Switch #2 Automatic system (requires around 20watts of the total 200watts the system will generate per hour)
<ul style="list-style-type: none"> The heat exchanger must be able to last throughout the winter without a significant 	4	Heat exchange efficiency (%) Difference in ground temperature	Target efficiency of minimum 90% (https://www.researchgate.net/post/What-is-the-average-efficiency-of-gas-water-heat-exchanger#:~:text=Average%20efficiency%20may%2)

increase in price for energy.			0be%20around%2085%25%20to%2090%25.&text=you%20can%20calculate%20the%20performance,exchanger%20you%20can%20follow%20it.)
Non-functional needs			
<ul style="list-style-type: none"> It must be low-tech and inexpensive (low cost of operation and installation) 	5	Cost (\$) of operation Cost (\$) of installation	Cost of installation and the chamber will be less or at least around \$1000. Cost of operation will be very cheap since the heat exchanger generates its own power using a solar system or turbine
<ul style="list-style-type: none"> The heat exchange chamber should be environmentally friendly, have zero emissions. 	5	Power generated by wind or solar energy (watts)	Same as the sustainable source of energy. (should be powered by solar panel or wind turbine) Emits 0 greenhouse gasses
<ul style="list-style-type: none"> The heat exchange chamber should be made out of cheap material. 	3	Cost (\$) of material	Cost of material will be under 100\$ https://www.concretenetwork.com/concrete-prices.html) however the turbine or solar system will make up a large part of the price (small solar panel \$400-700) https://climatebiz.com/200-watt-solar-panels/)
<ul style="list-style-type: none"> The heat exchange chamber should 	3	Material durability (years) Material reactions with elements in soil and water	Product life: 35 - 40 years.

<p>last 35 - 40 years.</p>			
<ul style="list-style-type: none"> A significant amount of energy is not lost to external elements 	<p>3</p>	<p>Heat exchange efficiency (%)</p>	<p>Target efficiency is 90% (https://www.researchgate.net/post/What-is-the-average-efficiency-of-gas-water-heat-exchanger#:~:text=Average%20efficiency%20may%20be%20around%2085%25%20to%2090%25.&text=you%20can%20calculate%20the%20performance,exchanger%20you%20can%20follow%20it.)</p>
<ul style="list-style-type: none"> Blower fan needs to be serviced when it malfunctions. Other than the blower fan, the system should not need maintenance. 	<p>2</p>	<p>Durability of blower fan (years) Accessibility of blower fan</p>	<p>Product life: 10-20 years before maintenance is needed (https://americanairconditioning.com/blog/how-long-should-your-furnace-blower-motor-last/#:~:text=Even%20though%20the%20manufacturer%20states,%2C%20use%2C%20and%20proactive%20maintenance.)</p>
<ul style="list-style-type: none"> Reduce electrical resistance by keeping cable short and components simple, simplifying the electrical system. 	<p>2</p>	<p>Installation setups</p>	<p>Short and simple cable setups, shorter than 60 m including all pipes</p>

<ul style="list-style-type: none"> Improve the efficiency of the system during the heating mode by combining another system to it such as a solar collector. 	4	Heat exchange efficiency (%) Addition of solar or wind energy	Target efficiency is 90 % (https://www.researchgate.net/post/What-is-the-average-efficiency-of-gas-water-heat-exchanger#:~:text=Average%20efficiency%20may%20be%20around%2085%25%20to%2090%25.&text=you%20can%20calculate%20the%20performance,exchanger%20you%20can%20follow%20it.)
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Constraints

Price (max 1000\$ including power source and material for heat exchanger and pipes, max 100\$ for material of heat exchanger)

Length of pipes (max 60 m to lower price and time of installation)

Power (must generate minimum 200 watts an hour to power blower fan and concentrate heat to main 20°C-23°C)

Efficiency (must be 90% efficient to keep the cost low and the system environmentally friendly)

Benchmark 1: User benchmarking updated

- Complaints regarding the high price and the level of difficulty to fix the geothermal heat exchanger.
- It is also said that the house would cool down really fast when the chamber is not running.
- Skilled installer is required for the best experience.
- Not as warm as other heating chambers, but generally nice to use.
- KW used in a cold minnesota winter is 5000 KW/ month for 5000sqft house with lots of windows

Takeaways: To further emphasize the importance of making the heat exchanger cost efficient and also making the only moving mechanical part the blower fan. If possible, enhance the chamber's ability to heat up the house. [1]

[1] Multiple Authors, "Residential Geothermal Users Customer Reviews," *GeoExchange® Forum*. [Online]. Available:

<https://www.geoexchange.org/forum/threads/residential-geothermal-users-customer-reviews.1050/1050/>. [Accessed: 02-Feb-2022].

Benchmark 2: Technical benchmark updated

- Dual source heat pump is similar to a geothermal heat exchanger, however it combines an air-source heat pump with a geothermal heat pump
- Uses geothermal heat to cool and heat homes

Takeaways: The dual source heat pump is inexpensive, however is much less energy efficient than a geothermal heat exchanger. Although, users of geothermal heat exchangers will have much cheaper energy bills over time due to the efficient and sustainable nature of a geothermal heat pump, and are said to make up for the disparity in price with their power bill within 5-10 years. [2]

[2] "Geothermal heat pumps," *Energy.gov*. [Online]. Available: <https://www.energy.gov/energysaver/geothermal-heat-pumps>. [Accessed: 02-Feb-2022].

Benchmark 3: New benchmark

- Geothermal heat pump that heats during the winter and cools during the summer
- Uses underground pipes they call and 'earth loop' to tap into the geothermal energy
- Collects from the underground heat and concentrates it, then pumps into the home to heat it
- Can divert heat that would go to waste to a hot water tank to make it more efficient and economical
- Claim to be more economical and more environmentally friendly and claim to provide cleaner air

Takeaways: This product is similar to the product we would like to design for our client, however, it does not contain a heat exchanger underground. It still has many ideas such as diverting unused heat to a hot water tank to make the product more economical and efficient that we can potentially be inspired from.

How a WaterFurnace system provides geothermal heating, geothermal cooling and hot water for your home. [Online]. Available: <https://www.waterfurnace.com/residential/about-geothermal/how-it-works>. [Accessed: 06-Feb-2022].

Reflection regarding how the client meeting affected our design process:

The client clarified a lot of things that we had previously talked about and wondered about amongst our design team. Some of the things he clarified were mechanics of the system (ie the only moving part being the blower fan), the lifespan of the system and the targeted indoor temperature he expects this system to maintain.

The client meeting was also valuable as we now have a better understanding of our clients most important needs; the need for the system to be environmentally friendly, cost efficient, and of course for the system to work as a cooler and heater. In this way, the client meeting was very helpful. Another thing that we found helpful that was briefly brought up in the client meeting was the diagram drawn for us. This gave us insight on how the design may look.

Other than that, we found that unfortunately the client did not go into specific detail and the Q&A posted on the Brightspace was rather vague. Many questions were answered informing us that the decisions were up to our discretion. After speaking with our project manager in a lab session, we have realized that this means that we have a lot of freedom in setting specific target specifications and in our material usage. Although we initially felt that we had a lack of guidance, we are now rising to the occasion of making these decisions ourselves and gauging our target specifications based on what we find appropriate.