Deliverable D – Conceptual Design

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GNG 1103 – Engineering Design

1 Introduction

In this report, with a knowledge of the user's needs and our developed design criteria, we explore subsystem features for our design. To do so, we split the design into five subsystems: electronics, power, airflow and pipes, drainage and filtering, and the main box unit. Individually, we generated ideas for each subsystem, then filtered them as a team to generate three final design concepts. To evaluate these concepts, we tested them against our previously defined design criteria and chose the option that best fits the client's needs.

2 Subsystem Concept Generation

2.1 Subsystem I: Electronics

Kirstyn Aranyosi:

I. We could implement a wireless underground sensor system (connected to a main hub above-ground) that can measure:
   - Pipe pressure to detect leaks
   - Temperature in the pipes, so we are not pumping cold air into a house we are trying to warm

II. A type of emergency shut off valve that could shut down the system should be implemented. In case a contaminant was to enter the air stream, there must be a fail-safe to ensure no contaminated air is dispensed to the house.

Jan Czajkowski:

I. All electronic circuits are connected inside the pipes and are separated by some specific distance. They measure the inside temperature of the pipe to make sure that it has the correct temperature. The air intake pipe must be able to be opened and closed remotely. The air intake pipe must have a clean air filter and an electronic system that can detect when it is compromised or in need of a change. Pipes will also be outfitted with enough fans to facilitate quiet and quick airflow into the building.

II. If we were to adopt solar panels into our design, we would need an electrical system that can shut off solar panels during the night and winter. We would also need a battery storage system that can accumulate excess energy obtained from the solar panels to store it.

Sarah Dumont:

I. It would be important to integrate an electronic system that will not break or have defaults. That way it is easy to maintain and easy to repair if broken. If there is a problem with the electrical system, it should alert the user so they will know what component is not working

Oscar Fillmore:

I. It is imperative that our electrical system have an external thermostat which can measure the temperature within the building. This thermostat will also have to send information to our unit telling it whether the house must be cooled or warmed or if the temperature should be maintained.

2.2 Subsystem II: Power

Kirstyn Aranyosi:

I. Solar panels could be used as a sustainable energy source, placed on a shed or house roof out of the way of ground traffic.
   - Solar panels that can be placed on a shed or house roof – out of the way of any ground traffic
   - Lithium-ion batteries are an attractive method of storage for excess energy, which will be needed every night, during most of the winter, and cloudy summers
   - Although extracting lithium itself, and some steps in constructing the batteries, is not environmentally friendly, Li-ion batteries remain a sustainable and renewable method in themselves

Jan Czajkowski:

I. If a user lives close to a natural river or creek, we may be able to install a small water dam that can produce enough energy to power the system.
II. An electric motor can be installed next to the house which will power the system throughout the whole year. It will draw electricity from the house power supply. It will not require an energy storage system as it does not depend on an independent power source.

Sarah Dumont:

I. Solar energy is the best option in our case, if we place solar panels on the roof of the user's house, we could store up a substantial amount of energy with a system similar to the one that tesla offers. The Tesla Powerwall stores energy for the night and seasons when there is less sunlight or energy available so that it can be used during the night.
II. Integrating sunlight windows on to the user's house would be a major power saving method since during the day they will not need to use as much energy for light.

Oscar Fillmore:

I. The THEC could be hooked up to the same power source of the house that it is powering, leaving there no need for any additional power generating system to be installed and would become more reliable during the winter season and at night.

2.3 Subsystem III: Airflow and Pipes

Kirstyn Aranyosi:

I. Pipes should be insulated to help maintain heat, especially in the winter. Although PVC pipes are inherent insulators, foam insulation can be wrapped around the pipes to provide further insulation.
   - PVC is optimal, as it will not corrode or infuse contaminants (like rust) into the air stream
   - However, PVC is not a heat conductor, so it would take longer for the air to warm up, or most of the warming would ideally be conducted elsewhere before the air is transported through the pipes

Jan Czajkowski:

I. Air intake pipe and air outtake pipe should be made out of PVC and properly insulated with recycled materials. Pipes contained within the box must be made out a conductive material such as copper. If metal pipes must be used, we should prevent rust via application of antirust paints. Fans will be placed throughout the pipes to ensure air does not come to a standstill.

