Deliverable D - Conceptual Design

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Abstract

This document provides an overview of our conceptual design for The Heat Exchange Chamber. Based on our previous design developments, we created diagrams and possible functional solutions. Our main purpose is to identify the most appropriate conceptual solution for the construction of our prototype.

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1.0 Introduction

Each of our group members has come up with conceptual designs of subsystems according to our design criterias and benchmarking. The designs were then combined into three fully functional solutions. We analyzed these solutions and selected the best one which we are going to use for our prototype.

2.0 Subsystems

We created 4 subsystems with known parameters that make up our fully functional solutions. They are the following : A blower fan, the sump pump and pipes, the heat exchange chamber, and the energy system.

-2.1 Ideas generated for the blower fan

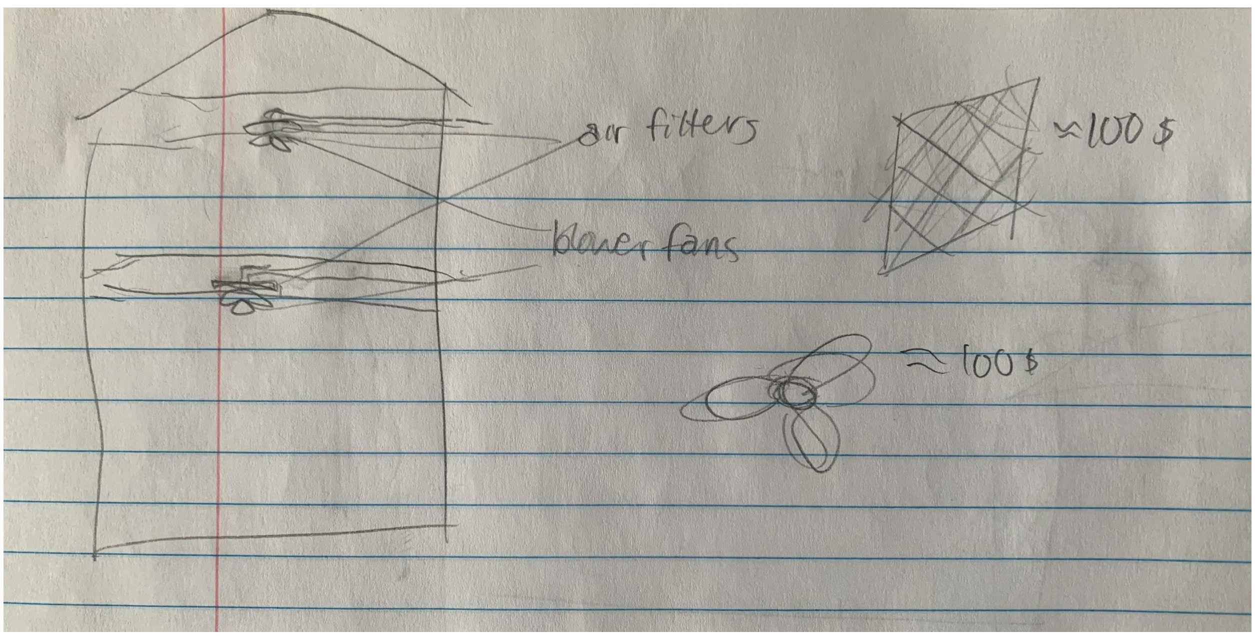

Figure 2.1.1 Kate Valentine's idea for the blower fan

In this idea for blower fans, two blower fans are spread out throughout the house to try and have equal airflow all around the house. Before the air is circulated using the cheap simple fans, it is transported through ducts that have simple, cheap air filters that can be purchased at any home hardware store. The air filters are to ensure that the quality and cleanliness of the air being circulated is adequate and healthy to breathe.

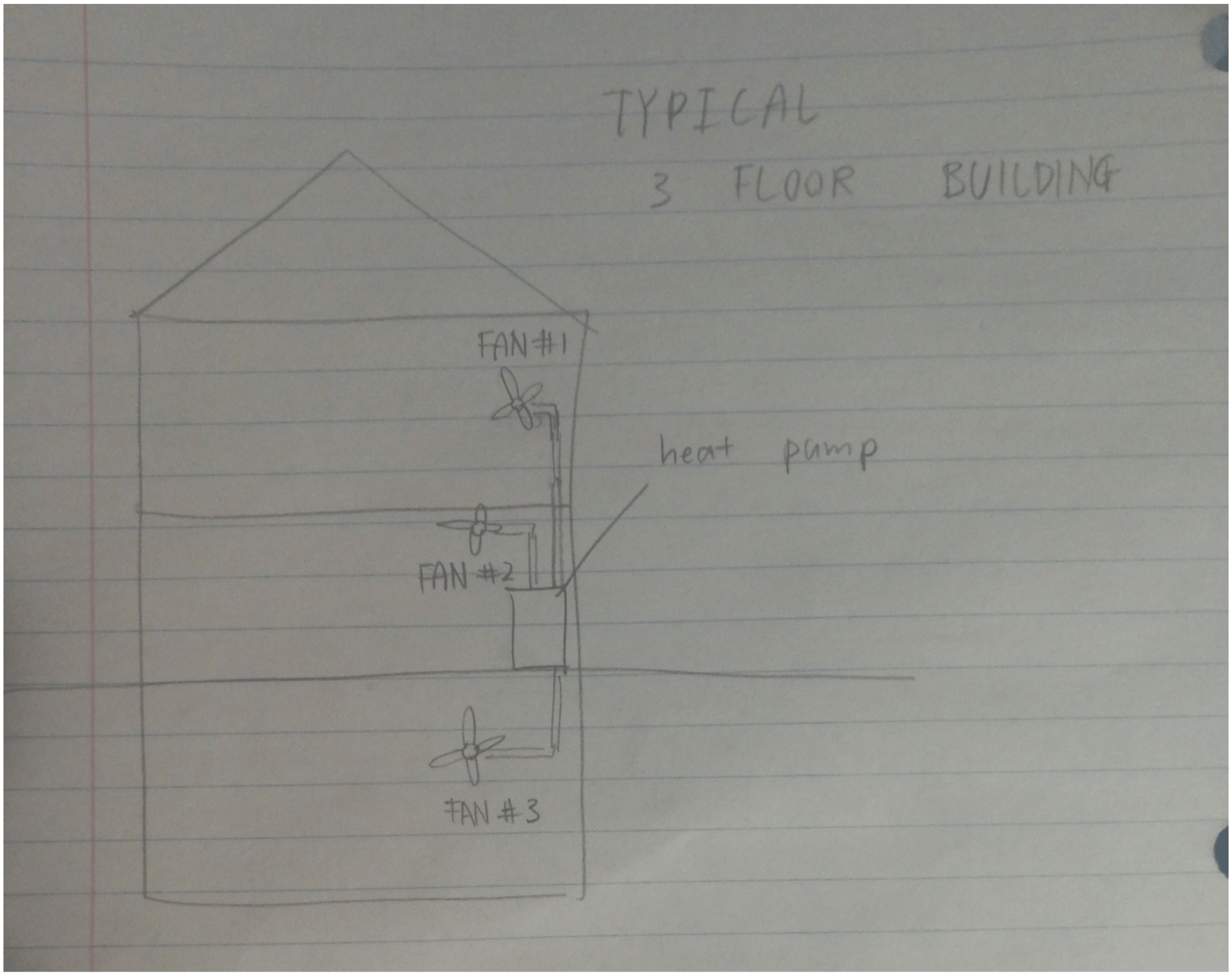

Figure 2.1.2 Liangyi Jinjing's idea for the blower fan

The blower fans will be connected to the heat pump via pipes. The fan will heat up or cool down the house with the hot or cold water brought up from the underground heat exchanger. There should be at least 3 fans in a 3 floor building so that the heat exchange chamber could heat up the entire house.

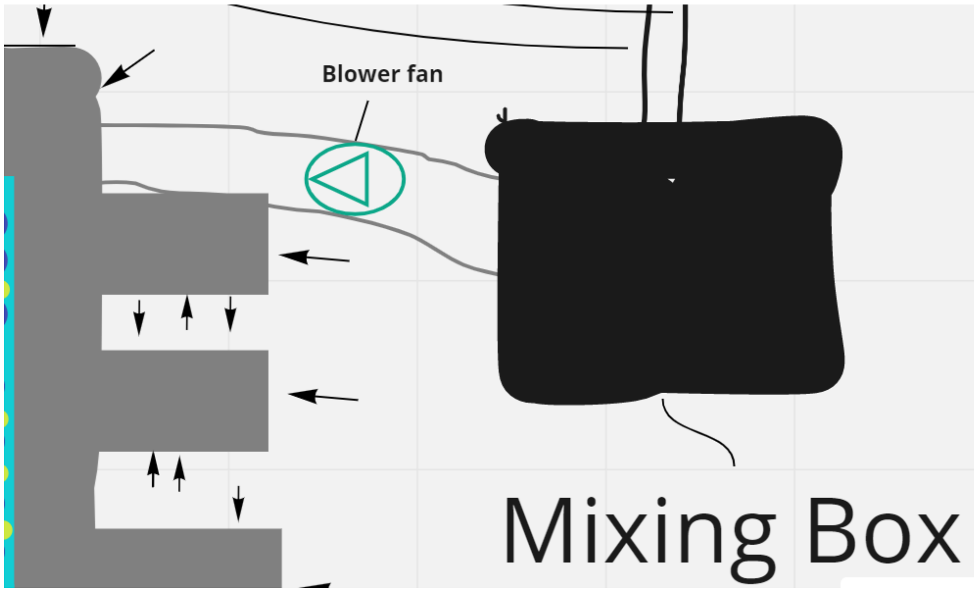

Figure 2.1.3 Rayane Laouadi's idea for the blower fan

The blower fan as shown in the figure above is placed between the air mixing box and the heat exchange chamber. The fan draws air from the outside and from the inside of the house (return air) and sends it to the pipe system of the heat exchange chamber. The fan is activated using house electricity or using its own solar rechargeable battery. The rechargeable battery is charged by a solar panel on the roof of the house.

