



GNG1103 [D1.1]  
**Design Project User and Product Manual**

**THE PELICANS: THERMAL HEAT EXCHANGE CHAMBER  
FINAL PROTOTYPE**

Submitted by:

D1.1: THE PELICANS

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# List of Acronyms and Glossary

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**Table 1. Acronyms**

<b>Acronym</b>	<b>Definition</b>
THEC	Thermal Heat Exchange Chamber
HEPA	High efficiency particulate air (filter)

**Table 2. Glossary**

<b>Term</b>	<b>Acronym</b>	<b>Definition</b>
High efficiency particulate air (filter)	HEPA	HEPA is an efficiency standard for air filters, and describes the type of air filter used in this design

# **1 Introduction**

This User and Product Manual (UPM) provides the information necessary for users and other designers to effectively use the Thermal Heat Exchange Chamber and for prototype documentation. The following details assume that the reader is familiar with the basics of harnessing geothermal energy, but provides all necessary design and operation details. This guide explains set up, use, troubleshooting, and documentation of the design in a chronological manner, with enough detail for the reader to operate or duplicate the design.

## 2 Overview

This product was created to address the sizeable environmental impact of residential climate control. As of 2019, the electricity and oil and gas sectors contributed 8.4% and 26% of greenhouse gas emissions, respectively (I). Current temperature regulation systems, like air conditioners and furnaces, are costly, unsustainable, and require continual maintenance. We set out to design an alternative method of regulating temperature without the need for fossil fuel-sourced electricity, instead harnessing the earth's constant heat reservoir and utilizing renewable energy, resulting in zero emissions.

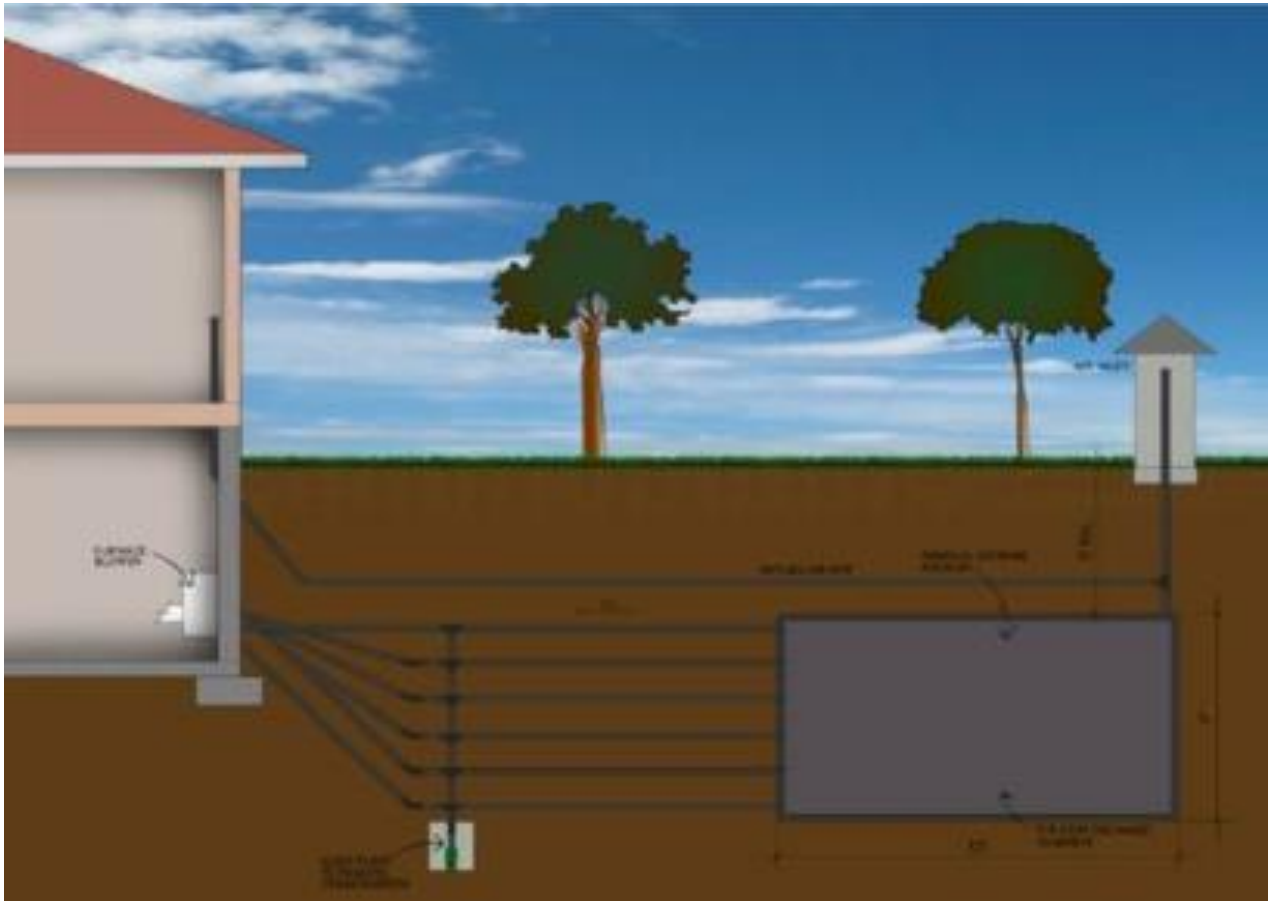


Figure 1: Our client's current THEC design

Given our client’s current design for a low-tech, sustainable, and adaptable thermal heat exchange chamber (see Figure 1), we analyzed and customized the model to be more practical and applicable to the average townhouse by scaling it down and improving its functionality.

To begin our design, we researched and interviewed users to generate a list of user needs. We identified the following needs: sustainable materials, sustainable power, cost efficiency, minimal maintenance, reliability. From these needs, we formulated a comprehensive problem statement to dictate the goal of the design.

**Problem Statement:** “Our client, on behalf of their customers, needs a low-tech, zero-emission, and inexpensive heat exchange chamber. The current GCHE needs to be modified to be more compact, have a sustainable power source, and be able to achieve higher temperatures in the winter, all in the scope of an average townhouse.”



**Figure 2: Final THEC prototype**



**Figure 3: Spiraling piping inside main box unit**

Physically, we sought to maximize heat transfer within our system while taking up minimal yard space. Our final prototype (see Figure 2) consists of a main housing unit, constructed from concrete, which houses a spiraling pipe network to maximize surface area (see Figure 3), and in turn maximize heat transfer. Extending from the pipe are two rigid PVC pipes; one leads from the air intake system to the box while the other travels from the box to the air outtake system. Notably, the final design includes the following key features:

- **Sensor system:** The sensors monitor the temperature in the system and in the house.

- **User interface:** The user interface provides the user with a refined and straightforward way to set an ideal temperature.
- **Maximized heat transfer:** The main housing unit is constructed out of concrete, which has a high thermal mass; inside, flexible vinyl pipes spiral to maximize heat transfer through surface area.
- **Quality air flow:** The systems features two fans, one at the inlet and one at the outlet, to maximize airflow. Additionally, a removable HEPA air filter is located at the inlet to prevent debris and small insects or animals from contaminating the air supply.
- **Sustainable energy:** The system is completely powered by renewable energy. The electronics system is connected to a solar panel to power the fans and temperature sensors. A lithium-ion battery is also connected to the electronics system to store excess energy, functioning as a power reserve.

The software system follows a simple series of steps to control the system. Figure 4 details how different user inputs prompt a specific action in the system, depending on current temperature conditions.