Evan Kerr:

I. Suggested to be PVC because of the cheapness of materials. The patent mentioned "schedule 40" PVC. These pipes should be secured in place somehow and should be sealed.

Sarah Dumont:

I. There should be a steady airflow always going through the pipes, so this means we need a fan that adjusts to how fast or how slow the air is changing temperature, so that when it exits the pipes into the house it will be the temperature desired by the user. Because we cannot control how fast the temperature changes because it depends on the temperature of the water. But we can change how fast the fan is going. So, if it takes more time for the air to cool down, the fan will then be slower.

Oscar Fillmore:

I. A furnace blower should be installed indie the house and connected to the PVC pipes from the THEC and be used to blast the warm air from the THEC and into the house.

2.4 Subsystem IV: Drainage and Filtering

Kirstyn Aranyosi:

I. The pipes in the system should be sloped to collect stagnant water buildup. The minimum pipe slope is a ¼ or ½ inch drop every horizontal foot of pipe.
II. The air filter for the system should be in an accessible location so that it can be easily changed. We could include an electronic sensor measuring the air flow through the filter:

    - When the air flow rate falls below a certain rate, the filter is too clogged and must be replaced
    - To eliminate the use of power, testing could be conducted to determine the lifespan of the filter

III. PVC pipes are the ideal choice, as they will not rust, corrode, or breed bacteria, provide a safe means to channel the air.

Jan Czajkowski:

I. Air filter will be placed at both ends of the system (intake and output pipes) to ensure excellent air quality and safety for users. There should be a water intake pipe that leads directly above ground. This will allow users to change water remotely without having to dig up the system. The water intake pipe will double as a pump to remove all water from the system as it is vacuum sealed so the water can be sucked out from the system and replaced with new water.

Evan Kerr:

I. A "sump pump" is recommended for fitting to the system and circulating the water to prevent unsanitary conditions.
    - Pros: Very effective, requires only purchase not construction
    - Cons: could be expensive, possibly loud

II. Air inlet pipes may be fitted with HEPA filters, additionally should be coated with mesh or fabric to prevent insects or small animals from entering the system. The HEPA filters are not required and any small covering like mesh or fabric would be cost-effective and easy.

Oscar Fillmore:

I. We should use a moisture eliminator to remove water from the PVC pipes carrying the air. The moisture eliminator functions like a dehumidifier and is placed inside the PVC pipes to absorb moisture so that the moisture doesn't go into the house through the pipes.

2.5 Subsystem V: Main Box Unit

Kirstyn Aranyosi:

I. Concrete is a favorable option for the main box unit. It is durable if installed correctly, and has a long lifespan in underground conditions.
    - Concrete is porous, so it does absorb water. The concrete's tendency to absorb water can be measured with "concrete moisture testing". The absorption of moisture shouldn't detract from its functionality.

- Concrete also absorbs heat, as it has a high thermal mass. Its ability to store heat would be useful when used in conjunction with the water inside the box, as water has a high specific heat capacity.
- Concrete, however, is not an environmentally friendly material. In all stages of production, concrete is said to produce 4-8% of the world's CO_2 emissions.

Jan Czajkowski:

I. The box can be made from recycled environmentally friendly materials that will have conductive properties that will ensure that the system pulls heat from the earth or pulls cold. Good alternatives to cement are pulverized fuel ash (PFA) or ground granulated blast furnace slag (GGBS).
    - PFA is made from the ash that is produced during coal burning. It is a substitute for cement in the production of cement. GGBS is produced when quenching molten or hot iron slag, a by-product of iron production which is a ferroalloy. Both PFA and GGBS, when used as a substitute for cement, will retain all properties of concrete but will be more sustainable and environmentally friendly.

Evan Kerr:

I. PVC box of approx. 3ftx2ftx2ft that must be able to withstand 29.2 kN/m^2. I chose PVC because the Canadian patent described that the box should be of PVC or concrete and PVC is more accessible to us.