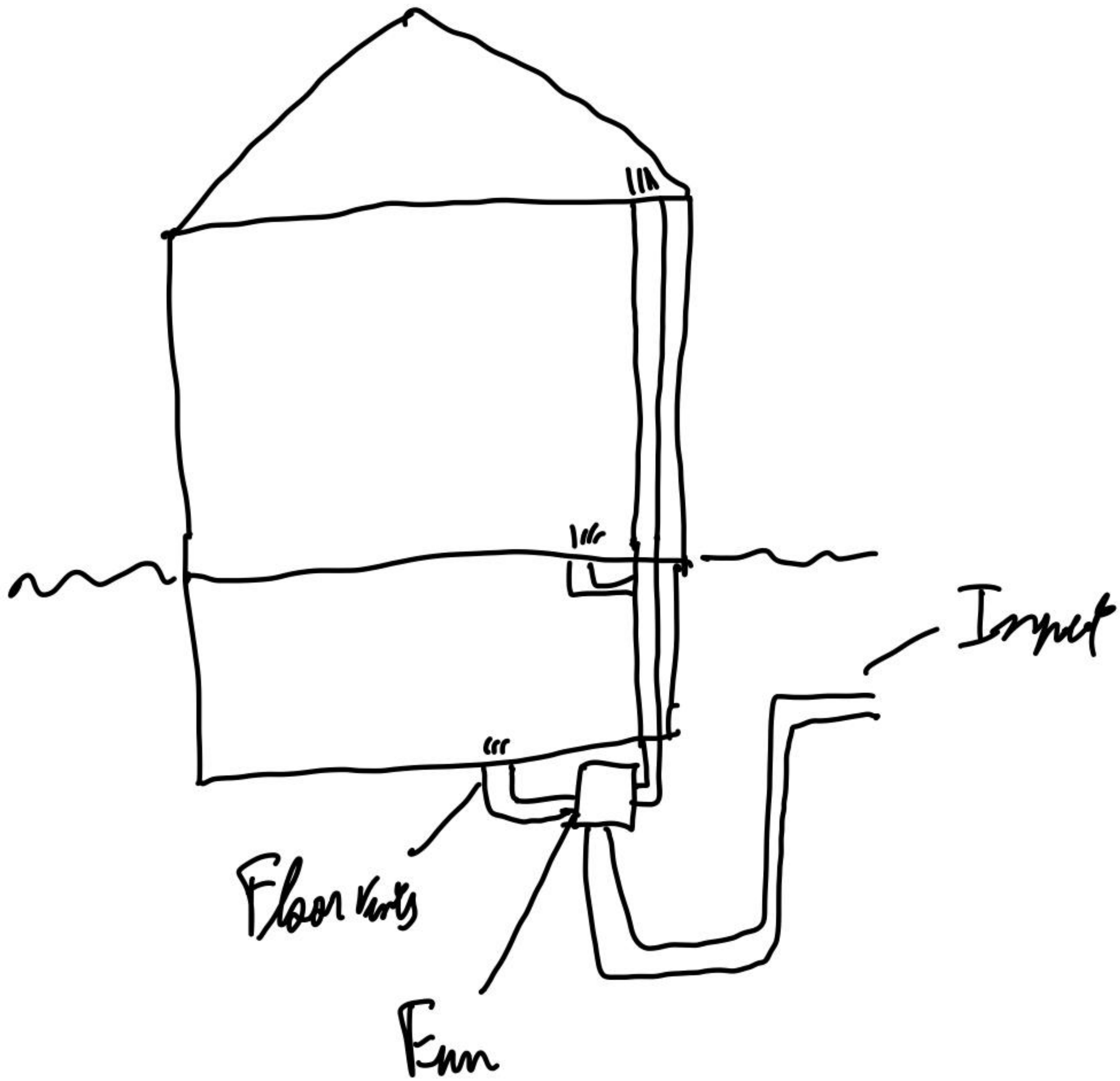

Figure 2.1.4 Tristan Ruel's idea for the blower fan

The blower fan as shown in the figure above is placed under the house and blows air up into the house. The air system blows air through floor vents for increased comfort and more efficient airflow. The fan will send air to all 3 floors of the house. This fan will run on 120VAC, it will be powered by the solar panels, wind turbine, batteries or electricity from the grid in case there isn't enough power being generated.

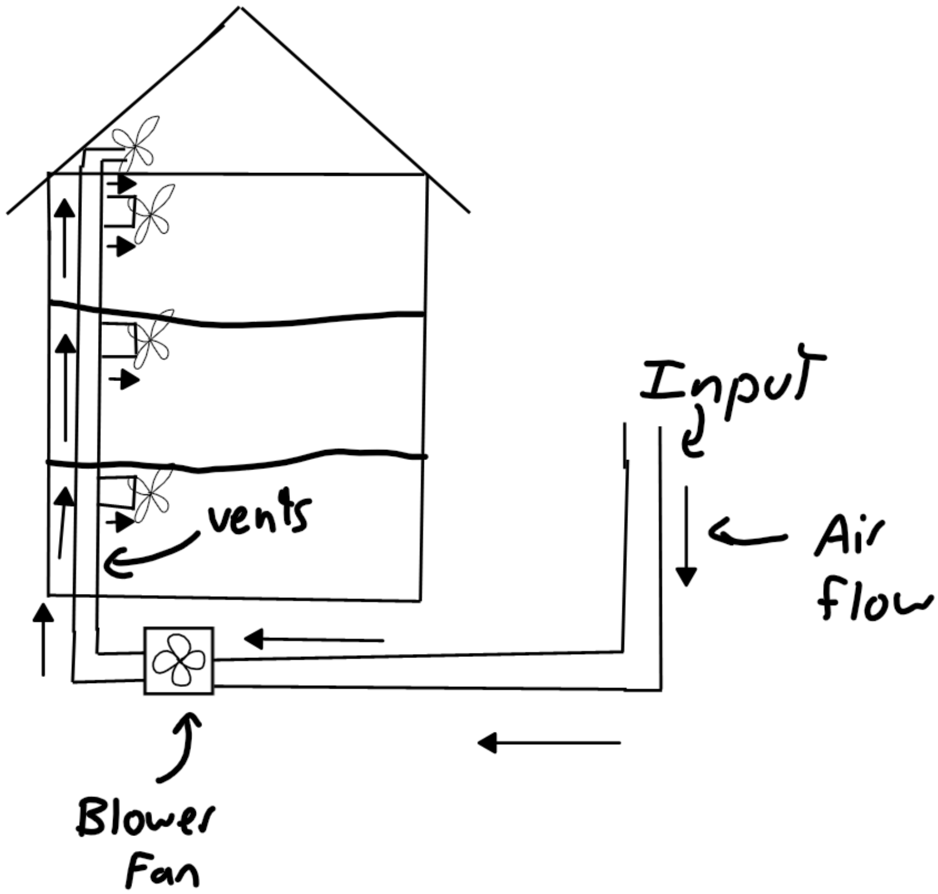

Figure 2.1.5 Anmol Brar's idea for the blower fan

The blower fan, as illustrated in the diagram above, is installed beneath the house and blows air into it. For greater comfort and more effective ventilation, the air system blows air through floor vents. The fan will circulate air across the house's three levels. This fan will run on 120V AC and will be powered by solar panels, wind turbines, batteries, or grid electricity if sufficient power is not generated.

2.2 Ideas generated for the sump pump and pipes

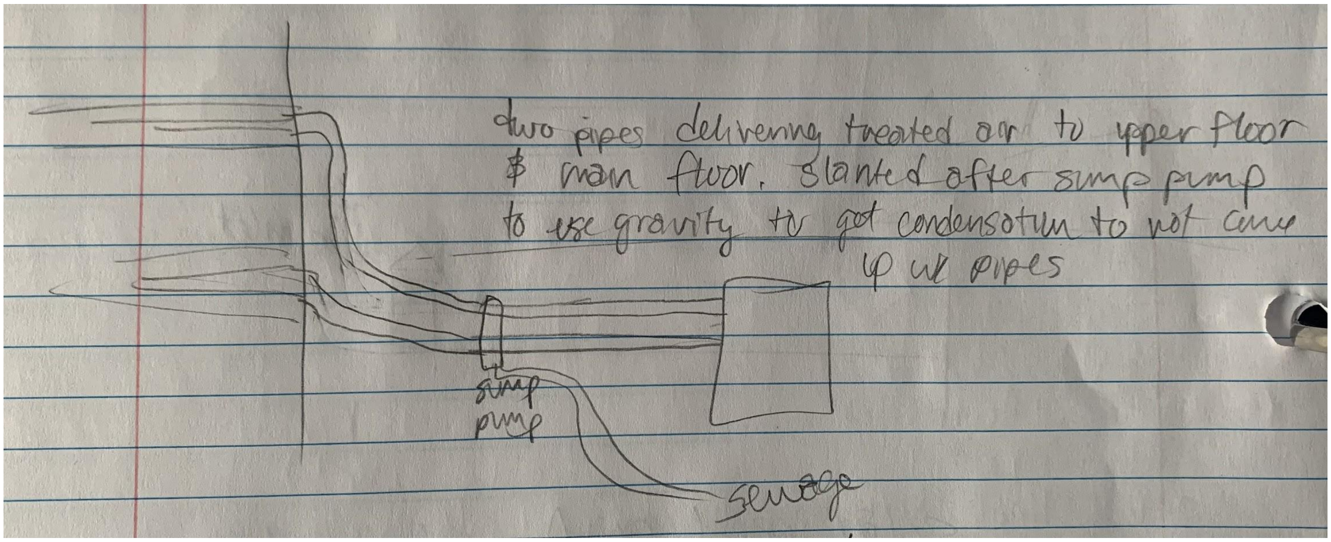

Figure 2.2.1 Kate Valentine's idea for the sump pump and supply pipe system

In this idea for the pipes and sump pump system, the pipes exit the box containing the thermal storage medium and the heat exchange system horizontally and underground. Due to the heat exchange that occurs in the heat exchanger, condensation in the pipes will inevitably be created. The sump pump pumps out the water that forms on the interior of the pipes. Because no system is perfect, some water and condensation will also be in the pipes after the airflow passes the sump pump. So for this reason, the pipes have an upwards slope so that gravity can assist the system and cause the water to accumulate at the bottom of the slope and the sump pump can pump it out into the sewage system.

