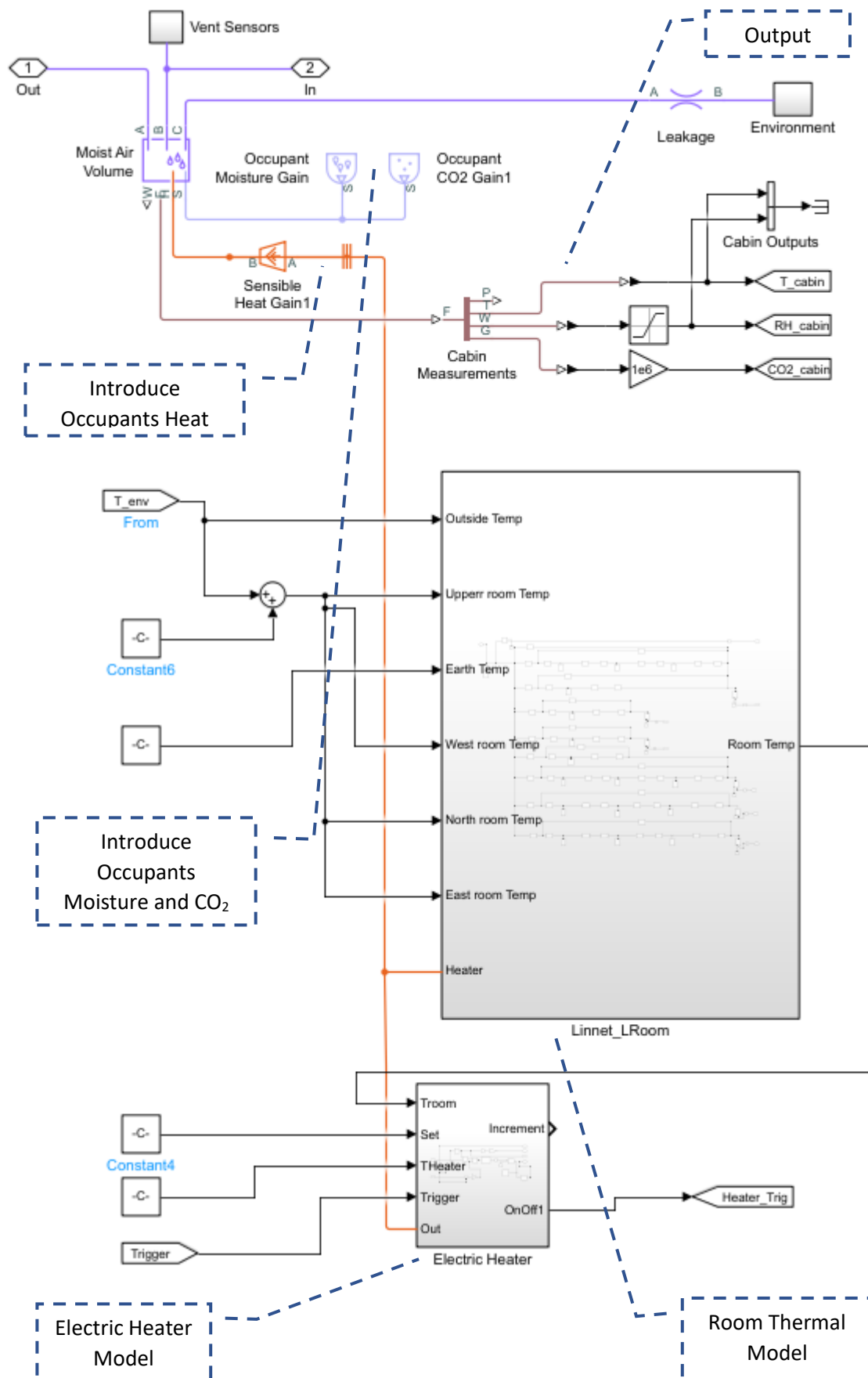
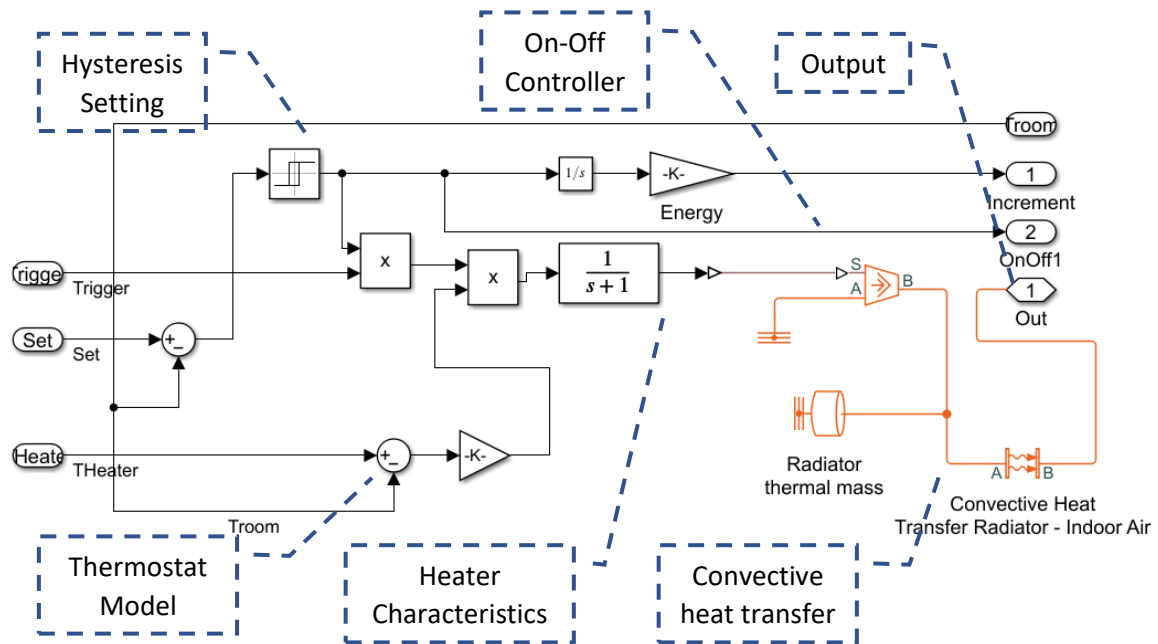


[illegible]

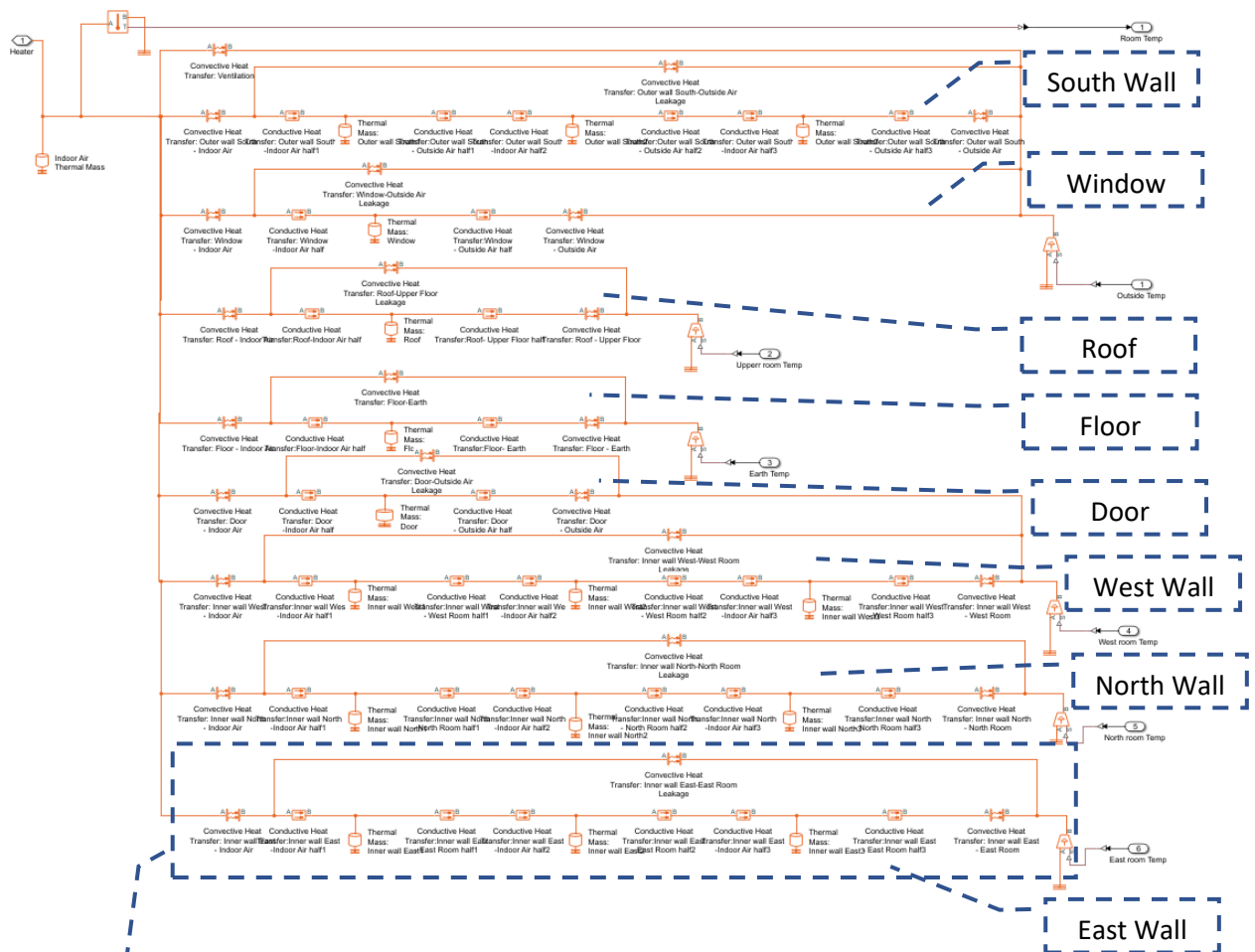
SIMSCAPE MATLAB Room Sub-system:

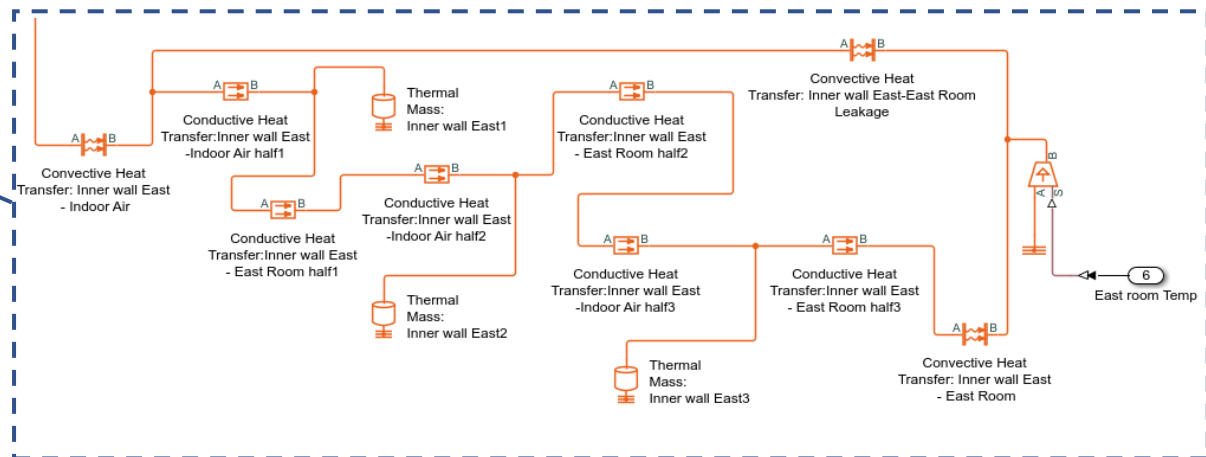


SIMSCAPE MATLAB Electric Heater Model Sub-system:



SIMSCAPE MATLAB Room Thermal Model Sub-system:



SIMSCAPE MATLAB Room Thermal Model Sub-system East Wall:

Simulation parameters involved in the MATLAB Model are as follows:

```
%-----
% Begin List of Constants for Heating Simulation Parameter
% Model: Living Room Flat Linnet Close
% For compare Liverpool (Crosby) and Kent (Gravesend)
% Construction data for 1920s' and 2010s'

classdef Const_Thermal_Sim

    properties(Constant = true)
        %variable:
        %Comfort_Temperature_Set_Point = 23 %degC
        Switch_On_Point = 0.01 %degC
        Switch_Off_Point = -0.01 %degC

        W_BioMaterial = 0.00567 %g/m2s Plain Earth Based Mortar
        Desorption_BioMaterial = 0.00467 %g/m2s Plain Earth Based Mortar
        % upon change, please update Const in lookup table Simscape:Room
        % other material properties defined in the South Wall area

        Ground_Temperature = 12 %degC
        Temp_Init_C = 12 %degC
        Room_Height = 2.4 %meter

        Temperature_Difference_In_Out = 2 %degC
        Heating_Cost = 2.5e-08 %GBP
        %Hygro
        Flow = 0.025 %m/s

        N_occupant = 4 %number of occupants
        %N_occupant = randi(4) %uniform integer 1 to 4
        T_occupant = 30 %deg C exhalation temperature
        W_occupant = (50-15)/3600 %g/s 50 g/h moisture gain per occupant
        %W_occupant = (40 + (55-40)*rand)/3600 %random activities 40 g/h sitting 55
        g/h very active
        CO2_occupant = 0.01 %g/s CO2 Gain per occupant
        Q_occupant = 100 %W sensible heat per occupant
        y_CO2_env = 4.000000000000000e-04 %CO2 environment
        p_env = 0.101325000000000 %Atmospheric pressure
        vent_area = 0.01 %m2 %Const_Thermal_Sim.vent_area
        %Ventilation_area = % 0.007 m2 with baffle, without baffle 0.01 m2
        RH_init = 0.5
        T_init = 12

        %air
```



```

Air_Specific_Heat_C = 1005.4 %J/(kg K) Capacity
Air_Density = 1.225 %kg/m3
Air_Mass =
Const_Thermal_Sim.Air_Density*Const_Thermal_Sim.Room_Height*Const_Thermal_Sim.Roof_Area %kg

Heat_transfer_Air = 20 %W/(m2 * K) (H)

%Windows and Doors
Window_Width = 2.42 %meter
Window_Height = 1.17 %meter
Window_Area = Const_Thermal_Sim.Window_Width *
Const_Thermal_Sim.Window_Height %meter2
%Window_U_value = 1.2 %W/m2K thermal conductivity/thickness
Window_Thermal_Conductivity = 0.78 %W/mK (k)
Window_Specific_Heat_C = 840 %J/(kg K) Capacity
Heat_transfer_Air_Window = 25 %W/m2K (H)
Heat_transfer_Window_Atm = 32 %W/m2K (H)
Window_Leak_Percent = 0.1
Window_Thickness = 0.02 %meter
Window_Density = 2700 %kg/m3

Door_Width = 0.85 %meter 2doors identical
Door_Height = 2 %meter
Door_Area = Const_Thermal_Sim.Door_Width * Const_Thermal_Sim.Door_Height
%meter2
%Door_U_Value = 1.2 %W/m2K
Door_Specific_Heat_C = 840 %J/(kg K) Capacity
Heat_transfer_Air_Door = 25 %W/m2K (H)
Heat_transfer_Door_Atm = 32 %W/m2K (H)
Door_Thermal_Conductivity = 0.78 %W/mK (k)
Door_Leak_Percent = 0.15
Door_Thickness = 0.04 %meter
Door_Density = 800 %kg/m3

%Walls
South_Wall_Length = 3.05 %meter
South_Wall_Area = Const_Thermal_Sim.South_Wall_Length *
Const_Thermal_Sim.Room_Height - Const_Thermal_Sim.Window_Area %meter2
%South_Wall_U_Value = 0.28 %W/m2K
Heat_transfer_Air_South_Wall1 = 24 %W/m2K (H)
Heat_transfer_South_Wall_Atm3 = 34 %W/m2K (H)
South_Wall_Leak_Percent = 0.01
%2010s'
%material inside C1 blockwork Concrete Block (Medium), C2
%insulation, C3 brick outside
South_Wall_Specific_Heat_C1 = 1000 %J/(kg K) Capacity
South_Wall_Specific_Heat_C2 = 1500 %J/(kg K) Capacity
South_Wall_Specific_Heat_C3 = 800 %J/(kg K) Capacity
South_Wall_Thermal_Conductivity1 = 0.510 %W/mK (k)
South_Wall_Thermal_Conductivity2 = 0.022 %W/mK (k)
South_Wall_Thermal_Conductivity3 = 0.98 %W/mK (k)
South_Wall_Thickness1 = 0.1 %meter
South_Wall_Thickness2 = 0.09 %meter
South_Wall_Thickness3 = 0.1025 %meter
South_Wall_Density1 = 1400 %kg/m3
South_Wall_Density2 = 30 %kg/m3
South_Wall_Density3 = 1920 %kg/m3
%1920s'
%material brick
South_Wall_Specific_Heat_C = 800 %J/(kg K) Capacity
South_Wall_Thermal_Conductivity = 0.98 %W/mK (k)
South_Wall_Thickness = 0.215 %meter
South_Wall_Density = 1920 %kg/m3
Heat_transfer_Air_South_Wall = 24 %W/m2K (H)
Heat_transfer_South_Wall_Atm = 34 %W/m2K (H)
%Additional Bio indoor layer : Earth mortar with saw mill residue
South_Wall_Specific_Heat_C_Bio = 847 %J/(kg K) Capacity

```

```

South_Wall_Thermal_Conductivity_Bio = 0.2 %W/mK (k)
South_Wall_Thickness_Bio = 0.015 %meter
South_Wall_Density_Bio = 1410 %kg/m3

West_Wall_Length = 4.35 %meter
West_Wall_Area = Const_Thermal_Sim.West_Wall_Length *
Const_Thermal_Sim.Room_Height- Const_Thermal_Sim.Door_Area %meter2
%West_Wall_U_Value = 0.28 %W/m2K
Heat_transfer_Air_West_Wall1 = 24 %W/m2K (H)
Heat_transfer_West_Wall_Atm3 = 34 %W/m2K (H)
West_Wall_Leak_Percent = 0.01
%2010s'
%material inside C1 blockwork Concrete Block (Medium), C2
%insulation, C3 brick outside
West_Wall_Specific_Heat_C1 = 1000 %J/(kg K) Capacity
West_Wall_Specific_Heat_C2 = 1500 %J/(kg K) Capacity
West_Wall_Specific_Heat_C3 = 800 %J/(kg K) Capacity
West_Wall_Thermal_Conductivity1=0.510 %W/mK (k)
West_Wall_Thermal_Conductivity2=0.022 %W/mK (k)
West_Wall_Thermal_Conductivity3=0.98 %W/mK (k)
West_Wall_Thickness1 = 0.1 %meter
West_Wall_Thickness2 = 0.09 %meter
West_Wall_Thickness3 = 0.1025 %meter
West_Wall_Density1 = 1400 %kg/m3
West_Wall_Density2 = 30 %kg/m3
West_Wall_Density3 = 1920 %kg/m3
%1920s'
%material brick
West_Wall_Specific_Heat_C = 800 %J/(kg K) Capacity
West_Wall_Thermal_Conductivity = 0.98 %W/mK (k)
West_Wall_Thickness = 0.215 %meter
West_Wall_Density = 1920 %kg/m3
Heat_transfer_Air_West_Wall = 24 %W/m2K (H)
Heat_transfer_West_Wall_Atm = 34 %W/m2K (H)

East_Wall_Length = 4.35 %meter
East_Wall_Area = Const_Thermal_Sim.East_Wall_Length *
Const_Thermal_Sim.Room_Height %meter2
%East_Wall_U_Value = 1.2 %W/m2K
Heat_transfer_Air_East_Wall1 = 24 %W/m2K (H)
Heat_transfer_East_Wall_Atm3 = 34 %W/m2K (H)
East_Wall_Leak_Percent = 0.01
%2010s'
%material inside C1 blockwork Concrete Block (Medium), C2
%insulation, C3 brick outside
East_Wall_Specific_Heat_C1 = 1000 %J/(kg K) Capacity
East_Wall_Specific_Heat_C2 = 1500 %J/(kg K) Capacity
East_Wall_Specific_Heat_C3 = 800 %J/(kg K) Capacity
East_Wall_Thermal_Conductivity1=0.510 %W/mK (k)
East_Wall_Thermal_Conductivity2=0.022 %W/mK (k)
East_Wall_Thermal_Conductivity3=0.98 %W/mK (k)
East_Wall_Thickness1 = 0.1 %meter
East_Wall_Thickness2 = 0.09 %meter
East_Wall_Thickness3 = 0.1025 %meter
East_Wall_Density1 = 1400 %kg/m3
East_Wall_Density2 = 30 %kg/m3
East_Wall_Density3 = 1920 %kg/m3
%1920s'
%material brick
East_Wall_Specific_Heat_C = 800 %J/(kg K) Capacity
East_Wall_Thermal_Conductivity = 0.98 %W/mK (k)
East_Wall_Thickness = 0.215 %meter
East_Wall_Density = 1920 %kg/m3
Heat_transfer_Air_East_Wall = 24 %W/m2K (H)
Heat_transfer_East_Wall_Atm = 34 %W/m2K (H)

North_Wall_Length = 3.05 %meter

```

```

    North_Wall_Area = Const_Thermal_Sim.North_Wall_Length *
Const_Thermal_Sim.Room_Height - Const_Thermal_Sim.Door_Area %meter2
%North_Wall_U_Value = 1.2 %W/m2K
Heat_transfer_Air_North_Wall1 = 24 %W/m2K (H)
Heat_transfer_North_Wall_Atm3 = 34 %W/m2K (H)
North_Wall_Leak_Percent = 0.01
%2010s'
%material inside C1 blockwork Concrete Block (Medium), C2
%insulation, C3 brick outside
North_Wall_Specific_Heat_C1 = 1000 %J/(kg K) Capacity
North_Wall_Specific_Heat_C2 = 1500 %J/(kg K) Capacity
North_Wall_Specific_Heat_C3 = 800 %J/(kg K) Capacity
North_Wall_Thermal_Conductivity1=0.510 %W/mK (k)
North_Wall_Thermal_Conductivity2=0.022 %W/mK (k)
North_Wall_Thermal_Conductivity3=0.98 %W/mK (k)
North_Wall_Thickness1 = 0.1 %meter
North_Wall_Thickness2 = 0.09 %meter
North_Wall_Thickness3 = 0.1025 %meter
North_Wall_Density1 = 1400 %kg/m3
North_Wall_Density2 = 30 %kg/m3
North_Wall_Density3 = 1920 %kg/m3
%1920s'
%material brick
North_Wall_Specific_Heat_C = 800 %J/(kg K) Capacity
North_Wall_Thermal_Conductivity = 0.98 %W/mK (k)
North_Wall_Thickness = 0.215 %meter
North_Wall_Density = 1920 %kg/m3
Heat_transfer_Air_North_Wall = 24 %W/m2K (H)
Heat_transfer_North_Wall_Atm = 34 %W/m2K (H)

%Floor and Roof
    Floor_Area = Const_Thermal_Sim.North_Wall_Length *
Const_Thermal_Sim.West_Wall_Length
    Floor_U_Value = 0.7 %W/m2K
    Floor_Specific_Heat_C = 835 %J/(kg K)
    Heat_transfer_Air_Floor = 12 %W/m2K (H)
    Heat_transfer_Floor_Earth = 20 %W/m2K (H)
    Floor_Thermal_Conductivity = 1 %0.038 %W/mK (k)
    Floor_Leak_Percent = 0.1
    Floor_Thickness = 0.2 %meter
    Floor_Density = 1920 %kg/m3

    Roof_Area = Const_Thermal_Sim.North_Wall_Length *
Const_Thermal_Sim.West_Wall_Length
    Roof_U_Value = 1.4 %W/m2K
    Roof_Specific_Heat_C = 835 %J/(kg K)
    Heat_transfer_Air_Roof = 12 %W/m2K (H)
    Heat_transfer_Roof_Atm = 38 %W/m2K (H)
    Roof_Thermal_Conductivity = 0.038 %W/mK (k)
    Roof_Leak_Percent = 0.02
    Roof_Thickness = 0.2 %meter
    Roof_Density = 1920 %kg/m3

%people
    People_Mass_Woman = 60 %kg
    People_Mass_Man = 75 %kg
    People_Mass_Children = 30 %kg
    Avg_Surface_Adult_Man = 1.9 %meter2
    Avg_Surface_Adult_Woman = 1.6 %meter2
    Avg_Surface_Children = 1.2 %meter2
    Body_Convection_Coef = 3.4 %W/m2K (H)
    mf = 0.22 %average 0.1 male athlete %the fraction of body fat by weight
    Body_specific_heat_C =(3.72 - 1.84 * Const_Thermal_Sim.mf) * 1000 %J/(kg K)
    Body_Temperature = 36 %degC

%Radiator
    Radiator_Heat_transfer_Coef = 100 %W/m2K (H)
    Radiator_Area = 0.9 * 0.4 %meter2 (S -> 5)

```

```

Radiator_Mass = 46.7 %Kg
Radiator_Specific_Heat_C = 447 %J/(kg K)
Radiator_Temp =40 %degC

%Heater
Heater_Air_Flow = 1

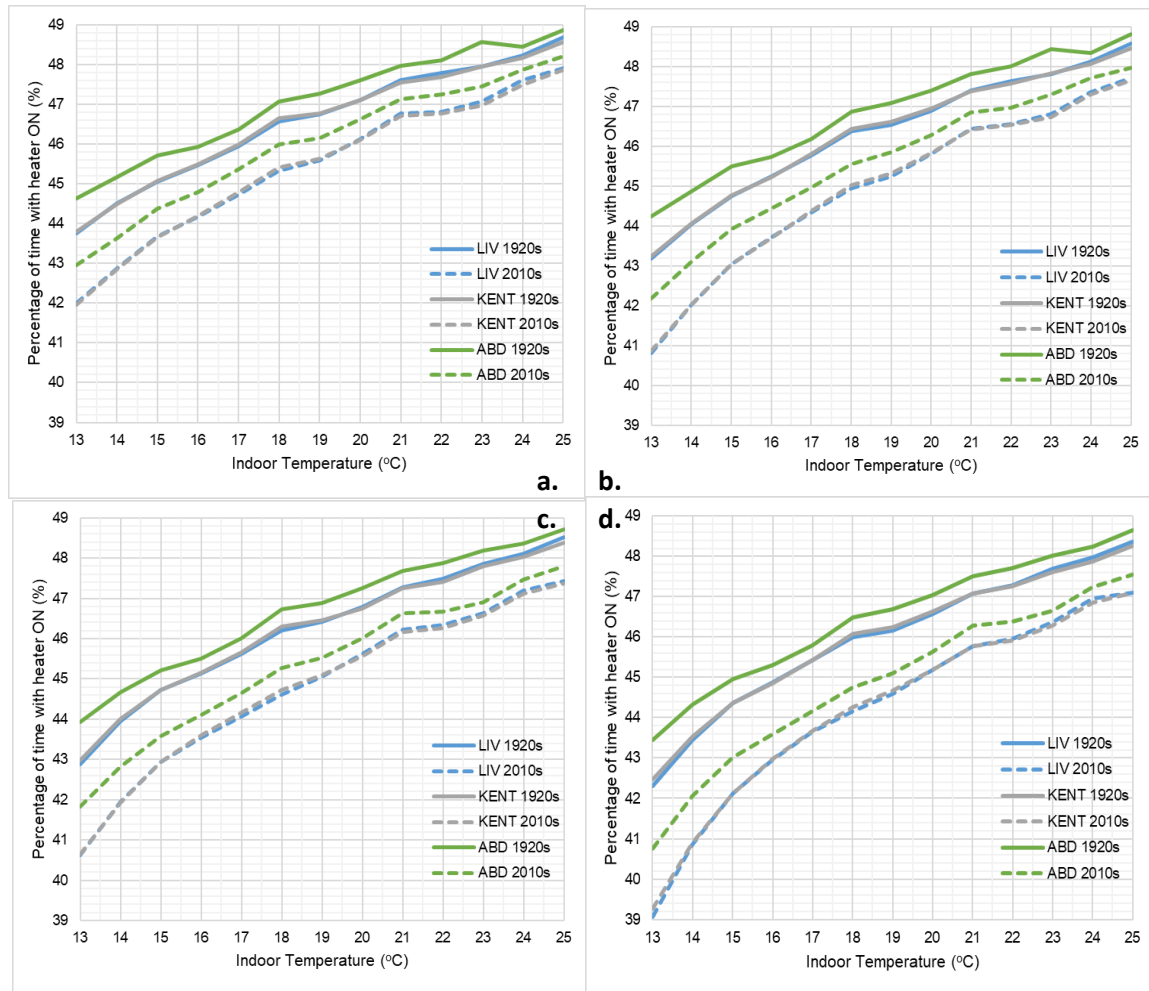
end
end

%Usage:
%
% Occupants:
% Convective Heat Transfer People-Indoor air:
% Area: Const_Thermal_Sim.Avg_Surface_Adult_women m^2
% Heat transfer coefficient:Const_Thermal_Sim.Body_Convection_Coeff W/(m^2K)
% Thermal Mass: Human Body
% Mass:Const_Thermal_Sim.People_Mass kg
% Specific heat: Const_Thermal_Sim.Body_specific_heat_C J/(kg K)
%
% Radiator:
% Convective Heat Transfer Radiator - Indoor air:
% Area: Const_Thermal_Sim.Radiator_Area m^2
% Heat transfer coefficient: Const_Thermal_Sim.Radiator_Heat_transfer_Coeff W/(m^2K)
% Thermal Mass: Radiator
% Mass:Const_Thermal_Sim.Radiator_Mass kg
% Specific heat: Const_Thermal_Sim.Radiator_Specific_Heat_C J/(kg K)
%
% Thermal Mass: Indoor Air
% Mass:Const_Thermal_Sim.Air_Mass kg
% Specific heat: Const_Thermal_Sim.Air_Specific_Heat_C J/(kg K)
%
% Walls, Doors, Windows, Floor and Roof:
% Convective Heat Transfer: Outer wall South - Indoor Air:
% Area: Const_Thermal_Sim.South_Wall_Area m^2
% Heat transfer coefficient: Const_Thermal_Sim.Heat_transfer_Air_South_Wall
W/(m^2K)
% Convective Heat Transfer: Outer wall South-Outside Air Leakage:
% Area: Const_Thermal_Sim.South_Wall_Area *
Const_Thermal_Sim.South_Wall_Leak_Percent m^2
% Heat transfer coefficient: Const_Thermal_Sim.Heat_transfer_South_Wall_Atm
W/(m^2K)
% Conductive Heat Transfer: Outer wall South-Indoor Air half
% Area:Const_Thermal_Sim.South_Wall_Area m^2
% Thickness:Const_Thermal_Sim.South_Wall_Thickness/2 m
% Thermal conductivity:Const_Thermal_Sim.South_Wall_Thermal_Conductivity W/(m K)
% Thermal Mass: Outer wall South
% Mass:Const_Thermal_Sim.South_Wall_Area * Const_Thermal_Sim.South_Wall_Thickness *
Const_Thermal_Sim.South_Wall_Density kg
% Specific heat: Const_Thermal_Sim.South_Wall_Specific_Heat_C J/(kg K)
% Conductive Heat Transfer: Outer wall South-Outside Air half
% Area:Const_Thermal_Sim.South_Wall_Area m^2
% Thickness:Const_Thermal_Sim.South_Wall_Thickness/2 m
% Thermal conductivity:Const_Thermal_Sim.South_Wall_Thermal_Conductivity W/(m K)
% Convective Heat Transfer: Outer wall South - Outside Air:
% Area: Const_Thermal_Sim.South_Wall_Area m^2
% Heat transfer coefficient: CConst_Thermal_Sim.Heat_transfer_South_Wall_Atm
W/(m^2K)
%
% End List of Constants for Heating Simulation Parameter
%-----

```

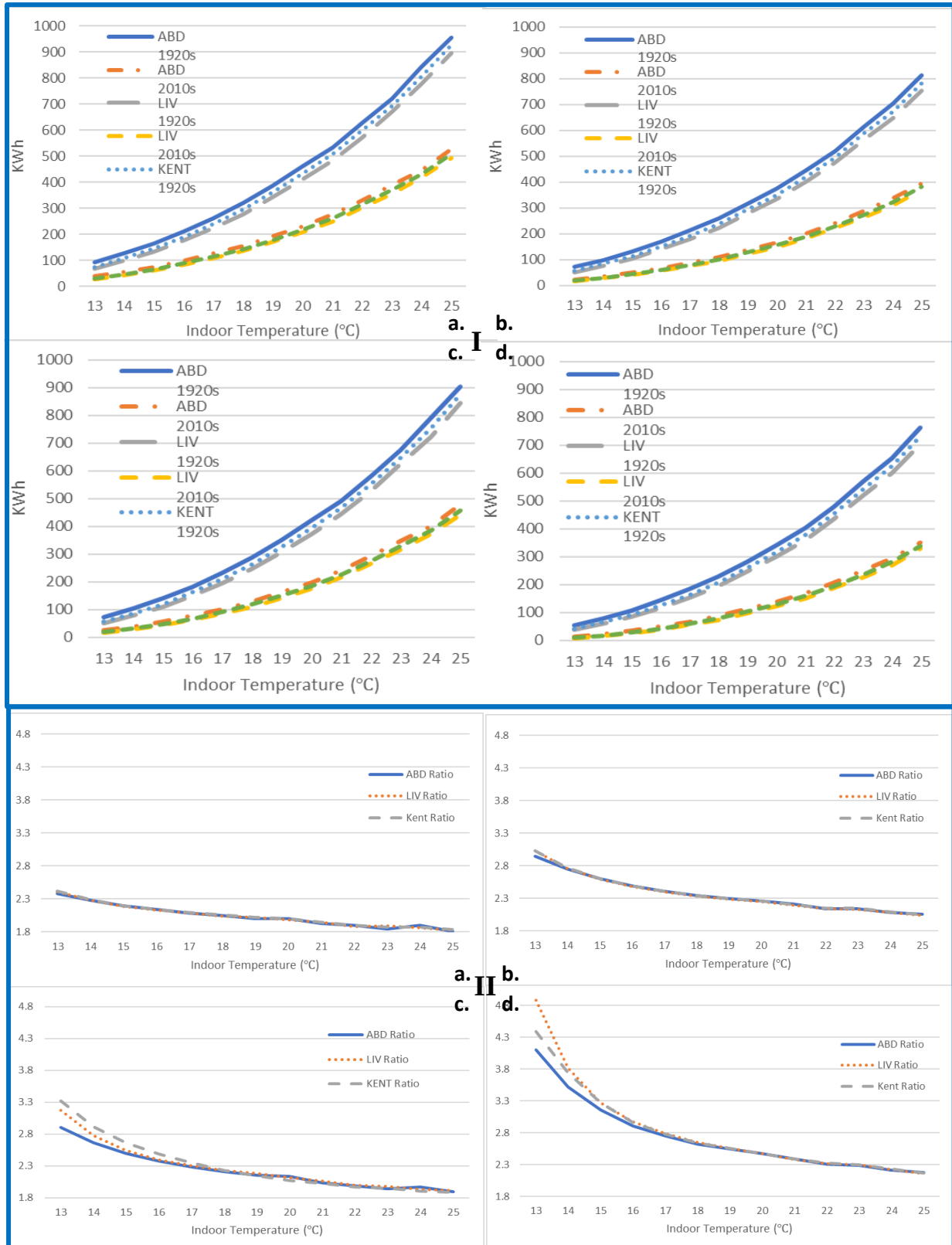
Appendix 2. Simulation Results

Comparison of the percentage of time with the heater ON in 2017:



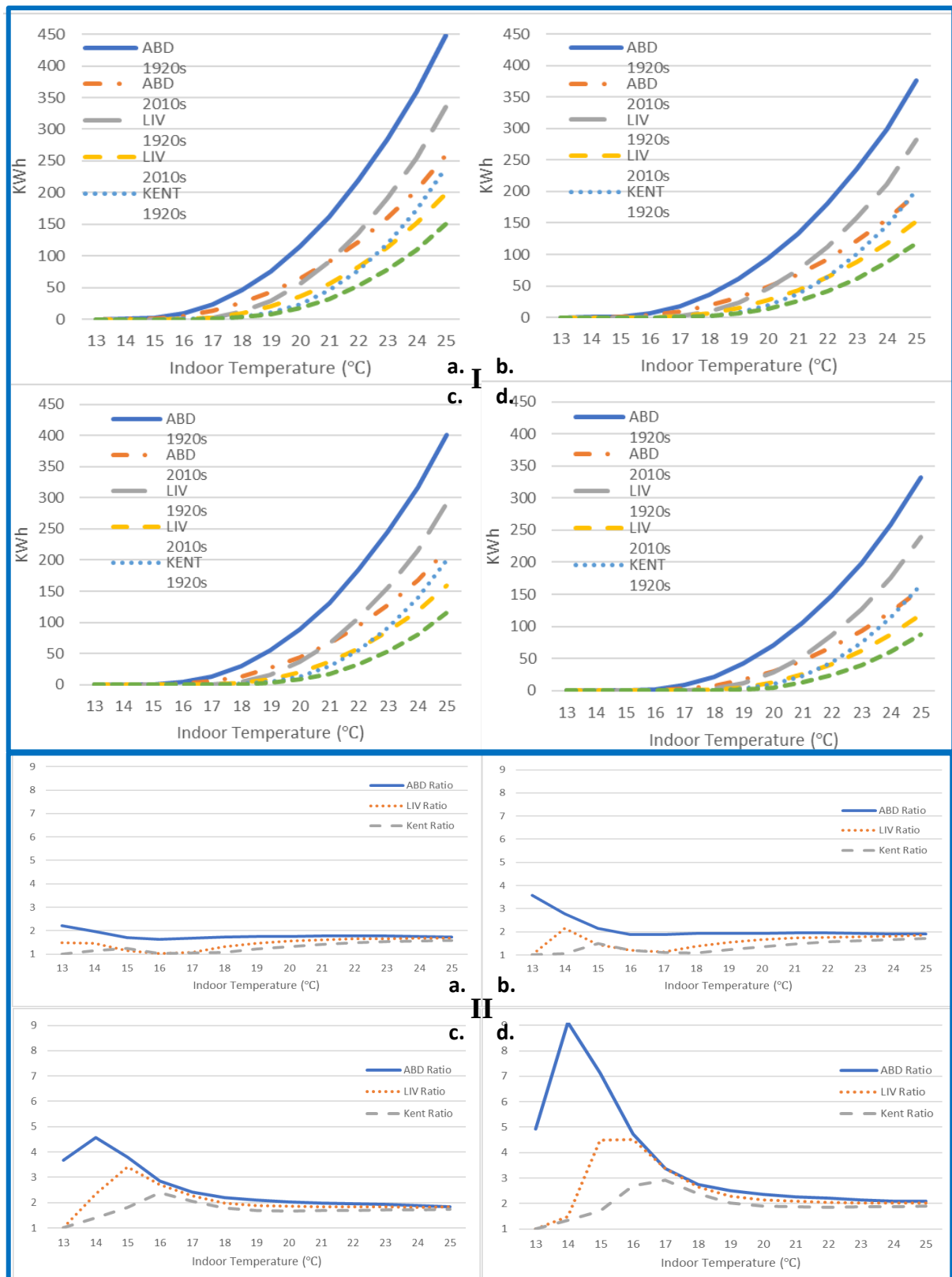
Comparison of the percentage of time with the heater ON in 2017 for the 1920s and 2010s housing typologies in Liverpool, Aberdeen, and Kent with a.) 2 occupants and flow 0.05m/s, b.) 2 occupants and flow 0.025, c.) 4 occupants and flow 0.05m/s and d.) 4 occupants and flow 0.025.

Energy comparison result from the MATLAB Model in three coldest months of the year 2017:



I. Heating energy comparison between the 1920s and 2010s housing typologies in Liverpool, Aberdeen, and Kent during three coldest months with a.) 2 occupants and flow 0.05m/s, b.) 2 occupants and flow 0.025, c.) 4 occupants and flow 0.05m/s and d.) 4 occupants and flow 0.025. **II.** Heating energy ratio during three coldest months, Y axis represents the energy ratio 1920s : 2010s.

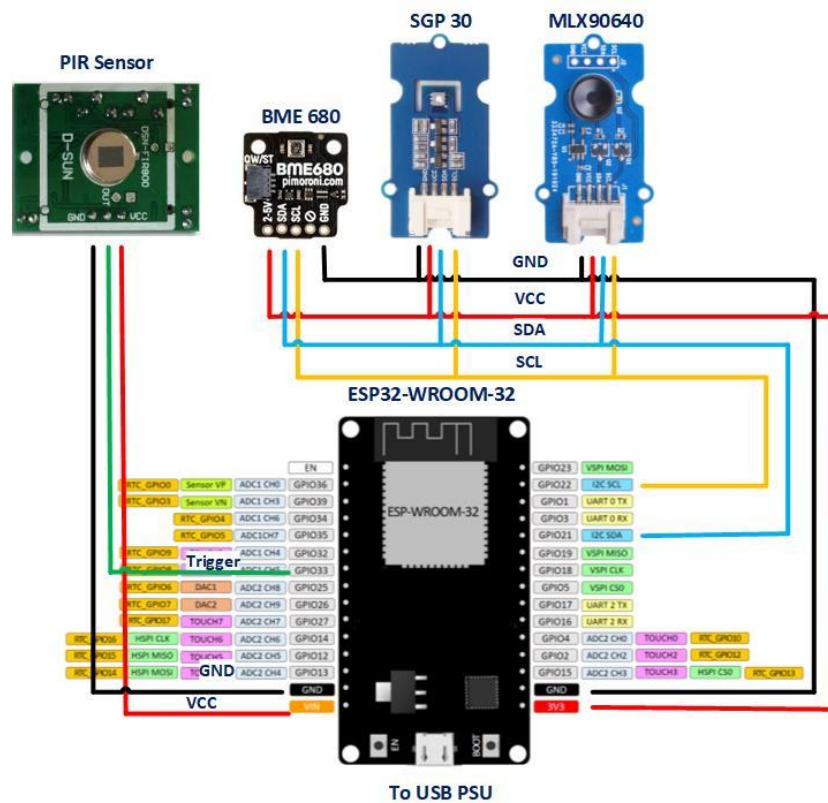
Energy comparison result from the MATLAB Model in three hottest months of the year 2017:



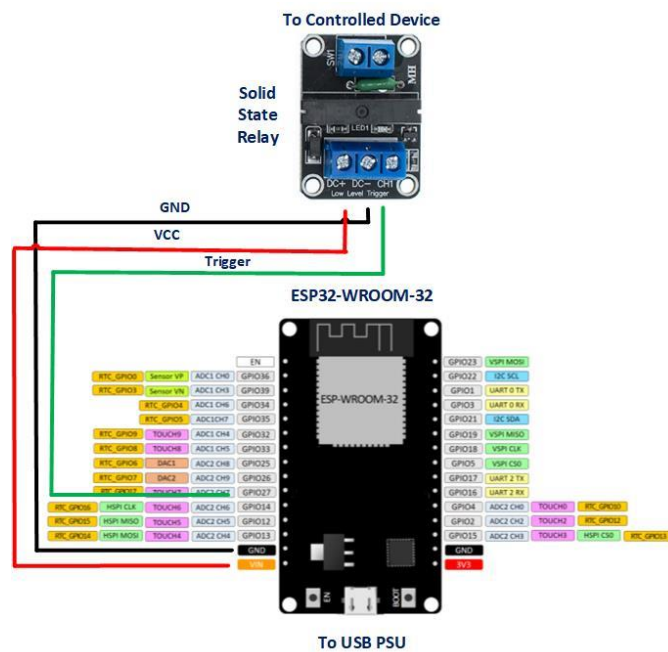
I. Heating energy comparison between the 1920s and 2010s housing typologies in Liverpool, Aberdeen, and Kent during three hottest months with a.) 2 occupants and flow 0.05m/s, b.) 2 occupants and flow 0.025, c.) 4 occupants and flow 0.05m/s and d.) 4 occupants and flow 0.025. **II.** Heating energy ratio during three hottest months, Y axis represents the energy ratio 1920s : 2010s.

Appendix 3. Module Diagram

Sensor with Occupant monitor and Thermal Camera Module Diagram:



Actuator (Heater) Control (On-Off controller) Module Diagram:



Appendix 4. Sensor Node Program

Standard sensor program:

```

/* Program for IOT node to detect temperature, humidity and air quality using SVM 30 sensor.
 * use MQTT data transfer and sleep capability to conserve power
 * karyono@umn.ac.id
 * SVM30 driver by paulvha@hotmail.com
 */
#define uS_TO_S_FACTOR 1000000ULL /* Conversion factor for micro seconds to seconds */
#define TIME_TO_SLEEP 900 //data sending every 15 minutes /* Time ESP32 will go to sleep (in seconds) */
#define SENSOR_ID "S001"
void update_humidity();
#include "Zanshin_BME680.h" // the Bosch BME680 Sensor library
#include <svm30.h>
#include "PubSubClient.h"
#include <WiFi.h>

const char *ssid = "IoTNetwork1"; // name of your WiFi network
const char *password = "*****"; // password of the WiFi network
const char *ID = "AirQuality"; // Name of device
IPAddress broker(192,168,0,101);
WiFiClient wclient;
PubSubClient client(wclient); // Setup MQTT client
// create instance
SVM30 svm;
// store values
struct svm_values v;

// Connect to WiFi network
void setup_wifi() {
  Serial.print("\nConnecting to ");
  Serial.println(ssid);
  WiFi.begin(ssid, password); // Connect to network
  while (WiFi.status() != WL_CONNECTED) { // Wait for connection
    delay(500);
    Serial.print(".");
  }
  Serial.println();
  Serial.println("WiFi connected");
  Serial.print("IP address: ");
  Serial.println(WiFi.localIP());
}

// Reconnect to client
void reconnect() {
  // Loop until we're reconnected
  while (!client.connected()) {
    Serial.print("Attempting MQTT connection...");
    // Attempt to connect
    if (client.connect(ID)) {
      Serial.println("connected");
    } else {
      Serial.print("failed, rc=");
      Serial.print(client.state());
      Serial.println(" try again in 5 seconds");
      // Wait 5 seconds before retrying
      delay(5000); } } }

float altitude(const int32_t press, const float seaLevel = 1013.25); ///< Forward function declaration with default value for sea level
float altitude(const int32_t press, const float seaLevel)

```

```

{
  /*
  * @brief This converts a pressure measurement into a height in meters
  * @details The corrected sea-level pressure can be passed into the function if it is know, otherwise the standard
  *           atmospheric pressure of 1013.25hPa is used (see https://en.wikipedia.org/wiki/Atmospheric_pressure)
  * @param[in] press Pressure reading from BME680
  * @param[in] seaLevel Sea-Level pressure in millibars
  * @return floating point altitude in meters.
  */
  static float Altitude;
  Altitude = 44330.0*(1.0-pow(((float)press/100.0)/seaLevel,0.1903)); // Convert into altitude in meters
  return(Altitude);
}
//Default BME680 Address= 0x76 or 0x77
BME680_Class BME680; ///< Create an instance of the BME680 class

void setup() {
  Serial.begin(115200);
  svm.SetTempCelsius(true);
  svm.begin();

  // try to detect SVM30 sensors
  if (svm.probe() == false) Serial.print("could not detect SVM30 sensors");
  Serial.print(F("CO2 \t")); Serial.print(F("TVOC \t")); Serial.print(F("H2 Sign \t")); Serial.print(F("Ethanol s \t"));
  Serial.print(F("Humidity \t")); Serial.print(F(" Temp C \t"));
  Serial.print(F("abs Hum \t")); Serial.print(F("heat_idx \t")); Serial.print(F("dew_pt C \t")); Serial.print(F(" CO2 BsL \t"));
  Serial.print(F("TVOC BsL \n"));
  svm.TriggerSGP30();

  while (!BME680.begin(I2C_STANDARD_MODE)) // Start BME680 using I2C, use first device found
  {
    Serial.println("Unable to find BME680. Trying again in 5 seconds.");
    delay(5000);
  } // of loop until device is located
  Serial.println("Setting 16x oversampling for all sensors");
  BME680.setOversampling(TemperatureSensor,Oversample16); // Use enumerated type values
  BME680.setOversampling(HumiditySensor, Oversample16); // Use enumerated type values
  BME680.setOversampling(PressureSensor, Oversample16); // Use enumerated type values
  Serial.println("Setting IIR filter to a value of 4 samples");
  BME680.setIIRFilter(IIR4); // Use enumerated type values
  Serial.print(F("Setting gas measurement to 320\xC2\xB0\x43 for 150ms\n")); // "°C" symbols
  BME680.setGas(320,150); // 320°C for 150 milliseconds

  setup_wifi(); // Connect to network
  client.setServer(broker, 1883);

  delay(15000); //wait for stable output according to the datasheet
  update_humidity();
  svm.GetValues(&v);
}

void loop() {

  char buff[128];
  if (!client.connected()) // Reconnect if connection is lost
  {
    reconnect();
  }
  client.loop();

  // update humidity based
  update_humidity();
  //BME680

```

```

static int32_t temp, humidity, pressure, gas;           // Variable to store readings
static char  buf[120];                                // Text buffer for sprintf
static char  bufID[17];                               // for ID
static float alt;                                     // temp variable for altitude
BME680.getSensorData(temp, humidity, pressure, gas);   // Get the most recent readings
int val_int;
uint8_t val_frac;

alt = altitude(pressure);                             // temp variable for altitude
val_int=(int)alt;
val_frac=(uint8_t)((alt - (float)val_int)*100);

//SVM30
svm.GetValues(&v);
Serial.print(v.CO2eq);Serial.print(F("\t")); Serial.print(v.TVOC); Serial.print(F("\t")); Serial.print(v.H2_signal);
Serial.print(F("\t\t")); Serial.print(v.Ethanol_signal); Serial.print(F("\t\t"));
Serial.print((float) v.humidity/1000); Serial.print(F("\t\t")); Serial.print((float) v.temperature/1000); Serial.print(F("\t\t"));
Serial.print(v.absolute_hum); Serial.print(F("\t\t"));
Serial.print(v.heat_index); Serial.print(F("\t\t")); Serial.print(v.dew_point); Serial.print(F("\t\t"));

//MQTT Send
sprintf(bufID, "room/sensor/%s", SENSOR_ID);
sprintf(buf, "%d.%d, %d.%d, %d.%d, %d.%d, %d.%d, %d.%d, %f, %d, %d, %d, %f, %f ",
(int8_t)(temp/100), (uint8_t)(temp%100), (int8_t)(humidity/1000), (uint16_t)(humidity%1000),
(int16_t)(pressure/100), (uint8_t)(pressure%100), val_int, val_frac, (int16_t)(gas/100), (uint8_t)(gas%100),
v.temperature/1000, v.temperature%1000, v.humidity/1000, v.humidity%1000, v.absolute_hum, v.CO2eq, v.TVOC,
v.H2_signal, v.Ethanol_signal, v.heat_index, v.dew_point);
client.publish(bufID, buf);delay(300);
uint16_t baseline;
svm.GetBaseLine_CO2(&baseline);
Serial.print(F("0x")); Serial.print(baseline, HEX);Serial.print(F("\t\t"));
svm.GetBaseLine_TVOC(&baseline);
Serial.print(F("0x")); Serial.println(baseline, HEX);

esp_sleep_enable_timer_wakeup(TIME_TO_SLEEP * uS_TO_S_FACTOR);
esp_deep_sleep_start();
}

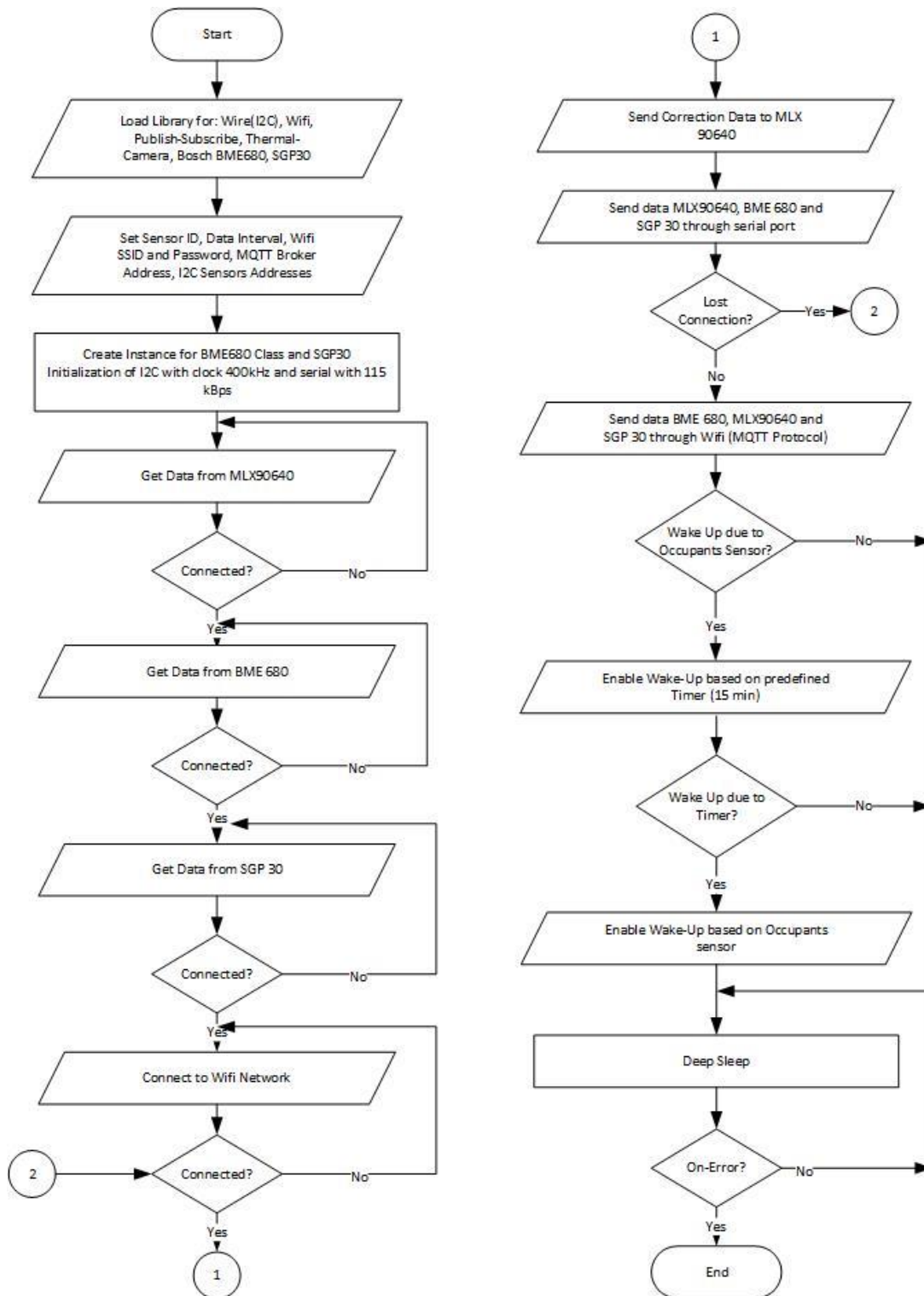
/* * update absolute humidity on the SGP30 based on the earlier reading of temperature and humidity
* from the SHTC1*/
void update_humidity() {
  svm.SetHumidity(v.absolute_hum);
  // give time to settle (max 10 according to datasheet)
  delay(10);
}

double RHtoAbsolute (float relHumidity, float tempC) {
  double eSat = 6.11 * pow(10.0, (7.5 * tempC / (237.7 + tempC)));
  double vaporPressure = (relHumidity * eSat) / 100; //millibars
  double absHumidity = 1000 * vaporPressure * 100 / ((tempC + 273) * 461.5); //Ideal gas law with unit conversions
  return absHumidity;
}

uint16_t doubleToFixedPoint( double number) {
  int power = 1 << 8;
  double number2 = number * power;
  uint16_t value = floor(number2 + 0.5);
  return value;
}

```

Sensor with Occupant monitor and Thermal Camera Flow Chart:



Sensor with Occupant monitor and Thermal Camera program:

```

/* Program to evaluate MLX90640 parameter, BME680 and SGP 30
* karyono@umn.ac.id
* use API directly from MELEXIS
* routine from Nathan S. Spark Fun Electronics
* BME680 use routine from Arnd\@SV-Zanshin
* Sinsirion SGP 30 routine from Ciara Jekel, Spark Fun
* MQTT from Alex Wende, SparkFun Electronics & Rui Santos
* use https://github.com/knolleary/pubsubclient/releases/tag/v2.8 pub sub client 2.8
*/

#include <Wire.h> //I2C connection
#include <WiFi.h>
#include "PubSubClient.h"
#include "MLX90640_API.h" // the Melexis MLX 90640 library
#include "MLX90640_I2C_Driver.h"
#include "Zanshin_BME680.h" // the Bosch BME680 Sensor library
#include "SparkFun_SGP30_Arduino_Library.h" //library: http://librarymanager/All#SparkFun_SGP30
#define BUTTON_PIN_BITMASK 0x200000000 // 2^33 in hex
#define uS_TO_S_FACTOR 1000000ULL /* Conversion factor for micro seconds to seconds */
#define TIME_TO_SLEEP 900 //15m /* Time ESP32 will go to sleep (in seconds) */
#define SENSOR_ID "S005"
#define THERMALCAM_ID "T005"
#define TA_SHIFT 8 //Default shift 8 degrees for MLX90640 in open air

const char *ssid = "IoTNetwork1"; // name of your WiFi network
const char *password = "*****"; // password of the WiFi network
const char *ID = "AirQuality"; // Name of device
// MQTT Broker IP address
IPAddress broker(192,168,0,101); // IP address of MQTT broker 192.168.0.32
WiFiClient wclient;
PubSubClient client(wclient); // Setup MQTT client
bool state=0;

const byte MLX90640_address = 0x33; //Default 7-bit unshifted address of the MLX90640
//Default BME680 Address= 0x76 or 0x77 //Default SGP30 Address= 0x58
float mlx90640To[768]; //thermal data
paramsMLX90640 mlx90640; //parameters to be passed

// Connect to WiFi network
void setup_wifi() {
  Serial.print("\nConnecting to ");
  Serial.println(ssid);
  WiFi.begin(ssid, password); // Connect to network

  while (WiFi.status() != WL_CONNECTED) { // Wait for connection
    delay(500);
    Serial.print(".");
  }
  Serial.println();
  Serial.println("WiFi connected");
  Serial.print("IP address: ");
  Serial.println(WiFi.localIP());
}

// Reconnect to client
void reconnect() {
  // Loop until we're reconnected
  while (!client.connected()) {
    Serial.print("Attempting MQTT connection...");
    // Attempt to connect
    if (client.connect(ID)) {

```

```

    Serial.println("connected");
  } else {
    Serial.print("failed, rc=");
    Serial.print(client.state());
    Serial.println(" try again in 5 seconds");
    // Wait 5 seconds before retrying
    delay(5000);
  } } }

BME680_Class BME680; ///< Create an instance of the BME680 class
float altitude(const int32_t press, const float seaLevel = 1013.25); ///< Forward function declaration with default value for
sea level
float altitude(const int32_t press, const float seaLevel)
{ /*
 * @brief This converts a pressure measurement into a height in meters
 * @details The corrected sea-level pressure can be passed into the function if it is know, otherwise the standard
 * atmospheric pressure of 1013.25hPa is used (see https://en.wikipedia.org/wiki/Atmospheric\_pressure)
 * @param[in] press Pressure reading from BME680
 * @param[in] seaLevel Sea-Level pressure in millibars
 * @return floating point altitude in meters. */
static float Altitude;
Altitude = 44330.0*(1.0-pow(((float)press/100.0)/seaLevel,0.1903)); // Convert into altitude in meters
return(Altitude);
}

SGP30 mySensor; //create an object of the SGP30 class

void print_wakeup_reason(){
  esp_sleep_wakeup_cause_t wakeup_reason;

  wakeup_reason = esp_sleep_get_wakeup_cause();

  switch(wakeup_reason)
  { case ESP_SLEEP_WAKEUP_EXT0 : Serial.println("Wakeup caused by external signal using RTC_IO");
//client.publish("room/sleep", "Wakeup caused by external signal using RTC_IO"); break;
    case ESP_SLEEP_WAKEUP_EXT1 : Serial.println("Wakeup caused by external signal using RTC_CNTL");
    case ESP_SLEEP_WAKEUP_TIMER : Serial.println("Wakeup caused by timer");
//client.publish("room/sleep", "Wakeup caused by timer"); break;
    case ESP_SLEEP_WAKEUP_TOUCHPAD : Serial.println("Wakeup caused by touchpad");
    case ESP_SLEEP_WAKEUP_ULP : Serial.println("Wakeup caused by ULP program");
    default : Serial.printf("Wakeup was not caused by deep sleep: %d\n",wakeup_reason);
//client.publish("room/sleep", "Wakeup was not caused by deep sleep"); break; } }

void setup()
{
  Wire.begin();
  Wire.setClock(400000); //Increase I2C clock speed to 400kHz
  Serial.begin(115200); //serial transfer speed
  while (!Serial); //Wait for user to open terminal
  Serial.println("MLX90640 BME680 and SGP30 data read");
  if (isConnected() == false)
  {
    Serial.println("MLX90640 not detected. Halting.....");
    while (1);
  }

  //Get device parameters - initialization
  int status;
  uint16_t eeMLX90640[832];
  status = MLX90640_DumpEE(MLX90640_address, eeMLX90640);
  if (status != 0)
    Serial.println("Failed to load system parameters");
  status = MLX90640_ExtractParameters(eeMLX90640, &mlx90640);

```

```

if (status != 0)
    Serial.println("Parameter extraction failed");
//Set refresh rate
MLX90640_SetRefreshRate(MLX90640_address, 0x03); //Set rate to 2Hz effective - Works
//Set resolution
MLX90640_SetResolution(MLX90640_address, 0x00); //Set resolution to 19-bit resolution

Serial.println("Initializing BME680 sensor");
while (!BME680.begin(I2C_STANDARD_MODE)) // Start BME680 using I2C, use first device found
{
    Serial.println("Unable to find BME680. Trying again in 5 seconds.");
    delay(5000);
} // of loop until device is located
Serial.println("Setting 16x oversampling for all sensors");
BME680.setOversampling(TemperatureSensor, Oversample16); // Use enumerated type values
BME680.setOversampling(HumiditySensor, Oversample16); // Use enumerated type values
BME680.setOversampling(PressureSensor, Oversample16); // Use enumerated type values
Serial.println("Setting IIR filter to a value of 4 samples");
BME680.setIIRFilter(IIR4); // Use enumerated type values
Serial.print(F("Setting gas measurement to 320\\xC2\\xB0\\x43 for 150ms\\n")); // "°C" symbols
BME680.setGas(320,150); // 320°C for 150 milliseconds

while (mySensor.begin() == false) {
    Serial.println("No SGP30 Detected. Check connections. Trying again in 5 seconds.");
    delay(5000);
}
//Initializes sensor for air quality readings
mySensor.initAirQuality();
setup_wifi(); // Connect to network
client.setServer(broker, 1883);
}

void loop()
{
    if (!client.connected()) // Reconnect if connection is lost
    {
        reconnect();
    }
    client.loop();

    float vdd;
    float Ta;

    //Print the wakeup reason for ESP32
    print_wakeup_reason();

    for (byte x = 0 ; x < 2 ; x++) //access all pages
    {
        uint16_t mlx90640Frame[834];
        int status = MLX90640_GetFrameData(MLX90640_address, mlx90640Frame);
        vdd = MLX90640_GetVdd(mlx90640Frame, &mlx90640);
        Ta = MLX90640_GetTa(mlx90640Frame, &mlx90640);
        float tr = Ta - TA_SHIFT; //Reflected temperature based on the sensor ambient temperature
        float emissivity = 0.95;
        MLX90640_CalculateTo(mlx90640Frame, &mlx90640, emissivity, tr, mlx90640To);
    }

    for (int x = 0 ; x < 768 ; x++) //send data via serial
    {
        if(x % 32 == 0) Serial.println();
        Serial.print(mlx90640To[x], 2);
        Serial.print(", ");
    }
}

```

```

Serial.println("");
Serial.print("Vdd : ");
Serial.print(vdd, 2);
Serial.println(" V");
Serial.print("Ta : ");
Serial.print(Ta, 2);
Serial.println(" deg C");

static char    buf[120];                // Text buffer for sprintf
static char    bufID[17];              // for ID
static int32_t temp, humidity, pressure, gas;    // Variable to store readings
static float    alt;                   // temp variable for altitude
static uint16_t loopCounter = 0;       // Display iterations
Serial.print(F("\nLoop Temp\xC2\xB0\x43 Humid% Press hPa Alt m Air m")); // Show header plus unicode "°C"
Serial.print(F("\xE2\x84\xA6\n==== ===== \n")); // and "?" symbols
BME680.getSensorData(temp, humidity, pressure, gas); // Get the most recent readings
sprintf(buf, "%4d ", ++loopCounter%9999); // Clamp iterations to 9999,
int val_int;
uint8_t val_frac;
alt = altitude(pressure); // temp variable for altitude
val_int=(int)alt;
val_frac=(uint8_t)((alt - (float)val_int)*100);
//humidity correction from BME680 output
float humidity2 = (double) humidity / 1000 ; //humiditySensor.toPercent();
float temperature = (double) temp / 100; //humiditySensor.toDegC();
//Convert relative humidity to absolute humidity
double absHumidity = RHtoAbsolute(humidity2, temperature);
//Convert the double type humidity to a fixed point 8.8bit number
uint16_t sensHumidity = doubleToFixedPoint(absHumidity);
mySensor.setHumidity(sensHumidity);
Serial.print("Absolute Humidity Compensation set to: ");
Serial.print(absHumidity);
Serial.println("g/m^3 ");
delay(100);

//measure CO2 and TVOC levels
mySensor.measureAirQuality();
Serial.print("CO2: ");
Serial.print(mySensor.CO2);
Serial.print(" ppm\tTVOC: ");
Serial.print(mySensor.TVOC);
Serial.println(" ppb");
//get raw values for H2 and Ethanol
mySensor.measureRawSignals();
Serial.print("Raw H2: ");
Serial.print(mySensor.H2);
Serial.print(" \tRaw Ethanol: ");
Serial.println(mySensor.ethanol);

//MQTT Send
sprintf(bufID, "room/sensor/%s", SENSOR_ID);

sprintf(buf, "%d.%d, %d.%d, %d.%d, %d.%d, 0, 0, %f, %d, %d, %d, %d, 0, 0 ",
(int8_t)(temp/100), (uint8_t)(temp%100), (int8_t)(humidity/1000), (uint16_t)(humidity%1000),
(int16_t)(pressure/100), (uint8_t)(pressure%100), val_int, val_frac, (uint16_t)(gas/100), (uint8_t)(gas%100), absHumidity,
mySensor.CO2, mySensor.TVOC, mySensor.H2, mySensor.ethanol);
client.publish(bufID, buf); delay(300);

char payload[4608]; //lack 4608 3841
char buf1[6];

sprintf(bufID, "room/sensor/%s", THERMALCAM_ID);
dtostrf(mlx90640To[0], 5, 2, payload);

```



```

for (int x = 1 ; x < 768 ; x++)
{
    dtostrf(mlx90640To[x],5, 2, buf1);
    strcat(payload,"");
    strcat(payload,buf1);
}
client.publish_P(bufID,payload,4608); //4608 3841 //pubsubclient header file #define MQTT_MAX_PACKET_SIZE 4609
delay (1000);

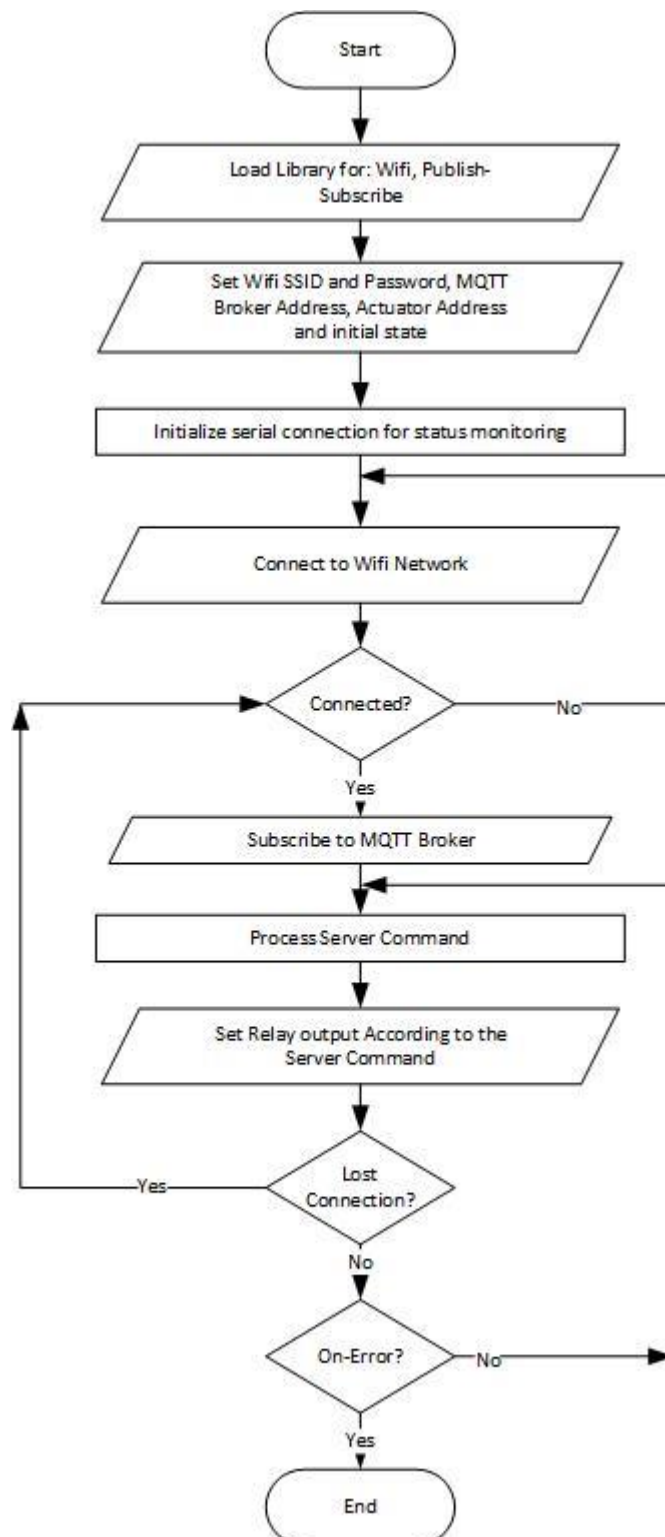
if (esp_sleep_get_wakeup_cause() == ESP_SLEEP_WAKEUP_EXT0)
{
    esp_sleep_enable_timer_wakeup(TIME_TO_SLEEP * uS_TO_S_FACTOR);
}
if (esp_sleep_get_wakeup_cause() != ESP_SLEEP_WAKEUP_EXT0) //ESP_SLEEP_WAKEUP_TIMER
{
    esp_sleep_enable_ext0_wakeup(GPIO_NUM_33,1); //1 = High, 0 = Low PIR Trigger
}
//Go to sleep now
Serial.println("Going to sleep now");
client.publish("room/sleep","T005 Going to sleep now");
esp_deep_sleep_start();
}

//Returns true if the MLX90640 is detected on the I2C bus
boolean isConnected()
{
    Wire.beginTransmission((uint8_t)MLX90640_address);
    if (Wire.endTransmission() != 0)
        return (false); //Sensor did not ACK
    return (true);
}

double RHtoAbsolute (float relHumidity, float tempC) {
    double eSat = 6.11 * pow(10.0, (7.5 * tempC / (237.7 + tempC)));
    double vaporPressure = (relHumidity * eSat) / 100; //millibars
    double absHumidity = 1000 * vaporPressure * 100 / ((tempC + 273) * 461.5); //Ideal gas law with unit conversions
    return absHumidity;
}

uint16_t doubleToFixedPoint( double number) {
    int power = 1 << 8;
    double number2 = number * power;
    uint16_t value = floor(number2 + 0.5);
    return value;
}

```

Actuator (Heater) Control Flow Chart:

Actuator (Heater) Control program:

```

/* ESP 32 for MQTT Solid State Relay activation
 * karyono@umn.ac.id
 * routine from Nathan S. Spark Fun Electronics
 * Rui Santos, randomnerdtutorials.com
 */

#include <PubSubClient.h>
#include <WiFi.h>
const char *ssid = "IoTNetwork1"; // name of your WiFi network
const char *password = "*****"; // password of the WiFi network
const char *ID = "Air Quallity"; // Name of device
const char *TOPIC = "room/actuator/A001"; // Topic to subscribe

IPAddress broker(192,168,0,101); // IP address of MQTT broker 192.168.0.101
WiFiClient wclient;
PubSubClient client(wclient); // Setup MQTT client
const int Relay = 27; // the Relay trigger pin (active low)

// Connect to WiFi network
void setup_wifi() {
  Serial.print("\nConnecting to ");
  Serial.println(ssid);
  WiFi.begin(ssid, password); // Connect to network
  while (WiFi.status() != WL_CONNECTED) { // Wait for connection
    delay(500);
    Serial.print(".");
  }
  Serial.println();
  Serial.println("WiFi connected");
  Serial.print("IP address: ");
  Serial.println(WiFi.localIP());
}

// Reconnect to client
void reconnect() {
  // Loop until we're reconnected
  while (!client.connected()) {
    Serial.print("Attempting MQTT connection...");
    // Attempt to connect
    if (client.connect(ID)) {
      Serial.println("connected");
      Serial.print("Subscribe to: ");
      Serial.println(TOPIC);
      Serial.println('\n');
      // Subscribe
      client.subscribe(TOPIC);
    } else {
      Serial.print("failed, rc=");
      Serial.print(client.state());
      Serial.println(" try again in 5 seconds");
      // Wait 5 seconds before retrying
      delay(5000); } }

void callback(char* topic, byte* message, unsigned int length) {
  Serial.print("Message arrived on topic: ");
  Serial.print(topic);
  Serial.print(". Message: ");
  String messageTemp;

  for (int i = 0; i < length; i++) {
    Serial.print((char)message[i]);

```

```
    messageTemp += (char)message[i];
}
Serial.println();

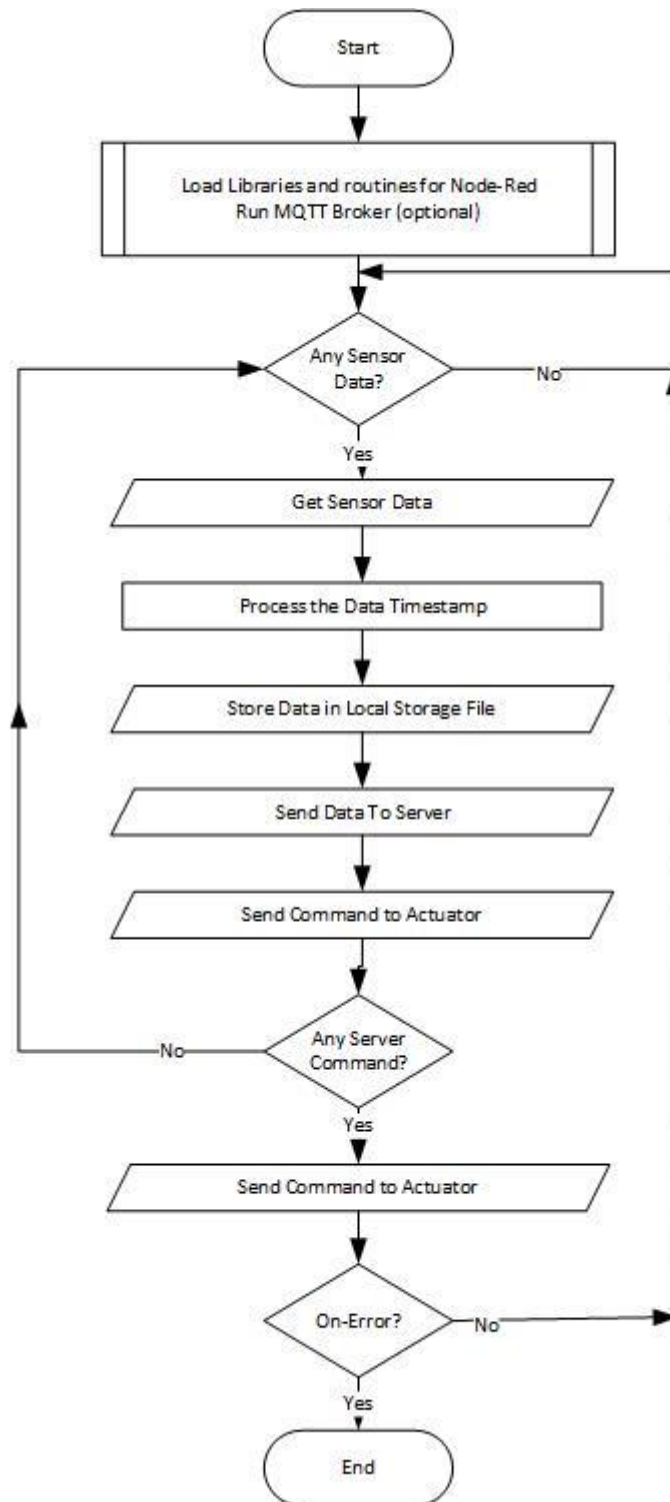
// check if the message is either "on" or "off".
// Changes the output state according to the message
if (String(topic) == TOPIC) {
    Serial.print("Changing output to ");
    if(messageTemp == "true"){
        Serial.println("on");
        digitalWrite(Relay, LOW);
    }
    else if(messageTemp == "false"){
        Serial.println("off");
        digitalWrite(Relay, HIGH);
    }
}
}

void setup()
{
    Serial.begin(115200); //serial transfer speed
    pinMode(Relay, OUTPUT);
    digitalWrite(Relay, HIGH);
    setup_wifi(); // Connect to network
    client.setServer(broker, 1883);
    client.setCallback(callback);
}

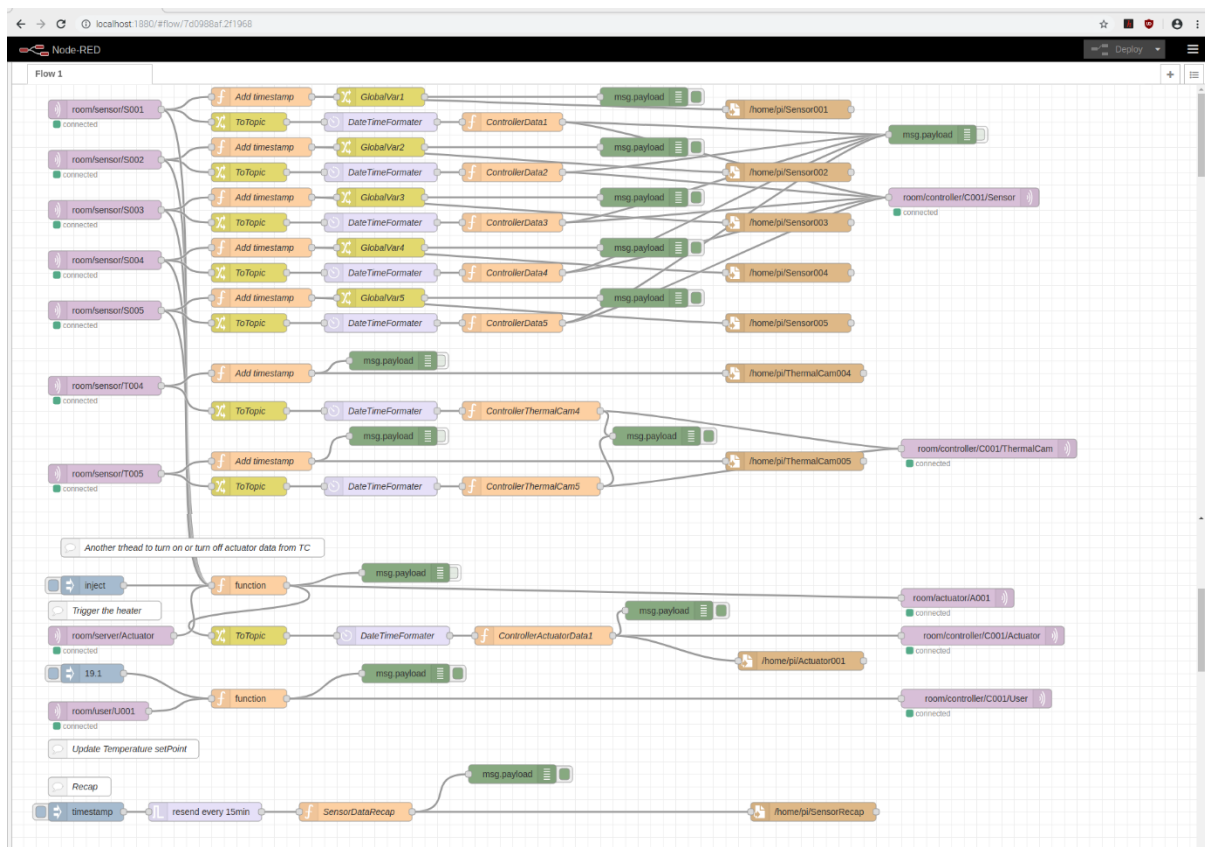
void loop()
{
    if (!client.connected()) // Reconnect if connection is lost
    {    reconnect(); }
    client.loop();
}
```

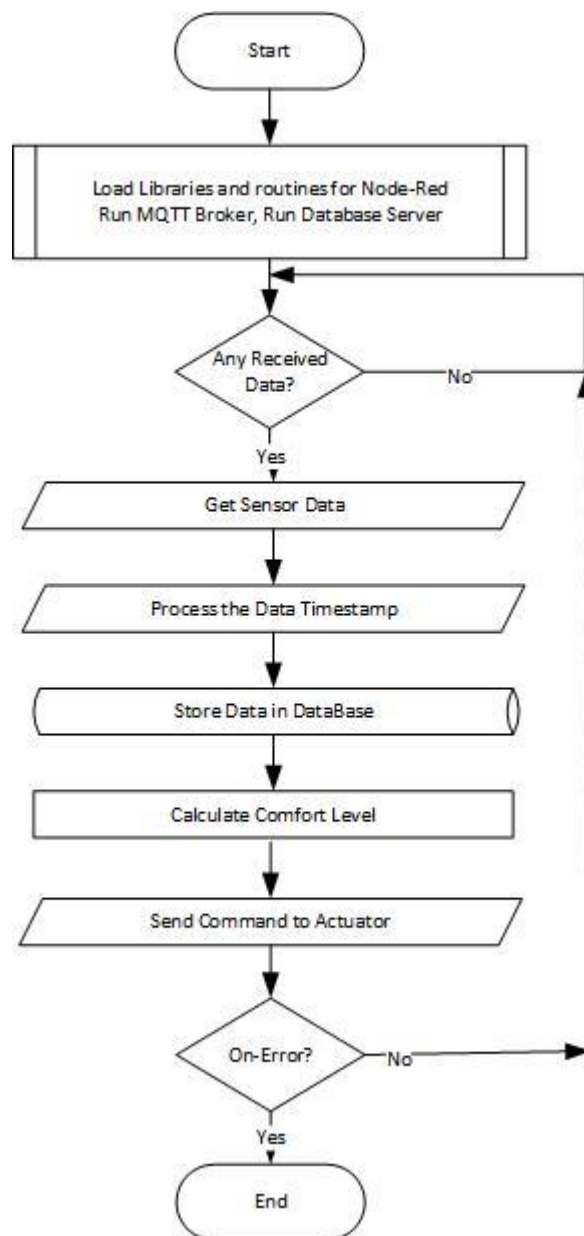
Appendix 5. Local Controller and Server Program

Flow Chart for Local Controller:

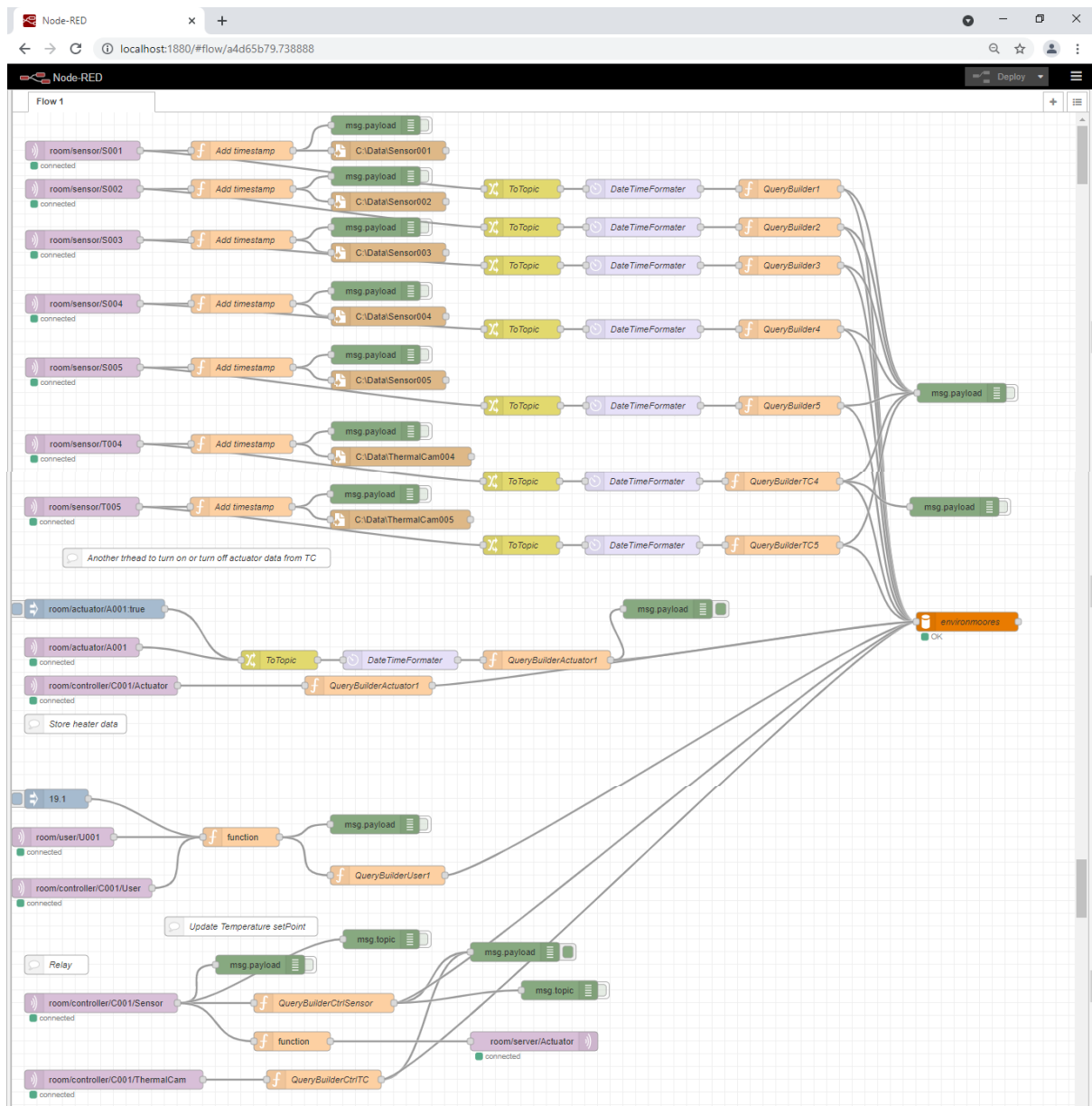


Node Red Program for Local Controller:



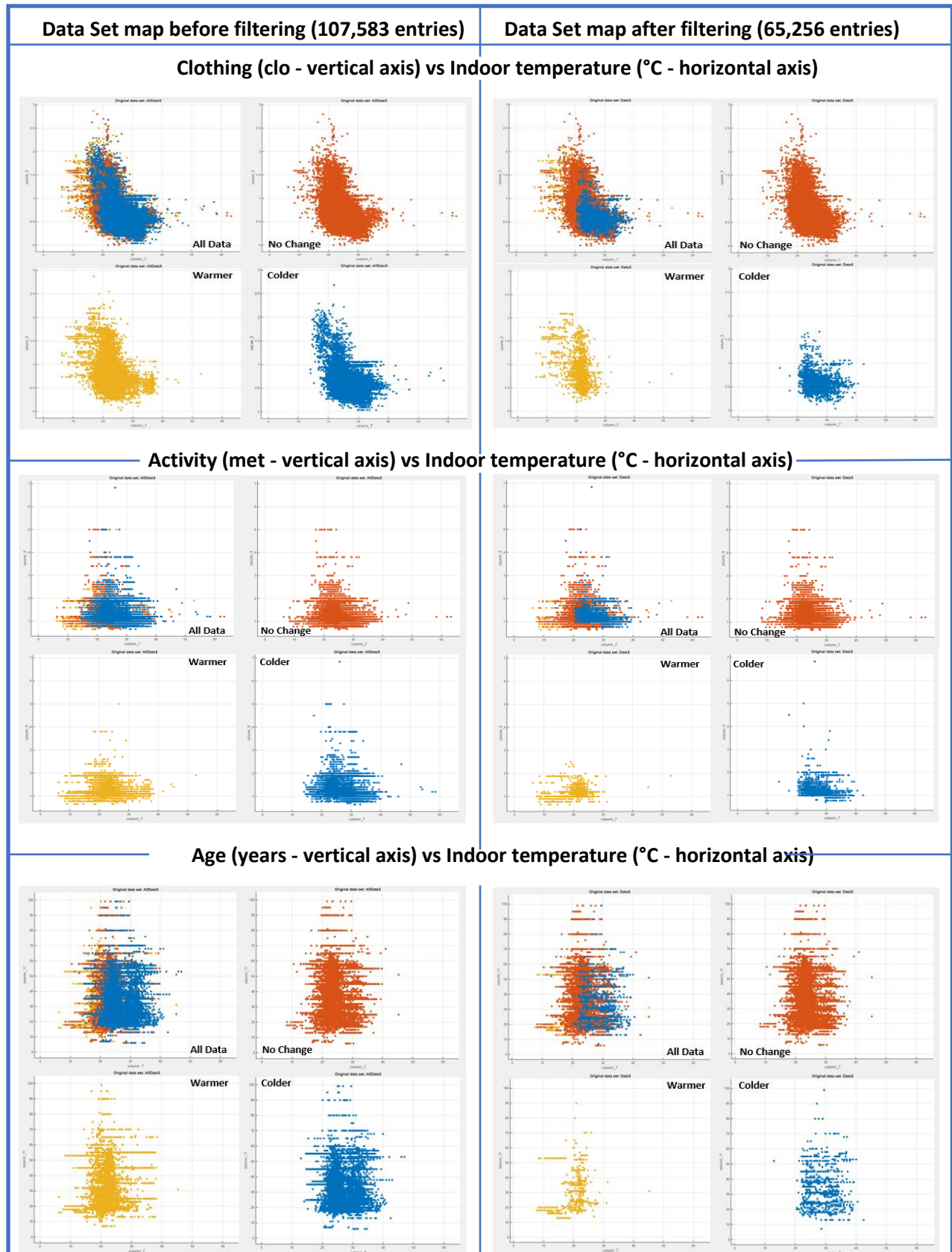
Flow Chart for Server:

Node Red Program for Server:



Appendix 6. Data Mapping for Learning Process

Data Mapping Before and After Filtering Process



Appendix 7. AI Classification Methods

CLASSIFICATION METHODS ACCURACY COMPARISON FOR DATABASE ALLOCATED FOR TRAINING AND VALIDATION (IN %)

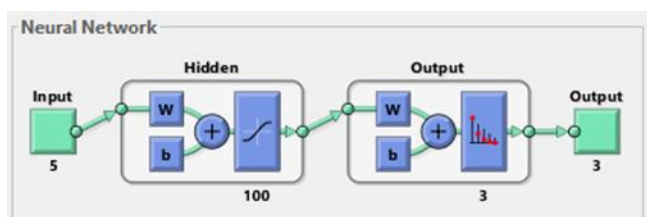
Classification Methods	Accuracy with all available data for training and validation (%) without PCA															Augmented Filtered ASHRAE without age Tested with All Data
	Filtered ASHRAE RP-884	Filtered ASHRAE RP-884 with All Data	Filtered ASHRAE RP-884 without age	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	
Fine Tree	59.20	89.60	53.90	53.80	42.50	90.20	51.60	48.50	90.30	51.90	45.00	89.80	52.40	49.00	89.70	93.80
Medium Tree	57.70	88.00	52.10	57.80	41.10	89.90	51.30	45.40	90.00	51.70	43.60	89.30	52.00	46.50	89.30	93.70
Coarse Tree	53.70	87.20	51.40	54.70	39.70	89.80	50.80	41.70	89.80	50.80	42.30	89.10	51.90	42.30	88.90	93.60
Linear Discriminant	51.40	87.30	52.00	52.00	38.50	89.80	51.30	40.70	89.50	52.30	42.00	89.00	51.60	43.60	88.70	93.60
Quadratic Discriminant	49.50	86.70	52.10	52.80	36.80	89.30	51.50	42.50	88.20	52.50	37.80	88.50	53.60	43.70	87.50	93.10
Gaussian Naïve Bayes	52.90	85.10	53.30	52.30	43.30	88.00	53.50	42.70	88.00	53.50	43.60	86.80	53.60	43.30	86.70	93.60
Kernel Naïve Bayes	55.70	87.50	52.30	55.70	43.20	90.20	51.90	42.60	90.10	51.80	47.40	89.10	52.20	46.00	89.10	95.50
Linear SVM	36.70	50.10	41.50	41.00	35.10	67.50	41.00	40.90	73.80	46.20	35.40	41.50	41.40	42.90	71.40	89.60
Quadratic SVM	38.20	50.30	41.50	41.40	35.10	67.50	41.00	40.90	73.80	46.20	35.40	41.50	41.40	42.90	71.40	89.60
Cubic SVM	27.10	47.20	41.40	41.40	35.10	67.50	41.00	40.90	73.80	46.20	35.40	41.50	41.40	42.90	71.40	89.60
Fine Gaussian SVM	45.40	53.60	42.50	52.10	41.20	38.70	41.50	56.10	74.80	46.90	41.40	42.70	42.40	53.60	73.20	89.70
Medium Gaussian SVM	38.50	51.80	42.40	45.20	38.70	38.20	41.20	49.70	74.00	46.40	38.10	41.90	41.80	47.40	72.20	89.70
Coarse Gaussian SVM	37.40	50.30	41.50	42.50	36.90	38.10	40.90	46.00	73.80	46.20	35.40	41.50	41.40	42.90	71.40	89.60
Fine KNN	73.00	95.60	53.10	87.20	50.70	91.10	51.90	79.30	97.10	55.90	56.00	92.40	54.40	81.20	97.40	98.80
Medium KNN	57.40	89.30	52.50	62.50	43.70	90.00	51.20	55.60	90.50	52.10	46.70	89.60	52.30	56.20	89.90	93.70
Coarse KNN	54.20	87.80	52.30	57.70	42.20	89.80	50.80	49.70	90.00	51.00	44.50	89.00	51.30	50.50	89.20	93.70
Cosine KNN	56.60	88.90	52.50	60.90	43.40	89.90	51.10	53.80	90.30	51.80	46.30	89.40	52.10	54.50	89.40	93.70
Cubic KNN	57.30	89.30	52.50	62.20	43.70	90.00	51.20	55.50	90.50	52.10	46.60	89.60	52.30	56.10	89.90	93.70
Weighted KNN	73.00	95.60	53.60	87.30	50.90	91.10	51.60	70.80	97.20	55.00	56.10	92.40	53.80	81.60	97.40	98.80
Ensemble Bagged Trees	58.30	88.30	52.10	58.20	41.60	89.90	51.10	45.70	90.00	51.00	43.70	89.30	51.60	47.30	89.30	93.70
Ensemble Subspace Discriminal	52.70	87.20	52.10	52.70	43.90	90.00	51.10	41.70	90.10	51.20	44.90	89.20	51.90	43.80	89.90	93.70
Ensemble Subspace KNN	94.10	99.10	53.50	78.50	79.80	97.60	56.40	59.50	93.80	53.30	86.30	96.60	58.50	58.50	93.20	98.80
Ensemble RUS Boosted Trees	41.20	49.20	47.00	42.90	41.10	57.20	50.10	42.40	43.80	47.10	36.30	48.90	47.70	35.00	46.70	93.70
Narrow Neural Network	40.00	88.50	52.50	45.90	38.00	35.50	31.90	47.30	73.10	43.40	37.30	89.20	42.00	45.90	71.40	93.70
Medium Neural Network	40.80	52.30	42.50	46.90	38.40	37.90	41.60	49.50	74.10	46.80	37.80	89.40	42.10	47.20	72.20	96.00
Wide Neural Network	42.20	90.40	52.50	50.10	34.60	36.20	32.20	49.30	90.30	52.00	38.80	42.20	42.60	49.40	72.50	96.10
Bi-layered Neural Network	40.50	88.80	52.50	48.50	38.20	89.70	51.30	49.50	73.30	44.10	37.80	89.30	51.90	47.80	89.20	96.00
Tri-layered Neural Network	55.50	52.30	42.50	48.60	26.80	89.70	51.30	50.50	90.20	51.70	38.00	89.40	52.30	48.20	89.50	96.00
Average	52.36	77.68	49.49	55.21	41.79	72.86	47.76	49.65	82.68	49.74	43.62	76.82	49.18	49.84	82.53	90.16
Classification Methods	Filtered ASHRAE RP-884	Filtered ASHRAE RP-884 with All Data	Filtered ASHRAE RP-884 without age	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Filtered ASHRAE Global Thermal Comfort Db II	Augmented Filtered ASHRAE without age Tested with All Data

Parameters for Each Classification Methods :

Fine Tree	Gini's diversity index, 100 max number of splits
Medium Tree	Gini's diversity index, 20 max number of splits
Coarse Tree	Gini's diversity index, 4 max number of splits
Linear Discriminant	Full covariance structure
Quadratic Discriminant	Full covariance structure
Gaussian Naïve Bayes	Gaussian, unbounded support
Kernel Naïve Bayes	Gaussian Kernel type, unbounded support
Linear SVM	1 box constraint level, auto kernel scale mode, one-vs-one multiclass method, standardise data
Quadratic SVM	1 box constraint level, auto kernel scale mode, one-vs-one multiclass method, standardise data
Cubic SVM	1 box constraint level, auto kernel scale mode, one-vs-one multiclass method, standardise data
Fine Gaussian SVM	1 box constraint level, kernel scale: 0.56, one-vs-one multiclass method, standardise data
Medium Gaussian SVM	1 box constraint level, kernel scale: 2.2, one-vs-one multiclass method, standardise data
Coarse Gaussian SVM	1 box constraint level, kernel scale: 8.9, one-vs-one multiclass method, standardise data
Fine KNN	1 Number of neighbours, Euclidean distance metric, Equal distance weight, standardise data
Medium KNN	10 Number of neighbours, Euclidean distance metric, Equal distance weight, standardise data
Coarse KNN	100 Number of neighbours, Euclidean distance metric, Equal distance weight, standardise data
Cosine KNN	10 Number of neighbours, Cosine distance metric, Equal distance weight, standardise data
Cubic KNN	10 Number of neighbours, Minkowski (Cubic) distance metric, Equal distance weight, standardise data
Weighted KNN	10 Number of neighbours, Euclidean distance metric, Squared distance weight, standardise data
Ensemble Boosted Trees	AdaBoost ensemble method, Decision Tree learner type, 20 maximum number of splits, 30 number of learners, 0.1 learning rate

Ensemble Bagged Trees	Bag ensemble method, Decision Tree learner type, 65260 maximum number of splits, 30 number of learners
Ensemble Subspace Discriminant	Subspace ensemble method, Discriminant learner type, 30 number of learners, 3 Subspace dimension
Ensemble Subspace KNN	Subspace ensemble method, Nearest neighbours learner type, 30 number of learners, 3 Subspace dimension
Ensemble RUS Boosted Trees	RUSBoost ensemble method, Decision Tree learner type, 20 maximum number of splits, 30 number of learners, 0.1 learning rate
Narrow Neural Network	1 Number of fully connected layers, layer size 10, ReLU Activation, 1000 iteration limit, 0 regularisation strength (Lambda), standardise data
Medium Neural Network	1 Number of fully connected layers, layer size 25, ReLU Activation, 1000 iteration limit, 0 regularisation strength (Lambda), standardise data
Wide Neural Network	1 Number of fully connected layers, layer size 100, ReLU Activation, 1000 iteration limit, 0 regularisation strength (Lambda), standardise data
Bilayered Neural Network	2 Number of fully connected layers, first and second layer size 10, ReLU Activation, 1000 iteration limit, 0 regularisation strength (Lambda), standardise data
Trilayered Neural Network	3 Number of fully connected layers, first, second and third layer size 10, ReLU Activation, 1000 iteration limit, 0 regularisation strength (Lambda), standardise data

ARTIFICIAL NEURAL NETWORK GENERATOR FUNCTION IN MATLAB:



```
function [Y,Xf,Af] = NN_All_DATA_Filter_Augmented(X,~,~)
%MYNEURALNETWORKFUNCTION neural network simulation function.
% Auto-generated by MATLAB, 13-Dec-2021 20:18:12.
% [Y] = myNeuralNetworkFunction(X,~,~) takes these arguments:
% X = 1xTS cell, 1 inputs over TS timesteps
% Each X{1,ts} = Qx5 matrix, input #1 at timestep ts. and returns:
% Y = 1xTS cell of 1 outputs over TS timesteps.
% Each Y{1,ts} = Qx3 matrix, output #1 at timestep ts.
% where Q is number of samples (or series) and TS is the number of timesteps.
% ===== NEURAL NETWORK CONSTANTS =====
```

% Input 1

```
x1_step1.xoffset = [0;0.65;-2;0.4;6];
x1_step1.gain =
[0.692041522491349;0.323624595469256;0.0306748466257669;0.0200803212851406;0.021505376344086];
x1_step1.ymin = -1;
```

% Layer 1

```
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0.074483730348480672867 2.0356883136258625555 -1.5061423589293538861 1.6478230004911569306 -
1.6904616999084620677;2.4857644060856594059 -0.90379658981683852481 2.0729301105235853342 -
1.5728977455334909319 -0.85439379803296655602;-0.33460523582985685076 -1.0436343815915747335
0.67361046512585798229 -1.9002021571356708662 -2.8217061714562663433;1.8209703541058619436 -
0.96075996885145176218 -0.89840775618274804071 2.5503734095746386501 0.78705789552229432626;-
0.63685784923824695358 -3.0158911222406135089 -2.7642414711957168372 0.081124498816804557766 -
0.5866377093748351701;-1.0128237261188319795 -1.0205142077699684844 2.258594208737778164 -
2.1163610073255028077 -0.63872708956974022509;1.0497793483329764808 0.45163891152118057493
0.34117375977606301252 -3.0348379787084023285 0.85075727324912164828;1.386316113321075294 -
1.9283270834904324698 0.86231970279884762043 0.27983538961784037991 1.9762739004299818557;
0.79858549018340163617 1.4468367730312727826 -1.144641107372331934 2.6549535253692755354
1.0825138732824148846;-1.8659157121931515544 -0.35867358162868639981 -1.2869482016635811483 -
2.3866795008506107578 0.0047177136742158334512;-1.0293504780729252346 1.8863772125672690905
1.5667333805908525424 -1.9393834947269898983 -0.98165358139780445335;-1.5800403931034876504
1.0250428689976440744 -1.2168445371697245161 1.8049458139865770523 -1.0259117881693613494;-
1.5658512891014411128 -0.5032690181234804605 -2.3018484217536472336 -1.6491240938939706329
1.2492373974622228427;-2.7819130052092120309 0.034019462524076317378 0.16389306385110985476 -
1.4084649113808331844 -1.0675655715903287213;-1.1269456143428169259 2.528738076667925494 -
1.4435412647351832938 0.62679750838672976254 -1.9695645166676478688];

% Layer 2

b2 = [0.44355050440920151811;-0.47443911143403744157;-0.25403225607630736116];

LW2_1 = [0.82122252591881295114 -0.40757915248685228082 0.53961598631511820123

0.021462844525445338301 0.72555745411823757696 0.32629463444057216215 0.42726025316586285774
0.42302689345992766645 0.31446178580502437416 -0.67598688408301732533 0.26545653833845500591
0.67671010641157403054 -0.76950979258171292585 -1.2107006845414105545 -0.45038078397529229813
0.83240839814607436864 1.4654391559978994231 -0.036163779807709968417 -0.4656536288650454658
0.48524901618662069636 1.7132764725520028826 0.94736277283507885905 0.86820181354980985322 -
0.6509967543547582336 -0.72060635830171027028 0.37384248994953767076 -0.63607992338644880892 -

0.03124768421004951377 -0.30418444147367279529 -0.99247525465705277448 -1.0168400800868941936
 1.0064628665791852669 -0.24054069184722742802 -0.51637693678291207711 -0.20094187142752095721 -
 0.9874970215596208245 -0.12098145873142830686 -0.16256280248693683044 -0.21127151034498126148
 1.6740852548969480384 -0.37503214614498509016 1.0760004485357546056 0.25435656596411887476
 0.17738536923267819723 -0.35042284543179397227 -0.7365466809556772132 0.98617805941814495885 -
 1.0830701489077039223 -1.5023231536289345378 0.4982203895083118228 -0.60347832586189187332 -
 0.71815361102970154406 1.3705505230864063471 0.64398833755907380905 -0.87181481845131725272
 0.60138942840981335358 0.19775639434318526 -0.92345994826914046261 0.26149467883023069792 -
 0.63262271978229089875 -0.64515622009751161237 -0.58986182683165311325 -0.85910250815115951628
 0.087570201067586755928 1.1863562536515226409 -0.62011659195628865415 -0.39520063466549837372
 -1.1789213925561567997 1.0957479326559584898 0.27624719539130332402 1.1924537717282892579
 0.33757527243659046778 -0.30433228041021759269 1.117577477066995506 1.0199655841669119649 -
 1.1390800025791125716 -0.92827085543174048254 0.39954734121850976614 0.35092442676609530983 -
 0.26384623347255325987 -0.68297372375793308219 0.18868784949831160502 -1.8116949954491718966
 0.81792837469566526121 0.3889607612007897619 -1.3228469310124464364 -0.45953390465675475474 -
 0.54311982075452058805 0.11879171550038715444 -1.6705396172646544972 0.68719071251676222545
 0.90280716384206860514 -0.63963105633332040245 0.73611531927405149389 -0.97376031835614096366
 -0.19755876539702624251 -0.73163800710579629527 -0.28354721724955828099 0.60202018954731728595
 0.40142397790110917466;0.78926661718783963639 0.13158004311324644764 -0.7221004328007404327 -
 1.0835195490490667769 0.17799242814454127593 1.3691041597705966293 0.054586854527874088816
 0.11563047181052285572 -0.19540567691657659277 1.1864693519241238384 -0.033187969991714742768
 0.1715973401709514623 -0.064144599854565997887 -0.65834234612348774274 -0.14283313932196578522
 -0.3667210391455033025 0.42739263537781280178 -0.089802300635897724934 -0.61732628597307714902
 -0.46774549427829409387 -0.52354711056066971508 0.31033628691514364428 1.0529076752332047207 -
 0.0088634397731239267237 0.52809803090844642526 -0.5903147772009628147 -
 0.062744902678186956213 -0.77405534935075304137 -0.42324737558696923223 -
 0.23221189372403977513 -0.34923757404309280217 0.57564958872474447649 0.56286739640070104773 -
 1.1471438758179870465 -0.75814292256268323023 -1.1483183139425872099 -0.947299309889549912
 0.68401507469399125405 -0.26538106755912233004 -0.60337258615401911932 -0.3132036836464473506 -
 0.034606317145721855744 -0.73011999996377752176 -0.39588970926048711041
 0.028188924593117024864 -0.4320518859974397663 -0.65235816352869224755 0.14658639300075296252
 -1.0904811790890820422 0.15578922667246547507 -0.20303782488879645873 0.099861219883756860427
 -1.0553706066411587816 0.85607442896974927926 -1.0022042286790231458 0.06420699712920888147
 0.086612167017497340704 0.92330944409785042915 0.17876404505034618198 -0.94874167967354205988
 0.81865927042703134919 -0.56651545919524359807 -0.52705672567913852689 -0.39287829036097998703
 0.83065609853982524946 -0.068596862623565277306 1.0373663458346240596 -0.97298198073358665994
 0.62800228421651460575 0.61794644965198575193 -0.60256379989552666387 0.77948576114536094472 -
 0.24933625661228475678 0.19160946850013860221 1.245017388469840558 -0.69191200872154345891 -
 0.044737781712246856014 0.10648791144423720711 0.33801572291064979625 1.2248783397229763281
 0.59082607227622785384 -0.70491296153403781855 0.57565698211404514595 -0.57439246954743283791
 -0.20062990367990518603 -0.49223060721778966187 1.1785299442464312047 -0.76487540328699776815 -
 0.083657750427619317901 -0.58476354252661477684 -0.49586716235044231427
 0.62735784852350173768 -0.78123819959157903003 -0.72734610514511377488 -0.44493701670660051883
 0.67964789534715519537 0.73853438062274467946 0.25937228665568223818 0.67597379858827222332 -
 0.66535417295450327568;0.4442163790398941936 -0.11932437824009616001 -0.098692158961562984065
 0.0069321726891970808157 -0.32611850816751491999 -0.37700687695631790453
 0.067401472226633951657 -0.2006493063343933736 0.17203490198579274306 -0.89752448870906120781
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 -0.50096616492626555583 0.64050809818756559988 -0.97610693645295376619 0.9254382585749848511 -
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 0.15672006591545942222 0.070212174442950622821 -0.17301501034799557366 0.5951594760101353021
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 0.38549422573966773964 -0.55822474265902577439 -0.10185024382277721444 0.4488764720329473934
 0.017507320467880040094 0.3526608011695152034 0.26515987151256076304 0.063640503100797912728


```

0.21442960550140116593 0.80040668722093843979 0.061506059740892668475 -0.97746748650601211761
0.83162940823158548742 -0.72299784889134366406 0.38912201115474226443 -0.10426633110096145129
-0.047904375908753862867 0.71106485679256636878 0.39860454780564569255 -
0.17636731738552030579 0.93398611913659357331 -0.054407474344754340467 -0.5496419115054873572
-0.24841594904518501941 0.7775343550917612756 -0.47043945212577337189 0.53031312431505550631
0.61754248767757613514 -0.45565556506648480228 0.35457245204666221206 1.049734936937525509 -
1.4786180498542309536 -1.4236897083458739388 -0.41240545281576818093 -0.36638253001400861164 -
0.76956431837735206347 0.093979190592540756688 0.75426971729941905132 0.65740465661596358959
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1.2949670540588857914 -0.11919101143890242778 -0.32823603578144844306 0.16227128243954086484
0.43545749314702608679 1.7070096360605264696 -0.82322062474536450427 0.47141352522500917788
0.46565707174739479068 0.94100654375305503585 0.19904399660312932507 -1.0546777720672770862
0.61469317118847832671 1.5101136491272113549 0.55828366578691857036 1.0297762158462775428];

```

```
% ===== SIMULATION =====
```

```
% Format Input Arguments
```

```
isCellX = iscell(X);
```

```
if ~isCellX
```

```
    X = {X};
```

```
end
```

```
% Dimensions
```

```
TS = size(X,2); % timesteps
```

```
if ~isempty(X)
```

```
    Q = size(X{1},1); % samples/series
```

```
else
```

```
    Q = 0;
```

```
end
```

```
% Allocate Outputs
```

```
Y = cell(1,TS);
```

```
% Time loop
```

```
for ts=1:TS
```

```
    % Input 1
```

```
    X{1,ts} = X{1,ts}';
```

```
    Xp1 = mapminmax_apply(X{1,ts},x1_step1);
```

```
    % Layer 1
```

```
    a1 = tansig_apply(repmat(b1,1,Q) + IW1_1*Xp1);
```

```
    % Layer 2
```

```
    a2 = softmax_apply(repmat(b2,1,Q) + LW2_1*a1);
```

```
    % Output 1
```

```
    Y{1,ts} = a2;
```

```
    Y{1,ts} = Y{1,ts}';
```

```
end
```

```
% Final Delay States
```

```
Xf = cell(1,0);
```

```
Af = cell(2,0);
```

```
% Format Output Arguments
```

```
if ~isCellX
```

```
    Y = cell2mat(Y);
```

```
end
```

```
end
```

```
% ===== MODULE FUNCTIONS =====
```

```
% Map Minimum and Maximum Input Processing Function
```

```
function y = mapminmax_apply(x,settings)
```

```
y = bsxfun(@minus,x,settings.xoffset);
```

```
y = bsxfun(@times,y,settings.gain);
```

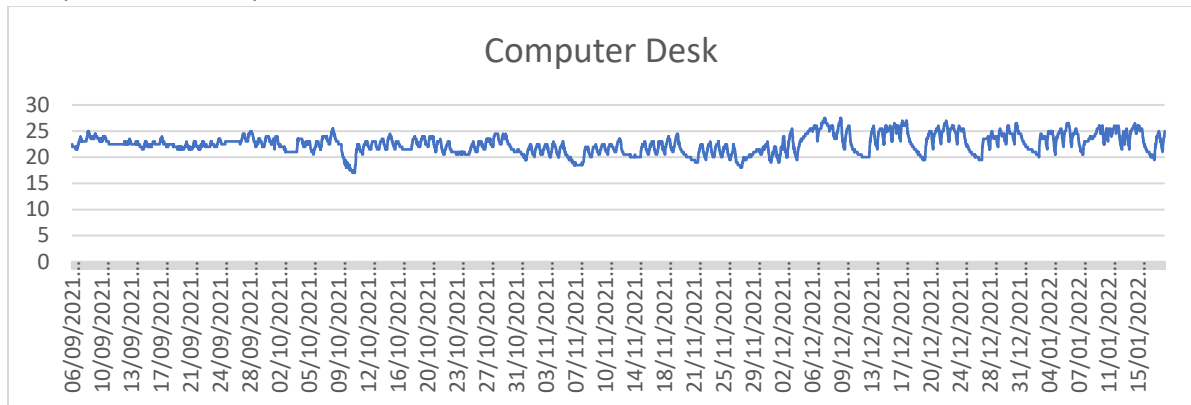
```
y = bsxfun(@plus,y,settings.ymin);
```