II. One side should open so that the interior may be accessed if needed, a simple hinge and clasp should suffice, which would be of negligible price or could be improvised. This opening should be in the top face of the box so that it need not be waterproof.

III. A rig of "schedule 40" PVC pipes inside the box will conduct a heat exchange between the water in the box and the air inside of the pipes. This rig of pipes should be optimized to have the largest surface area per volume. At exit points, the pipes should be airtight, sealed with silicon perhaps.

Sarah Dumont:

I. We could layer the inside of the box with a sheet of stainless steel because it does not rust, it is also a great heat conducting metal. It is also expensive so that is why I would only put a sheet instead of making the whole box from stainless steel. This metal absorbs heat from areas of high temperature and moves it toward areas of lower temperature.

3 Design Concepts

Concept 1:

<u>Electronics:</u>

- Sensor system to detect temperature in pipes

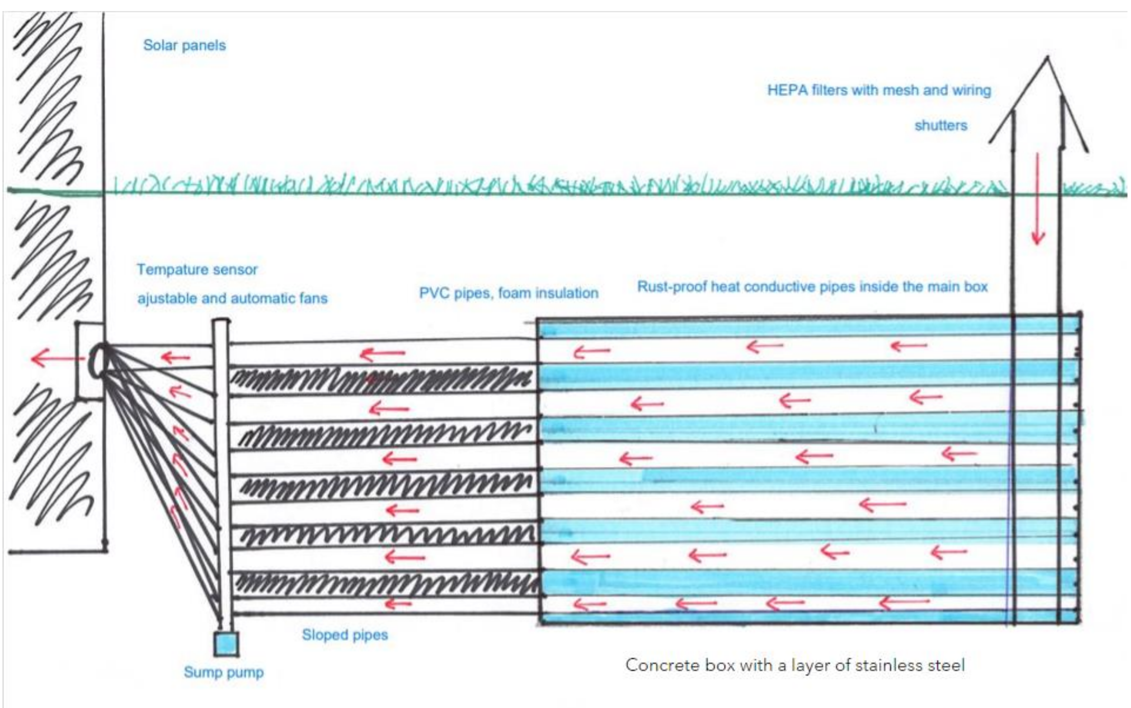
- Sensor system to detect leaks in pipes
- Open and close air intake pipe (shutters)
- Airflow system which uses fans automatically turns on
- Connect energy source (solar panels) to circuitry for fans and user interface panel

Power:
- Solar panels supply power to fan, user interface and all electronic systems.
- Store excess power in Lithium-Ion battery

Airflow and Pipes:
- PVC pipes, foam insulation
- Rust-proof heat conductive pipes inside main box unit to conduct heat
- Adjustable fans to direct airflow

Drainage and Filtering:
- Sloped pipes to collect stagnant water
- Sump pump to expel water
- HEPA filters with mesh/wiring to filter air and protect from insects and small animals