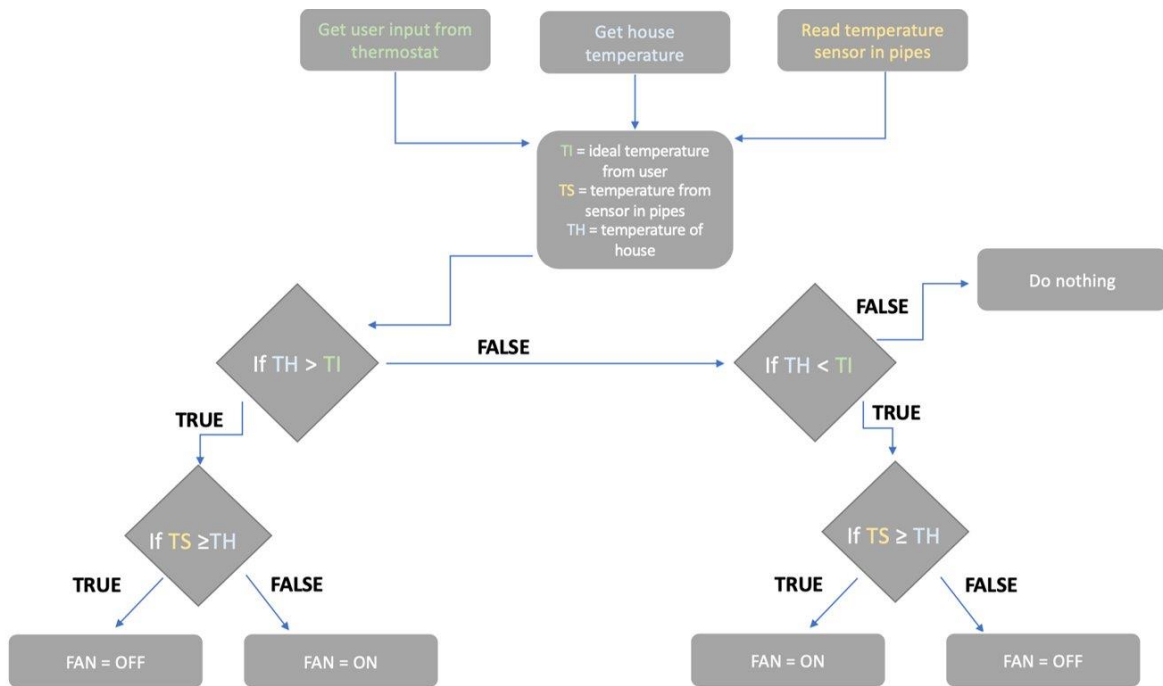


Figure 4: Software flowchart

## 2.1 Cautions & Warnings

It should be noted that the battery should be initialized with complete charge before putting the system into operation.

Additionally, this particular system is designed to be immersed in clay soil with a constant temperature range of 10°C to 16°C. Other soils with varying compositions are not guaranteed to provide the necessary conditions for heat exchange.



### **3 Getting started**

First, the user must attach a fully charged 1000 mAh lithium-ion battery to the solar circuit system. Then the user must plug in the solar panel circuitry into the user interface module (the Arduino uno) with the positive pin being inserted into VCC and the negative pin going into ground. Once the user interface turns on, the user must enter their desired temperature.

The second phase of setting up the system is to set up the air intake module. The sliding cover must be removed and stored in a safe place for future use.

#### **3.1 Configuration Considerations**

No tools or any sort of equipment are needed to properly configure this system once it has been completely assembled. It is very intuitive and low maintenance; it does not require any sort of special training to use. All the users must do is press and hold a button until a screen displays their desired temperature.

#### **3.2 User Access Considerations**

The users of this system are homeowners and those who live in the house. As such, the system may be used by an age range of approximately 20 to 80 years old. Our system is designed to be low-maintenance and low-tech to appeal to any age of user. The system can be completely controlled through the user interface panel located inside the household. Outside the house, the air intake pipe can be shut to create a closed loop through a manually sliding cover. Additionally, the air filter is located outside in the air intake unit and will have to be changed. Therefore, unless physically compromised, all users should be able to manage the system with minimal effort.

#### **3.3 Accessing/setting-up the System**

Turning on the system requires minimal effort. No login credentials are needed and the setup phase of the system (once the system is built), is relatively easy. Simply adjust the temperature with the two buttons

### 3.4 System Organization & Navigation

#### 3.4.1 Cement Housing Unit

The cement housing is 18” by 18” by 12” and made entirely from concrete and quick-dry cement. This unit contains a network of spiraling vinyl pipes, which are held in place by laser-cut acrylic stands. This concrete unit is constructed to be buried six feet underground and connects to both the air intake system and the pipe network through rigid PVC pipes (see Figure 5).

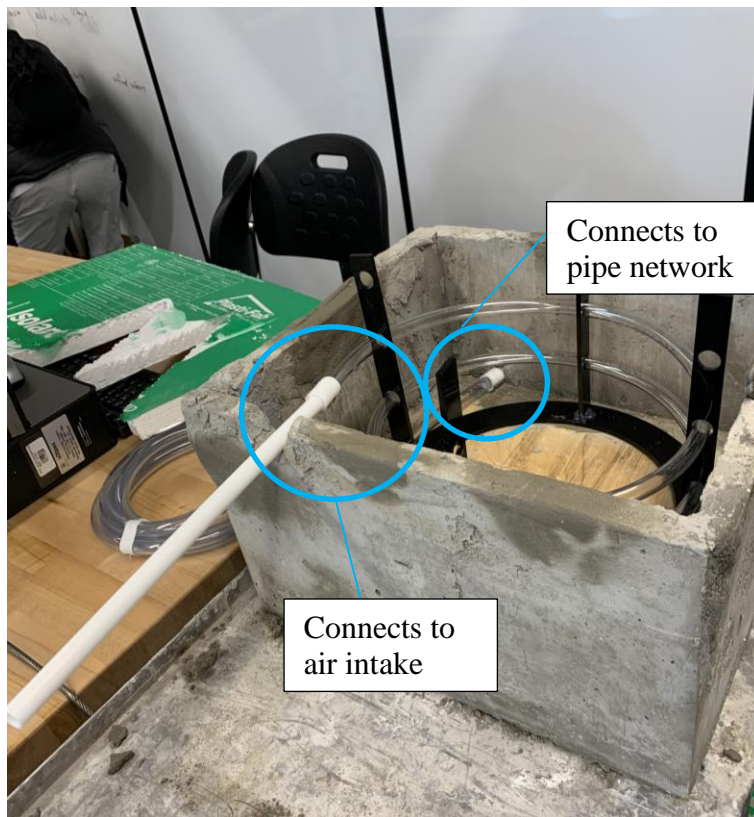


Figure 5: Concrete housing unit and pipe network

### 3.4.2 Pipe Network

The pipe network starts at the air intake system and ends at the air outlet. From the air intake system to the concrete housing unit, the piping is rigid PVC, which is an insulator, is cost-effective, and can withstand the pressures of the soil. Once the rigid piping enters the concrete unit (see Figure 5), the pipe medium changes to flexible vinyl. The flexibility of the vinyl allows the piping to spiral around the inside of the box, increasing surface area and thereby increasing heat transfer. Upon exiting the concrete unit, the piping once again becomes rigid PVC. This last section of piping travels from the concrete unit to the air outlet system, which channels the air into the house.

The inside of our box will be 16in x 16in, and our vinyl pipes will be spiraling around the center of the box with 2in of space on either side. So, each loop of piping will have a 12in diameter. Our current design involves 3 loops, so we calculated the required piping as follows:

$$\begin{aligned}L &= 3C \\ &= 3\pi d \\ &= 3\pi(12in) \\ &= 3\pi(1ft) \\ &= 9.42ft\end{aligned}$$

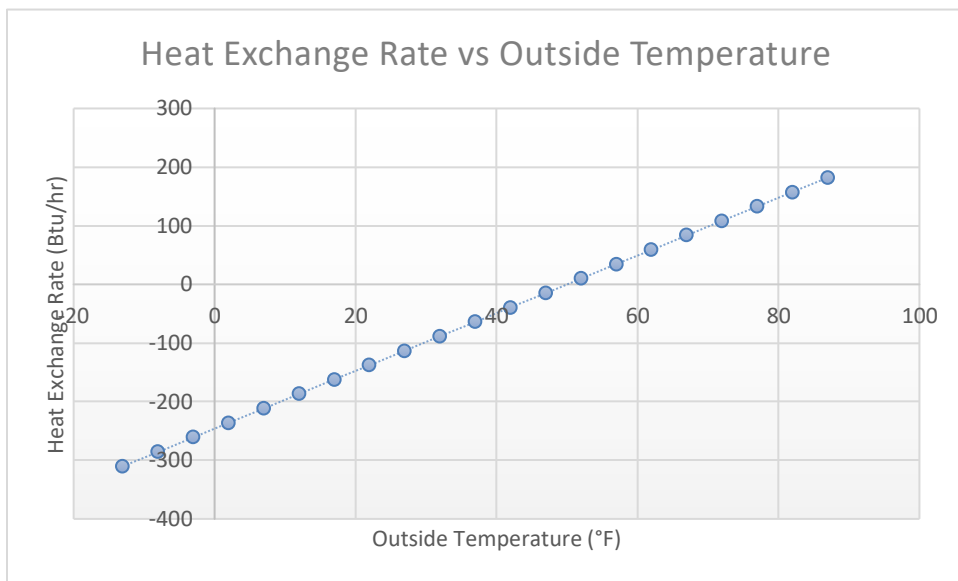
Using this length of piping, the heat exchange rate can be calculated using the formula:  $A = \frac{Q}{U\Delta T}$   
→  $Q = AU\Delta T$ . To begin, the surface area of the pipe must be calculated. Our pipes have a diameter of 0.5in, which is equivalent to 0.0416667ft.