```
end
% Competitive Soft Transfer Function
function a = softmax_apply(n,~)
if isa(n,'gpuArray')
    a = iSoftmaxApplyGPU(n);
else
    a = iSoftmaxApplyCPU(n);
end
end
function a = iSoftmaxApplyCPU(n)
nmax = max(n,[],1);
n = bsxfun(@minus,n,nmax);
numerator = exp(n);
denominator = sum(numerator,1);
denominator(denominator == 0) = 1;
a = bsxfun(@rdivide,numerator,denominator);
end
function a = iSoftmaxApplyGPU(n)
nmax = max(n,[],1);
numerator = arrayfun(@iSoftmaxApplyGPUHelper1,n,nmax);
denominator = sum(numerator,1);
a = arrayfun(@iSoftmaxApplyGPUHelper2,numerator,denominator);
end
function numerator = iSoftmaxApplyGPUHelper1(n,nmax)
numerator = exp(n - nmax);
end
function a = iSoftmaxApplyGPUHelper2(numerator,denominator)
if (denominator == 0)
    a = numerator;
else
    a = numerator ./ denominator;
end
end
% Sigmoid Symmetric Transfer Function
function a = tansig_apply(n,~)
a = 2 ./ (1 + exp(-2*n)) - 1;
end
```

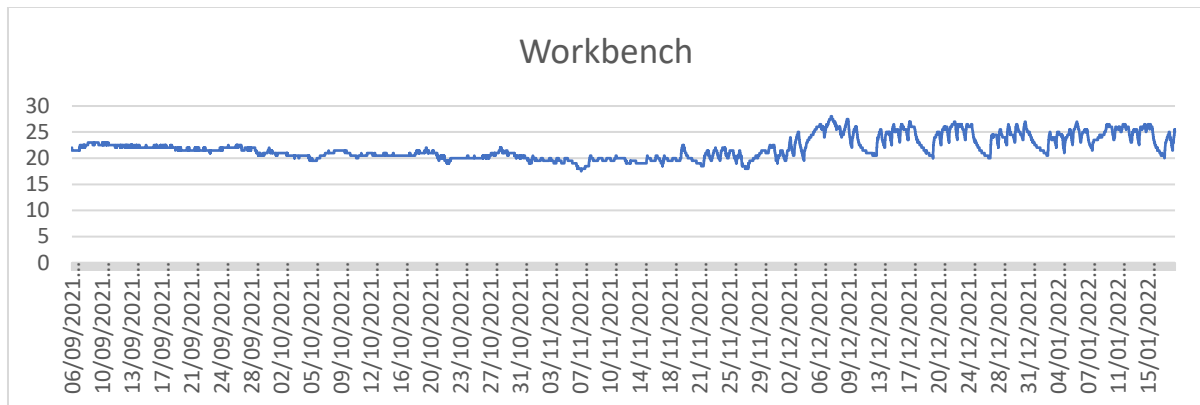
Function call: NN_All_DATA_Filter_Augmented([clo met Temp Hum age]);

Appendix 8. Laboratory Trial Results

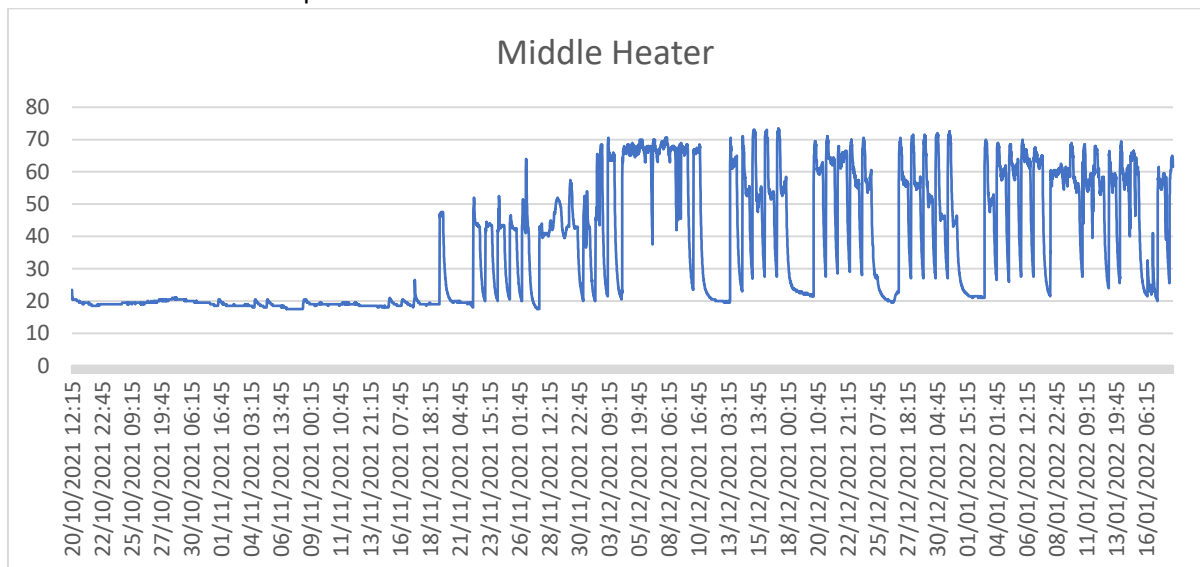
Computer Desk Temperature:



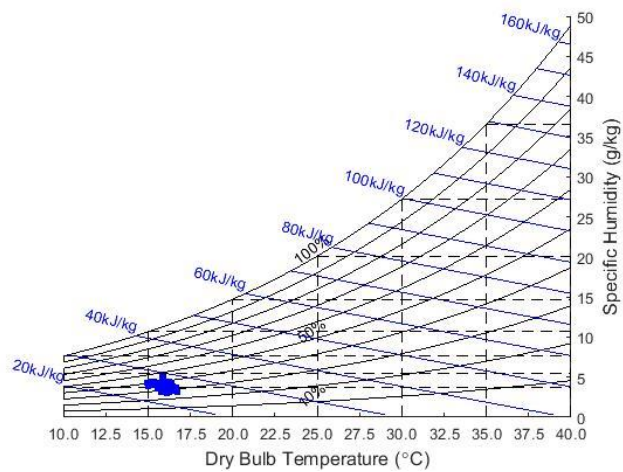
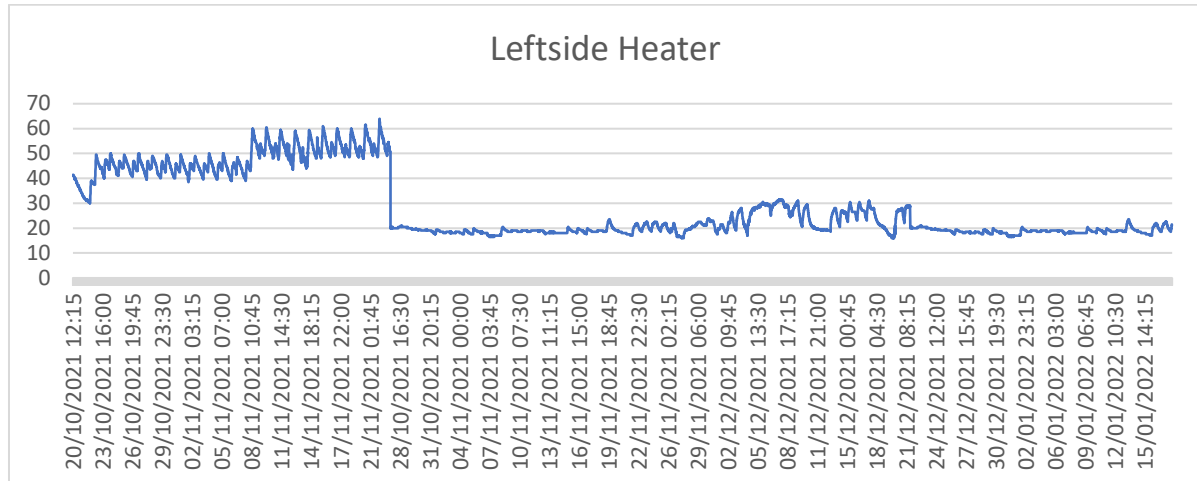
Workbench Temperature:



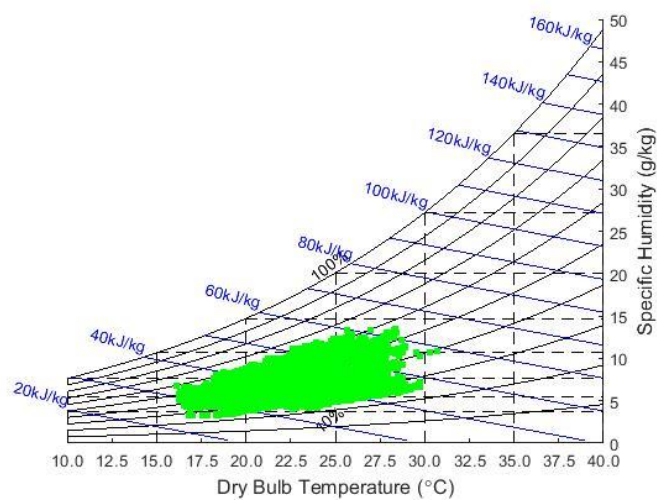
Middle room heater temperature:



Left side room heater temperature:



The psychrometric mapping of uncomfortable zone detected by sensor 3.



The psychrometric mapping of comfort zone detected by sensor 3.

Appendix 9. BRE House Trial Results

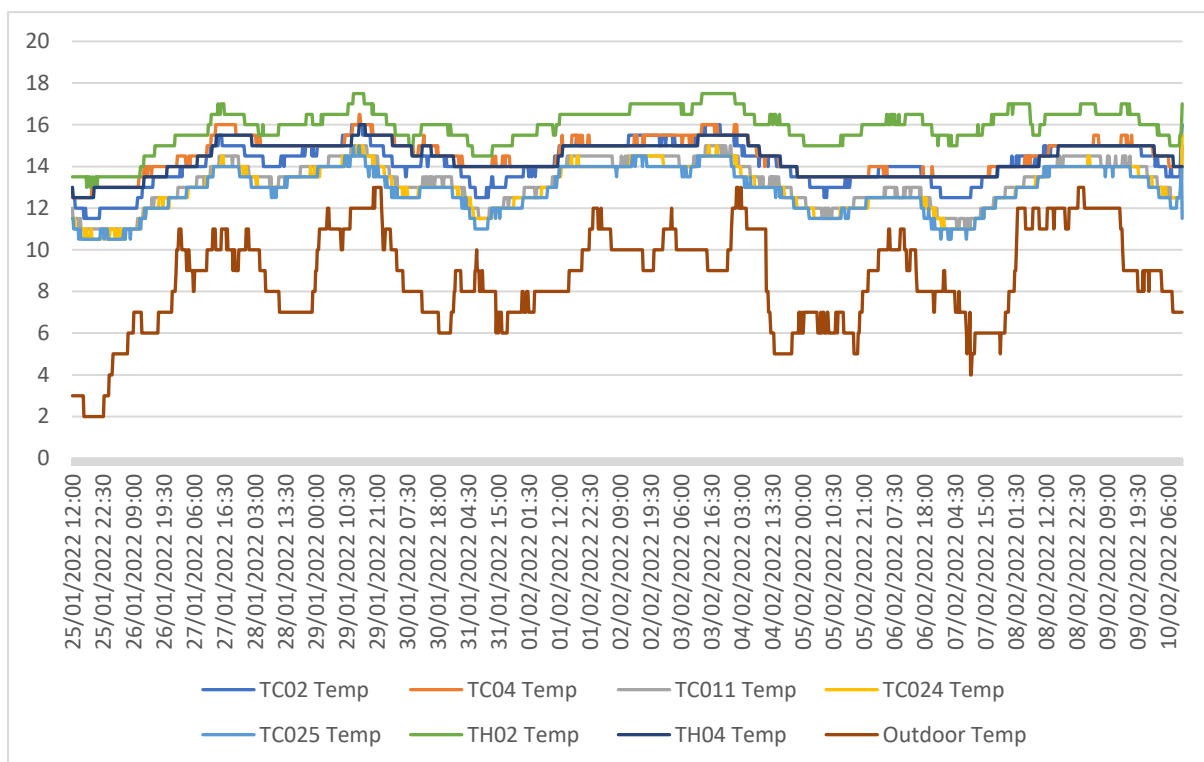
The Summary of the BRE House Trials

No People Present					People Present									
					Day					Night				
Test Period	Avg Outdoor Temp	Avg Stairs Temp	Avg Room Temp	Comfort %	Test Period	Avg Outdoor Temp	Avg Stairs Temp	Avg Room Temp	Comfort %	Test Period	Avg Outdoor Temp	Avg Stairs Temp	Avg Room Temp	Comfort %
1	8.53	14.10	14.53	36.03	3	7.23	14.29	14.37	20.62	5	9.06	16.81	17.83	100
2	7.96	13.80	13.74	3.50	4	6.89	14.70	14.08	23.85	7	8.27	15.29	16.46	71.09
9	12.93	19.11	19.27	100.00	8	9.79	16.24	16.77	62.13	10	11.40	18.85	19.18	100

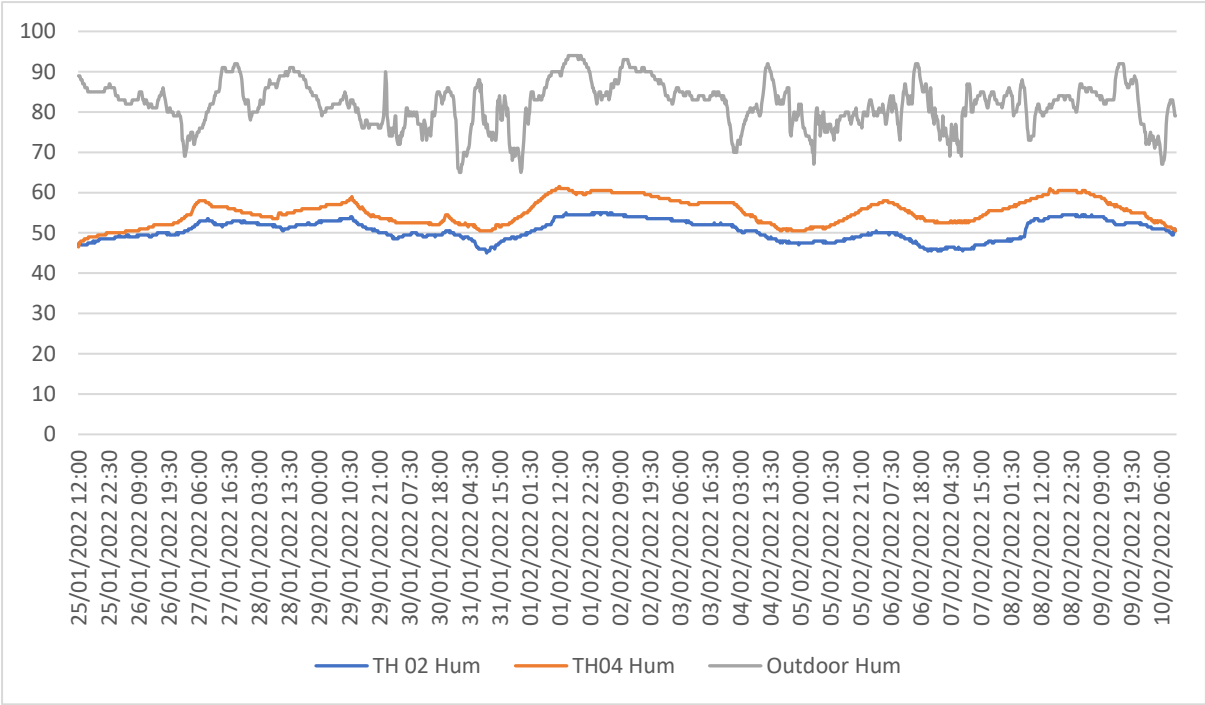
All Temperatures are in °C and Relative Humidity in %.

First Period

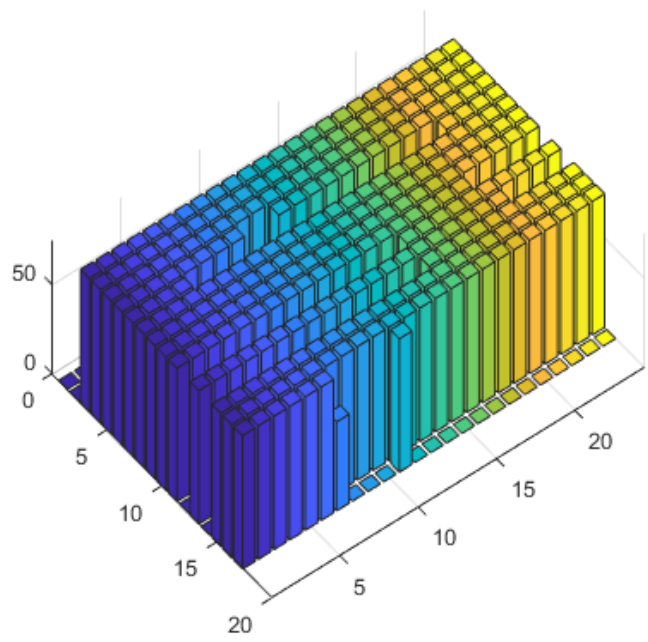
Temperature:



Humidity:



TH002 Desk

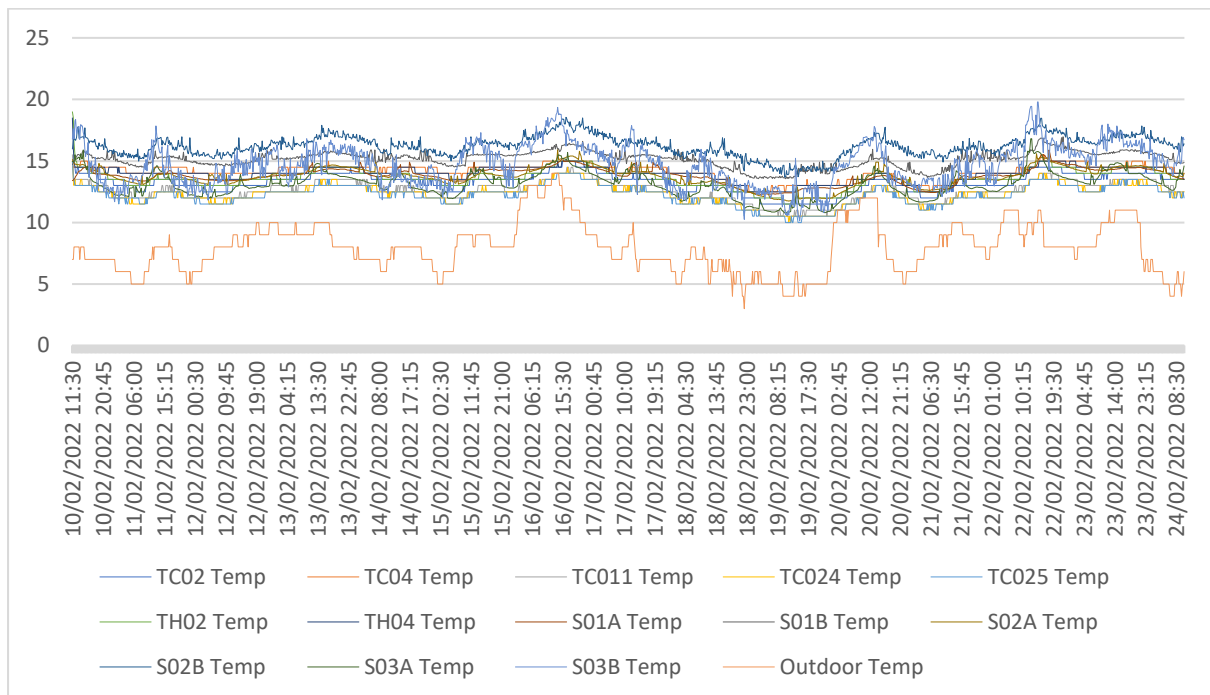


Second Period

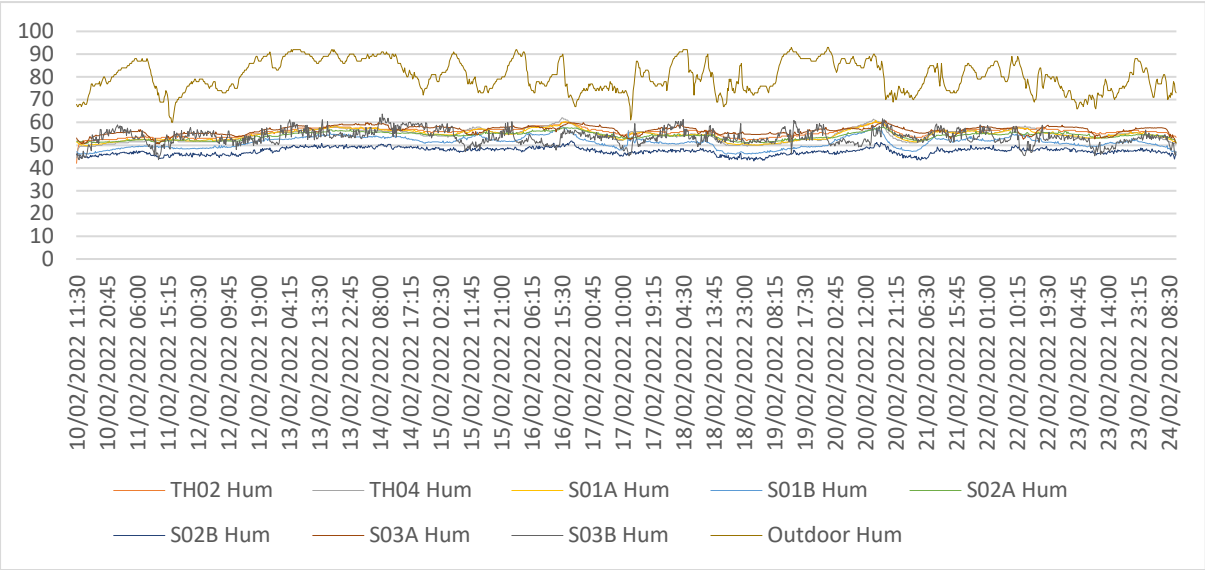
Sensor	Location	Installation Date	Data Processing
01	Outside room, stairs	10/02/2022 11:30	24/02/2022 11:00
02	desktop	10/02/2022 11:30	24/02/2022 11:00
03	window	10/02/2022 11:30	24/02/2022 11:00
05	desktop	10/02/2022 11:30	24/02/2022 11:00
TC011	heater (surface)	10/02/2022 11:30	24/02/2022 11:00
TC024	heater (top left)	10/02/2022 11:30	24/02/2022 11:00
TC025	heater (top right)	10/02/2022 11:30	24/02/2022 11:00
TH002	desk	10/02/2022 11:30	24/02/2022 11:00
TH004	Outside room, stairs	10/02/2022 11:30	24/02/2022 11:00

Temperature	TC02 Temp	TC04 Temp	TC011 Temp	TC024 Temp	TC025 Temp	TH02 Temp	TH04 Temp	S01A Temp	S01B Temp	S02A Temp	S02B Temp	S03A Temp	S03B Temp	Outdoor Temp
Max	15.00	15.50	15.50	15.00	15.00	19.00	18.50	15.90	16.98	15.90	18.57	16.80	19.81	14.00
Min	11.50	12.50	10.50	10.00	10.00	11.50	12.50	12.29	13.56	11.74	13.69	10.76	10.12	3.00
Average	13.24	14.13	12.60	12.33	12.22	13.57	13.95	13.80	15.14	13.74	16.21	13.10	14.70	7.96
StdDev	0.78	0.63	0.80	0.82	0.83	0.81	0.64	0.66	0.65	0.79	0.85	1.04	1.68	2.07
Humidity						TH02 Hum	TH04 Hum	S01A Hum	S01B Hum	S02A Hum	S02B Hum	S03A Hum	S03B Hum	Outdoor Hum
Max						60.00	62.00	60.95	58.16	57.81	51.93	60.77	63.73	93.00
Min						40.00	39.50	49.68	45.94	50.75	43.11	50.59	43.55	60.00
Average						55.75	54.45	54.64	51.22	54.10	47.40	56.52	53.57	80.33
StdDev						1.95	2.66	2.32	2.53	1.61	1.56	1.81	3.21	6.87

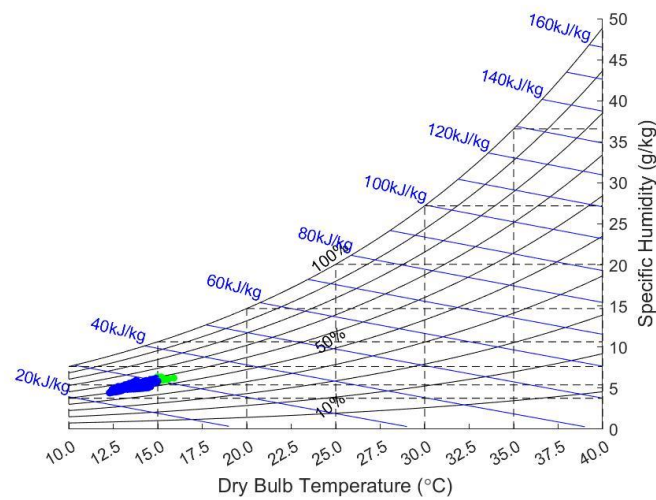
Temperature:



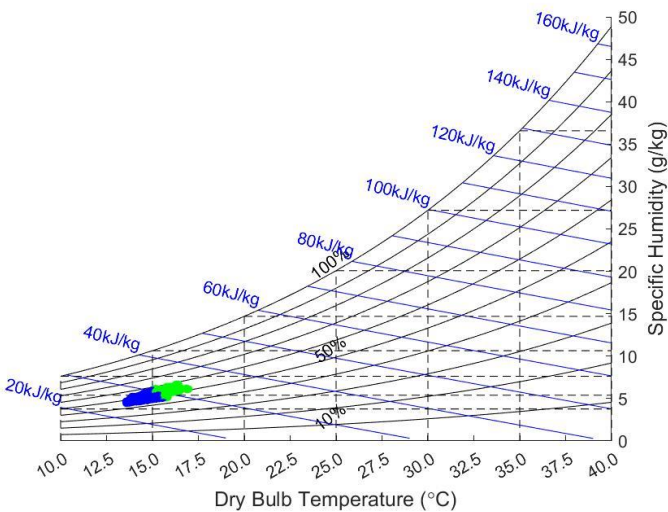
Humidity:



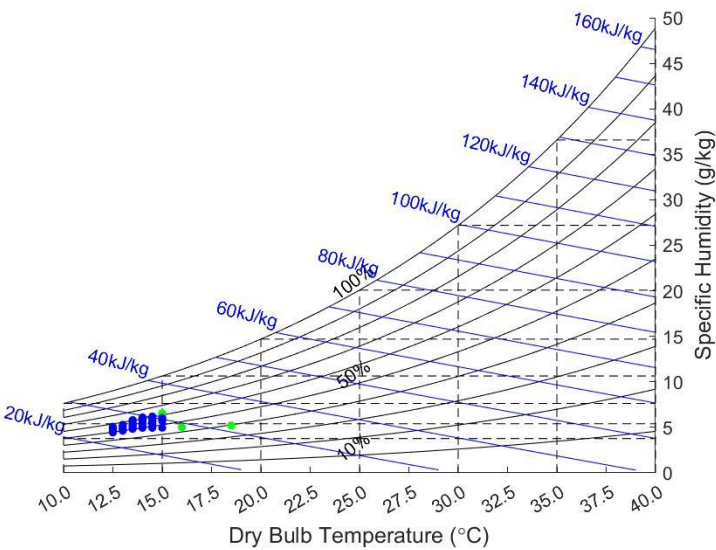
Sensor1A (Black Globe) Result, Comfort Outside the room 2.76% Comfort



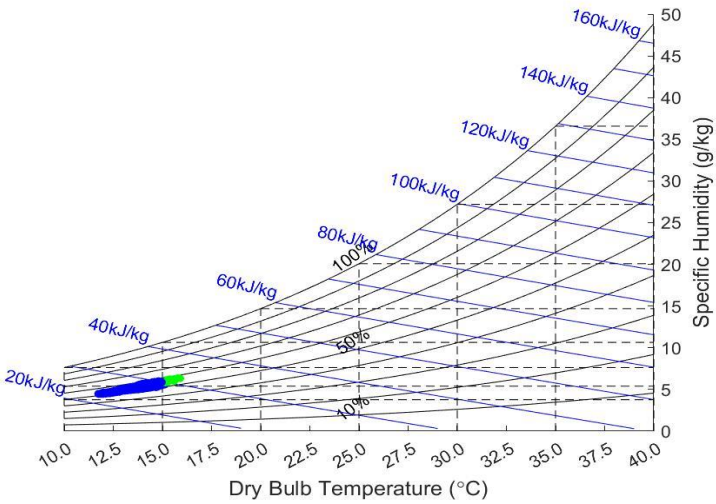
Sensor1B Result, Comfort Outside the room 47.36% Comfort



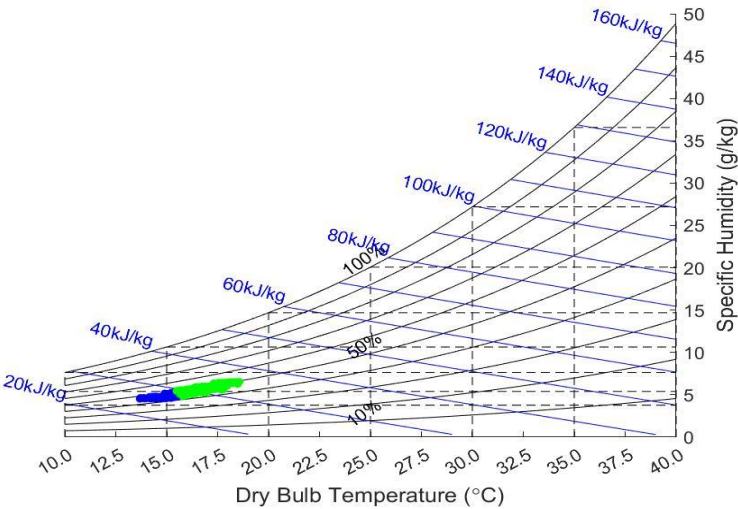
TH04 Result, Comfort Outside the room 2.23% Comfort



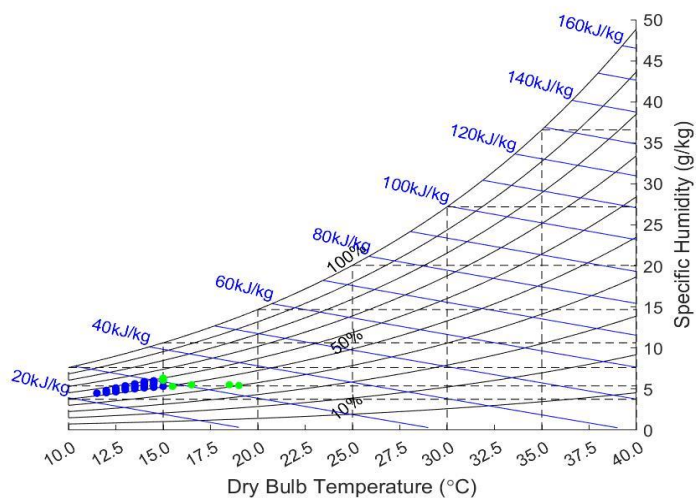
Sensor2A (Black Globe) Result, Comfort Inside the room 3.50% Comfort



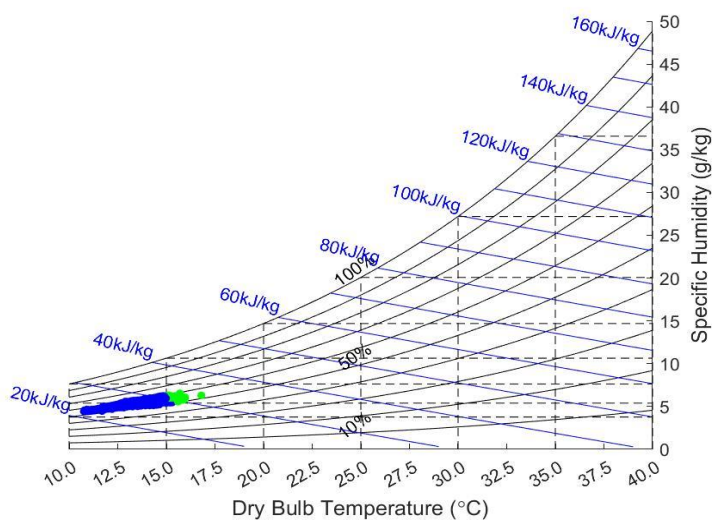
Sensor2B Result, Comfort Inside the room 79.08% Comfort



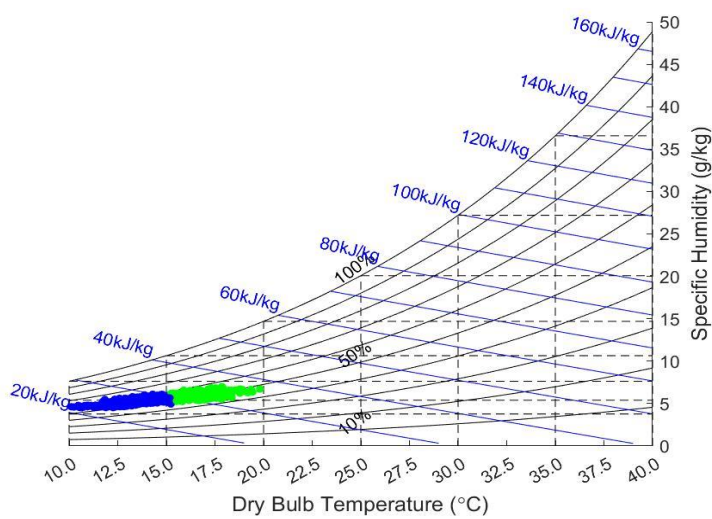
TH02 Result, Comfort Inside the room 4.02% Comfort



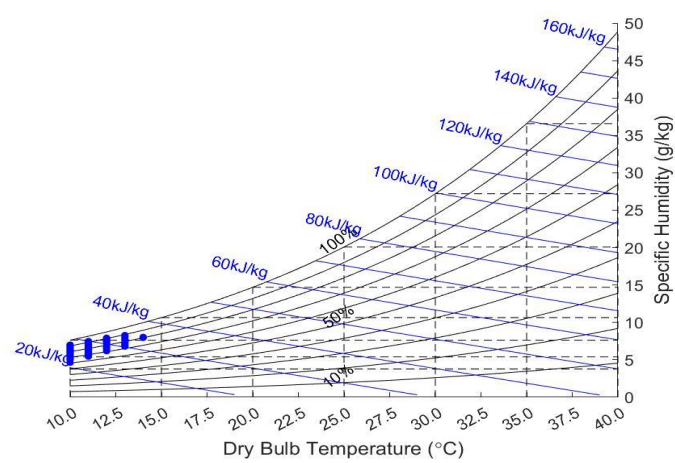
Sensor3A (Black Globe) Result, Comfort near Window 2.98% Comfort



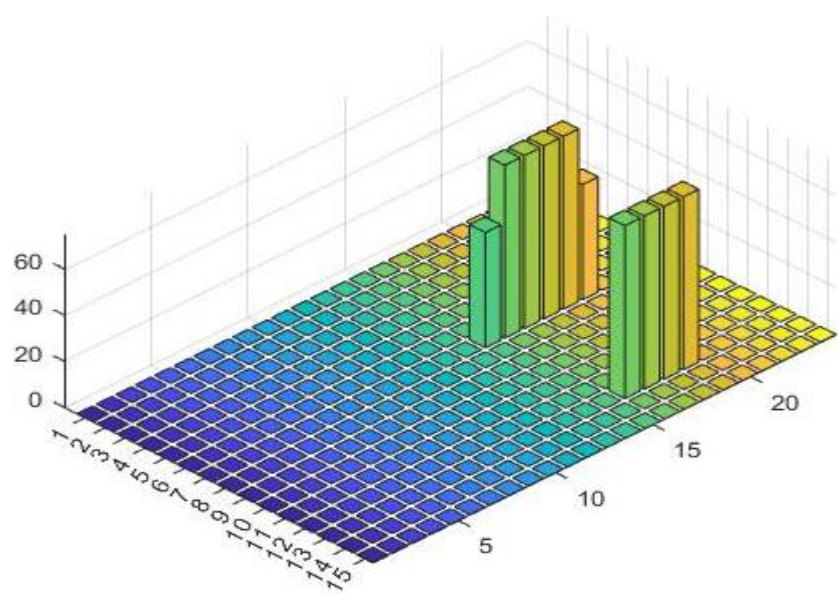
Sensor3B Result, Comfort near Window 41.25% Comfort



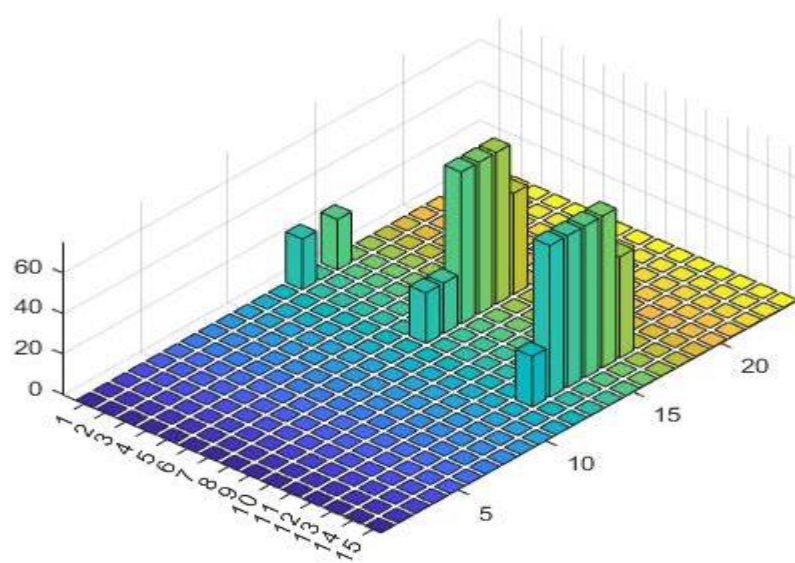
Outdoor Result, 0% Comfort



Sensor 1 Stairs:



Sensor 3 Window:



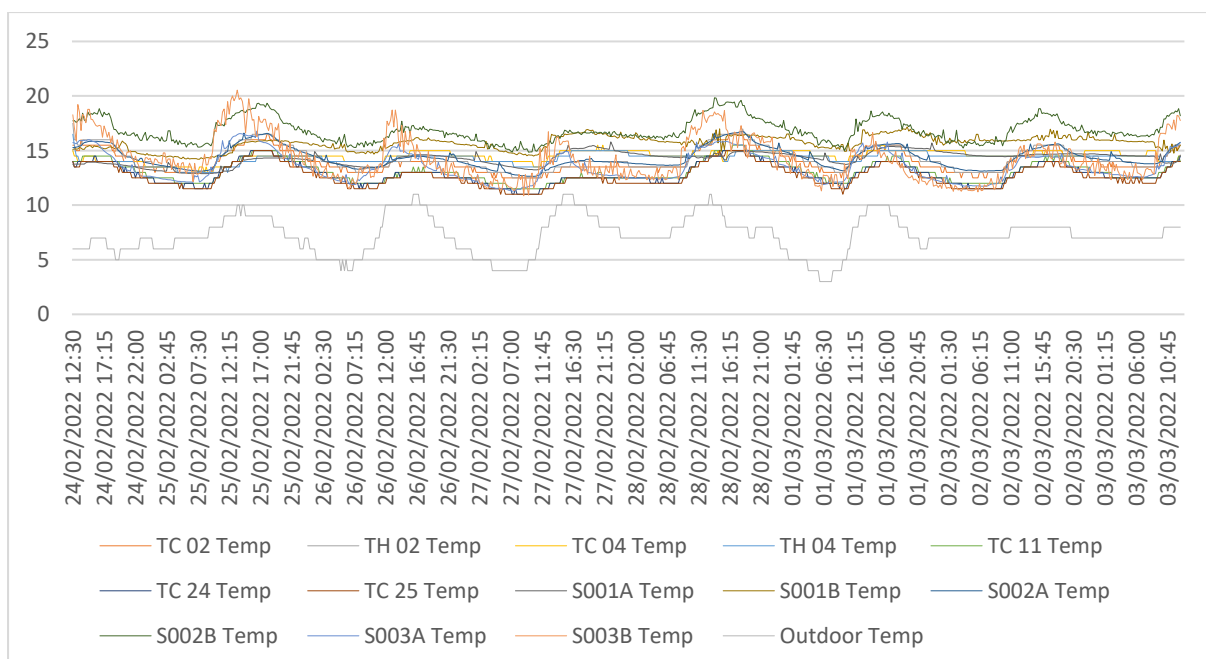
Third Period

Sensor	Location	Installation Date	Data Processing
01	Outside room, stairs	24/02/2022 12:30	03/03/2022 12:45
02	desktop	24/02/2022 12:30	03/03/2022 12:45
03	window	24/02/2022 12:30	03/03/2022 12:45
05	desktop	24/02/2022 12:30	03/03/2022 12:45
TC011	heater (surface)	24/02/2022 12:30	03/03/2022 12:45
TC024	heater (top left)	24/02/2022 12:30	03/03/2022 12:45
TC025	heater (top right)	24/02/2022 12:30	03/03/2022 12:45
TH002	desk	24/02/2022 12:30	03/03/2022 12:45
TH004	Outside room, stairs	24/02/2022 12:30	03/03/2022 12:45

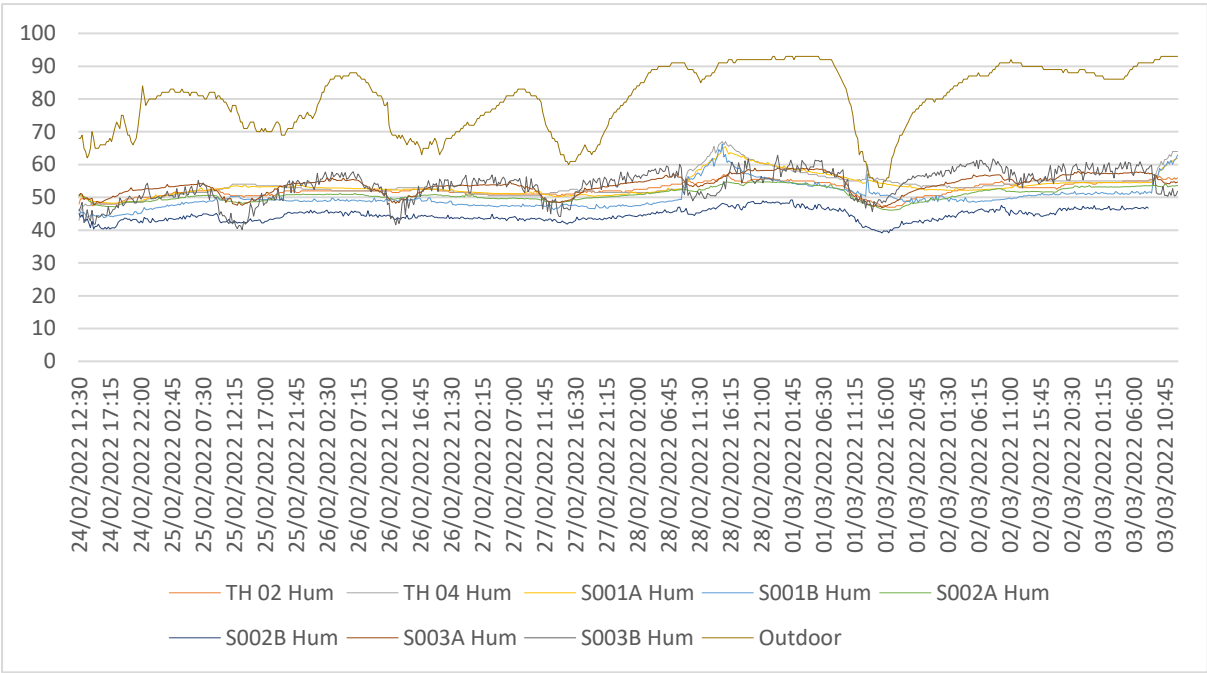
	TC 02 Temp	TH 02 Temp	TC 04 Temp	TH 04 Temp	TC 11 Temp	TC 24 Temp	TC 25 Temp	S001A Temp	S001B Temp	S002A Temp	S002B Temp	S003A Temp	S003B Temp	Outdoor Temp
Minimum	12.50	12.50	13.00	13.00	11.50	11.00	11.00	12.89	14.21	12.64	14.85	11.28	10.86	3.00
Maximum	16.50	17.50	15.50	16.50	15.50	15.00	15.00	15.80	17.17	16.74	19.84	16.80	20.54	11.00
Average	14.01	14.28	14.50	14.32	13.08	12.89	12.69	14.29	15.70	14.37	16.83	13.50	14.22	7.23
Std. Dev	0.99	1.05	0.49	0.49	0.96	0.98	1.01	0.61	0.64	0.97	1.08	1.31	2.00	1.70

	TH 02 Hum	TH 04 Hum	S001A Hum	S001B Hum	S002A Hum	S002B Hum	S003A Hum	S003B Hum	Outdoor
Minimum	47.00	43.00	48.23	43.82	46.12	39.15	46.87	40.16	53.00
Maximum	57.00	67.00	65.48	66.23	54.75	50.29	58.93	62.87	93.00
Average	52.26	53.77	53.51	50.11	50.84	44.58	53.79	53.73	80.08
Std. Dev	2.08	3.61	3.21	3.64	2.00	1.92	2.95	4.68	9.98

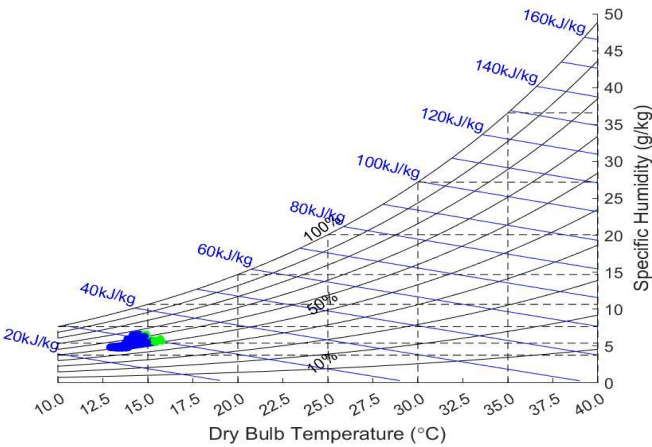
Temperature:



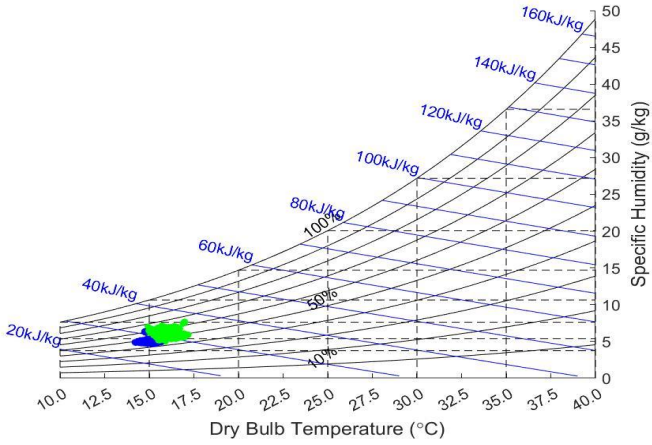
Humidity:



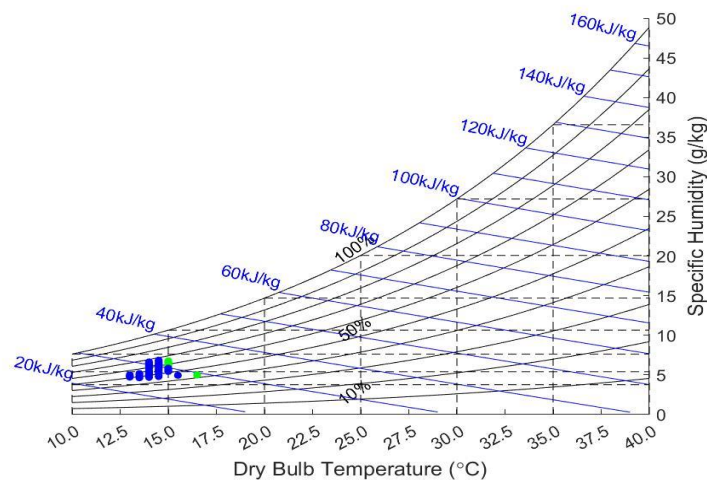
Sensor1A (Black Globe) Result, Comfort Outside the room 8.16% Comfort



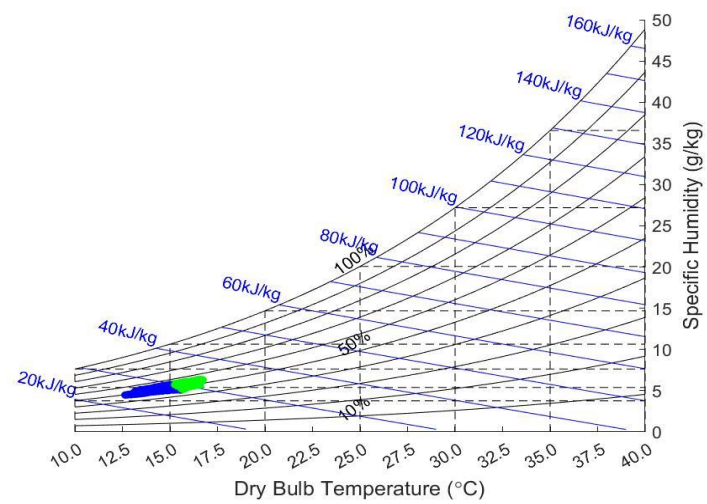
Sensor1B Result, Comfort Outside the room 72.11% Comfort



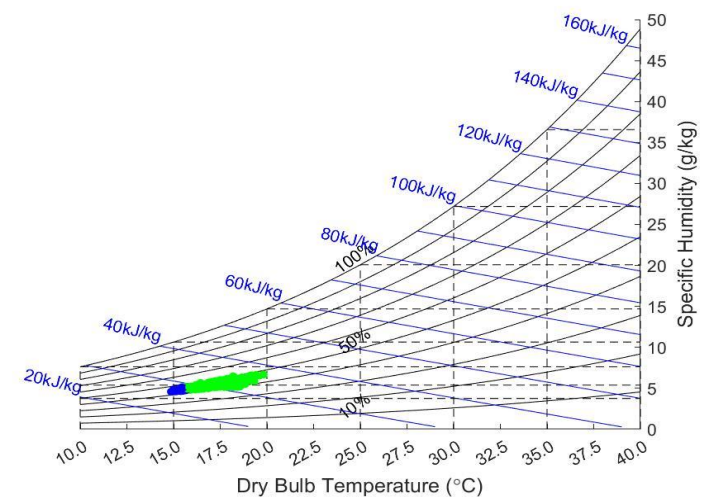
H04 Result, Comfort Outside the room 5.34% Comfort



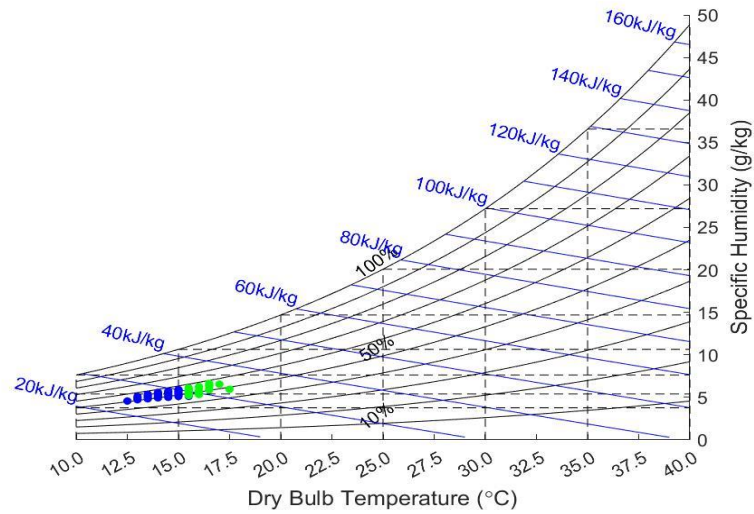
Sensor2A (Black Globe) Result, Comfort Inside the room 20.62% Comfort



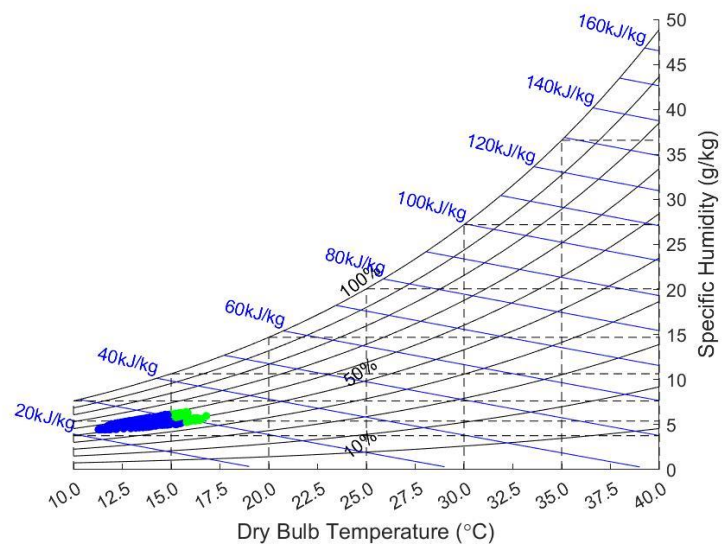
Sensor2B Result, Comfort Inside the room 85.31% Comfort



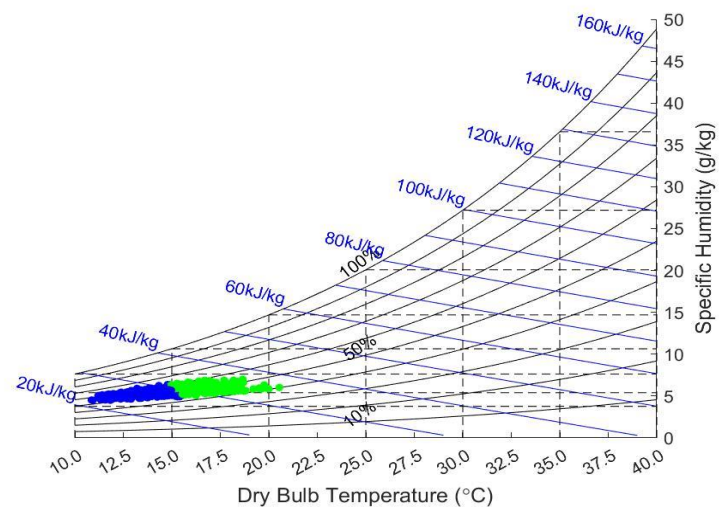
TH02 Result, Comfort Inside the room 20.62% Comfort



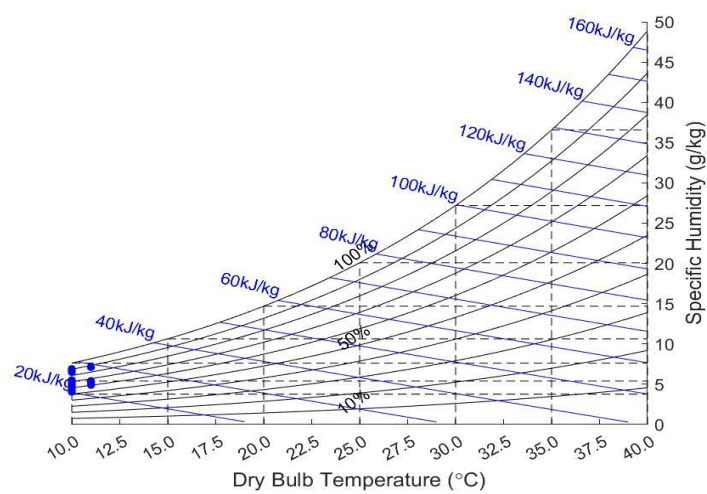
Sensor3A (Black Globe) Result, Comfort near Window 12.91% Comfort



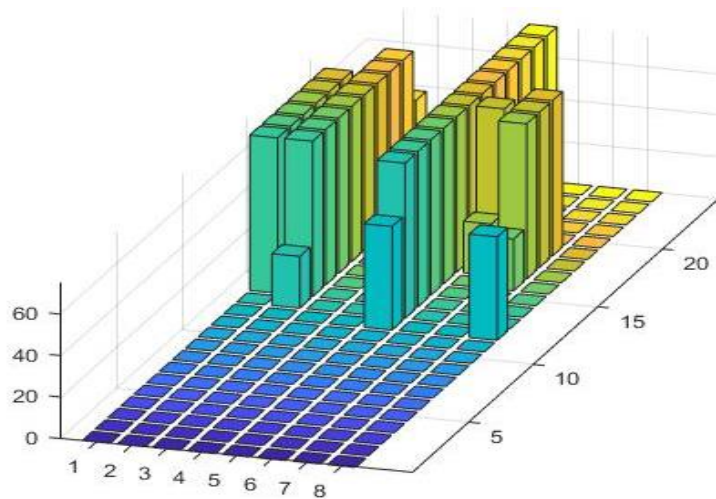
Sensor3B Result, Comfort near Window 26.85% Comfort



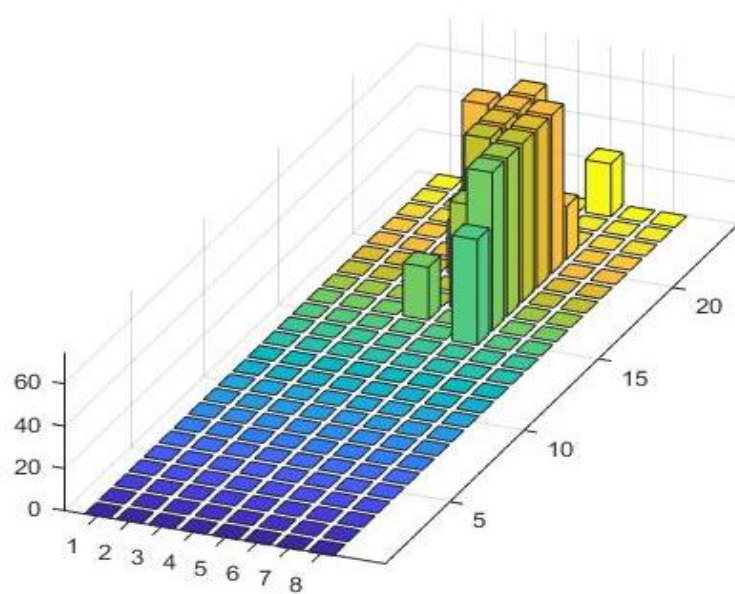
Outdoor Result, 0% Comfort



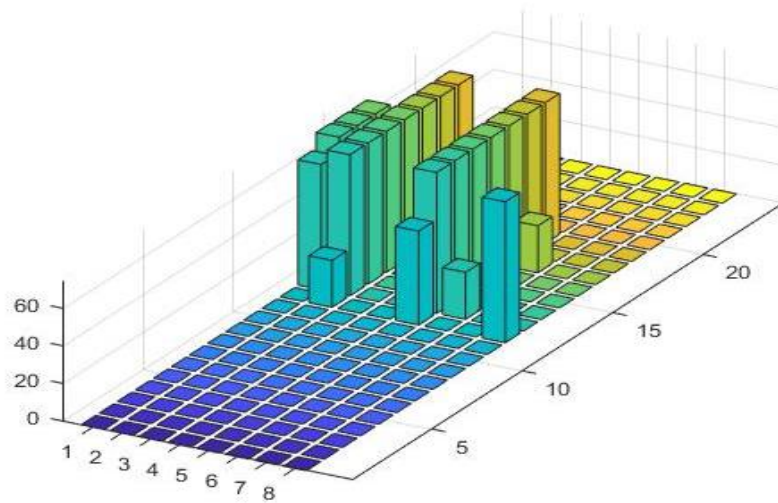
Sensor 2(Room)



Sensor 1 (stairs)



Sensor 3 (window)

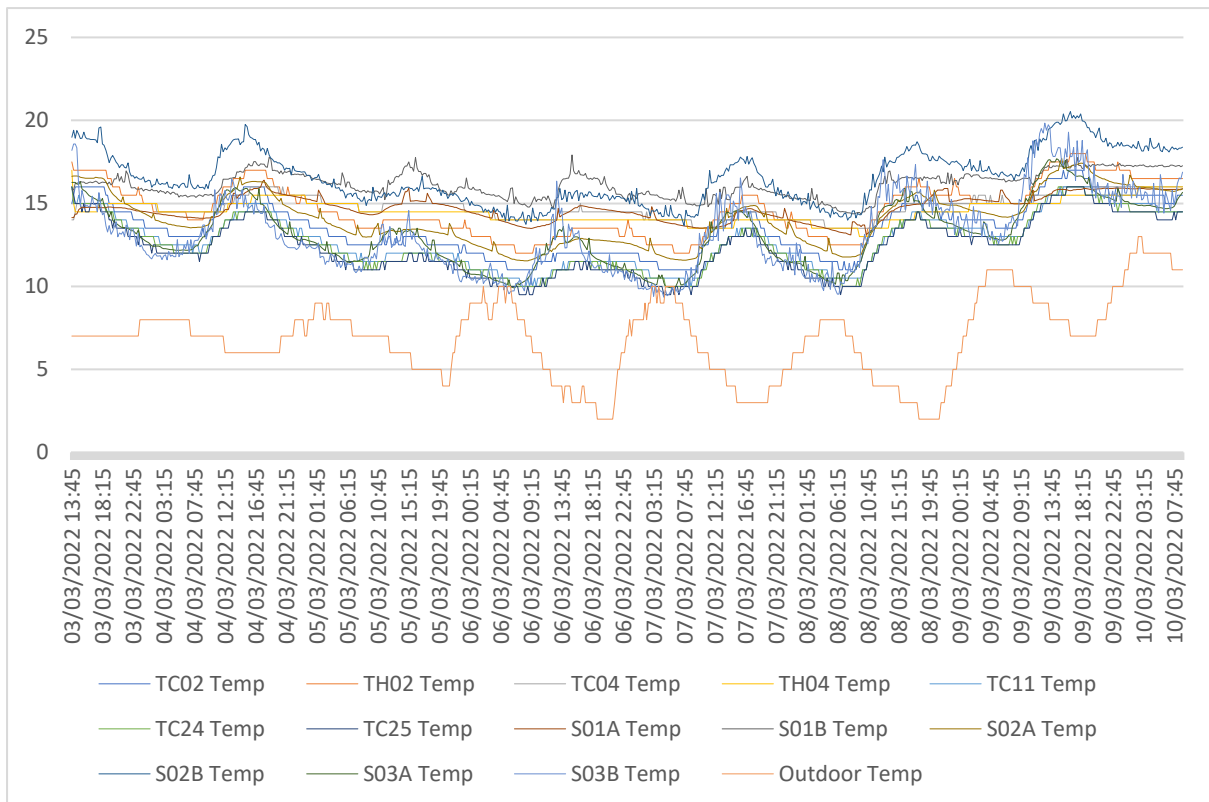
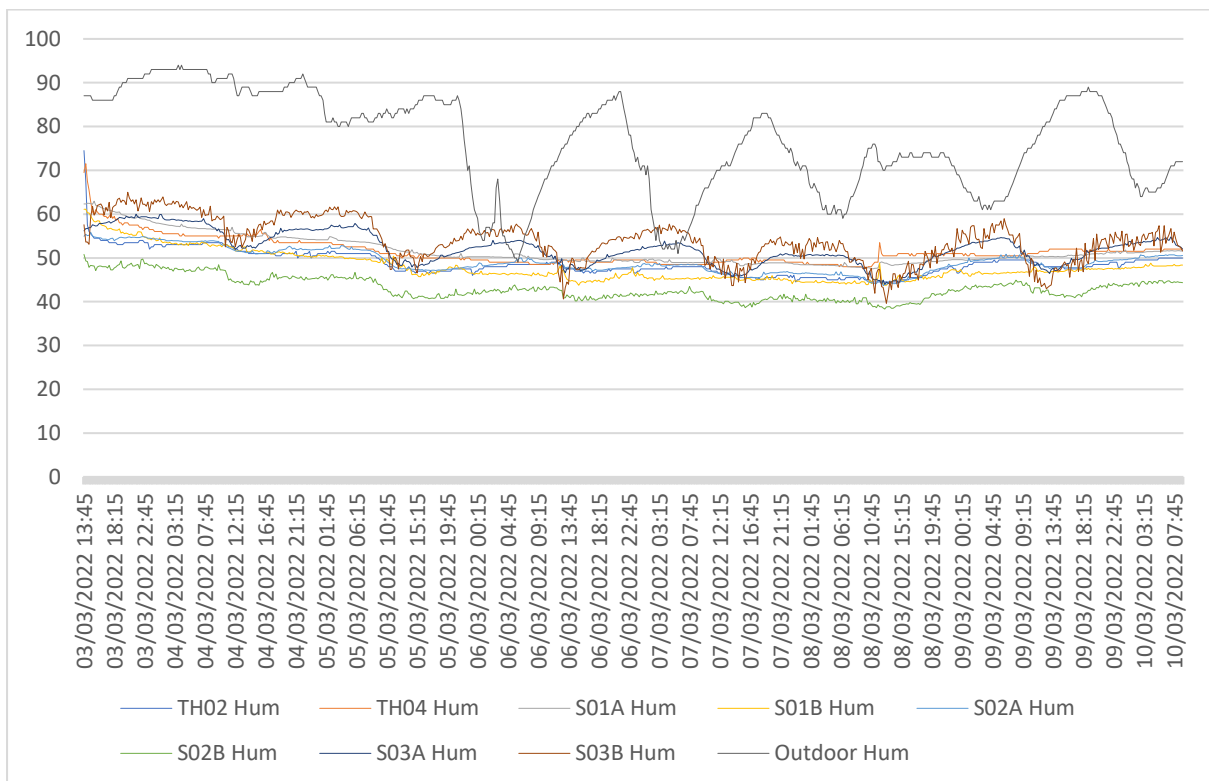


Fourth Period

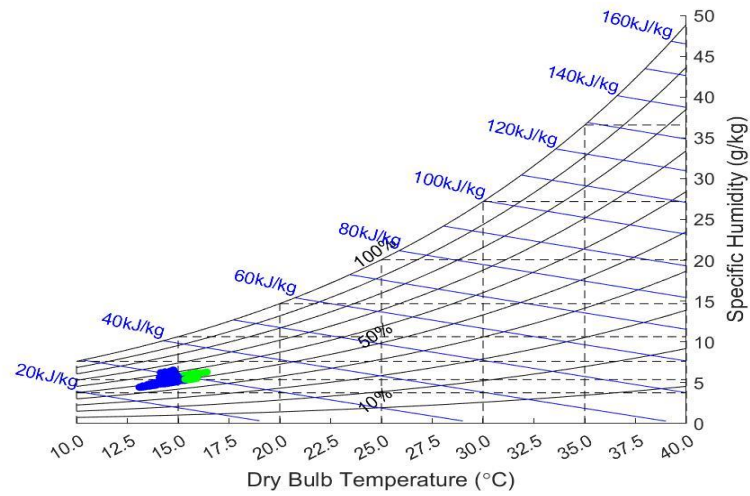
Sensor	Location	Installation Date	Data Processing
01	Outside room, stairs	03/03/2022 13:45	10/03/2022 09:00
02	desktop	03/03/2022 13:45	10/03/2022 09:00
03	window	03/03/2022 13:45	10/03/2022 09:00
05	desktop	03/03/2022 13:45	10/03/2022 09:00
TC011	heater (surface)	03/03/2022 13:45	10/03/2022 09:00
TC024	heater (top left)	03/03/2022 13:45	10/03/2022 09:00
TC025	heater (top right)	03/03/2022 13:45	10/03/2022 09:00
TH002	desk	03/03/2022 13:45	10/03/2022 09:00
TH004	Outside room, stairs	03/03/2022 13:45	10/03/2022 09:00

	TC 02 Temp	TH 02 Temp	TC 04 Temp	TH 04 Temp	TC 11 Temp	TC 24 Temp	TC 25 Temp	S001A Temp	S001B Temp	S002A Temp	S002B Temp	S003A Temp	S003B Temp	Outdoor Temp
Minimum	11.00	12.00	13.50	13.00	10.00	10.00	9.50	13.10	14.35	11.54	13.66	9.91	9.35	2.00
Maximum	17.00	18.00	16.00	17.00	16.00	16.00	16.00	16.40	17.92	17.70	20.53	17.69	19.84	13.00
Average	13.51	14.67	14.79	14.53	12.76	12.57	12.34	14.70	16.13	14.08	16.57	13.12	13.18	6.89
Std. Dev	1.62	1.58	0.71	0.68	1.60	1.63	1.68	0.76	0.78	1.57	1.61	1.90	2.31	2.43

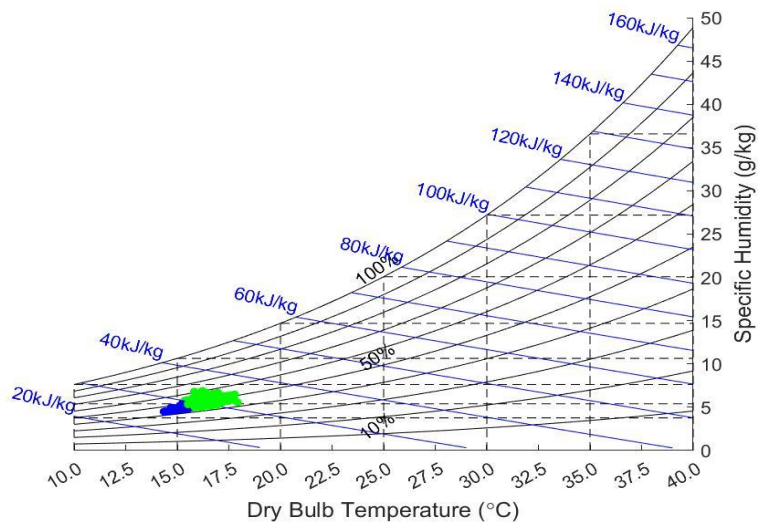
	TH 02 Hum	TH 04 Hum	S001A Hum	S001B Hum	S002A Hum	S002B Hum	S003A Hum	S003B Hum	Outdoor
Minimum	44.50	47.50	47.50	43.74	43.65	38.31	43.97	39.62	49.00
Maximum	74.50	71.50	62.95	61.11	55.87	50.79	59.97	64.99	94.00
Average	48.71	51.44	51.58	47.93	49.21	43.03	52.22	54.06	76.53
Std. Dev	2.86	3.05	3.41	3.42	2.73	2.60	3.70	5.00	11.41

Temperature:**Humidity:**

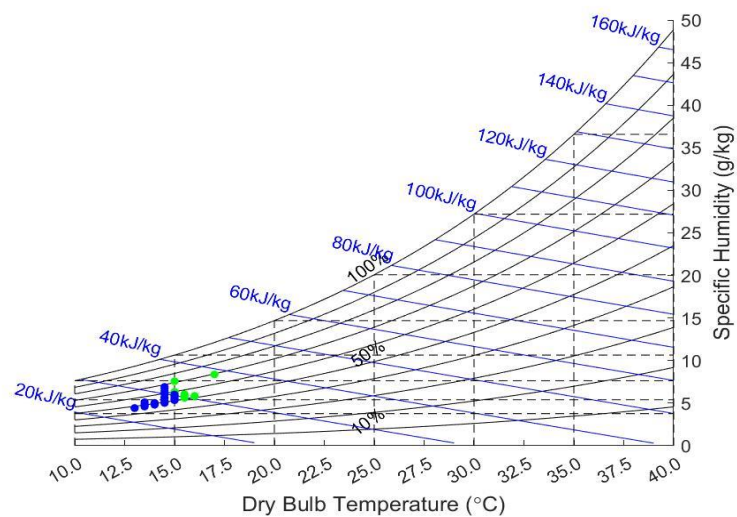
Sensor1A (Black Globe) Result, Comfort Outside the room 23.85% Comfort



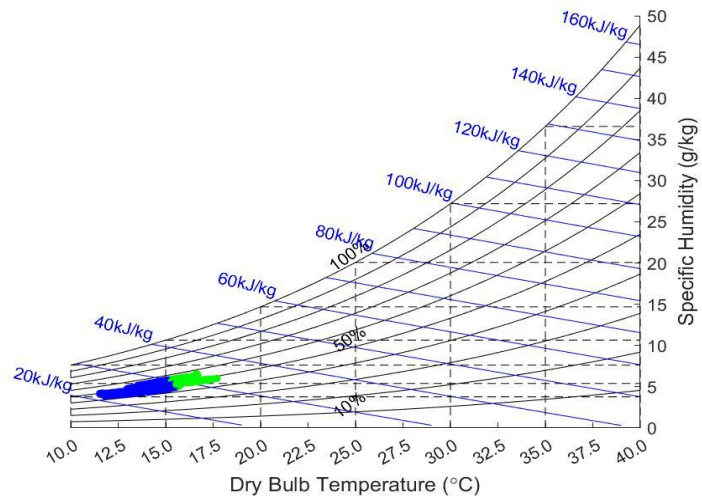
Sensor1B Result, Comfort Outside the room 75.54% Comfort



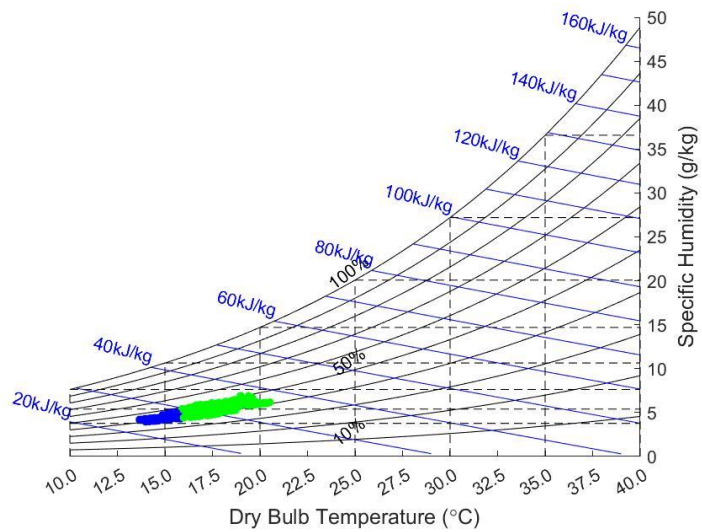
TH04 Result, Comfort Outside the room 18.81% Comfort



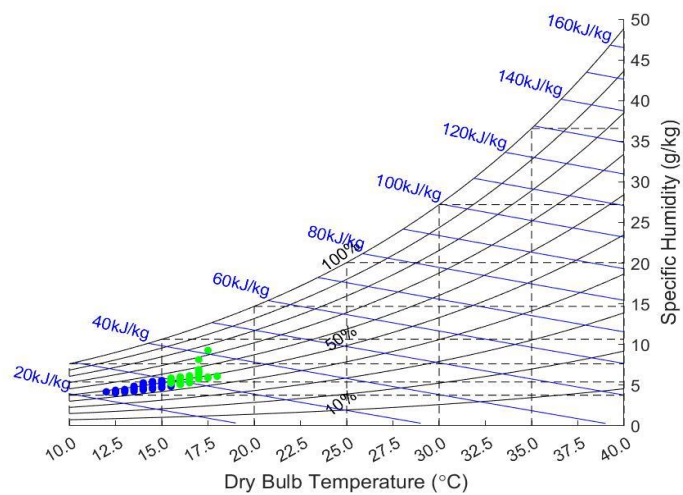
Sensor2A (Black Globe) Result, Comfort Inside the room 23.85% Comfort



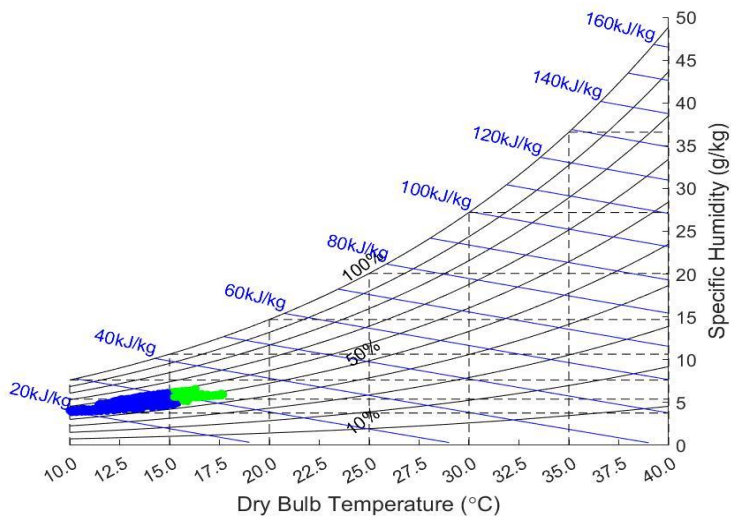
Sensor2B Result, Comfort Inside the room 61.77% Comfort



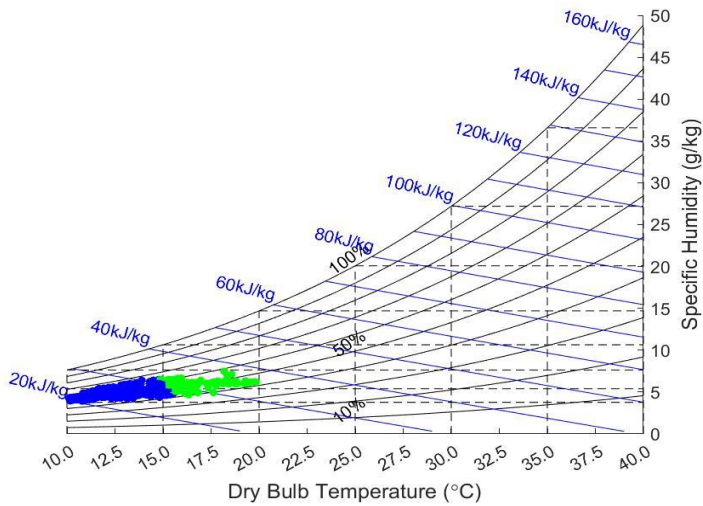
TH02 Result, Comfort Inside the room 32.42% Comfort



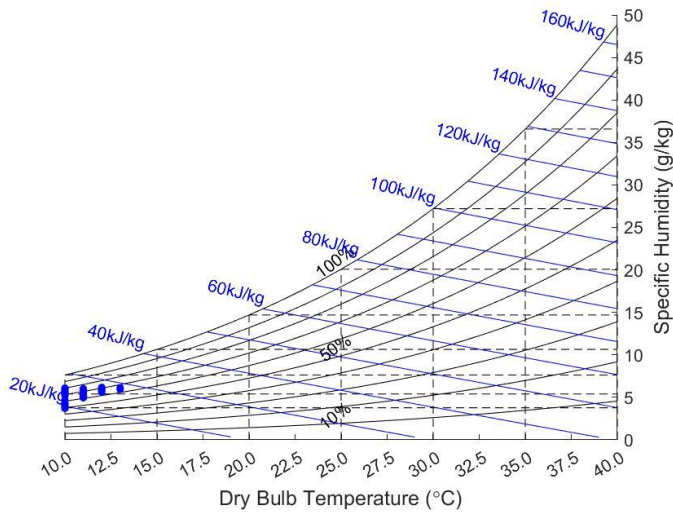
Sensor3A (Black Globe) Result, Comfort near Window 15.60% Comfort



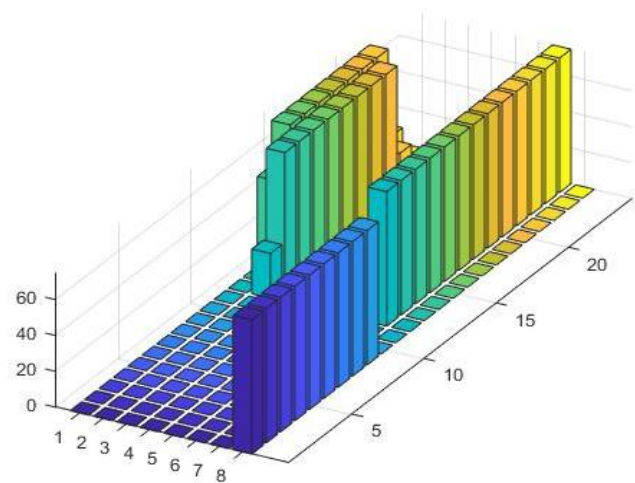
Sensor3B Result, Comfort near Window 21.41% Comfort