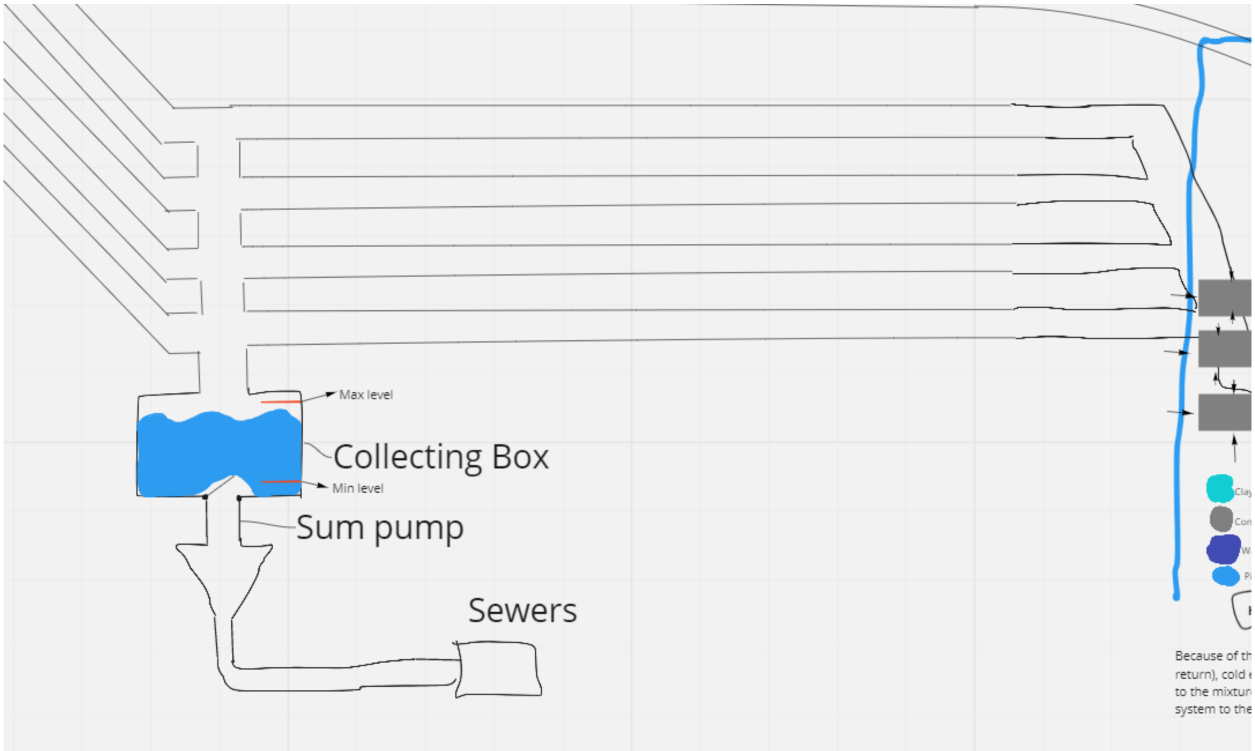

Figure 2.2.2 Rayane Laouadi's idea for the sump pump and supply pipe system

The conceptual design of the sump pump and supply pipe system is shown in the figure above. A set of horizontal pipes collects energy from the heat exchange chamber which are connected to a second set of inclined pipes. Water condensed in the pipes is collected at the bottom of the inclined pipes and then goes to a small reservoir. The reservoir is equipped with a sensor that indicates the level of water inside it. If the water level reaches the maximum height the water pump which is connected at the bottom of the reservoir is triggered to evacuate this water to the sewer system. The pump is automatically stopped if the water reaches its minimum level in the reservoir.

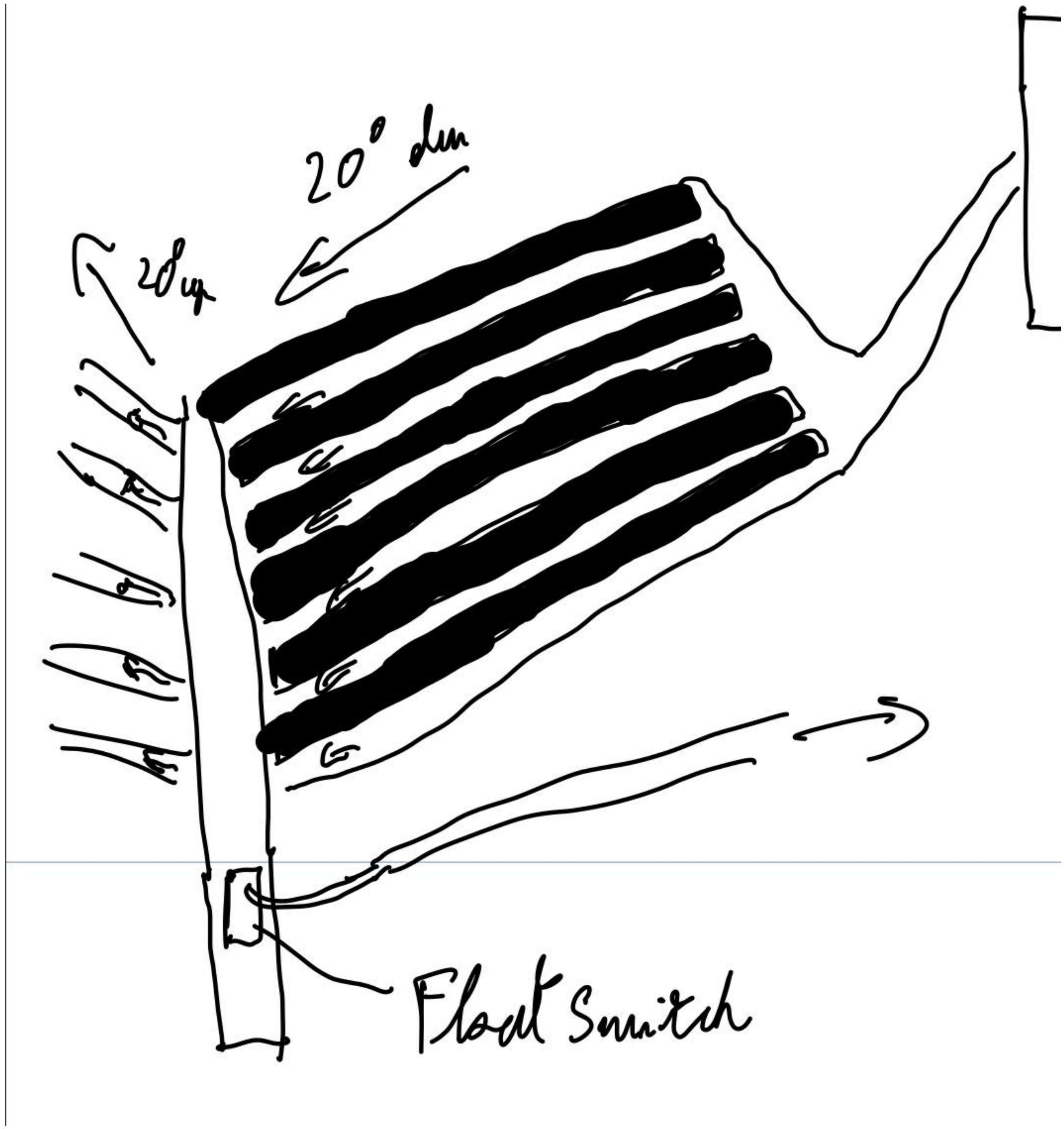

Figure 2.2.3 Tristan Ruel's idea for the sump pump and supply pipe system

This sump pump design is located right before the pipes that lead to the final blower fan. Since there will be condensation on the 6 pipes that precede it, these pipes will be at a 20 degree downwards angle to allow all the water to fall into the location of the sump pump. Once the water reaches a predetermined height, the float switch will activate the sump pump and allow it to evacuate the water.

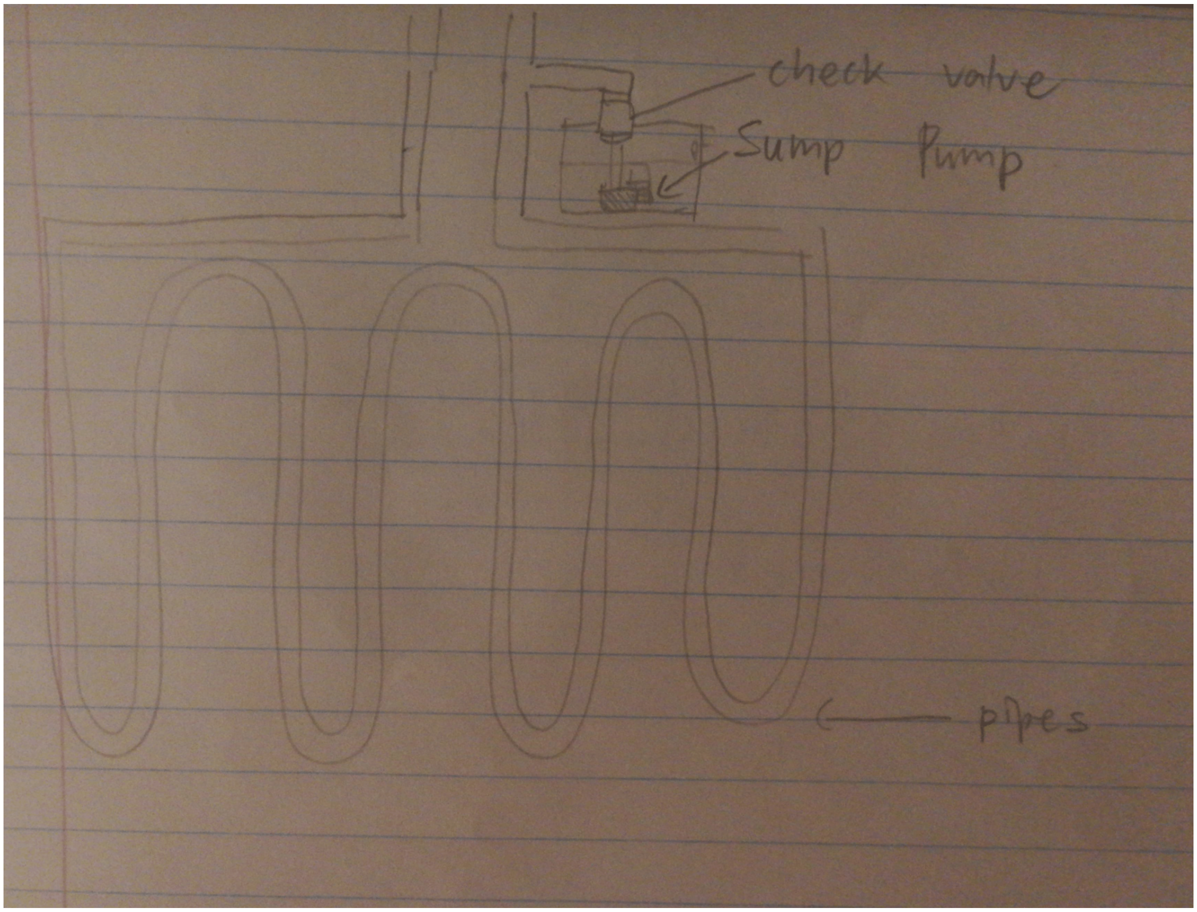

Figure 2.2.4 Liangyi Jinjing's idea for the sump pump and supply pipe system

The pipes will have to be long to efficiently extract heat from the ground. Ideally the pipes should also be on the same level and be close together so that it is easier to install and takes up less space. Therefore, it is optimal to position them horizontally in a pattern similar to the one in the diagram. The pipes will be in a closed circuit that connects to the house, in between, a sump pump will have to be installed to eliminate excessive moisture and avoid flooding.