$$\begin{aligned}SA &= 2\pi rh = \pi dh \\ SA &= \pi(0.0416667ft)(9.42ft) \\ SA &= 1.23 ft^2\end{aligned}$$

Now, using the previous formula with a temperature difference of 35°F and a heat transfer coefficient of 4 Btu/hr:

$$Q = AU\Delta T = (1.23ft^2) \left( 4 \frac{Btu}{hr} \right) (35^\circ F) = 172.2 \frac{Btu}{hr}$$

Therefore, the expected heat exchange rate of our system at a 35°F temperature difference is 172.2 Btu/hr. Of course, this value will change depending on the external temperature throughout the seasons. The following graph (see Figure 6) depicts the relationship between the outside temperature and the heat exchange rate of the system, making the ground temperature be constant.



**Figure 6: Heat exchange rate as a function of external temperature**

### 3.4.3 Air outlet and inlet

The air intake system is connected to the rest of the THEC through a rigid PVC pipe (see Figure 7). The system features a small housing unit, which holds the air filter, first fan, and a manually closing cover to seal the system in a closed loop. The sides of the housing unit are perforated to allow for air flow while still ensuring small animals are kept out. On the other hand, the air outlet system, pictured in Figure 8, features the second fan, and connects directly to the ventilation system of the user's house.



**Figure 7: Air intake system**



**Figure 8: Air outlet system**

### **3.4.4 Electronic system and Power**

As depicted in Figure 9, the two fans, lithium-ion battery, buttons, and solar panels are all connected to an Arduino Uno, the microcontroller of the system. The electronics system is completely powered by renewable energy; specifically, solar panels. These panels are connected to a lithium-ion battery, which acts as an energy reserve in the case of insufficient power. To justify the mAh of our system's battery, we performed the following calculations. These calculations assume that the longest period that our system will go without direct power from the solar panels is 12 hours. In these 12 hours, the temperature sensor would be running for the full 12 hours, while the 2 fans would only be running for 2 hours, and the sump pump would be running for 10 minutes. As evident from our calculations, our system would require a battery with a rating of approximately 900 mAh. A battery of this nature will certainly cut down on costs compared to

our current choice. Regarding our actual prototype, a 700 mAh battery has been tested and will suffice.

*Calculating current usage of our 3 electronics:*

Temp Sensor:

$$I=PV=0.000205 \text{ W} \quad 5.5 \text{ V}=3.727 \times 10^{-4} \text{ A} \quad I=PV=0.000205 \text{ W} \quad 5.5 \text{ V}=3.727 \times 10^{-4} \text{ A}$$

Fans (2):

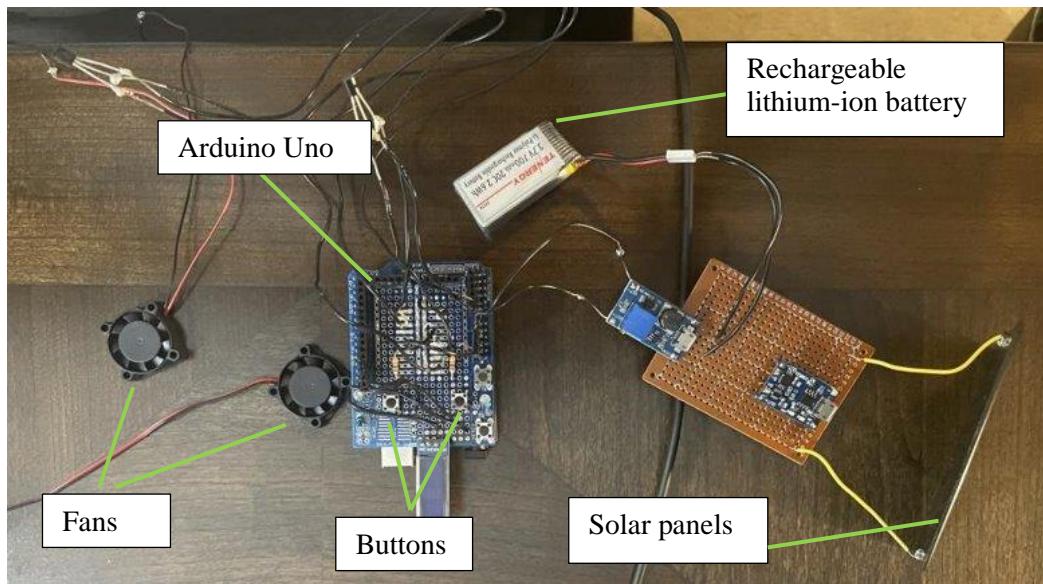
$$I=2PV=21.08 \text{ W} \quad 5 \text{ V}=0.432 \text{ A} \quad I=2PV=21.08 \text{ W} \quad 5 \text{ V}=0.432 \text{ A}$$

Sump pump:

$$I=PV=0.51 \text{ W} \quad 6 \text{ V}=0.085 \text{ A} \quad I=PV=0.51 \text{ W} \quad 6 \text{ V}=0.085 \text{ A}$$

$$mAh=1000[(3.727 \times 10^{-4} \text{ A})(12 \text{ hrs})+(0.432 \text{ A})(2 \text{ hrs})+(0.085 \text{ A})(0.167 \text{ hrs})]=882.6674 \text{ mAh}$$

These calculations assume that the longest period that our system will go without direct power from the solar panels is 12 hours. In this 12 hour period, the temperature sensor would be running for the full 12 hours, while the 2 fans would only be running for 2 hours, and the sump pump would be running for 10 minutes. As evident from our calculations, our system would require a battery with a rating of approximately 900 mAh.



**Figure 8: Electronics configuration**

**Arduino code:**

```
#include <Arduino.h>
#include <U8g2lib.h>
#include <SPI.h>
#include <Wire.h>
//Variables and declarations:
U8G2_SSD1306_128X32_UNIVISION_F_HW_I2C u8g2(U8G2_R0);
float temp = 20; //Ideal and initial temperature in celsius using this for button input
//-----
const int button1 = 10;
const int button2 = 9;
int butstat1 = 0;
int butstat2 = 0;
//-----
const int outf = 8;
const int infan = 7;
//-----
int thermostat = 0;

int temperaturesensor=1;
//-----

void setup(void)
{
  Serial.begin(9600);
  u8g2.begin();

  pinMode(button1, INPUT);
```



```

pinMode(button2, INPUT);

pinMode(outfan, OUTPUT);
pinMode(infan, OUTPUT);
}

void loop()
{

butstat1 = digitalRead(button1);
butstat2 = digitalRead(button2);

if (butstat1 == HIGH)
{
delay(200);
temp = temp + 1;
Serial.println(temp);
String temp1= String(temp);
//display Temperature on OLED
u8g2.clearBuffer();
u8g2.setFont(u8g2_font_ncenB08_tr);
u8g2.drawStr(0, 10, temp1.c_str());
u8g2.sendBuffer();
}
else if (butstat2 == HIGH)
{
delay(200);
temp = temp - 1;
Serial.println(temp);
String temp2 = String(temp);
//display temperature on OLED
u8g2.clearBuffer();
u8g2.setFont(u8g2_font_ncenB08_tr);
u8g2.drawStr(0, 10, temp2.c_str());
u8g2.sendBuffer();
}
else if (butstat1 == LOW)
{
temp = temp;
}
else if (butstat2 == LOW)
{
temp = temp;
}

// read thermostat in celcius
int readthermostat = analogRead(thermostat);
float vTH = readthermostat * 4.68;
vTH /= 1024;
float thermostatcelsius = (vTH - 0.5) * 100;

//read pipe temperature in celsius
int readtemperaturesensor = analogRead(temperaturesensor);