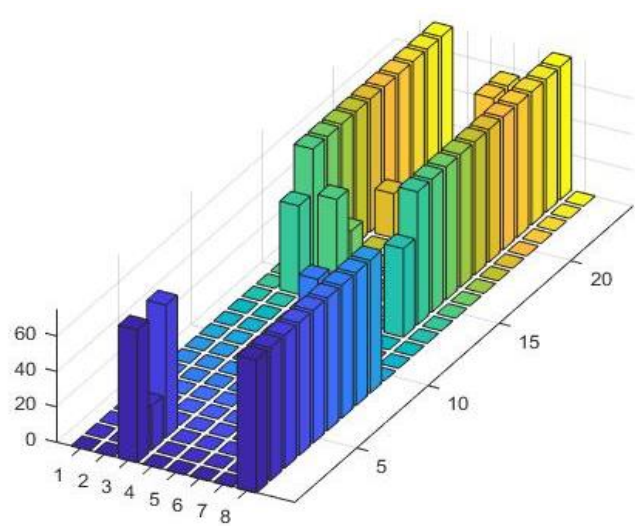
Outdoor Result, 0% Comfort



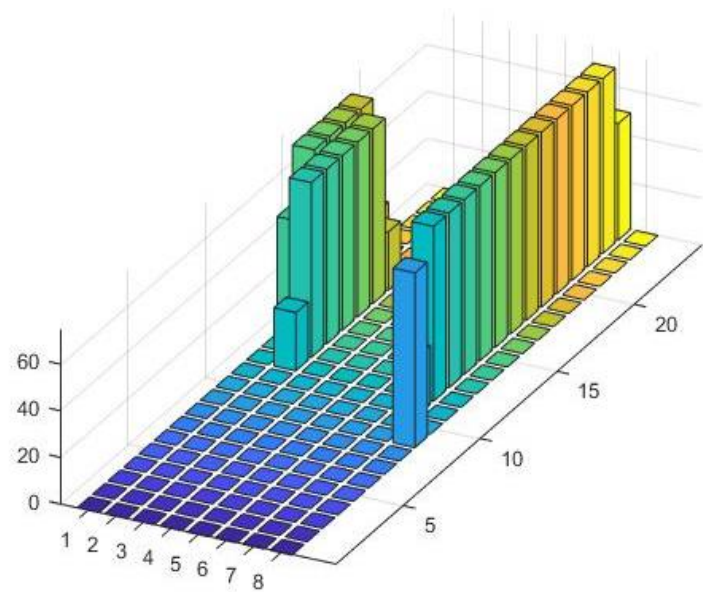
Sensor 2(Room)



Sensor 1 (stairs)



Sensor 3 (window)



Fifth Period

Sensor	Location	Installation Date	Data Processing
01	Outside room, stairs	11/03/2022 20:15	17/03/2022 08:45
02	desktop	11/03/2022 20:15	17/03/2022 08:45
03	window	11/03/2022 20:15	17/03/2022 08:45
05	desktop	11/03/2022 20:15	17/03/2022 08:45
TC011	heater (surface)	11/03/2022 20:15	17/03/2022 08:45
TC024	heater (top left)	11/03/2022 20:15	17/03/2022 08:45
TC025	heater (top right)	11/03/2022 20:15	17/03/2022 08:45
TH002	desk	11/03/2022 20:15	17/03/2022 08:45
TH004	Outside room, stairs	11/03/2022 20:15	17/03/2022 08:45

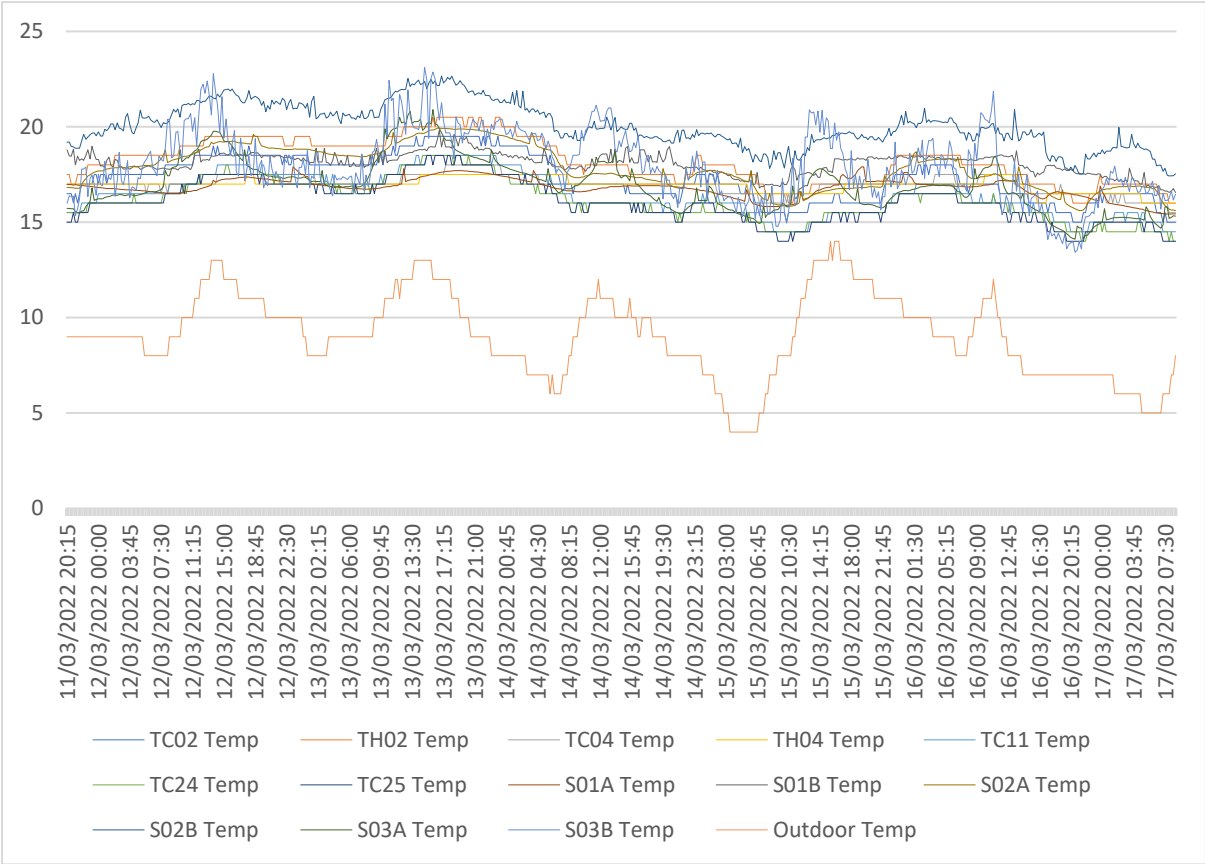
	TC 02 Temp	TH 02 Temp	TC 04 Temp	TH 04 Temp	TC 11 Temp	TC 24 Temp	TC 25 Temp	S001A Temp	S001B Temp	S002A Temp	S002B Temp	S003A Temp	S003B Temp	Outdoor Temp
Minimum	15.00	16.00	15.50	16.00	14.50	14.00	14.00	15.43	16.56	15.61	17.42	14.11	13.43	4.00
Maximum	19.50	20.50	18.00	17.50	18.50	18.50	18.50	17.90	19.81	19.93	22.67	20.90	23.12	14.00
Average	17.32	18.21	17.00	16.95	16.44	16.16	16.09	16.81	18.09	17.83	20.06	16.95	18.02	9.06
Std. Dev	1.17	1.16	0.48	0.36	1.11	1.09	1.11	0.51	0.56	1.12	1.17	1.39	1.83	2.18

	TH 02 Hum	TH 04 Hum	S001A Hum	S001B Hum	S002A Hum	S002B Hum	S003A Hum	S003B Hum	Outdoor
Minimum	44.50	47.00	47.92	44.57	44.91	39.34	44.18	39.15	49.00
Maximum	52.50	53.50	53.96	50.85	52.71	47.24	56.58	59.89	91.00
Average	46.74	50.06	50.19	47.07	46.83	41.69	49.66	48.87	76.26
Std. Dev	1.64	1.68	1.45	1.47	1.59	1.45	2.56	3.82	9.15

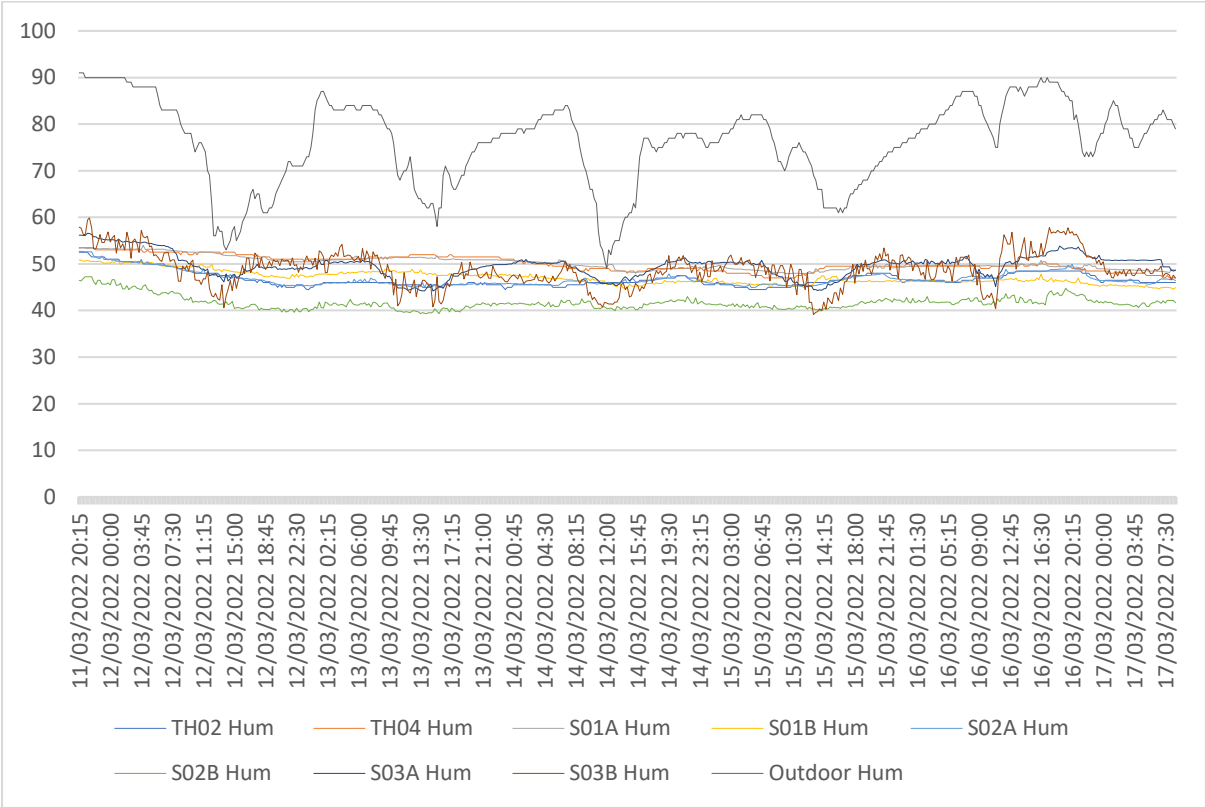
Air velocity

Parameters	Unit	Room
Velocity min	m/s	0.03
Velocity max	m/s	0.08
Velocity avg	m/s	0.05
Temperature min	°C	19.3
Temperature max	°C	20.0
Temperature avg	°C	19.5

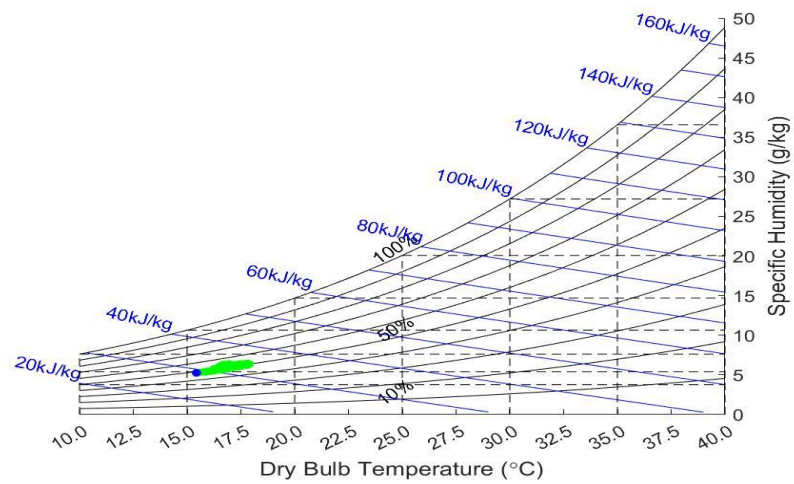
Temperature:



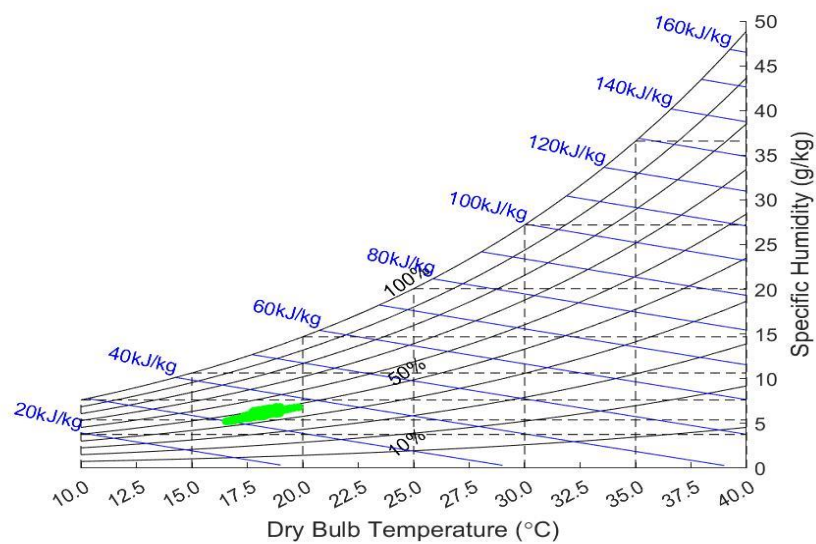
Humidity:



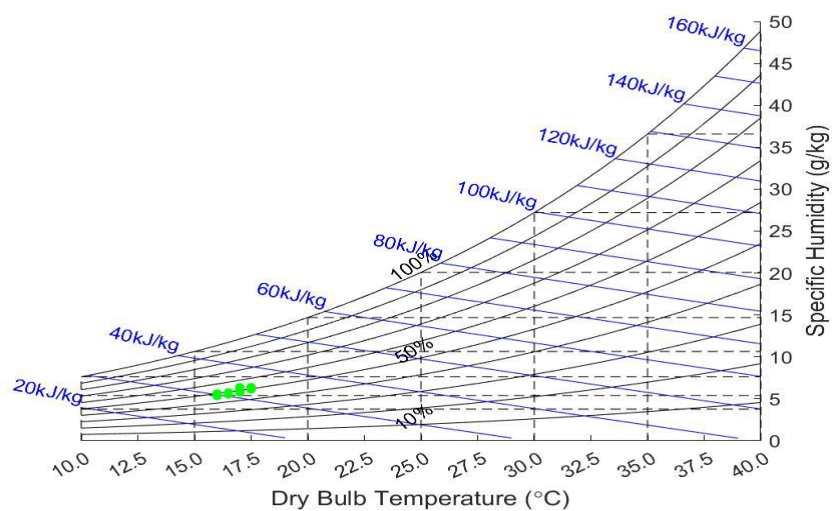
Sensor1A (Black Globe) Result, Comfort Outside the room 98.49% Comfort



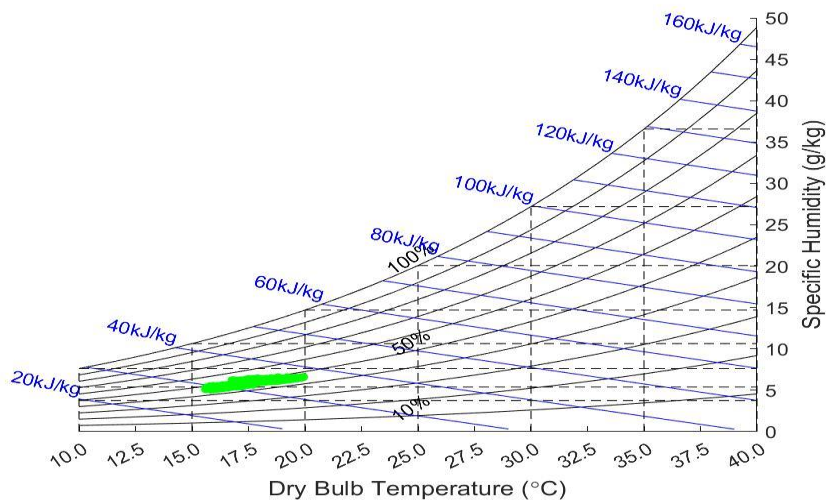
Sensor1B Result, Comfort Outside the room 100% Comfort



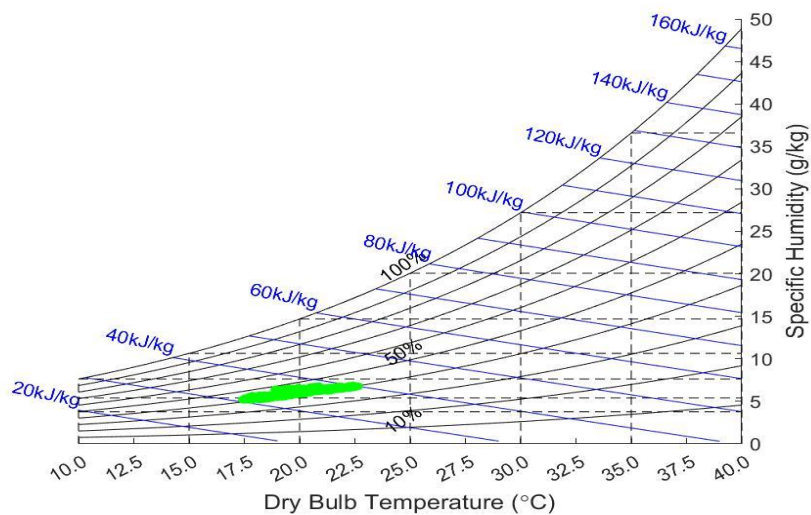
TH04 Result, Comfort Outside the room 100% Comfort



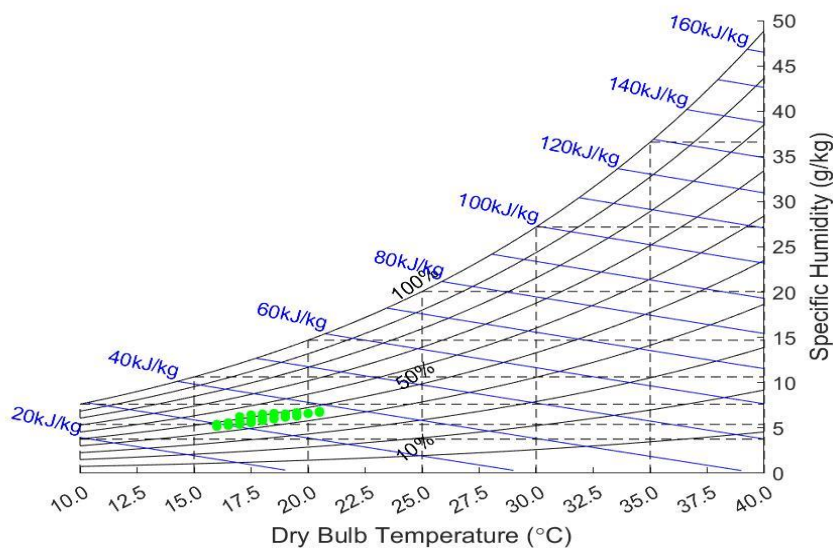
Sensor2A (Black Globe) Result, Comfort Inside the room 100% Comfort



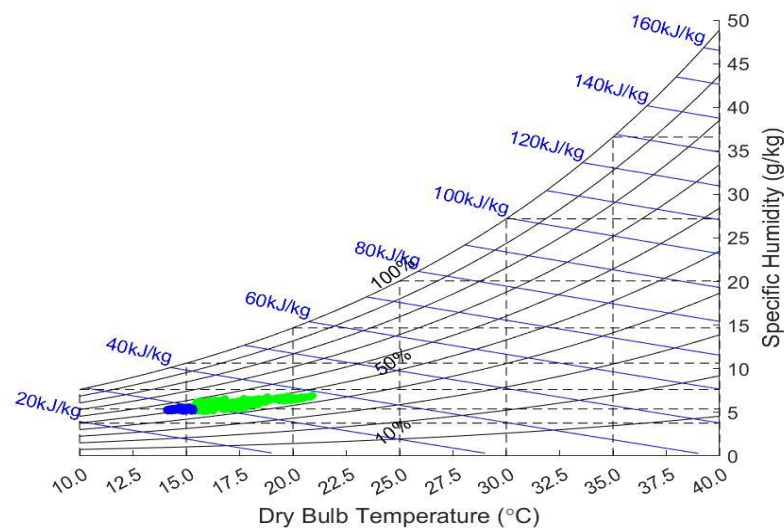
Sensor2B Result, Comfort Inside the room 100% Comfort



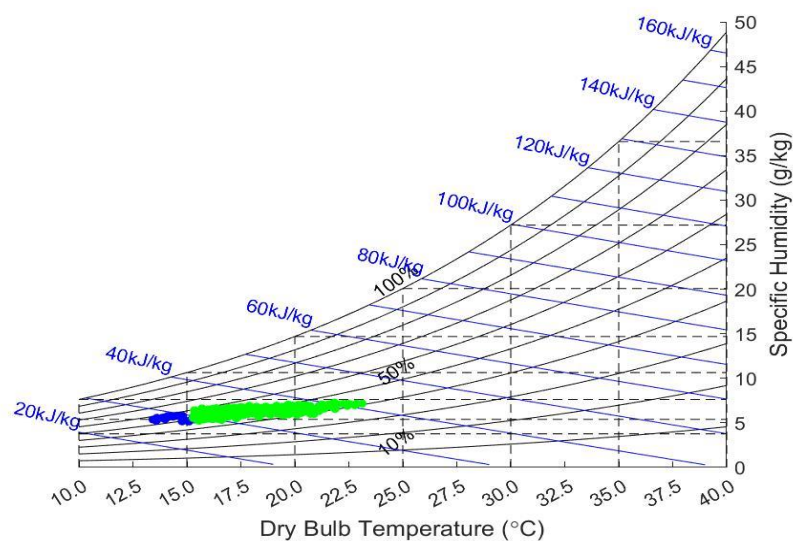
TH02 Result, Comfort Inside the room 100% Comfort



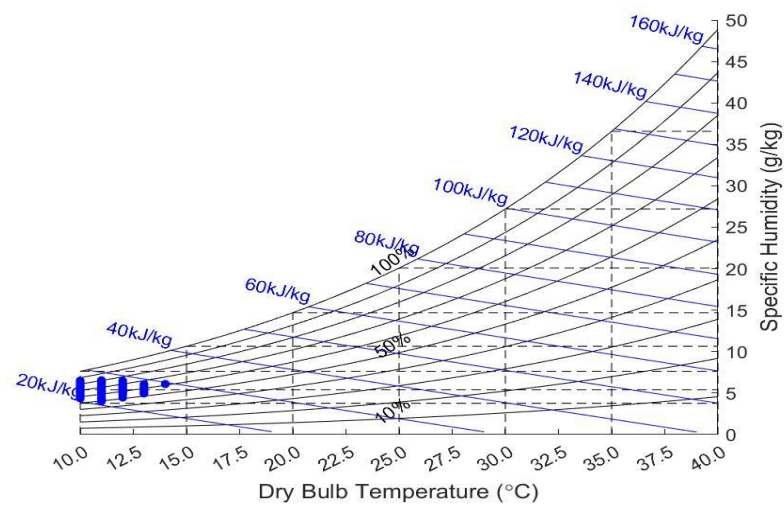
Sensor3A (Black Globe) Result, Comfort near Window 87.01% Comfort



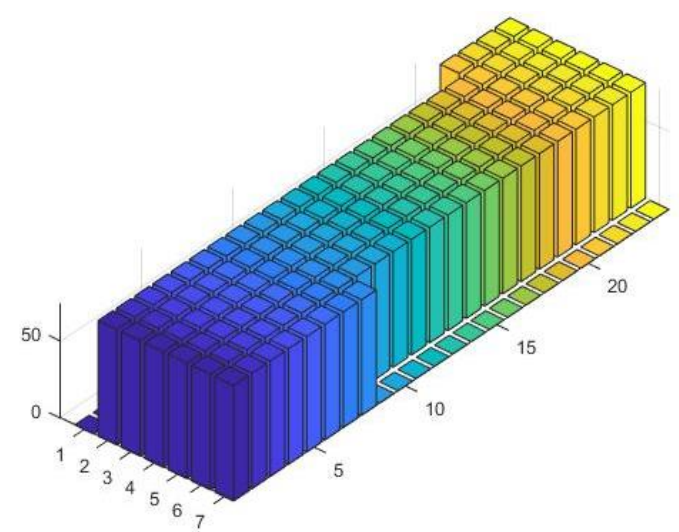
Sensor3B Result, Comfort near Window 95.10% Comfort



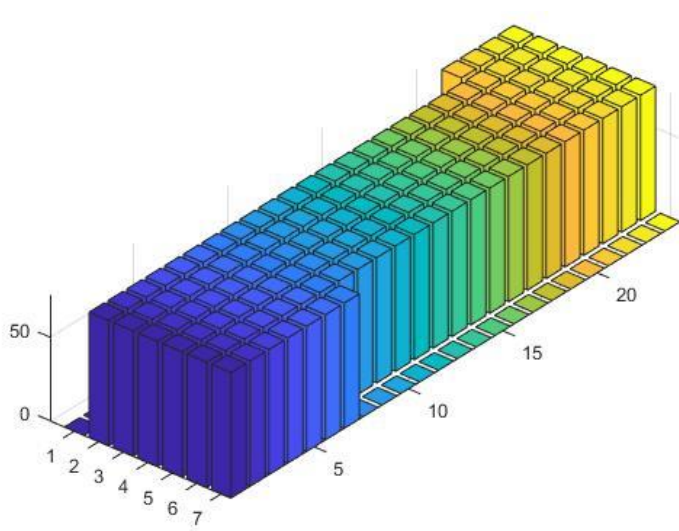
Outdoor Result, 0% Comfort



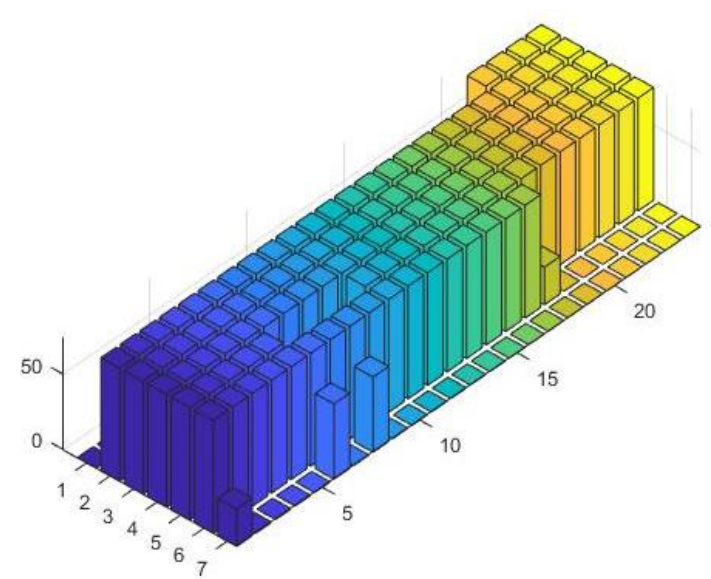
Sensor 2(Room)



Sensor 1 (stairs)



Sensor 3 (window)



Sixth Period

Sensor	Location	Installation Date	Data Processing
01	Outside room, stairs	24/03/2022 09:15	31/03/2022 08:45
02	desktop	24/03/2022 09:15	31/03/2022 08:45
03	window	24/03/2022 09:15	31/03/2022 08:45
05	desktop	24/03/2022 09:15	31/03/2022 08:45
TC011	heater (surface)	24/03/2022 09:15	31/03/2022 08:45
TC024	heater (top left)	24/03/2022 09:15	31/03/2022 08:45
TC025	heater (top right)	24/03/2022 09:15	31/03/2022 08:45
TH002	desk	24/03/2022 09:15	31/03/2022 08:45
TH004	Outside room, stairs	24/03/2022 09:15	31/03/2022 08:45

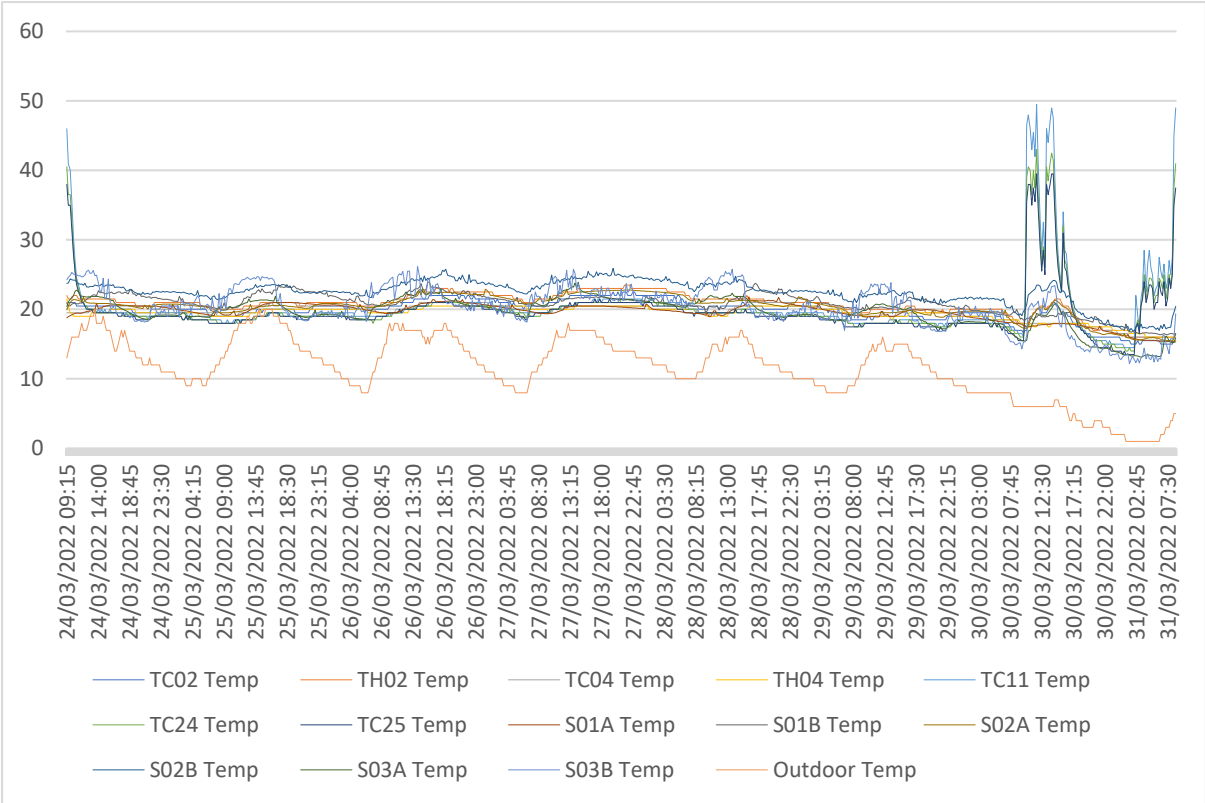
	TC 02 Temp	TH 02 Temp	TC 04 Temp	TH 04 Temp	TC 11 Temp	TC 24 Temp	TC 25 Temp	S001A Temp	S001B Temp	S002A Temp	S002B Temp	S003A Temp	S003B Temp	Outdoor Temp
Minimum	15.00	16.00	15.50	15.50	14.50	14.00	13.50	15.30	16.35	15.43	16.88	13.13	12.19	1.00
Maximum	22.50	23.50	21.00	21.50	49.50	43.00	39.50	21.80	23.95	22.90	25.90	23.90	26.22	20.00
Average	19.84	20.72	19.62	19.42	20.42	19.94	19.69	19.57	20.85	20.38	22.48	19.54	20.30	11.63
Std. Dev	1.68	1.69	1.27	1.09	4.82	3.89	3.56	1.35	1.55	1.69	1.82	2.23	3.03	4.52

	TH 02 Hum	TH 04 Hum	S001A Hum	S001B Hum	S002A Hum	S002B Hum	S003A Hum	S003B Hum	Outdoor
Minimum	36.50	37.00	35.73	30.47	34.58	30.64	35.24	34.14	32.00
Maximum	44.00	49.00	47.90	46.46	44.82	40.54	48.47	52.95	87.00
Average	40.64	43.47	43.31	40.95	40.51	36.68	42.98	43.70	68.63
Std. Dev	1.66	1.69	1.88	2.20	1.85	1.71	2.63	4.40	14.03

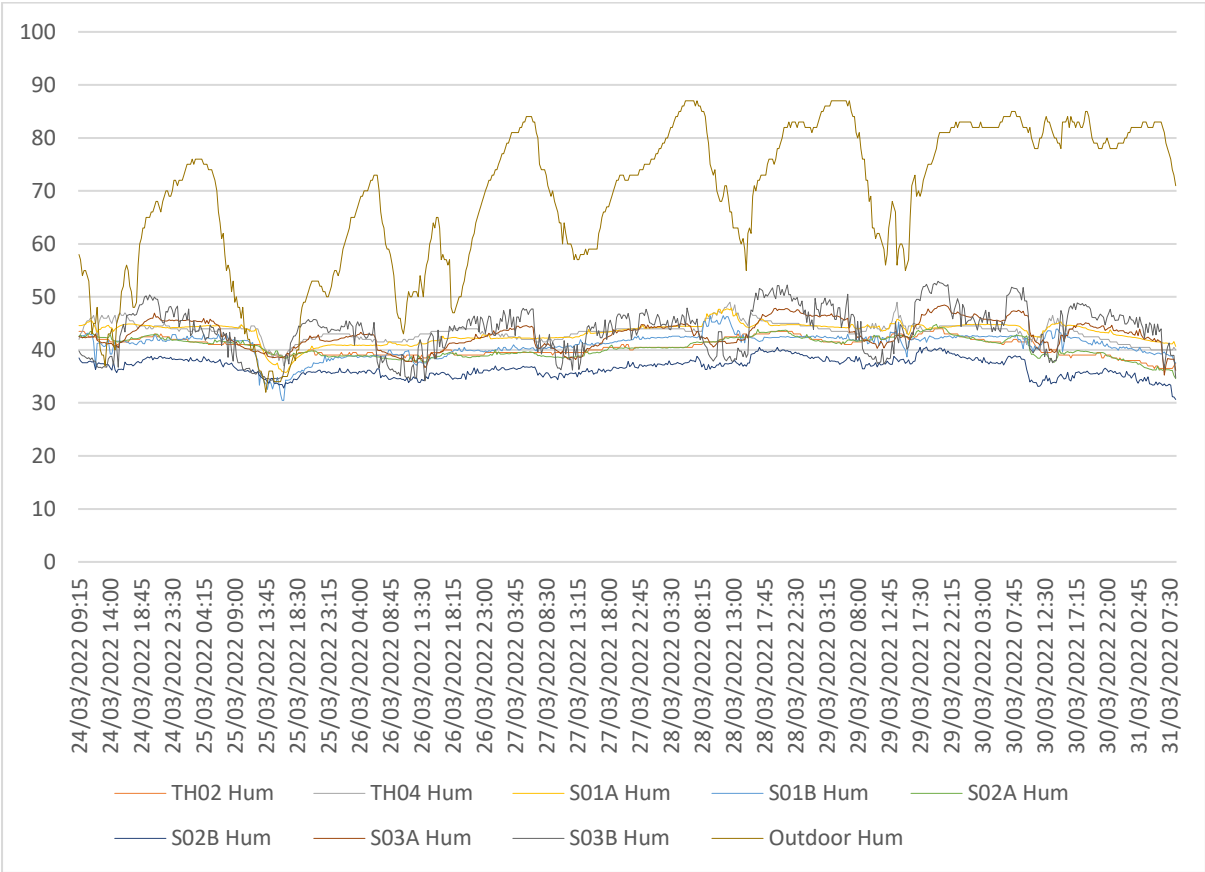
Air velocity

Parameters	Unit	Window	Room	Window
Velocity min	m/s	0.04	0.03	0.03
Velocity max	m/s	0.09	0.16	0.23
Velocity avg	m/s	0.06	0.06	0.09
Temperature min	°C	19.1	18.1	16.1
Temperature max	°C	21.5	19	17.1
Temperature avg	°C	20.2	18.5	16.6

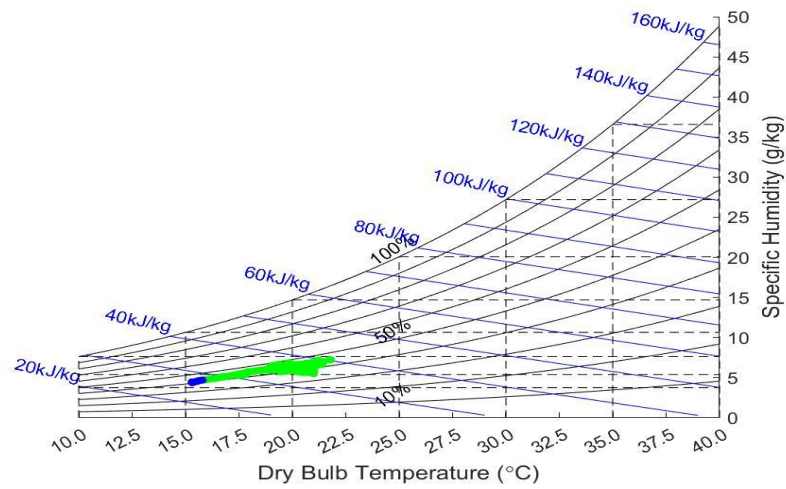
Temperature:



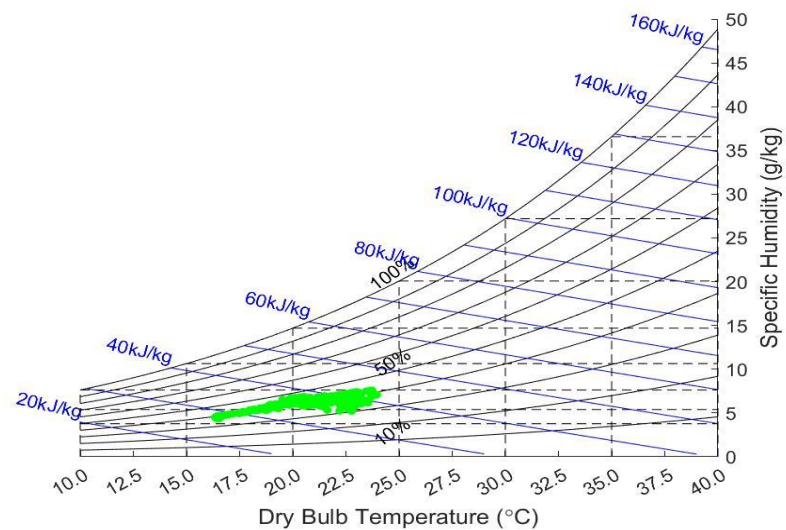
Humidity:



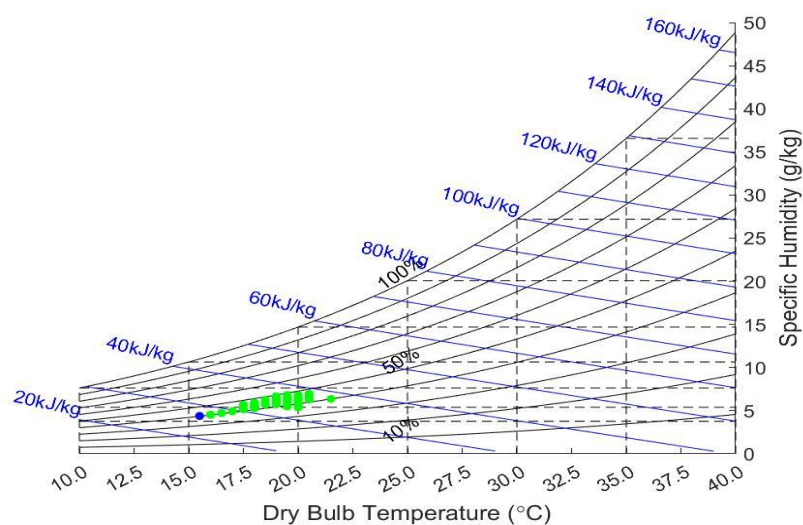
Sensor1A (Black Globe) Result, Comfort Outside the room 96.13% Comfort



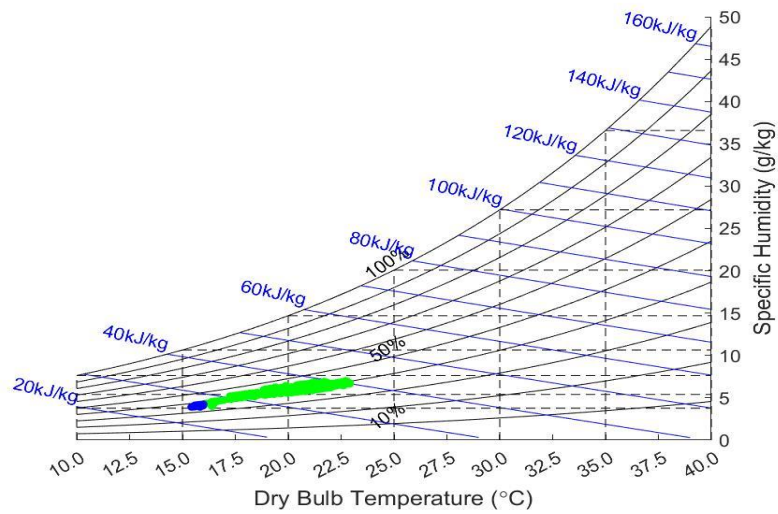
Sensor1B Result, Comfort Outside the room 100% Comfort



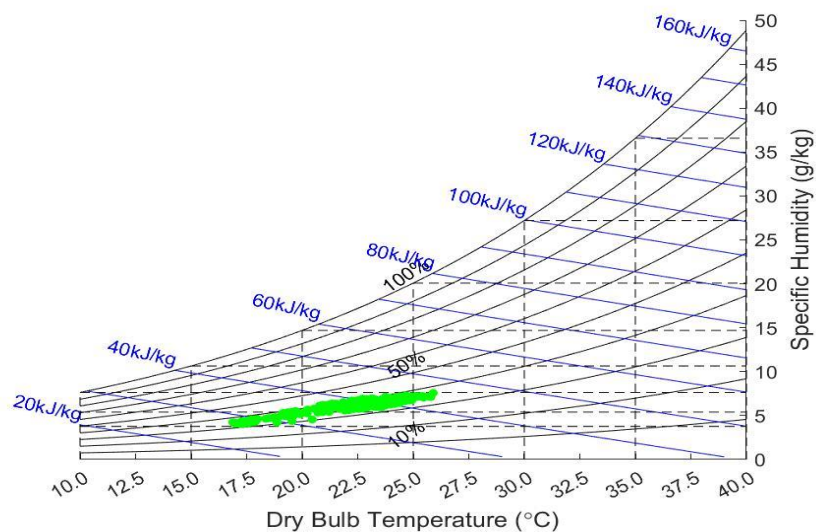
TH04 Result, Comfort Outside the room 99.70% Comfort



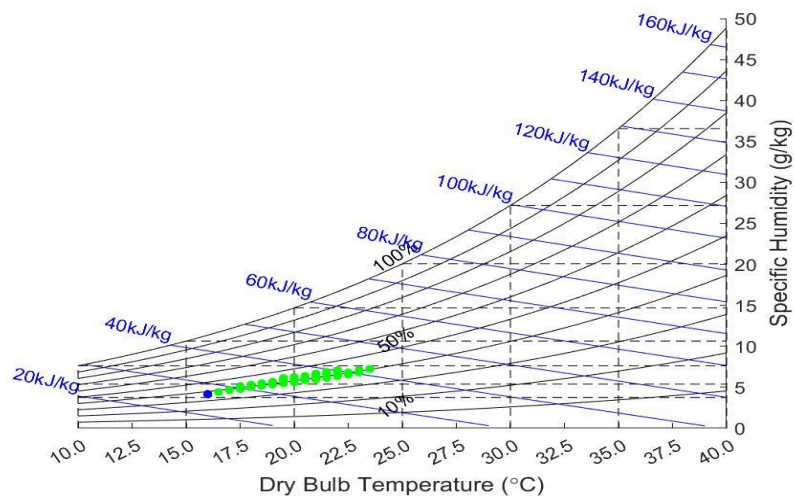
Sensor2A (Black Globe) Result, Comfort Inside the room 95.53% Comfort



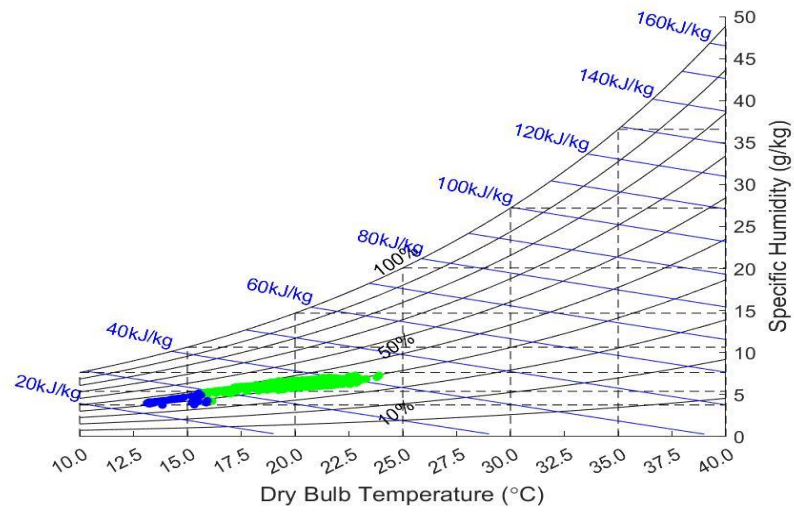
Sensor2B Result, Comfort Inside the room 100% Comfort



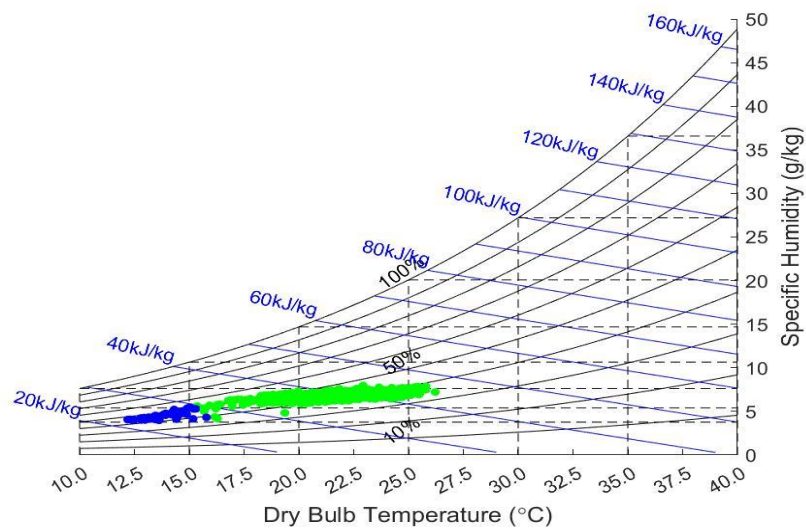
TH02 Result, Comfort Inside the room 96.72% Comfort



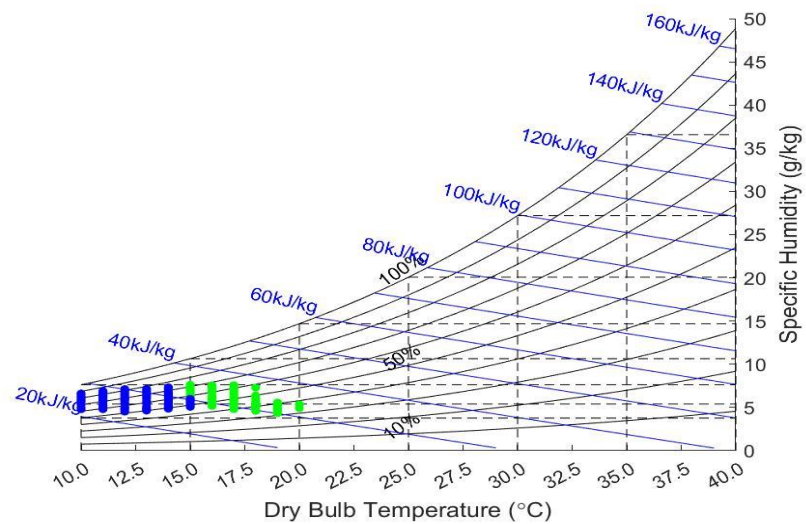
Sensor3A (Black Globe) Result, Comfort near Window 90.76% Comfort



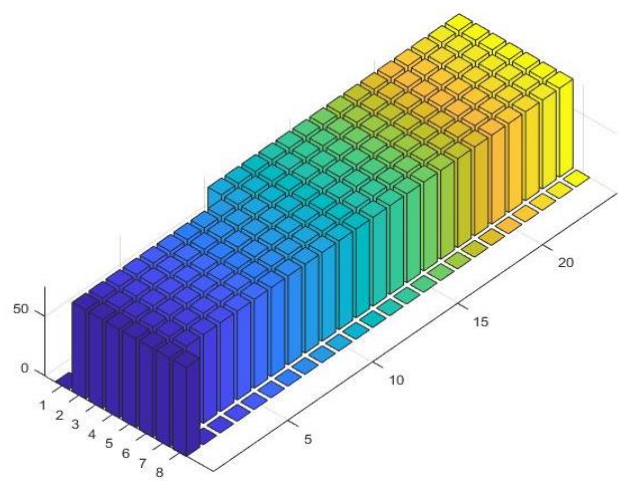
Sensor3B Result, Comfort near Window 90.46% Comfort



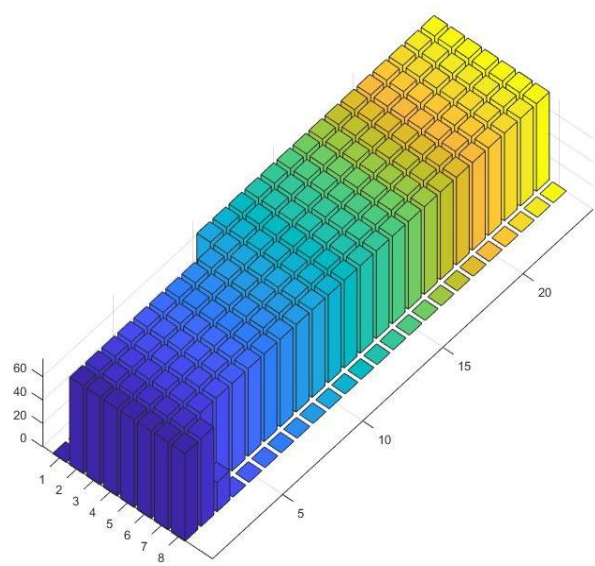
Outdoor Result, 26.83% Comfort



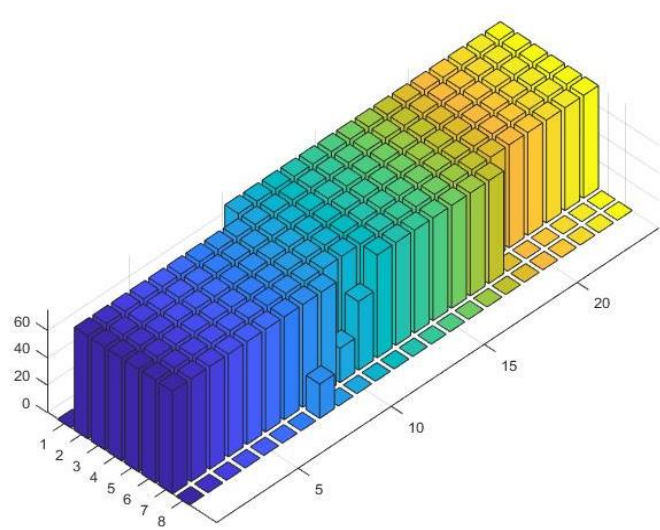
Sensor 2(Room)



Sensor 1 (stairs)



Sensor 3 (window)



Seventh Period

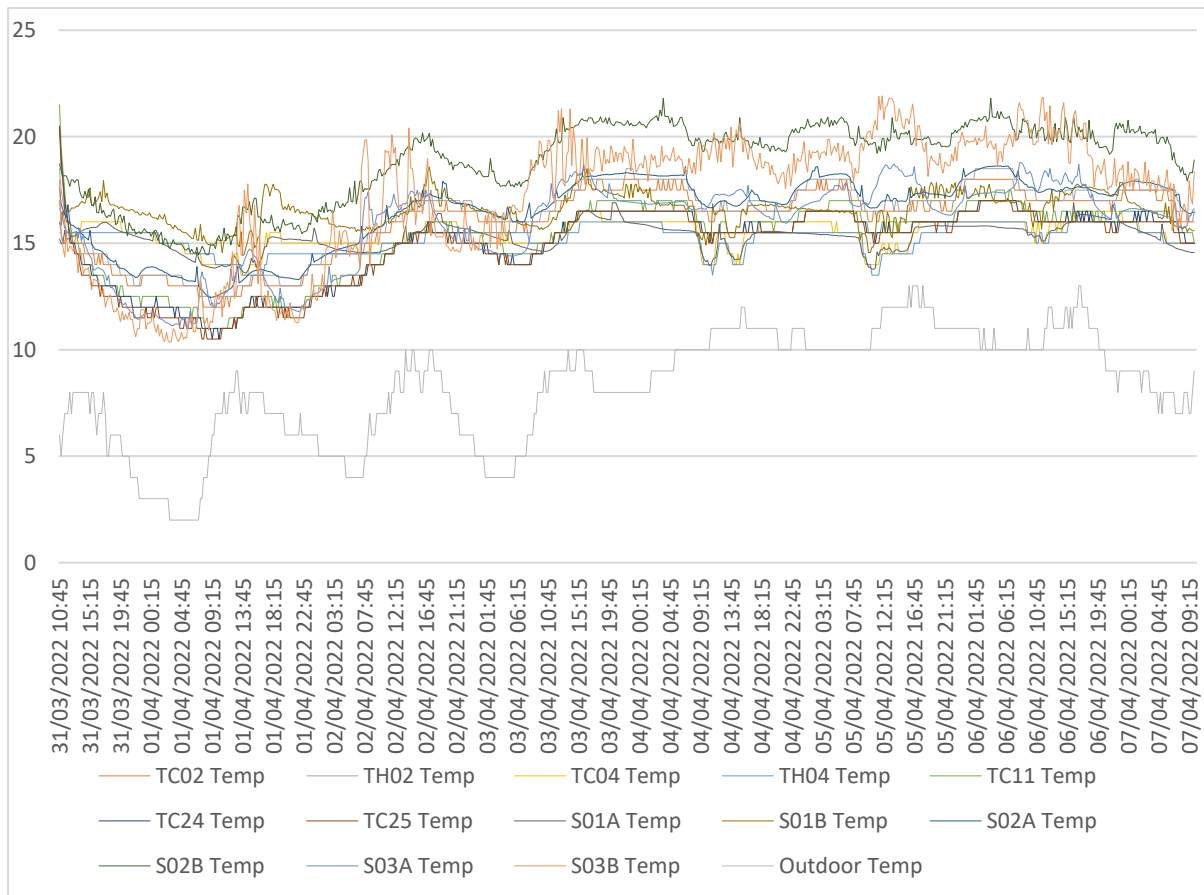
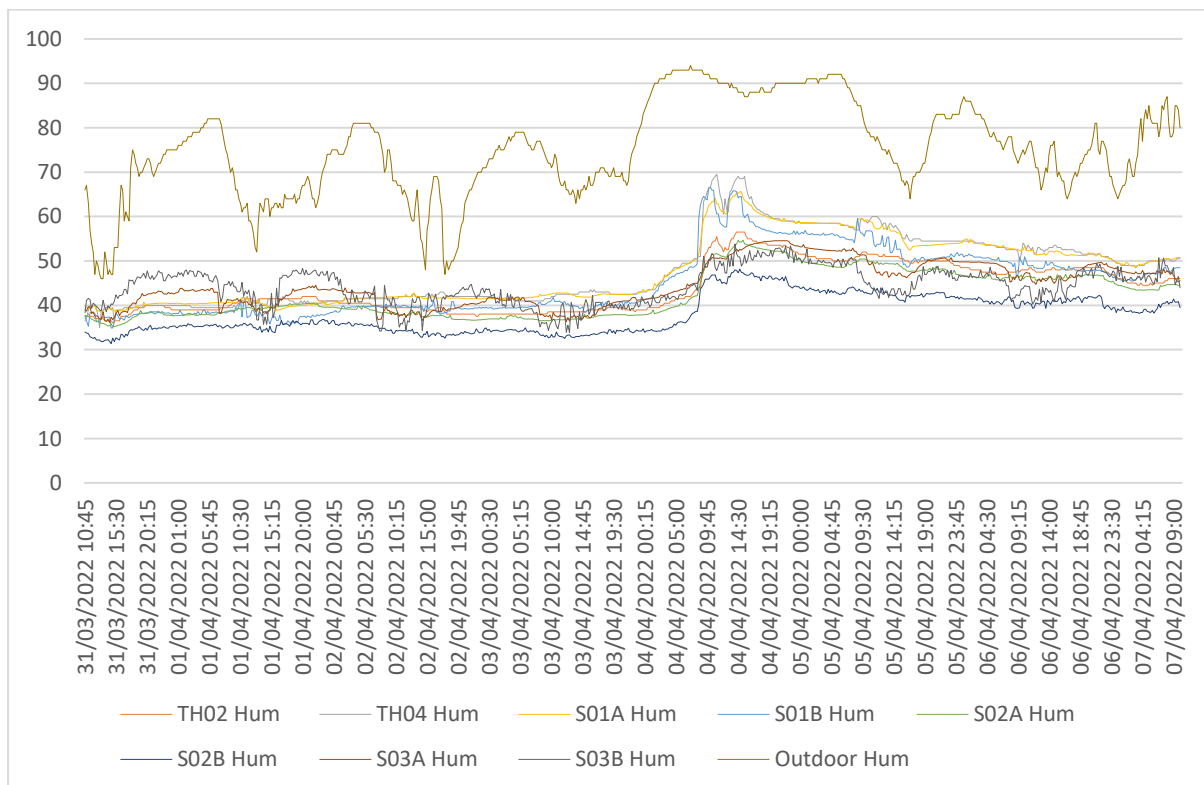
Sensor	Location	Installation Date	Data Processing
01	Outside room, stairs	31/03/2022 10:45	07/04/2022 10:15
02	desktop	31/03/2022 10:45	07/04/2022 10:15
03	window	31/03/2022 10:45	07/04/2022 10:15
05	desktop	31/03/2022 10:45	07/04/2022 10:15
TC011	heater (surface)	31/03/2022 10:45	07/04/2022 10:15
TC024	heater (top left)	31/03/2022 10:45	07/04/2022 10:15
TC025	heater (top right)	31/03/2022 10:45	07/04/2022 10:15
TH002	desk	31/03/2022 10:45	07/04/2022 10:15
TH004	Outside room, stairs	31/03/2022 10:45	07/04/2022 10:15

	TC 02 Temp	TH 02 Temp	TC 04 Temp	TH 04 Temp	TC 11 Temp	TC 24 Temp	TC 25 Temp	S001A Temp	S001B Temp	S002A Temp	S002B Temp	S003A Temp	S003B Temp	Outdoor Temp
Minimum	12.00	12.00	13.50	13.50	11.00	10.50	10.50	13.60	14.42	12.46	14.45	11.00	10.36	2.00
Maximum	18.00	21.00	16.50	17.00	24.00	22.50	22.50	16.90	18.58	18.70	21.81	18.79	21.92	13.00
Average	15.98	16.26	15.44	15.22	15.18	14.93	14.81	15.29	16.57	16.46	18.81	15.82	17.08	8.27
Std. Dev	1.67	1.72	0.68	0.64	1.79	1.77	1.84	0.64	0.77	1.70	1.89	2.04	3.07	2.62

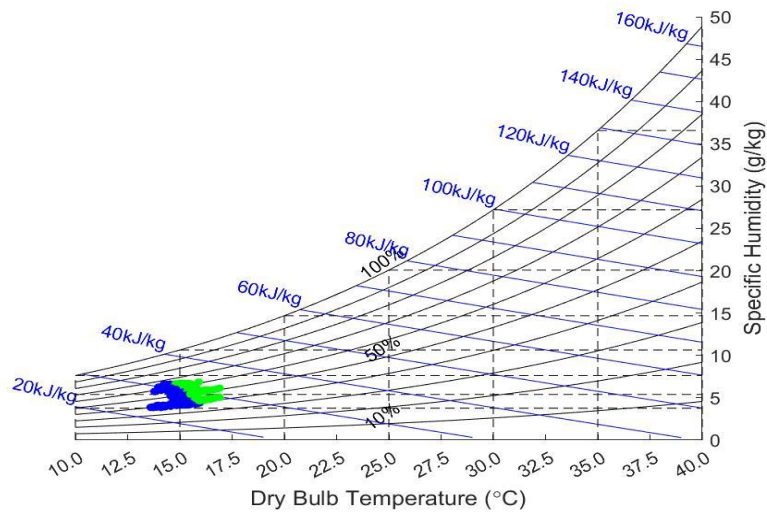
	TH 02 Hum	TH 04 Hum	S001A Hum	S001B Hum	S002A Hum	S002B Hum	S003A Hum	S003B Hum	Outdoor
Minimum	33.50	35.00	38.42	34.89	35.22	31.38	36.14	33.85	46.00
Maximum	56.50	69.50	65.58	66.65	54.68	48.15	54.56	53.83	94.00
Average	43.87	47.82	47.58	45.19	42.44	37.97	44.56	44.28	75.04
Std. Dev	5.50	7.93	7.47	7.51	5.31	4.28	5.01	4.14	10.74

Air velocity

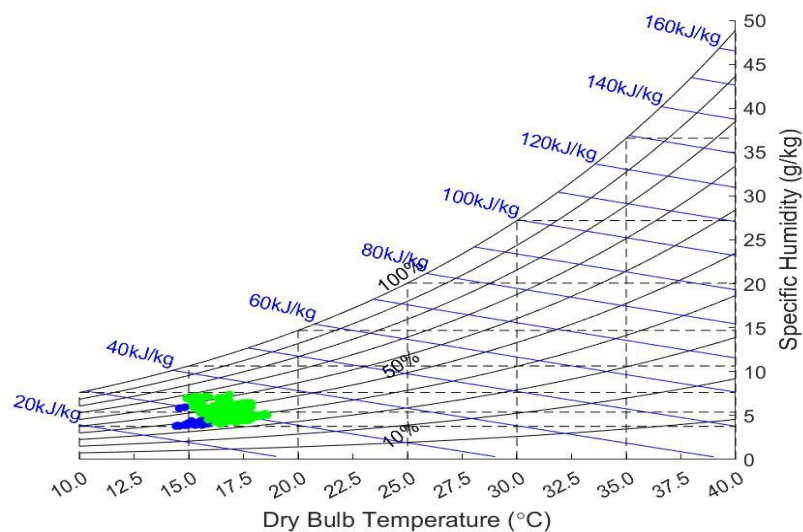
Parameters	Unit	Window	Room	Window
Velocity min	m/s	0.03	0.03	0.01
Velocity max	m/s	0.14	0.07	0.14
Velocity avg	m/s	0.07	0.05	0.07
Temperature min	°C	19.2	16.6	16.5
Temperature max	°C	20.3	19.1	16.8
Temperature avg	°C	19.7	17.5	16.5

Temperature:**Humidity:**

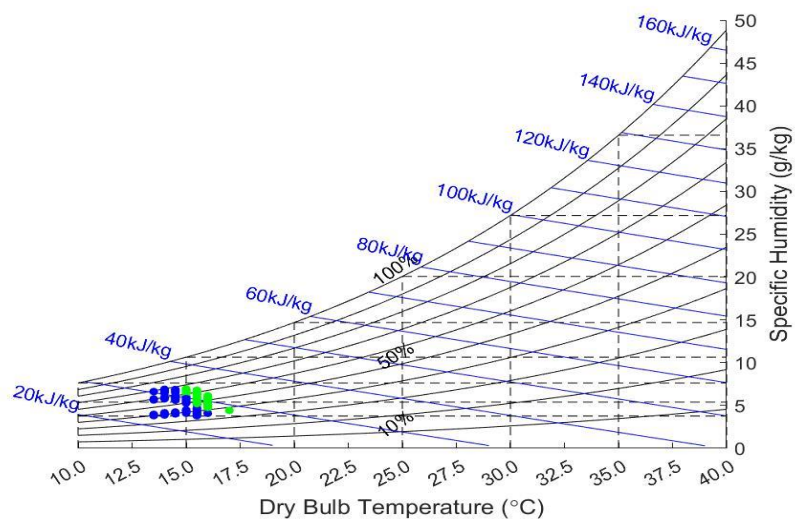
Sensor1A (Black Globe) Result, Comfort Outside the room 45.45% Comfort



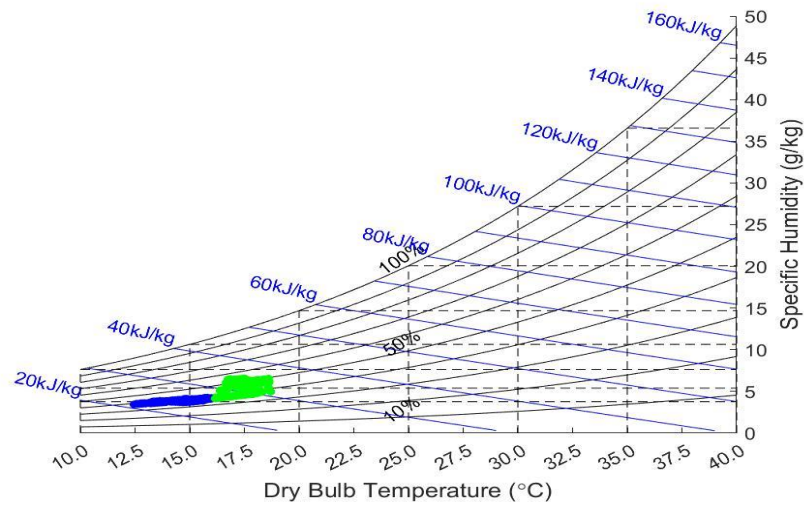
Sensor1B Result, Comfort Outside the room 83.31% Comfort



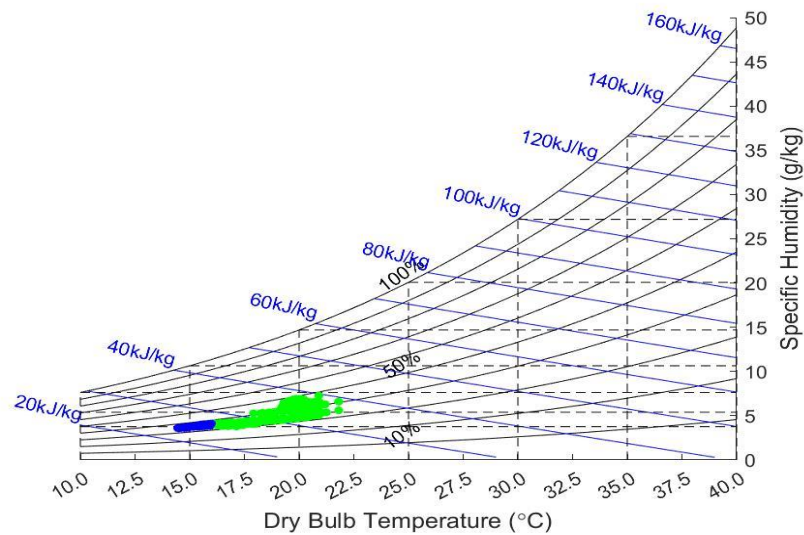
TH04 Result, Comfort Outside the room 41.88% Comfort



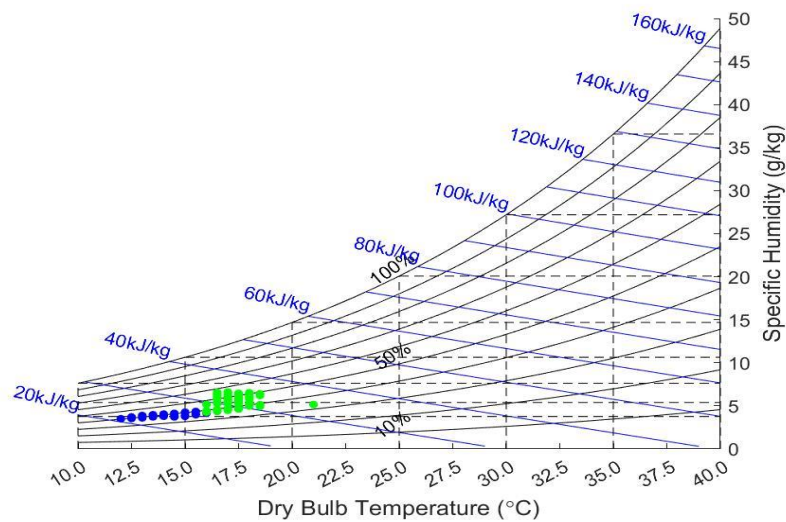
Sensor2A (Black Globe) Result, Comfort Inside the room 71.09% Comfort



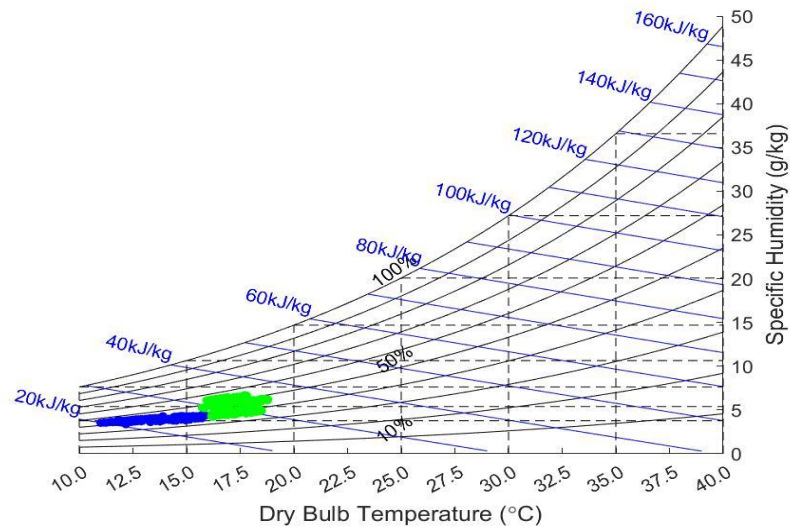
Sensor2B Result, Comfort Inside the room 85.54% Comfort



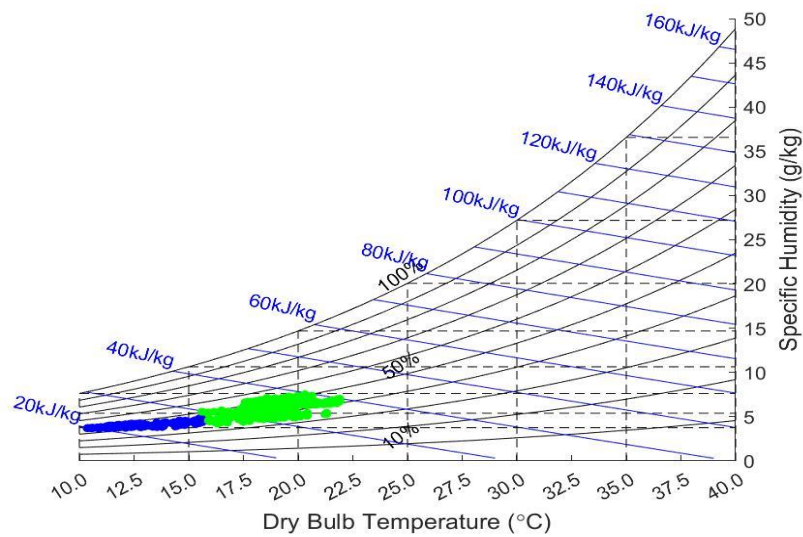
TH02 Result, Comfort Inside the room 71.98% Comfort



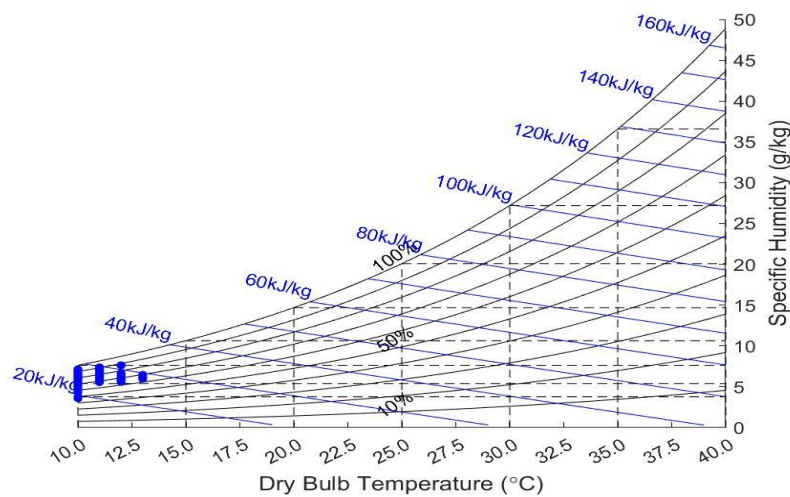
Sensor3A (Black Globe) Result, Comfort near Window 65.42% Comfort



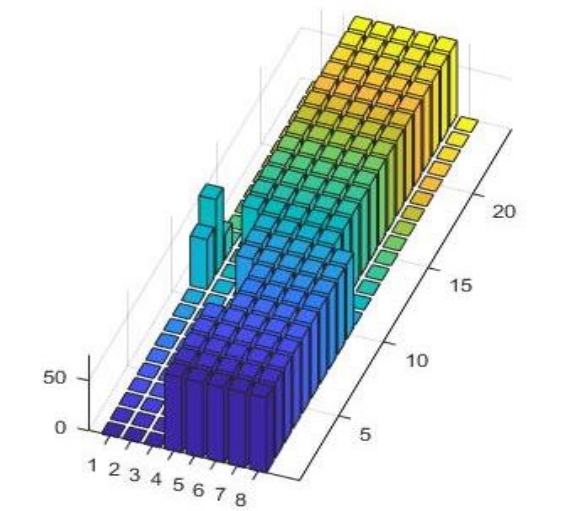
Sensor3B Result, Comfort near Window 68.26% Comfort



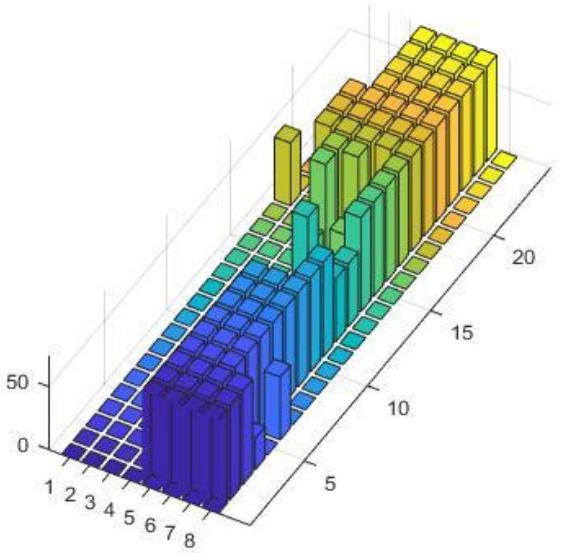
Outdoor Result, 0% Comfort



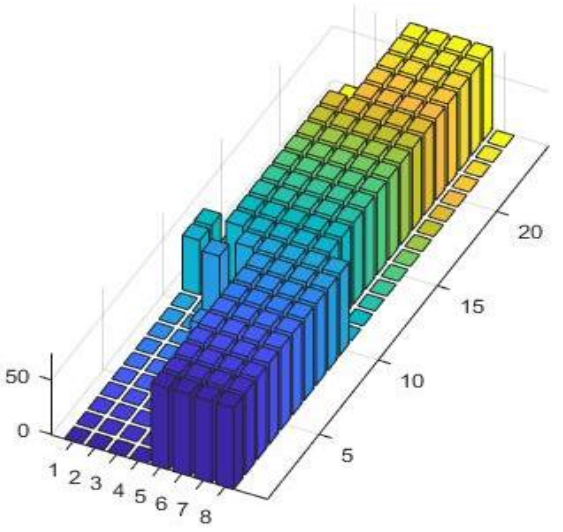
Sensor 2(Room)



Sensor 1 (stairs)



Sensor 3 (window)



Eighth Period

Sensor	Location	Installation Date	Data Processing
01	Outside room, stairs	07/04/2022 11:00	14/04/2022 09:45
02	desktop	07/04/2022 11:00	14/04/2022 09:45
03	window	07/04/2022 11:00	14/04/2022 09:45
05	desktop	07/04/2022 11:00	14/04/2022 09:45
TC011	heater (surface)	07/04/2022 11:00	14/04/2022 09:45
TC024	heater (top left)	07/04/2022 11:00	14/04/2022 09:45
TC025	heater (top right)	07/04/2022 11:00	14/04/2022 09:45
TH002	desk	07/04/2022 11:00	14/04/2022 09:45
TH004	Outside room, stairs	07/04/2022 11:00	14/04/2022 09:45

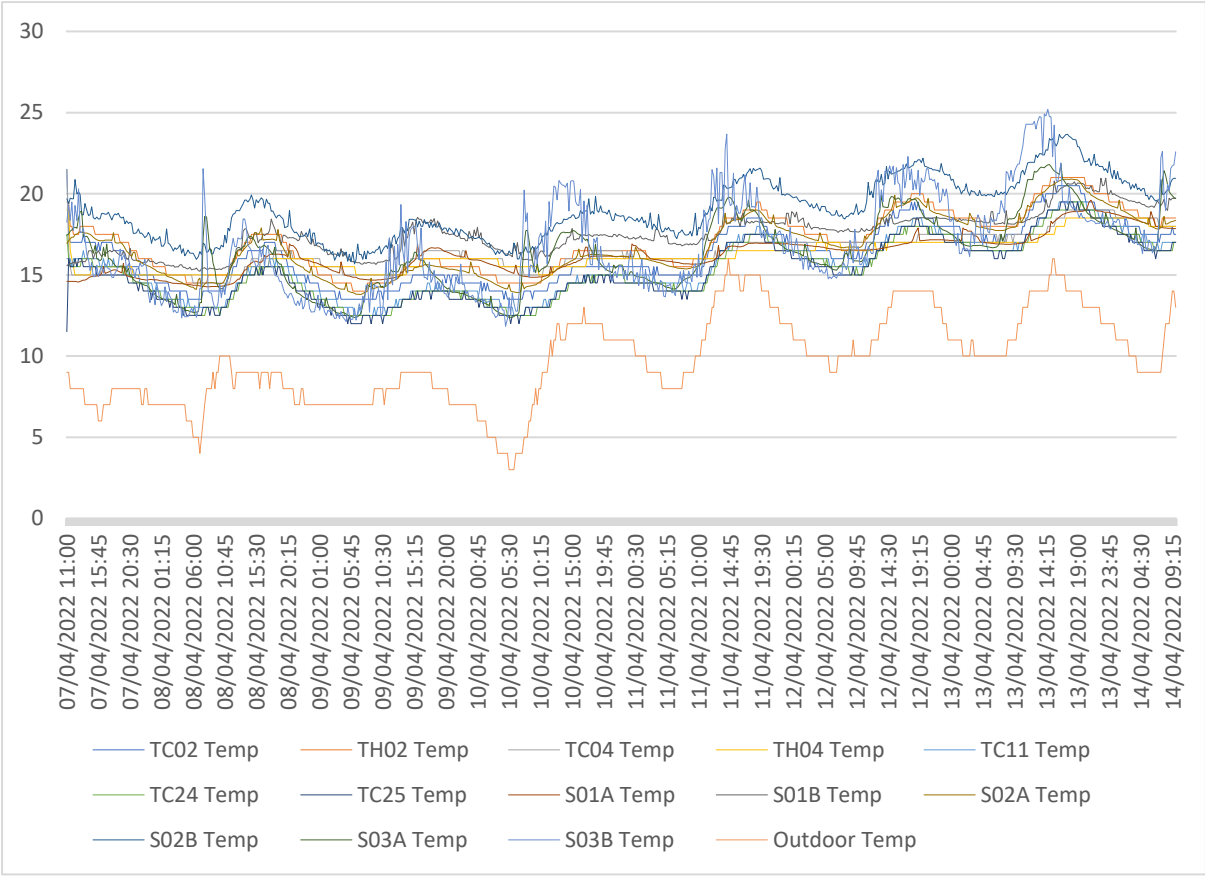
	TC 02 Temp	TH 02 Temp	TC 04 Temp	TH 04 Temp	TC 11 Temp	TC 24 Temp	TC 25 Temp	S001A Temp	S001B Temp	S002A Temp	S002B Temp	S003A Temp	S003B Temp	Outdoor Temp
Minimum	13.50	14.00	14.50	15.00	12.50	12.50	11.50	14.27	15.22	13.80	15.67	12.38	11.83	3.00
Maximum	21.50	21.00	21.50	19.00	19.50	19.50	19.50	19.60	20.96	20.91	23.65	21.80	25.19	16.00
Average	16.23	17.04	16.43	16.24	15.49	15.27	15.16	16.24	17.53	16.77	19.00	16.30	16.73	9.79
Std. Dev	1.85	1.81	1.17	1.01	1.84	1.85	1.89	1.21	1.30	1.81	1.85	2.24	2.92	2.74

	TH 02 Hum	TH 04 Hum	S001A Hum	S001B Hum	S002A Hum	S002B Hum	S003A Hum	S003B Hum	Outdoor
Minimum	38.50	43.00	43.68	39.96	38.11	33.78	35.70	33.39	42.00
Maximum	49.50	51.50	51.95	49.28	47.90	43.29	51.50	57.25	91.00