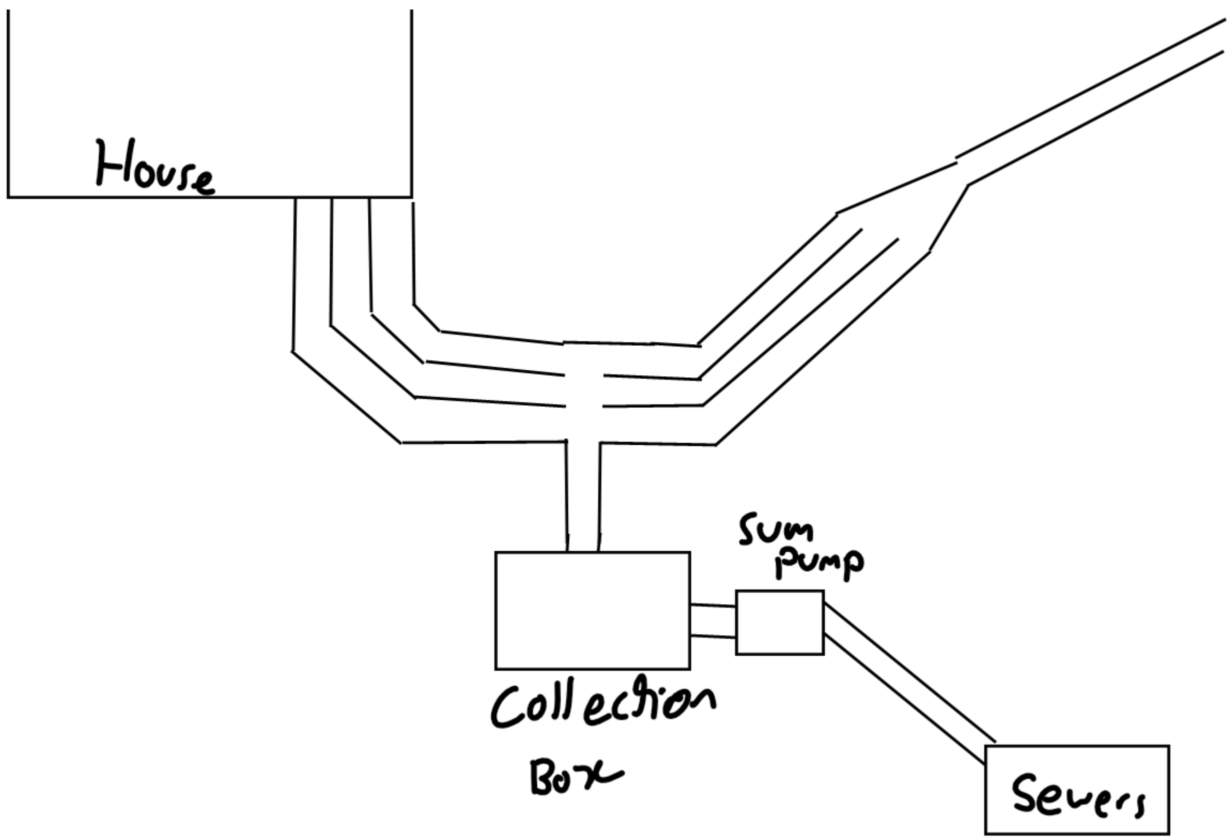

Figure 2.2.5 Anmol Brar's idea for the sump pump and supply pipe system

To effectively collect heat from the ground, the pipes will need to be lengthy. The pipes should ideally be on the same level and close together to make installation easier and take up less space. As a result, it's best to arrange them horizontally in a pattern similar to the one shown in the diagram. The pipes will be connected to the home in a closed circuit, and a sump pump will be required in the interim.

2.3 Ideas generated for the heat exchange chamber

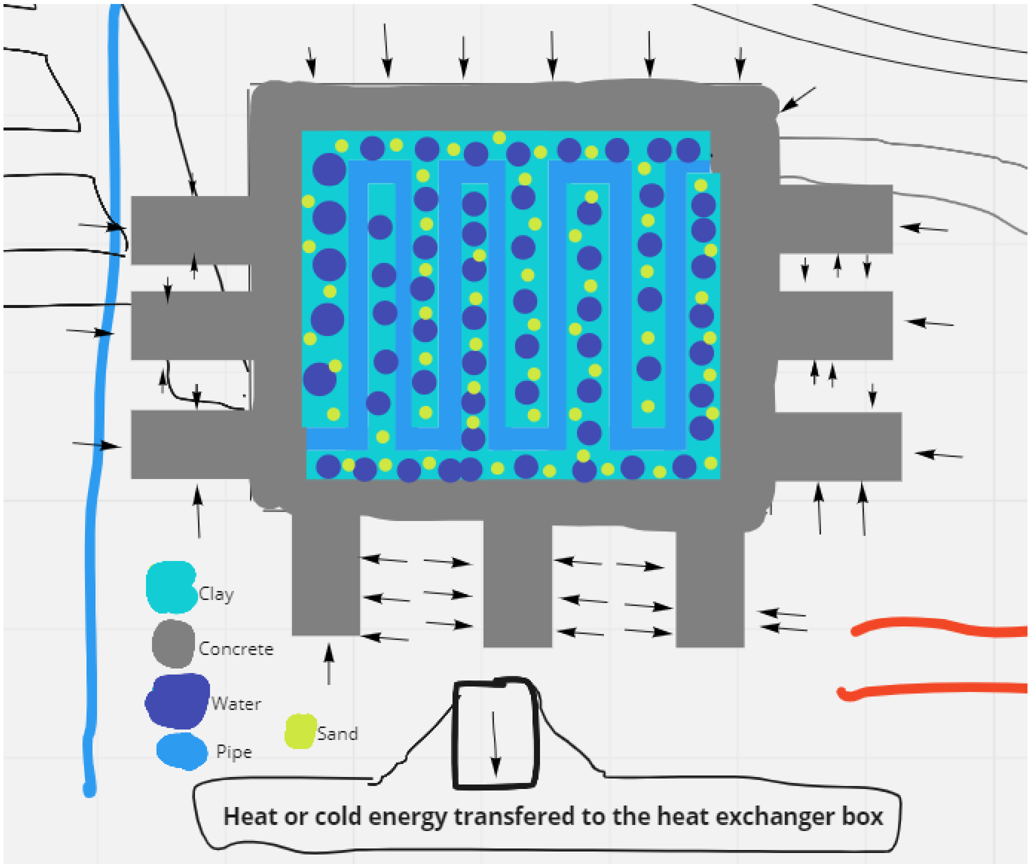

Figure 2.3.1 Rayane Laouadi's idea for the heat exchange chamber

The proposed conception of the heat exchange chamber consists of three parts. First part is the concrete wall surrounding the heat storage medium (clay, sand and water). Concrete walls have a high conductivity so that it can transfer heat or cold from the ground to the heat storage medium. To increase this heat transfer the concrete wall is fitted with concrete fins as shown in the figure. The fins increase the heat exchange surface area to collect more thermal energy from the ground.

Fins are fitted around the concrete wall to increase the heat exchange surface area to collect more thermal energy from the ground

The second part is the heat storage medium which consists of clay and water. To increase the capacity of heat storage we have added sand particles in the mixture. The third part is the piping system that collects energy from the heat storage medium to the air in the pipe. We used vertical pipe layouts as shown in the figure. The spacing between the pipes is selected to supply the required energy from the ground.

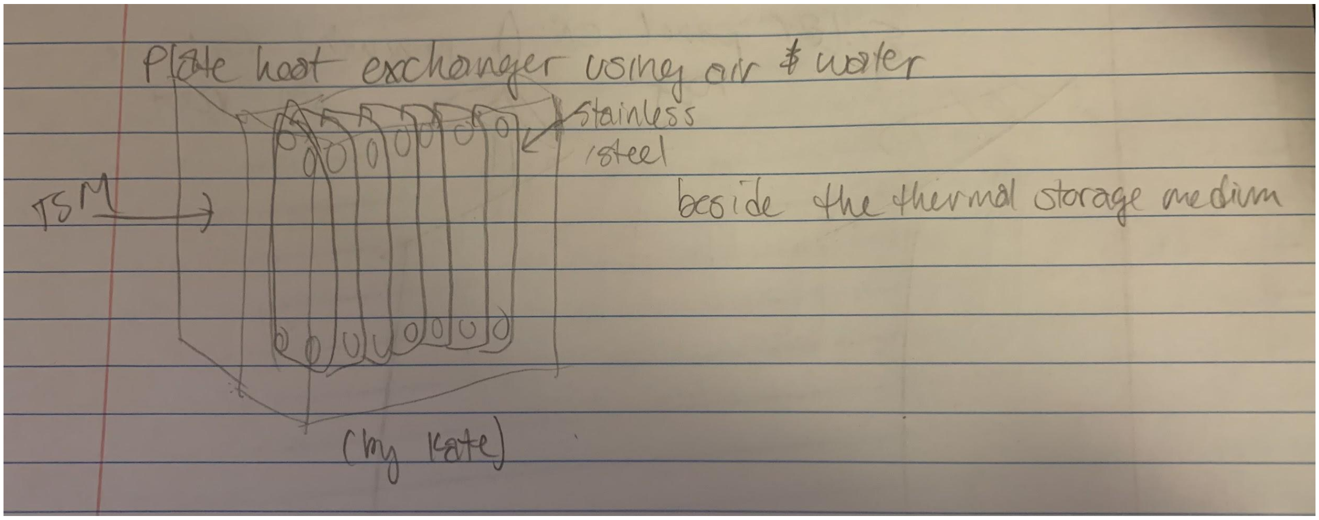

Figure 2.3.2 Kate Valentine's idea for the heat exchange chamber

In this sketch, you see a plate heat exchanger which are often the types of heat exchangers used in residential and/or furnace replacing systems (https://www.thomasnet.com/articles/process-equipment/understanding-heat-exchangers/). The heat exchanger is contained in the system surrounded by the thermal storage medium which is insulated by clay. The heat exchanger is made of stainless steel and uses air and water to carry out the heat exchange.