Main Box Unit:
- Concrete box with a layer of stainless steel



Concept 2:

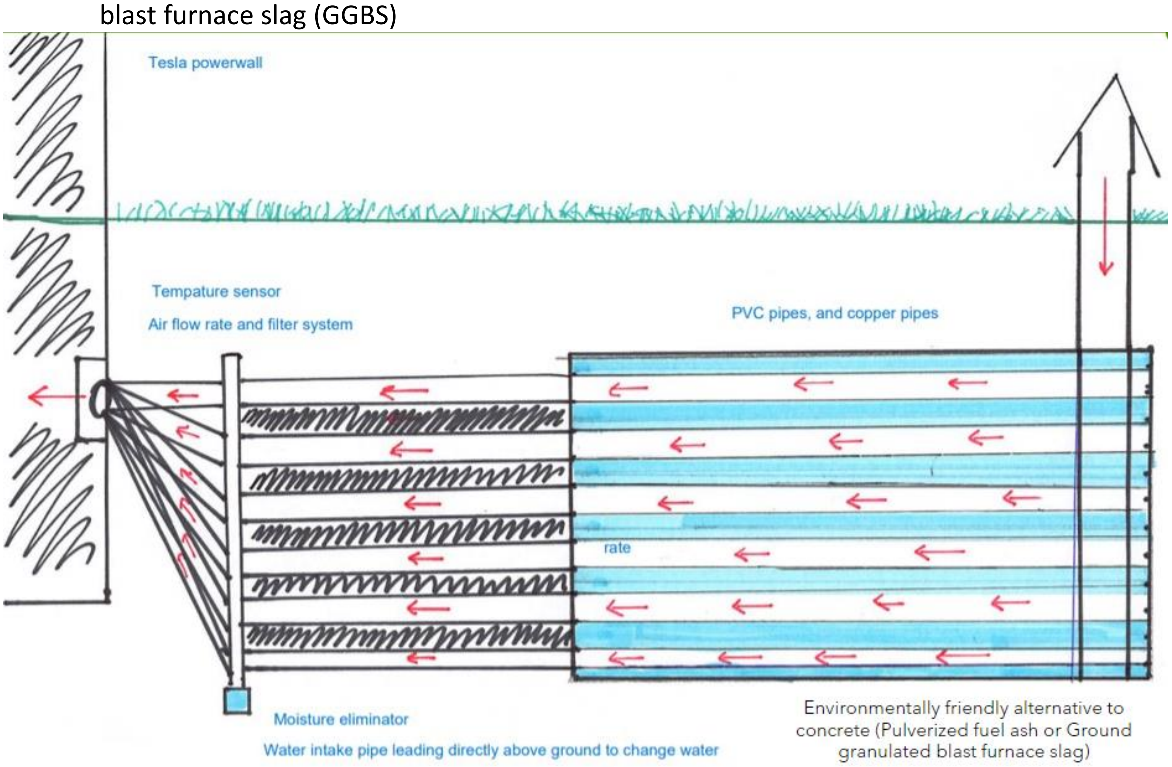
Electronics:
- Sensor system to detect air flow rate through the filter
- Sensor system to detect temperature changes

Power:
- Tesla Powerwall

Airflow and Pipes:
- PVC pipes and copper pipes

Drainage and Filtering:
- Moisture eliminator
- Water intake pipe leading directly above ground to change water

Main Box Unit:
- Environmentally friendly alternative to concrete: pulverized fuel ash (PFA) or ground granulated blast furnace slag (GGBS)



Concept 3:

Electronics:
- Sensor system to measure temperature

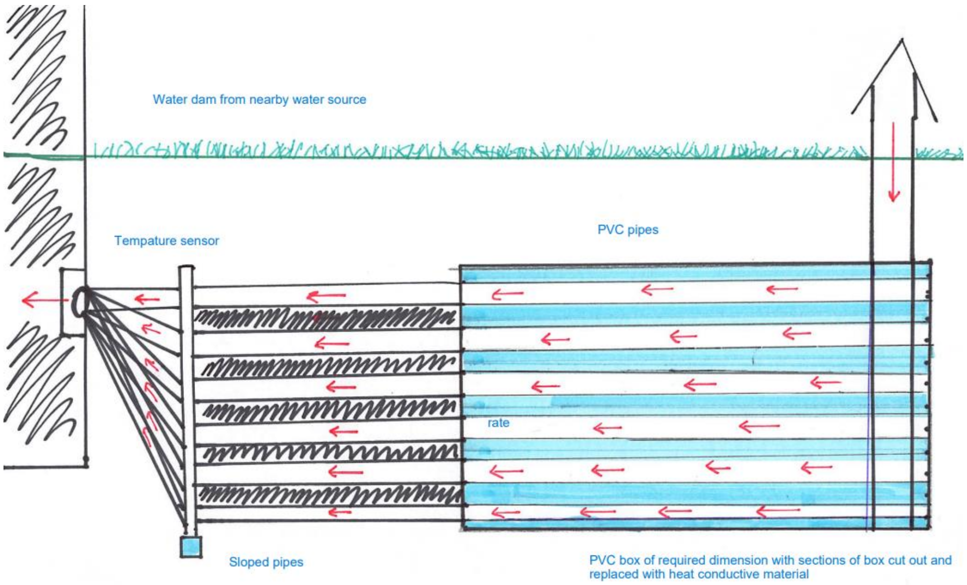
Power:
- Water dam from nearby water source

Airflow and Pipes:

- PVC pipes

<u>Drainage and Filtering:</u>
- Replaceable filter to filter air from insects and debris
- Sloped pipes to collect stagnant water

<u>Main Box Unit:</u>
- PVC box of required dimensions with sections of box cut out and replaced with heat conductive materials



4 Analysis and Evaluation of Concepts

	Specifications	Concept 1	Concept 2	Concept 3
	FUNCTIONAL			
1	Can reach desired temperature	The box material will facilitate heat transfer between the earth to the air within the pipes. The earth will either heat up or cool down the air by accepting or giving heat to the air within the pipes. Temperature sensors will make sure the air within the pipe will reach the desired temperature before being blown into the house.	The box material will facilitate heat transfer between the earth to the air within the pipes. The earth will either heat up or cool down the air by accepting or giving heat to the air within the pipes Temperature sensors will make sure the air within the pipe will reach the desired temperature before being blown into the house.	The box material will facilitate heat transfer between the earth to the air within the pipes. The earth will either heat up or cool down the air by accepting or giving heat to the air within the pipes Temperature sensors will make sure the air within the pipe will reach the desired temperature before being blown into the house.

2	Keep temperature steady	Electronic circuits and sensors that detect temperature change inside pipes Fan system will allow air to sit inside pipe to be warmed or cooled and once it reaches desired temperature, it will be blown into the building	Electronic sensor system that will detect airflow and temperature and will also regulate periodic fan blowing. Fans will blow periodically every 15 minutes (ample time to allow the air to cool or warm up to desired temperature)	The electronic circuitry will detect when the temperature within the pipe is correct. The box will be constructed in a symmetric fashion and all pipes contained within the box will have equal exposure.
3	Minimal maintenance	All systems are automated except for air filter cleaning.	Users will have to replace moisture eliminators periodically.	Users will have to clean air filters every month to ensure they do not become clogged or compromised
4	Durable materials	Concrete and PVC do not degrade or corrode so our product will be long-lived	The cement that we will use will be environmentally friendly recycled materials like fly ash or GGBS. This will ensure that our concrete is greener and more sustainable	Most of our prototypes will be built from PVC plastic, which is an exceptionally durable and long-lived material.
5	Cleaning/ filtering	Air that enters the system passes through an air filter at the air intake pipe and is once again filtered when leaving the system at the output pipe.	There will be filters at the air intake pipe and we will install sloped pipes within the system to ensure that the water that accumulates from condensation will be expelled and will not stagnate. Furthermore, there will be moisture eliminators installed throughout the pipes to prevent water condensation.	This prototype will utilize replaceable air filters that will prevent debris, insects, and water from entering the system. Our product will also have sloped pipes that will prevent water stagnation.
6	Insulation	The outtake and intake pipes will be placed inside larger pipes whose insides will be lined with insulative material	PVC pipes are excellent insulators. Their insulation can be further reinforced with foam.	PVC pipes are excellent insulators. Their insulation can be further reinforced with foam.
	NON-FUNCTIONAL			
14	Sustainable materials	Concrete is a sustainable material	Our sustainable concrete will keep all the properties of regular concrete, but	The box will be made from recycled PVC plastics. This makes for a greener and