Average	43.40	46.96	46.93	44.21	43.09	38.70	44.86	46.75	70.33
Std. Dev	2.24	2.21	2.34	2.32	2.30	2.22	3.56	4.78	12.93

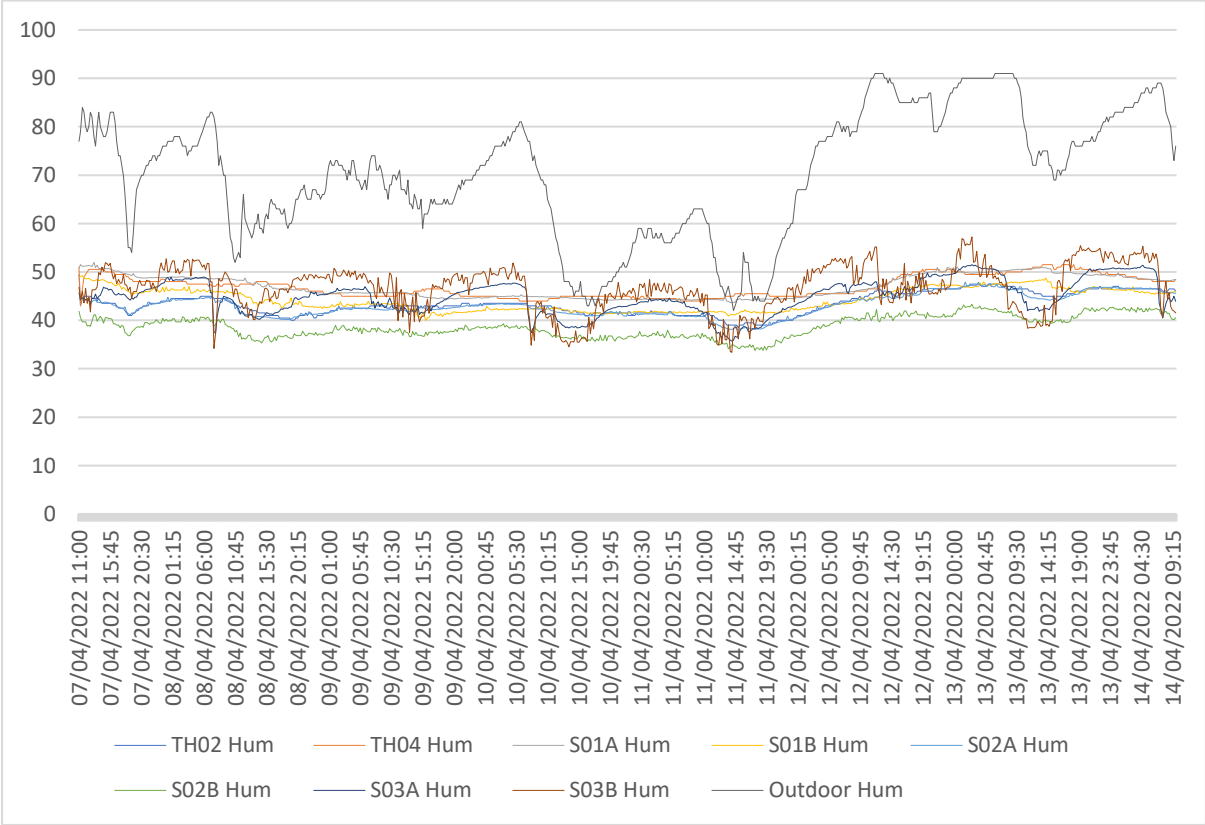
Air velocity

Parameters	Unit	Window	Room	Window
Velocity min	m/s	0.03	0.03	0.02
Velocity max	m/s	0.09	0.14	0.07
Velocity avg	m/s	0.05	0.05	0.04
Temperature min	°C	21.6	18.9	18.9
Temperature max	°C	22.7	21.4	19.6
Temperature avg	°C	22.2	19.8	19.3

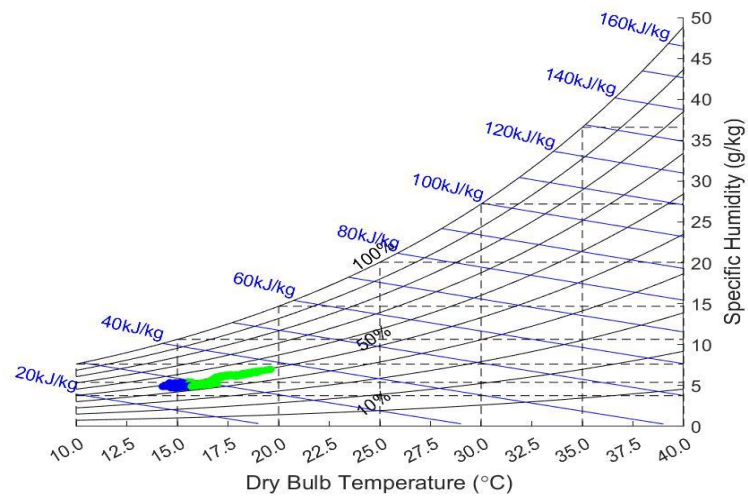
Temperature:



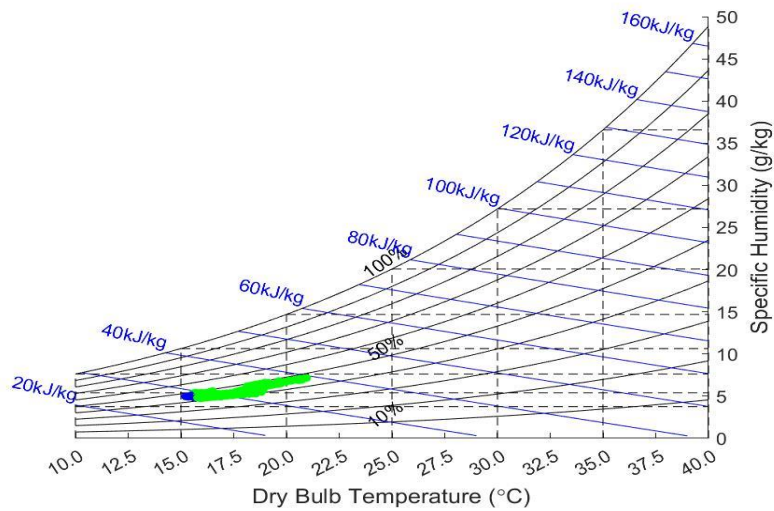
Humidity:



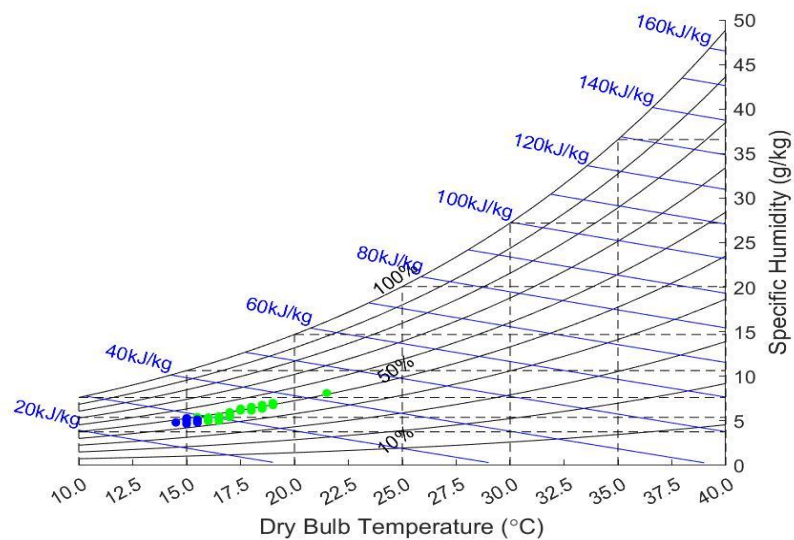
Sensor1A (Black Globe) Result, Comfort Outside the room 67.06% Comfort



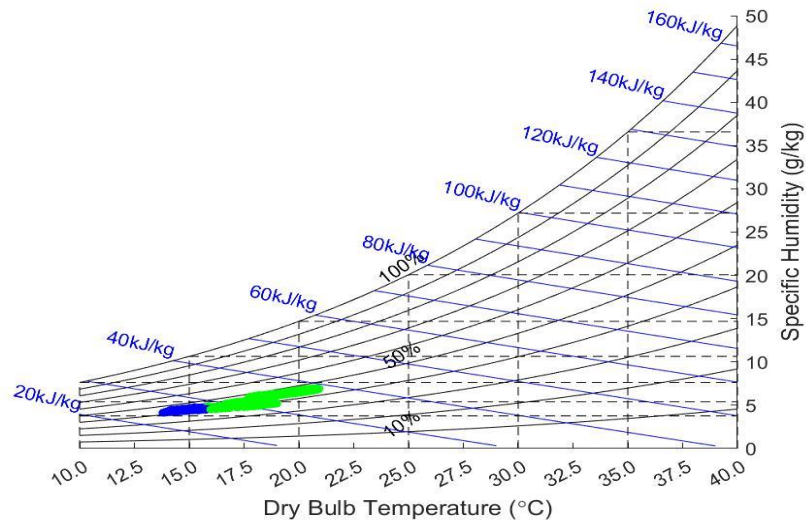
Sensor1B Result, Comfort Outside the room 93.71% Comfort



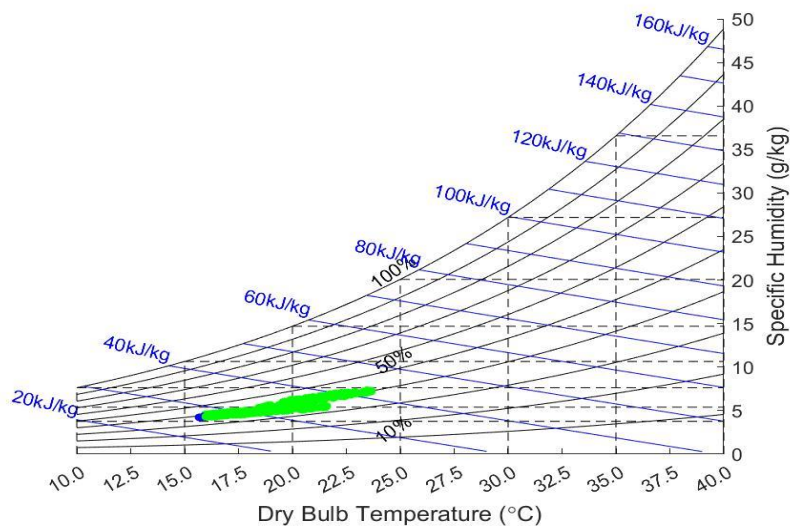
TH04 Result, Comfort Outside the room 73.05% Comfort



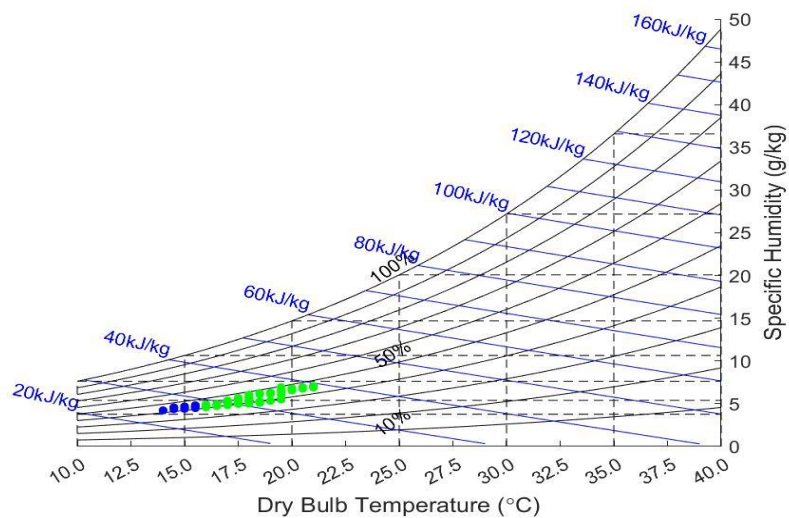
Sensor2A (Black Globe) Result, Comfort Inside the room 62.13% Comfort



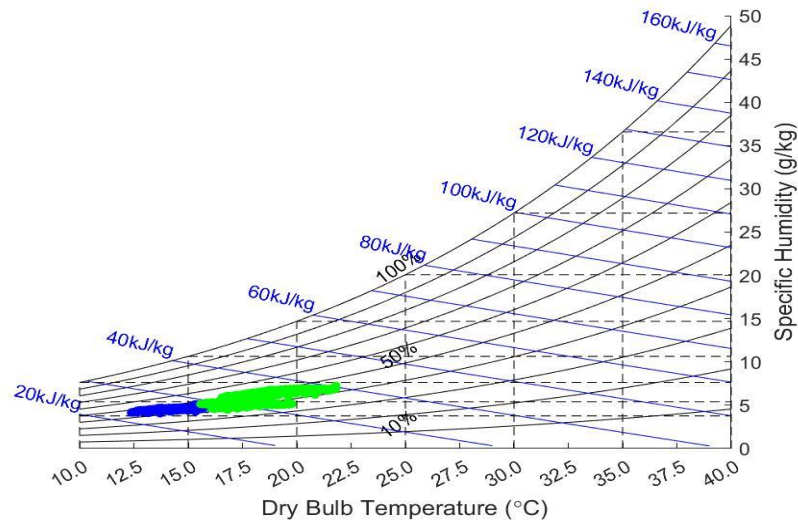
Sensor2B Result, Comfort Inside the room 99.10% Comfort



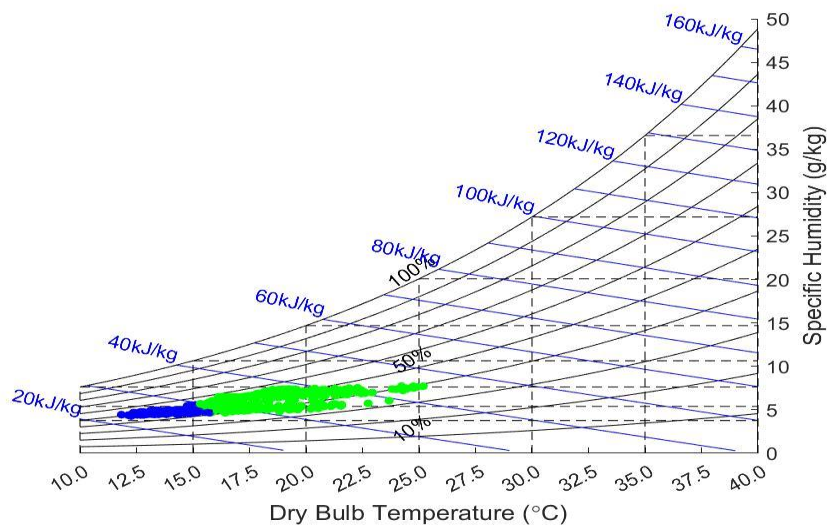
TH02 Result, Comfort Inside the room 70.21% Comfort



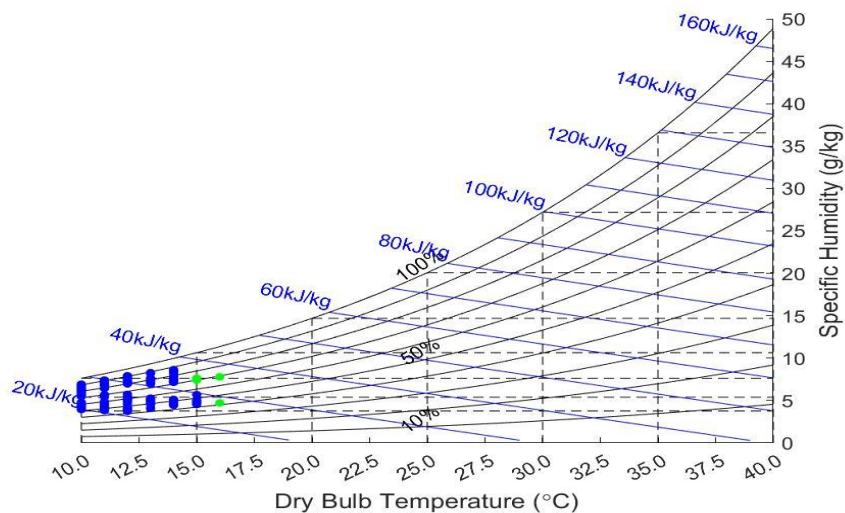
Sensor3A (Black Globe) Result, Comfort near Window 58.08% Comfort



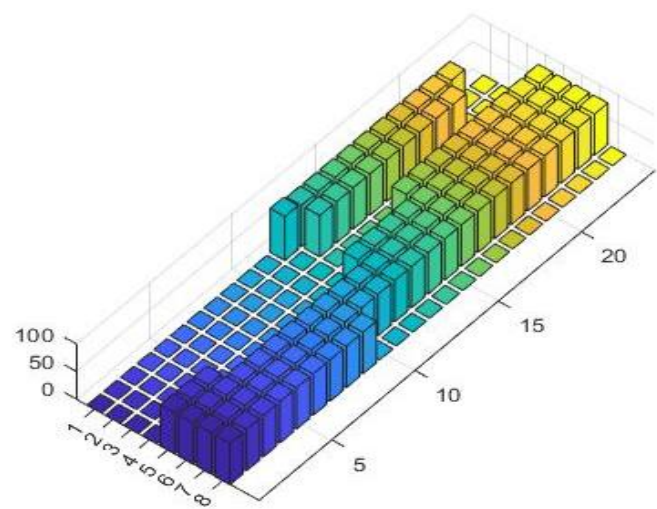
Sensor3B Result, Comfort near Window 58.23% Comfort



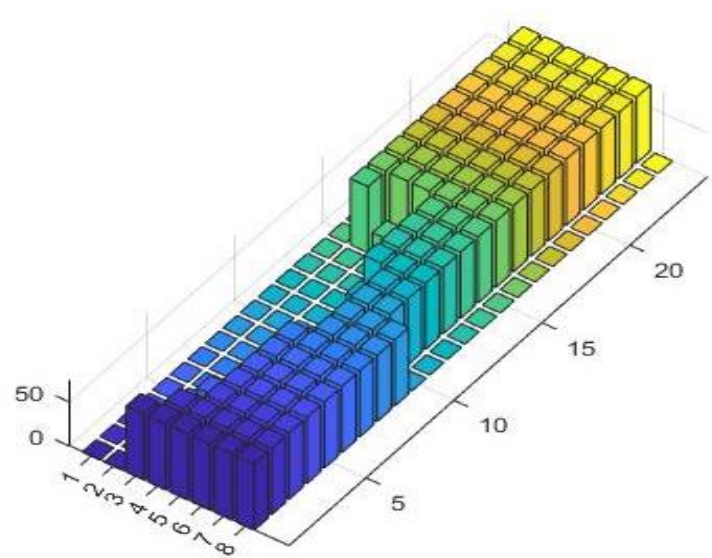
Outdoor Result, 1.65% Comfort



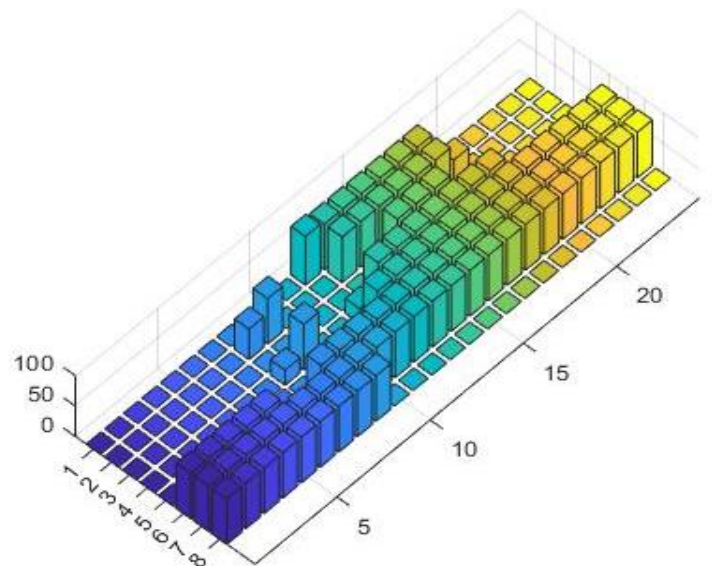
Sensor 2(Room)



Sensor 1 (stairs)



Sensor 3 (window)



Ninth Period

Sensor	Location	Installation Date	Data Processing
01	Outside room, stairs	14/04/2022 11:00	21/04/2022 10:15
02	desktop	14/04/2022 11:00	21/04/2022 10:15
03	window	14/04/2022 11:00	21/04/2022 10:15
05	desktop	14/04/2022 11:00	21/04/2022 10:15
TC011	heater (surface)	14/04/2022 11:00	21/04/2022 10:15
TC024	heater (top left)	14/04/2022 11:00	21/04/2022 10:15
TC025	heater (top right)	14/04/2022 11:00	21/04/2022 10:15
TH002	desk	14/04/2022 11:00	21/04/2022 10:15
TH004	Outside room, stairs	14/04/2022 11:00	21/04/2022 10:15

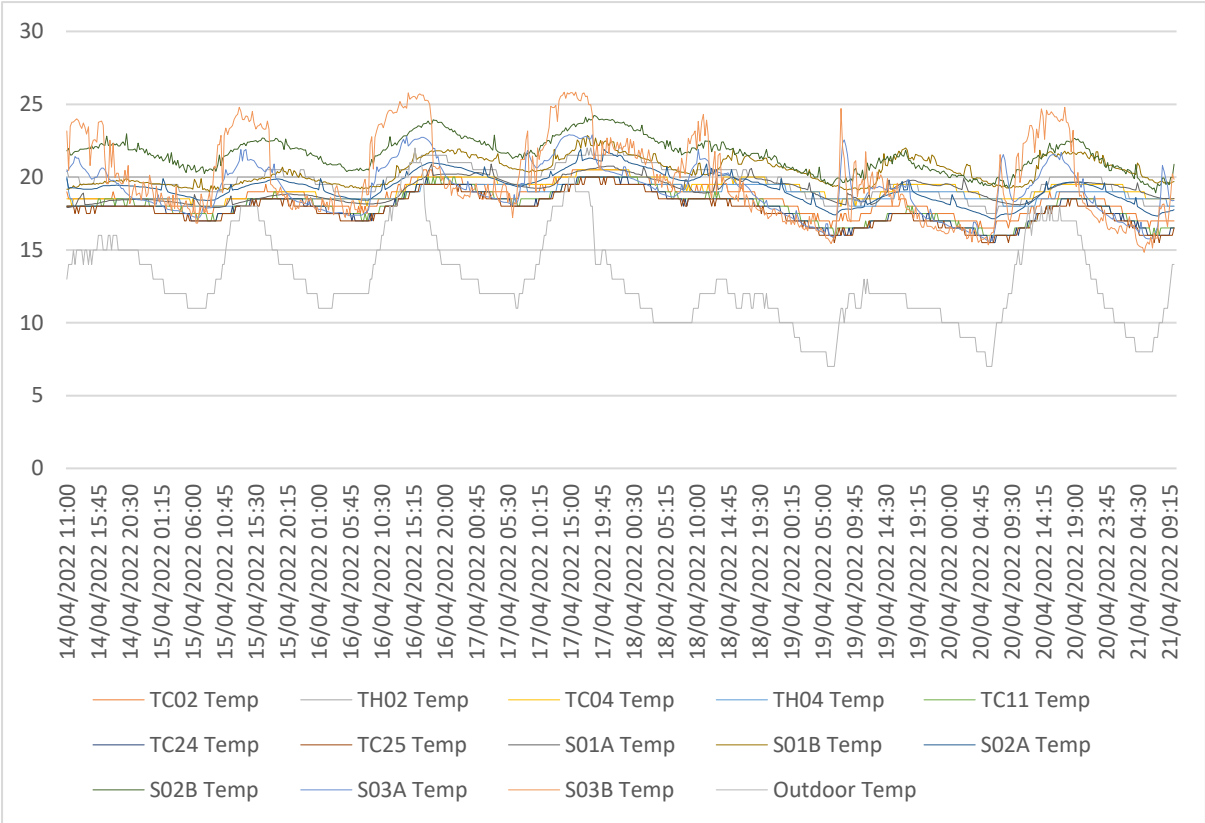
	TC 02 Temp	TH 02 Temp	TC 04 Temp	TH 04 Temp	TC 11 Temp	TC 24 Temp	TC 25 Temp	S001A Temp	S001B Temp	S002A Temp	S002B Temp	S003A Temp	S003B Temp	Outdoor Temp
Minimum	16.50	17.50	18.00	18.00	16.00	15.50	15.50	17.89	18.99	17.14	18.92	15.60	14.83	7.00
Maximum	20.50	22.00	20.50	22.00	20.00	20.00	20.00	20.90	22.85	21.90	24.23	22.91	25.84	22.00
Average	18.52	19.72	19.15	18.84	18.04	17.90	17.74	19.11	20.43	19.27	21.56	19.14	19.91	12.93
Std. Dev	1.00	1.02	0.66	0.59	1.03	1.06	1.06	0.76	0.92	1.03	1.17	1.76	2.84	3.03

	TH 02 Hum	TH 04 Hum	S001A Hum	S001B Hum	S002A Hum	S002B Hum	S003A Hum	S003B Hum	Outdoor
Minimum	40.50	42.00	43.92	41.18	41.26	36.20	36.61	35.22	43.00
Maximum	49.50	53.50	51.99	48.77	49.84	44.17	52.86	58.74	88.00
Average	45.90	48.85	48.20	45.41	46.02	41.01	47.00	48.44	71.94
Std. Dev	2.00	1.92	1.84	1.96	1.97	1.79	3.53	5.43	11.02

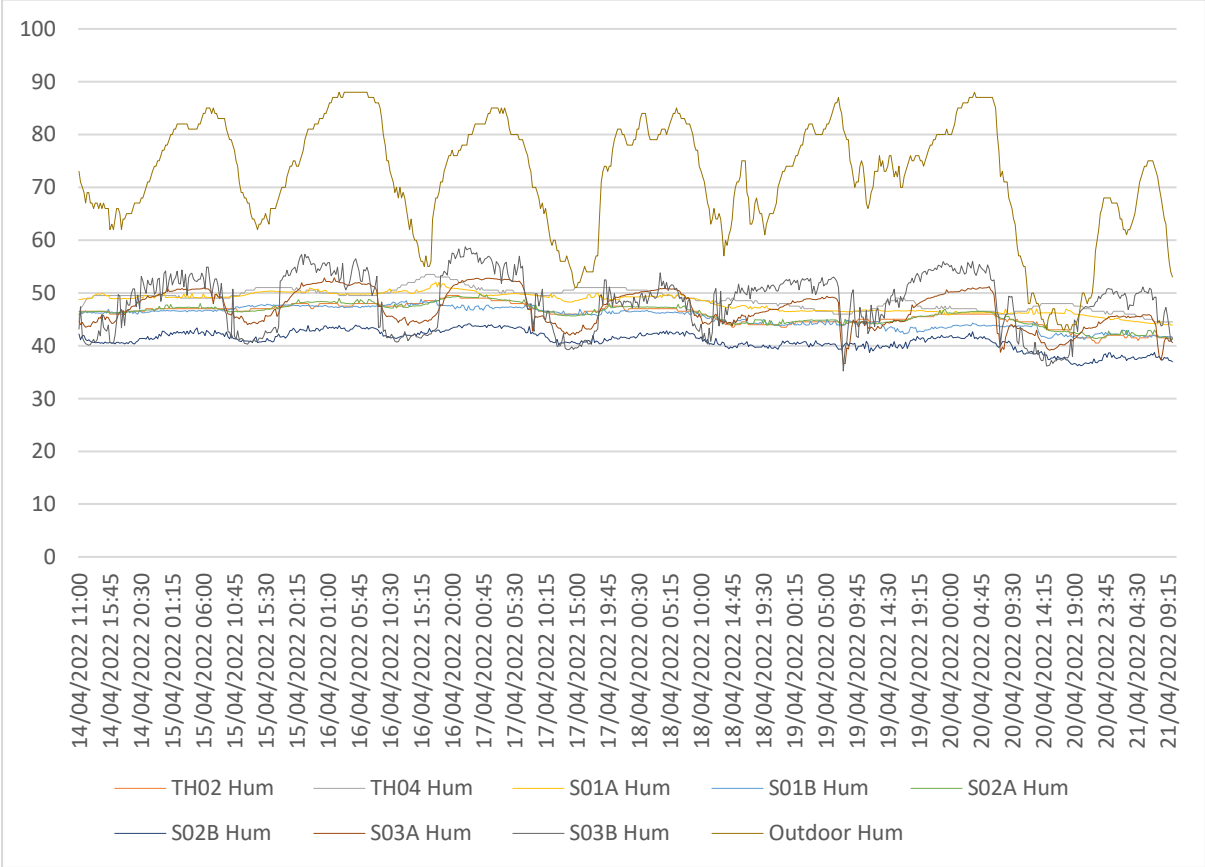
Air velocity

Parameters	Unit	Window	Room	Window
Velocity min	m/s	0.04	0.04	0.01
Velocity max	m/s	0.21	0.12	0.20
Velocity avg	m/s	0.11	0.06	0.09
Temperature min	°C	22.2	18.4	18.3
Temperature max	°C	24.1	21.6	19.5
Temperature avg	°C	23.2	19.6	19.0

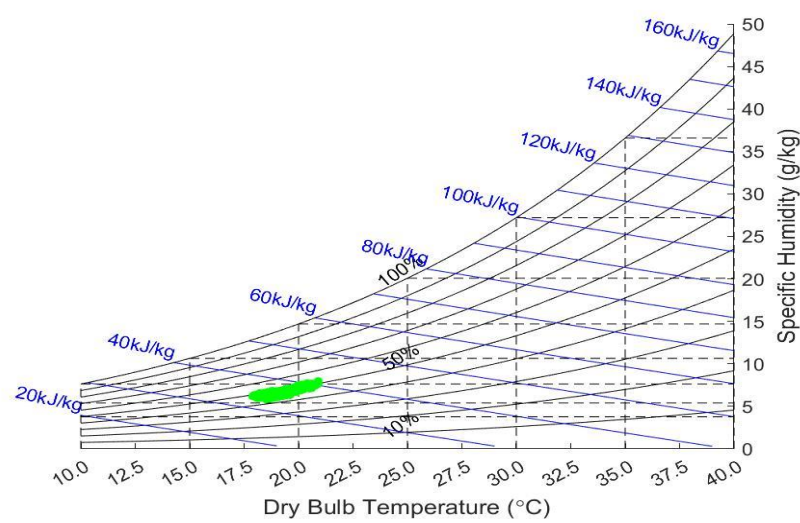
Temperature:



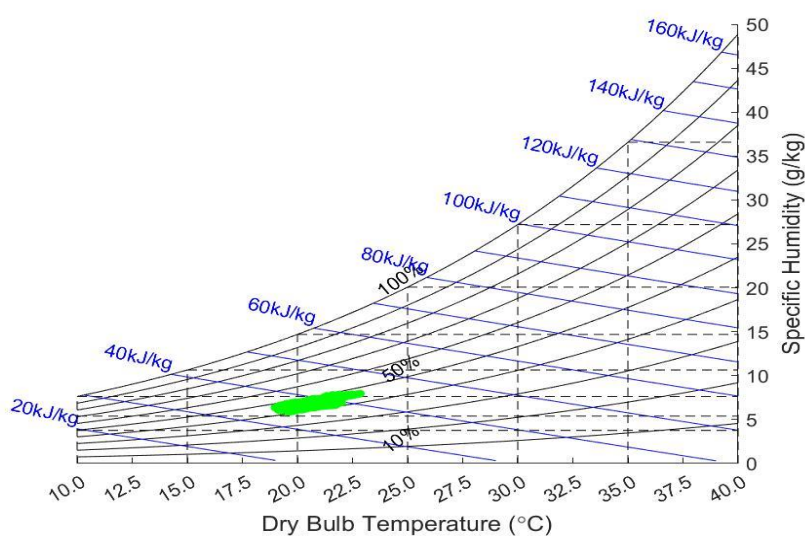
Humidity:



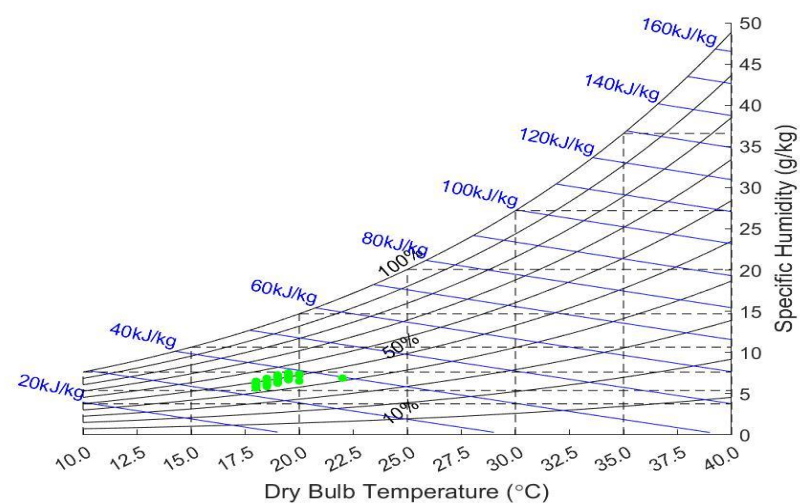
Sensor1A (Black Globe) Result, Comfort Outside the room 100% Comfort



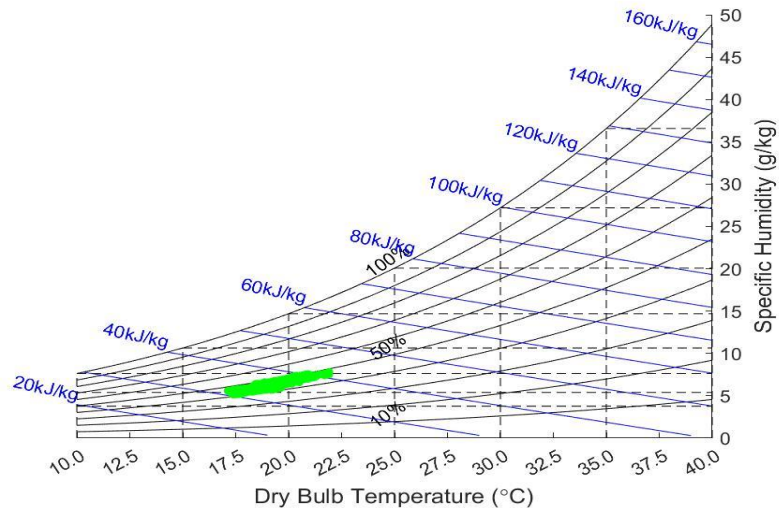
Sensor1B Result, Comfort Outside the room 100% Comfort



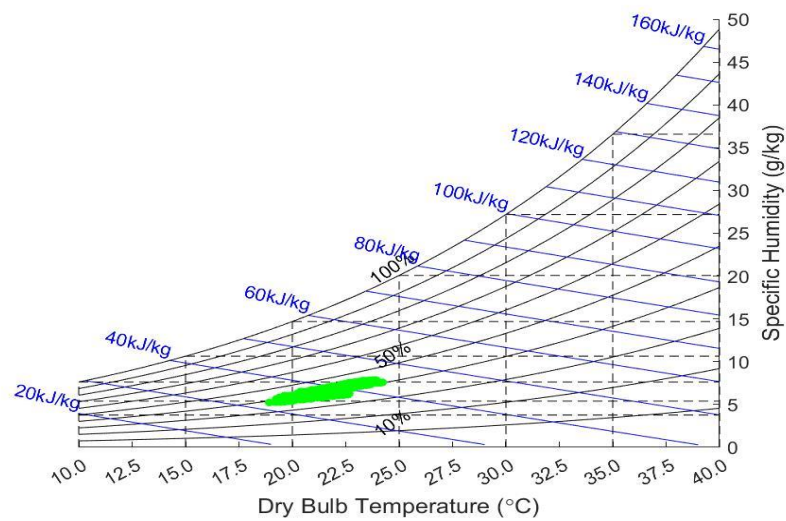
TH04 Result, Comfort Outside the room 100% Comfort



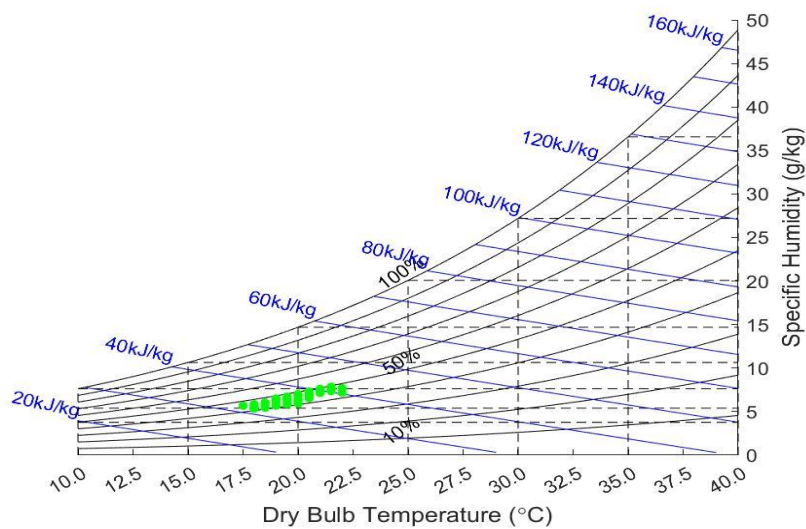
Sensor2A (Black Globe) Result, Comfort Inside the room 100% Comfort



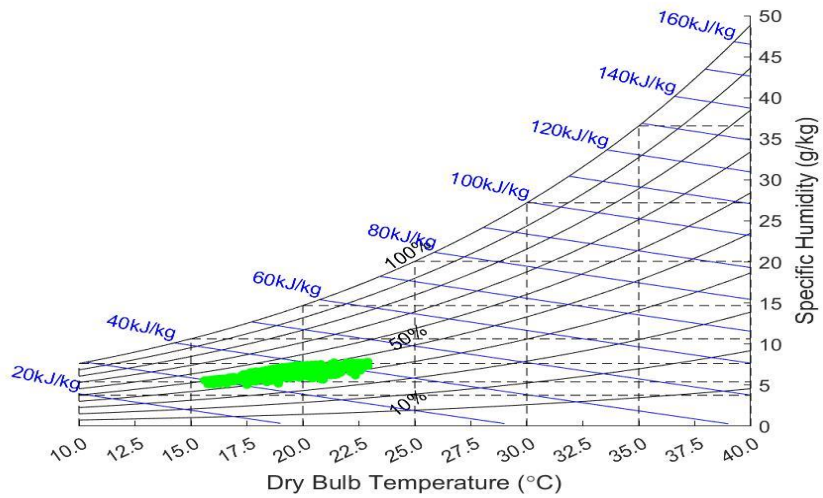
Sensor2B Result, Comfort Inside the room 100% Comfort



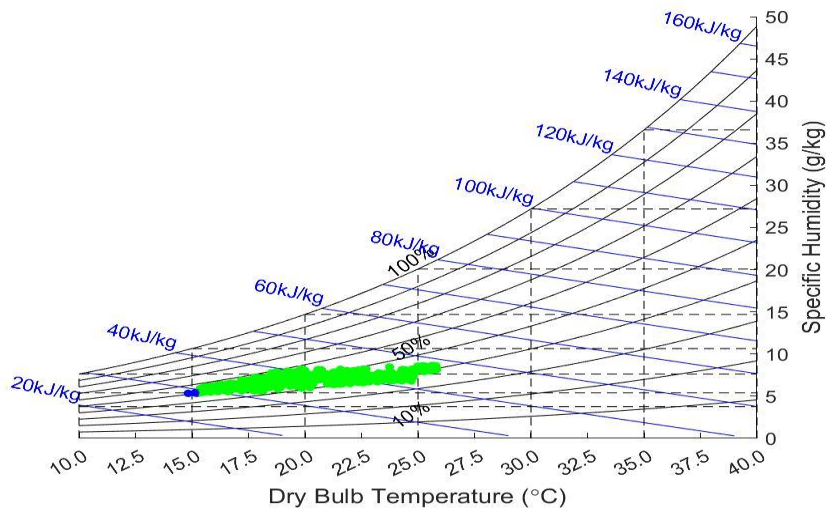
TH02 Result, Comfort Inside the room 100% Comfort



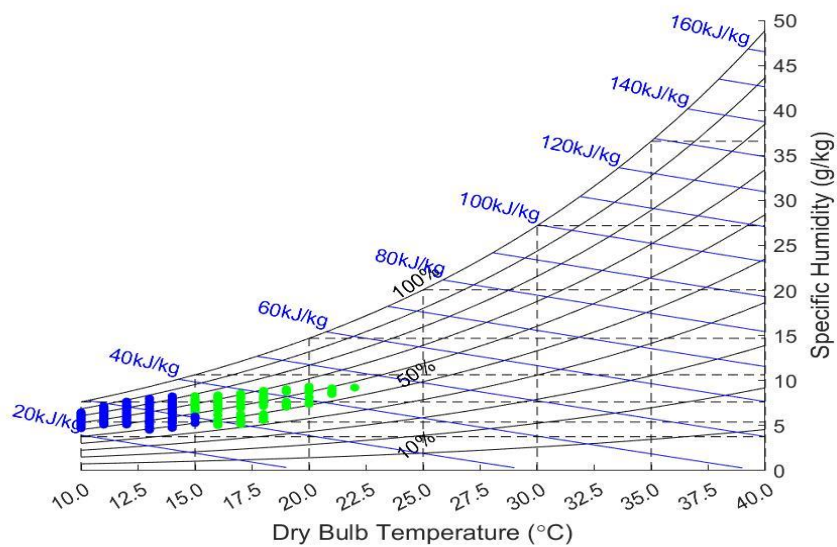
Sensor3A (Black Globe) Result, Comfort near Window 100% Comfort



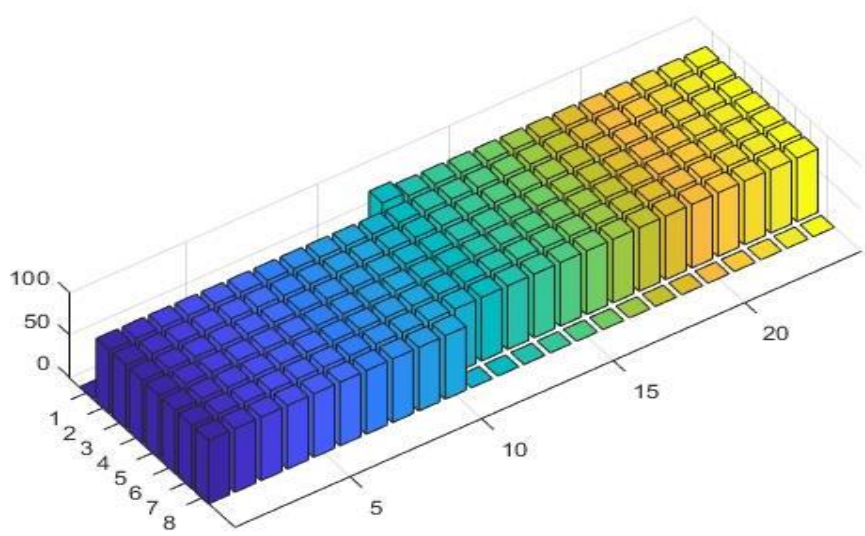
Sensor3B Result, Comfort near Window 99.10% Comfort



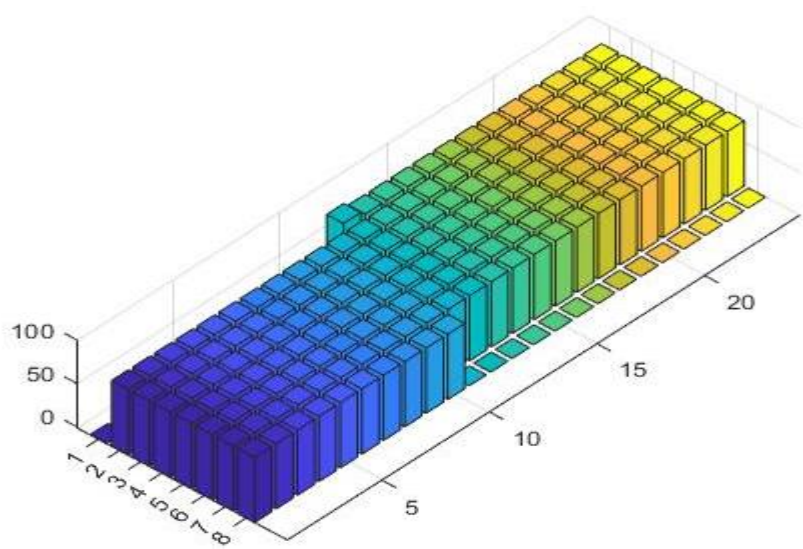
Outdoor Result, 26.57% Comfort



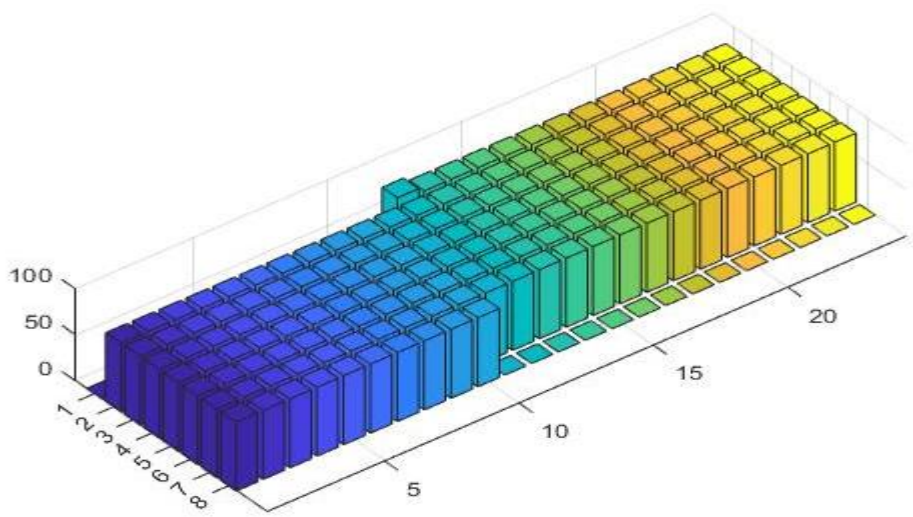
Sensor 2(Room)



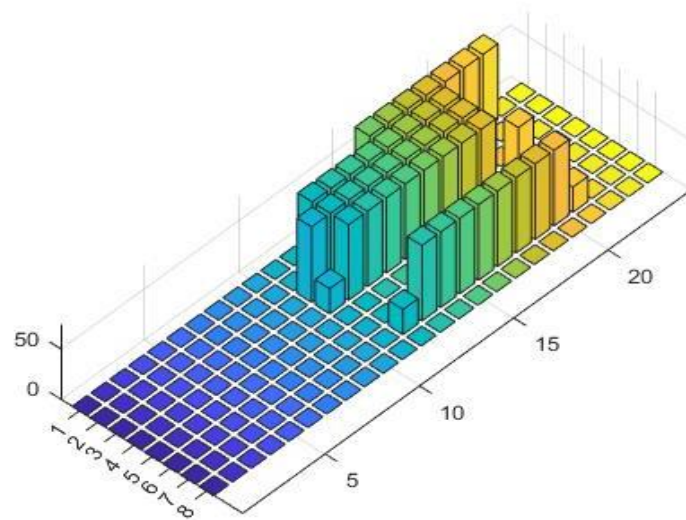
Sensor 1 (stairs)



Sensor 3 (window)



Outdoor



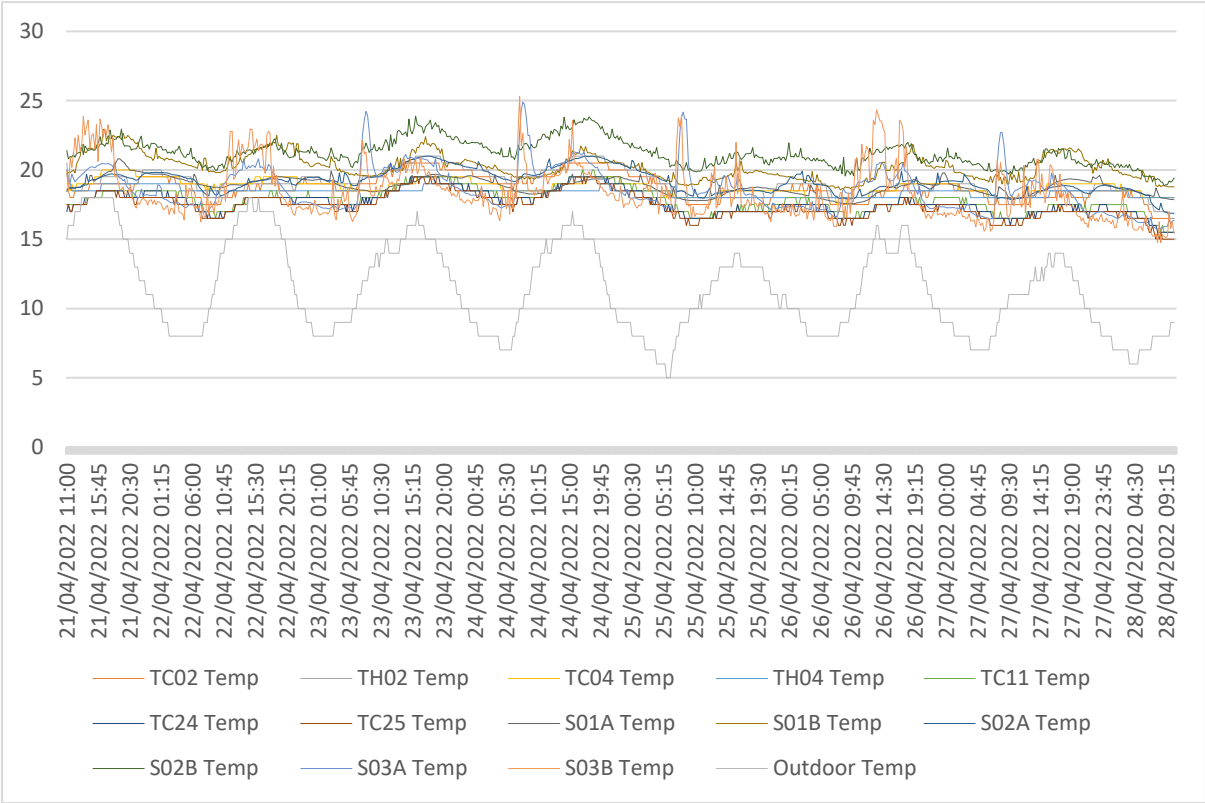
Tenth Period

Sensor	Location	Installation Date	Data Processing
01	Outside room, stairs	21/04/2022 11:00	28/04/2022 10:45
02	desktop	21/04/2022 11:00	28/04/2022 10:45
03	window	21/04/2022 11:00	28/04/2022 10:45
05	desktop	21/04/2022 11:00	28/04/2022 10:45
TC011	heater (surface)	21/04/2022 11:00	28/04/2022 10:45
TC024	heater (top left)	21/04/2022 11:00	28/04/2022 10:45
TC025	heater (top right)	21/04/2022 11:00	28/04/2022 10:45
TH002	desk	21/04/2022 11:00	28/04/2022 10:45
TH004	Outside room, stairs	21/04/2022 11:00	28/04/2022 10:45

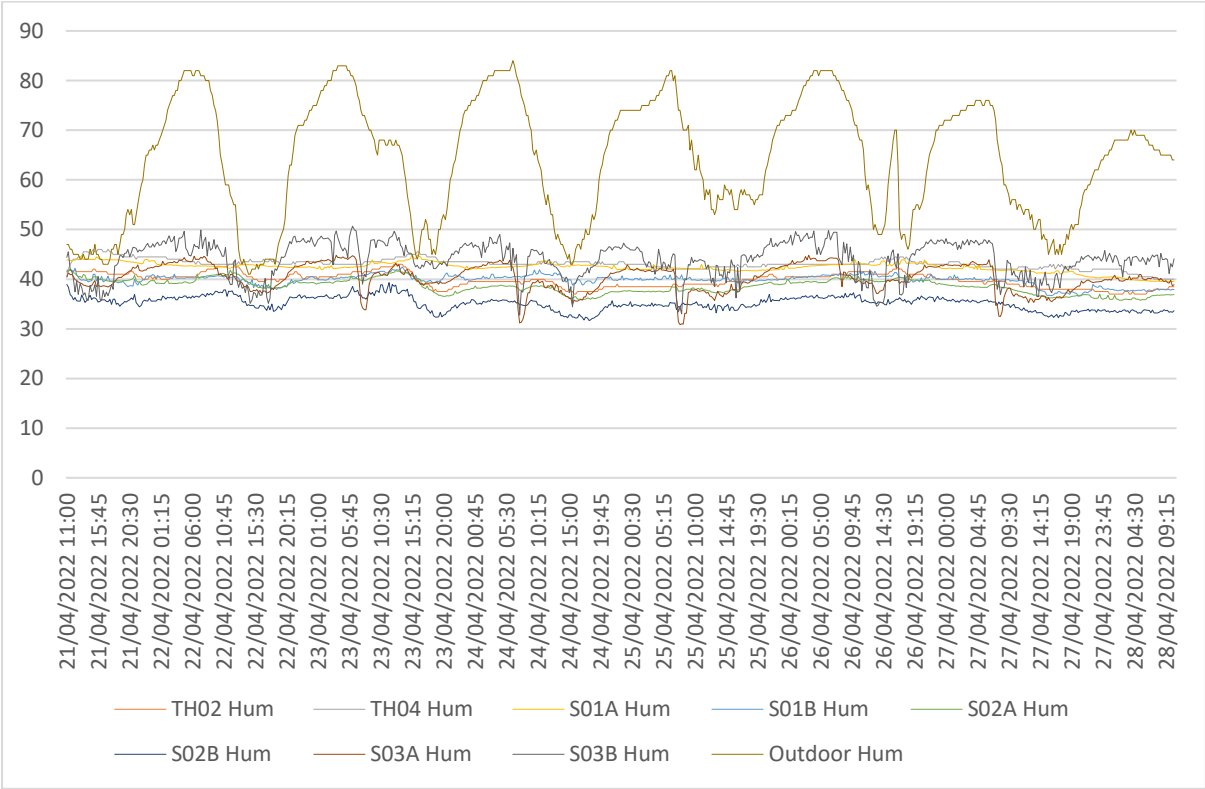
	TC 02 Temp	TH 02 Temp	TC 04 Temp	TH 04 Temp	TC 11 Temp	TC 24 Temp	TC 25 Temp	S001A Temp	S001B Temp	S002A Temp	S002B Temp	S003A Temp	S003B Temp	Outdoor Temp
Minimum	16.50	16.50	17.50	18.00	15.50	15.50	15.00	17.57	18.55	16.86	18.87	15.72	14.76	5.00
Maximum	20.50	23.00	20.00	22.50	20.00	19.50	19.50	20.80	22.93	21.00	23.89	24.90	25.30	18.00
Average	18.70	19.05	18.80	18.40	17.83	17.65	17.44	18.85	20.23	19.18	21.21	18.62	18.41	11.40
Std. Dev	0.90	0.91	0.53	0.37	0.86	0.87	0.90	0.60	0.91	0.85	0.95	1.57	1.91	3.28

	TH 02 Hum	TH 04 Hum	S001A Hum	S001B Hum	S002A Hum	S002B Hum	S003A Hum	S003B Hum	Outdoor
Minimum	35.50	37.50	39.51	36.56	35.75	31.66	30.85	32.76	41.00
Maximum	43.00	46.00	44.95	42.47	41.91	39.30	44.82	50.67	84.00
Average	39.79	43.09	42.41	39.85	38.60	35.18	40.27	43.94	63.90
Std. Dev	1.46	1.05	1.00	1.08	1.45	1.38	2.69	3.60	12.29

Temperature:



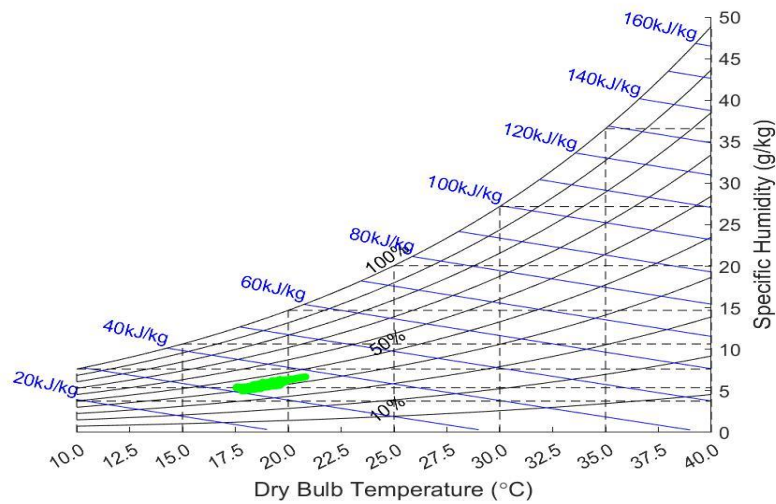
Humidity:



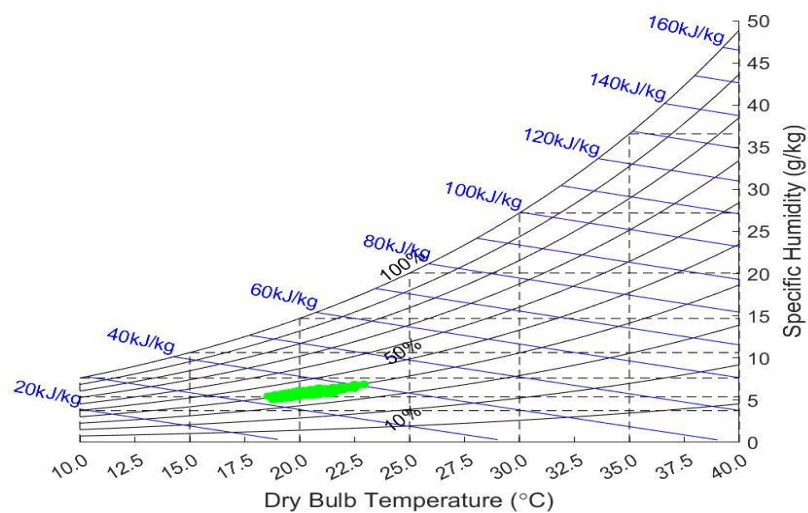
Air velocity

Parameters	Unit	Window	Room	Window
Velocity min	m/s	0.07	0.04	0.03
Velocity max	m/s	0.19	0.11	0.16
Velocity avg	m/s	0.13	0.05	0.09
Temperature min	°C	22.5	18.0	17.5
Temperature max	°C	24.2	22.0	17.7
Temperature avg	°C	23.2	19.4	17.5

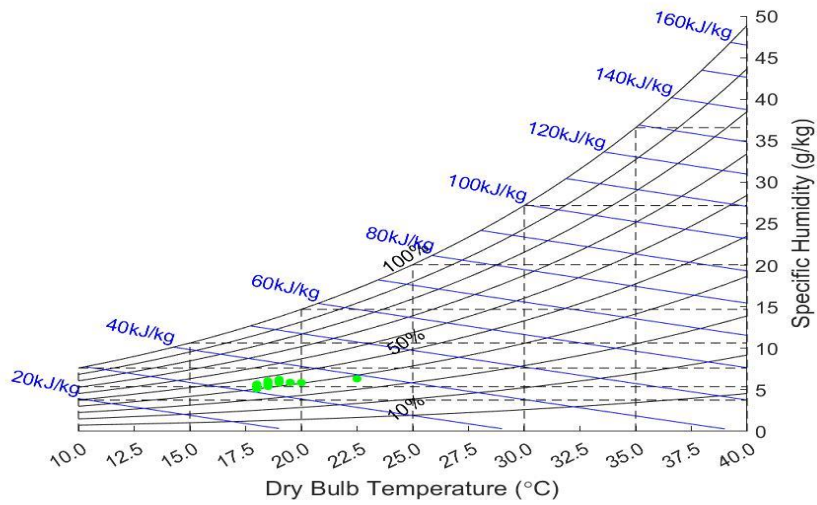
Sensor1A (Black Globe) Result, Comfort Outside the room 100% Comfort



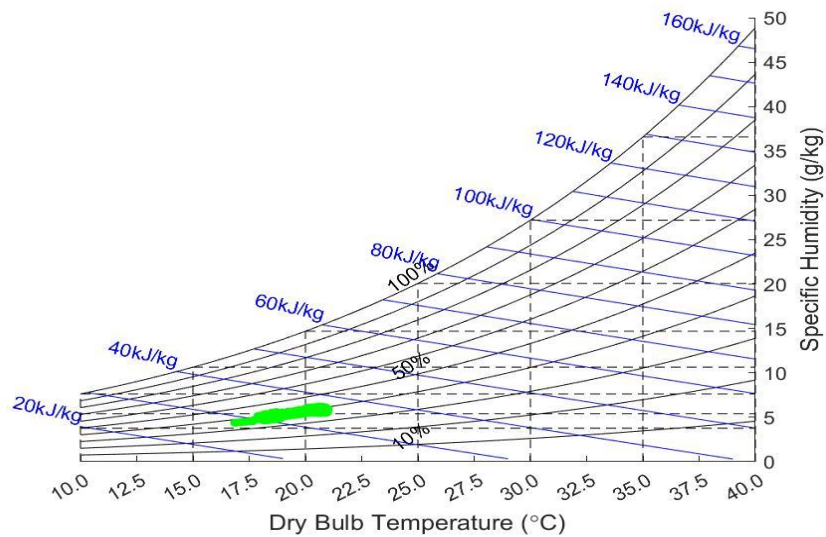
Sensor1B Result, Comfort Outside the room 100% Comfort



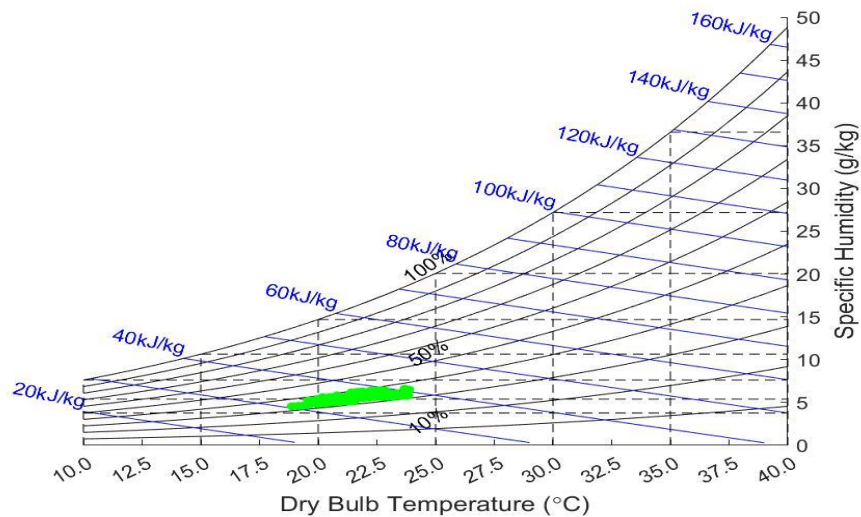
TH04 Result, Comfort Outside the room 100% Comfort



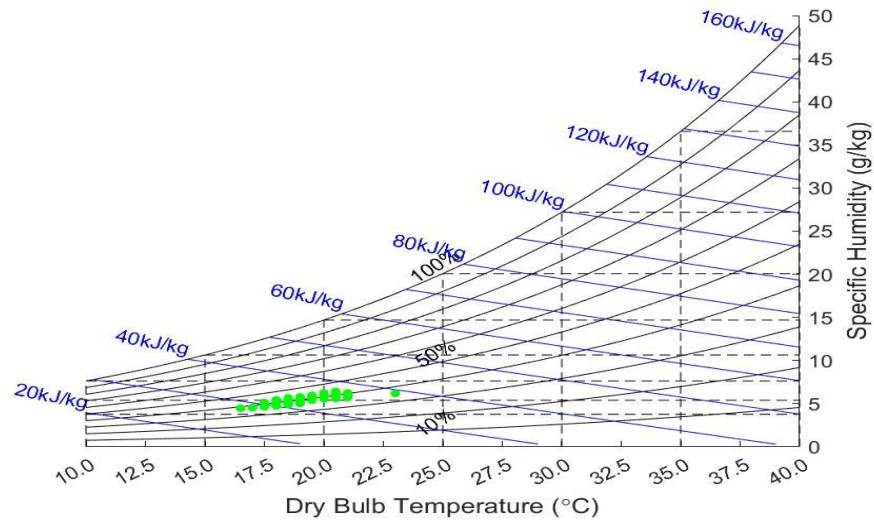
Sensor2A (Black Globe) Result, Comfort Inside the room 100% Comfort



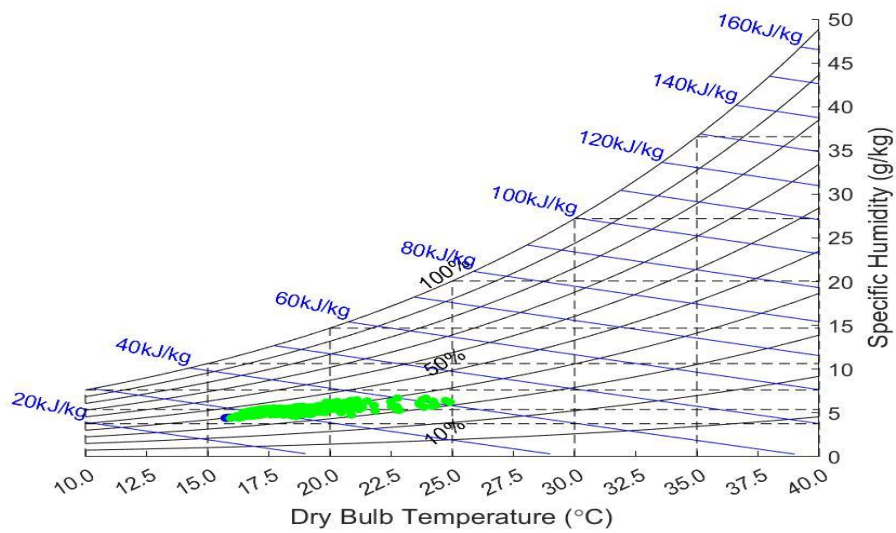
Sensor2B Result, Comfort Inside the room 100% Comfort



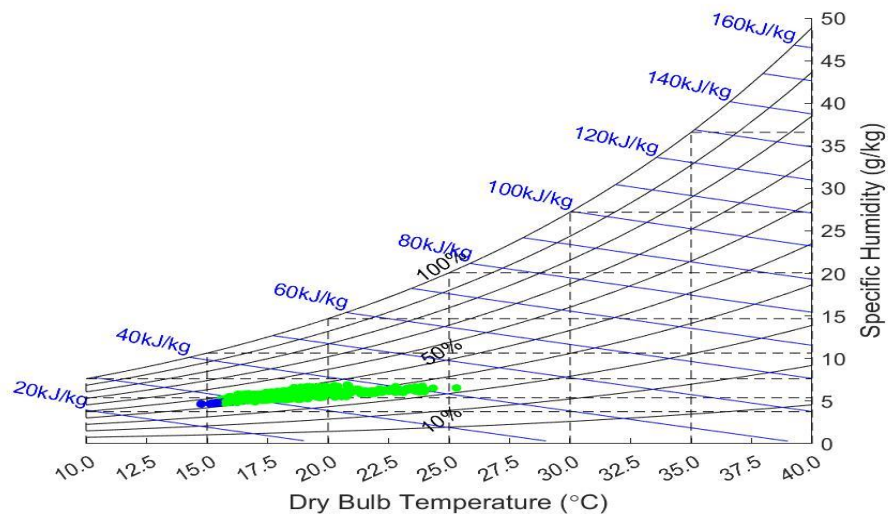
TH02 Result, Comfort Inside the room 100% Comfort



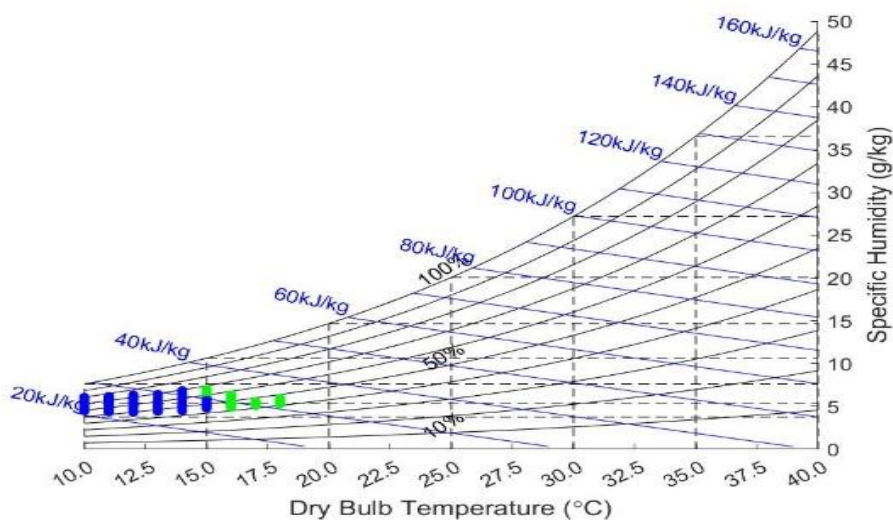
Sensor3A (Black Globe) Result, Comfort near Window 98.81% Comfort



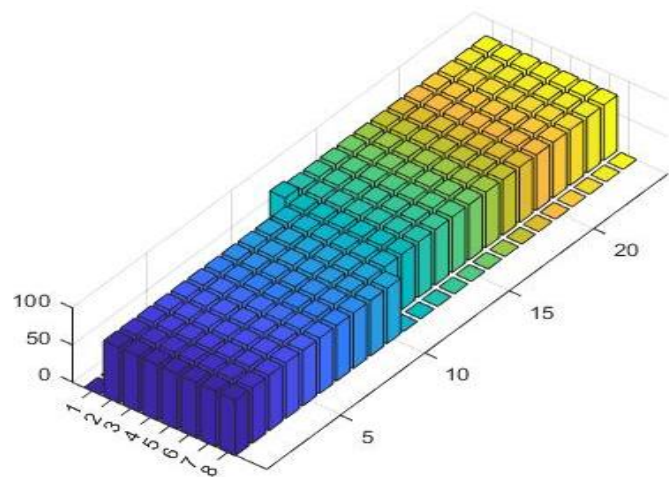
Sensor3B Result, Comfort near Window 97.77% Comfort



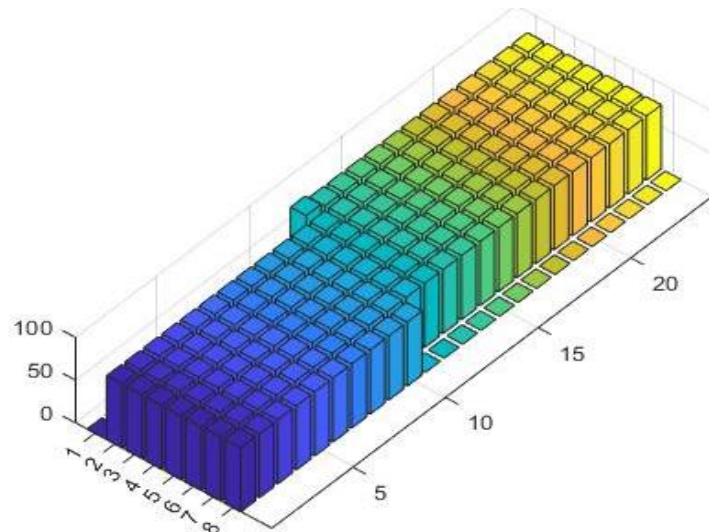
Outdoor Result, 15.18% Comfort



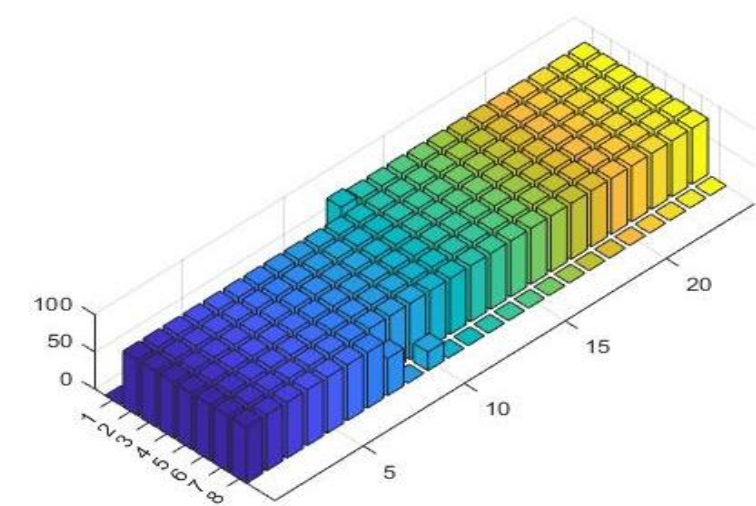
Sensor 2(Room)



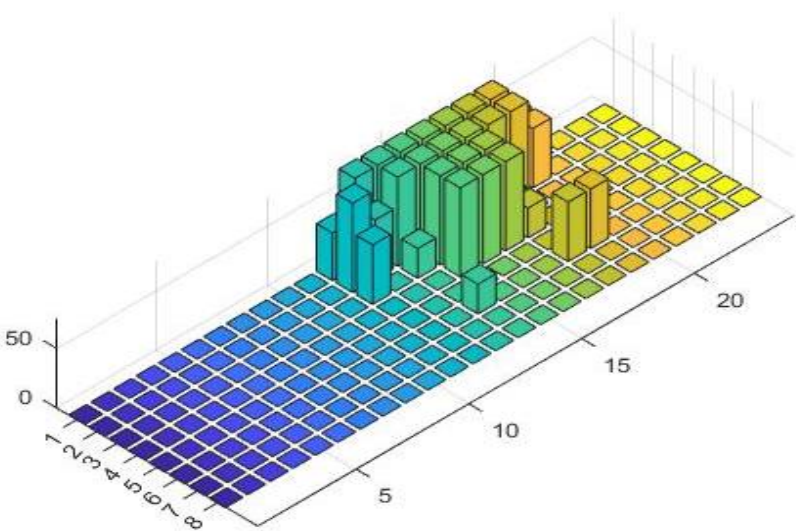
Sensor 1 (stairs)



Sensor 3 (window)

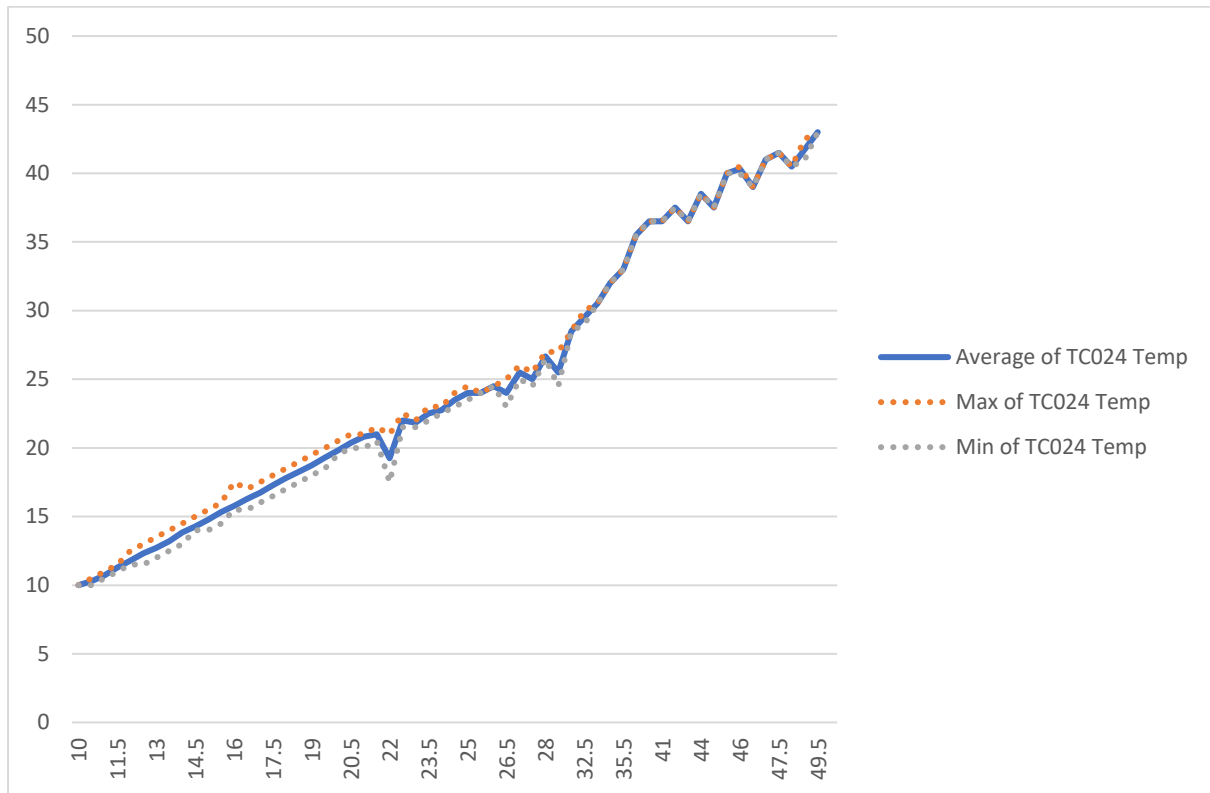


Outdoor

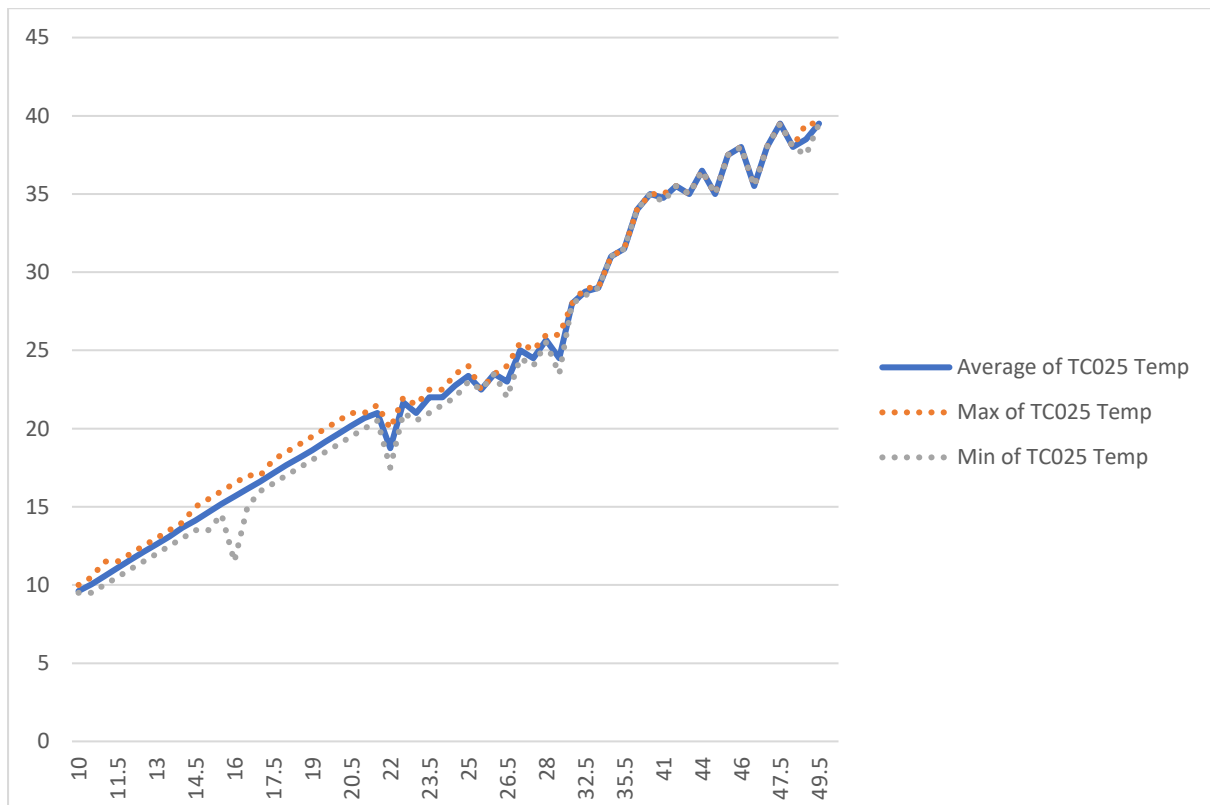


COTS Temperature Sensors comparison Chart from 7,361 data with 15 minutes interval (X and Y axis are the temperature value in °C):

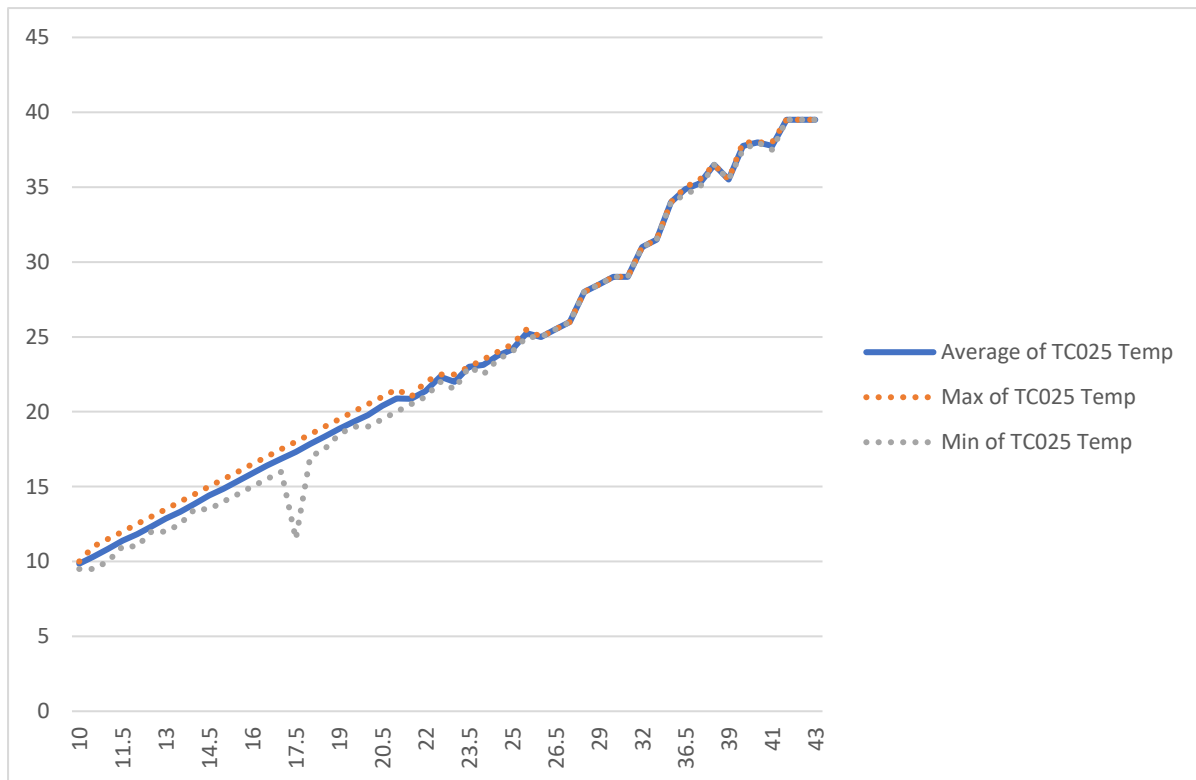
TC011 against TC024, with R-Squared value of 0.984:



TC011 against TC025, with R-Squared value of 0.974:

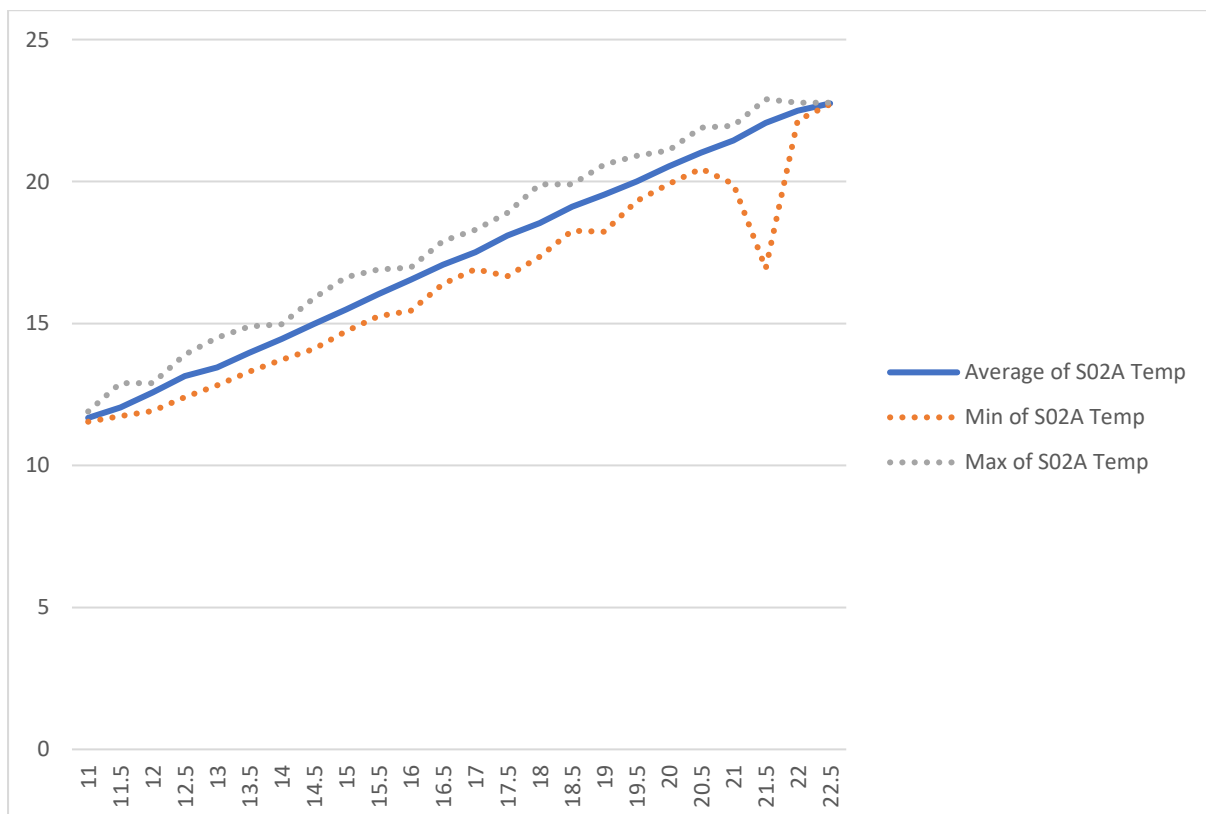


TC024 against TC025, with R-Squared value of 0.990:

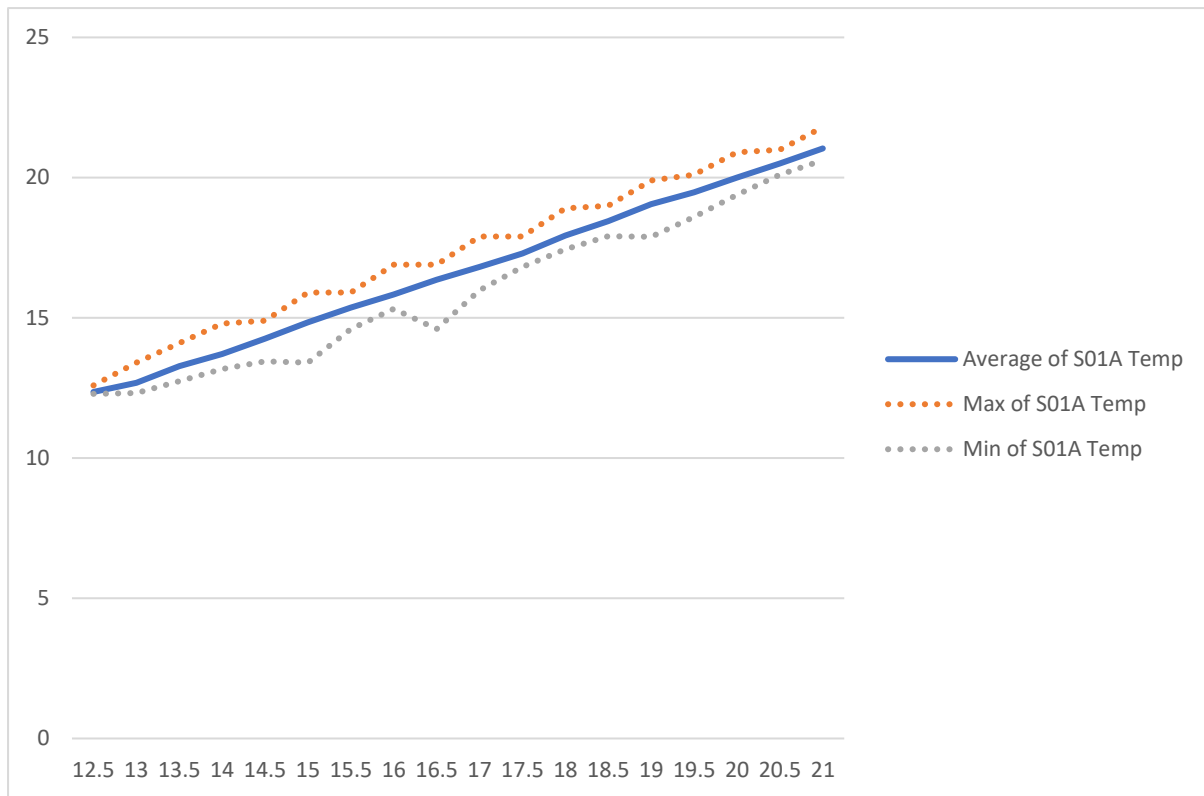


COTS Temperature Sensors and IoT Temperature Sensors comparison Chart from 7,361 data with 15 minutes interval (X and Y axis are the temperature value in °C):

Center of the Room-Black Globe Sensor, TC02 against S02A with R-Squared value of 0.990:

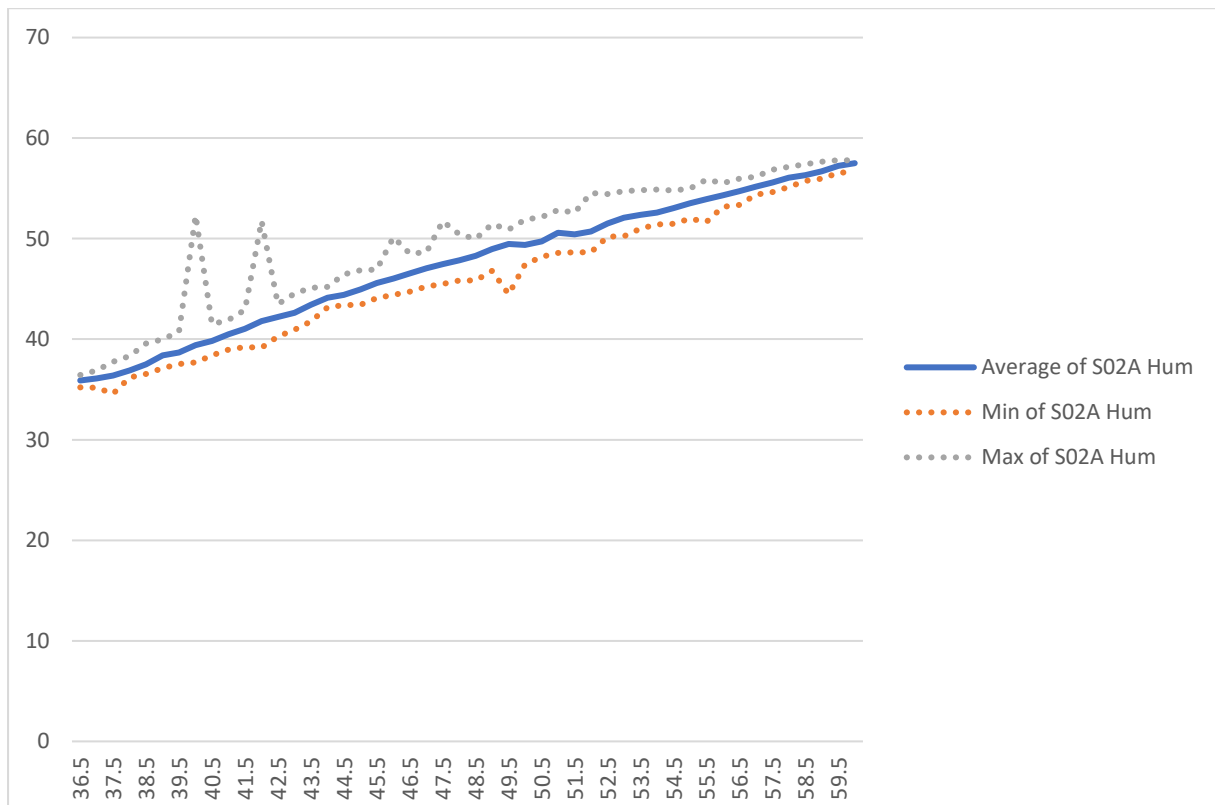


Stairs-Black Globe Sensor, TC04 against S01A with R-Squared value of 0.986:

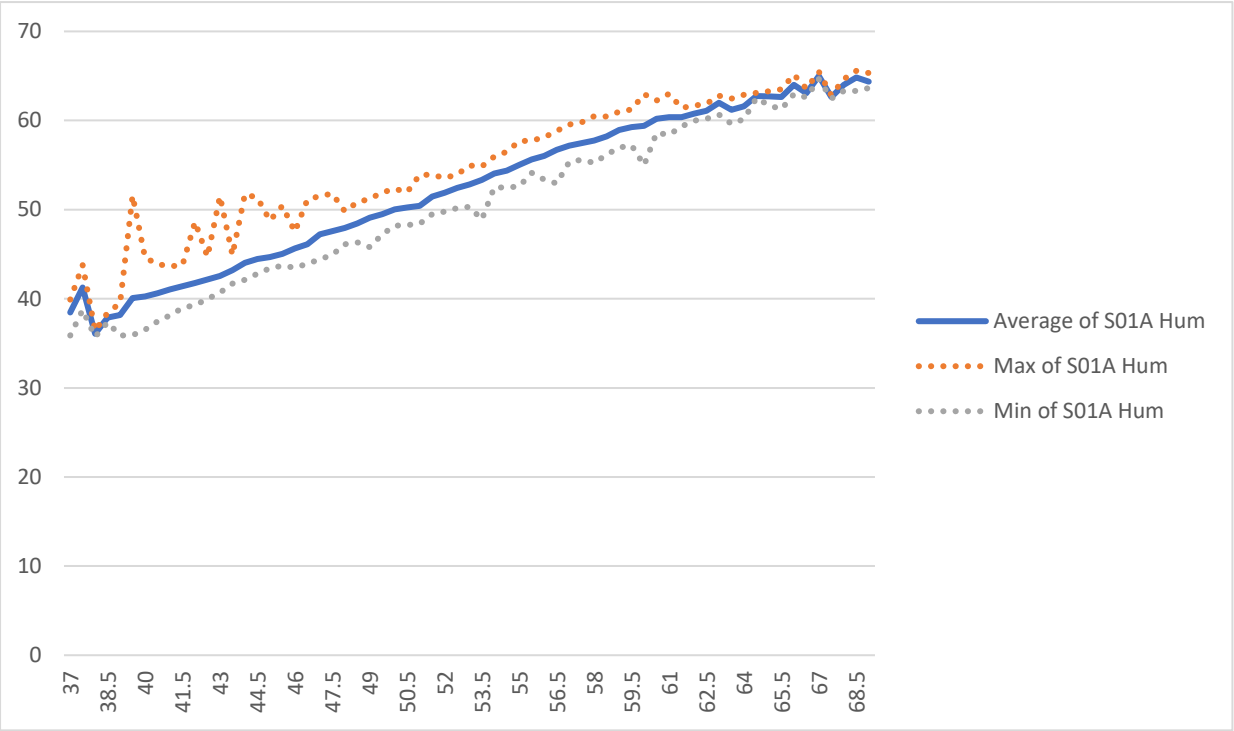


COTS Humidity Sensors and IoT Humidity Sensors comparison Chart from 7,361 data with 15 minutes interval (X and Y axis are the Relative Humidity value in %):

Center of the Room Sensor, TH 02 against S02A with R-Squared value of 0.974:



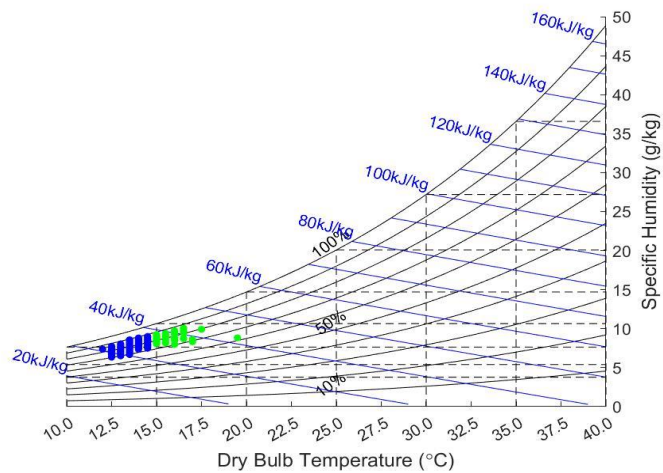
Stairs Sensor, TC04 against S01A with R-Squared value of 0.967:



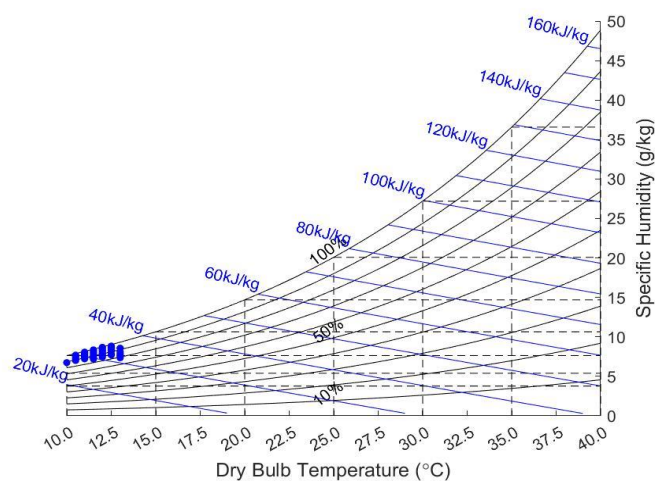
Appendix 10. Case Studies Results

The Case of Humid Dwelling

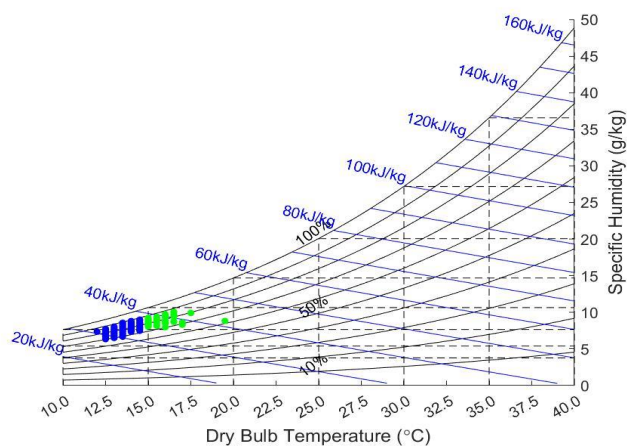
Sensor TH 03, Comfort in the Living room 13.28% Comfort



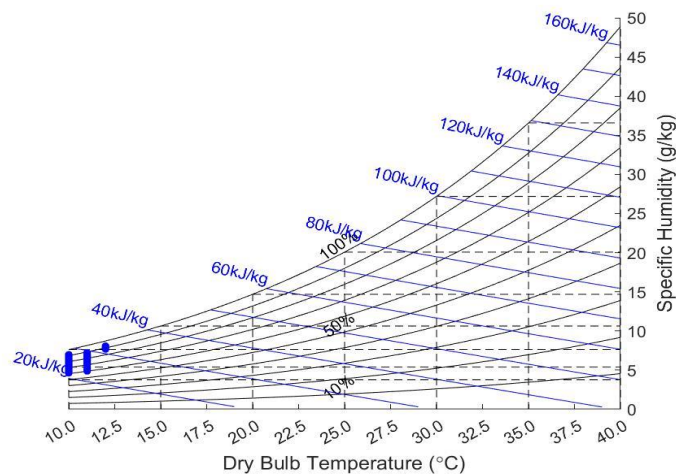
Sensor TH 06, Comfort in the Bedroom 0% Comfort



Sensor TH 03, Comfort in the kitchen 9.70% Comfort



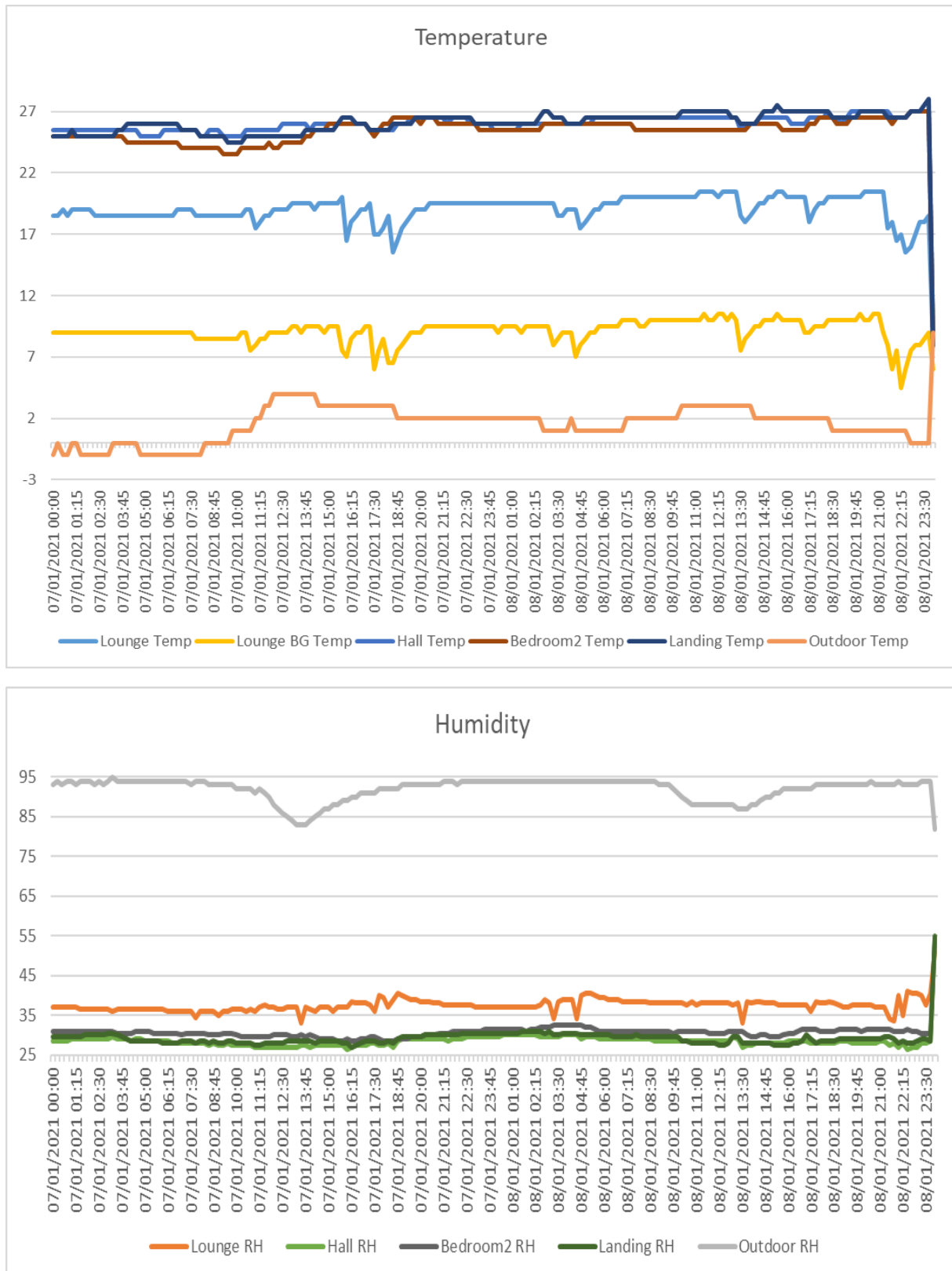
Outdoor Result, 0% Comfort

*The New Dwellings*

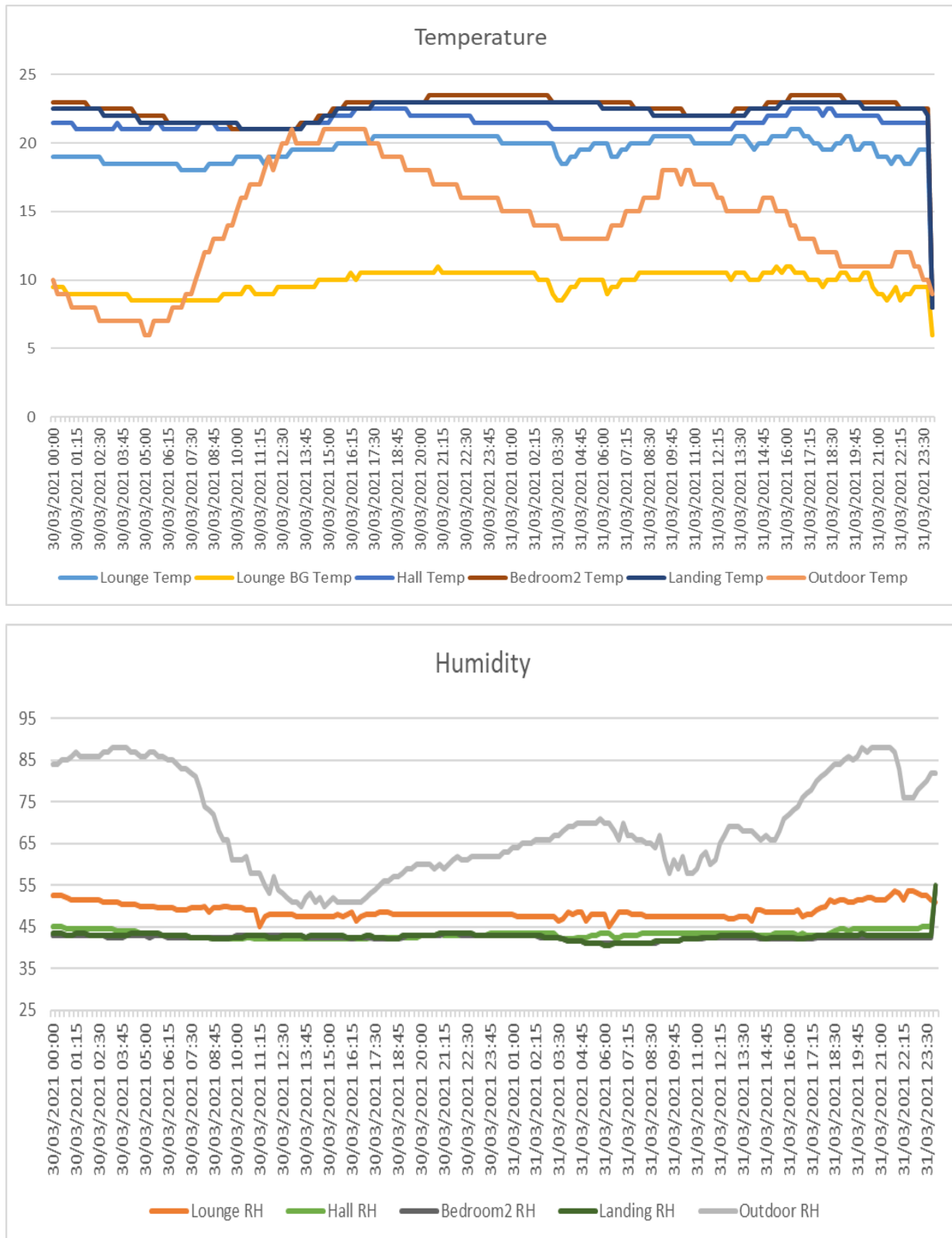
The example of the initial and the last 15 raw data items are as follows:

	Time	Lounge T	Lounge R	Lounge C	Lounge B	Hall Tem	Hall RH	Hall Dew	Bedroom	Bedroom	Bedroom	Landing	Landing	Landing	Outdoor	Outdoor	Outdoor DewP
1	19/10/2020 13:00	20	54	10.4	8.5	21.5	50	10.6	21.5	50.5	10.8	21.5	51	10.9	12	82	9
2	19/10/2020 13:15	20	54	10.4	9	21.5	50	10.6	21.5	51	10.9	21.5	51	10.9	12	80	9
3	19/10/2020 13:30	21	53.5	11.2	21	22	49	10.8	22	50.5	11.3	22	50.5	11.3	13	80	9
4	19/10/2020 13:45	21	54	11.3	10	21.5	50.5	10.8	21.5	51	10.9	21.5	51.5	11.1	13	79	9
5	19/10/2020 14:00	21	54	11.3	9.5	21	51	10.5	21.5	51.5	11.1	21	51.5	10.6	13	79	9
6	19/10/2020 14:15	20.5	54	10.9	9.5	21	51.5	10.6	21	51.5	10.6	21	52	10.8	13	79	9
7	19/10/2020 14:30	20.5	54	10.9	9.5	20.5	51.5	10.2	21	52	10.8	20.5	52.5	10.5	13	79	9