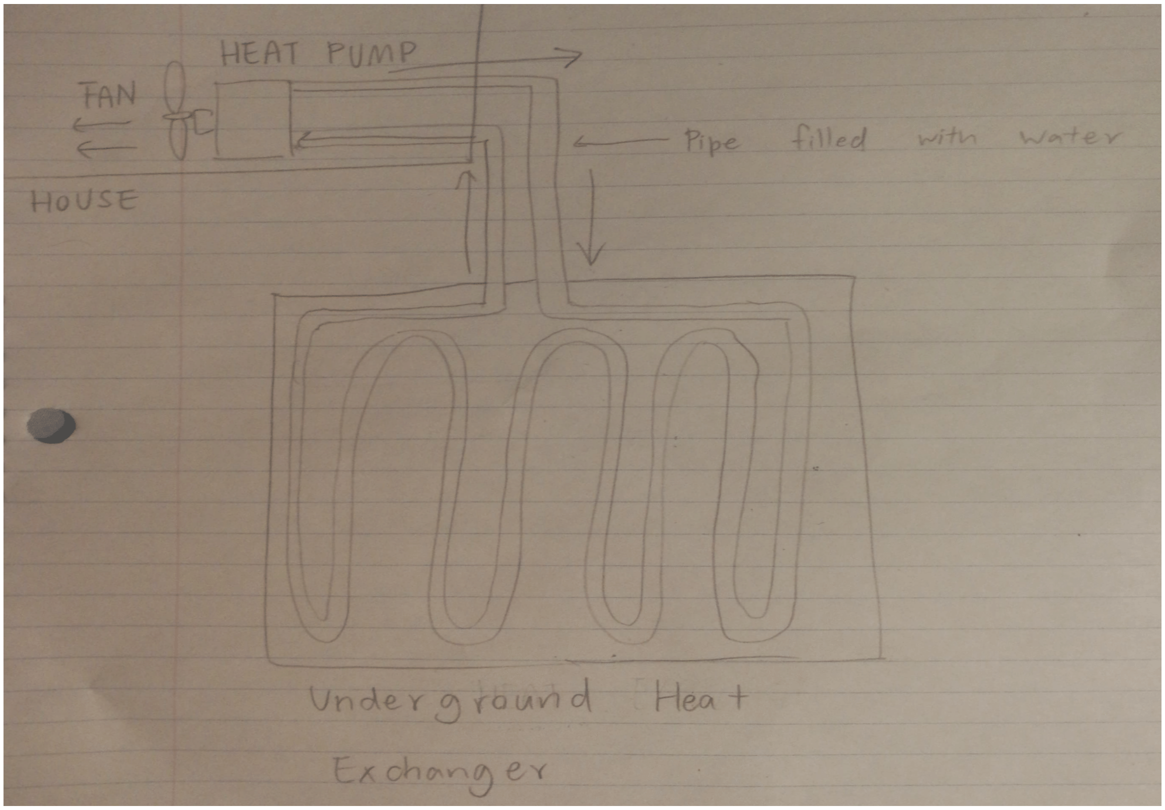

Figure 2.3.3 Liangyi Jinjing's idea for the heat exchange chamber

The main body for the heat exchanger should be the pipes containing the water. While they are underground, they extract energy from underground and bring it back into the heat pump. The energy stored in water will then be used to heat up or cool down the house.

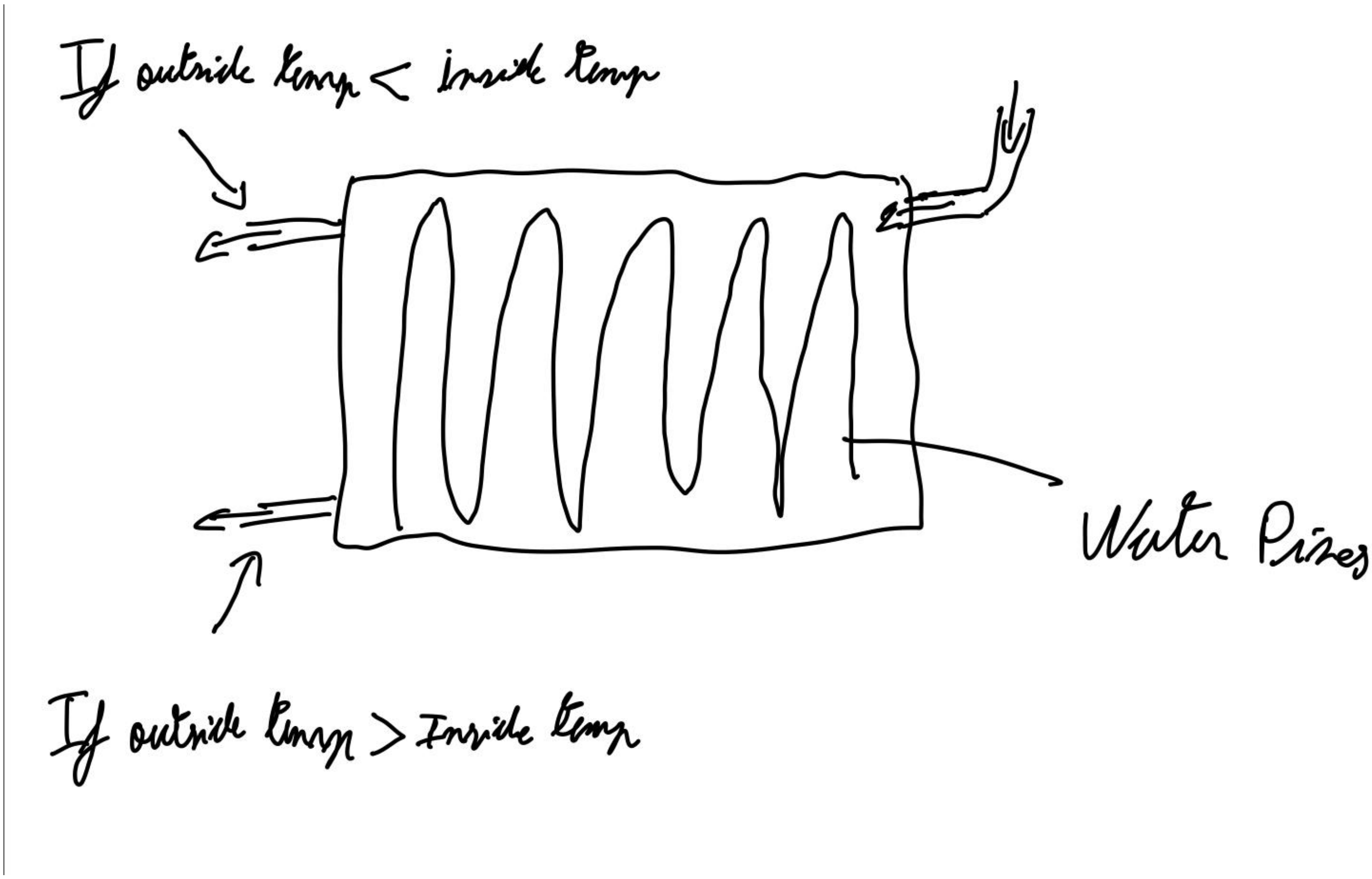

Figure 2.3.4 Tristan Ruel's idea for the heat exchange chamber

This heat exchanger is relatively straight forward, the water pipes act as a "capacitor" to the heat exchanger. They line the side of the exchanger and are highly thermally conductive. This means that when the air from the outside will come in contact with the water pipes, the transfer of heat will be fast. Then, using an arduino, we can control solenoid valves to only let the air at the top or bottom of the heat exchanger continue on to allow for maximum efficiency within the system.

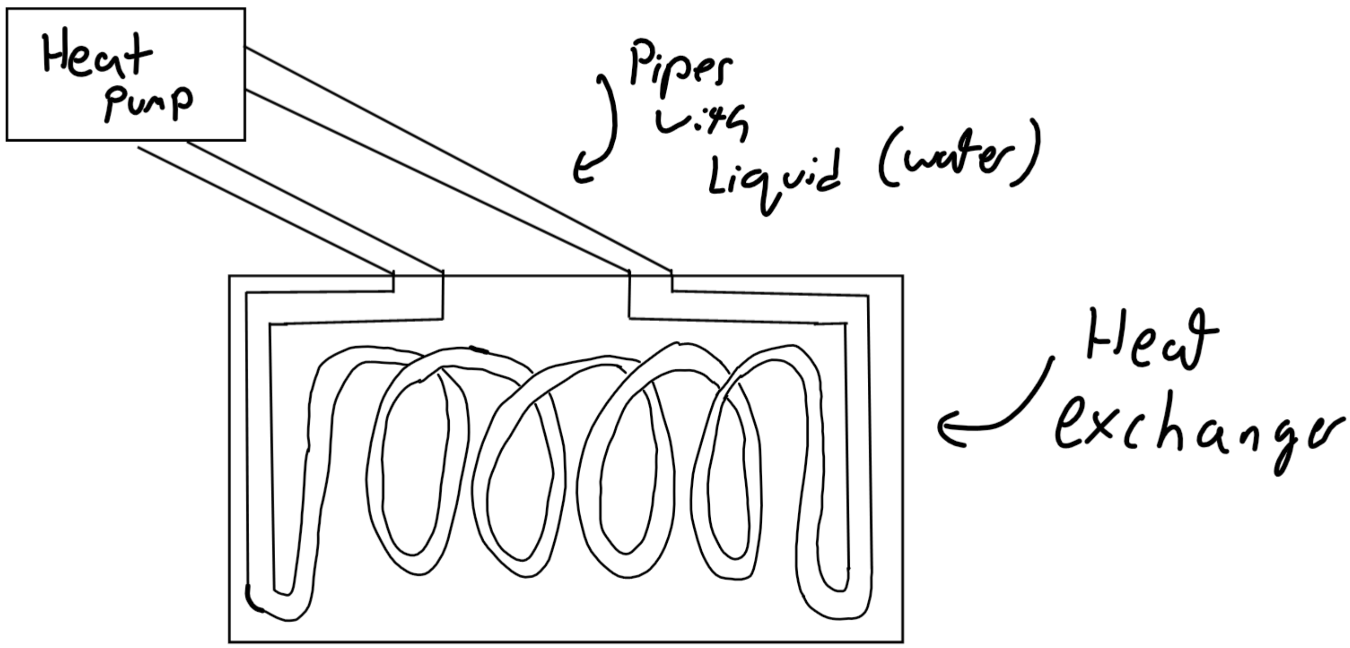

Figure 2.3.5 Anmol Brar's idea for the heat exchange chamber

The pipes that carry the water should be the major body of the heat exchanger. They gather energy from underground and return it to the heat pump while they are underground. The stored energy in water will then be utilized to heat or cool the home.