```

```

float vTS = readtemperaturesensor * 4.68;
vTS /= 1024;
float temperaturesensorcelsius = (vTS - 0.5) * 100;

// if thermostat > temp and pipe air > temp -> fan off:
if ((thermostatcelsius > temp) && (temperaturesensorcelsius > temp))
{
    digitalWrite(outfan, LOW);
    digitalWrite(infan, LOW);

    Serial.println("--case1");
    Serial.println(temperaturesensorcelsius);
    Serial.println(thermostatcelsius);
    delay(1000);
}

// if thermostat > temp and pipe air < temp -> fan on:
else if ((thermostatcelsius > temp) && (temperaturesensorcelsius < temp))
{
    digitalWrite(outfan, HIGH);
    digitalWrite(infan, HIGH);

    Serial.println("--case2");
    Serial.println(temperaturesensorcelsius);
    Serial.println(thermostatcelsius);
    delay(1000);
}

// if thermostat < temp and pipe air > temp -> fan on:
else if ((thermostatcelsius < temp) && (temperaturesensorcelsius > temp))
{
    digitalWrite(outfan, HIGH);
    digitalWrite(infan, HIGH);

    Serial.println("--case3");
    Serial.println(temperaturesensorcelsius);
    Serial.println(thermostatcelsius);
    delay(1000);
}

// if thermostat < temp and pipe air < temp -> fan off:
else if ((thermostatcelsius < temp) && (temperaturesensorcelsius < temp))
{
    digitalWrite(outfan, LOW);
    digitalWrite(infan, LOW);

    Serial.println("--case4");
    Serial.println(temperaturesensorcelsius);
    Serial.println(thermostatcelsius);
    delay(1000);
}

```

```
//code for sumppump timer-----  
digitalWrite(sumppump, HIGH);  
delay(300000); // Wait for 5 minutes  
digitalWrite(sumppump, LOW);  
delay(262800000); // Wait for 1 entire month  
//code for sumpump timer-----  
}
```

### **3.5 Exiting the System**

As mentioned previously, the system is very hands-off and thus low maintenance. Much like an air conditioning system, the system never really turns off, it only has two modes: being interacted by a user and idling. The system will always turn on. To stop using the system, the user must simply cease interaction and ensure that the system is set to their preferred temperature in degrees centigrade.

## **4 Using the System**

### **4.1 Adjusting the temperature**

This feature of the system is the feature that the user will be using the most, if not all the time with this system. To adjust the temperature, our system sports the previously mentioned user interface system (this is a part of the electronic system). To utilize this, all the users must do to set their desired temperature is to increase or decrease the number displayed on the OLED screen by pressing one of the two buttons on the Proto shield. Apart from the troubleshooting that may be required for this feature, no other interactions are needed to properly use it.

## **4.2 Replacing the Air filter**

The second feature that the users will need to know how to manipulate and operate will be the air filter located inside of the air inlet. We recommend that users change this Hepa filter once every 4 months, to ensure that the air being blown into the house is clean and safe to breath. This filter prevents unwanted debris and bacteria from entering the system and causing system failure, so it is vital that the users know how to operate it (if it were to be used in real life). To replace the filter, simply remove the old filter that was placed inside the air inlet on top of the fan by removing it with the filter holding tray that is inside the air inlet. Afterwards, insert a new unused Hepa filter into the tray and reinsert it into the air inlet.

### **4.2.1 Air filter tray**

This feature also contains a very important tool that enables the user to easily replace the air filter for this system: a tray that holds the air filter. This tray can be pulled out from the inside of the system and slipped back in once the filter has been changed thanks to its handle.

## **5 Troubleshooting & Support**

### **5.1 Error Messages or Behaviors**

The following errors could potentially arise when operating the system. Firstly, the HEPA air filter may be compromised by external damage, whether that be weather or wild animals. In either case, the air filter must be replaced in order to maintain a safe air supply. If wild animals continue to damage the filter, additional mesh may be attached to keep them out.

Secondly, the electronics system may malfunction. Check to ensure that all wires are properly connected, and the system is not overheating. Next, ensure that no moisture is present around or on the electronics. If the electronic system is wet, immediately disconnect the power. Remove the majority of the liquid with a lint-free cloth, and afterward, go over the circuit board with a cotton swab dipped in isopropyl alcohol to remove any remaining moisture (II). Ensure that the system is completely dry before reconnecting power.

Thirdly, if the solar panels seem to be nonfunctional, first ensure that the connections to the Arduino circuit board are intact. Next, look for an obstruction on or above the panels that may be preventing sunlight from hitting the panels. As a last resort, examine the power inverted to confirm it is effectively converting DC to AC.

Fourthly, the pipe network may experience leaks or cracks. If this is the case, it is imperative to fill any cracks to maintain a clean air supply. To reconnect any pipes, apply PVC cement and let set. If cracks are present within a segment of pipe, that segment should be replaced.

## **5.2 Special Considerations**

Should the temperature begin increasing on the OLED display randomly without user input, the user should unplug the Arduino uno from the solar circuitry and then reconnect it. Should the issue persist, the user should remove the Proto shield from the Arduino uno. If this does not fix the issue, the user should then always place the Arduino uno on a piece of non-conductive material like thick rubber or plastic and then try the steps again.

## **5.3 Maintenance**

As mentioned previously above, this system does not require much maintenance to avoid failure. It is designed to be capable of performing its duties over an extended period, for a long time. That being said, a few problems could foreseeably arise due to the prototype using inferior quality cables and wires. Overextending, bending, or tightening the cables makes them weaker and weaker and eventually they snap. Therefore, basic knowledge of soldering wires together will be required to fix some issues.

If we are to consider a real-life version of this prototype, knowledge of section 4.2 will also be required to maintain system integrity. We cannot forget that users will need to replace the air filter enclosed in this system at regular intervals, to avoid unclean air being blown into the building.

## 5.4 Support

Should the user ever require assistance, they may use the following contact information. Anyone in the following list will be able to answer all questions regarding any issues they may encounter while using this system, however, it is important to note that some members of this team have more experience in certain subsystems of this prototype, so their specialty is included beside their name. It is recommended that the user contact a member of this group with more experience related to their problem. Ex: If user John has an issue with the code (user interface not responding, fans not turning on), they should first contact Jan or Kirstyn.

- Jan Czajkowski (Electronics, Code, Soldering): **jczej018@uottawa.ca**
- Kirstyn Aranyosi (Code, Heat exchange chamber): **karan093@uottawa.ca**
- Oscar Fillmore (Pipes, Heat exchange chamber): **ofill090@uottawa.ca**
- Sarah Dumont (Air inlet, 3D printing, Laser cutting): **sdumo090@uottawa.ca**
- Evan Kerr (Heat exchange chamber, General Repairs, Molds): **ekerr052@uottawa.ca**