8	19/10/2020 14:45	20.5	54	10.9	9.5	20.5	51.5	10.2	21	52	10.8	20.5	52.5	10.5	13	78	9
9	19/10/2020 15:00	20.5	54	10.9	9.5	20.5	51.5	10.2	21	52	10.8	20.5	52.5	10.5	13	78	9
10	19/10/2020 15:15	20.5	54	10.9	10	20.5	51.5	10.2	21	52	10.8	21	52.5	10.9	13	77	9
11	19/10/2020 15:30	20.5	54	10.9	10	20.5	51.5	10.2	21	52	10.8	21	52	10.8	13	78	9
12	19/10/2020 15:45	20.5	54	10.9	10.5	21	51.5	10.6	21	52	10.8	21	52	10.8	13	77	9
13	19/10/2020 16:00	20.5	54	10.9	10.5	21	51.5	10.6	21.5	51.5	11.1	21	51.5	10.6	13	78	10
14	19/10/2020 16:15	20.5	54	10.9	10.5	21	51.5	10.6	21.5	51.5	11.1	21.5	51.5	11.1	13	78	9
15	19/10/2020 16:30	20.5	54	10.9	10.5	21	51.5	10.6	21.5	51.5	11.1	21.5	51.5	11.1	13	78	9
16	19/10/2020 16:45	20.5	54	10.9	10.5	21	51.5	10.6	21.5	51.5	11.1	21.5	51.5	11.1	13	78	9
16367	08/04/2021 00:30	18.5	37.5	3.7	8.5	21	32.5	3.9	21.5	33	4.6	21.5	31.5	3.9	6	77	2
16368	08/04/2021 00:45	18.5	37	3.6	8.5	21.5	32.5	4.3	21.5	32.5	4.3	22	31.5	4.3	6	75	2
16369	08/04/2021 01:00	18.5	37	3.6	8.5	21.5	32.5	4.3	21.5	33	4.6	22	31.5	4.3	6	76	2
16370	08/04/2021 01:15	18.5	37.5	3.7	8.5	21	32.5	3.9	21.5	33	4.6	21.5	31.5	3.9	6	77	2
16371	08/04/2021 01:30	18.5	37.5	3.7	8.5	21	32.5	3.9	21.5	33	4.6	21.5	31.5	3.9	6	80	3
16372	08/04/2021 01:45	18.5	37.5	3.7	8.5	21	32.5	3.9	21.5	33	4.6	21.5	31.5	3.9	6	82	3
16373	08/04/2021 02:00	18.5	37.5	3.7	8.5	21	32.5	3.9	21.5	33	4.6	21.5	31.5	3.9	6	84	4
16374	08/04/2021 02:15	18.5	37.5	3.7	8.5	21	32.5	3.9	21	33	4.1	21.5	32	4.1	6	86	4
16375	08/04/2021 02:30	18	37	3.1	8.5	21	32.5	3.9	21	33	4.1	21.5	32	4.1	6	87	4
16376	08/04/2021 02:45	18	37	3.1	8.5	21	32.5	3.9	21.5	33	4.6	21.5	32.5	4.3	6	88	5
16377	08/04/2021 03:00	18	37	3.1	8.5	21	32.5	3.9	21.5	33.5	4.8	21.5	33	4.6	7	89	5
16378	08/04/2021 03:15	18	37.5	3.3	8.5	21	32.5	3.9	21	33	4.1	21.5	32.5	4.3	8	90	6
16379	08/04/2021 03:30	18	37.5	3.3	8.5	21	32.5	3.9	21	33	4.1	21	32.5	3.9	8	90	6
16380	08/04/2021 03:45	18	37.5	3.3	8	21	32.5	3.9	21	33.5	4.3	21	32.5	3.9	8	88	6
16381	08/04/2021 04:00	18	38	3.5	8	21	32.5	3.9	21	33.5	4.3	21	33	4.1	8	87	6
16382	08/04/2021 04:15	18	38	3.5	8.5	21	32.5	3.9	21	34	4.6	21	33	4.1	8	86	6

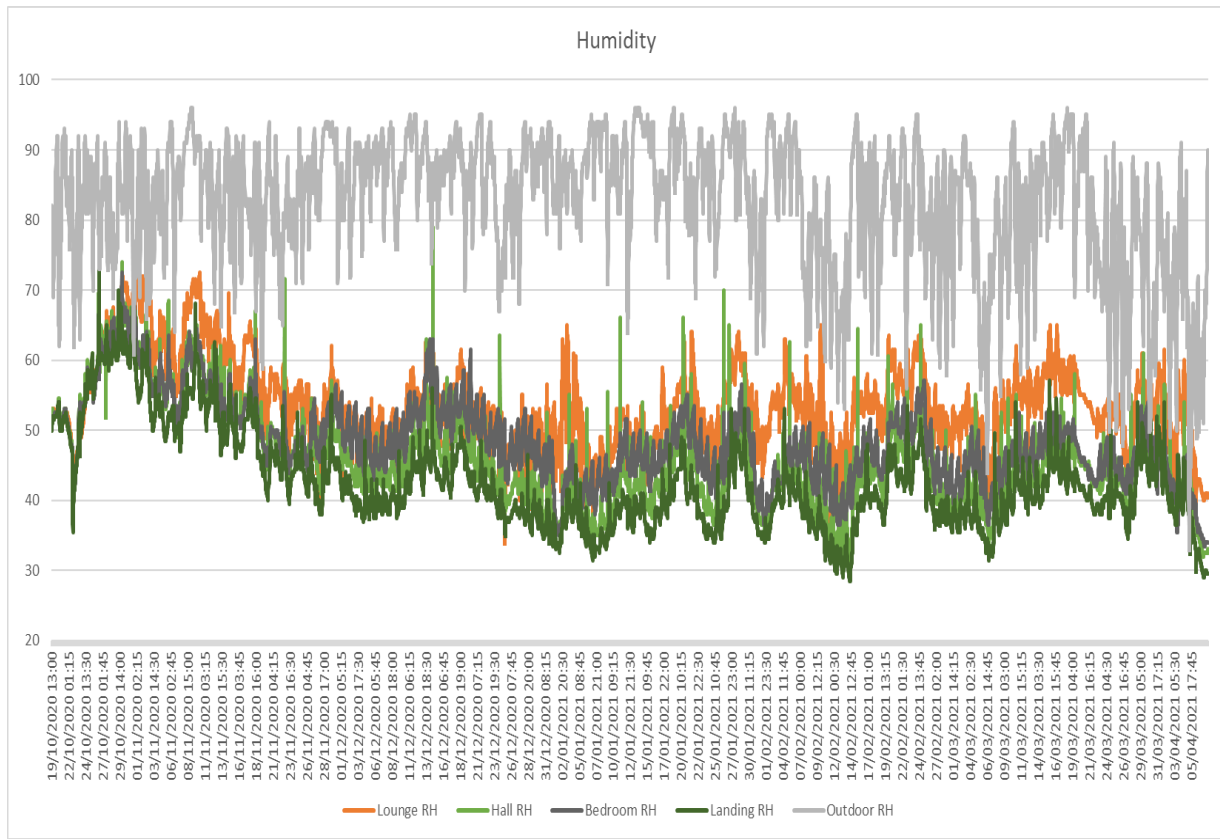
The indoor thermal and humidity condition during the low outdoor temperature is as follows:



The indoor thermal and humidity condition during the high outdoor temperature is as follows:



For the house number 19, the humidity chart during the observation period is presented in the following figure:



The summary of the RH data can be seen in the following table:

RH	Lounge	Hall	Bedroom2	Landing	Outdoor
Max	73.50	79.00	74.50	75.00	96.00
Min	34.00	30.50	33.50	28.50	33.00
Average	54.13	45.92	48.42	42.69	82.54
Std Dev	5.98	6.98	6.08	6.92	9.38

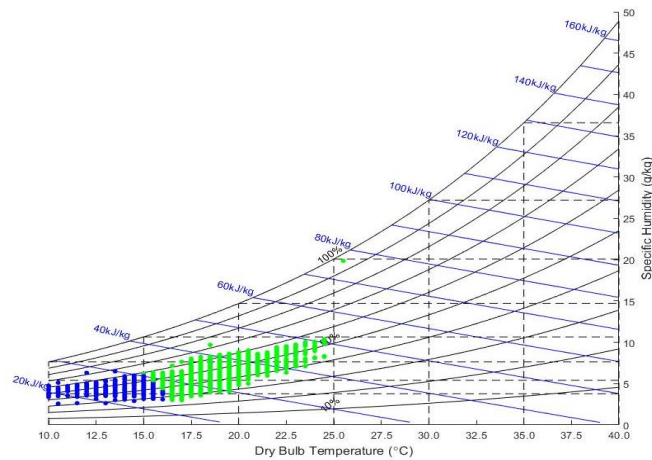
Further assessment to the observation data (4095 hours span) shows the uncomfortable RH condition, which is displayed in the following table:

Uncomfortable RH	Lounge	Hall	Bedroom2	Landing
RH >70% (hours)	53.5	2.25	2.75	0.25
RH <30 % (hours)	0.00	0.00	0.00	25.50
Percentage	1.31	0.05	0.07	0.62

This result shows that the temperature set point for the landing room should be lowered and the set point temperature in the lounge should be raised. The temperature set point less than 20 °C is preferable.

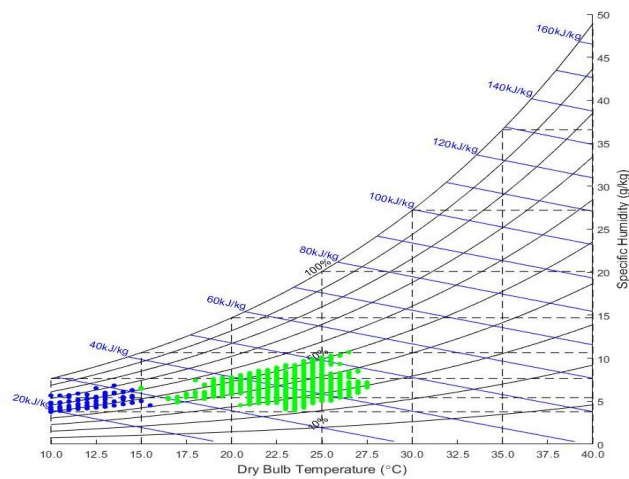
Lounge for House number 15 (Clothing insulation 1 clo, Activity value 1.5, Age 40.5)

Comfort level 96.18%. The Psychrometric chart for Lounge:



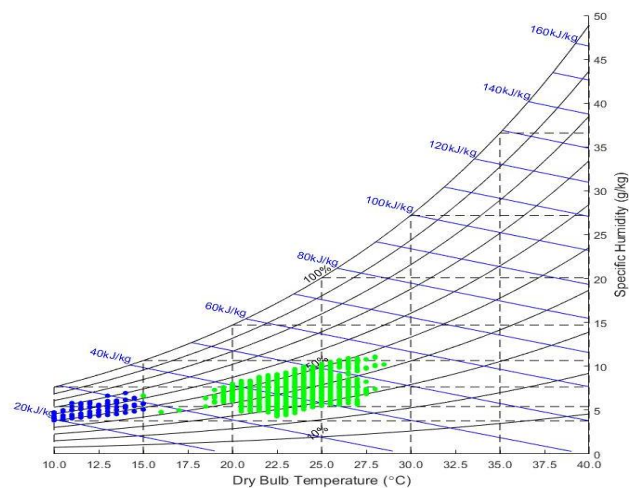
Hall for House number 15 (Clothing insulation 1 clo, Activity value 1.5, Age 40.5)

Comfort level 97.80%. The Psychrometric chart for Hall:



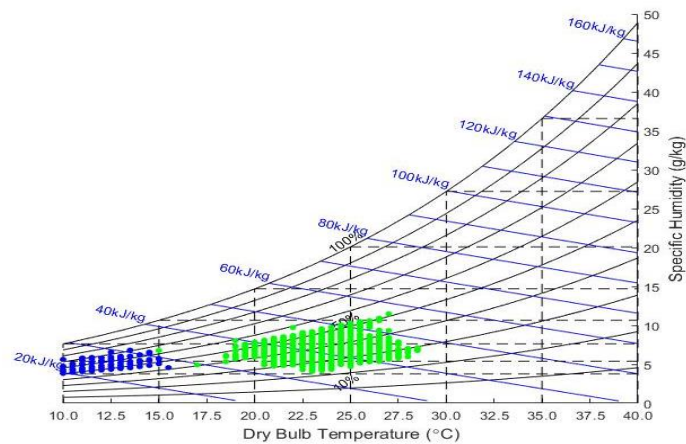
Bedroom for House number 15 (Clothing insulation 1 clo, Activity value 1.5, Age 40.5)

Comfort level 97.81%. The Psychrometric chart for Bedroom:



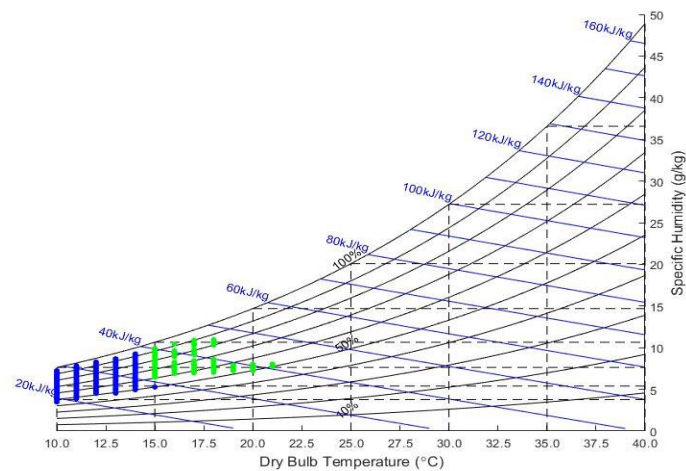
Landing for House number 15 (Clothing insulation 1 clo, Activity value 1.5, Age 40.5)

Comfort level 97.75%. The Psychrometric chart for Landing:



Outdoor for House number 15 (Clothing insulation 1 clo, Activity value 1.5, Age 40.5)

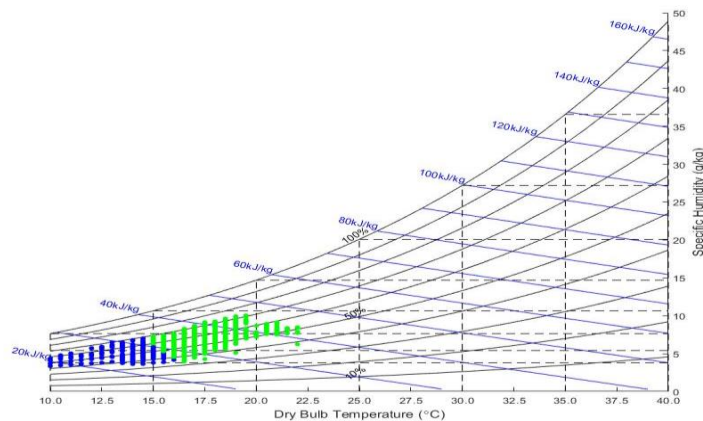
Comfort level 2.46%. The Psychrometric chart for Outdoor:



The uncomfortable condition for indoor happened due to the heater that was turned off and the indoor temperature fallen below 15°C.

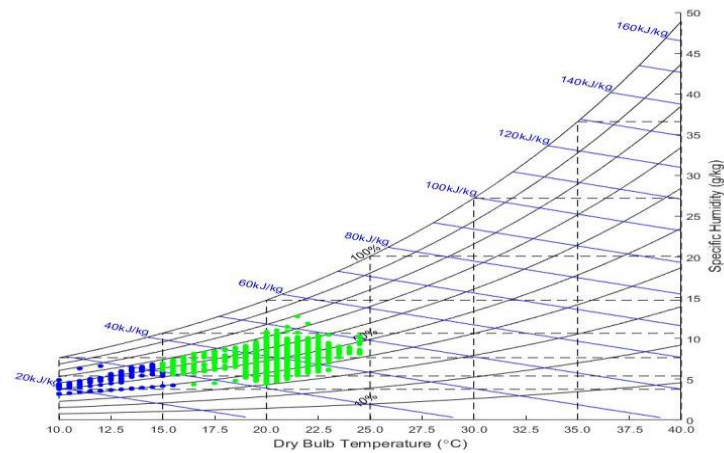
Lounge for House number 19 (Clothing insulation 1 clo, Activity value 1.5, Age 40.5)

Comfort level 87.54%. The Psychrometric chart for Lounge:



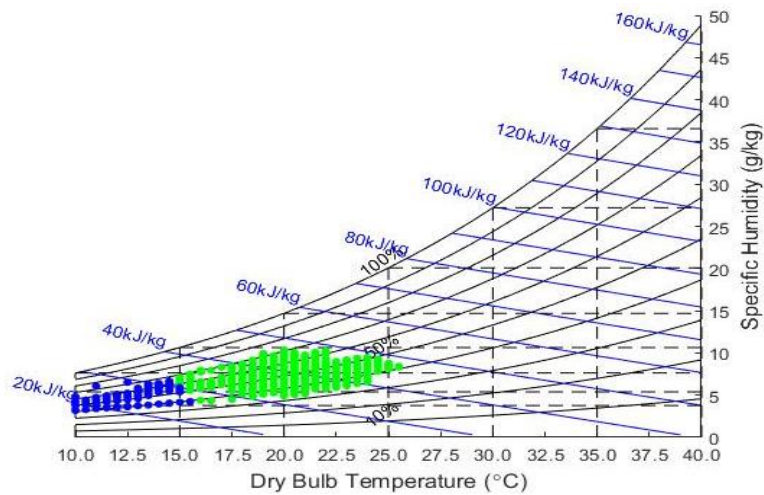
Hall for House number 19 (Clothing insulation 1 clo, Activity value 1.5, Age 40.5)

Comfort level 96.37%. The Psychrometric chart for Hall:



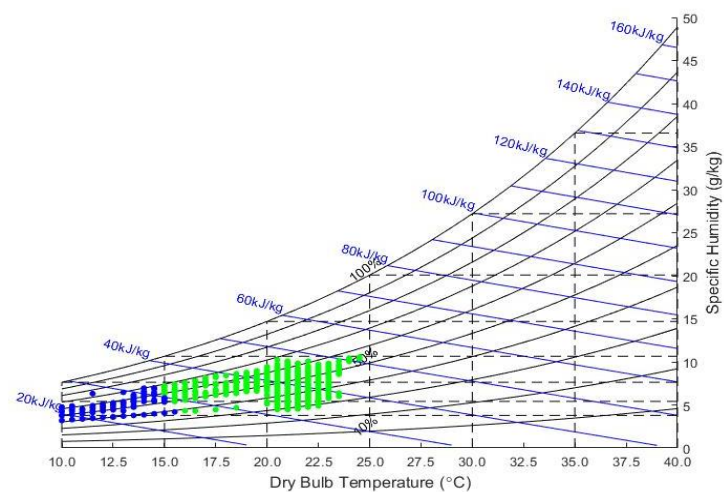
Bedroom for House number 19 (Clothing insulation 1 clo, Activity value 1.5, Age 40.5)

Comfort level 96.31%. The Psychrometric chart for Bedroom:



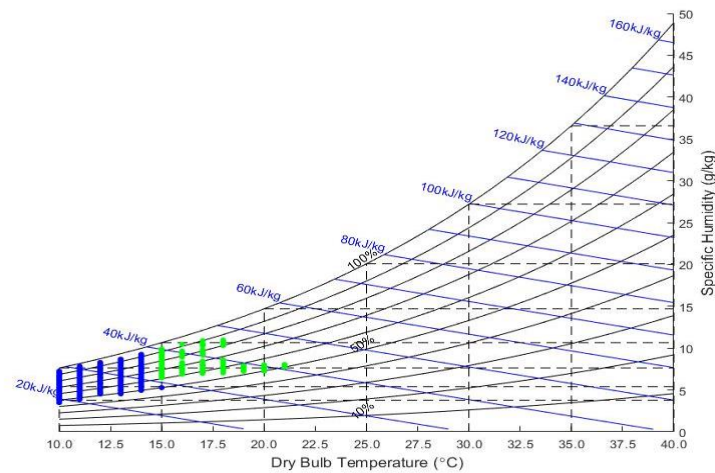
Landing for House number 19 (Clothing insulation 1 clo, Activity value 1.5, Age 40.5)

Comfort level 96.20%. The Psychrometric chart for Landing:



Outdoor for House number 19 (Clothing insulation 1 clo, Activity value 1.5, Age 40.5)

Comfort level 2.46%. The Psychrometric chart for Outdoor:



The uncomfortable condition for indoor happened due to the heater that was turned off and the indoor temperature fallen below 15°C.

The Refurbished Flats

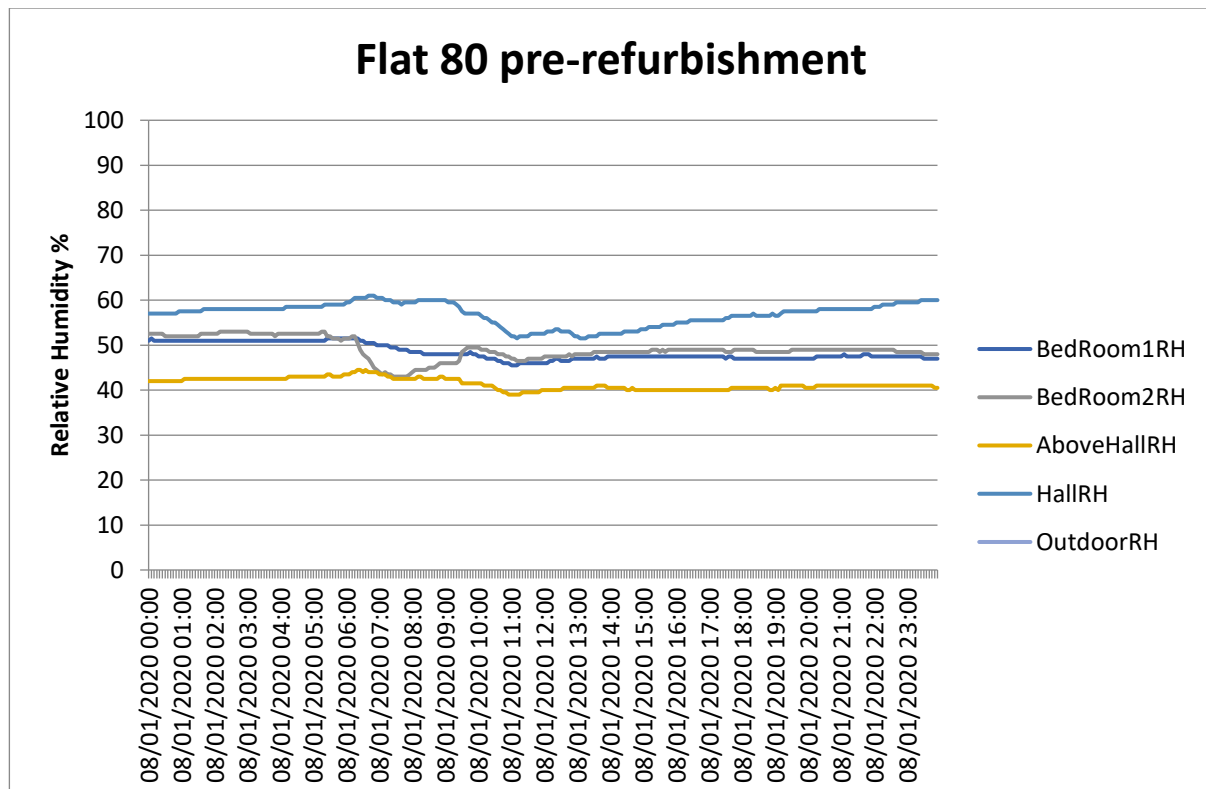
Flat numbers and the data captured:

	Flat 80 A	Flat 89 A			
Start	20/12/2019 00:00	30/11/2019 00:02			
End	19/02/2020 00:00	24/01/2020 00:02			
interval	5'	5'			
	Flat 80 B	Flat 89 B	Flat 38 A	Flat 49 A	Flat 41 A
Start	20/02/2020 00:00	25/01/2020 00:00	19/02/2020 15:30	18/02/2020 11:00	24/01/2020 11:45
End	11/06/2020 00:00	21/03/2020 00:00	11/06/2020 12:35	10/06/2020 08:05	16/05/2020 08:50
interval	5'	5'	5'	5'	5'
	Flat 80 C	Flat 89 C	Flat 38 B	Flat 49 B	Flat 41 B
Start	18/12/2020 12:00	n/a	18/12/2020 12:00	n/a	18/12/2020 12:00
End	26/02/2021 10:40		26/02/2021 11:30		26/02/2021 11:20
interval	10'		10'		10'
	Flat 80 D		Flat 38 C	Flat 49 C	Flat 41 C
Start	26/02/2021 11:00		26/02/2021 11:40	n/a	26/02/2021 11:20
End	20/06/2021 05:10		12/07/2021 21:00		12/07/2021 20:40
interval	10'		10'		10'

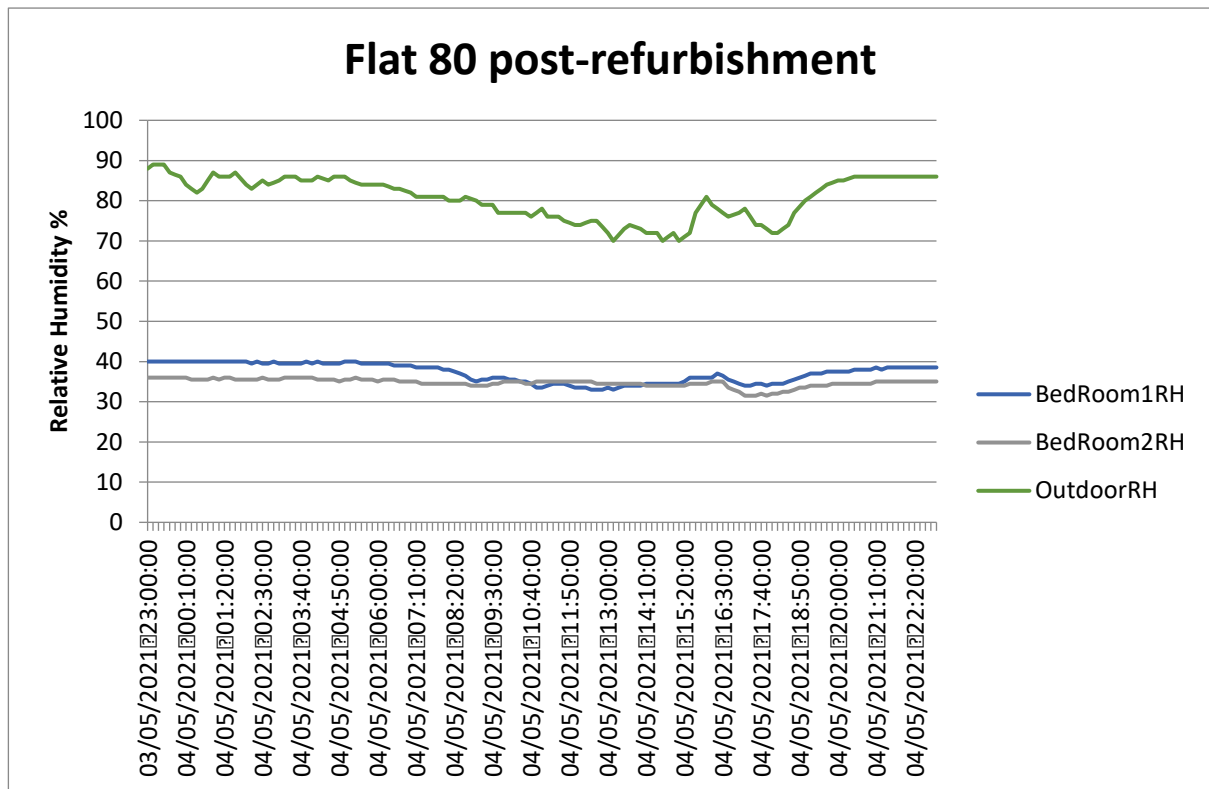
The sensors state:

Flat No	Status	Sensor ID	State	Start Logging
Flat 89	Missing	TCL 002, TCL003, THL 003	first installation	29/11/2019
	Missing	TCL 001, THL 001, TCL 004, THL 004, THL 002	second installation	24/01/2020
	Not Active	TH 001, TC 001, TC 043	third installation	18/12/2020
Flat 80	Active	TC 003, TH 003, TC 004, TH 004, TC 005, TH 005, TC 009, TC 010, TC 011, TH 009	first installation	19/12/2019
			second installation	19/02/2020
			third installation	18/12/2020
Flat 49	Not Active	TC 017, TH 017, TC 018, TH 018, TC 019, TH 019, TH 022, TC 029, TC 030, TC 031, TC 032 <problem with permit>	first installation	18/02/2020
			second installation	18/12/2020
			third installation	N/A
Flat 41	Missing	TC 023	first installation	24/01/2020
	Replaced with	TC 046	second installation	18/12/2020
		TC 002, TH 002, TC 012, TH 012, TC 013, TH 013, TC 022, TC 046, TC 024, TC 025, TH 010	third installation	N/A
Flat 38	Active	TC 006, TH 006, TC 007, TH 007, TC 008, TH 008, TC 033, TC 034, TC 035, TH 023	first installation	20/02/2020
			second installation	18/12/2020
			third installation	26/02/2021

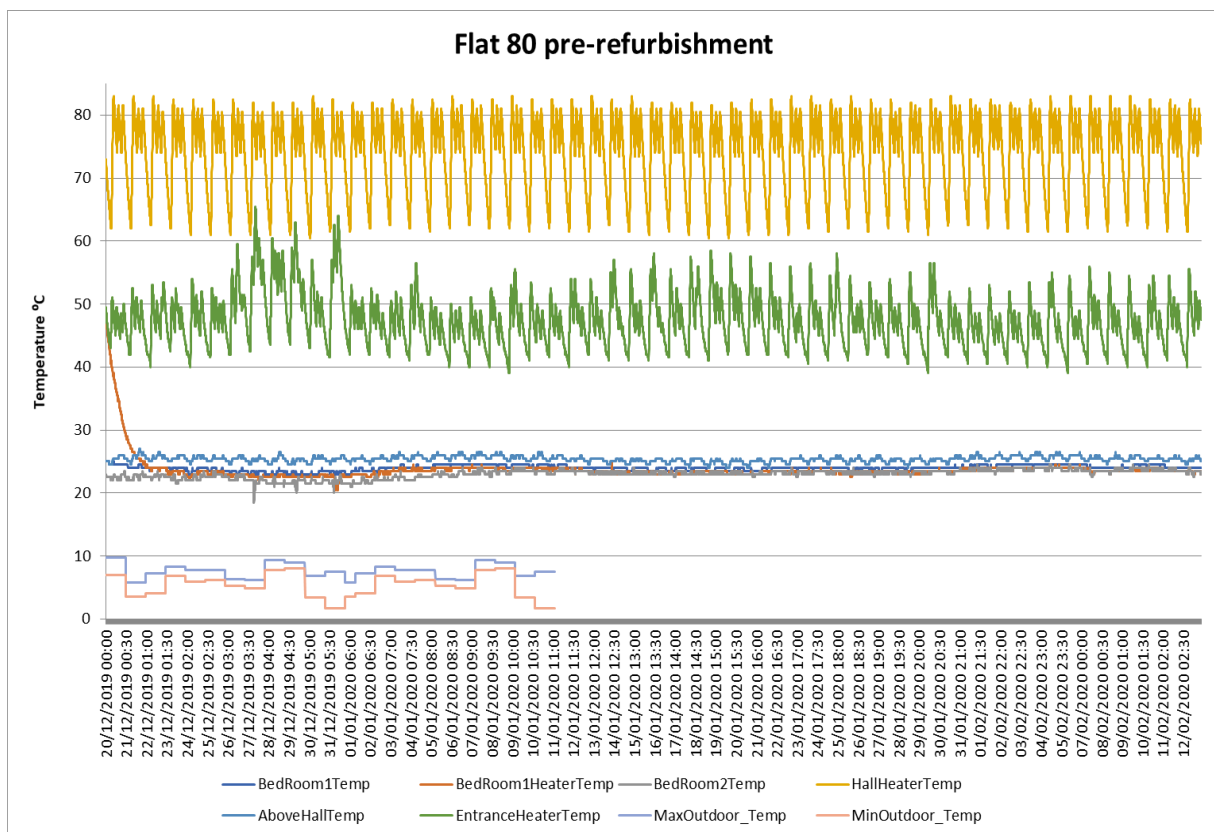
Daily humidity chart for Flat 80 in post-refurbishment phase:



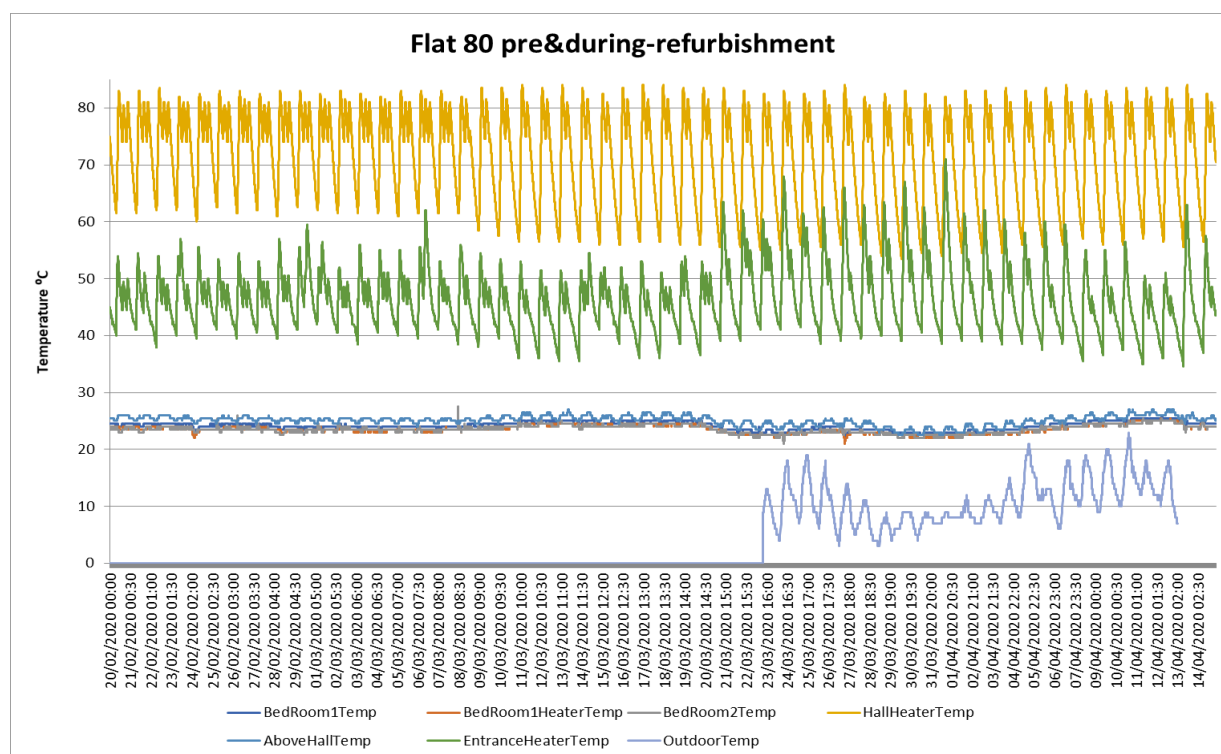
Daily humidity chart for Flat 80 in pre-refurbishment phase:



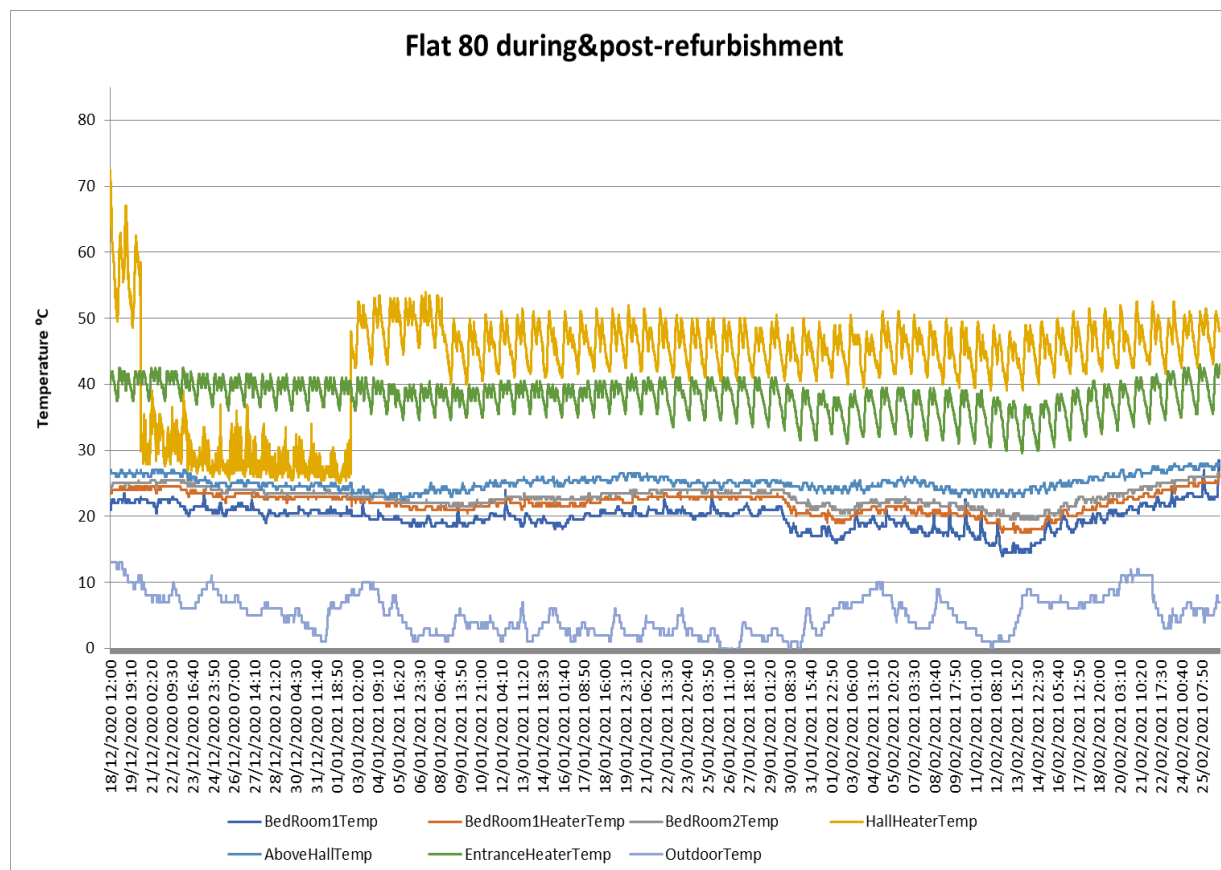
Temperature Chart for Flat 80 in pre-refurbishment phase:



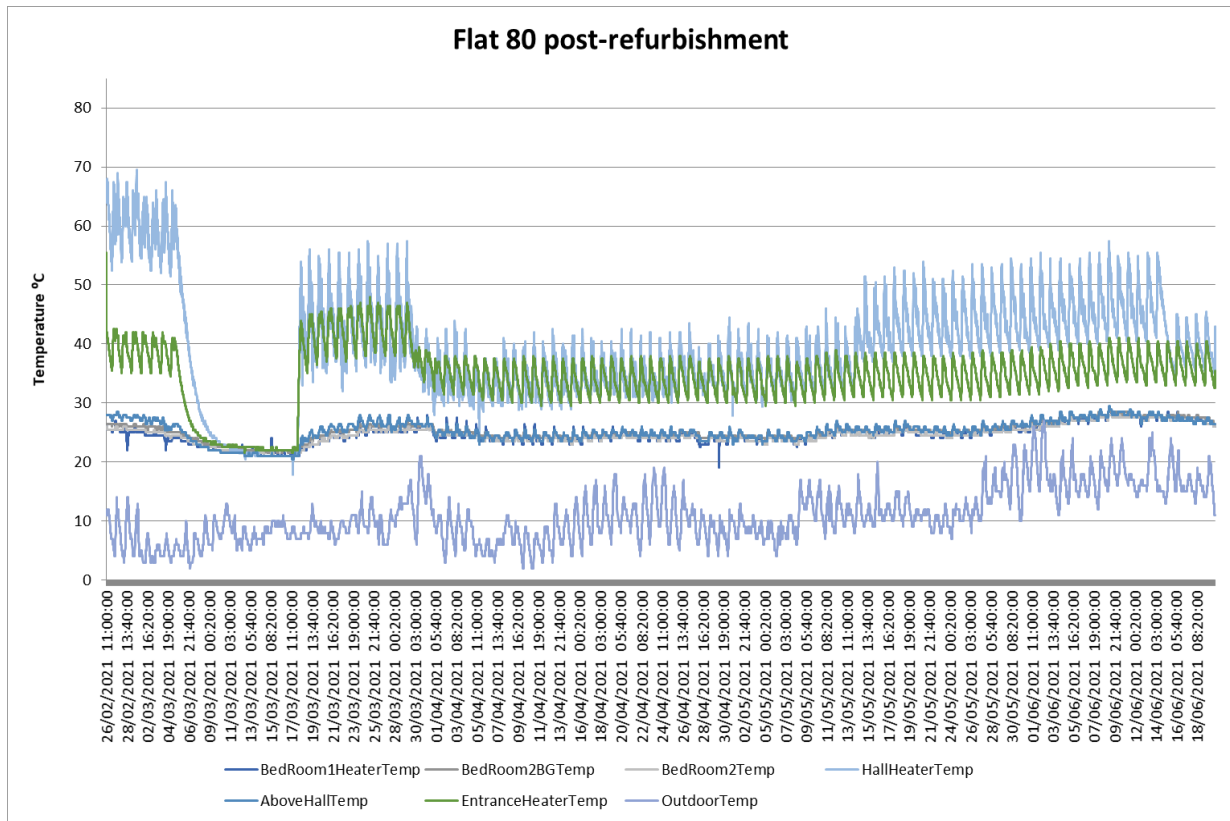
Temperature Chart for Flat 80 in pre and during-refurbishment phase:



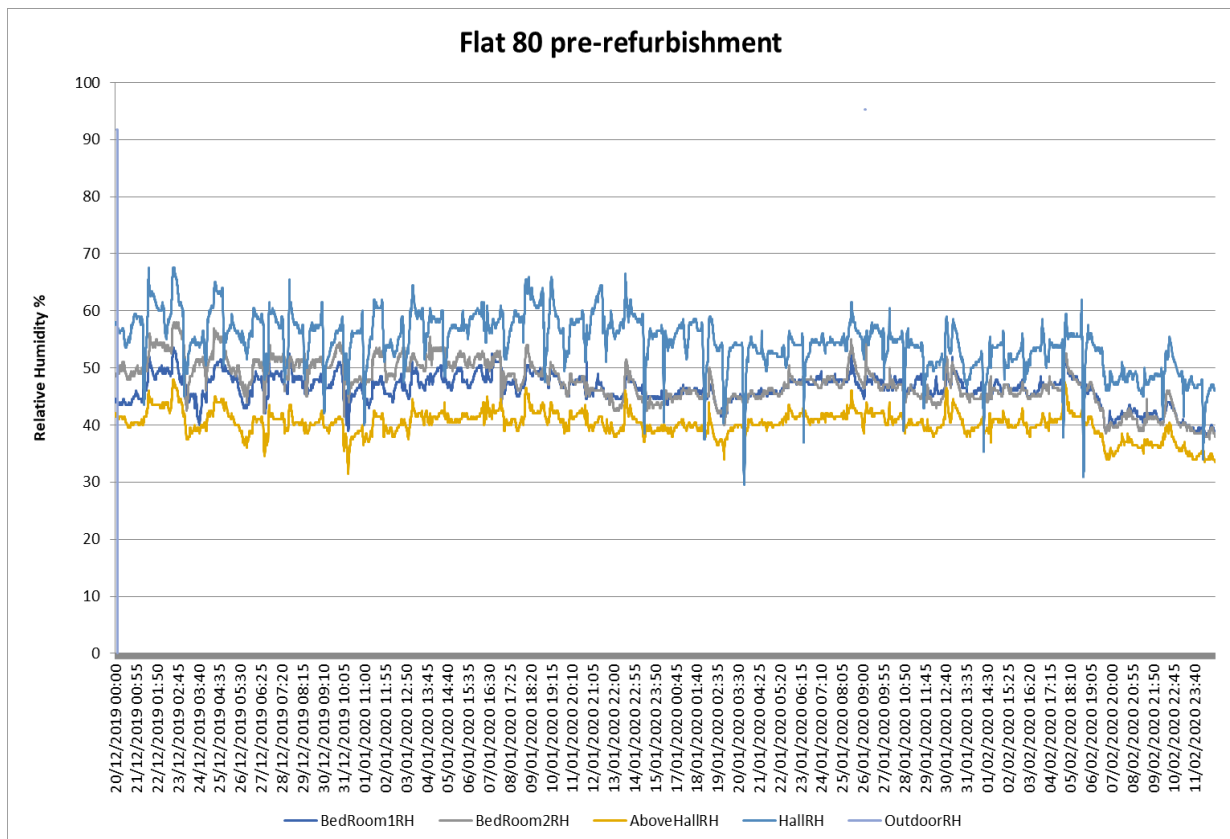
Temperature Chart for Flat 80 in during and post-refurbishment phase:



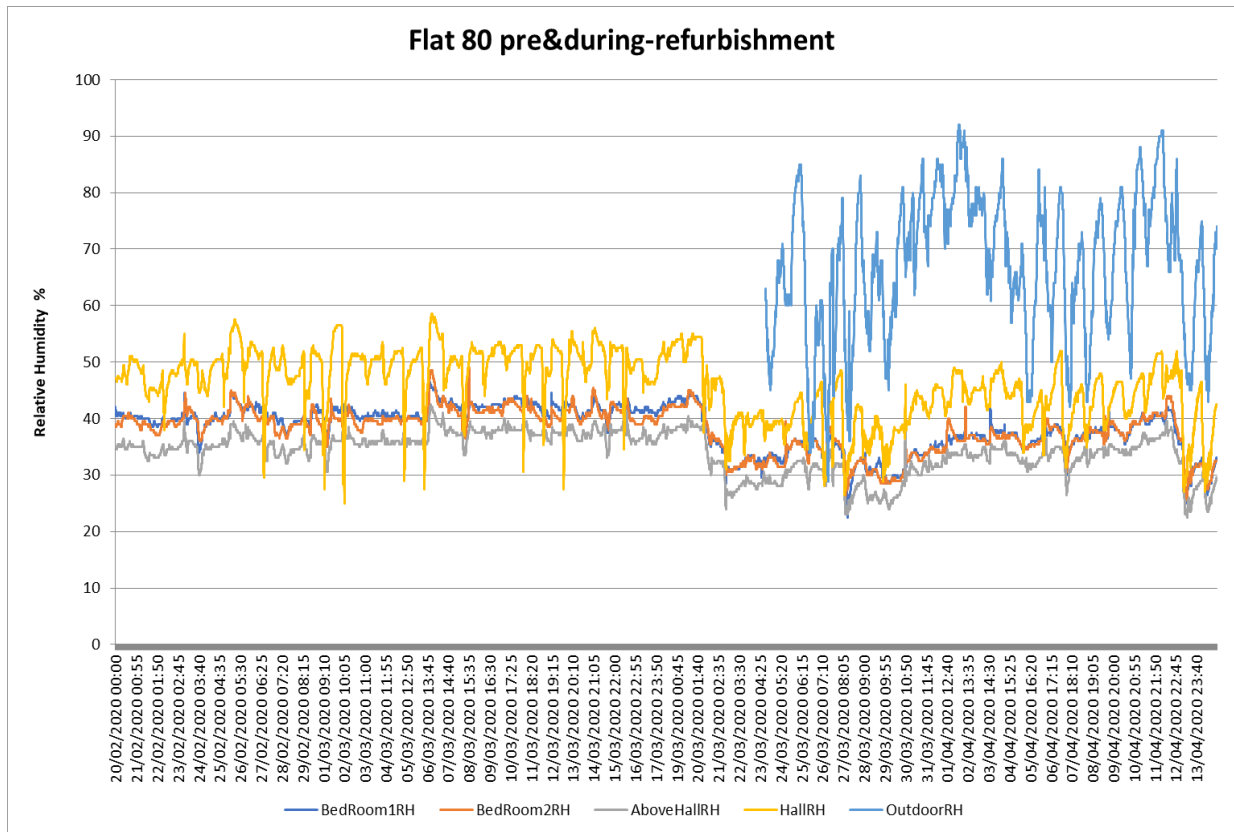
Temperature Chart for Flat 80 in post-refurbishment phase:



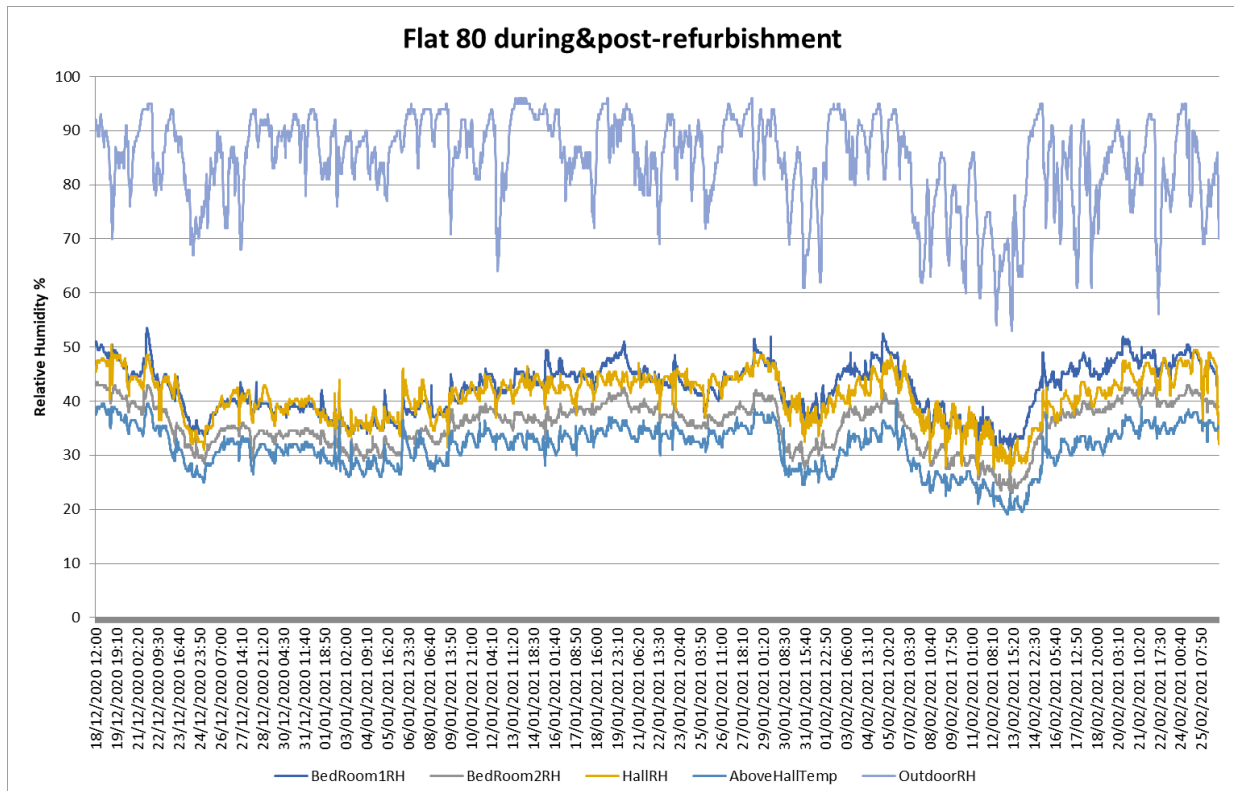
Humidity Chart for Flat 80 in pre-refurbishment phase:



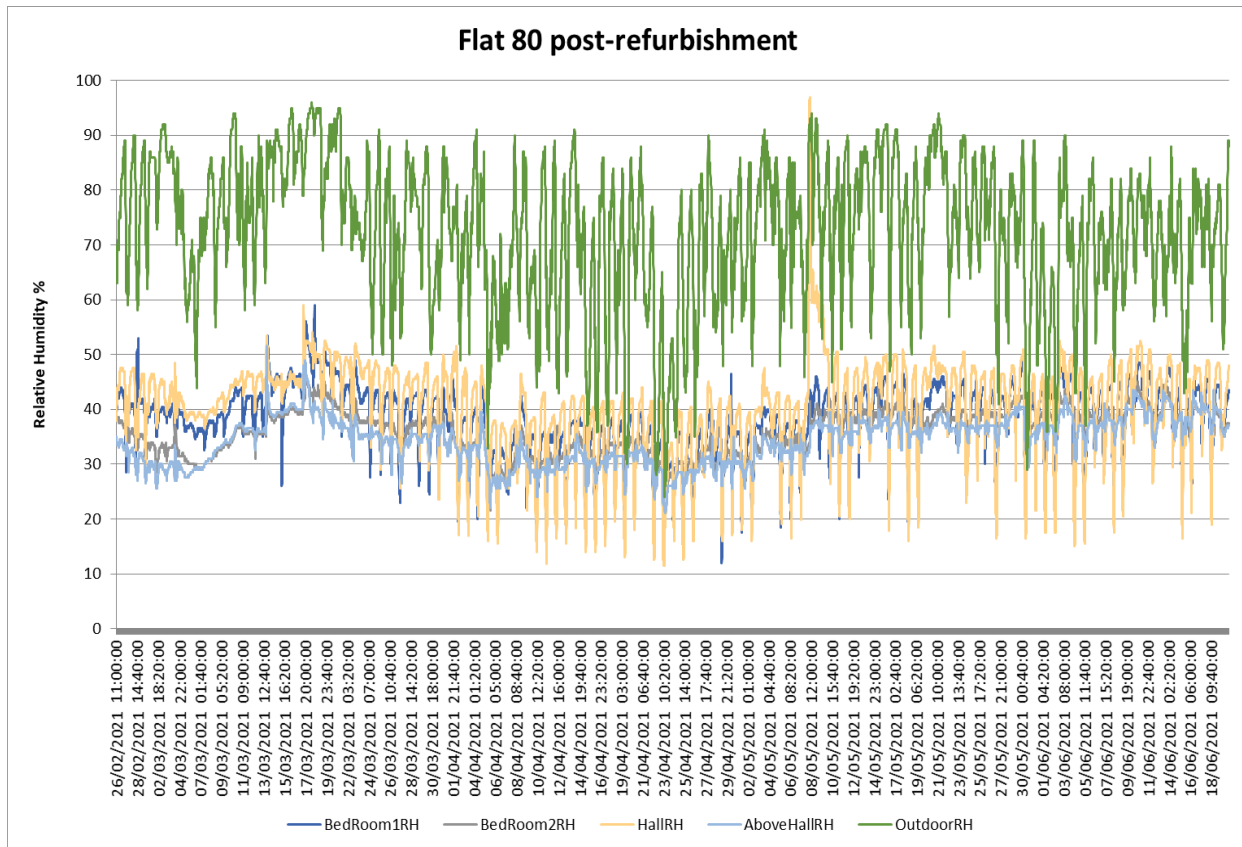
Humidity Chart for Flat 80 in pre and during-refurbishment phase:



Humidity Chart for Flat 80 in during and post-refurbishment phase:



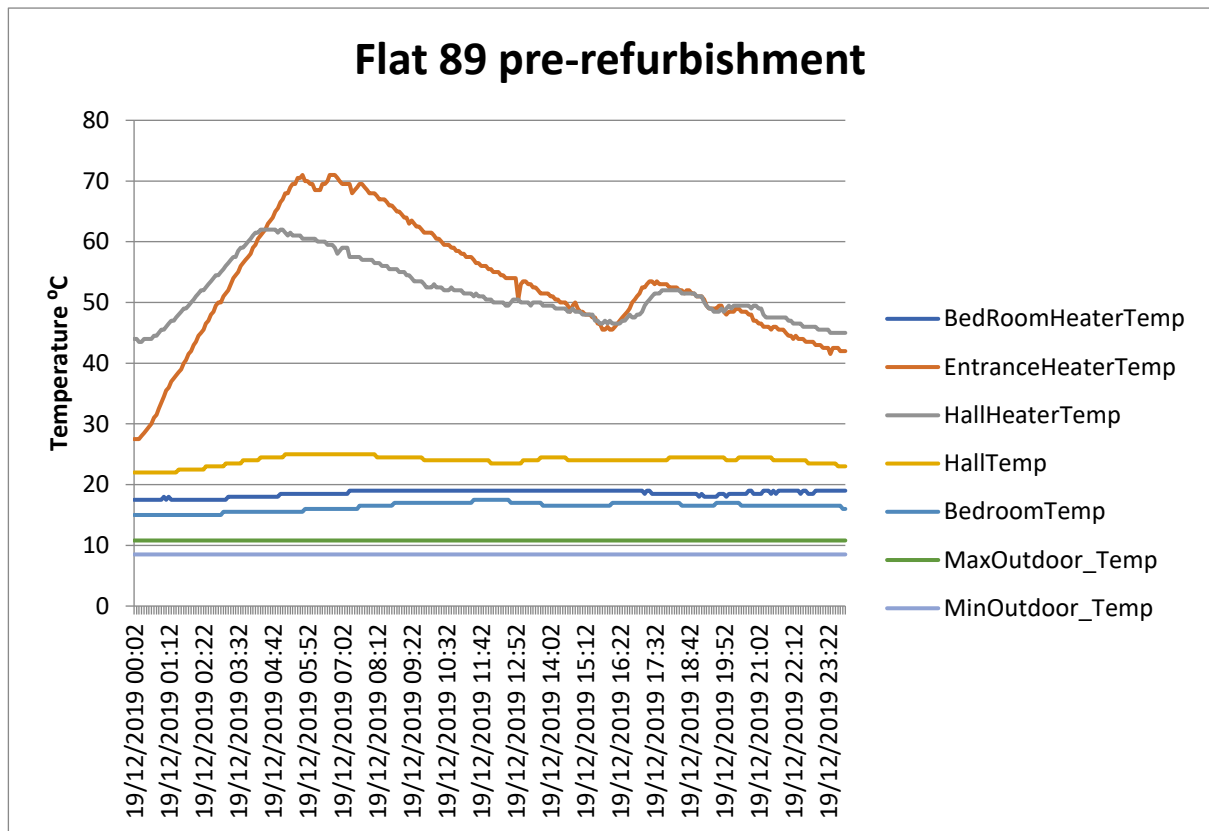
Humidity Chart for Flat 80 in post-refurbishment phase:



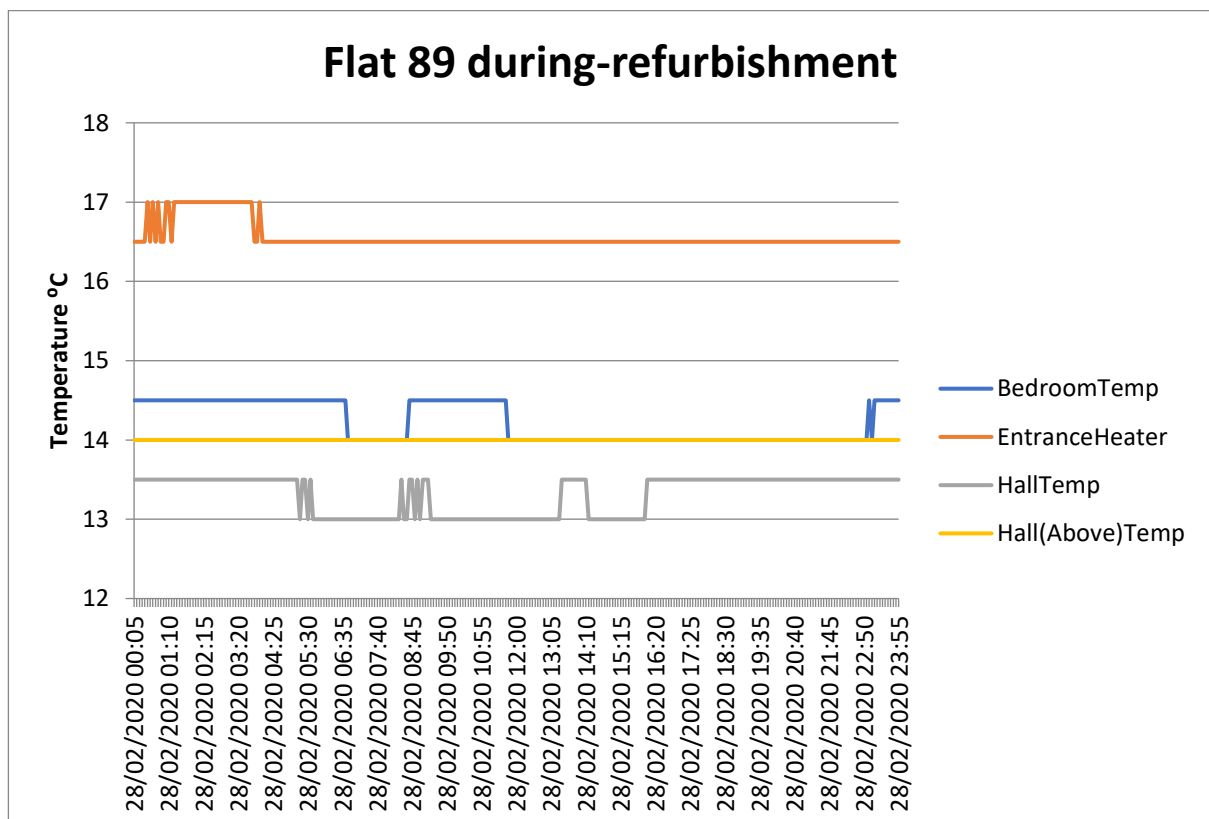
Flat 89 Temperature

The data obtained for Flat 89 is incomplete, due to the occupant passed away and then leaved empty. If compared to Flat 80 in pre-refurbishment period, Flat 89 heaters had higher temperature peaks which were 70 °C for entrance heater but less peak number. The temperature peaks were only two instead of three likes in the flat 80. On the contrary the hall heater setting was less compared to Flat 89. The temperature setting was resulting in the peak temperature of 60 °C with two peaks. This setting was to achieve indoor temperature of about 20 °C when the outdoor temperature was about 10 °C. This setting was different flat by flat according to the behaviour and occupant's preferences. During refurbishment, the flat then left empty with no heater turned on. In this state, the indoor temperature was plummeting to about 14 °C, the entrance still had higher temperature compared to other rooms due to the heat from the building common area.

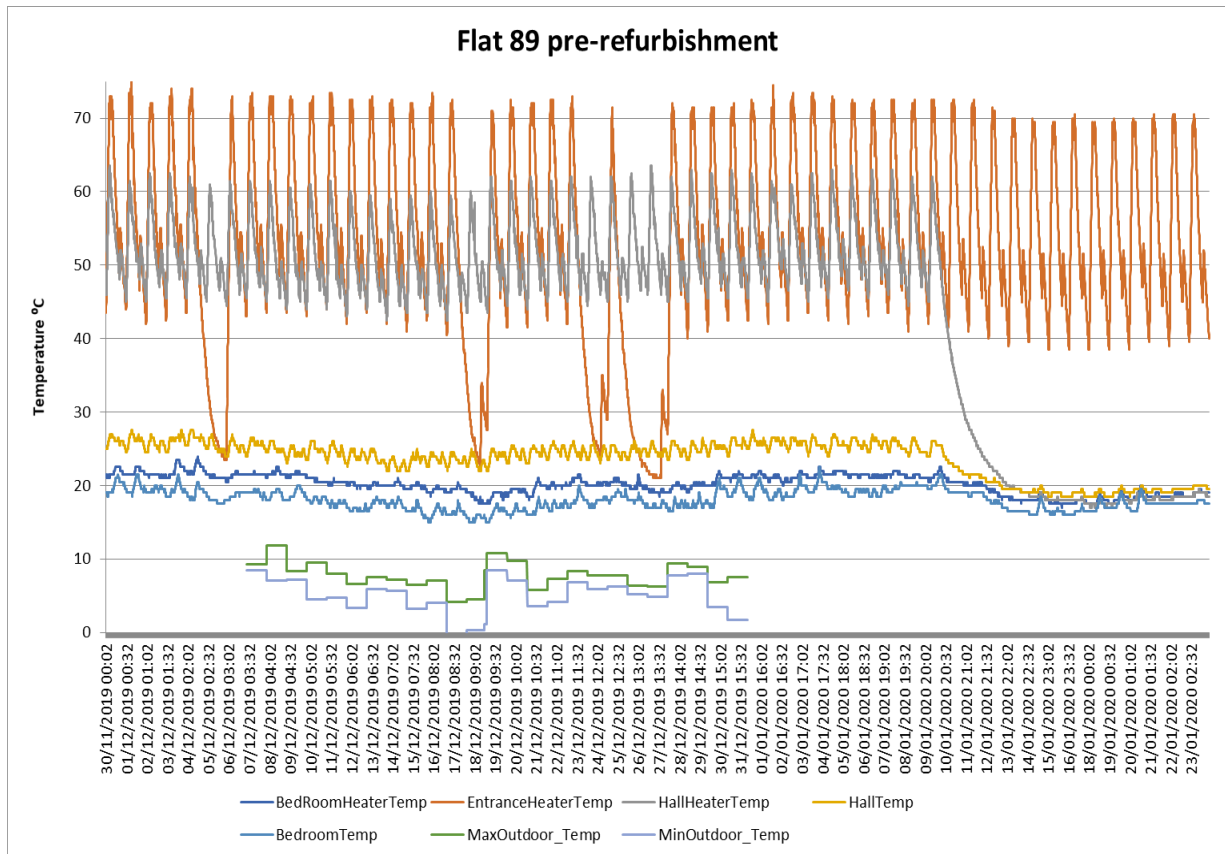
Daily temperature chart for Flat 89 in pre-refurbishment phase:



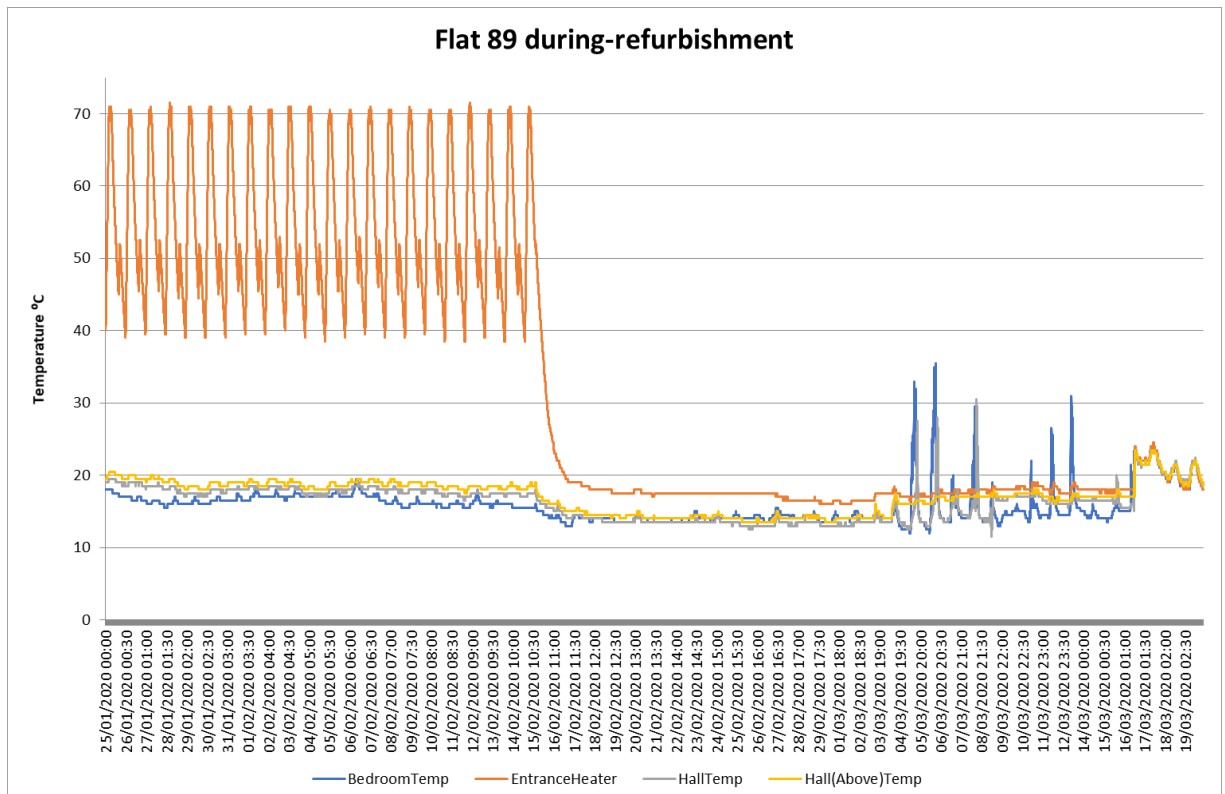
Daily temperature chart for Flat 89 during-refurbishment phase:



Temperature Chart for Flat 89 in pre-refurbishment phase:



Temperature Chart for Flat 89 in during-refurbishment phase:



The parameters summary for Flat 89:

Summary for Flat 89	Pre refurbishment		During refurbishment	