-2.4 Ideas generated for the energy system

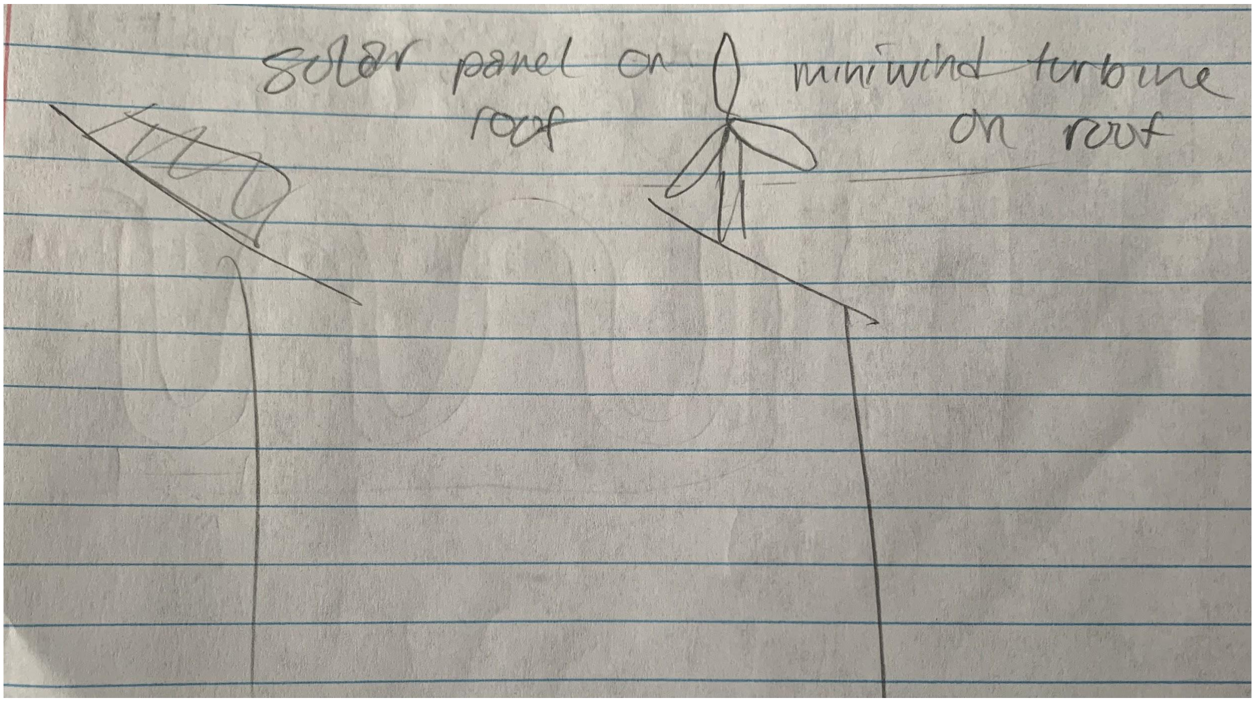

Figure 2.4.1 Kate Valentine's idea for the energy system

Depending on the environment where the system is installed, we can use either a small scale wind turbine or a small solar panel. If the geographic area has more wind, then we use the turbine and if the area gets a lot of sun, then we use the solar panel. As many people have fenced-in yards, trees and shrubs that block wind, and tall trees and a tall home that cast shadows, the best place for both a small turbine and a small solar panel is the roof of the home. The energy collected is then diverted to the system through wires along the wall that run to the underground system.

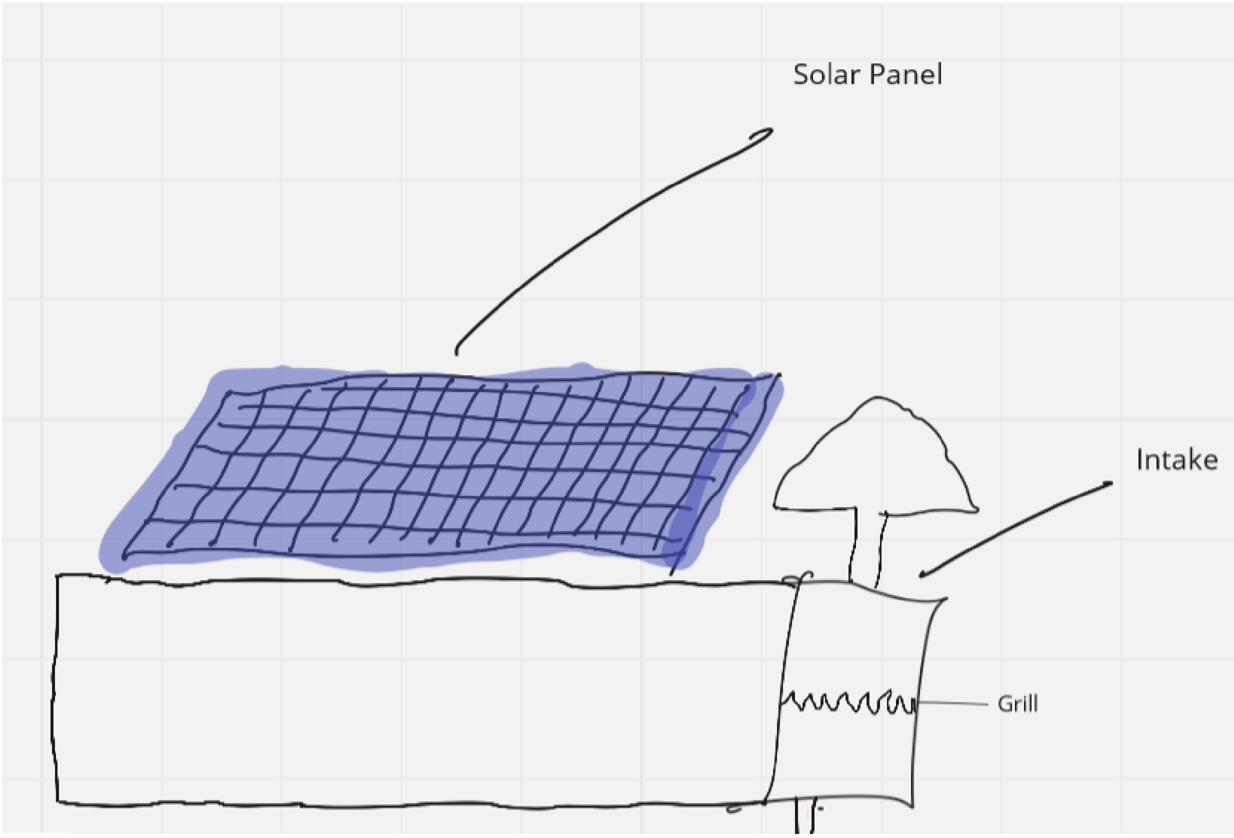

Figure 2.4.2 Liangyi Jinjing's concept for the energy system

The energy source should be connected to the intake and the grill, which goes to the valve. Another reason that the chamber should be supplied via solar panels or small wind turbines is because of that The Heat Exchange Chamber should be environmentally friendly and have zero emission.

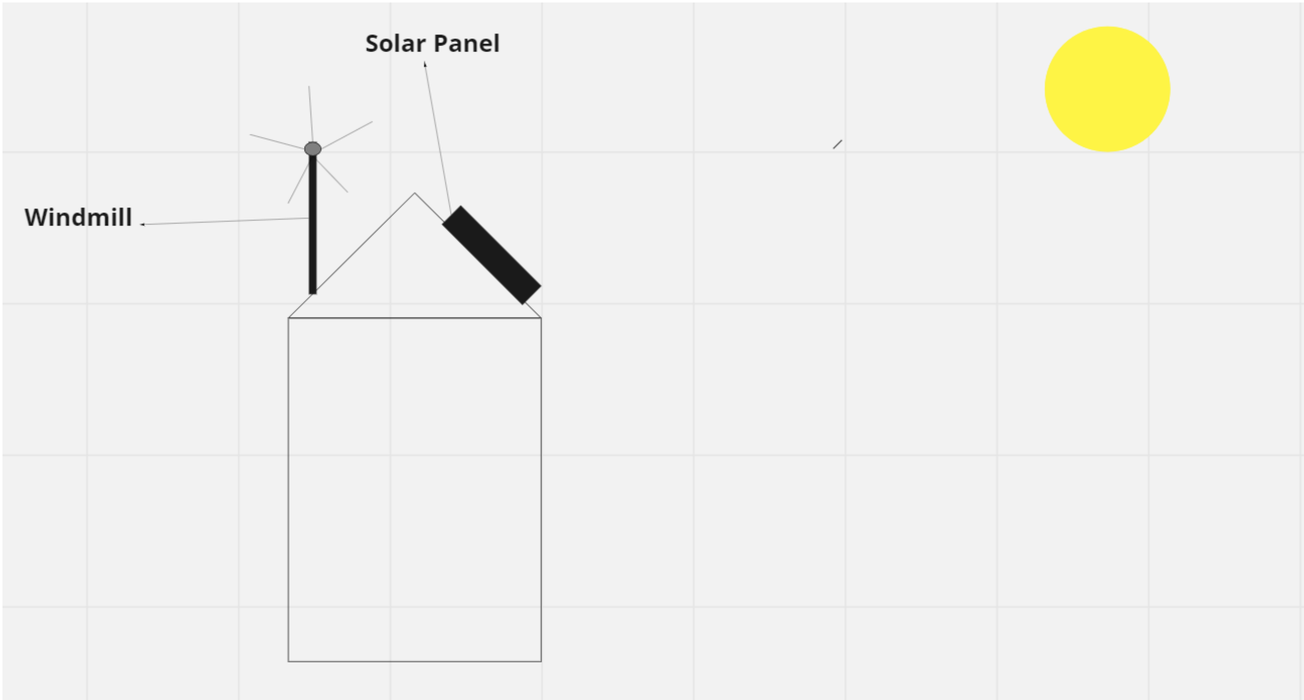

Figure 2.4.3 Rayane Laouadi's concept for the energy system

This figure shows an energy system that can harvest renewable energy from the sun and wind. In places where there is a lot of sun, solar panels are used to generate electricity from sunlight.