## 6 Product Documentation

### 6.1 Electronics and Code

#### 6.1.1 BOM (Bill of Materials)

Should the user

Item name	Recommended Model	Quantity	Price	Hyperlink
Arduino Uno	Arduino Uno	1	10\$	<a href="https://3dprintingcanada.com/products/arduino-uno-r3-with-usb-cable?variant=14108869001259&amp;ab_version=A&amp;gclid=Cj0KCQjw3v6SBhCsARIsACyrRAnitByv5kTtyR8zrsgOXkfZiy6o13MS8vCOTXNJi5h3vfKBvYsYCs4aAowhEALw_wcB">https://3dprintingcanada.com/products/arduino-uno-r3-with-usb-cable?variant=14108869001259&amp;ab_version=A&amp;gclid=Cj0KCQjw3v6SBhCsARIsACyrRAnitByv5kTtyR8zrsgOXkfZiy6o13MS8vCOTXNJi5h3vfKBvYsYCs4aAowhEALw_wcB</a>
Arduino Uno Proto shield	Arduino uno Proto shield	1		<a href="https://www.banggood.com/328-ProtoShield-Prototype-Expansion-Board-Geekcreit-for-Arduino-products-that-work-with-official-Arduino-boards-p-926451.html?utm_source=googleshopping&amp;utm_medium=cpc_organic&amp;gmcCountry=CA&amp;utm_content=minha&amp;utm_campaign=minha-ca-en-pc&amp;currency=CAD&amp;cur_warehouse=CN&amp;createTmp=1&amp;utm_source=googleshopping&amp;utm_medium=cpc_us&amp;utm_content=nolan&amp;utm_campaign=aceng-pmax-ca-roas-20220402&amp;ad_id=&amp;gclid=Cj0KCQjw3v6SBhCsARIsACyrRAmwnLfyiUJo-nKXyaP9LduyrmwLpQNttQo6Qyt8a2lbcCP9eYPziSUaAivlEALw_wcB">https://www.banggood.com/328-ProtoShield-Prototype-Expansion-Board-Geekcreit-for-Arduino-products-that-work-with-official-Arduino-boards-p-926451.html?utm_source=googleshopping&amp;utm_medium=cpc_organic&amp;gmcCountry=CA&amp;utm_content=minha&amp;utm_campaign=minha-ca-en-pc&amp;currency=CAD&amp;cur_warehouse=CN&amp;createTmp=1&amp;utm_source=googleshopping&amp;utm_medium=cpc_us&amp;utm_content=nolan&amp;utm_campaign=aceng-pmax-ca-roas-20220402&amp;ad_id=&amp;gclid=Cj0KCQjw3v6SBhCsARIsACyrRAmwnLfyiUJo-nKXyaP9LduyrmwLpQNttQo6Qyt8a2lbcCP9eYPziSUaAivlEALw_wcB</a>

Electrical cables	Electrical cables of 0.4mm diameter	~25 feet (cumulative)	5\$	<a href="https://makerstore.ca/shop/ols/products/5ft-hook-up-wire-22awg-black">https://makerstore.ca/shop/ols/products/5ft-hook-up-wire-22awg-black</a>
Sump pump	Vipe mini Sump pump	1	9.4\$	<a href="https://www.amazon.com/Vipe-Micro-Submersible-Motor-Water/dp/B01N0X3CW4/ref=sr_1_101?keywords=mini+sump+pump&amp;qid=1644973260&amp;sr=8-101">https://www.amazon.com/Vipe-Micro-Submersible-Motor-Water/dp/B01N0X3CW4/ref=sr_1_101?keywords=mini+sump+pump&amp;qid=1644973260&amp;sr=8-101</a>
Solar panels	CANADUINO 5V	1	3.73\$	<a href="https://www.amazon.ca/CANADUINO-Solar-Panel-100mA-500mW/dp/B07GD96FKZ/ref=sr_1_52?crid=1TCZUXEYEE16H&amp;keywords=solar+panel&amp;qid=1644975609&amp;refinements=p_36%3A12035760011&amp;rnid=12035759011&amp;s=lawn-garden&amp;srefix=solar+panel%2Caps%2C82&amp;sr=1-52">https://www.amazon.ca/CANADUINO-Solar-Panel-100mA-500mW/dp/B07GD96FKZ/ref=sr_1_52?crid=1TCZUXEYEE16H&amp;keywords=solar+panel&amp;qid=1644975609&amp;refinements=p_36%3A12035760011&amp;rnid=12035759011&amp;s=lawn-garden&amp;srefix=solar+panel%2Caps%2C82&amp;sr=1-52</a>
Printed circuit board	AUSTOR PCB boards	1	0.6\$	<a href="https://www.amazon.ca/gp/product/B074X2GDH2/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&amp;psc=1">https://www.amazon.ca/gp/product/B074X2GDH2/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&amp;psc=1</a>
OLED Display	Baqi 091" OLED display	1	5.33\$	<a href="https://edu-makerlab.odoo.com/shop/product/oled-display-139?search=display#attr=247">https://edu-makerlab.odoo.com/shop/product/oled-display-139?search=display#attr=247</a>
Lithium-Ion batteries	3.7V 700 mAh TENERGY	1	2.67\$	<a href="https://liionwholesale.com/collections/batteries/products/dmegc-inr18650-26e-18650-15a-flat-top-2600mah?variant=39353214468165">https://liionwholesale.com/collections/batteries/products/dmegc-inr18650-26e-18650-15a-flat-top-2600mah?variant=39353214468165</a>
Button	6mm x 6mm digital button	2	0.1\$	<a href="https://edu-makerlab.odoo.com/shop/product/tactile-button-37?search=button">https://edu-makerlab.odoo.com/shop/product/tactile-button-37?search=button</a>
Voltage booster	Eiechip 5V step-up booster	1	1.8\$	<a href="https://www.amazon.ca/gp/product/B07RNBJK5F/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&amp;psc=1">https://www.amazon.ca/gp/product/B07RNBJK5F/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&amp;psc=1</a>
Battery charger	TP4056-Lithium battery charger	1	2.4\$	<a href="https://www.amazon.ca/gp/product/B06XNXHY6W/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&amp;th=1">https://www.amazon.ca/gp/product/B06XNXHY6W/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&amp;th=1</a>



U8G2 Arduino library	U8G2 library by Oliver	N/A	N/A	<a href="https://www.instructables.com/Tutorial-to-Interface-OLED-091inch-128x32-With-Ard/">https://www.instructables.com/Tutorial-to-Interface-OLED-091inch-128x32-With-Ard/</a>
Arduino IDE	The Arduino IDE	N/A	N/A	<a href="https://www.arduino.cc/en/software/">https://www.arduino.cc/en/software/</a>
Arduino Libraries	Arduino libraries	N/A	N/A	<a href="https://www.arduino.cc/en/software/">https://www.arduino.cc/en/software/</a>
Tinker Cad	Tinker CAD	N/A	N/A	<a href="https://www.tinkercad.com/">https://www.tinkercad.com/</a>
Temperature sensor	TMP36GT9Z	2	4.94\$	<a href="https://www.robotshop.com/ca/en/temperature-sensor-tmp36.html?gclid=Cj0KCQjw5-WRBhCKARIsAAId9FINABix4_h7_b3Esro7b1nftx-U7HYK0Wp4e6kg95R-kRSEIrhIN5MaAk1_EALw_wcB">https://www.robotshop.com/ca/en/temperature-sensor-tmp36.html?gclid=Cj0KCQjw5-WRBhCKARIsAAId9FINABix4_h7_b3Esro7b1nftx-U7HYK0Wp4e6kg95R-kRSEIrhIN5MaAk1_EALw_wcB</a>
Electric fans	GDSTIME small fan	2	10.3\$	<a href="https://www.amazon.ca/Gdstime-25mm-7mm-Brushless-Cooling/dp/B078KBTTY5/ref=sr_1_6?gclid=CjwKCAiAvaGRBhBlEiwAiY-yMG0NgfQS1muLxmEr_WuHuCuRFHdMD6lchPAnQpyxZlpXpYAMuNjIBRoCfYkQAvD_BwE&amp;hvadid=353568130271&amp;hvdev=c&amp;hvlocphy=9000660&amp;hvnetw=g&amp;hvqmt=b&amp;hvrnd=18322015581709022926&amp;hvtargid=kwd-297818438556&amp;hydadcr=24665_9784586&amp;keywords=small+electronic+fan&amp;qid=1646877878&amp;refinements=p_36%3A12035760011&amp;rnid=12035759011&amp;s=electronics&amp;sr=1-6">https://www.amazon.ca/Gdstime-25mm-7mm-Brushless-Cooling/dp/B078KBTTY5/ref=sr_1_6?gclid=CjwKCAiAvaGRBhBlEiwAiY-yMG0NgfQS1muLxmEr_WuHuCuRFHdMD6lchPAnQpyxZlpXpYAMuNjIBRoCfYkQAvD_BwE&amp;hvadid=353568130271&amp;hvdev=c&amp;hvlocphy=9000660&amp;hvnetw=g&amp;hvqmt=b&amp;hvrnd=18322015581709022926&amp;hvtargid=kwd-297818438556&amp;hydadcr=24665_9784586&amp;keywords=small+electronic+fan&amp;qid=1646877878&amp;refinements=p_36%3A12035760011&amp;rnid=12035759011&amp;s=electronics&amp;sr=1-6</a>
Solder	Rosin Core solder	Variable	N/A	<a href="https://www.canadiantire.ca/en/pdf/aim-electrisol-60-40-rosin-core-solder-113-g-0586204p.0586204.html?gclid=Cj0KCQjw3v6SBhCsARIsACyrRAMYW3Ix_T3ICjHQWkoYLvX4S">https://www.canadiantire.ca/en/pdf/aim-electrisol-60-40-rosin-core-solder-113-g-0586204p.0586204.html?gclid=Cj0KCQjw3v6SBhCsARIsACyrRAMYW3Ix_T3ICjHQWkoYLvX4S</a>