	Mean	Std Dev	Mean	Std Dev
BedRoom1Temperature (°C)	18.052	1.341	15.825	2.371
HallTemperature (°C)	23.662	2.493	17.131	2.267
HallHeaterTemperature (°C)	44.280	14.214	16.361	2.470
EntranceHeaterTemperature (°C)	52.708	12.467	32.261	18.630
Outdoor Temperature (°C)	*6.459	*1.897	*12.609	*4.224

NOTE: * incomplete data

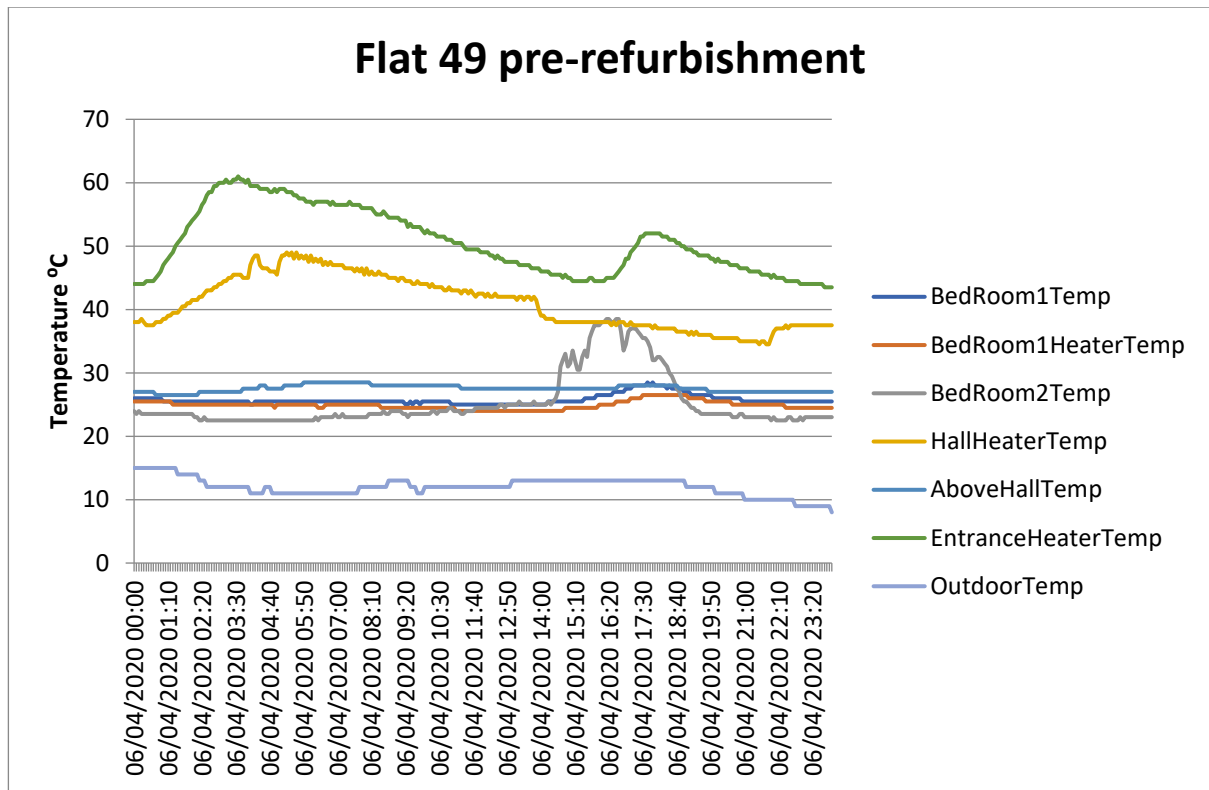
Flat 49

The parameters summary for Flat 49:

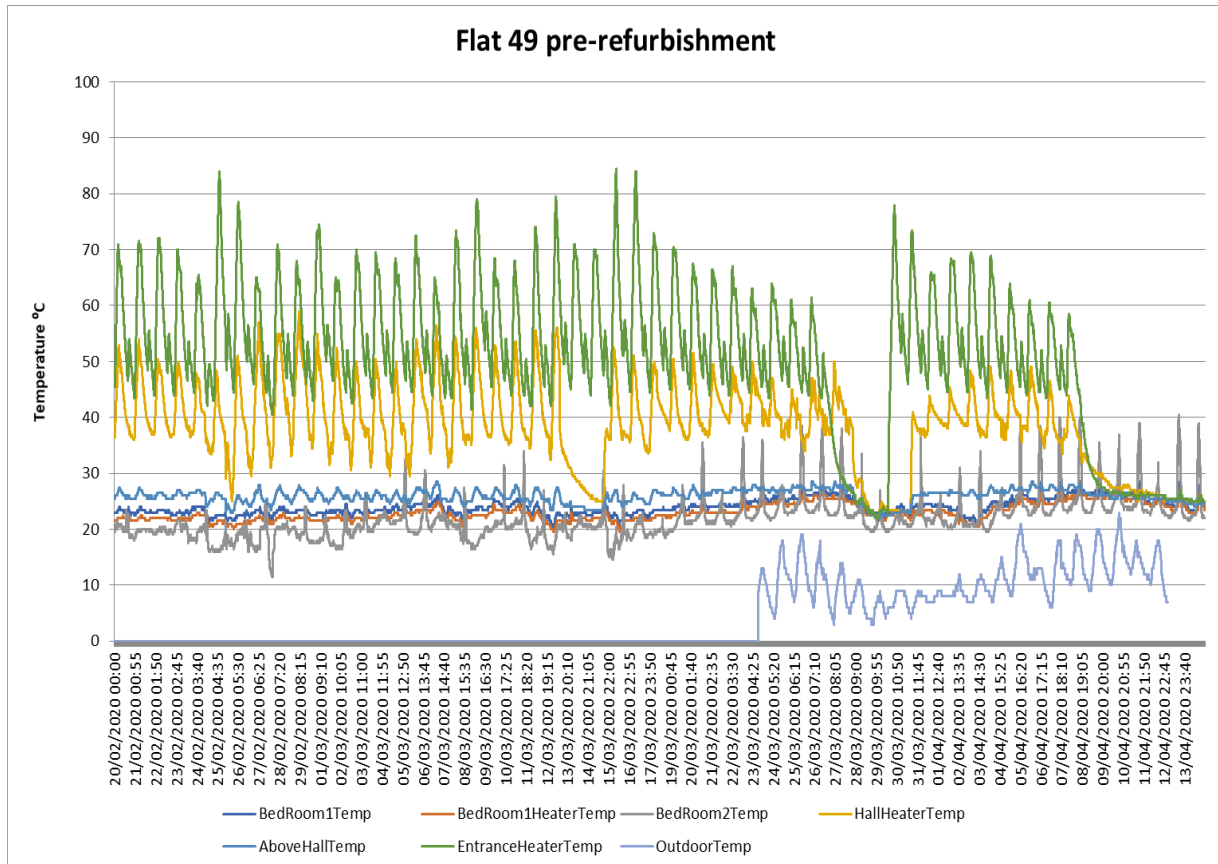
Summary for Flat 49	Pre&During refurbishment	
Parameters	Mean	Std Dev
BedRoom1Temperature (°C)	24.920	1.676
BedRoom1HeaterTemperature (°C)	23.059	1.525
BedRoom2Temperature (°C)	23.287	4.117
HallHeaterTemperature (°C)	35.656	8.401
AboveHallTemperature (°C)	25.938	1.237
EntranceHeaterTemperature (°C)	45.523	14.292
Outdoor Temperature (°C)	*12.609	*4.224
Outdoor Relative Humidity (%)	*66.934	*12.809
Indoor Relative Humidity (%)	35.692	6.154

NOTE: * incomplete data

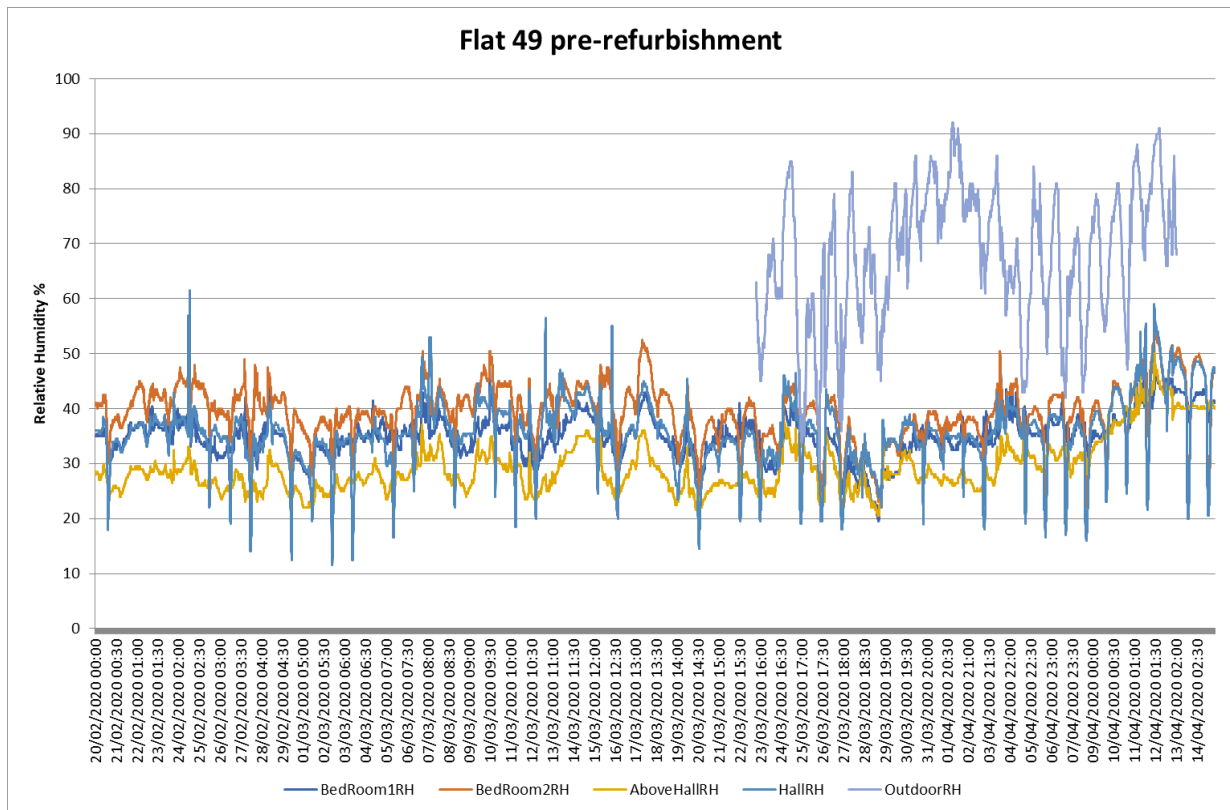
Daily temperature chart for Flat 49 during-refurbishment phase:



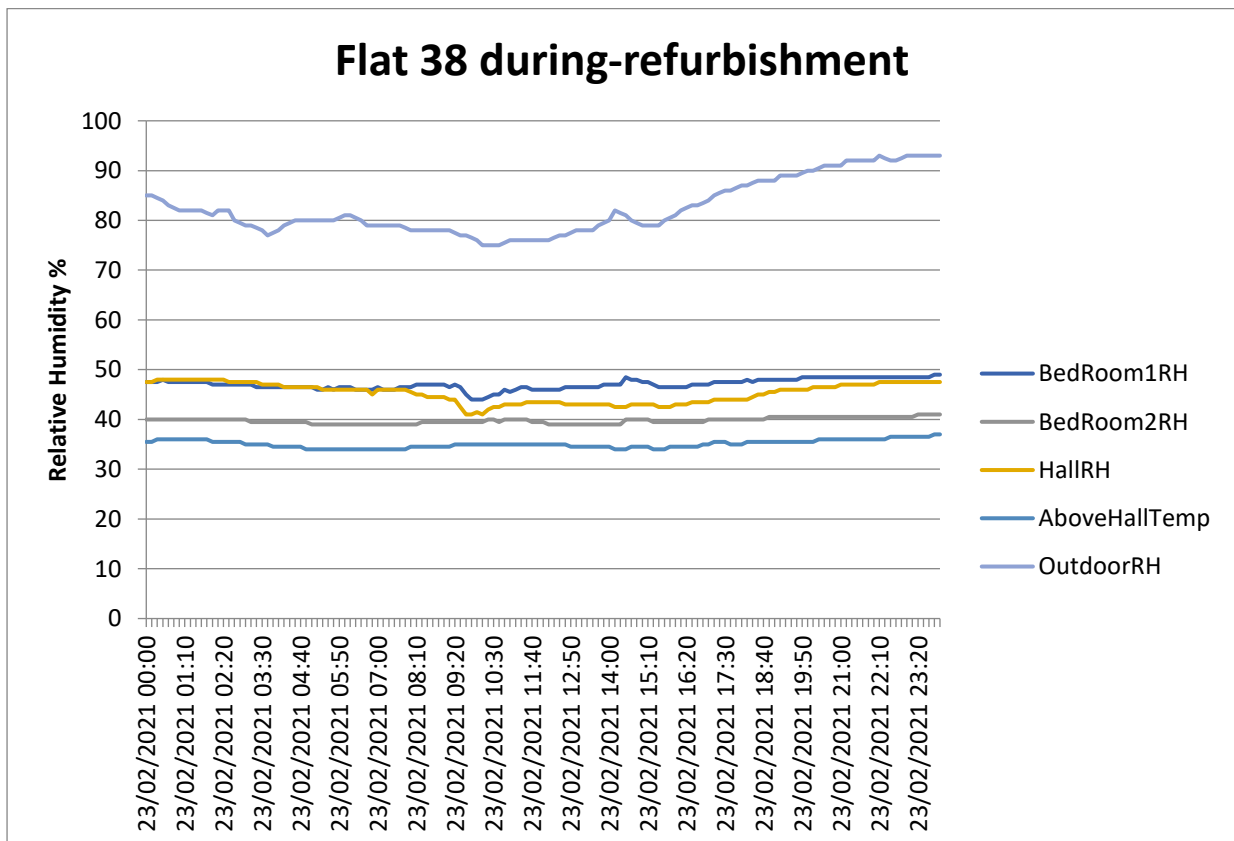
Temperature Chart for Flat 49 in pre-refurbishment phase:



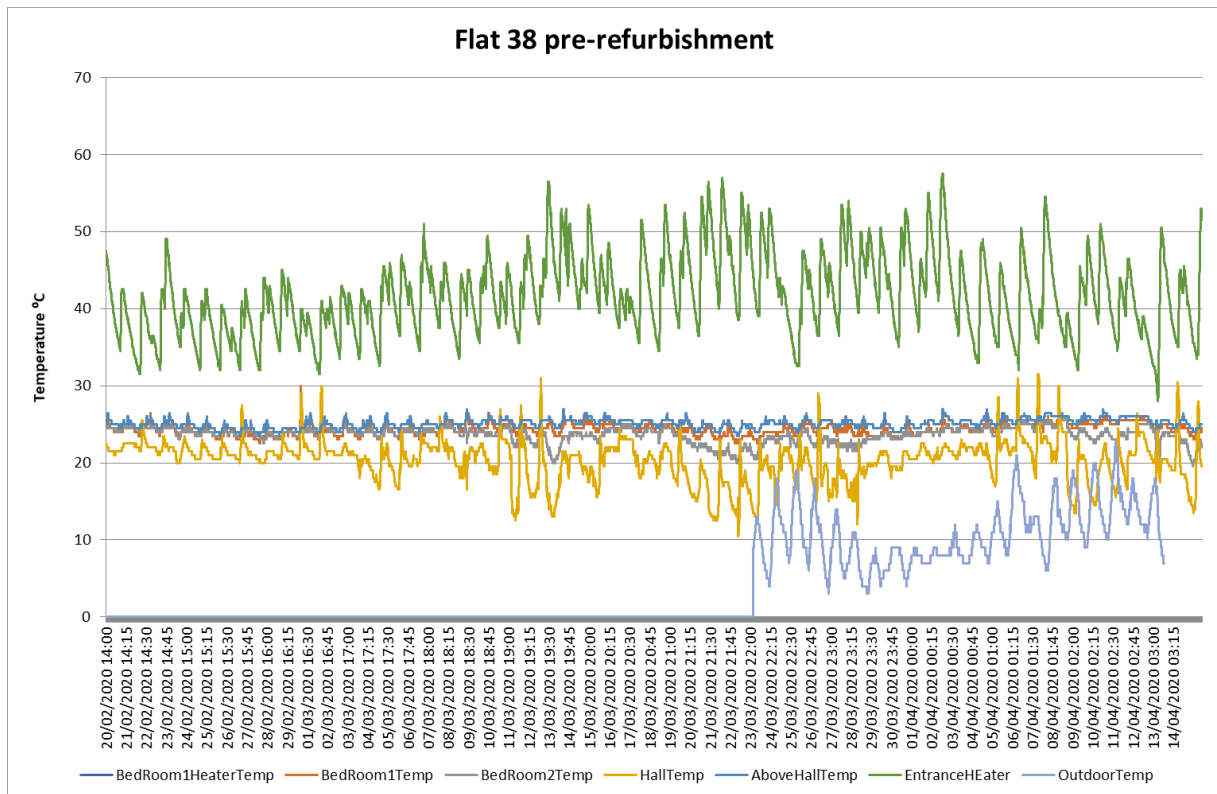
Humidity Chart for Flat 49 in pre-refurbishment phase:



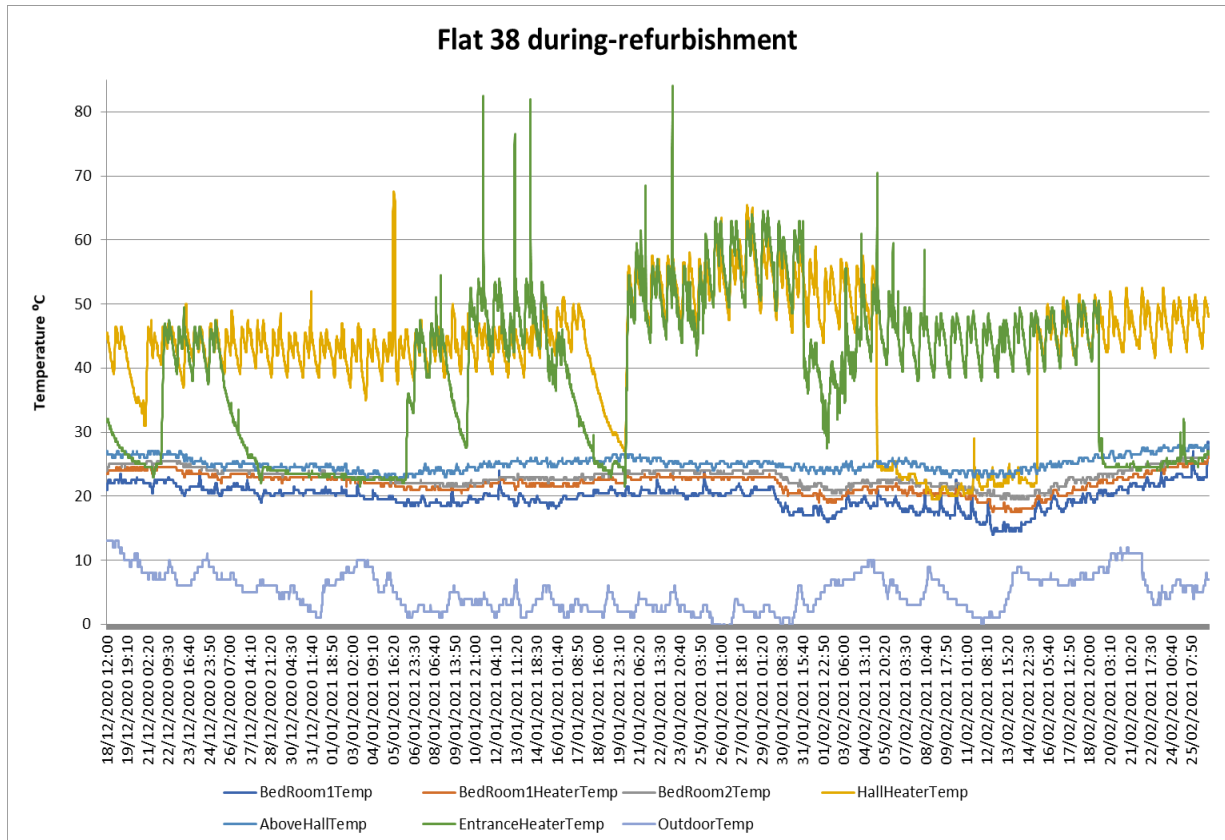
Daily humidity chart for Flat 38 during-refurbishment phase:



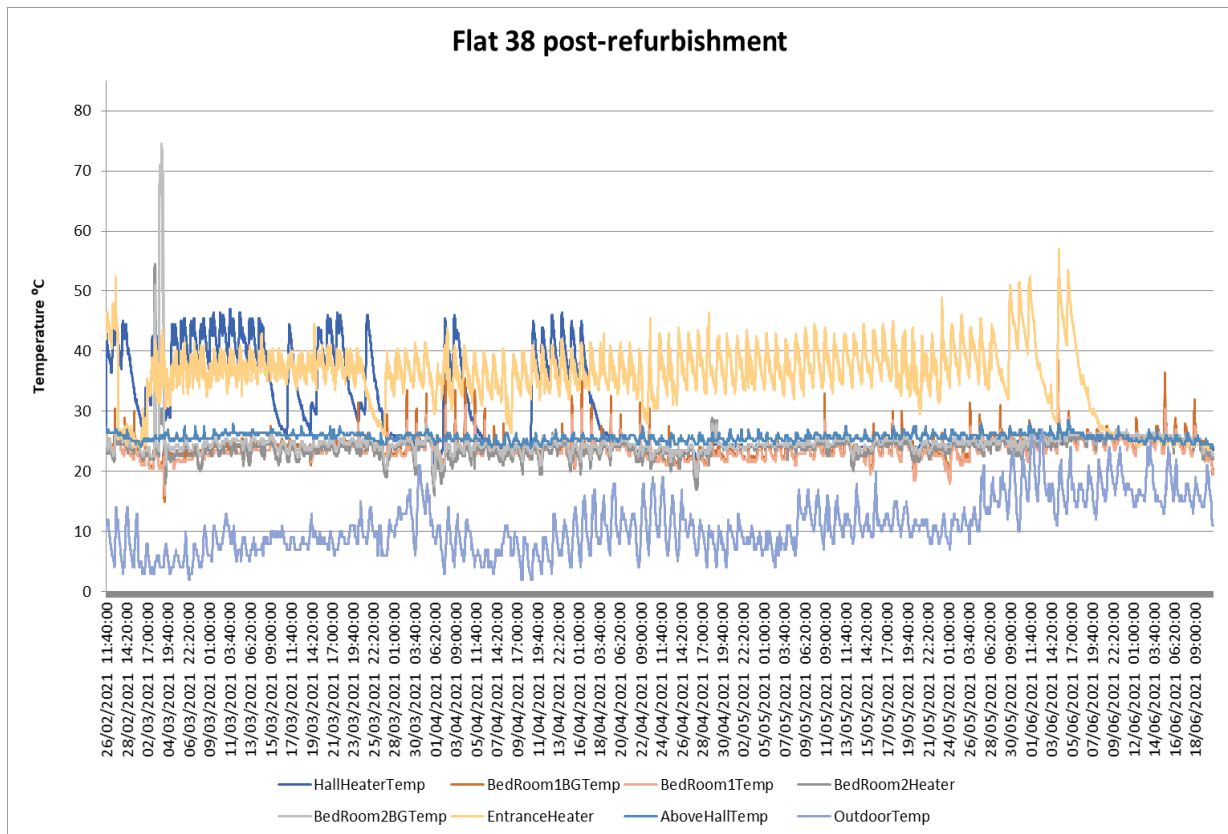
Temperature Chart for Flat 38 in pre-refurbishment phase:



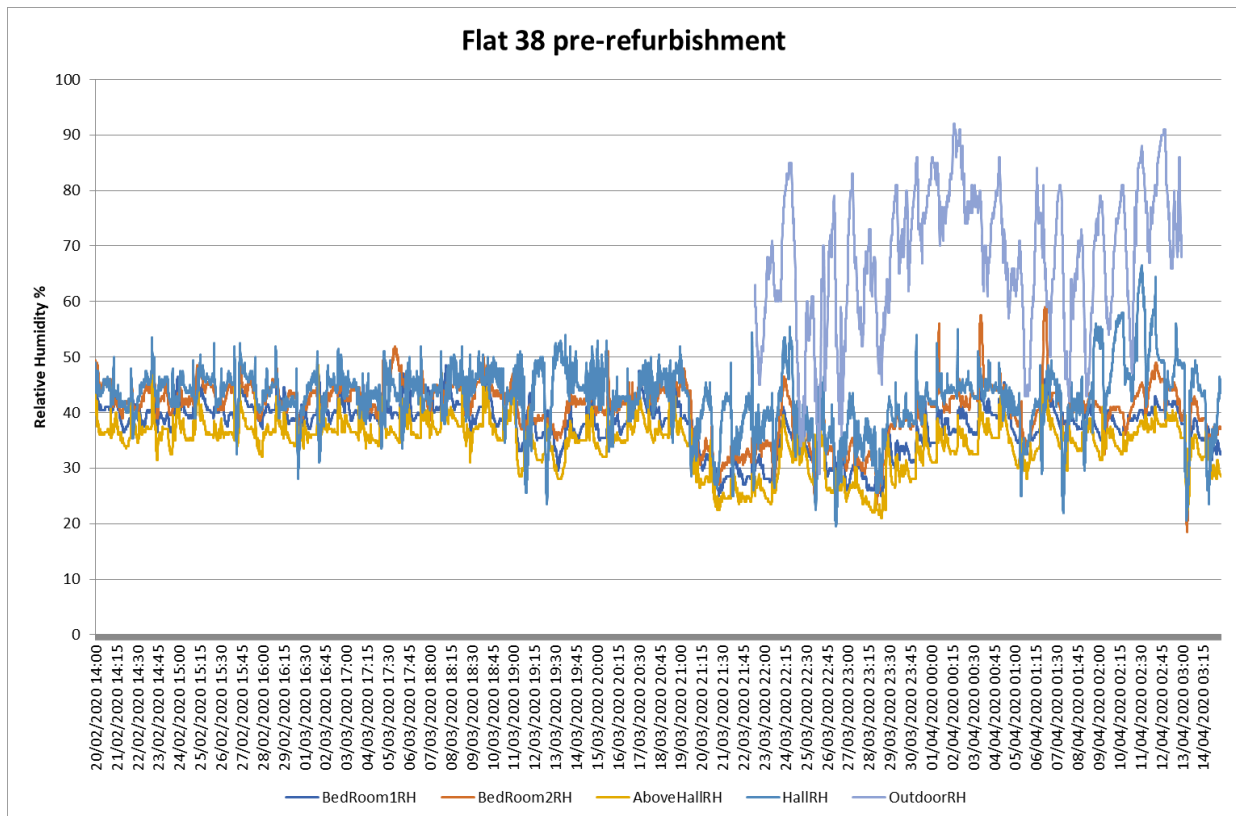
Temperature Chart for Flat 38 during-refurbishment phase:



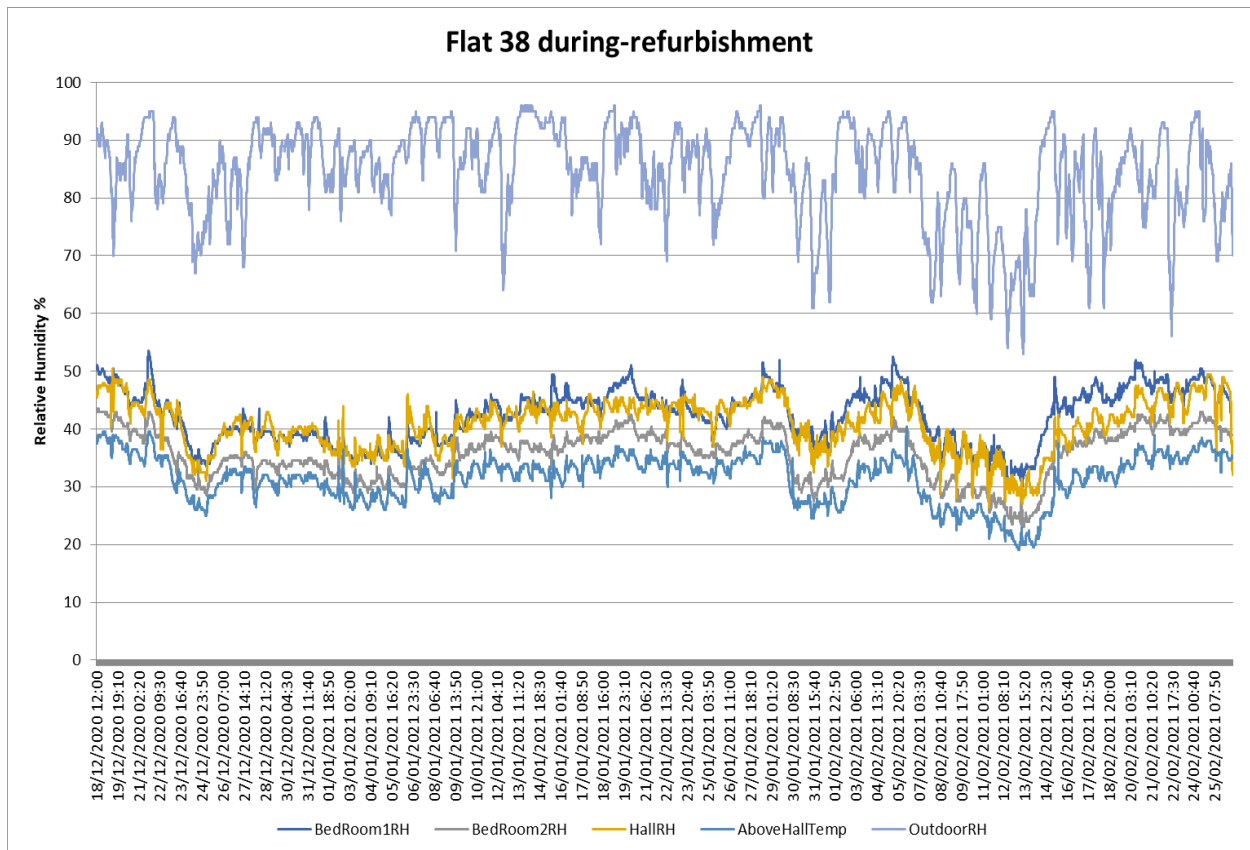
Temperature Chart for Flat 38 in post-refurbishment phase:



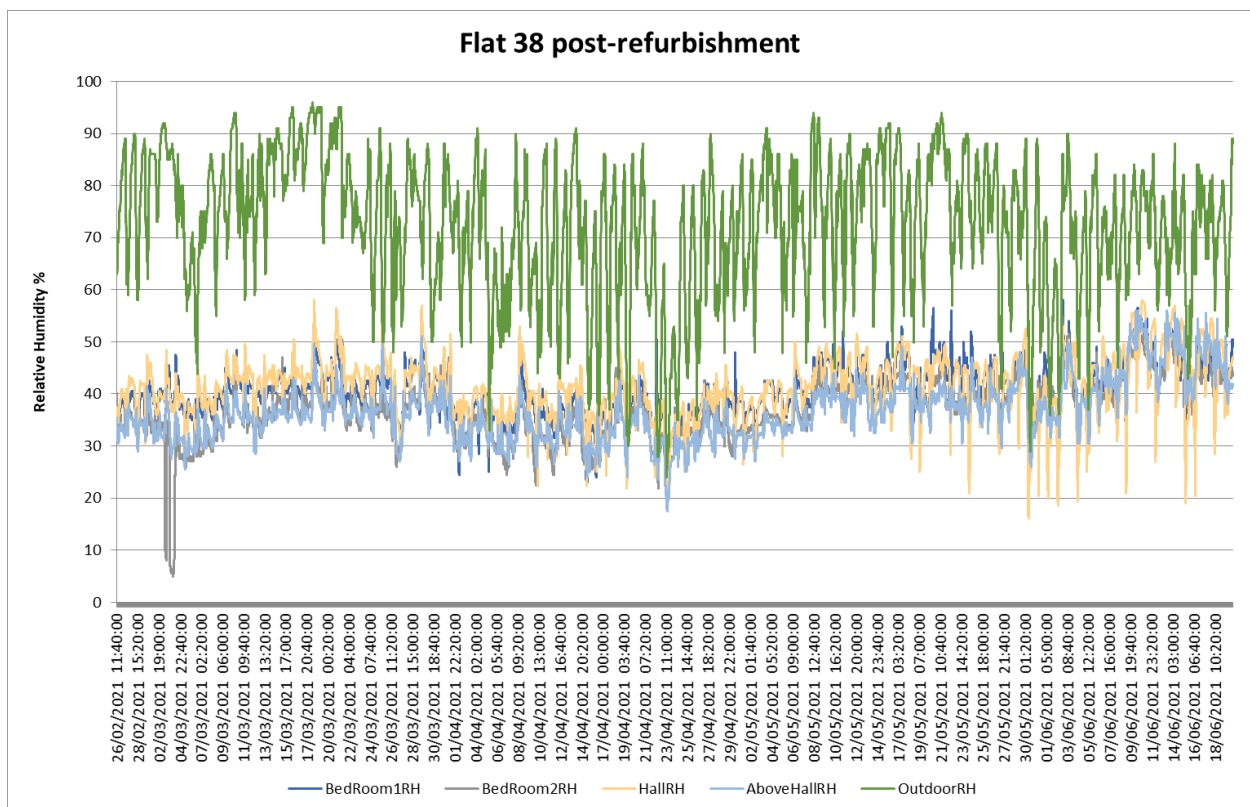
Humidity Chart for Flat 38 in pre-refurbishment phase:



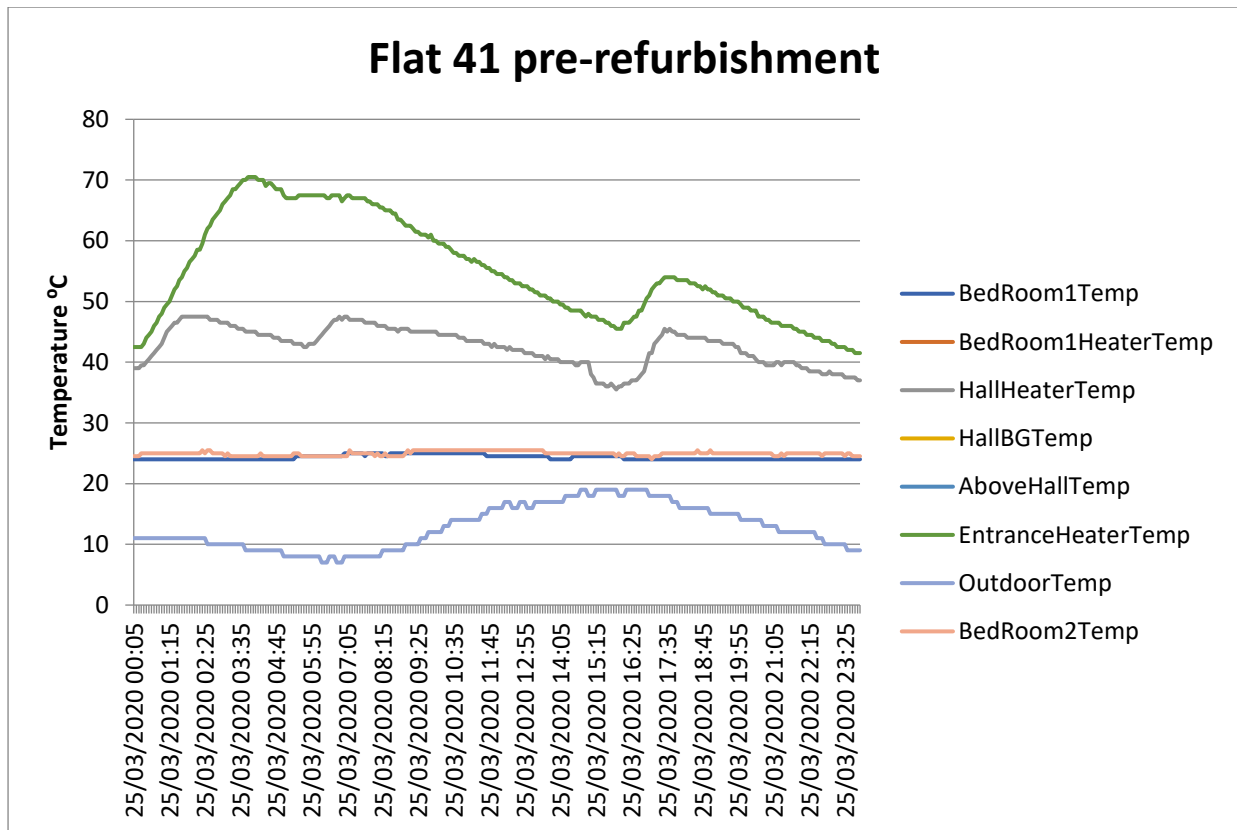
Humidity Chart for Flat 38 during-refurbishment phase:



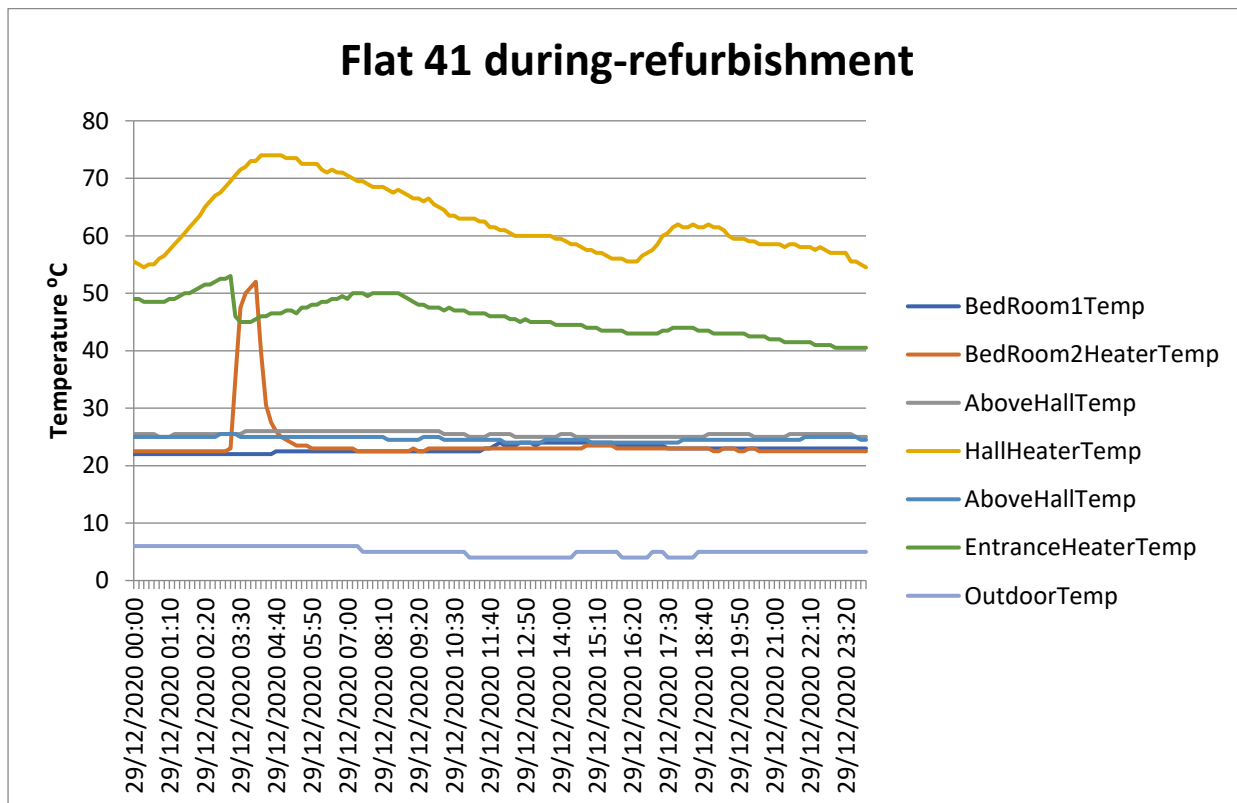
Humidity Chart for Flat 38 in post-refurbishment phase:



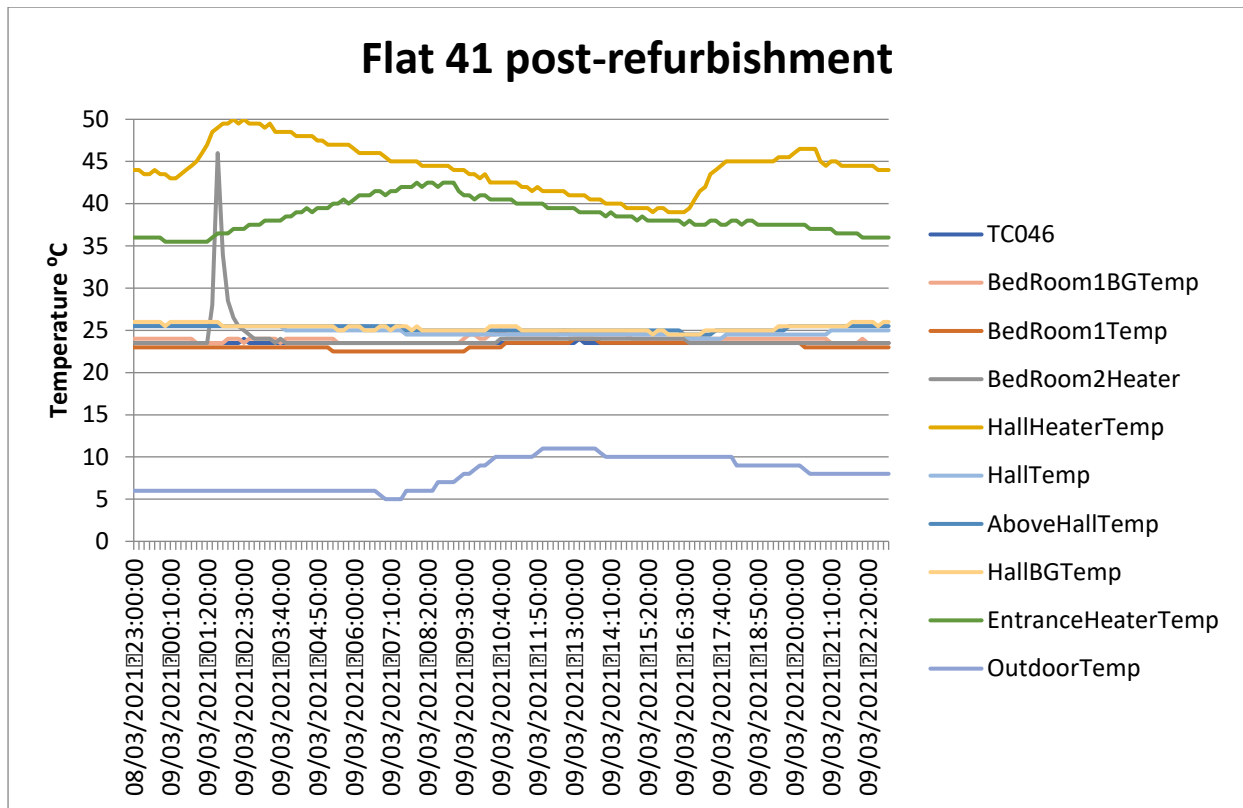
Daily temperature chart for Flat 41 in pre-refurbishment phase:



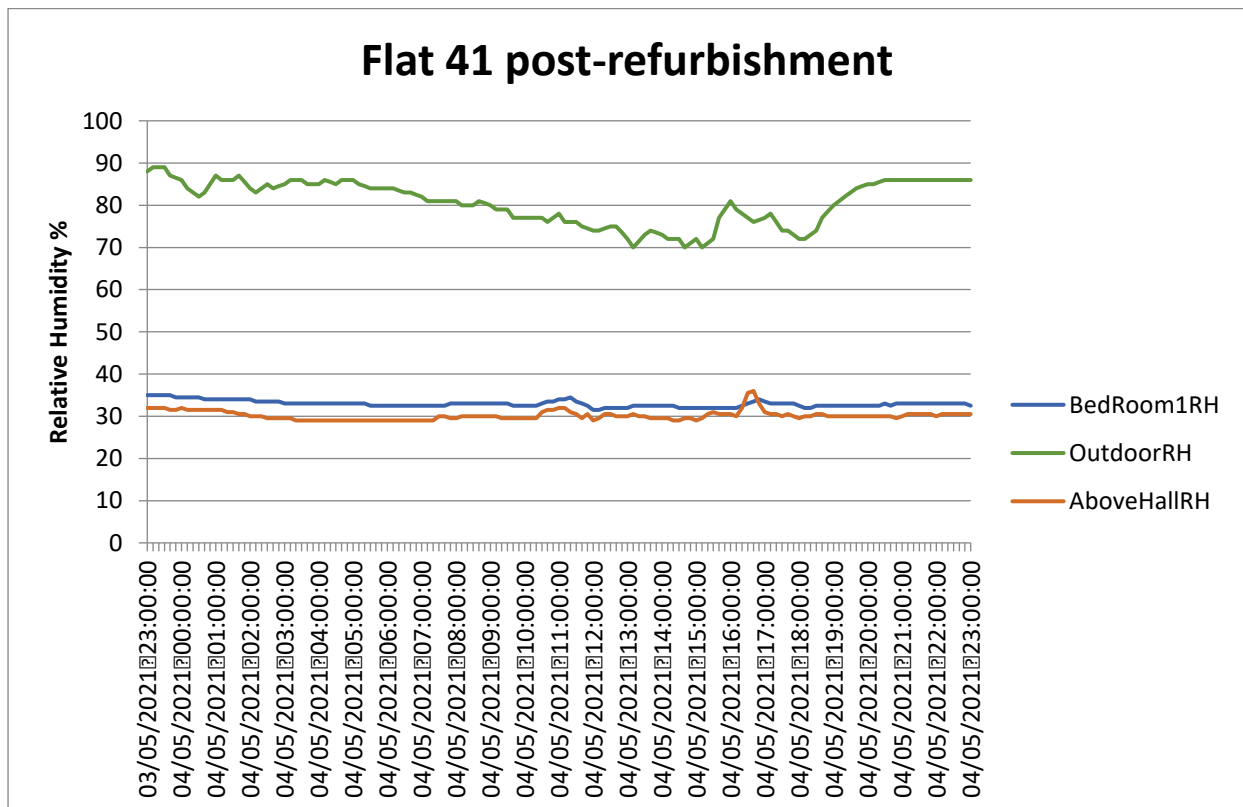
Daily temperature chart for Flat 41 during-refurbishment phase:



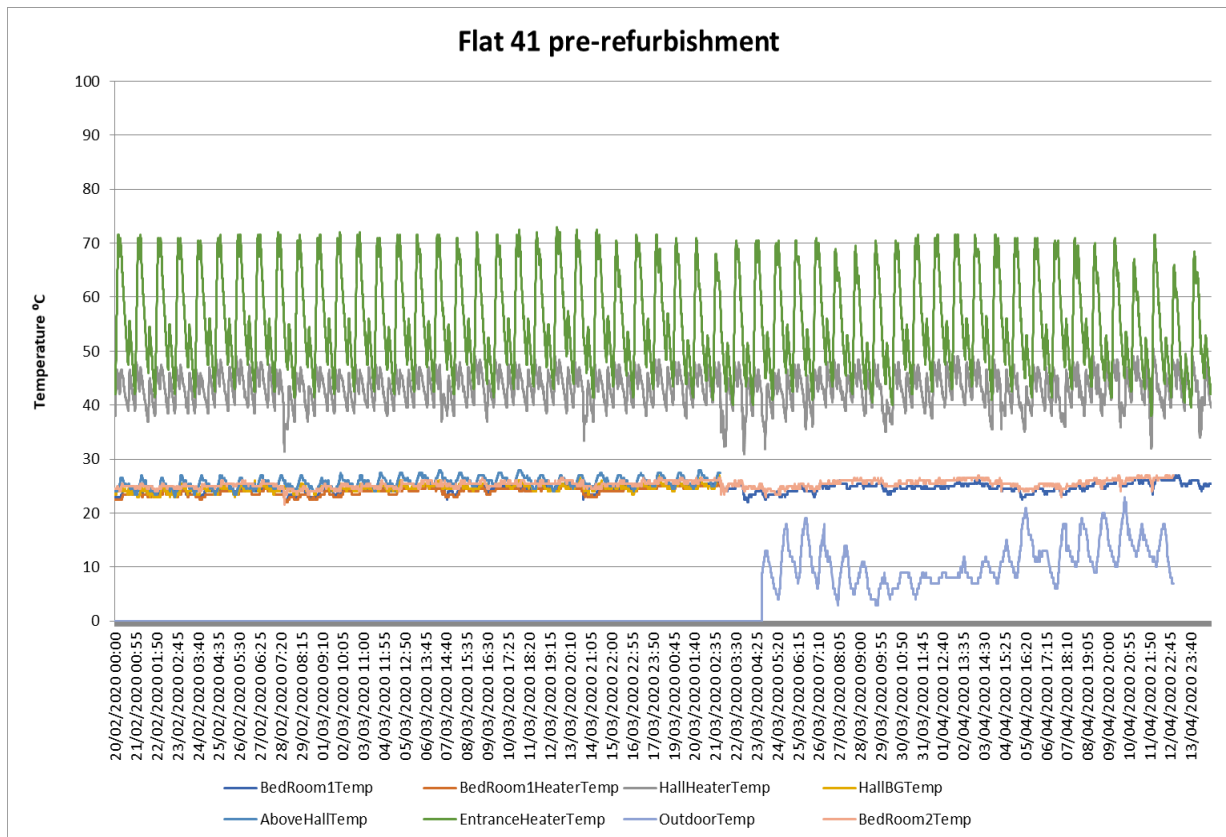
Daily temperature chart for Flat 41 in post-refurbishment phase:



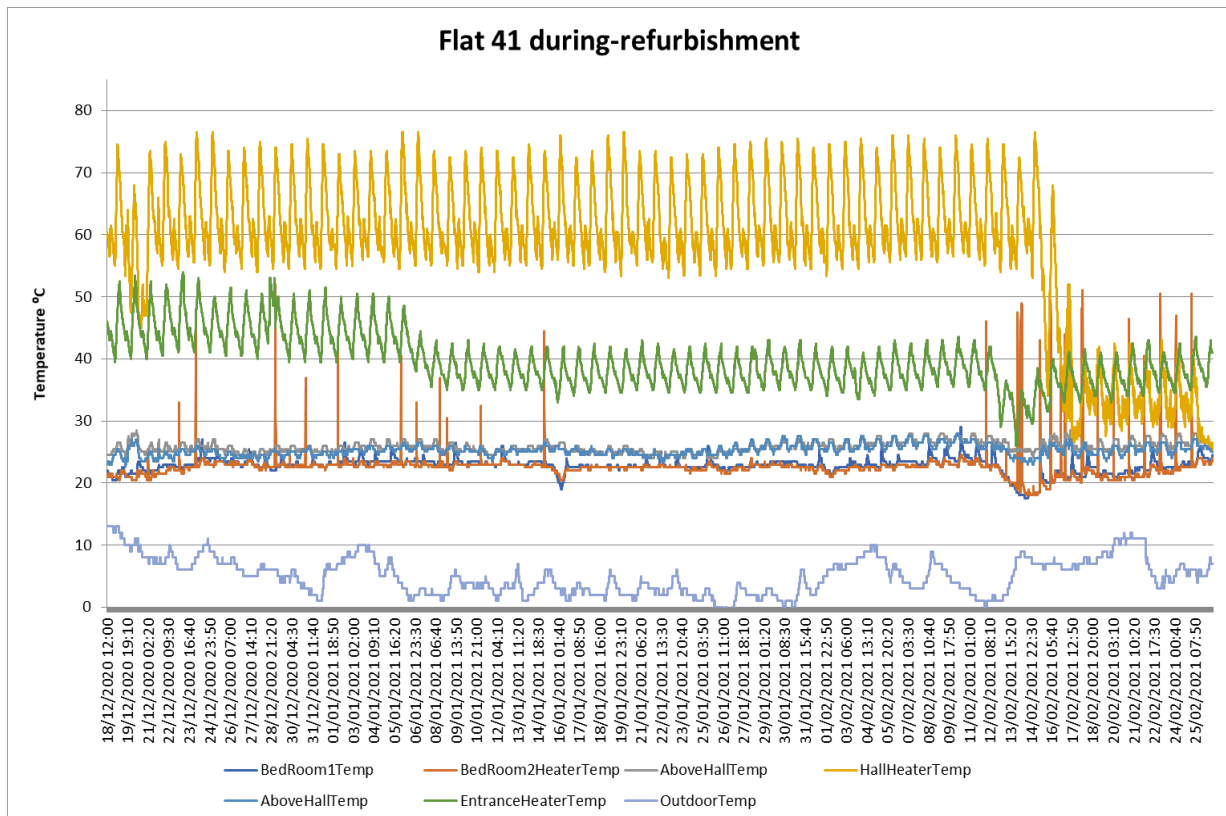
Daily humidity chart for Flat 41 in post-refurbishment phase:



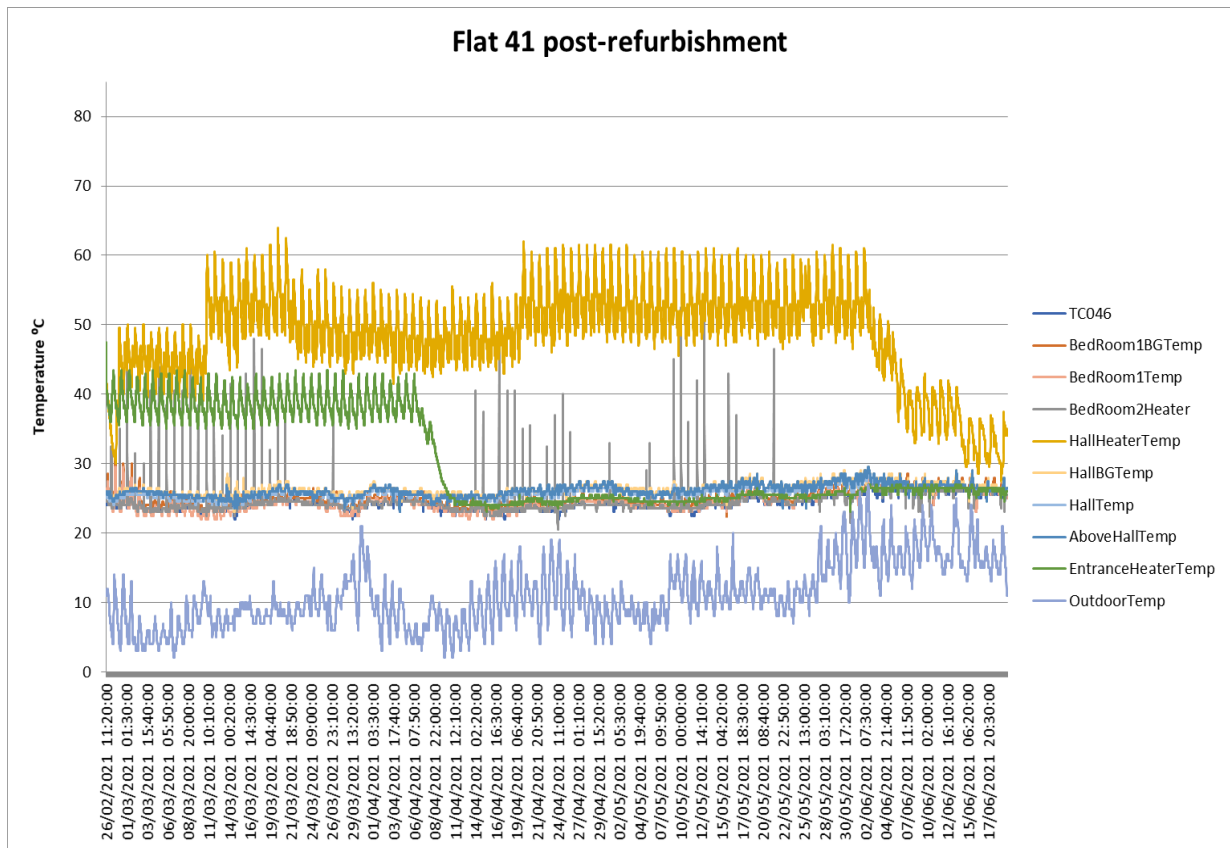
Temperature Chart for Flat 41 in pre-refurbishment phase:



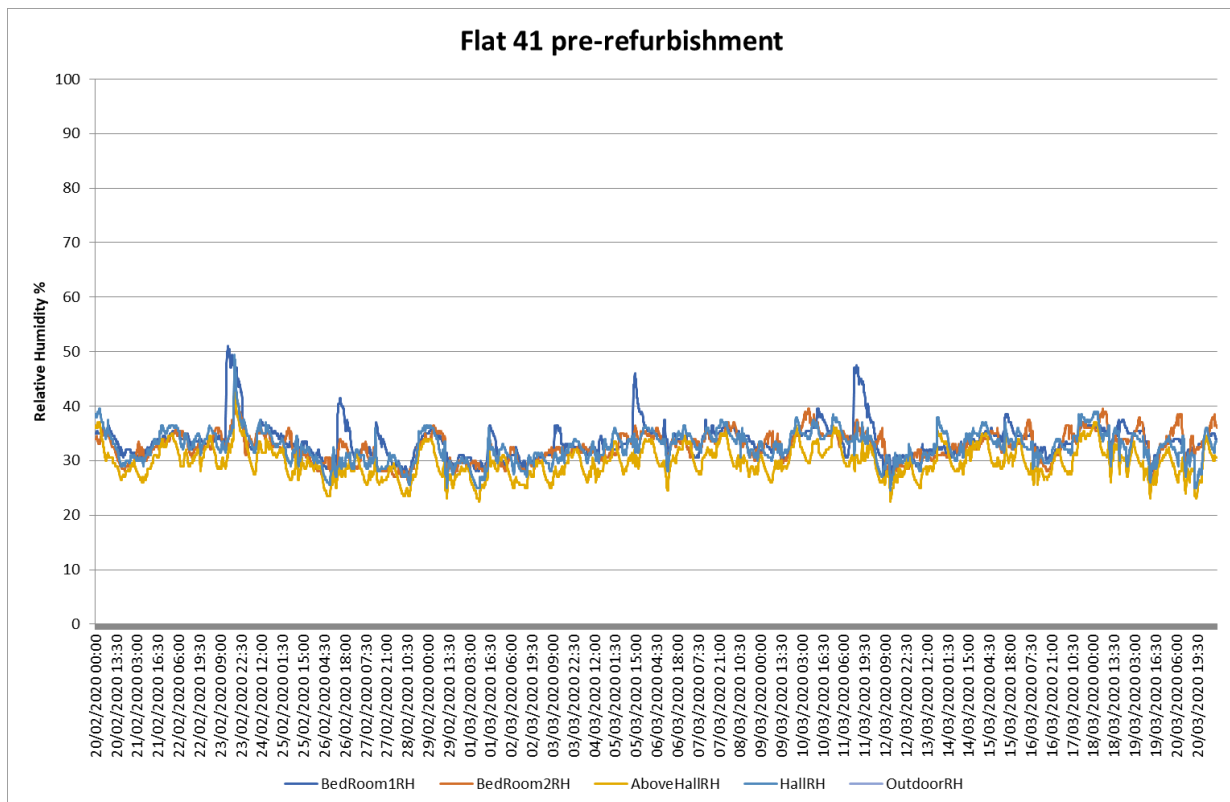
Temperature Chart for Flat 41 during-refurbishment phase:



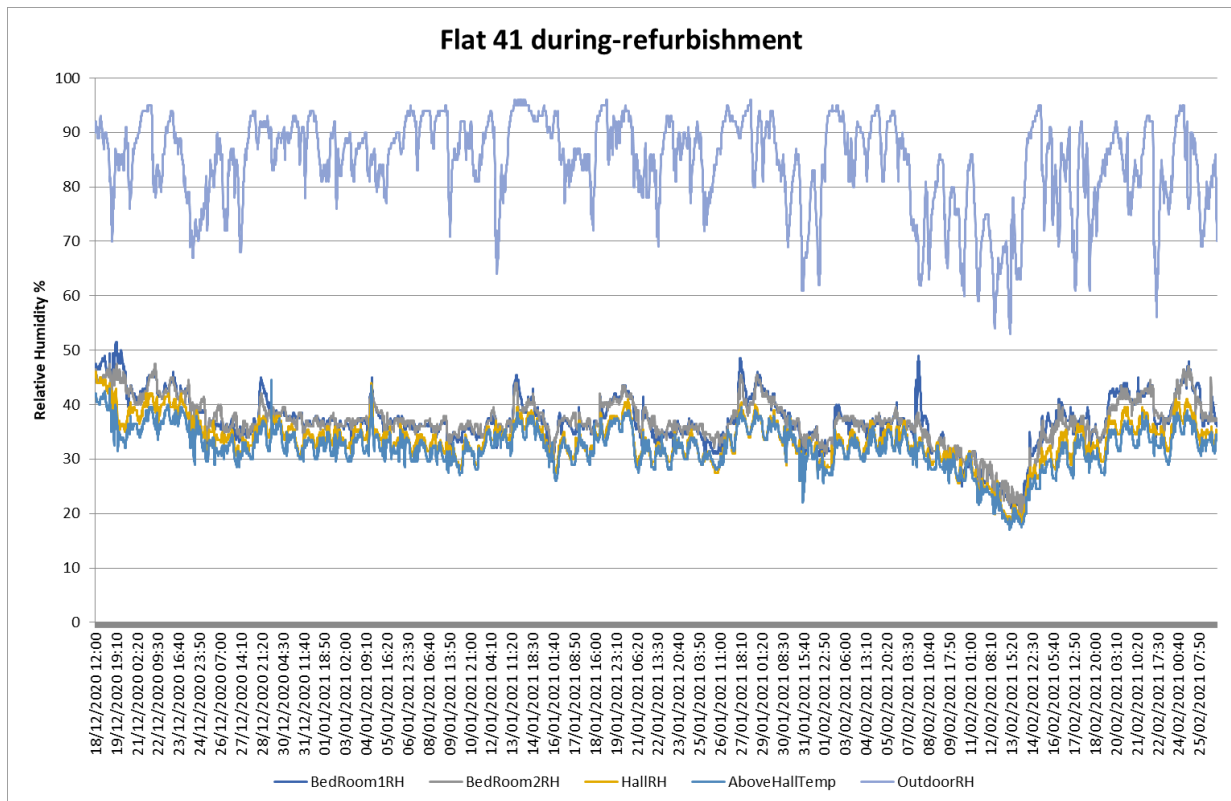
Temperature Chart for Flat 41 in post-refurbishment phase:



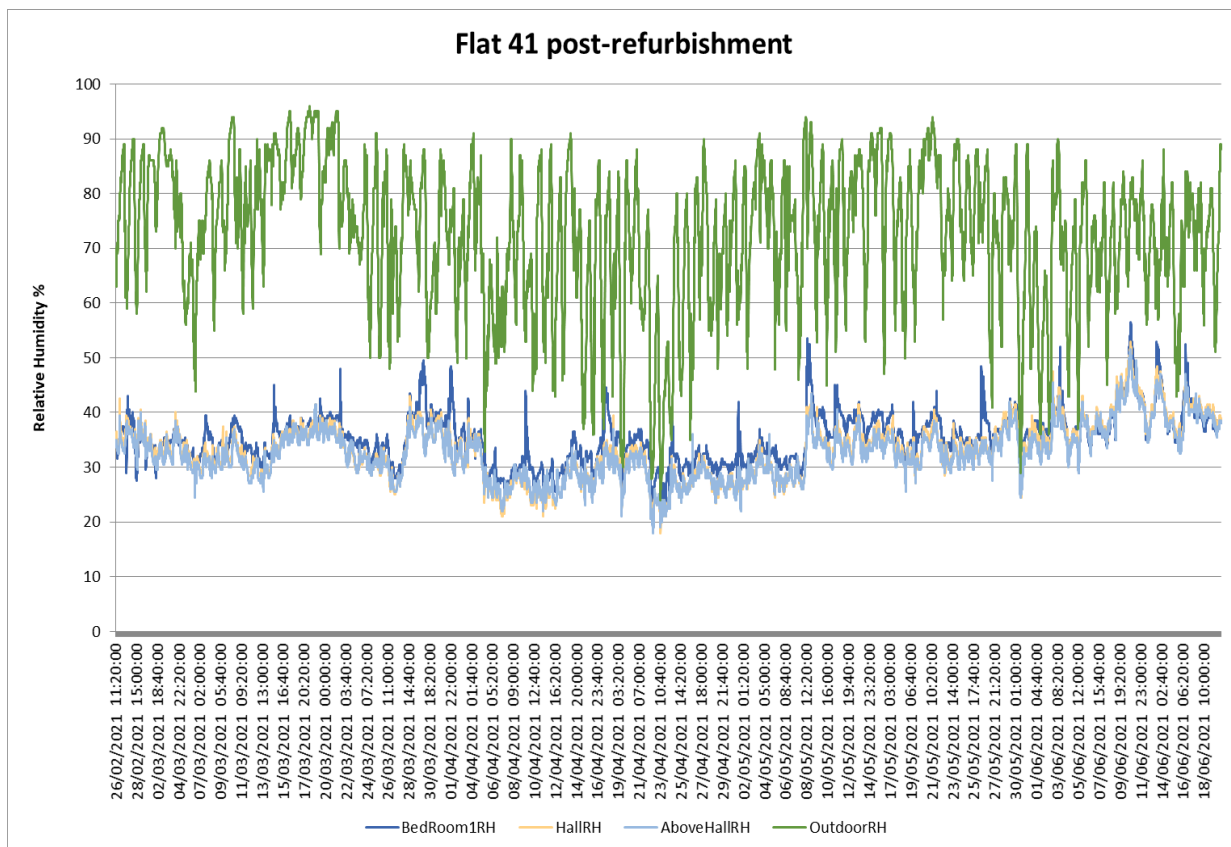
Humidity Chart for Flat 41 in pre-refurbishment phase:



Humidity Chart for Flat 41 during-refurbishment phase:



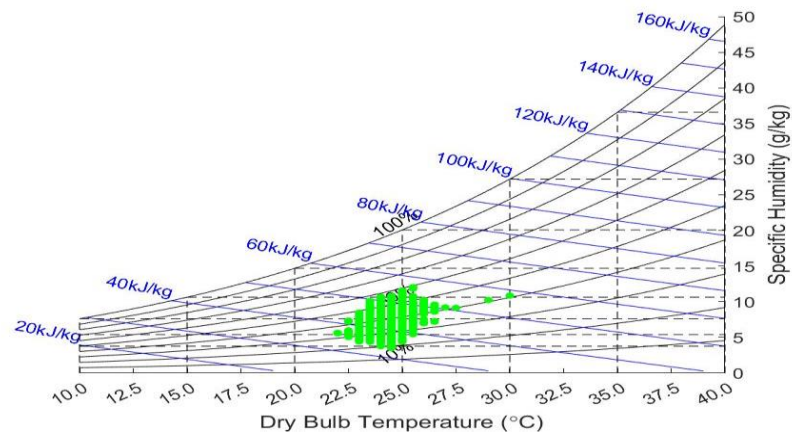
Humidity Chart for Flat 41 in post-refurbishment phase:



AI Model Analysis for Flat 38, before Refurbishment:

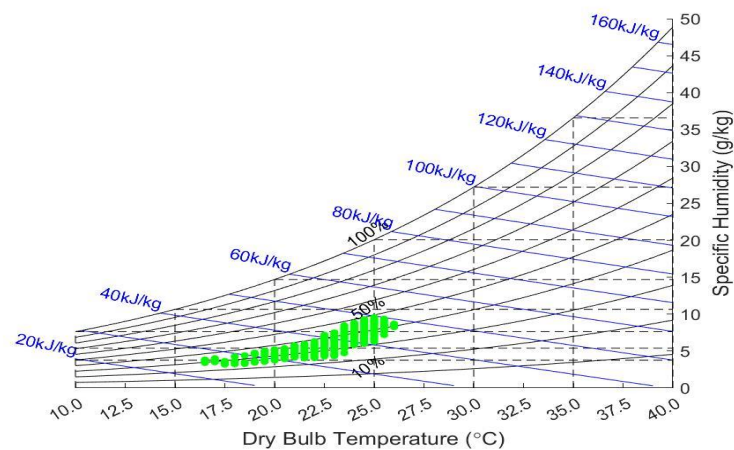
Bedroom1 comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

100% in comfort condition. Psychrometric chart:



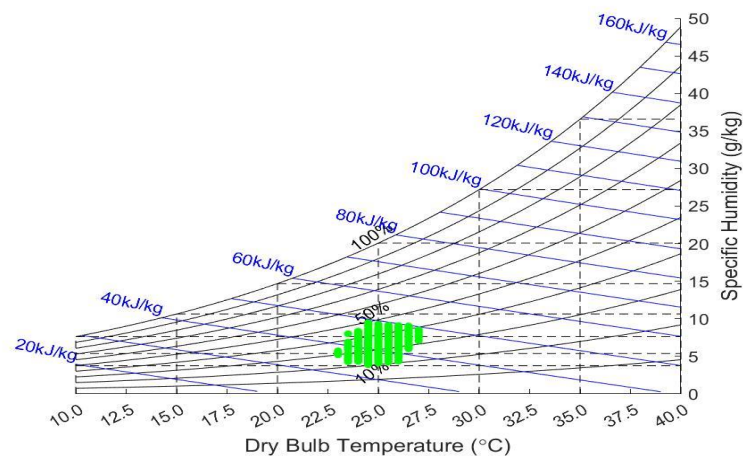
Bedroom2 comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

100% in comfort condition. Psychrometric chart:



Above Hall comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

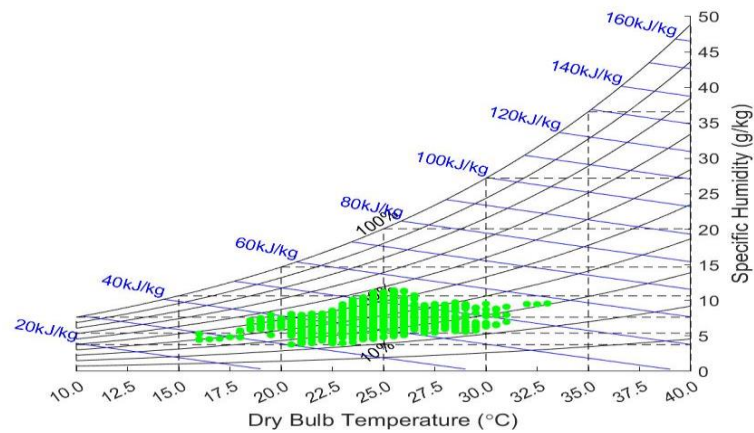
100% in comfort condition. Psychrometric chart:



AI Model Analysis for Flat 38, After Refurbishment:

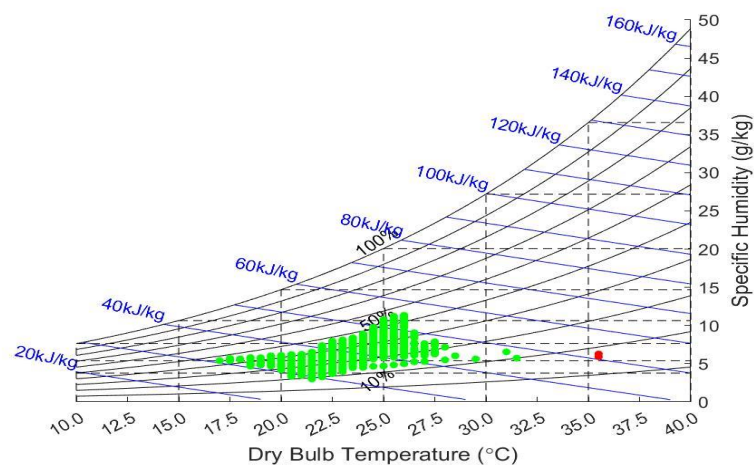
Bedroom1 comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

100% in comfort condition. Psychrometric chart:



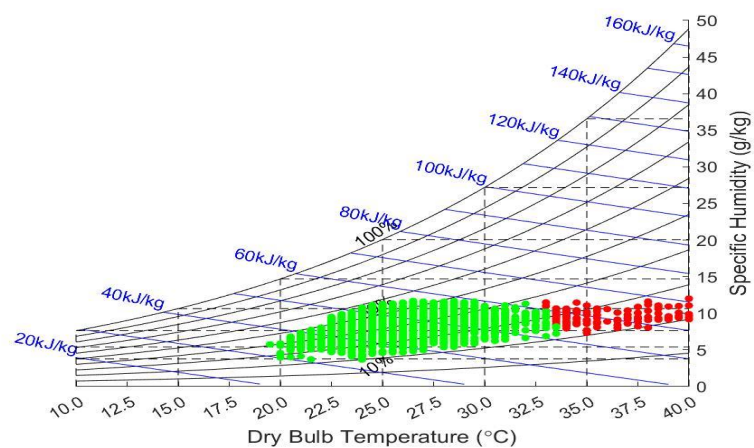
Bedroom2 comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

99.44% in comfort condition. Psychrometric chart:



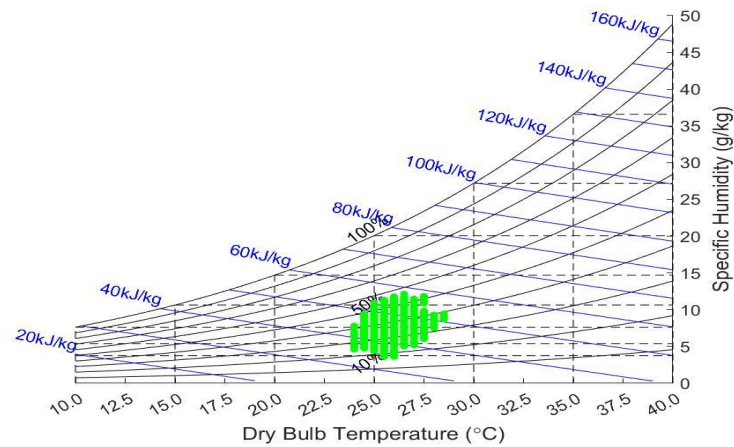
Hall comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

98.97% in comfort condition. Psychrometric chart:



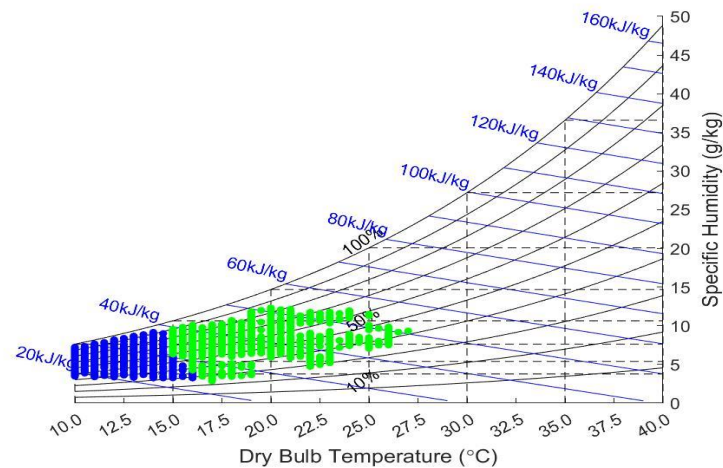
Above Hall comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

100% in comfort condition. Psychrometric chart:



Outdoor comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

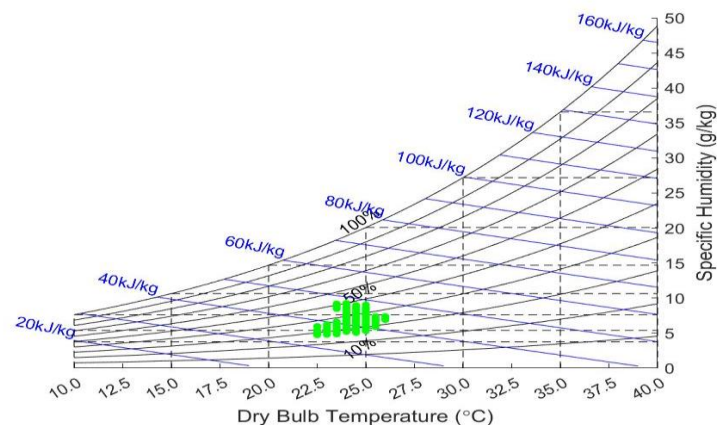
20.96% in comfort condition. Psychrometric chart:



AI Model Analysis for Flat 41, before Refurbishment:

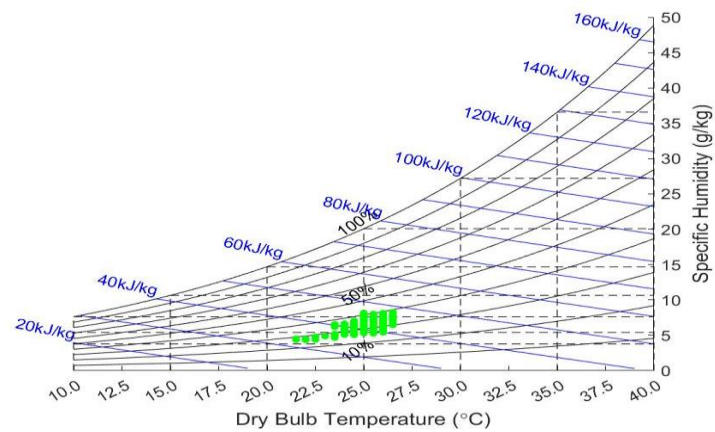
Bedroom1 comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

100% in comfort condition. Psychrometric chart:



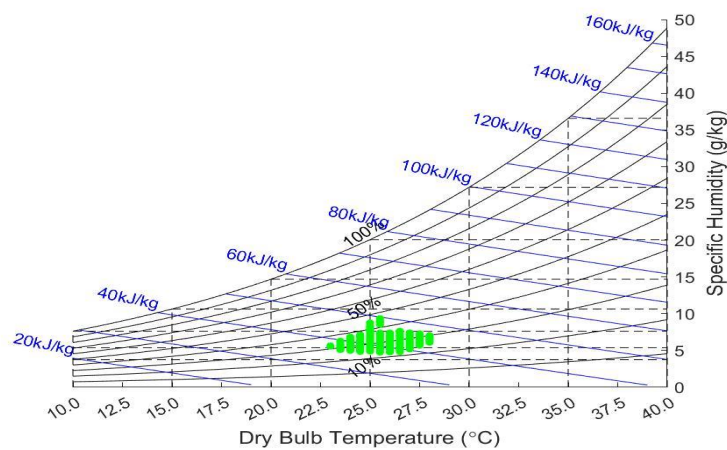
Bedroom2 comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

100% in comfort condition. Psychrometric chart:



Above Hall comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

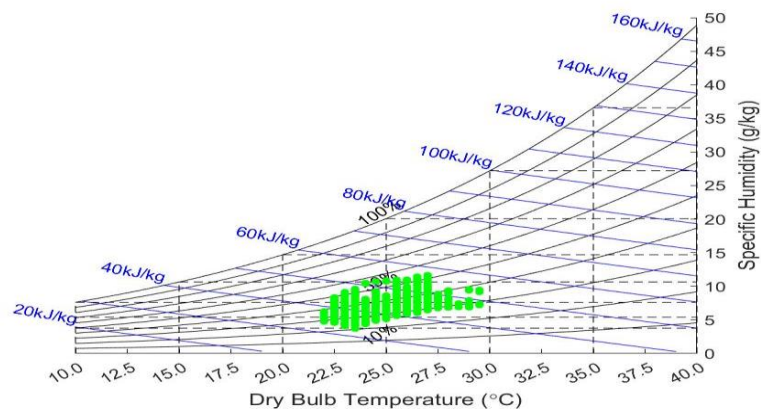
100% in comfort condition. Psychrometric chart:



AI Model Analysis for Flat 41, After Refurbishment:

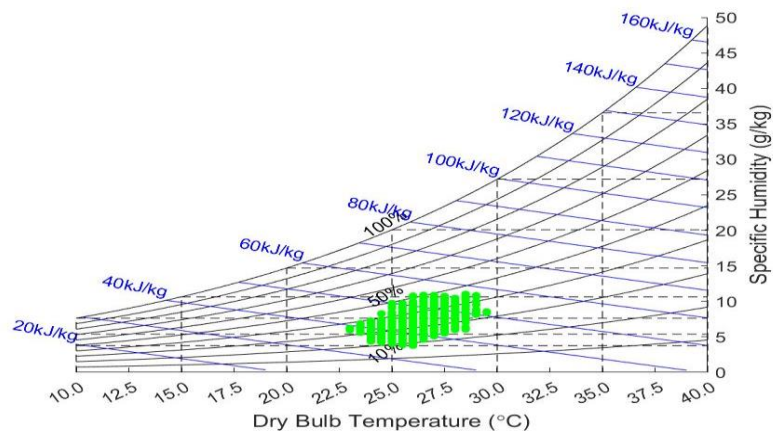
Bedroom1 comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

100% in comfort condition. Psychrometric chart:



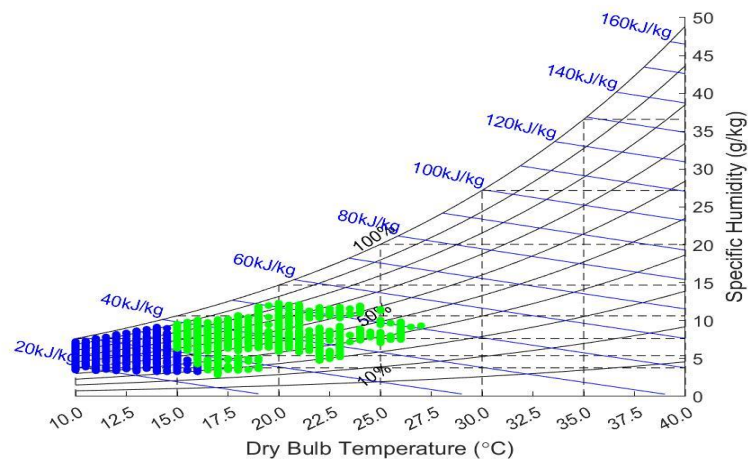
Above Hall comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

100% in comfort condition. Psychrometric chart:



Outdoor comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

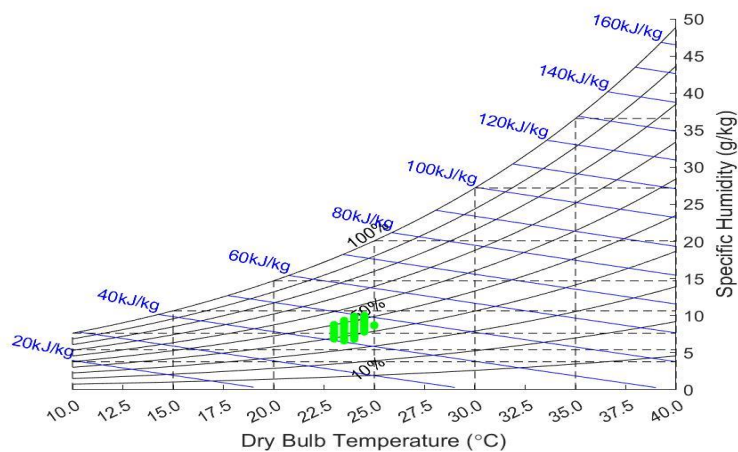
20.96% in comfort condition. Psychrometric chart:



AI Model Analysis for Flat 80, before Refurbishment:

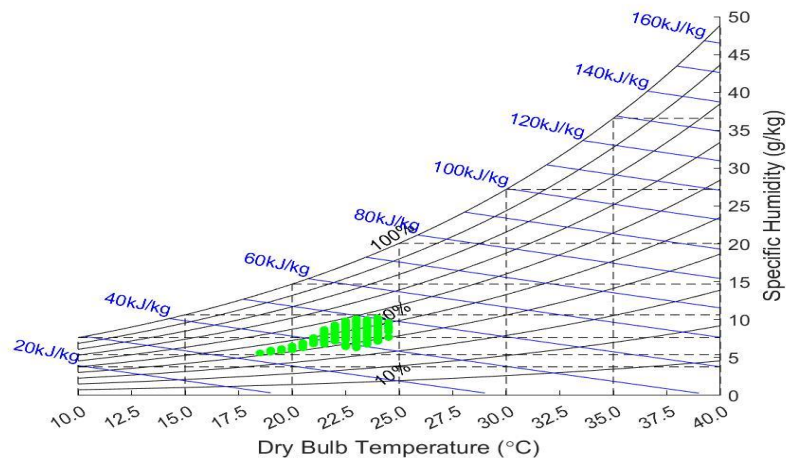
Bedroom1 comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

100% in comfort condition. Psychrometric chart:



Bedroom2 comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

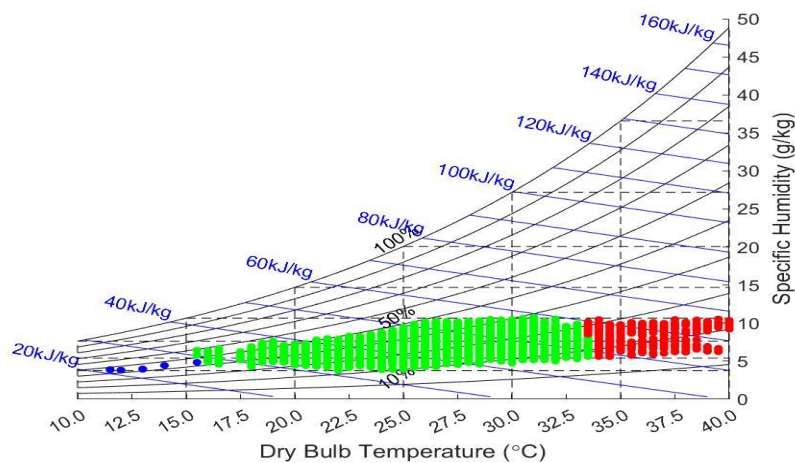
100% in comfort condition. Psychrometric chart:



AI Model Analysis for Flat 80, After Refurbishment:

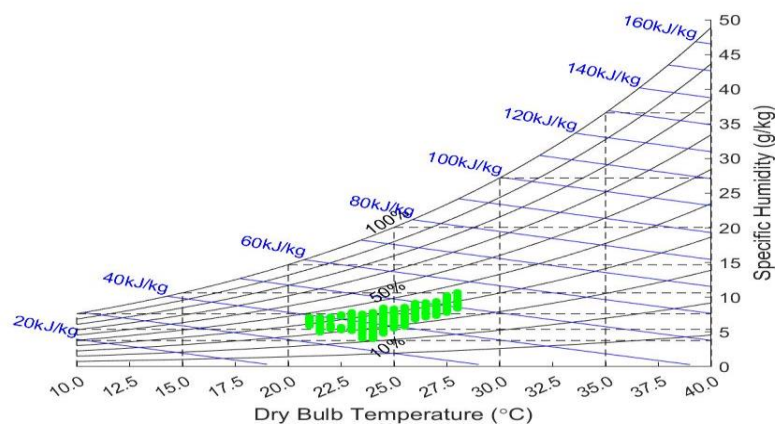
Bedroom1 comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

96.70% in comfort condition. Psychrometric chart:



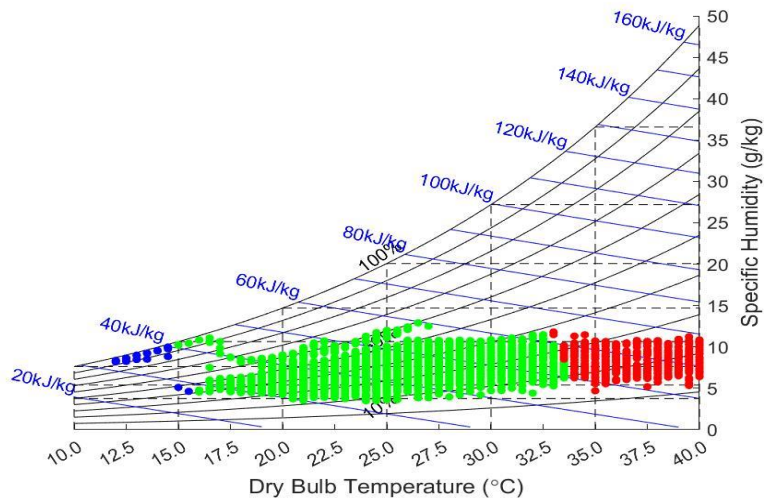
Bedroom2 comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

100 % in comfort condition. Psychrometric chart:



Hall comfort map (Assumption Clothing value 1 clo, Activity 1.5 met, age 40.5 years)

93.95% in comfort condition. Psychrometric chart:



The Implementation of the New Materials for Thermal Improvement

Phase1

Sensor Installation and Data Range

Summary	House #1		2 bed bungalow	
Sensor ID	Area	Location	Start Logging	Stop Logging
EC 05	Front living room	window	27/07/2021 14:15	24/01/2022 17:00
EH 05	Front living room	window	27/07/2021 14:15	24/12/2021 10:15
EC 12	Front living room	radiator	27/07/2021 14:15	24/01/2022 17:00
EH 14	Front living room	room	27/07/2021 14:15	24/12/2021 10:15
EC 06	Back bedroom	window	27/07/2021 14:15	24/01/2022 17:00
EH 06	Back bedroom	window	27/07/2021 14:15	24/12/2021 10:15
EC 20	Back bedroom	radiator	27/07/2021 14:15	24/01/2022 17:00
EH 13	Back bedroom	room	27/07/2021 14:15	24/12/2021 10:15

Summary	House #3		1 bed bungalow	
Sensor ID	Area	Location	Start Logging	Stop Logging
EC 09	Back bedroom	window	27/07/2021 13:45	24/12/2021 10:15
EH 09	Back bedroom	window	27/07/2021 13:45	24/01/2022 16:00
EC 14	Back bedroom	radiator	27/07/2021 13:45	24/01/2022 16:00
EH 20	Back bedroom	room	27/07/2021 13:45	24/12/2021 10:15
EC 10	Back living room	window	27/07/2021 13:45	24/01/2022 16:00
EH 10	Back living room	window	27/07/2021 13:45	24/12/2021 10:15
EC 11	Back living room	radiator	27/07/2021 13:45	24/01/2022 15:45
EH 17	Back living room	room	27/07/2021 13:45	19/12/2021 08:45
Summary	House #4		3 bed house	

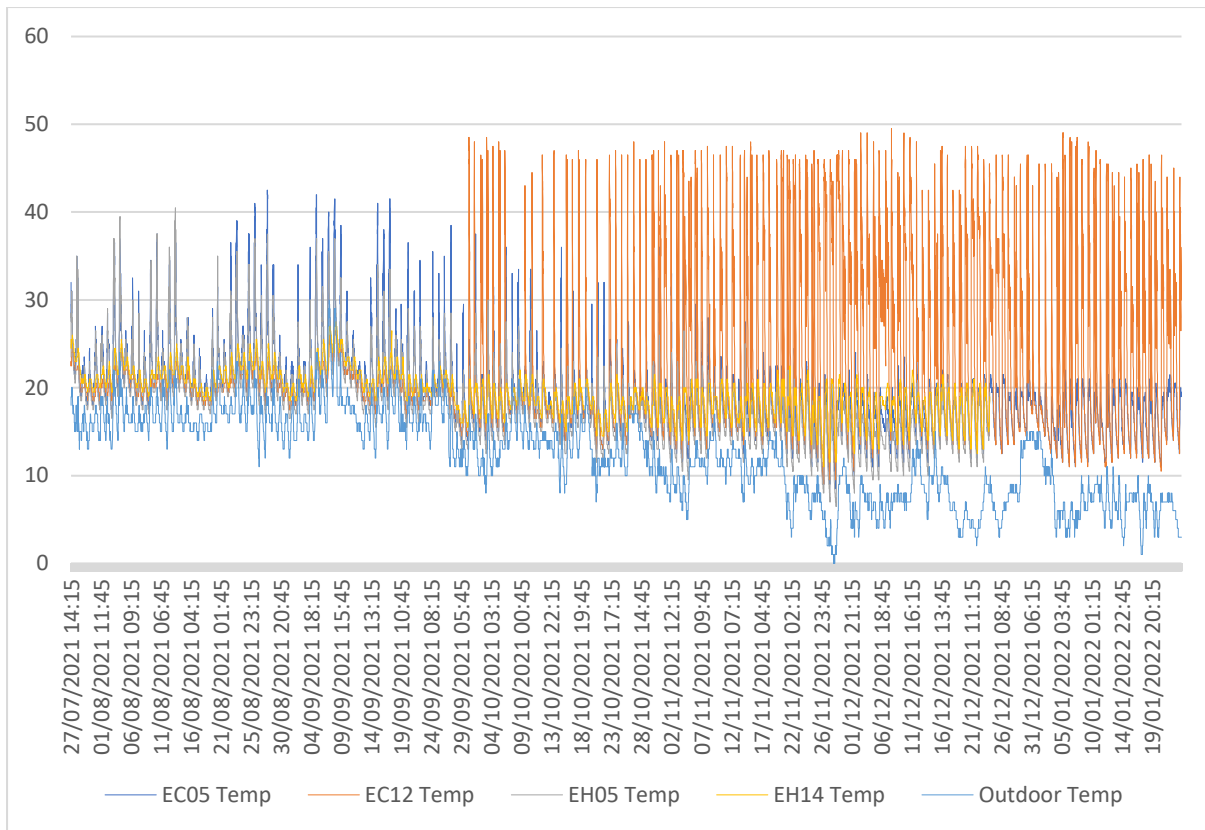
Sensor ID	Area	Location	Start Logging	Stop Logging
EC 01	Downstairs, living room	window	27/07/2021 15:30	03/02/2022 17:15
EH 01	Downstairs, living room	window	27/07/2021 15:30	24/12/2021 10:15
EC 16	Downstairs, living room	radiator	27/07/2021 15:30	03/02/2022 17:15
EH 19	Downstairs, living room	room	27/07/2021 15:30	24/12/2021 10:15
EC 08	Upper Bedroom	window	27/07/2021 15:30	03/02/2022 17:15
EH 08	Upper Bedroom	window	27/07/2021 15:30	24/12/2021 10:15
EC 15	Upper Bedroom	radiator	27/07/2021 15:30	03/02/2022 17:15
EH 11	Upper Bedroom	room	27/07/2021 15:30	24/12/2021 10:15

Summary	House #5		3 bed house	
Sensor ID	Area	Location	Start Logging	Stop Logging
EC 03	Downstairs, living room	window	27/07/2021 16:00	03/02/2022 18:30
EH 03	Downstairs, living room	window	27/07/2021 16:00	24/12/2021 10:15
EC 17	Downstairs, living room	radiator	27/07/2021 16:00	03/02/2022 18:30
EH 16	Downstairs, living room	room	27/07/2021 16:00	24/12/2021 10:15
EC 04	Upper Front Bedroom	window	27/07/2021 16:00	03/02/2022 18:30
EH 04	Upper Front Bedroom	window	27/07/2021 16:00	24/12/2021 10:15
EC 18	Upper Front Bedroom	radiator	27/07/2021 16:00	03/02/2022 18:30
EH 15	Upper Front Bedroom	room	27/07/2021 16:00	24/12/2021 10:15

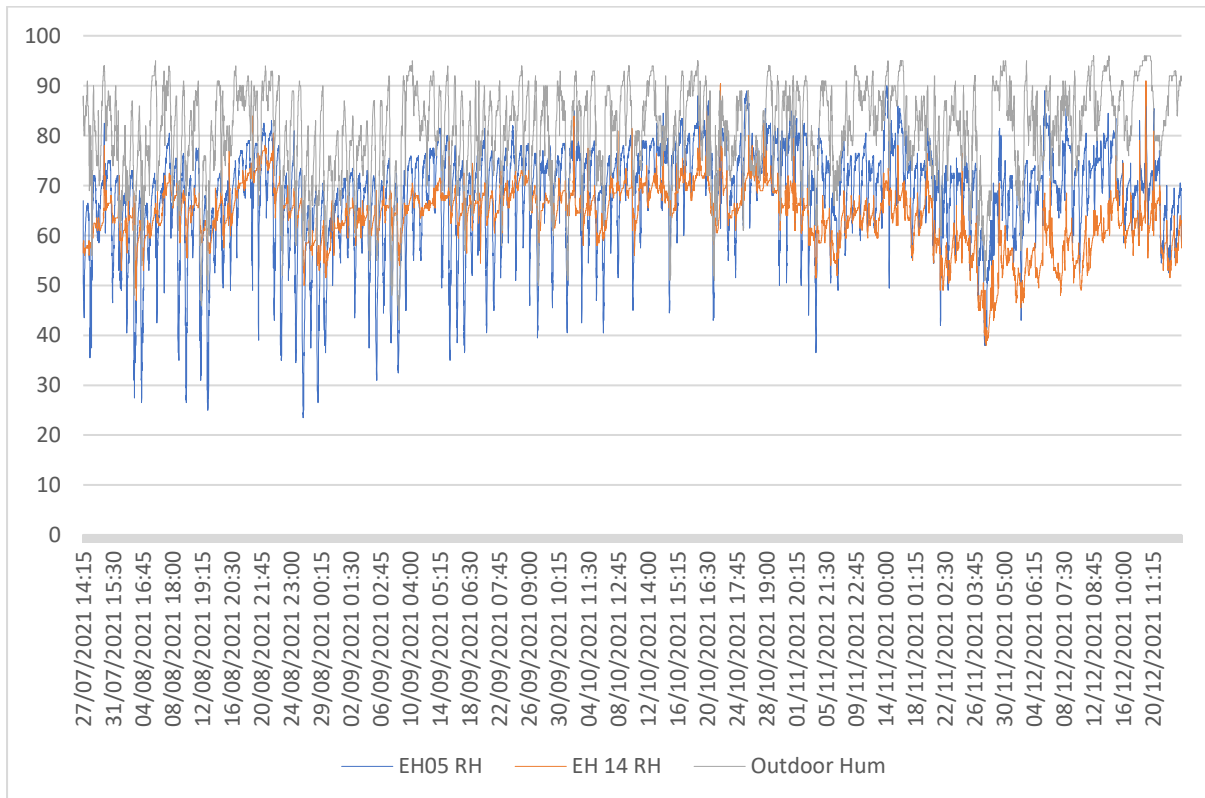
Summary of the Sensor Reading for House #1

Temperature(°C)	Living room				Bedroom				Outdoor
	EC 05	EH05	EC 12	EH14	EC 06	EH06	EC 20	EH13	
Minimum	8.50	6.50	9.00	11.00	7.00	6.00	9.00	10.50	0.00
Maximum	42.50	40.50	49.50	27.50	37.50	45.00	60.00	25.50	30.00
Average	19.03	18.31	21.95	19.40	17.74	17.58	22.32	18.23	12.25
StdDev	4.35	4.49	8.11	2.56	3.72	4.18	9.53	2.53	4.89
Humidity(%)									
Minimum		23.50		38.00		21.00		41.50	43.00
Maximum		90.00		91.00		91.00		80.00	96.00
Average		68.12		63.84		67.41		66.97	81.00
StdDev		10.01		6.14		9.48		6.20	9.13

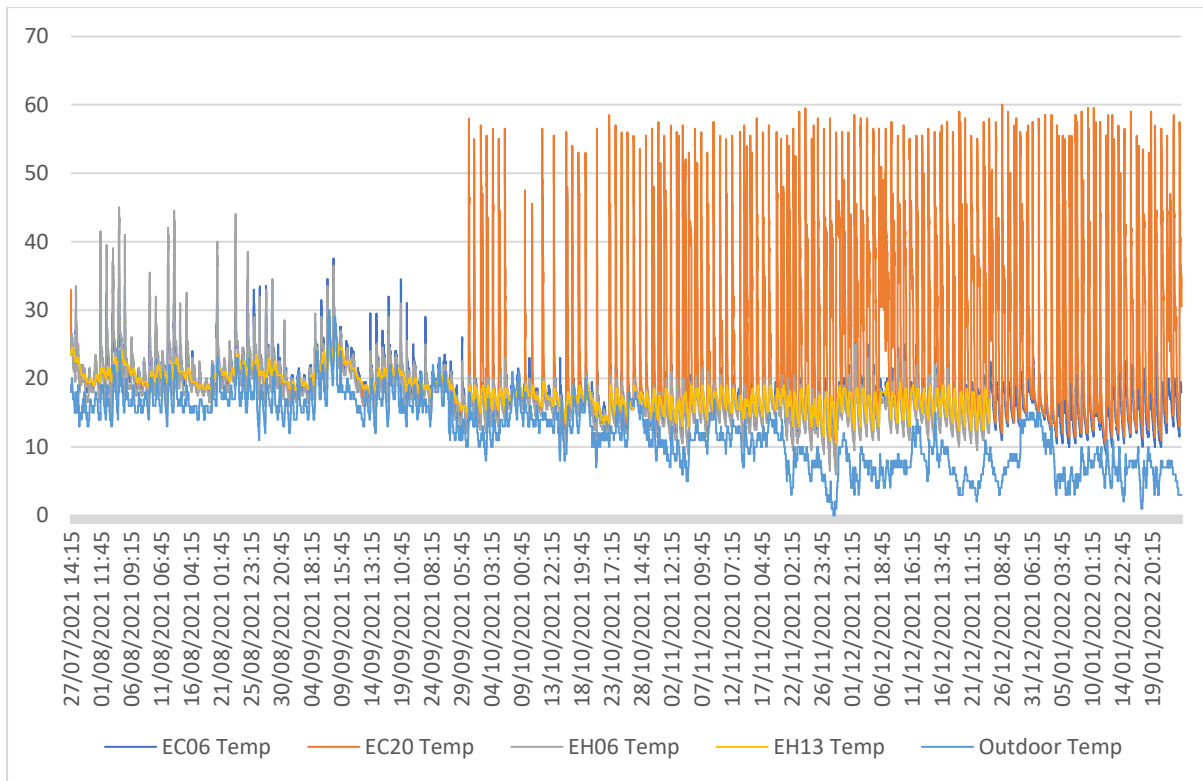
House #1 - Living room – Temperature



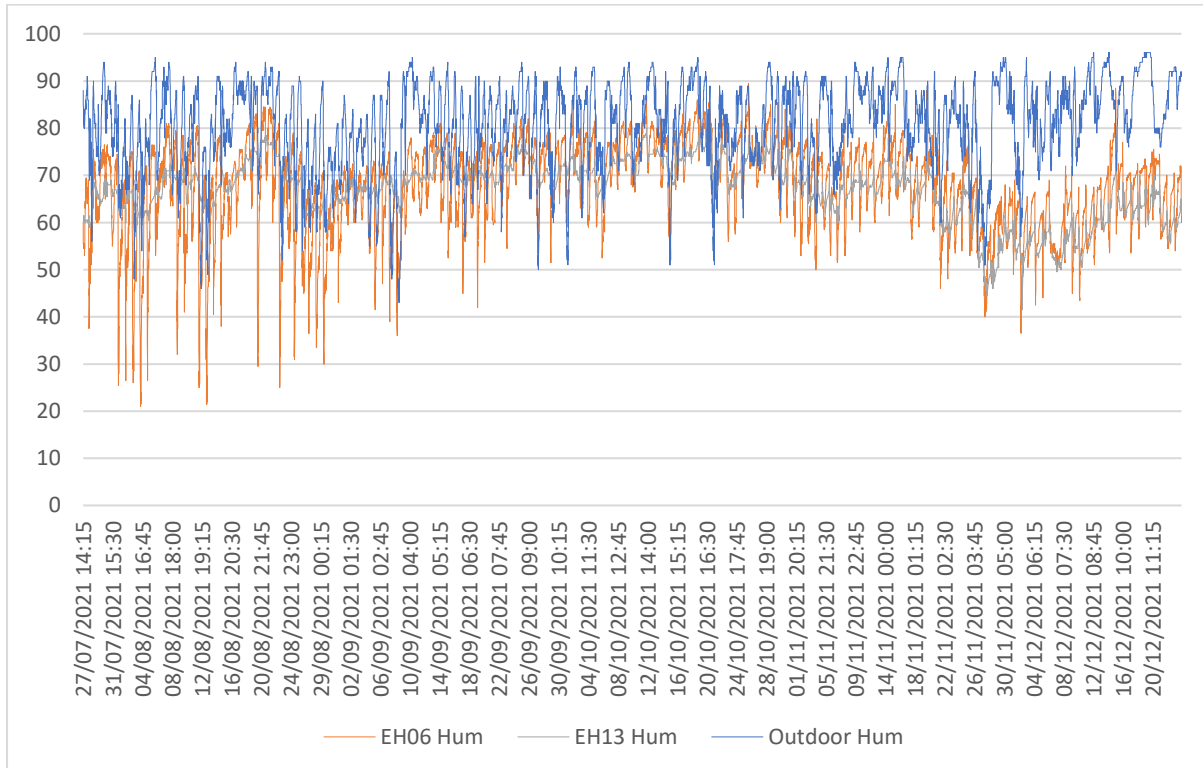
House #1 - Living room – Relative Humidity



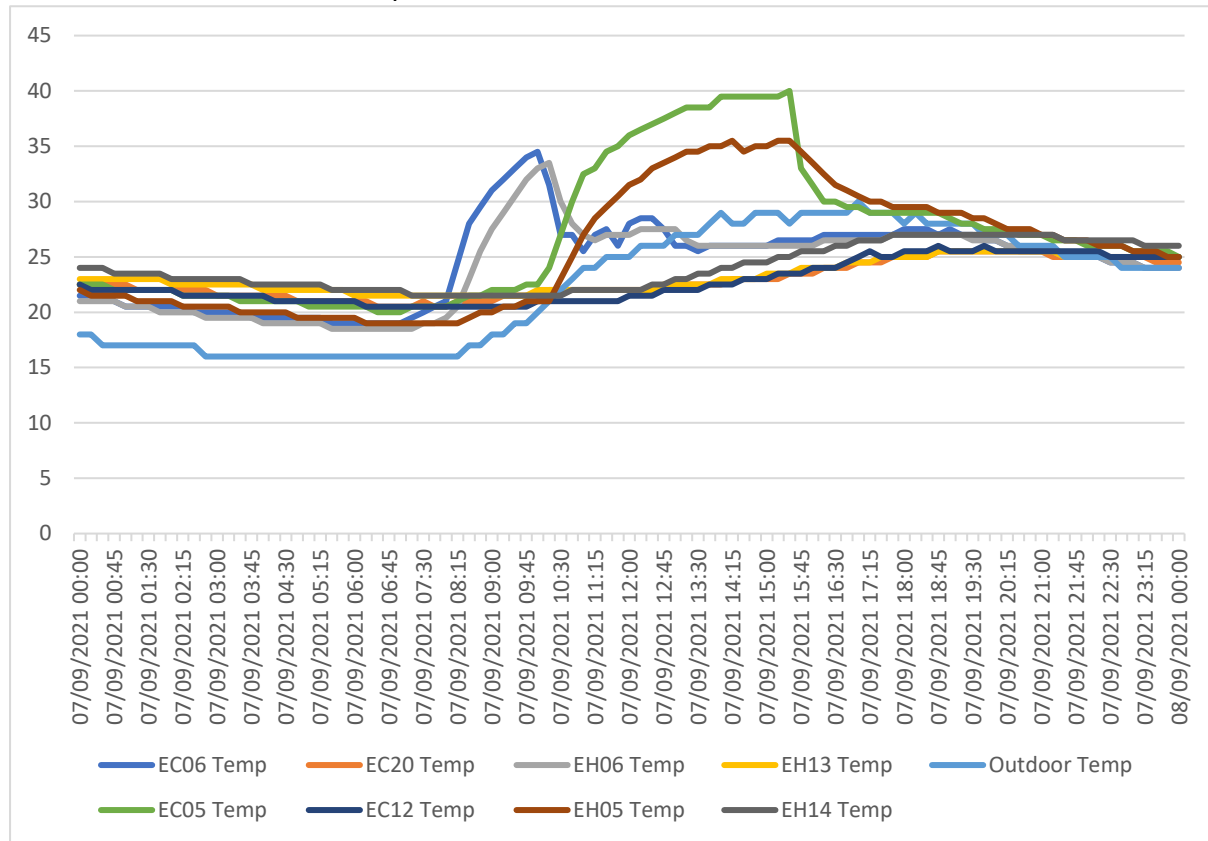
House #1 – Bedroom – Temperature



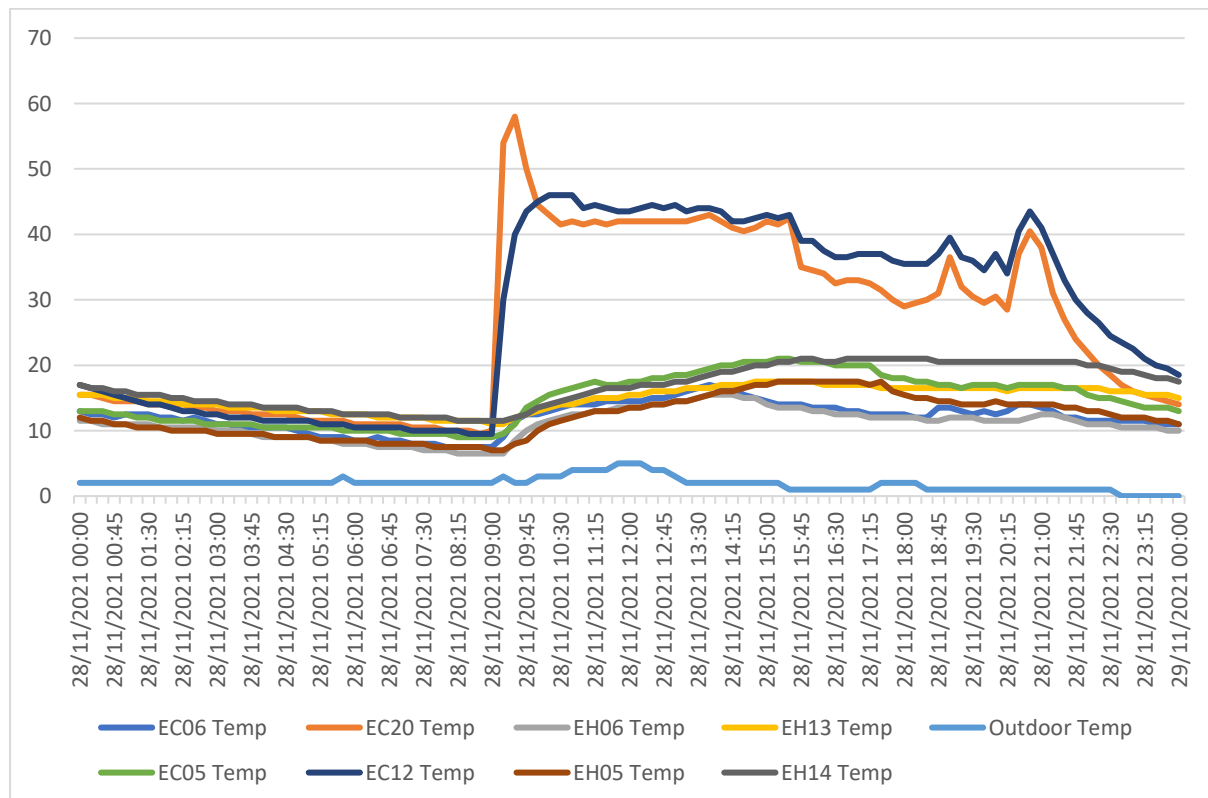
House #1 – Bedroom – Relative Humidity



House #1 – Max Outside Temperature



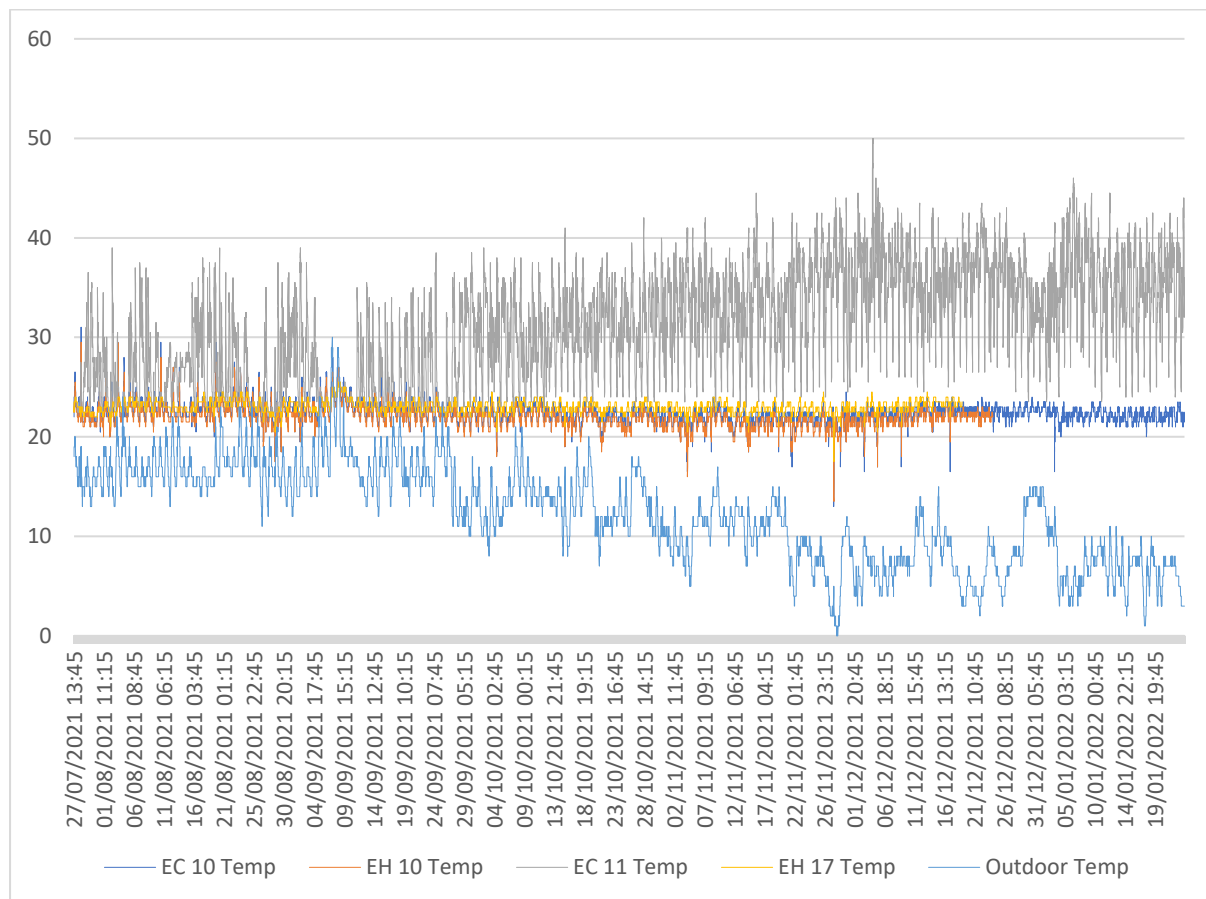