In other places where wind is present, a small windmill is used to generate electricity from wind energy at the house level. This renewable energy system is used to operate fans and sump pumps during the house cooling.

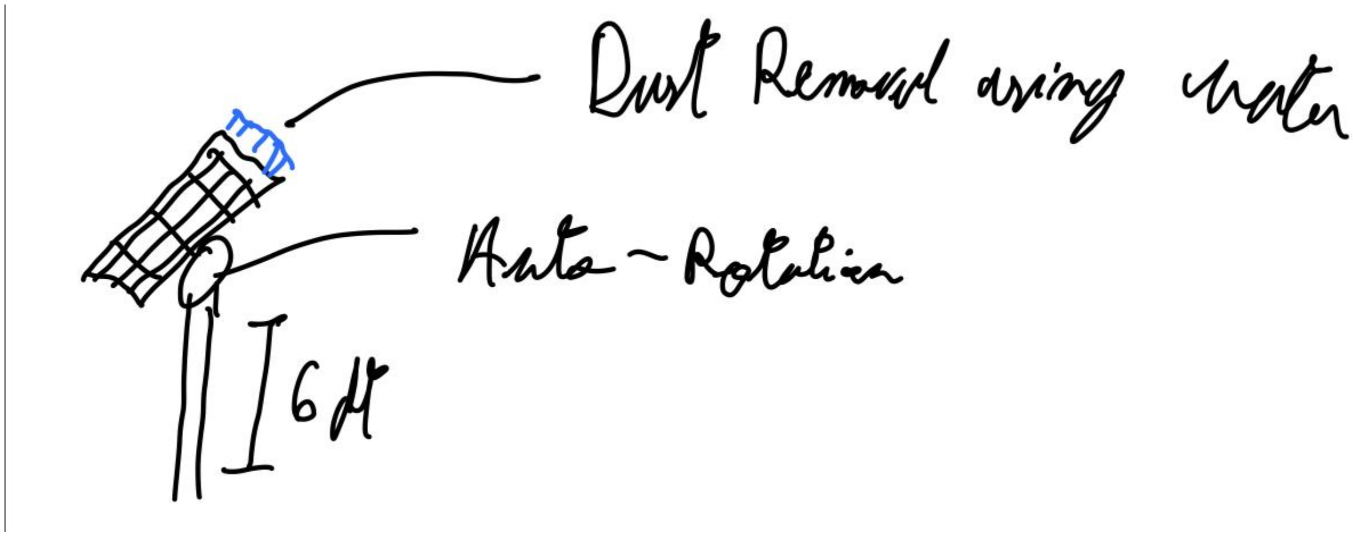

Figure 2.4.4 Tristan Ruel's concept for the energy system

This power system allows the solar panel to operate at maximum efficiency as they have an automatically adjusting support that guarantees best solar contact as well as a water deluge system to ensure the solar panels remain clean for the best possible efficiency. Additionally, having the solar panels 6 feet above the ground allows them to be usable in the winter or during periods of severe flooding.

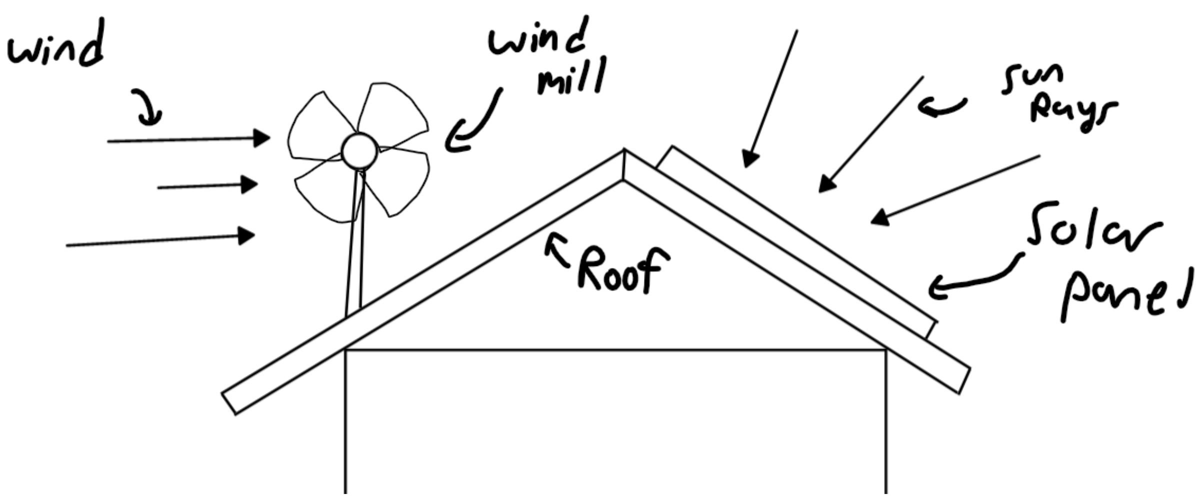

Figure 2.4.5 Anmol Brar's concept for the energy system

The energy source should be linked to the intake, which leads to the valve. Another reason the Heat Exchange Chamber should be powered by solar panels or small wind turbines is that it should be environmentally friendly and emit no emissions.

3.0 Fully Functional Solutions

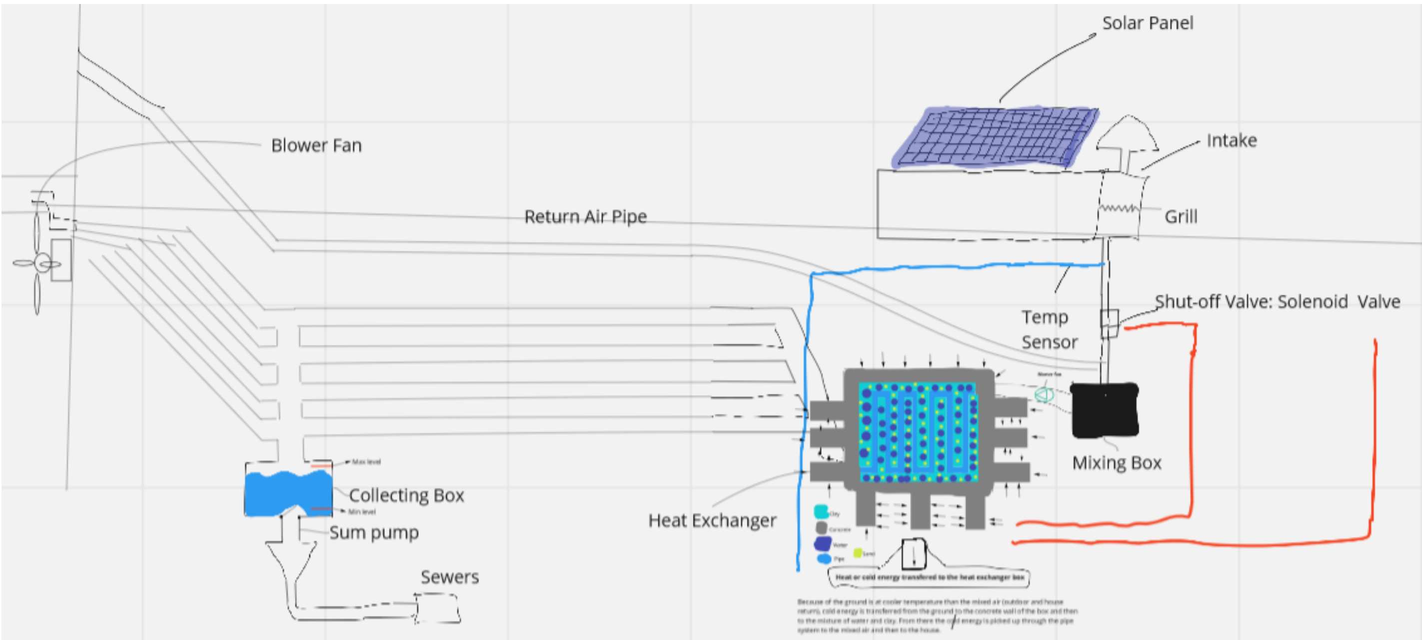

Figure 3.1 Fully Functional Solution #1

In this fully functional solution, we used a unique design for the heat exchanger that uses pipes. In the text box below the heat exchanger, the heat exchanger is explained: “Because the ground is at cooler temperature than the mixed air (outdoor and house return), cold energy is transferred from the ground to the concrete wall of the box and then to the mixture of water and clay. From there the cold energy is picked up through the pipe system to the mixed air and then to the house.” We also decided to use a solar panel that is elevated above the ground along with the air intake. The pipes run horizontally from the heat exchanger and thermal storage medium. They come in contact with a sump pump that deals with the condensation in the pipes. The upward slope after the sump pump is crucial to ensure moisture is dealt with by the sump pump. The pipes run to the house where there is a singular air filter and a fan that distributes air into the basement. Since all homes are typically built with conventional air ducts, the system then connects with the air ducts of the home to distribute the warmed or cooled air to the rest of the home.