				hOIrHRs3pCyZPiey0VJ_wCMaM - L6bUaApnTEALw_wcB&gclsrc=aw.ds#store=422
Resistor		2	0.1\$	<a href="https://www.digikey.ca/en/products/detail/stackpole-electronics-inc/CF14JT220R/1830334?utm_adgroup=General&amp;utm_source=google&amp;utm_medium=cpc&amp;utm_campaign=Smart%20Shopping_Product_Zombie%20SKUS&amp;utm_term=&amp;productid=1830334&amp;gclid=Cj0KCQjw3v6SBhCsARIsACyrRAn-CL5Nnrg7T1Kjch6DCNhm3Cqs9DDGrc7K-GhA3vOkPreuXB1qwJgaApBDEALw_wcB">https://www.digikey.ca/en/products/detail/stackpole-electronics-inc/CF14JT220R/1830334?utm_adgroup=General&amp;utm_source=google&amp;utm_medium=cpc&amp;utm_campaign=Smart%20Shopping_Product_Zombie%20SKUS&amp;utm_term=&amp;productid=1830334&amp;gclid=Cj0KCQjw3v6SBhCsARIsACyrRAn-CL5Nnrg7T1Kjch6DCNhm3Cqs9DDGrc7K-GhA3vOkPreuXB1qwJgaApBDEALw_wcB</a>

### 6.1.2 Equipment list

To build this subsystem, the user needs the following pieces of equipment:

- Soldering kit (soldering iron, iron holder, brass sponge)
- Large, ventilated space OR Ventilation machine
- Light source
- Computer
- Internet
- Arduino cable (usb 3 to usb B)
- Voltmeter (DIGIFLEX)
- Scissors
- Helping hand stand
- Wire stripper

### 6.1.3 Instructions

The electrical subsystem may be the most time-consuming subsystem needed to be built in this prototype. The user may begin by uploading the Arduino code file found in Appendix I to the Arduino Uno module. This is done by connecting the Arduino to your computer with the

connection cable. To do this the user must follow these steps:

1. Install the Arduino IDE
2. Install the U8G2 library
3. Download the .ino file found in Appendix I of this document
4. Open the code file in the Arduino IDE (simply double click on the file)
5. Connect the Arduino Uno to your computer
6. Verify that the proper port is selected for upload and is also recognized by the IDE
7. Add the U8G2 library to the code file
8. Upload the code to the Arduino Uno

Prior to creating the circuit, one should view/read the following resources on soldering to avoid mistakes or destruction to electrical components: [Soldering Tutorial for Beginners: Five Easy Steps](#)



<https://www.makerspaces.com/how-to-solder/>

## **PART 1: BATTERY CHARGER**

Heat up the soldering iron and turn on your lights. Take the electrical wiring and strip away around 2-3 cm of wire insulation. Cut off this exposed piece of wire. Next, take the TP4056 (battery charger) and place it in one pincer of the helping hand stand. In the other pincer, place the piece of cut wire. Carefully insert this piece of wire into the hole labeled with a “+” with a small piece of this wire sticking out from the top of this hole.

Once stable tin soldering iron, apply solder to area (don't let it spill over to other holes) and let cool. Repeat this process with “-”, “B+”, “B-”, “Out +”, “Out -” on TP4056 and holes “VIN +”, “VIN -”, “OUT+”, “Out-”.

Next, for the solar panel, cut 10 cm wire. Strip 1 cm off the ends of the wire , solder one end to positive cathode on the solar panel (don't solder the other end to anything). Repeat for negative cathode.

Take the Printed circuit board and insert the ends of the solar panel wires on one end of the board on opposite side of this end. Solder it. You should use a helping hand to make it easier.

Take the TP4056 and place it on the circuit board with the “+” and “-” holes facing the same end as the solar panel. When placing the “pins” of the TP4056 (the pieces of wire you've soldered into the component), leave at least 1 hole of space between them but aim for 2 as this will make the process easier. Solder it to the board. Use the helping hand.

Place the Voltage booster in the PCB. Make sure the VIN+ and VIN- pins are aligned with the OUT+ and OUT- pins of the TP4056 respectively. Don't put them too closely together. Leave 10

holes of space or so between the two components. Again, don't place the voltage booster's pins too closely together, leave at least 1 hole of space. Solder it to the board.

Connections: Using pieces of completely stripped wire and solder, make the following connections:

TP4056 and Solar Panel:

- Positive cathode and "+"
- Negative cathode and "-"

TP4056 and Battery:

- B+ to 10 cm long wire
- B- to 10 cm long wire

TP4056 and Voltage Booster

- OUT+ to VIN+
- OUT- to VIN-

Voltage Booster to arduino: don't plug it in yet

- OUT+ to VCC (use 20 cm long wire)
- OUT - to GND (use 20 cm long wire)

## **PART 2: User Interface**

Take the Protoboard and place the OLED display at the very edge of the protoboard (same end as the reset button on the Arduino Uno). Carefully solder all pins firmly into the board; make sure you don't make any solder bridges between the pins as this can create a short circuit.

Make the following connections:

- SDA to 10 cm wire
- SCL to 10 cm wire
- GND to GND strip on proto shield
- VCC to 5V strip on proto shield

Insert the stripped ends of the connected wire to SDA and SCL underneath the protoboard on the actual Arduino Uno. To do this, bend the wire around the edge of the protoboard and leave enough exposed wire underneath so that when you place the Proto shield on top of the Uno, it will snap right into the right holes.

Next, place the buttons on your Arduino board. Be sure to place far enough from each other, as cramping can be an issue on proto shields. It is recommended to place one button on the right side of the board and the other button on the left side of the board. Solder the buttons onto the board. After, place the resistors on the side of the board with the most space beneath the button. Be sure to align it with either one of the soldered button pins and then solder the resistor to the proto shield, cutting off any excess piece of wire or solder.

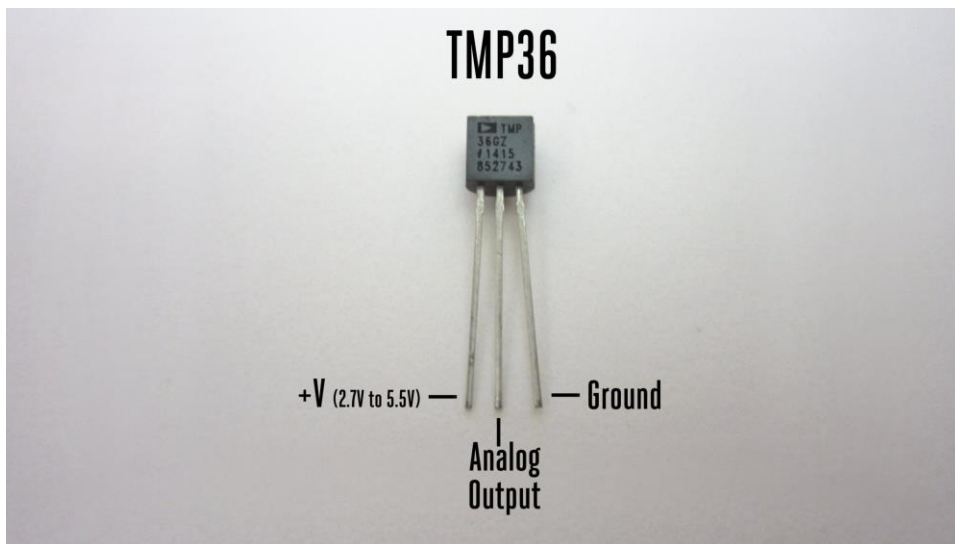
Make the following connections using solder and small pieces of stripped wire:

- Resistors to aligned button pins
- Button pin directly adjacent to button pin connected to resistor should be connected to the 5v strip on the proto shield
- Second end of the resistor to the ground strip
- Button pin opposite of the button resistor pin connected to a 10 cm long wire

Insert the stripped ends of the connected button wires to input pins 13 and 12.