			will be superior because its cement will be made from fly ash and ggbs	more sustainable solution for our prototype
15	Sustainable power	Will be using solar panels installed on roof of building	A tesla Powerwall will furnish more than enough electricity to the system all year round	Should the user have a water source like a river or a creek, we will install a small and affordable.
16	Noise	The sump pump could generate noise.	No noise	No noise

We decided on Concept 1 based on its feasibility and capability to reach all our specified design criteria. Firstly, Concept 1 features a sensor system to measure the temperature in the pipes, detect vulnerabilities in the pipes, and automatically monitor the fan, shutter, and solar power systems. This sensor system will ensure that the air in the pipes has stabilized to the appropriate temperature before entering the house and will also alter the fan's speed or run time based on how much heat the house will need to reach the desired temperature. This way, our system is not pumping in cold air, which would lower the house temperature and force the system to overcompensate. Ideally, our electronic system will be connected to a main user control panel that will allow the user to monitor conditions within the system.

Secondly, we will use solar panels to sustainably harvest power; excess power will be stored in a Lithium-Ion battery. Because Lithium-Ion batteries are rechargeable, they are a sustainable option. Although the recycling process of these batteries is not yet perfected, Lithium-Ion batteries are increasing popular in electronics and electric cars, and "scientists are confident that innovation and technological developments will find solutions as lithium batteries become more prevalent."

Thirdly, we will implement PVC pipes with foam insulation in our system. These pipes are cost-efficient, durable, and will not rust or develop bacteria from stagnant water buildup. However, because PVC pipes are insulative, we will need to put conductive pipes inside the box to better transfer heat from the ground to the air in the pipes, using a water medium.

Fourthly, to ensure cleanliness, our pipe network will be sloped to collect stagnant water from condensation, which will then be removed through a sump pump. All stabilized air leaving the system will go through a HEPA filter with fine mesh, protecting against insects and small animals.

Finally, our main box unit will be constructed from concrete, which is durable and able to withstand underground conditions for decades. To increase the heat conductivity inside the unit, the concrete will be lined with stainless steel, which is rust-proof and has a high heat capacity, absorbing heat from areas of high temperature and redirecting it to areas of lower temperature. Because the box would only be lined with stainless steel, not built entirely from it, the cost of the material would be significantly lower.

5 Conclusions and Recommendations

We firmly believe that concept 1 is our best-developed solution and is also the most realistically attainable. The electronic system will be very simple and efficient, and it will accomplish all the tasks that we initially needed it to do. It will measure temperature in the pipes, open and close the air intake shutter, enable and disable the fans, regulate the user interface, accept power from the solar panels and regulate energy storage. However, this means that our prototype will be heavily reliant on circuitry and coding which will require many hours of troubleshooting and testing. Additionally, we must pay a large amount of money for the solar cells, the diversity of materials, the sump pump, and the lithium-Ion battery. We felt that the added sustainability of the solar power was worth the additional cost as the environmental impact of the system was a high priority need for us in our design. The sump pump also seemed vital as a step to keep the water clean and avoid introducing hazardous mold into the home.

In short, we believe that our first global solution is our strongest and most realistically achievable concept for a prototype due to its efficiency, the type of materials used to build it and because it fulfilled all specifications and user needs specified in deliverable C and B. However, it is not unlikely that we might alter the final prototype if we find that other ideas or concepts within this document are better suited for our product. We might also change our project if we find that certain subsystems or ideas are superior to the current ones. One such problem that we may face in the very near future is the scarcity of solar panels that are integral to our prototype. There are very few that we know of, and they may not provide enough energy to power our solution, let alone store electricity for later use. Furthermore, we may also find that the concrete is not environmentally friendly enough and we may opt for another solution.

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