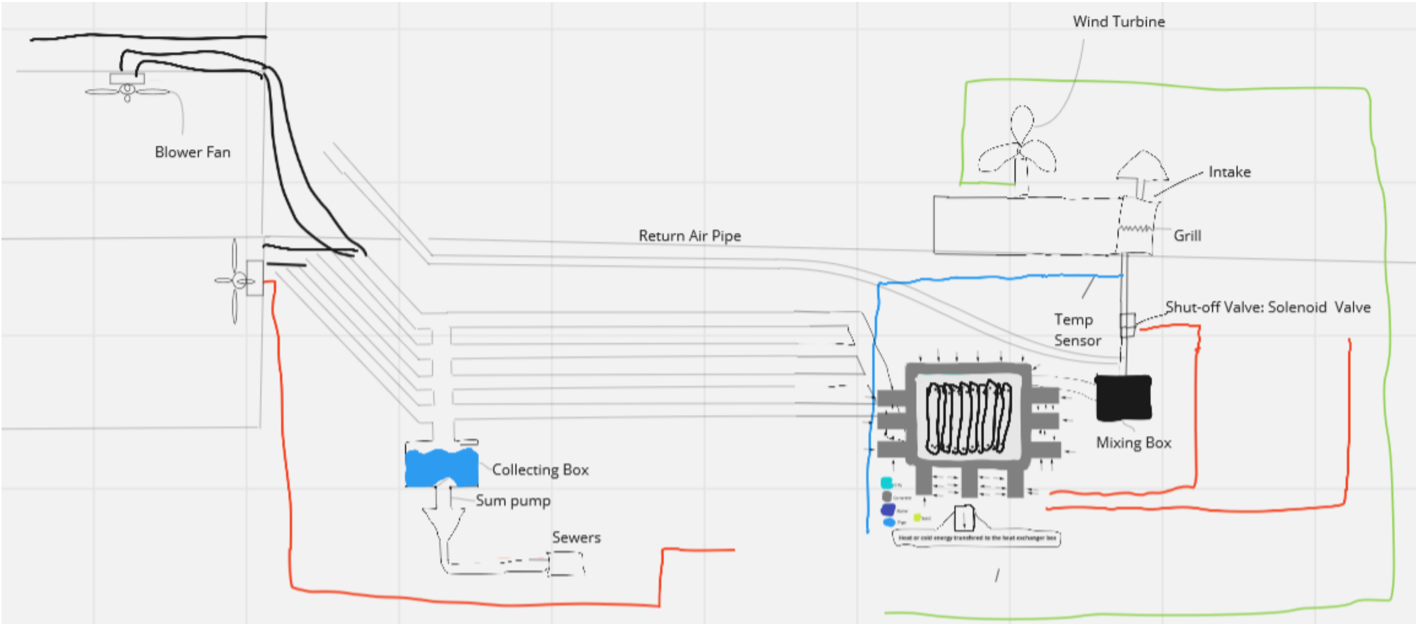

Figure 3.2 Fully functional solution #2

In this fully functional solution, we have replaced the pipe heat exchanger with a conventional plate heat exchanger. The plate heat exchangers are typically the type of heat exchanged used in residential systems. The solar panel was replaced by a small wind turbine which will generate energy to power the fans and the automatic valve systems. The wind turbine is elevated so it can be in contact with more wind, along with the air intake. The same pipe setup as the previous design is used, and the same thermal storage medium is used. The pipes run from the system to the home in two separate entrances in this design. Instead of connecting the treated air entrances to the home's ducts, there is an entrance for each floor. The entrance for the air does not have a filter in this case, as it is not economically feasible as the money was used to create two separate entrances to the home.

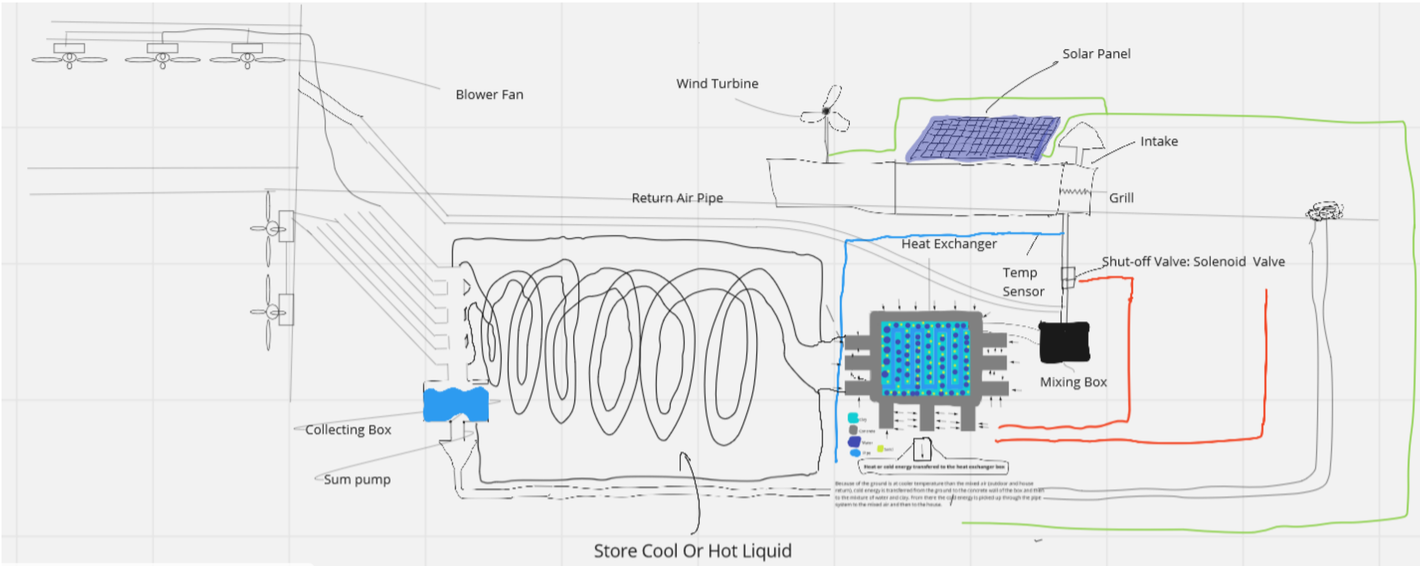

Figure 3.3 Fully functional solution #3

In this solution, we combined the functions of the solar panel and the wind turbine to generate more power for this system. To ensure that the air is hot or cold enough, it travels through a chamber of cold or warm liquid that is brought to the correct temperature by the energy of the system. The air goes through a coiled pipe and continues to be heated or warmed. The heat exchanger design is the same as solution #1 and the sump pump remains consistent. However, in this design, the pipes go to the basement and the upper floors. They do not connect to the ducts of the home, and instead, the system has air filters and multiple fans to disperse the heated or cooled air into the house. To increase the efficiency of the system for environmental reasons, the moisture that the sump pump removes is distributed to a sprinkler system for the owner's yard. The water is instead put to use to water the lawn instead of adding to the sewage that needs to be treated by the water treatment plants.

4.0 Analysis and Evaluation

As a team, we decided that solution #1 was the best for us. The first solution that we came up with, solution #3, was found to be too idealistic and not realistic enough. As great as it would be to take the water that the sump pump pumped out of the system and redistribute it to vegetal growth, it is not feasible. We reiterated back to our needs identification and reminded ourselves that the two most crucial needs of our client were that this system is net-zero, and that it is economically feasible. While trying to improve the sustainability of this system, we got ahead of ourselves in the price domain. It is not economically feasible to build pipes and a sprinkler system to redistribute the water that the sump pump removed from the system. Although it was a creative idea, the increase in price is not worth the small positive environmental impact a sprinkler system would have.

Not only was the sprinkler system not economically feasible on solution #3, but also the amount of piping to create multiple entrances into the home. In this system, we had multiple pipes running to different entrances in the home and into the home where the air was then distributed through multiple openings. All of the openings were then filtered and had fans to disperse the air. After we came together, we realized that the cost of extra material for the piping and also for the multiple filters and fans drove the price of the system up significantly.

Also, on solution #3, our initial design to perfect the heat exchanger involved a coiled tube the air would go through to then be further heated or further cooled. This was designed to lessen the strain on the heat exchanger and thermal storage medium, but also to ensure that the air dispersed into the house would be warm enough or cool enough. Although we added both a turbine and a solar panel to create the extra energy needed for this system, this system did involve extra material for the chamber in which the coiled tube ran through and for both the solar panel and the turbine, which further drove the price up.

We were far too ambitious, trying to create a system as convenient and luxurious as possible for clients in our first design, solution #3. We realized after deliberating that we needed to be much more realistic and stick to a strict budget.

Solution #2 was a much more close contender with solution #1. The major differences between solution #2 and solution #1 are the turbine and the solar panel, and also the way the air enters the house. We also experimented with different types of heat exchangers, but we figured, ultimately, those are interchangeable between designs. After deliberating as a group and reading forums, we found that it's much more common for residences to use solar panels for renewable power rather than small turbines. Because of this, we figured that there would be more professionals ready to install solar panels than wind turbines, and industries with more competition often have more competitive prices. So, we decided that a solar panel is a better alternative for economical reasons.

Solution #2 has multiple pipes entering the home at different entrances, and a fan to disperse air on each floor. We knew as we were designing solution #2 that having more than fan was a more expensive alternative, so we gave up the air filters that filter the air before the fans disperse it. However, a group member suggested that we connect a pipe to the ducts in the house, as most houses have conventional ducts for heating and cooling systems that already exist. We all liked this idea so we added it to our final design. We all agreed that this was a fantastic alternative to having multiple entrances for the air, and keeping a singular air filter to ensure that the air is cleaned before it is distributed in the ducts of the house. We still kept a fan to distribute the air where the pipes came in on solution #1, but one fan is much more economically efficient than two.

5.0 Conclusion

In conclusion, our team has opted for design solution #1 as it combines multiple needed features to increase efficiency as well as assure a low build, installation and operation cost. Design solution #1 is simpler than the two other ones (use of only solar power instead of a rotating wind turbine) that allows the system to be more reliable, simpler and easier to implement. This solution is the perfect balance between it being too idealistic while still being innovative with the systems we implement. This solution allows us many options down the road to integrate electrical systems powered by arduinos in the future for example to ensure the system runs efficiently. We have achieved this by using the “no decision is final” and “open to any suggestion to improve” approach. The team has been working collaboratively from the start and this has allowed for all ideas to be heard and considered. This is a very positive experience for the team as we have been able to learn from each other, gain experience and build strong relationships which will further our success in the future.