## **PART 3: Fans and Temperature sensors**

Take two 10 cm long pieces of wire and strip the ends. Solder one piece onto the 5v line/strip on the proto shield and the other on the Ground. Next take one of the temperature sensor and solder the two pieces of wire to their corresponding pins on the TMP36 (see diagram below). Take a third piece of 10 cm long wire with stripped ends and solder it to the middle pin and insert the end of this wire into the A0 input on the proto shield. Repeat this process but with 25 cm long pieces of wire for the second Temperature sensor and insert it's middle wire into the A1 input slot.



Finally, take two pieces of 20 cm long wire, strip the ends and connect one to input slot 11 and the other to the Ground strip on the proto shield. Solder the wire connected to the input slot to the red wire on the fan. Solder the wire soldered to the ground strip to the black wire of the fan. Repeat this process but with 50 cm long wires and insert one into input slot 10.

## **6.2 Heat exchange chamber**

### **6.2.1 BOM (Bill of Materials)**

Item name	Recommended Model	Quantity	Price	Hyperlink
Cement	SAKRETE concrete mix 30kg	2 bags	10.8\$	<a href="https://www.homedepot.ca/product/sakrete-concrete-mix-30-kg/1000109060">https://www.homedepot.ca/product/sakrete-concrete-mix-30-kg/1000109060</a>

Plywood	Large pieces of scrap plywood	Variable	0	N/A
Carbon Fiber Netting	Carbon fiber netting for concrete	~896 square inches	0	N/A
Wood screws	Hillman deck screw brown #8X1-1/2	Variable	N/A	<a href="https://www.lowes.ca/product/deck-screws/hillman-deck-screw-brown-8x1-12-pack-of-100-2708791?cq_src=google_ads&amp;cq_cmp=11263039837&amp;cq_con=115866621492&amp;cq_term=&amp;cq_med=&amp;cq_plac=&amp;cq_net=u&amp;cq_pos=&amp;cq_plt=gp&amp;&amp;cm_mmc=paid_search--google--aw_smart_shopping_generic_hardware--71700000073600165&amp;gclid=Cj0KCQjw3v6SBhCsARIsACyrRAI0EXIYfFHMdxIK2_LGL2pUOfbjAtTpfabsB0yPzhsERX4YRawVEd4aAolGEALw_wcB&amp;gclsrc=aw.ds">https://www.lowes.ca/product/deck-screws/hillman-deck-screw-brown-8x1-12-pack-of-100-2708791?cq_src=google_ads&amp;cq_cmp=11263039837&amp;cq_con=115866621492&amp;cq_term=&amp;cq_med=&amp;cq_plac=&amp;cq_net=u&amp;cq_pos=&amp;cq_plt=gp&amp;&amp;cm_mmc=paid_search--google--aw_smart_shopping_generic_hardware--71700000073600165&amp;gclid=Cj0KCQjw3v6SBhCsARIsACyrRAI0EXIYfFHMdxIK2_LGL2pUOfbjAtTpfabsB0yPzhsERX4YRawVEd4aAolGEALw_wcB&amp;gclsrc=aw.ds</a>

### 6.2.2 Equipment list

To build this subsystem, the user needs the following pieces of equipment:

- Miter saw, table saw OR vertical saw
- Electric drill
- Wheelbarrow
- Shovel(s)
- Water hose
- Poking stick
- Quick set cement (for repairs)

### 6.2.3 Instructions

Firstly, the concrete mold must be constructed. We started by building the outer shell of the mold. We took six sheets of plywood and measured them to the required dimensions. Then we



assembled it by bolting all the sides together with screws and nails along the edges and on the corners.

Next, we built the inner shell, which would give our cement cast its box properties. The procedure to build the inner shell was identical to that of the outer shell, however it was smaller and featured four overhanging pieces of wood that were drilled into the top rim of the outer shell to ensure that the inner shell would remain stationary while the cement would set. Finally, we cut several pieces of carbon fibre netting and lined the inside of the mold walls with it where the concrete would set vertically.

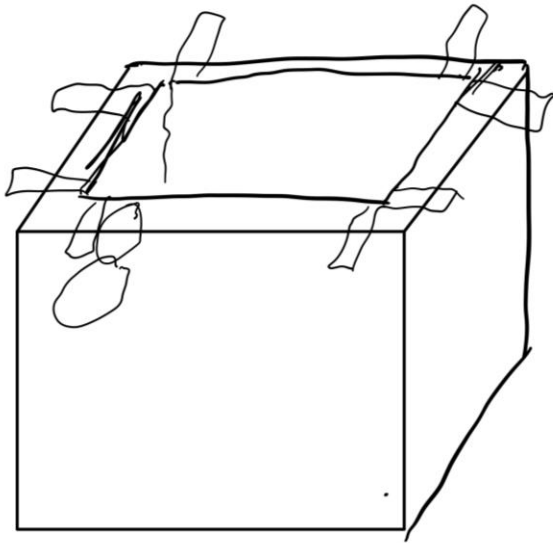
Once our mold was built, we were ready to begin mixing our cement. We took two bags of concrete and poured them into a wheelbarrow. Then we began mixing it, adding water periodically to the mix until it reached our desired consistency.

Using a flat edge spade, we began slowly pouring the concrete into the mold. We would stop periodically to allow the concrete to settle at the bottom of the box and we would also use a cement poking stick to ensure it settled well. Once the cement settled and the box was cast, we carefully removed the wooden mold and we could now use the box.

Final Product:



Plywood mold:



## 6.3 Piping

### 6.3.1 BOM (Bill of Materials)

Item name	Recommended Model	Quantity	Price	Hyperlink
PVC pipe	½ inch schedule 40 PVC piping	>=10 feet in length	2.53\$	<a href="https://www.homedepot.ca/product/ipex-homerite-products-pvc-1-2-inches-x-10-ft-schedule-40-plain-end-pipe/1000100828">https://www.homedepot.ca/product/ipex-homerite-products-pvc-1-2-inches-x-10-ft-schedule-40-plain-end-pipe/1000100828</a>
PVC elbow	½ inch 90 degree elbow	1	0.56\$	<a href="https://www.homedepot.ca/product/lesso-1-2-in-pvc-schedule-40-90-degree-elbow/1000166792">https://www.homedepot.ca/product/lesso-1-2-in-pvc-schedule-40-90-degree-elbow/1000166792</a>
PVC t joint	½ inch diameter t joint	1	0.56	<a href="https://www.homedepot.ca/product/lesso-pvc-tee-soc-x-soc-x-soc-1-2-inch/1000166805">https://www.homedepot.ca/product/lesso-pvc-tee-soc-x-soc-x-soc-1-2-inch/1000166805</a>
1/4inch thick acrylic laser cutting sheets	¼ inch acrylic sheet	12-inch x 24-inch x 1/4 inch	3.5\$	<a href="https://makerstore.ca/shop/ols/products/acrylic-12-inch-x-24-inch">https://makerstore.ca/shop/ols/products/acrylic-12-inch-x-24-inch</a>
Flexible Vinyl Pipe	Everbilt ½ inch vinyl piping	10 feet in length	5.61\$	<a href="https://www.homedepot.com/p/Everbilt-1-2-in-I-D-x-5-8-in-O-D-x-10-ft-Clear-Vinyl-Tubing-T10006010/304185142">https://www.homedepot.com/p/Everbilt-1-2-in-I-D-x-5-8-in-O-D-x-10-ft-Clear-Vinyl-Tubing-T10006010/304185142</a>

### 6.3.2 Equipment list

To build this subsystem, the user needs the following pieces of equipment:

- Electric Miter saw OR small hand-held saw
- Laser cutter
- Hot glue gun
- Tape
- Makeshift stand

### 6.3.3 Instructions

Laser cut vinyl pipe stand:

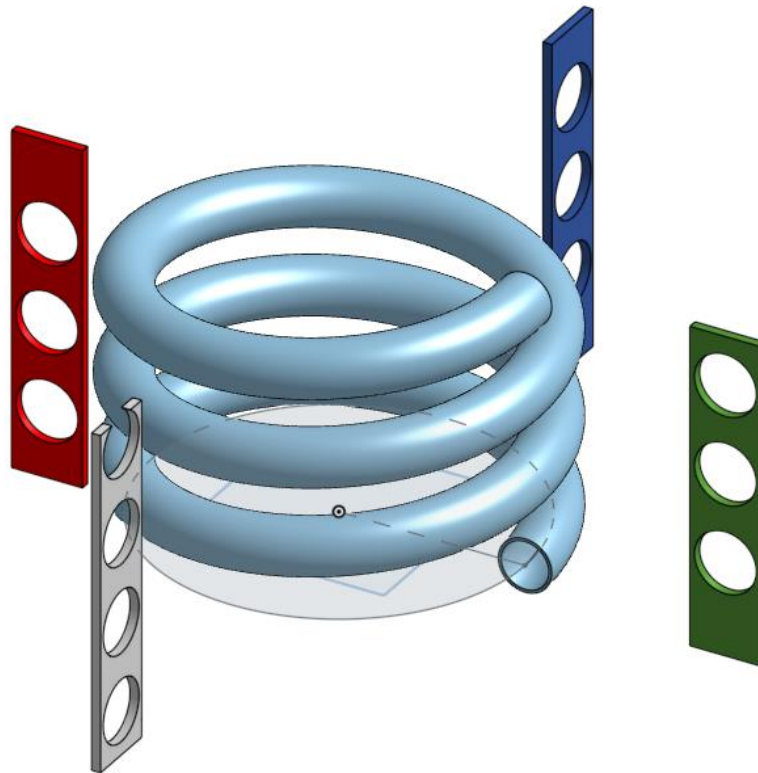
1. Download the files for the pipe stand
2. Laser cut the vinyl pieces
3. Glue the stand together (don't place the columns out of order)
4. Once stand is rigid, insert the vinyl coil
5. Once aligned with inlet and outlet holes, glue the stand to the bottom of the box
6. Cut 4 pieces of pipe with the exacto knife: one 5 inch piece, three 2 inch pieces

To assemble the pipe system, connect two 2-inch segments with a T joint. Glue this piece to the bottom end of the vinyl coil. Then, connect the 5-inch piece to the 2-inch piece with the 90-degree elbow joint. Glue the 5-inch segment to the top end of the vinyl coil.

Final Product:



3D rendering:



## 6.4 Air Inlet

### 6.4.1 BOM (Bill of Materials)

Item name	Recommended Model	Quantity	Price	Hyperlink
MDF laser cutting sheets	¼ inch MDF material sheet	12 inch x 24 inch x ¼ inch	3.5\$	<a href="https://makerstore.ca/shop/ols/products/mdf/v/M003-1-4-12-NCH">https://makerstore.ca/shop/ols/products/mdf/v/M003-1-4-12-NCH</a>
3D printing plastic	3D printing plastic filament	Variable	0\$	N/A (supplied at print shop)

### 6.4.2 Equipment list

To build this subsystem, the user needs the following pieces of equipment:

- Laser cutter

- 3D printer
- USB drive
- SD card
- Hot glue gun

### 6.4.3 Instructions

3D printed parts: Fan holder and inlet connection piec

1. Download the Fan holder files
2. Upload the fan holder files to an SD card
3. Insert SD card into the 3d printer and select the proper files
4. Print the following pieces: the fan holder (Piece 1) twice, and the inlet holder (Piece 2) once
5. Glue the one piece 1 and the larger 3d printed piece together and place this object on top of the 2-inch pipe connected to the 90-degree elbow joint.
6. Place the second piece 1 to the other end of the pipe system.





Laser cut pieces:

1. Download Air inlet file
2. Using laser cutting software and a laser cutter, laser cut the pieces from a sheet of MDF
3. Carefully pop out the MDF pieces and then glue them together
4. Glue this object to a larger 3d printed object



Fully assembled Inlet:



## **6.5 Testing & Validation**

Linked below is a video demonstration of our final functionality test. To test the feasibility and functionality of this test, we devised a test. In it, we had to simulate one of the cases where the fans would turn on and another where the fans would turn off. To verify that a case in which the fans would turn on, we put the final prototype in a room with constant temperature of 20 degrees Celsius so that the “thermostat” would read a constant temperature. Then, we would hold the second temperature sensor between a person’s fingers so it would heat up and we set the preferred temperature to be 25 degrees centigrade. In this situation, the temperature inside the pipes is higher than the temperature inside the house, so the fans should turn on to warm the house, and they did. Once we let go of the pipe temperature sensor, the fans turned off as now the both the temperature inside the pipes and inside the house was lower than the preferred temperature. This demonstrated that our system worked as intended and was fully functional as it maintained the correct temperature within the pipes, and it also promoted airflow into the hypothetical building. In short, the final test was a success.

[Video 1](#)



## **7 Conclusions and Recommendations for Future Work**

Our group felt that we should have allotted more time to building the actual prototype. We did not realize the extent of the prototyping process and would have benefitted from more time to build and test our subsystems. In the future, and especially now with our experience, we will be able to more accurately judge the time required for each stage and create a realistic timeline. We encountered some serious problems when prototyping, like our box breaking our circuit shorting, but by persevering and seeking help from others we overcame them.

If we had been given some more time, we would investigate an alternative method to heat the air faster in the winter. Certain teams solved this issue by heating the air inside their pipes with heated pieces of wire or copper coils surrounding the water. We would have to devise and create a certain number of prototypes and then test them to discover the most efficient and environmentally friendly solution to heat up air within the pipes. Towards the end of the

semester, we wanted to design, create and test a user interface holder. It would have basically been a housing unit for all the electronics. Unfortunately, we ran out of time, and we did not create one in time for the final prototype, but it would have been an important addition to our final prototype.

## **8 Bibliography**

- (I) <https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/sources-sinks-executive-summary-2021.html>
- (II) [https://www.pcbway.com/blog/Engineering\\_Technical/How\\_to\\_Clean\\_an\\_Electronic\\_Circuit\\_Board\\_After\\_It\\_Got\\_Wet.html](https://www.pcbway.com/blog/Engineering_Technical/How_to_Clean_an_Electronic_Circuit_Board_After_It_Got_Wet.html)

# APPENDICES

## 9 APPENDIX I: Design Files

Table 3. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
Project Code	<a href="https://makerepo.com/jczaj018/1112.gng1103-d1-1-the-heat-exchange-chamber-">https://makerepo.com/jczaj018/1112.gng1103-d1-1-the-heat-exchange-chamber-</a> Located in project files drop down menu	April 20th, 2022
Fan holder	<a href="https://makerepo.com/jczaj018/1112.gng1103-d1-1-the-heat-exchange-chamber-">https://makerepo.com/jczaj018/1112.gng1103-d1-1-the-heat-exchange-chamber-</a> Located in project files drop down menu	April 20th, 2022
Air inlet pieces	<a href="https://makerepo.com/jczaj018/1112.gng1103-d1-1-the-heat-exchange-chamber-">https://makerepo.com/jczaj018/1112.gng1103-d1-1-the-heat-exchange-chamber-</a> Located in project files drop down menu	April 20th, 2022
MakerRepo	<a href="https://makerepo.com/jczaj018/1112.gng1103-d1-1-the-heat-exchange-chamber-">GNG1103 D1 1 The Heat Exchange Chamber</a> <a href="https://makerepo.com/">  MakerRepo (makerepo.com)</a>	March 13, 2022
Inlet Holder	<a href="https://makerepo.com/jczaj018/1112.gng1103-d1-1-the-heat-exchange-chamber-">https://makerepo.com/jczaj018/1112.gng1103-d1-1-the-heat-exchange-chamber-</a> Located in project files drop down menu	April 20th, 2022

Pipe stand	<a href="https://makerepo.com/jczaj018/1112.gng1103-d1-1-the-heat-exchange-chamber-">https://makerepo.com/jczaj018/1112.gng1103-d1-1-the-heat-exchange-chamber-</a> Located in project files drop down menu	April 20th, 2022
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