House #1 – Min Outside Temperature



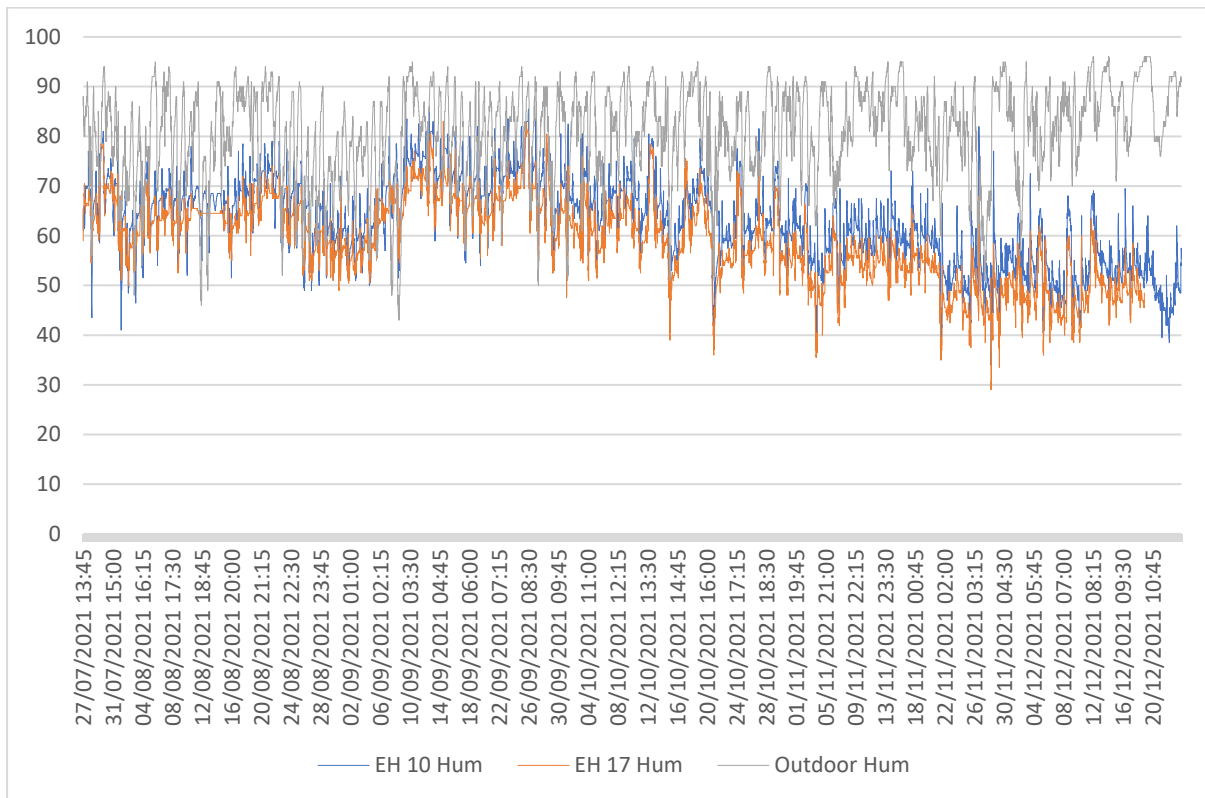
Summary of the Sensor Reading for House #3

Temperature(°C)	Bedroom				Living room				Outdoor
	EC 09	EH 09	EC 14	EH20	EC 10	EH10	EC 11	EH17	
Minimum	10.00	10.50	18.50	17.50	13.00	13.50	21.50	17.50	0.00
Maximum	27.00	26.50	56.50	26.50	31.00	29.50	50.00	25.50	30.00
Average	20.68	20.48	32.98	23.35	22.42	21.97	31.11	23.03	12.25
StdDev	2.83	2.84	7.45	0.80	0.98	1.03	5.55	0.62	4.89
Humidity(%)									
Minimum		30.00		28.00		34.00		29.00	43.00
Maximum		87.00		84.00		85.50		83.00	96.00
Average		59.22		56.06		62.52		58.98	81.00
StdDev		8.91		8.35		8.33		8.26	9.13

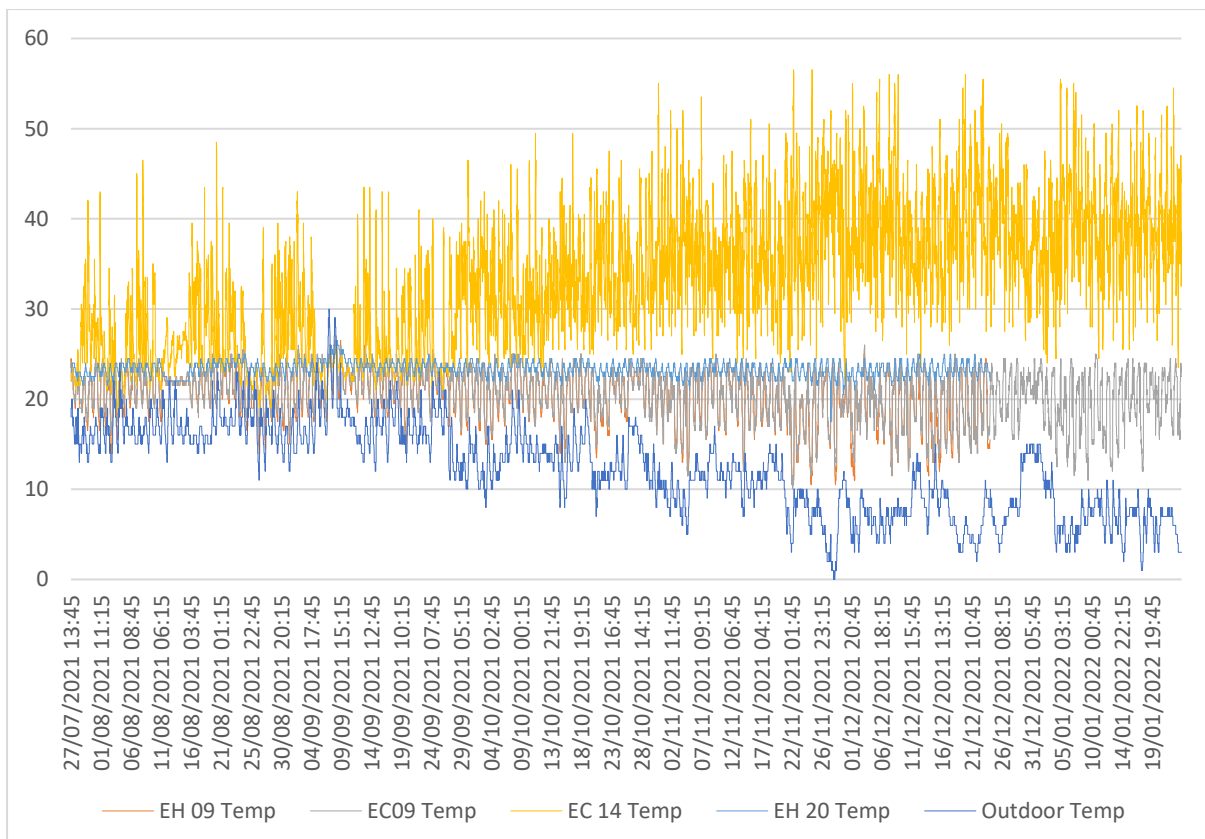
House #3 - Living room – Temperature



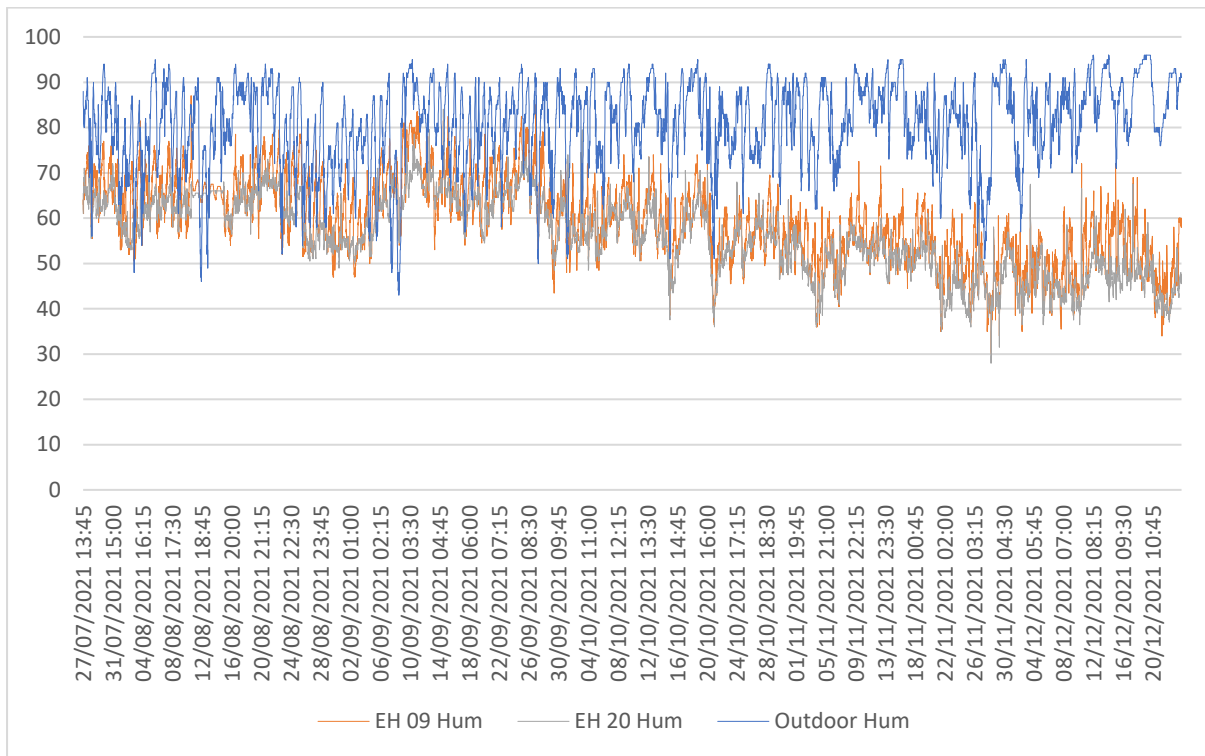
House #3 - Living room – Relative Humidity



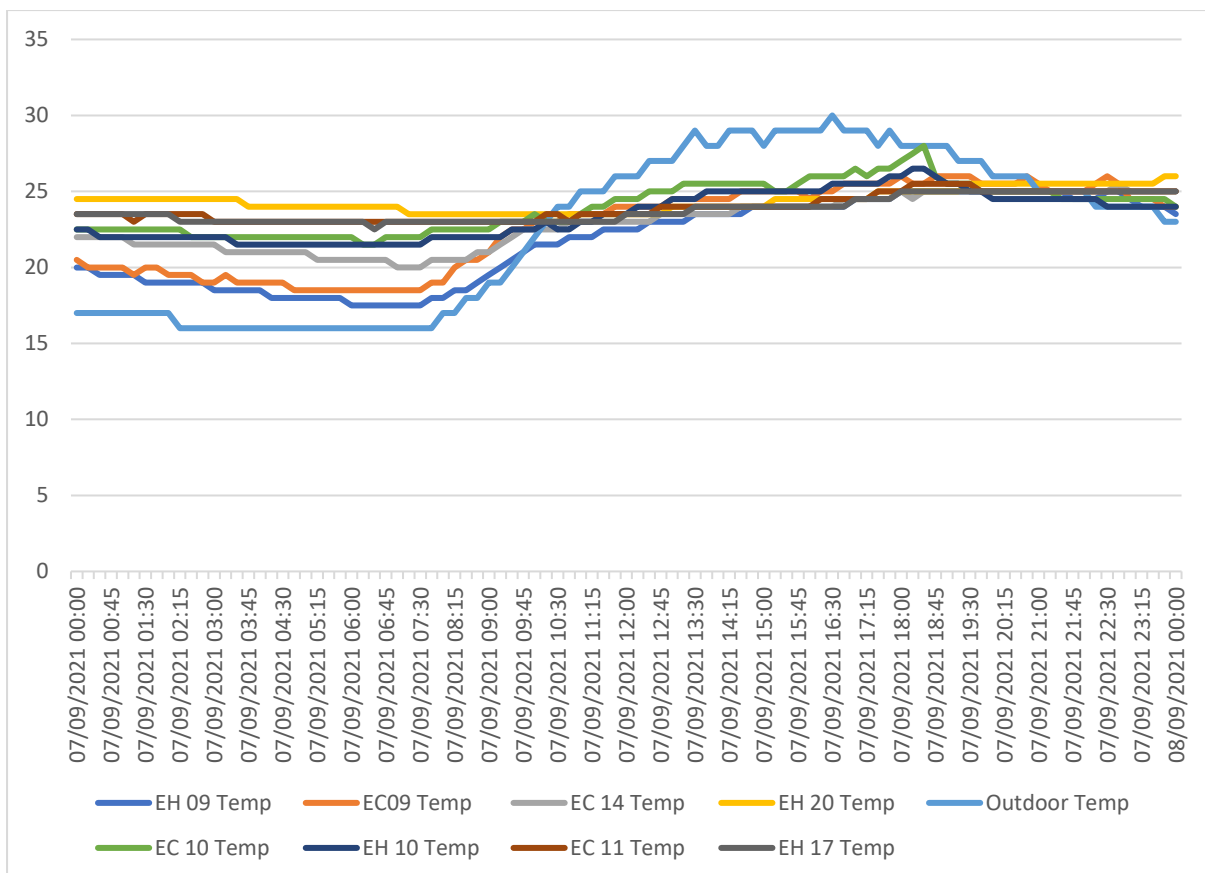
House #3 – Bedroom – Temperature



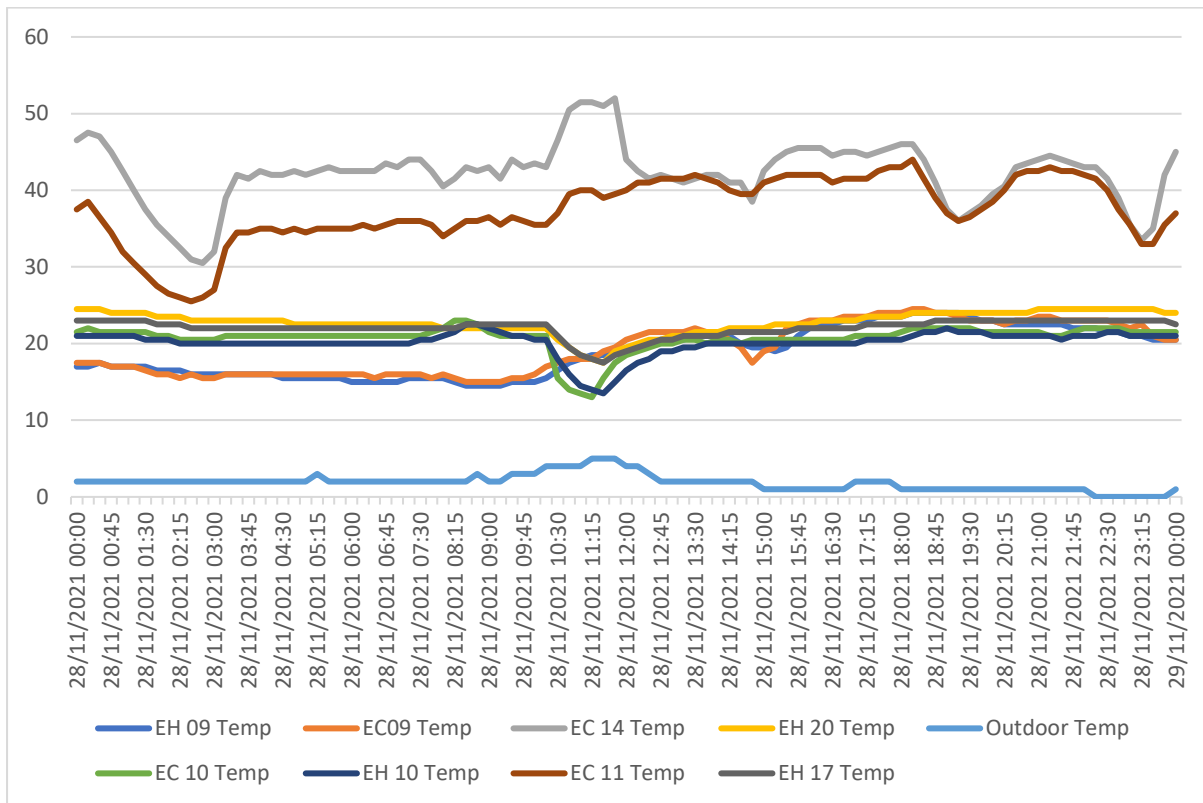
House #3 – Bedroom – Relative Humidity



House #3 – Max Outside Temperature



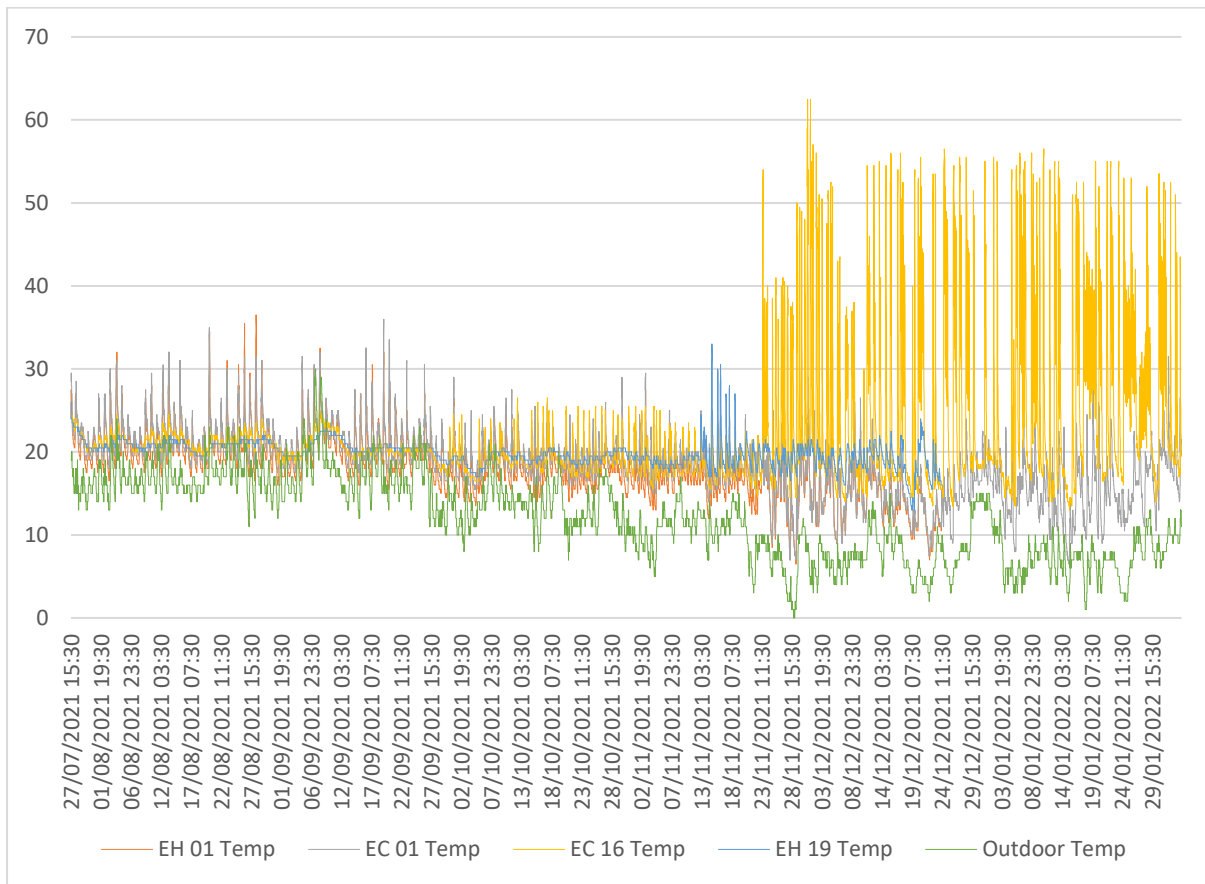
House #3 – Min Outside Temperature



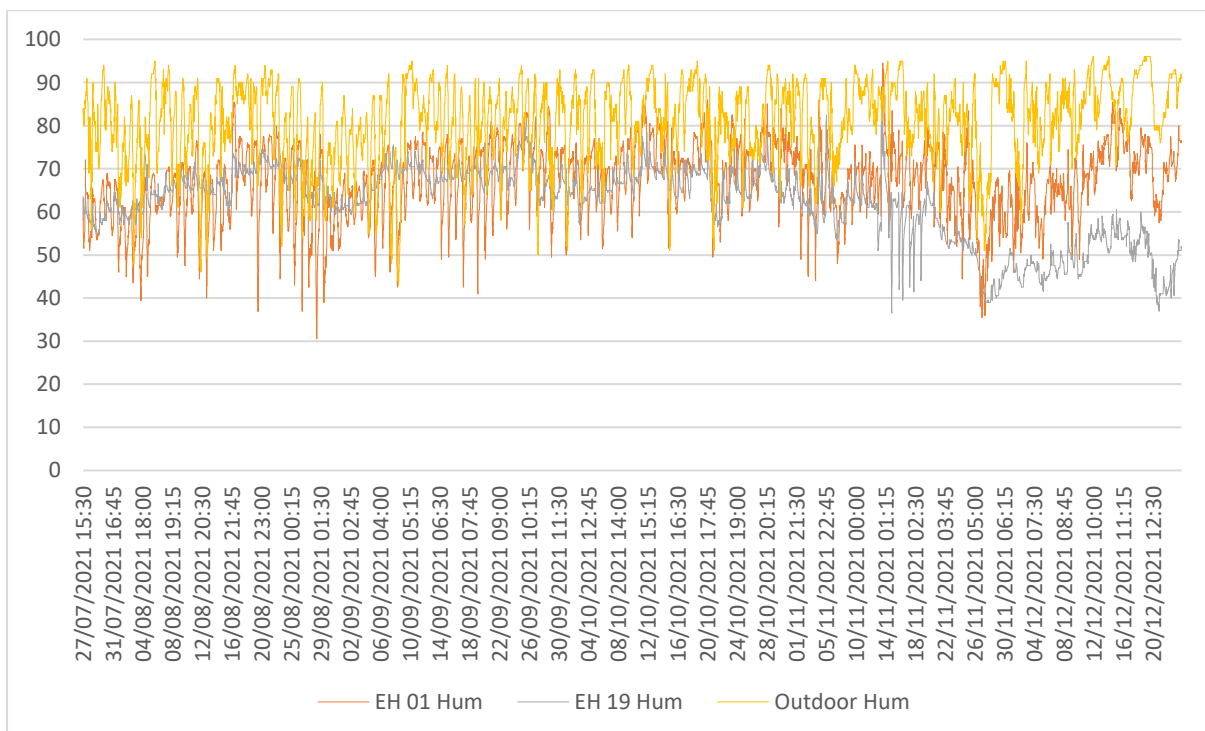
Summary of the Sensor Reading for House #4

Temperature(°C)	Living room				Bedroom				Outdoor
	EC 01	EH01	EC 16	EH19	EC 08	EH08	EC 15	EH11	
Minimum	6.50	6.50	13.00	13.00	12.00	12.00	12.00	14.50	0.00
Maximum	36.00	36.50	62.50	33.00	32.00	30.00	64.50	25.50	30.00
Average	18.48	18.10	21.91	19.87	19.40	19.31	22.72	20.18	12.05
StdDev	3.97	3.69	7.06	1.49	2.65	2.34	8.60	1.66	4.87
Humidity(%)									
Minimum		30.50		36.50		40.50		39.50	43.00
Maximum		94.50		88.00		85.50		78.00	96.00
Average		66.77		61.91		64.03		60.22	81.00
StdDev		8.40		8.48		6.75		5.90	9.13

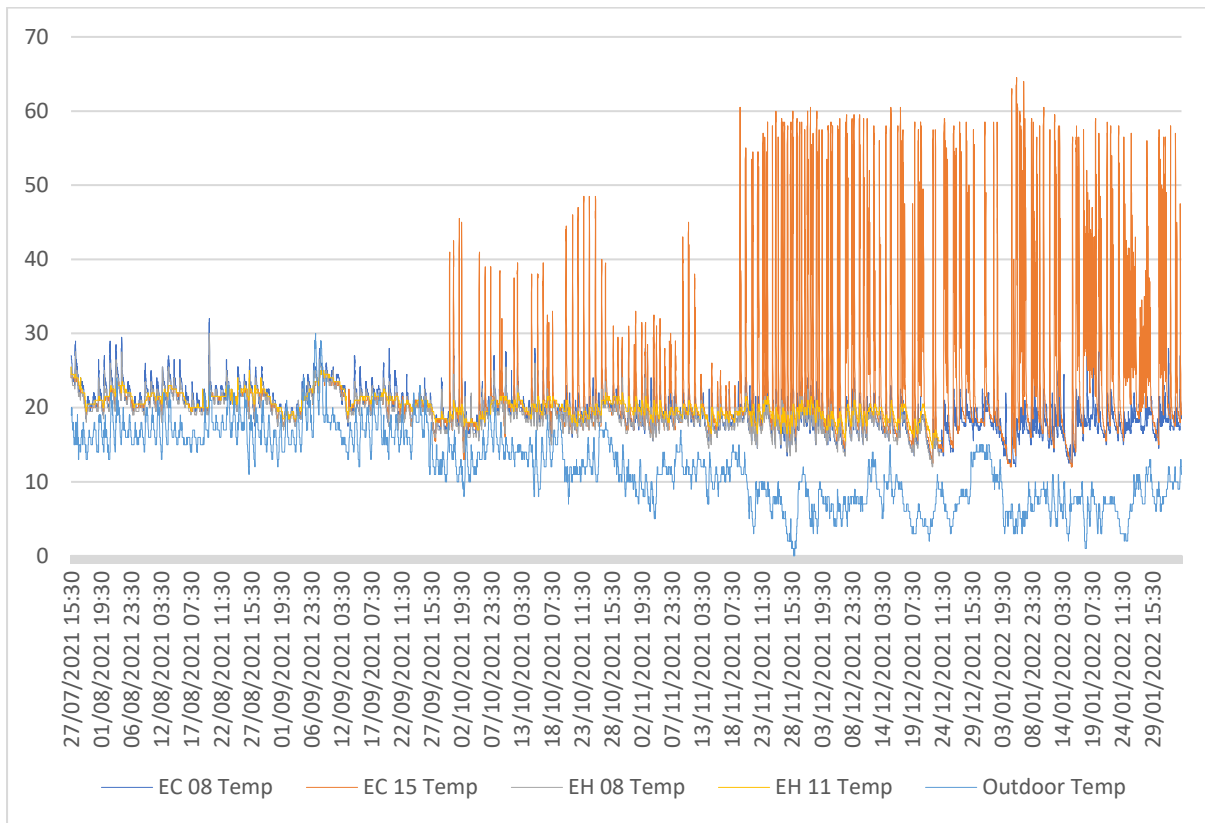
House #4 - Living room – Temperature



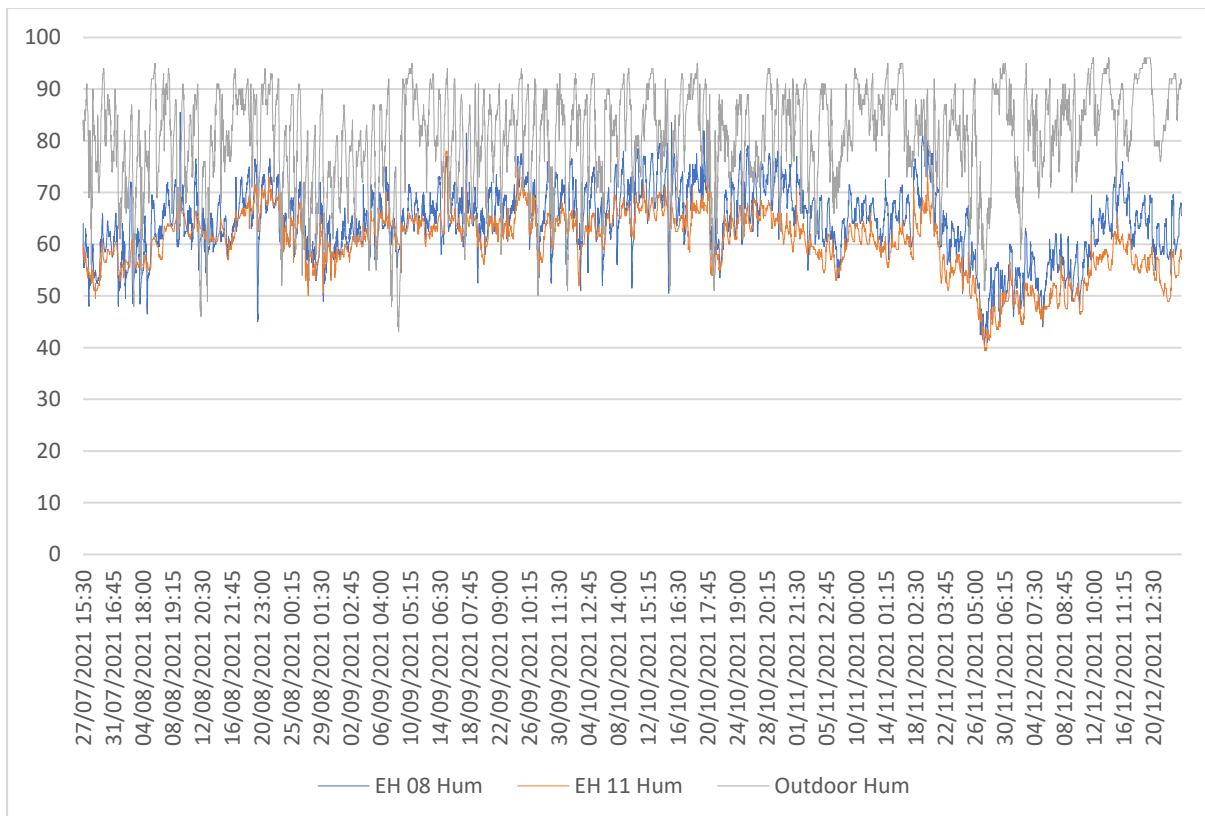
House #4 - Living room – Relative Humidity



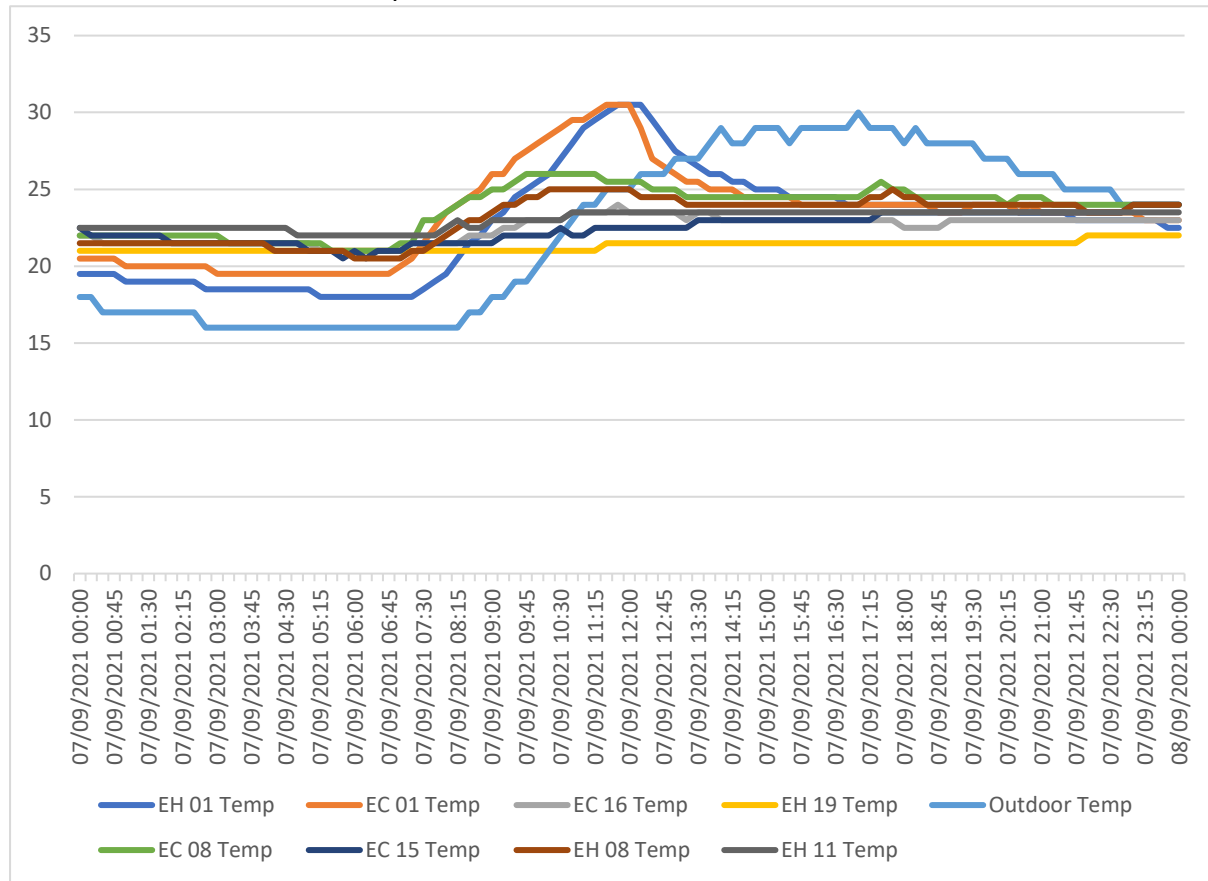
House #4 – Bedroom – Temperature



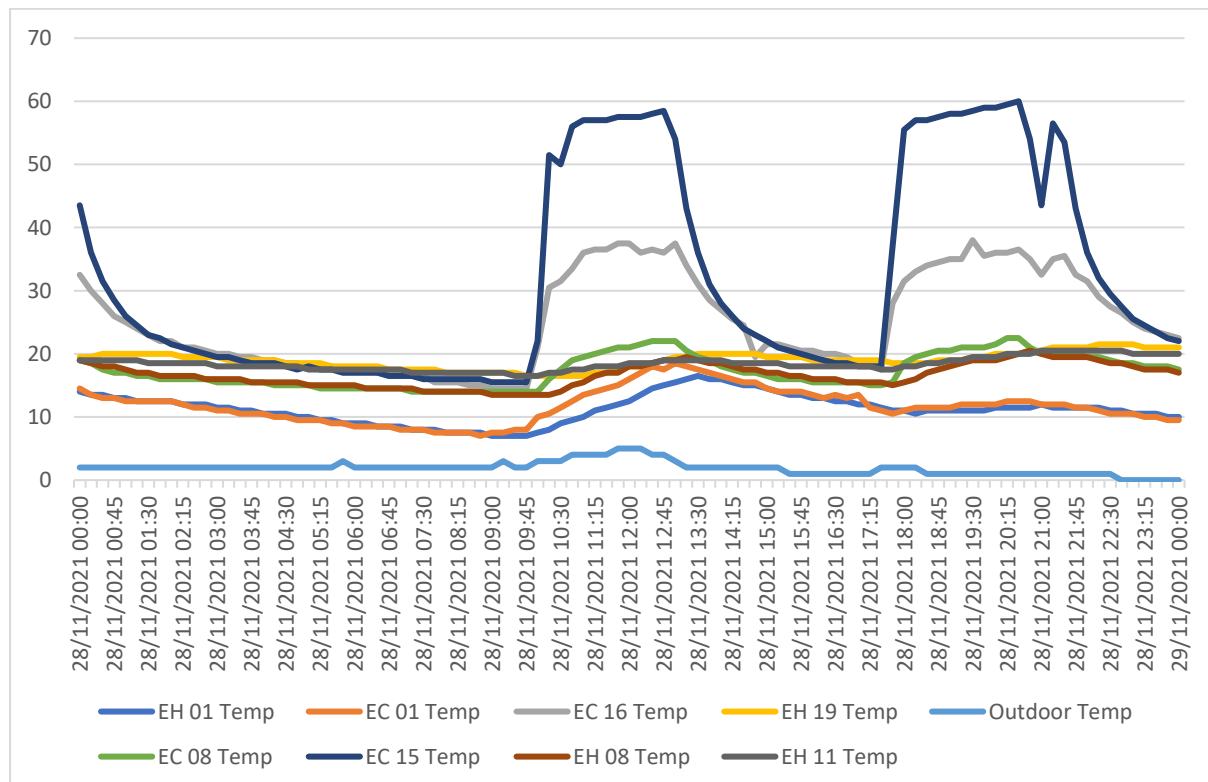
House #4 – Bedroom – Relative Humidity



House #4 – Max Outside Temperature



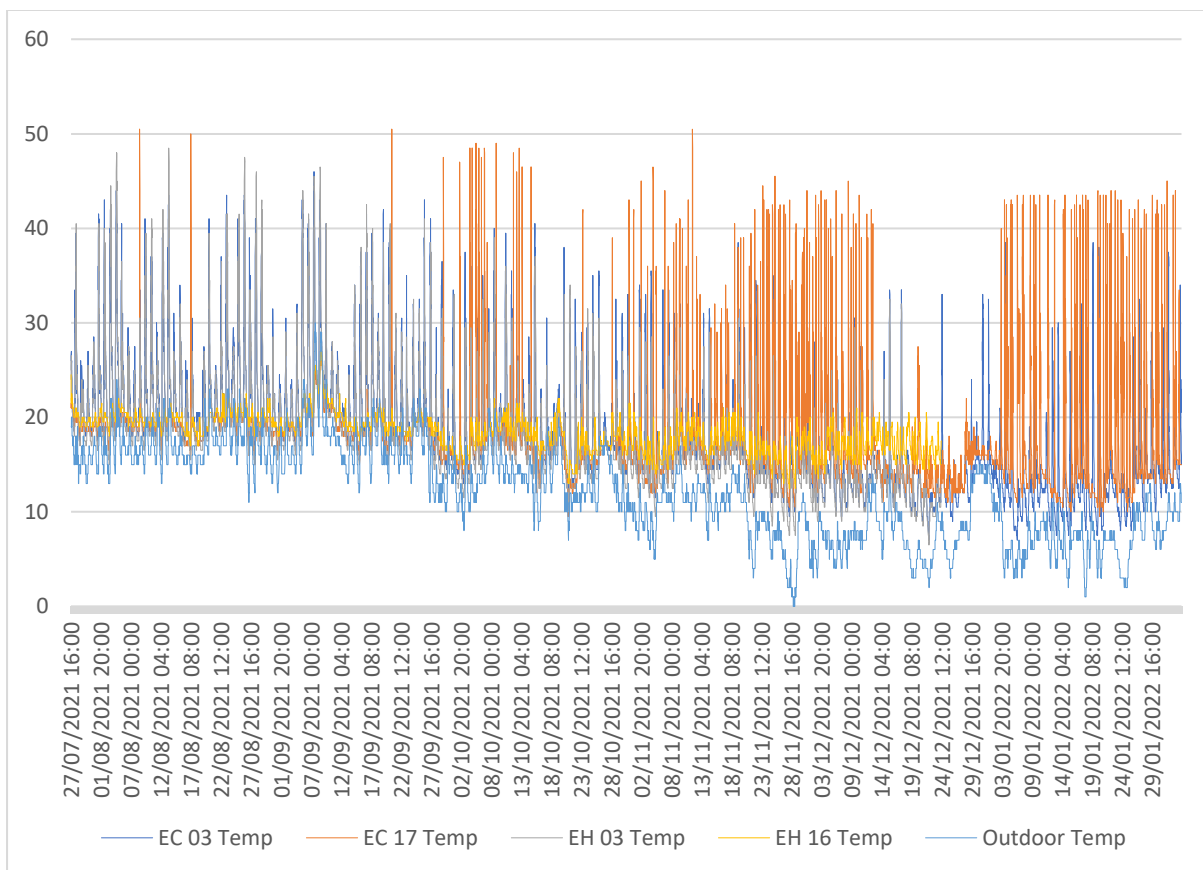
House #4 – Min Outside Temperature



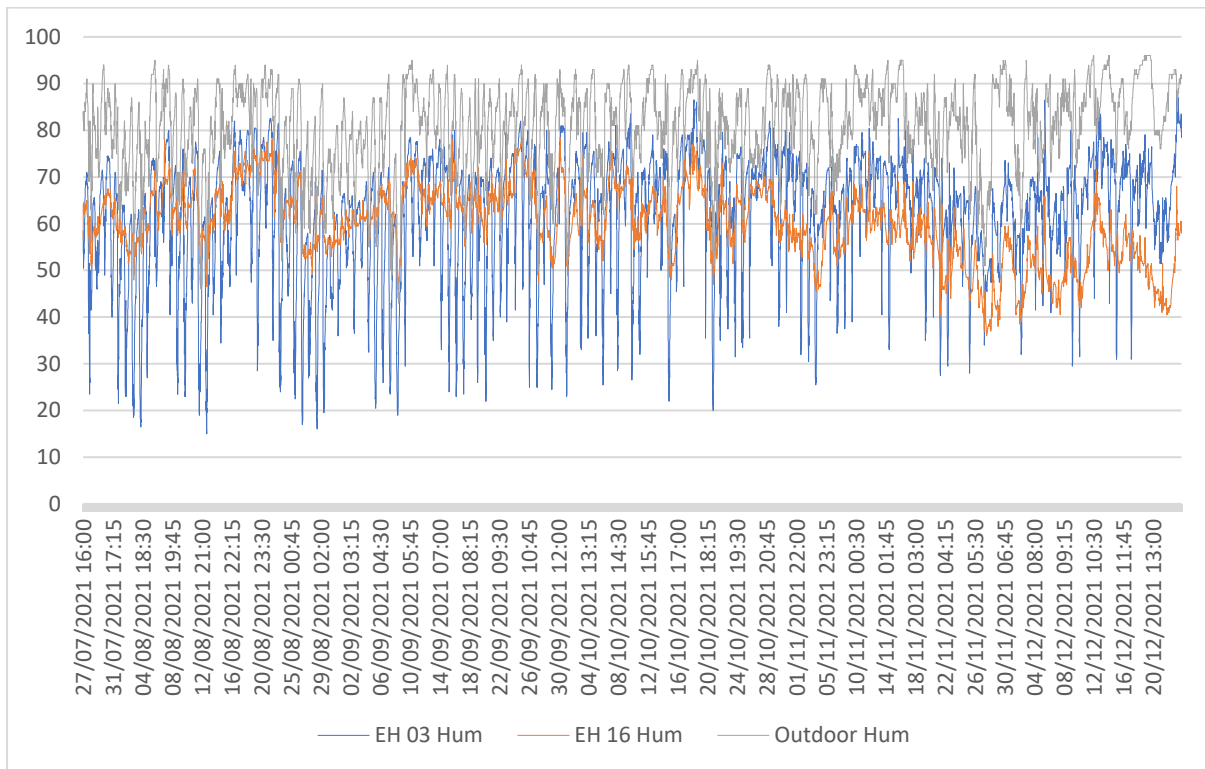
Summary of the Sensor Reading for House #5

Temperature(°C)	Living room				Bedroom				Outdoor
	EC 03	EH03	EC 17	EH16	EC 04	EH04	EC 18	EH15	
Minimum	7.00	6.50	9.50	12.50	10.00	10.00	12.00	14.50	0.00
Maximum	46.00	48.50	50.50	27.00	48.00	44.50	58.00	27.50	30.00
Average	17.88	18.09	17.57	18.35	19.65	19.52	22.87	19.38	12.05
StdDev	5.85	5.83	4.67	1.99	5.03	4.25	10.13	1.78	4.87
Humidity(%)									
Minimum		15.00		36.00		20.00		36.00	43.00
Maximum		88.50		78.50		90.50		77.00	96.00
Average		62.15		59.88		59.62		58.36	81.00
StdDev		12.88		7.91		11.89		7.48	9.13

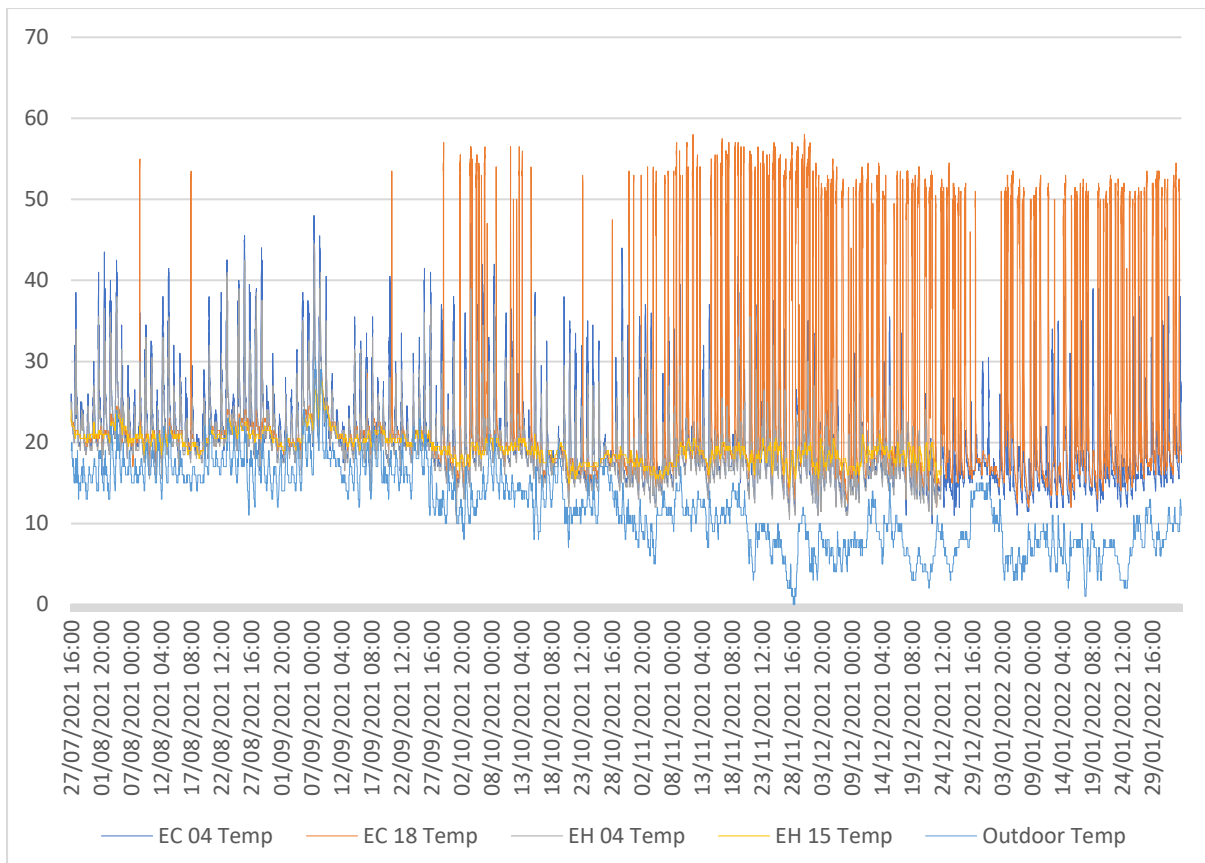
House #5 - Living room – Temperature



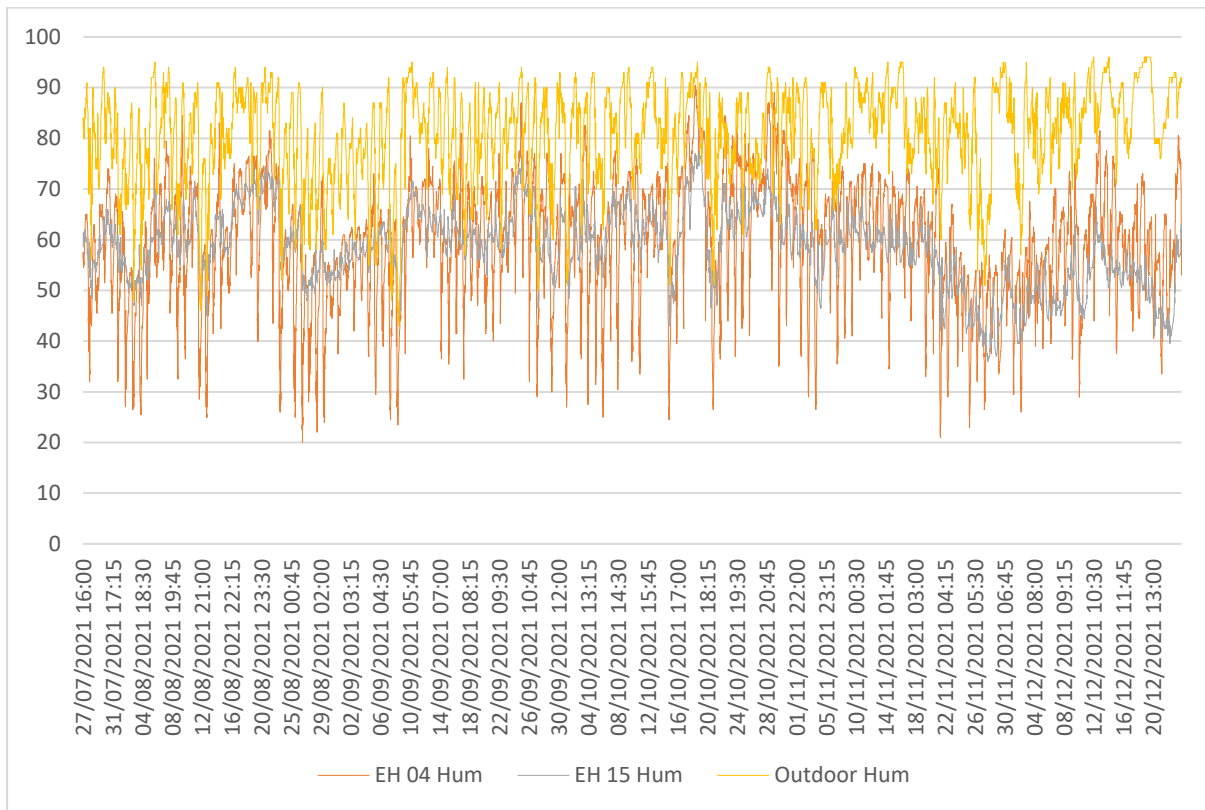
House #5 - Living room – Relative Humidity



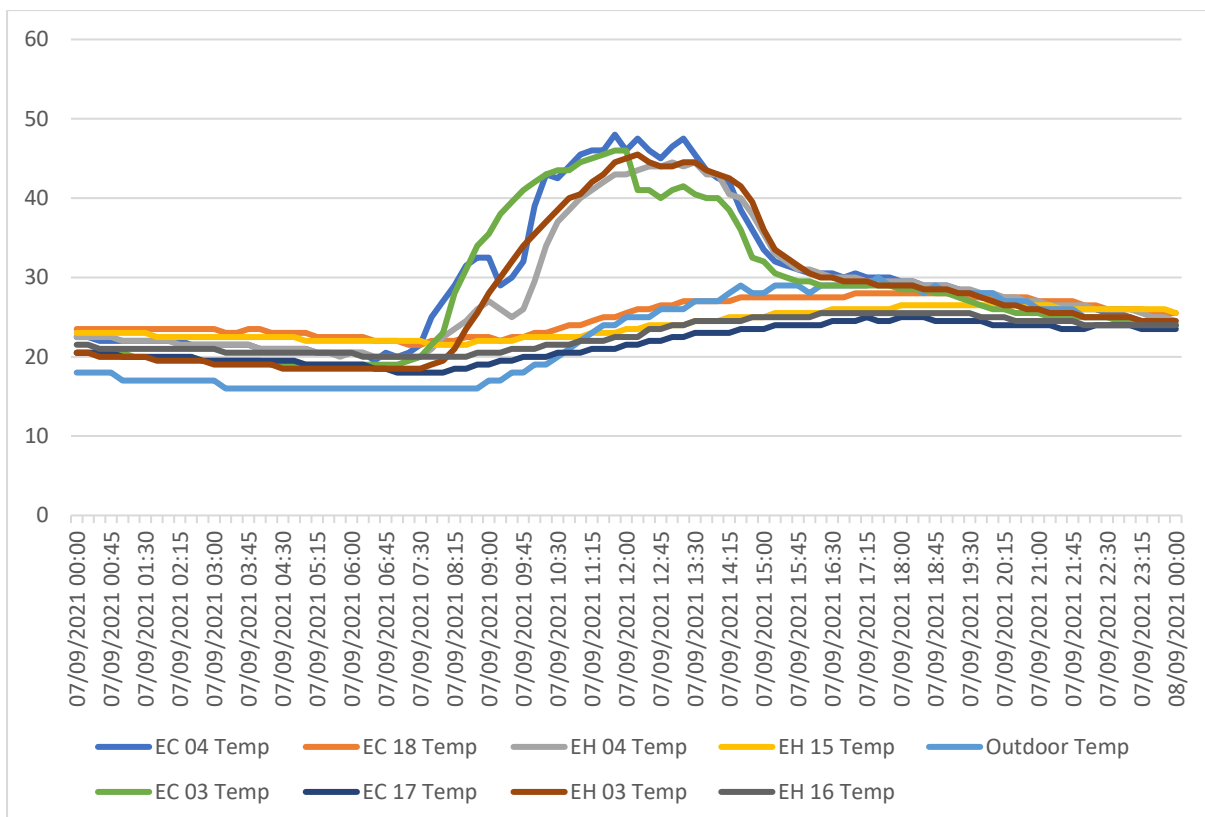
House #5 – Bedroom – Temperature



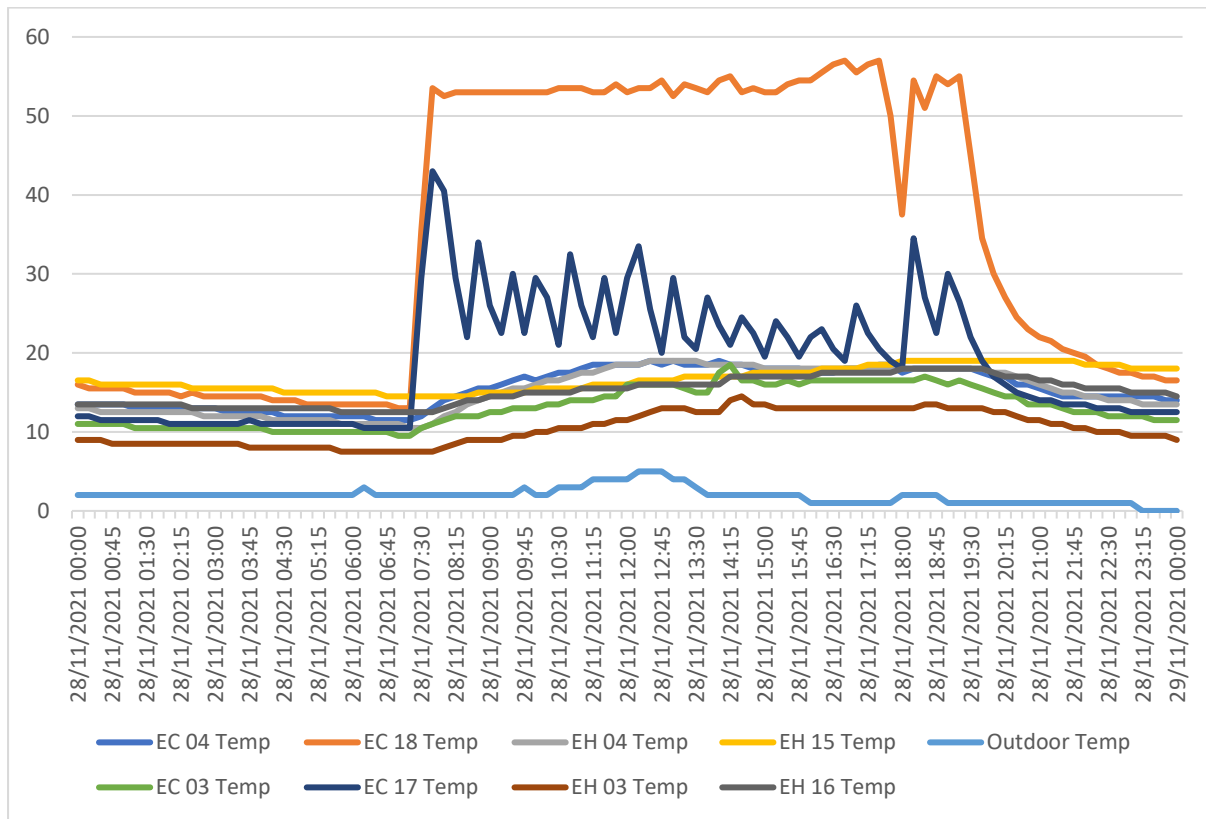
House #5 – Bedroom – Relative Humidity



House #5 – Max Outside Temperature

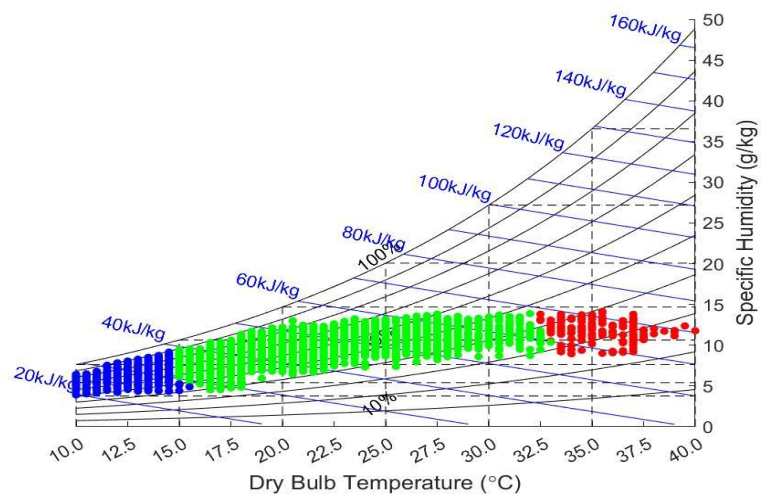


House #5 – Min Outside Temperature

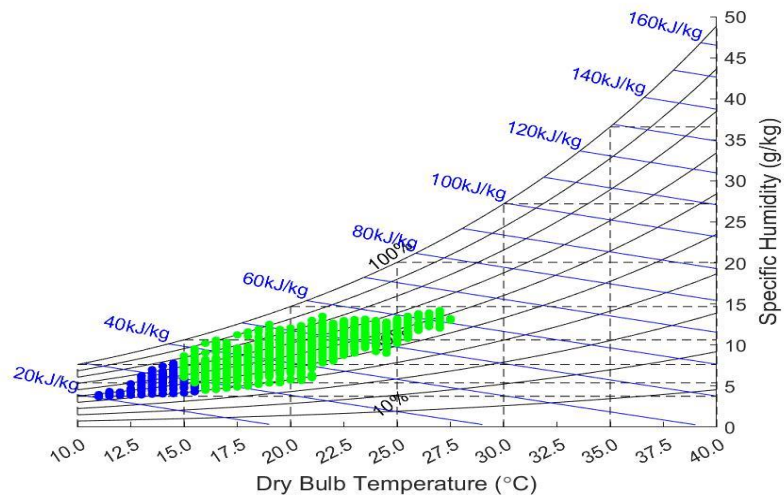


The comfort map from Artificial Intelligence Model Output

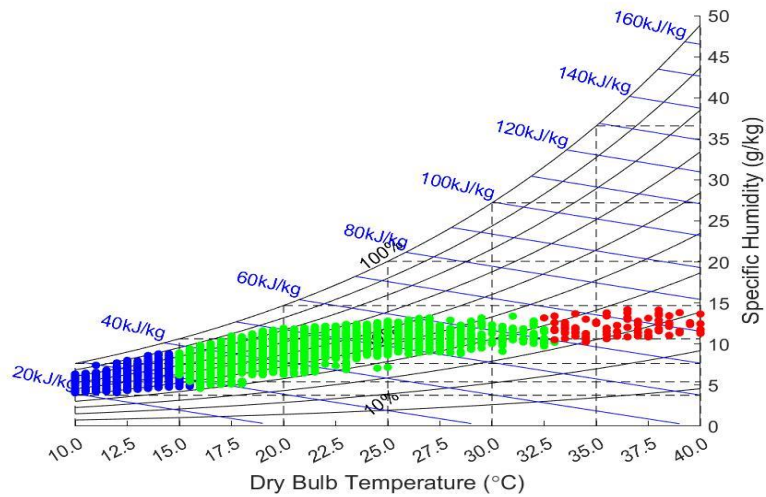
H1RoomEH05 = 77.94% Comfort



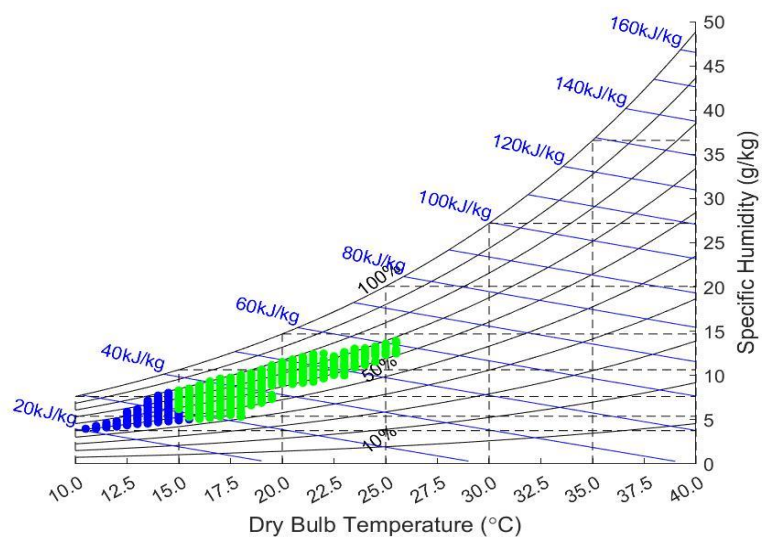
H1RoomEH14 = 95.40% Comfort



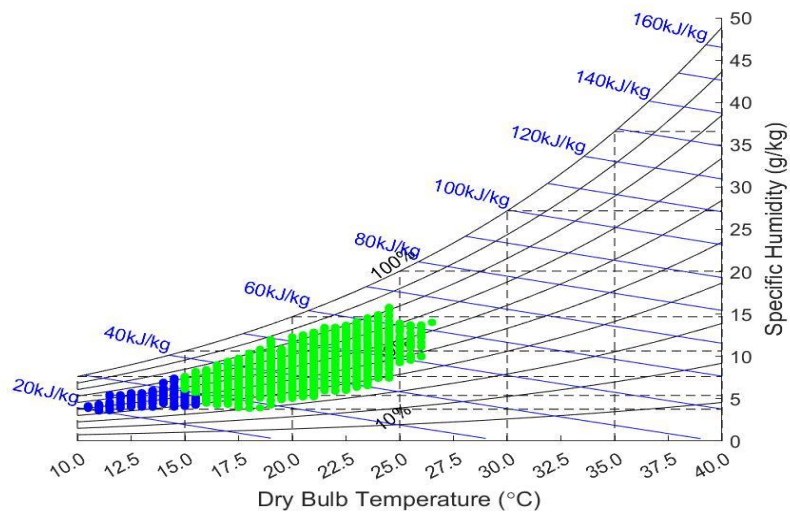
H1RoomEH06 = 74.72% Comfort



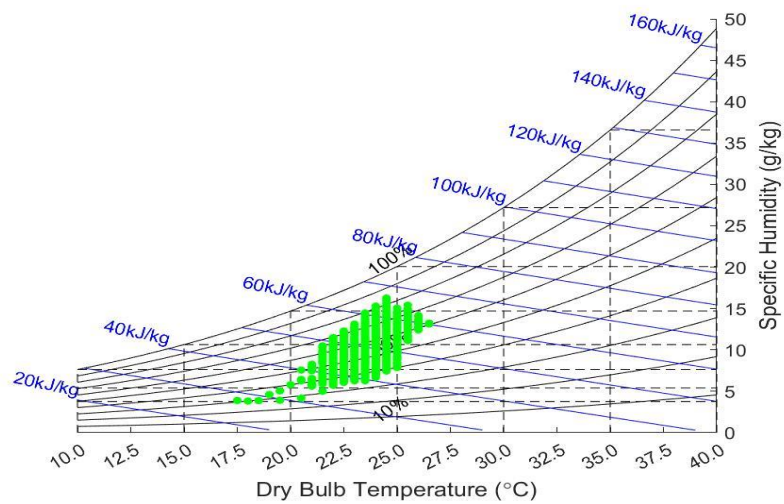
H1RoomEH13 = 91.20% Comfort



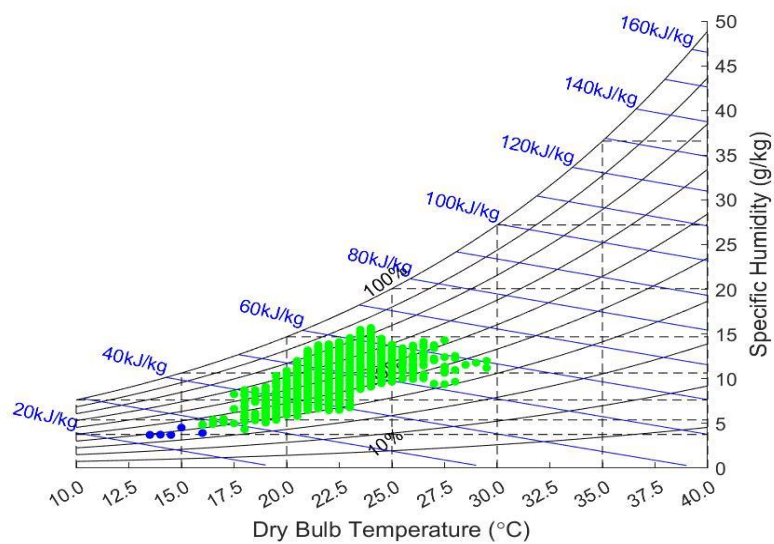
H3RoomEH09= 94.38% Comfort



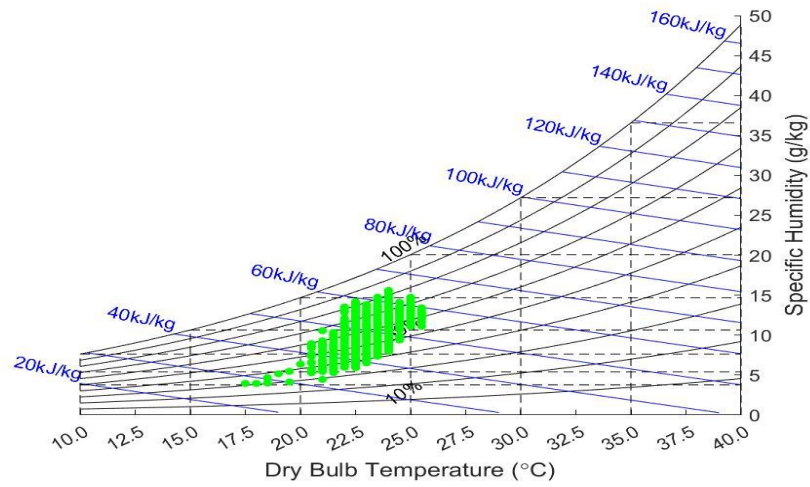
H3RoomEH20=100 % Comfort



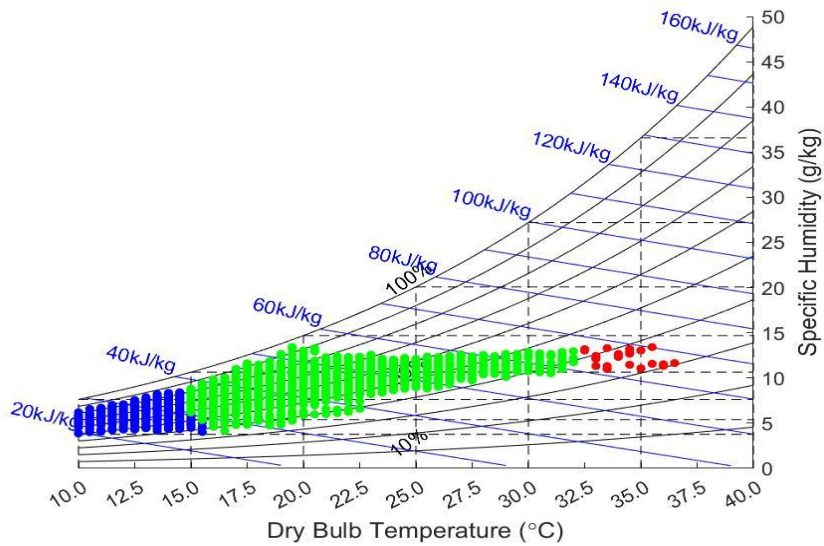
H3RoomEH10= 99.97% Comfort



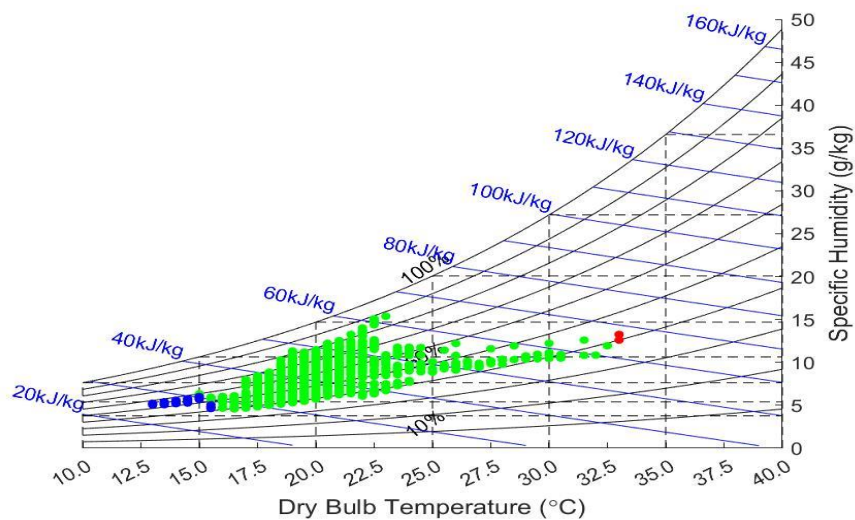
H3RoomEH17= 100% Comfort



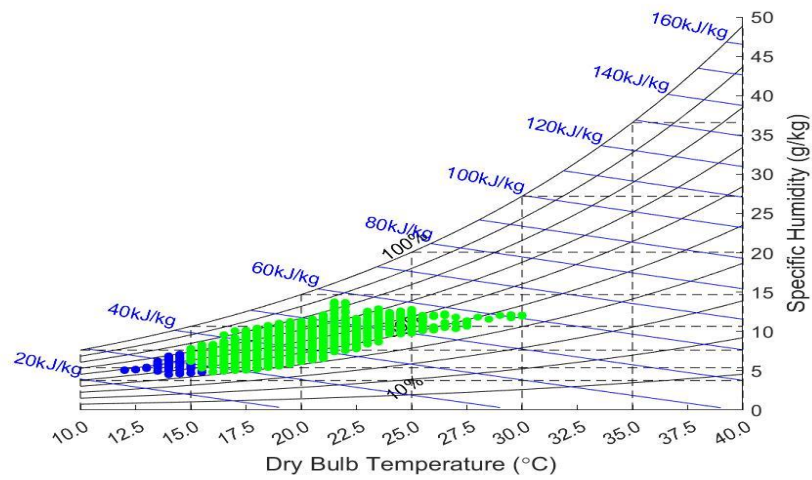
H4RoomEH01= 84.31% Comfort



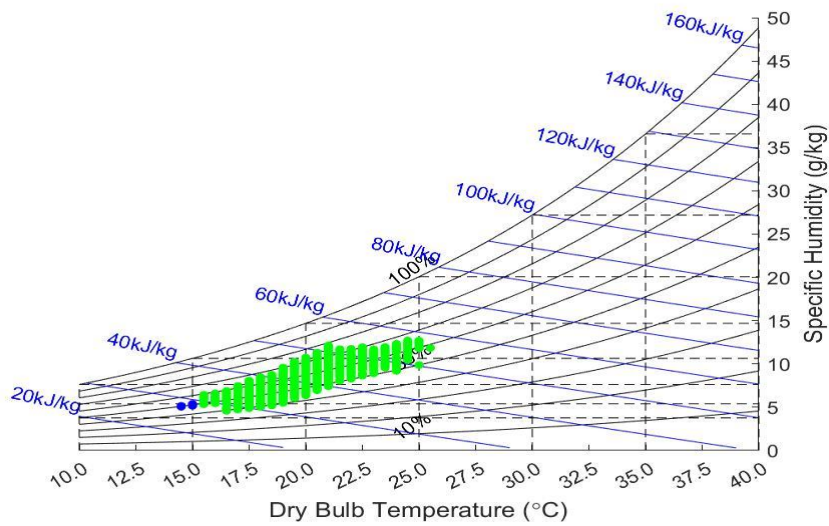
H4RoomEH19= 99.19% Comfort



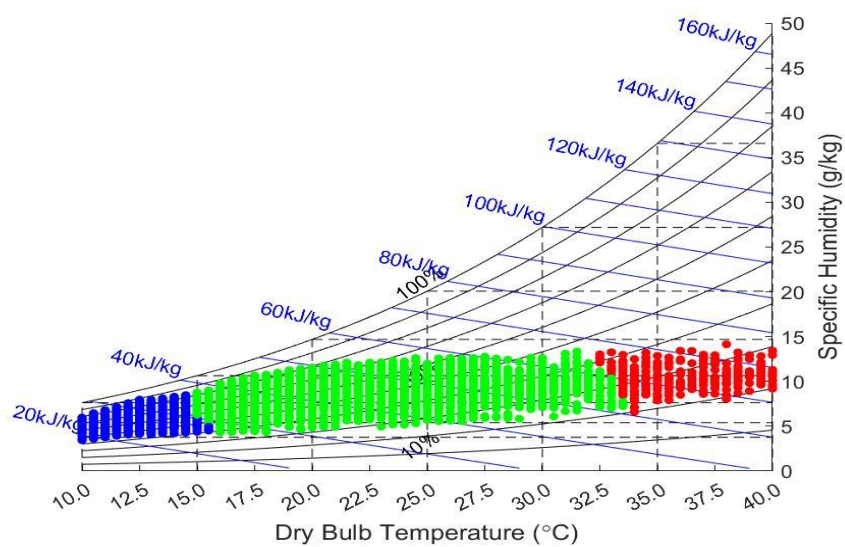
H4RoomEH08= 96.82% Comfort



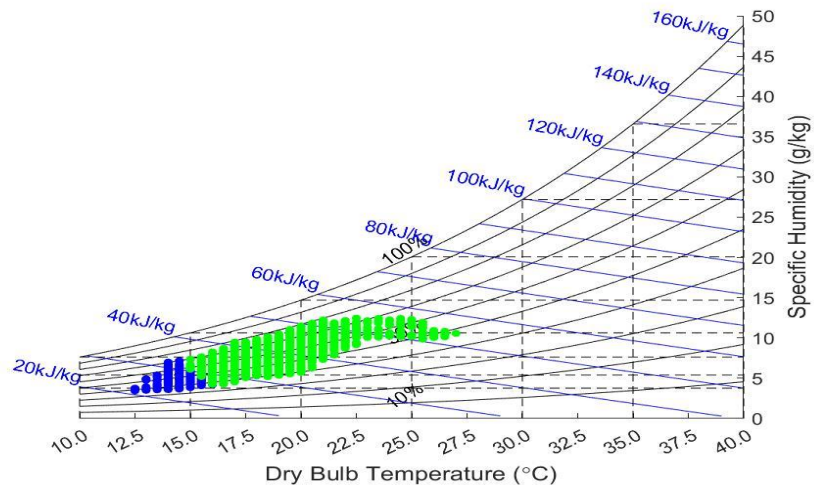
H4RoomEH11= 99.81% Comfort



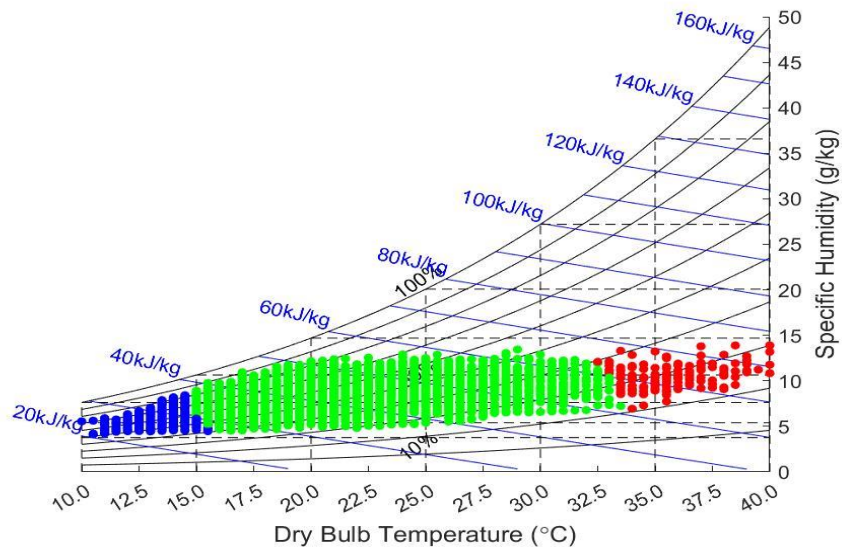
H5RoomEH03= 67.60% Comfort



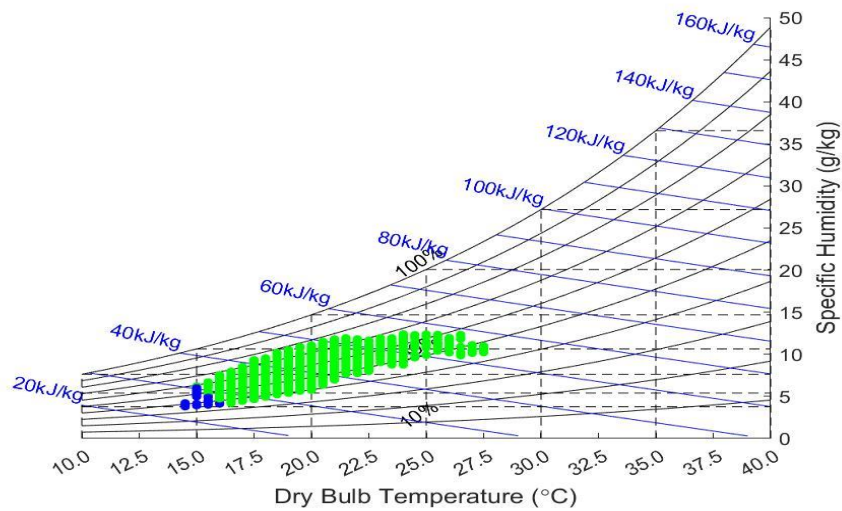
H5RoomEH16= 93.74% Comfort



H5RoomEH04= 87.91% Comfort



H5RoomEH15= 99.37% Comfort



Phase 2

Sensor Installation and Data Range

Summary	House #1		2 bed bungalow	
Sensor ID	Area	Location	Start Logging	Stop Logging
EC 05	Front living room	window	03/02/2022 17:30	05/05/2022 00:15
EH 05	Front living room	window	03/02/2022 17:30	05/05/2022 00:15
EC 12	Front living room	radiator	03/02/2022 17:30	05/05/2022 00:15
EH 14	Front living room	room	03/02/2022 17:30	05/05/2022 00:15
EC 06	Back bedroom	window	03/02/2022 17:30	05/05/2022 00:15
EH 06	Back bedroom	window	03/02/2022 17:30	05/05/2022 00:15
EC 20	Back bedroom	radiator	03/02/2022 17:30	05/05/2022 00:15
EH 13	Back bedroom	room	03/02/2022 17:30	05/05/2022 00:15

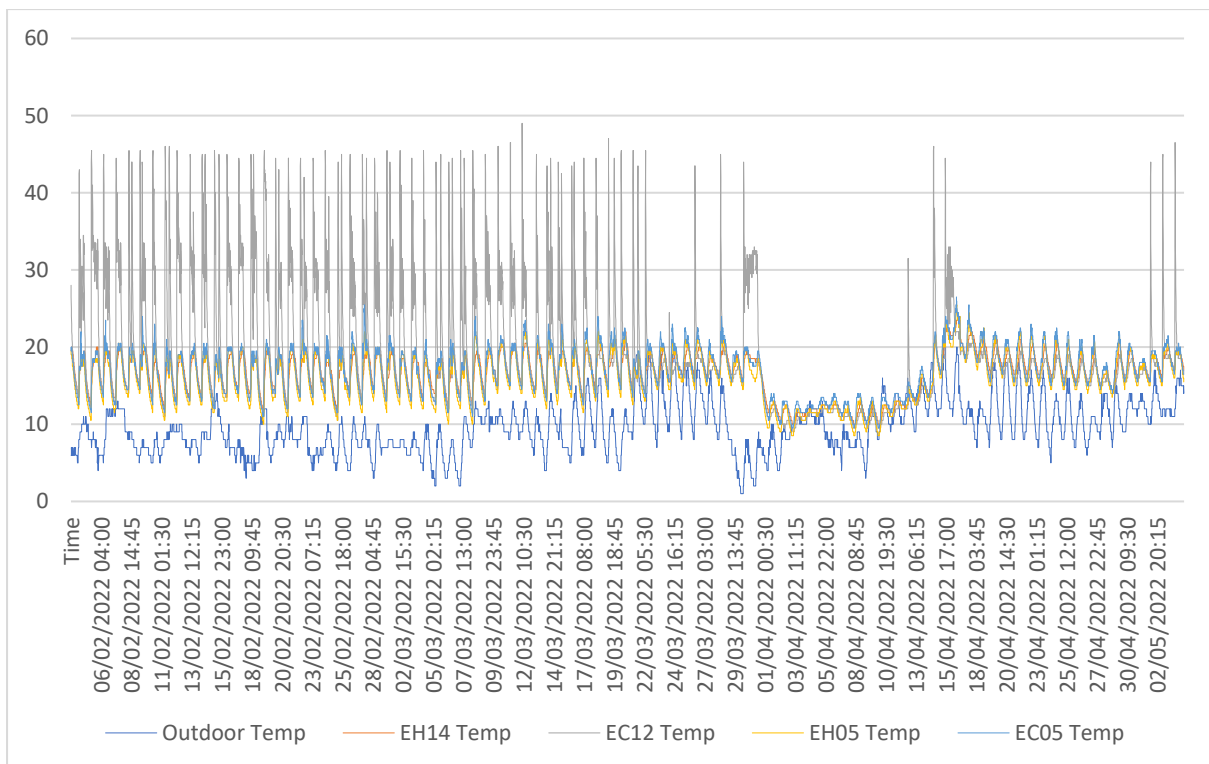
Summary	House #3		1 bed bungalow	
Sensor ID	Area	Location	Start Logging	Stop Logging
EC 09	Back bedroom	window	03/02/2022 17:30	05/05/2022 00:15
EH 09	Back bedroom	window	03/02/2022 17:30	05/05/2022 00:15
EC 14	Back bedroom	radiator	03/02/2022 17:30	05/05/2022 00:15
EH 20	Back bedroom	room	03/02/2022 17:30	05/05/2022 00:15
EC 10	Back living room	window	03/02/2022 17:30	05/05/2022 00:15
EH 10	Back living room	window	03/02/2022 17:30	05/05/2022 00:15
EC 11	Back living room	radiator	03/02/2022 17:30	05/05/2022 00:15
EH 17	Back living room	room	03/02/2022 17:30	05/05/2022 00:15

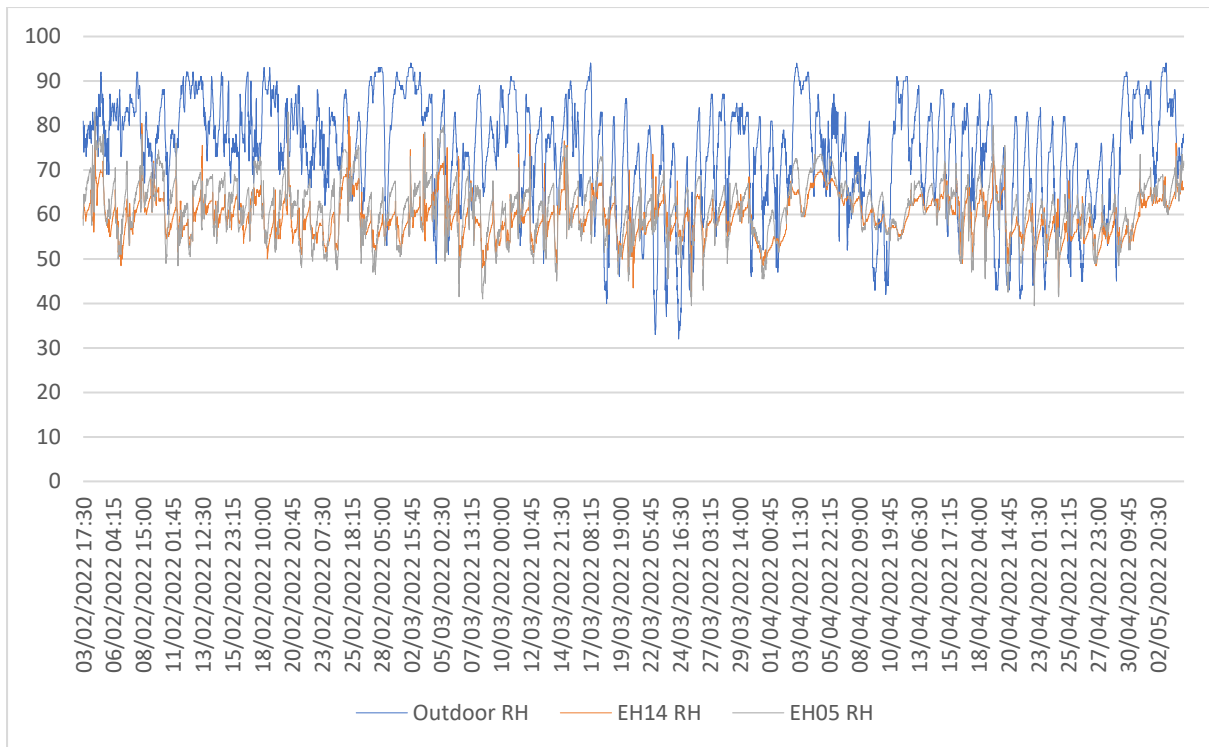
Summary	House #4		3 bed house	
Sensor ID	Area	Location	Start Logging	Stop Logging
EC 01	Downstairs, living room	window	03/02/2022 17:30	05/05/2022 00:15
EH 01	Downstairs, living room	window	03/02/2022 17:30	05/05/2022 00:15
EC 16	Downstairs, living room	radiator	03/02/2022 17:30	05/05/2022 00:15
EH 19	Downstairs, living room	room	03/02/2022 17:30	05/05/2022 00:15
EC 08	Upper Bedroom	window	03/02/2022 17:30	05/05/2022 00:15
EH 08	Upper Bedroom	window	03/02/2022 17:30	05/05/2022 00:15
EC 15	Upper Bedroom	radiator	03/02/2022 17:30	05/05/2022 00:15
EH 11	Upper Bedroom	room	03/02/2022 17:30	05/05/2022 00:15

Summary	House #5		3 bed house	
Sensor ID	Area	Location	Start Logging	Stop Logging
EC 03	Downstairs, living room	window	03/02/2022 17:30	05/05/2022 00:15
EH 03	Downstairs, living room	window	03/02/2022 17:30	05/05/2022 00:15
EC 17	Downstairs, living room	radiator	03/02/2022 17:30	05/05/2022 00:15
EH 16	Downstairs, living room	room	03/02/2022 17:30	05/05/2022 00:15
EC 04	Upper Front Bedroom	window	03/02/2022 17:30	05/05/2022 00:15
EH 04	Upper Front Bedroom	window	03/02/2022 17:30	05/05/2022 00:15
EC 18	Upper Front Bedroom	radiator	03/02/2022 17:30	05/05/2022 00:15
EH 15	Upper Front Bedroom	room	03/02/2022 17:30	24/04/2022 18:45

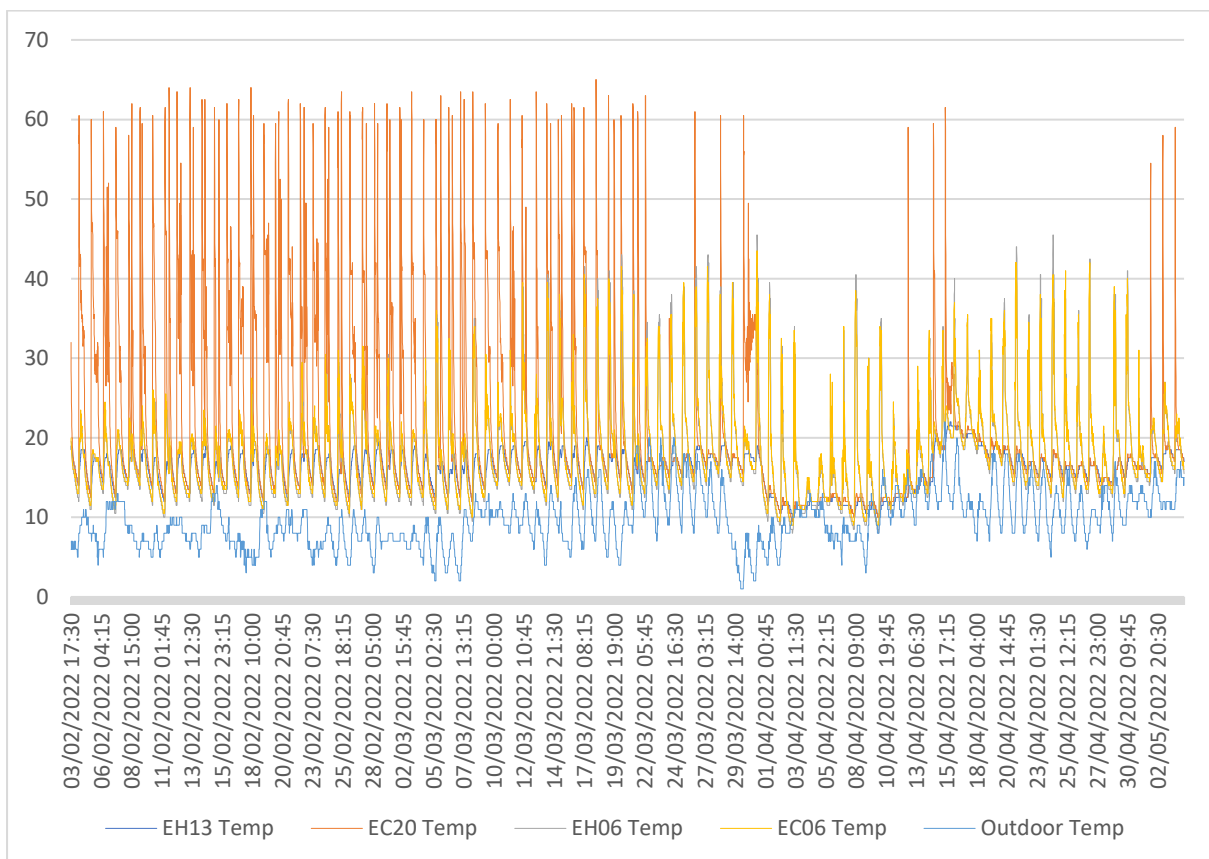
House #1

Temperature(°C)	Living room				Bedroom				Outdoor
	EC 05	EH 05	EC 12	EH 14	EC 06	EH 06	EC 20	EH 13	
Minimum	9.50	8.50	9.00	10.00	9.00	8.00	9.50	10.00	1.00
Maximum	26.50	25.50	49.00	24.00	43.50	45.50	65.00	22.00	22.00
Average	16.93	16.14	19.22	16.60	17.93	17.55	20.79	15.97	9.68
StdDev	3.05	3.14	7.52	2.70	5.62	5.81	10.61	2.39	3.37
Humidity(%)									
Minimum		39.50		42.00		15.00		45.00	32.00
Maximum		83.00		82.00		77.00		73.00	94.00
Average		61.56		59.56		52.74		57.94	74.39
StdDev		6.29		4.68		11.24		4.43	11.96

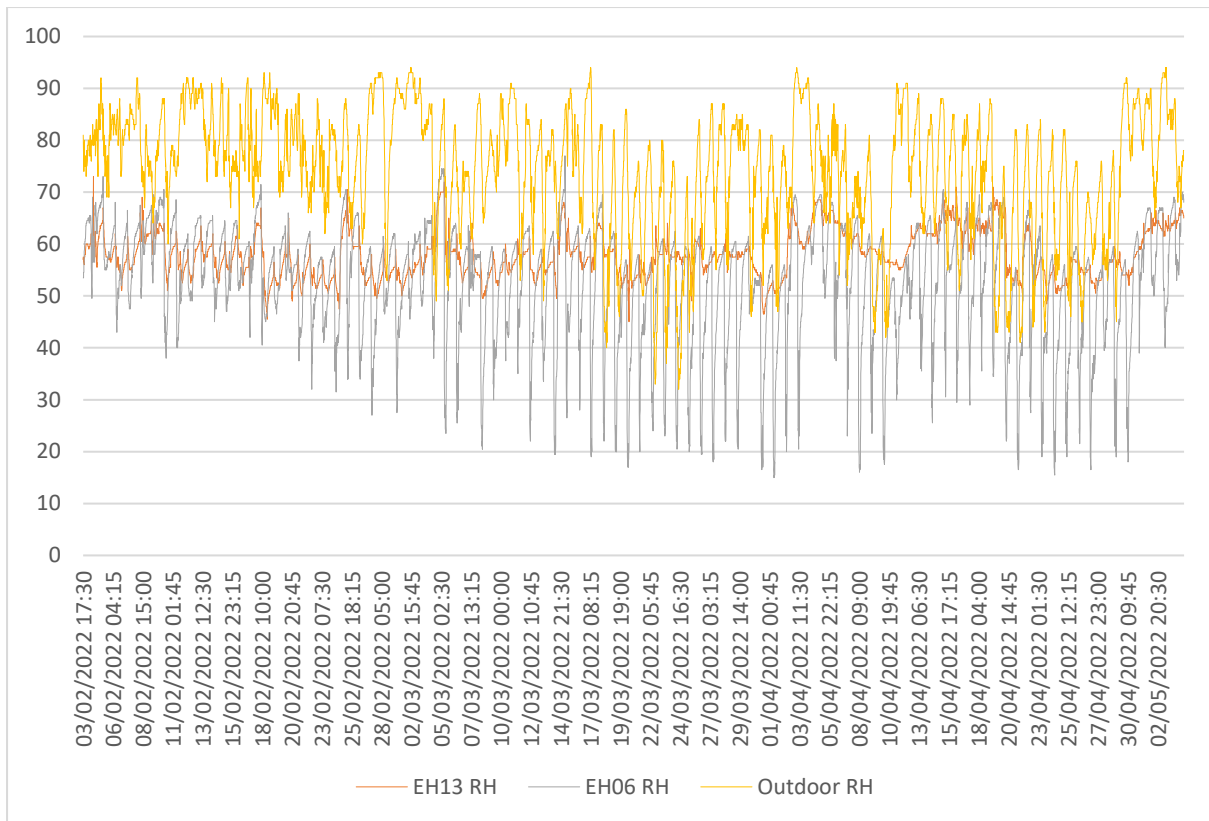
House #1 - Living room – Temperature**House #1 - Living room – Relative Humidity**



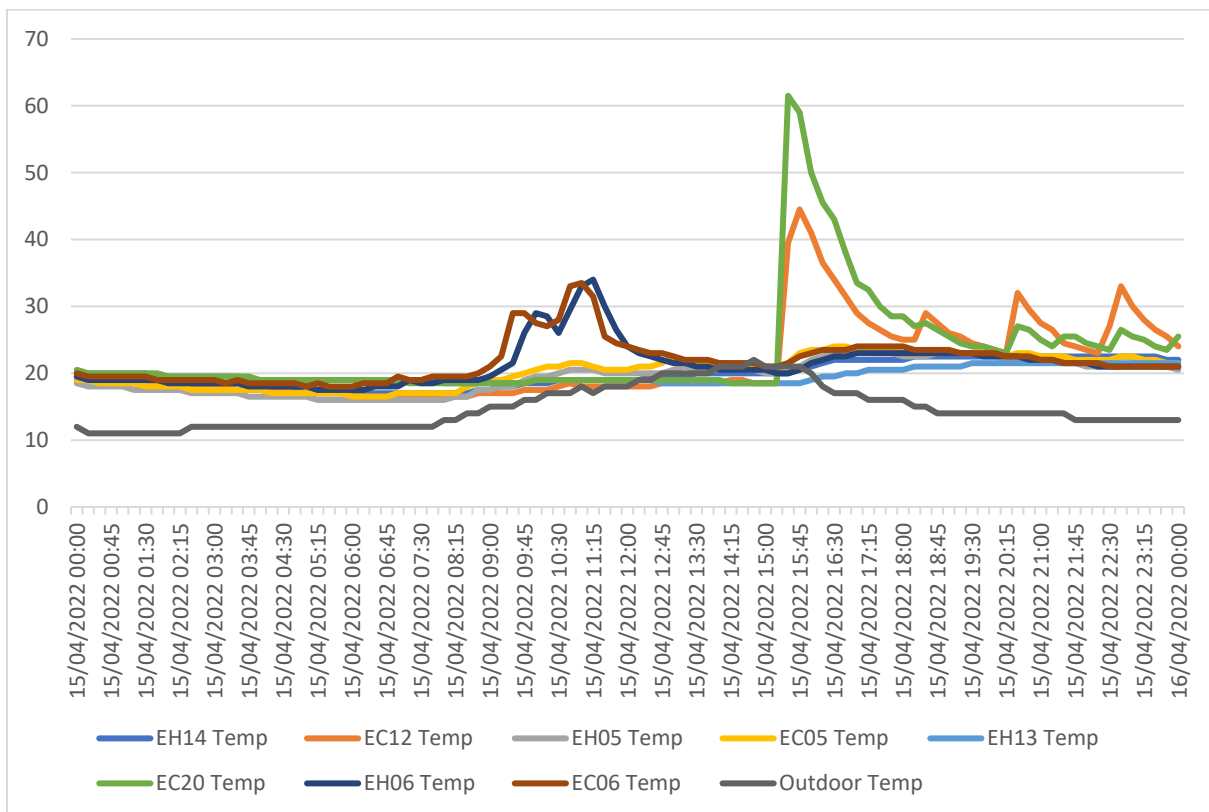
House #1 – Bedroom – Temperature



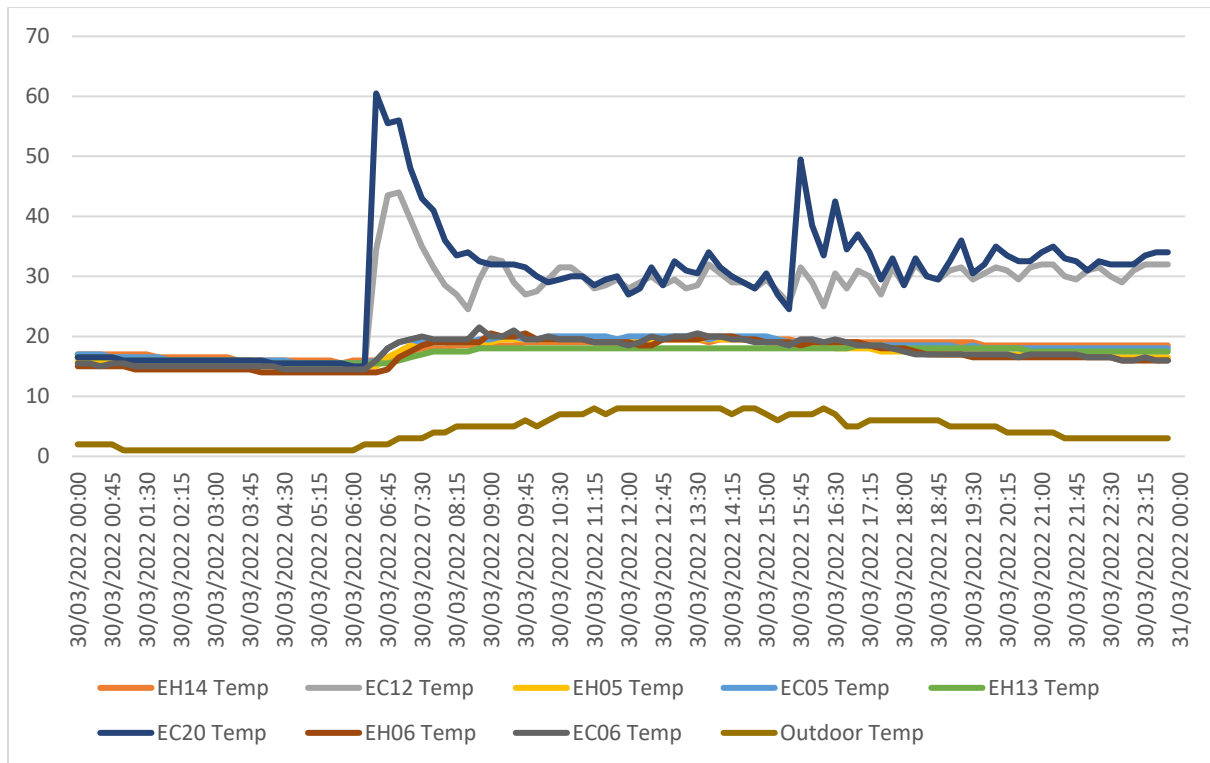
House #1 – Bedroom – Relative Humidity



House #1 – Max Outside Temperature



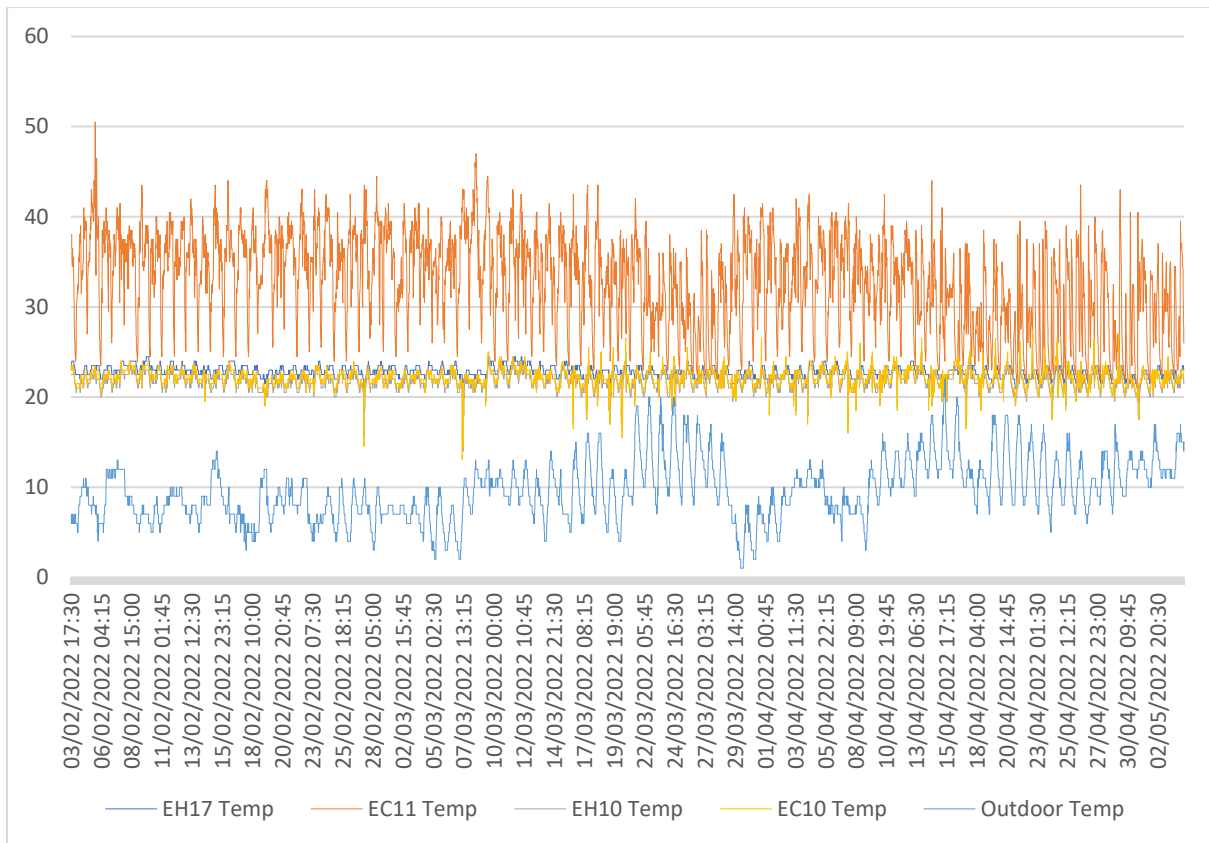
House #1 – Min Outside Temperature



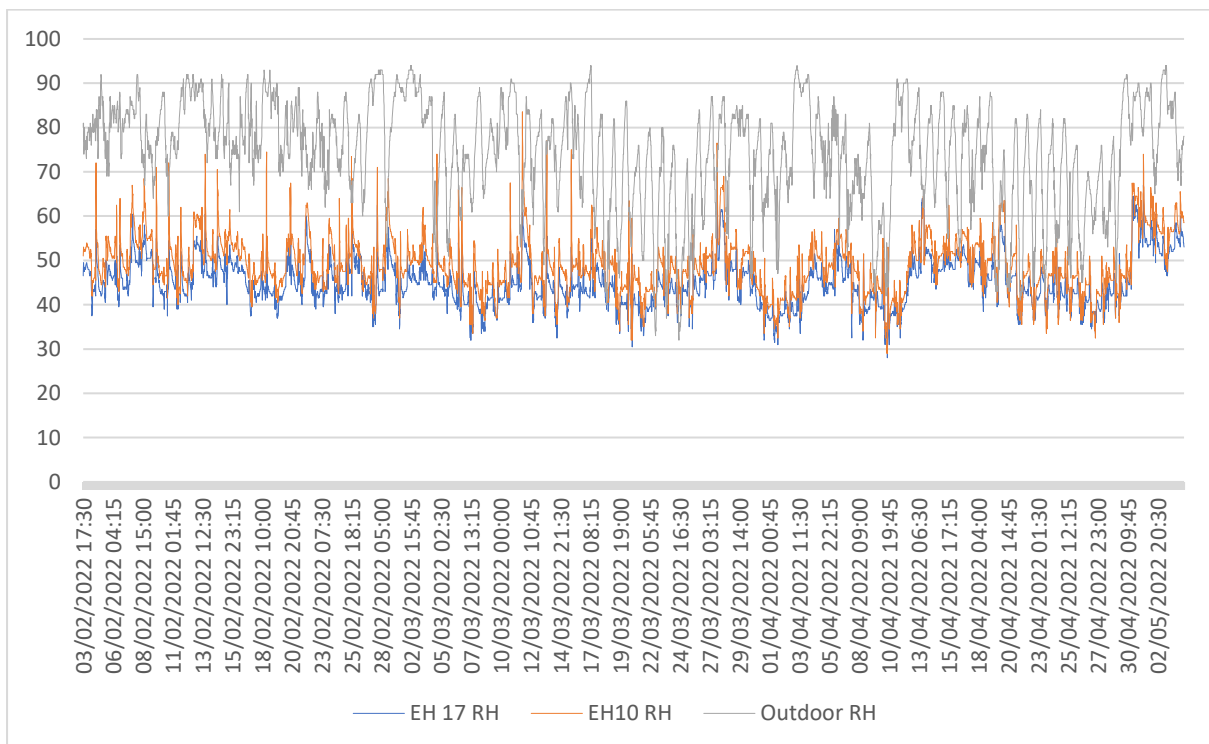
House #3

Temperature(°C)	Bedroom				Living room				Outdoor
	EC 09	EH 09	EC 14	EH 20	EC 10	EH 10	EC 11	EH 17	
Minimum	9.00	7.00	17.50	20.50	13.00	14.00	21.00	19.00	1.00
Maximum	28.00	27.50	58.00	25.00	27.50	27.00	50.50	24.50	22.00
Average	20.00	19.36	36.14	23.13	22.19	21.71	32.86	22.81	9.68
StdDev	3.69	4.19	6.99	0.94	0.99	0.94	5.21	0.66	3.37
Humidity(%)									
Minimum		27.00		28.50		29.00		28.00	32.00
Maximum		71.00		68.00		83.50		67.00	94.00
Average		48.53		44.13		48.95		45.08	74.39
StdDev		7.53		5.10		6.29		5.25	11.96

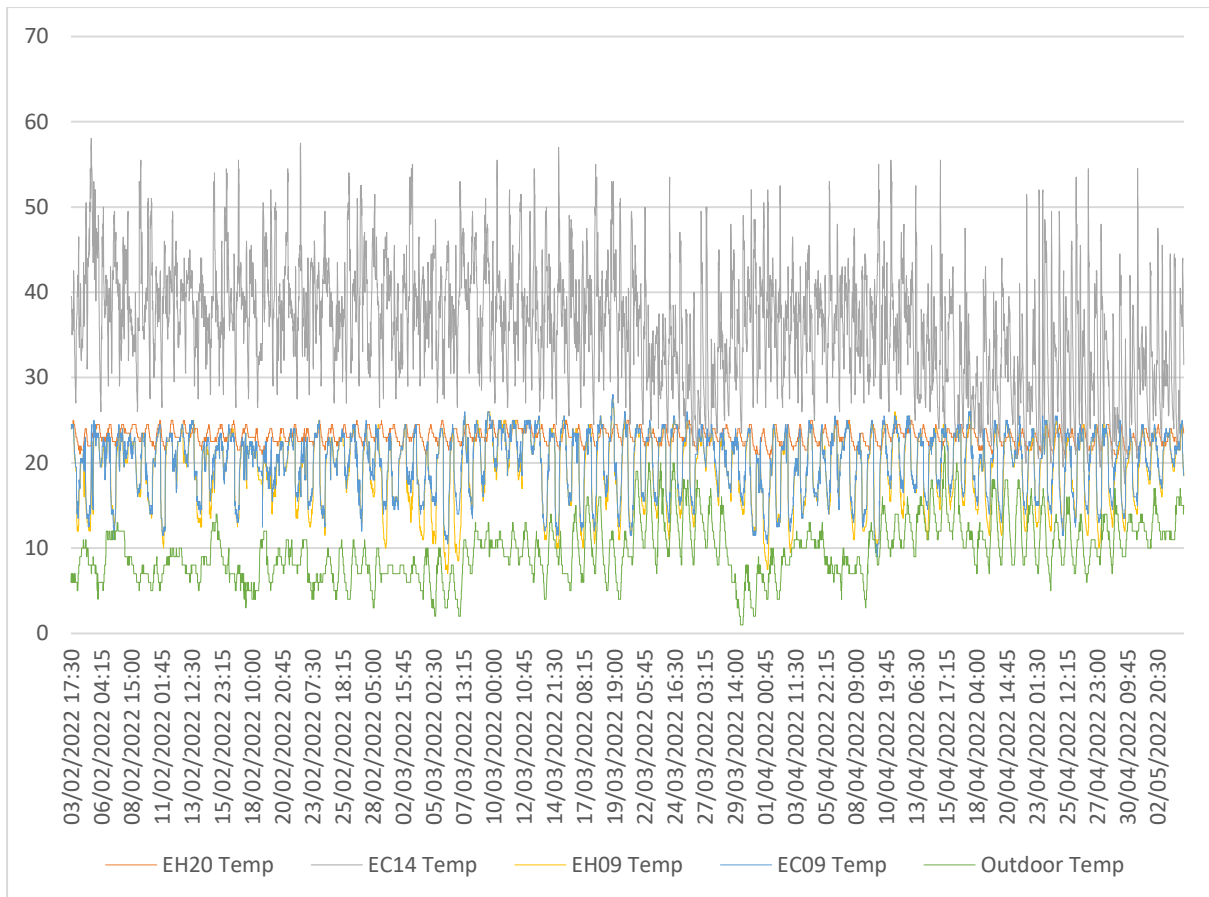
House #3 - Living room – Temperature



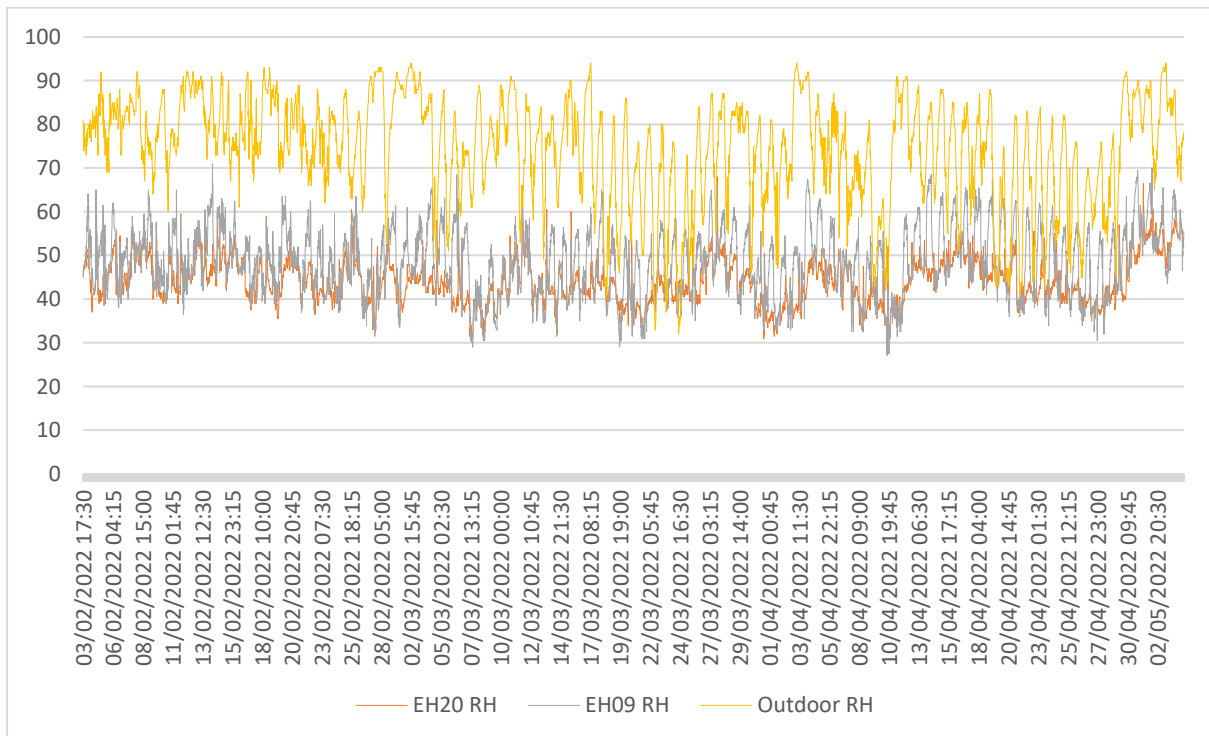
House #3 - Living room – Relative Humidity



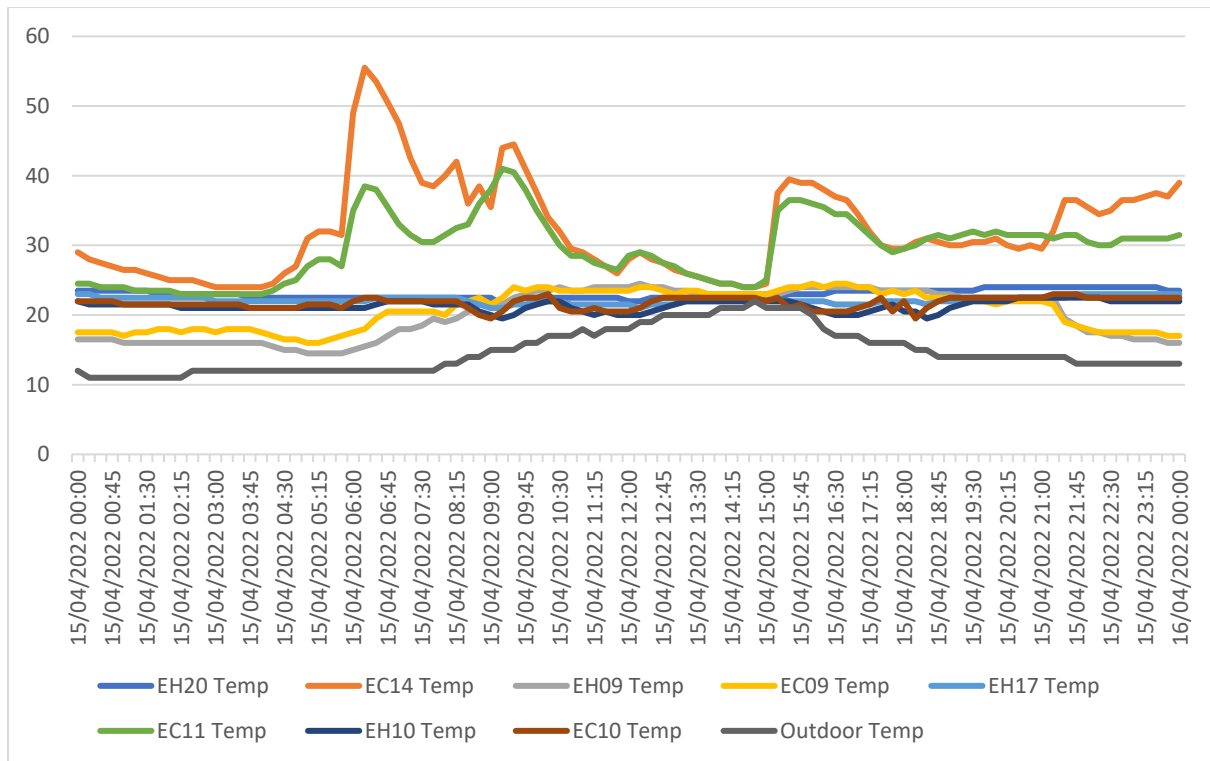
House #3 – Bedroom – Temperature



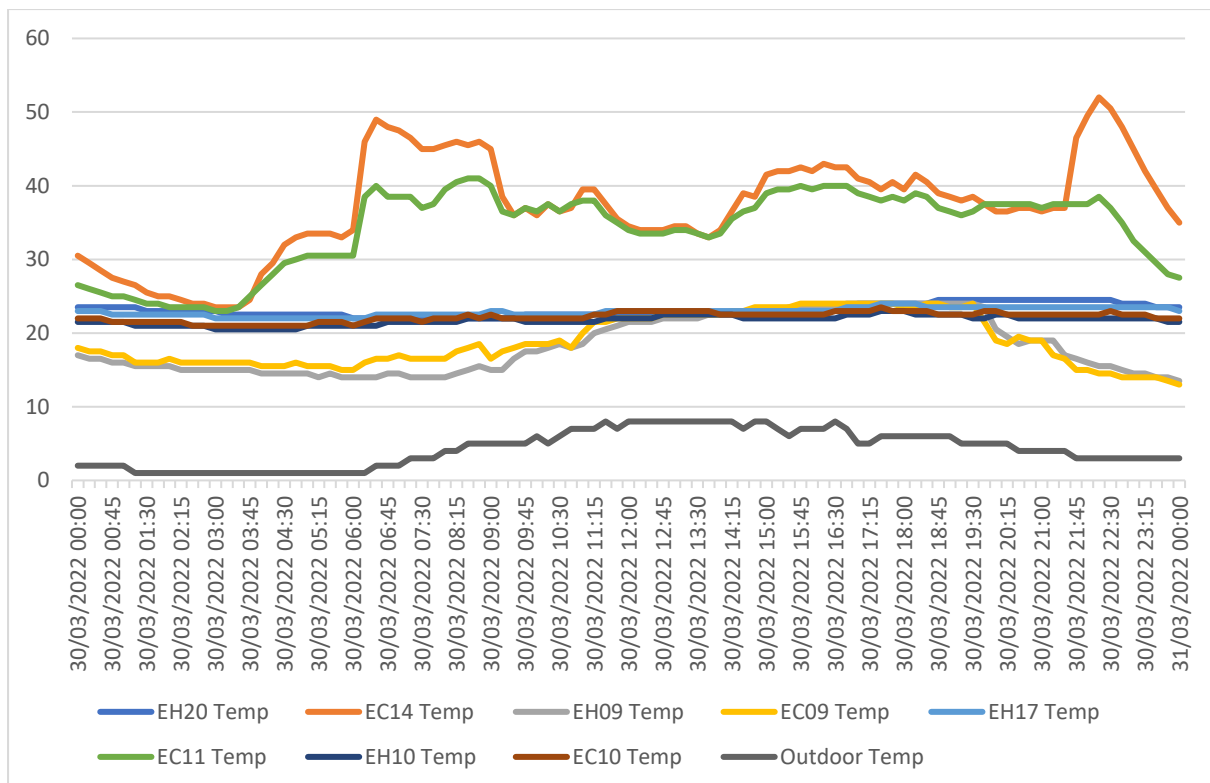
House #3 – Bedroom – Relative Humidity



House #3 – Max Outside Temperature



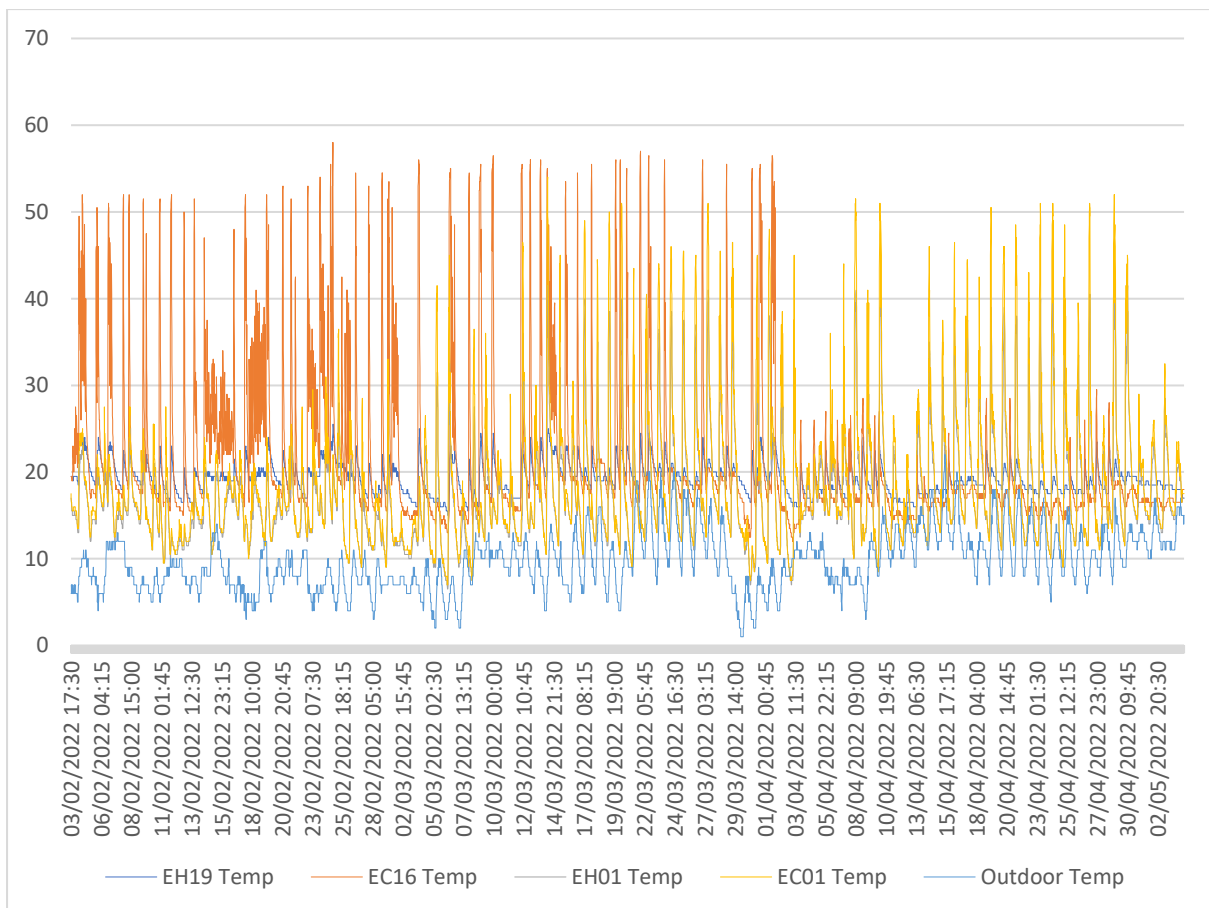
House #3 – Min Outside Temperature



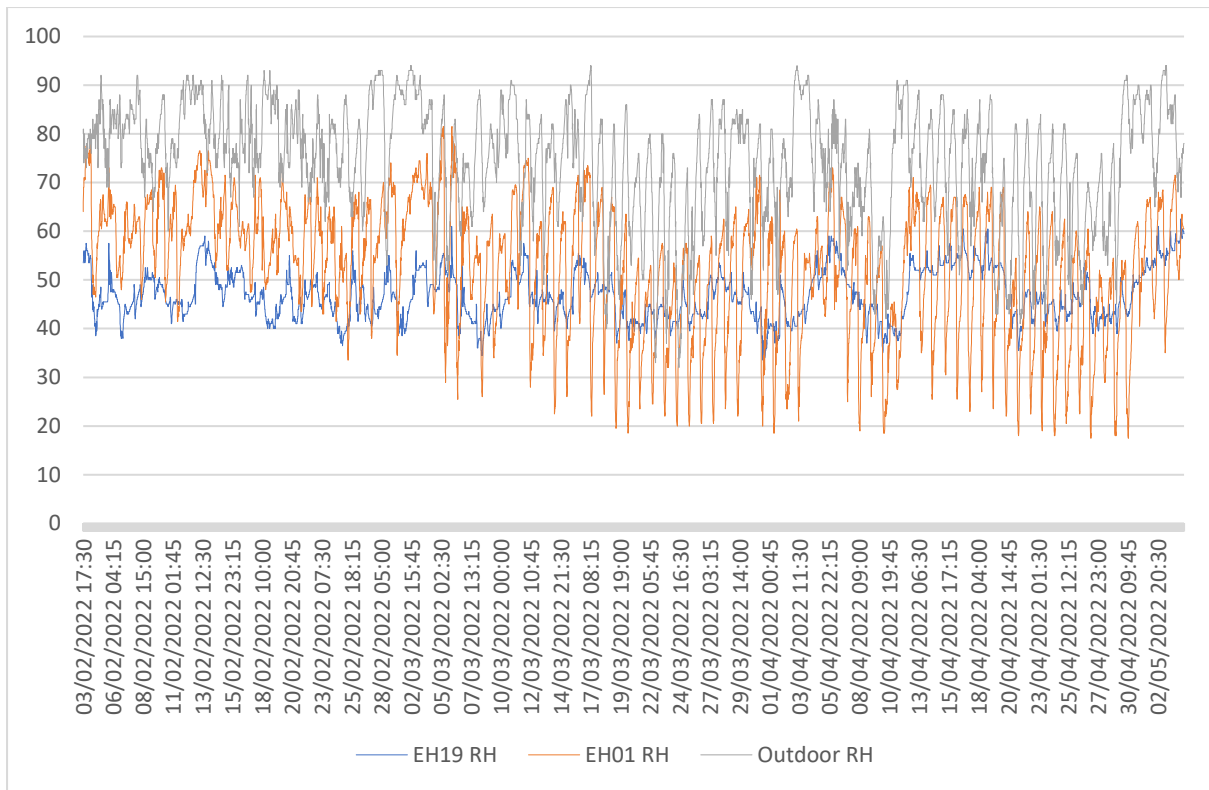
House #4

Temperature(°C)	Living room				Bedroom				Outdoor
	EC 01	EH 01	EC 16	EH 19	EC 08	EH 08	EC 15	EH 11	
Minimum	7.00	6.50	12.00	15.00	12.00	12.00	13.50	14.50	1.00
Maximum	54.00	42.00	58.00	25.50	37.50	30.50	54.50	22.00	22.00
Average	18.44	17.05	20.93	19.17	18.83	17.77	21.46	18.35	9.68
StdDev	7.69	5.92	8.25	1.71	3.58	2.27	7.81	1.36	3.37
Humidity(%)									
Minimum		17.50		33.50		32.00		42.00	32.00
Maximum		81.50		62.50		80.00		74.50	94.00
Average		52.71		46.87		56.79		53.56	74.39
StdDev		13.32		5.06		7.49		4.44	11.96

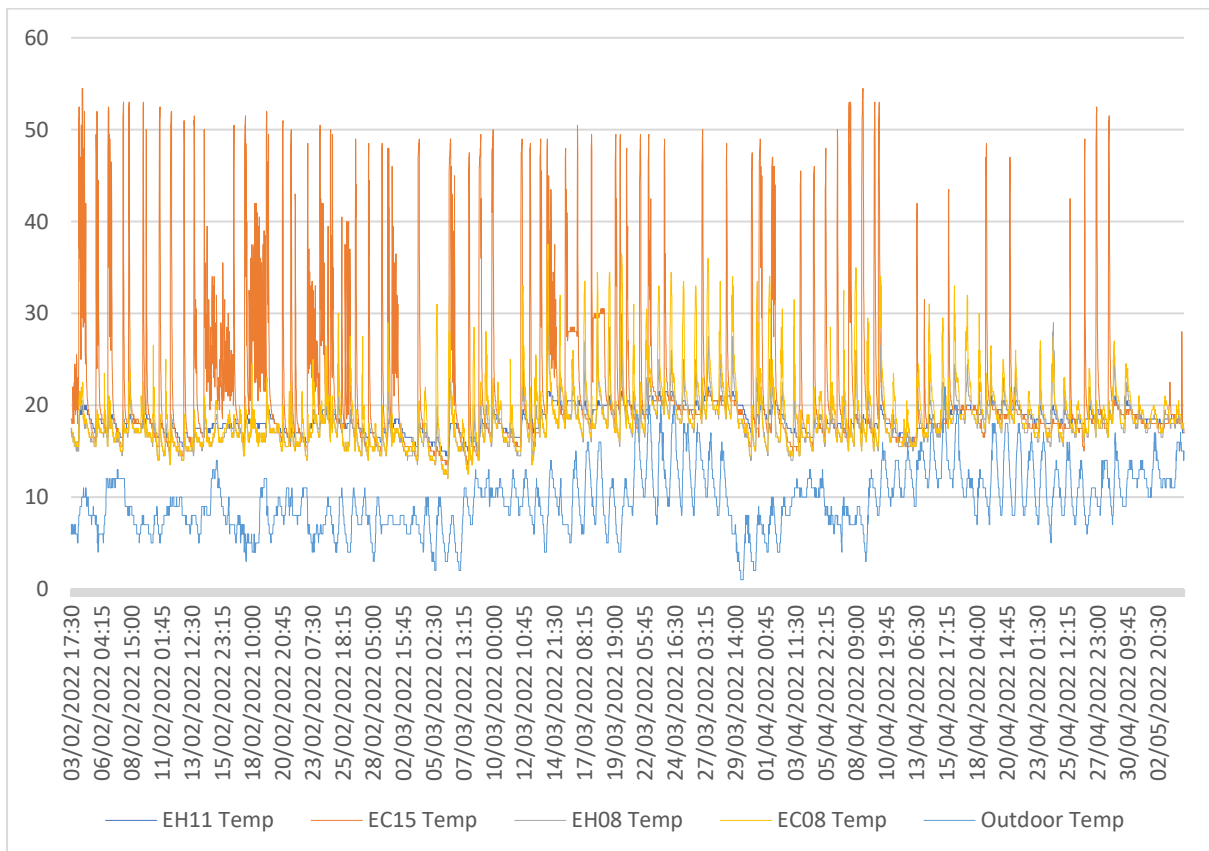
House #4 - Living room – Temperature



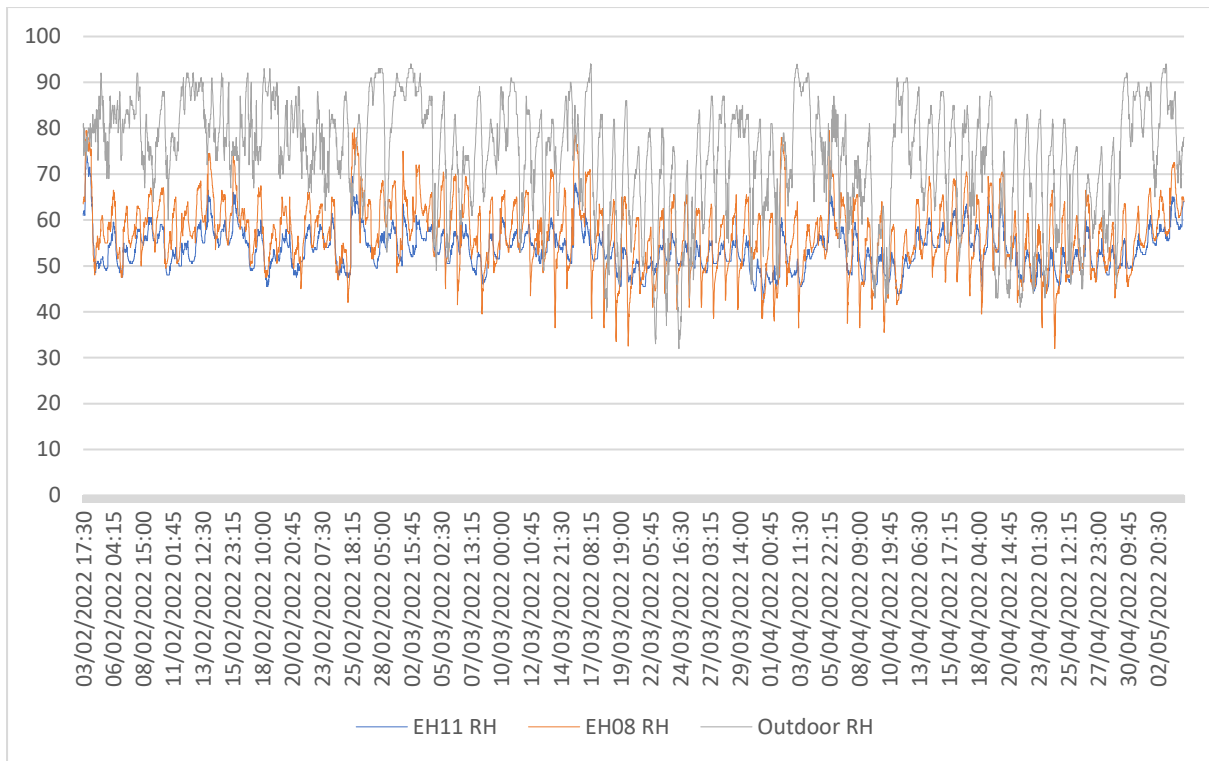
House #4 - Living room – Relative Humidity



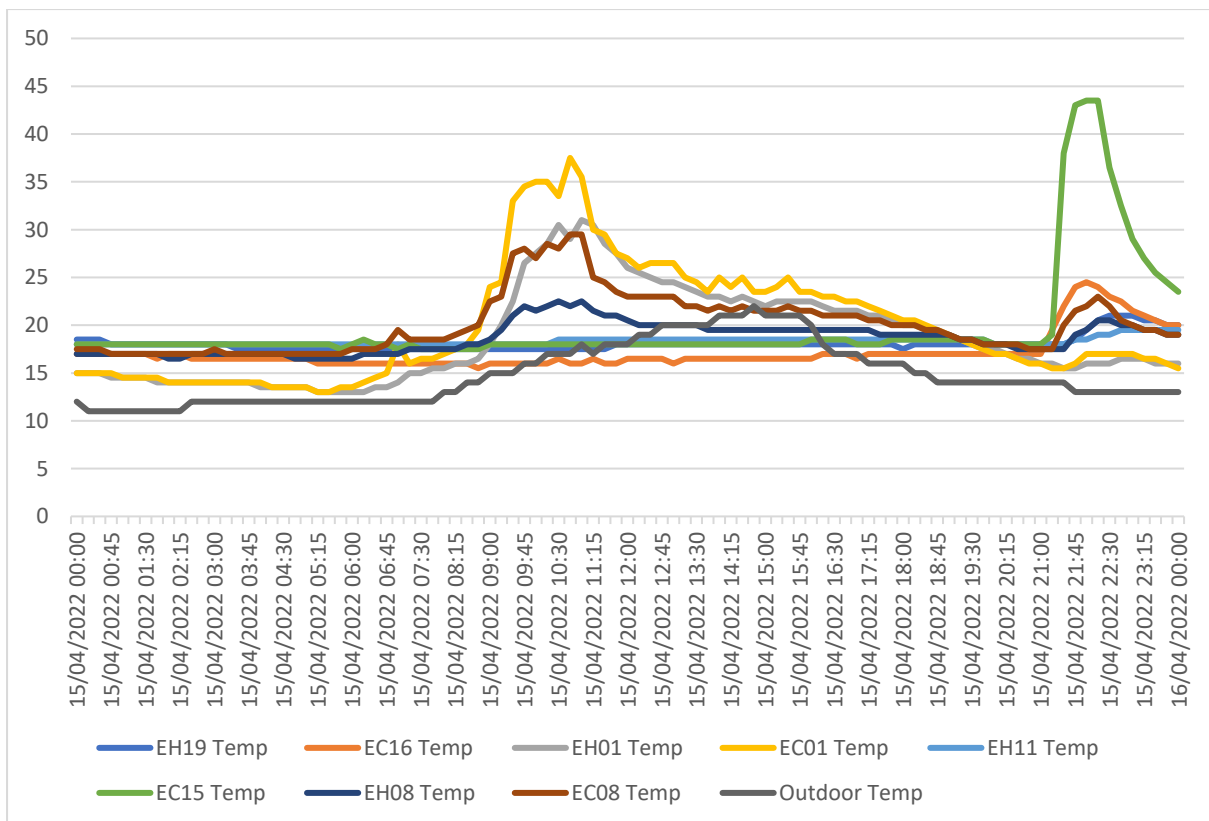
House #4 – Bedroom – Temperature



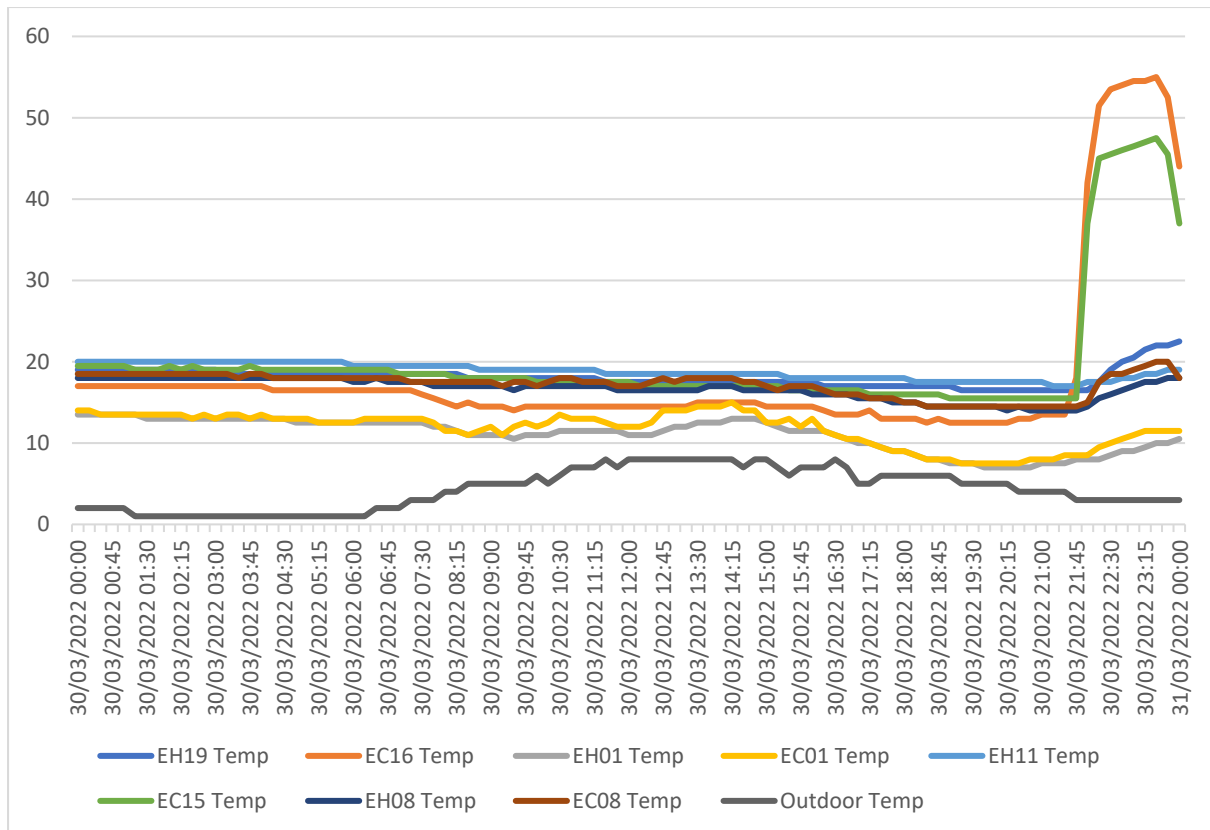
House #4 – Bedroom – Relative Humidity



House #4 – Max Outside Temperature



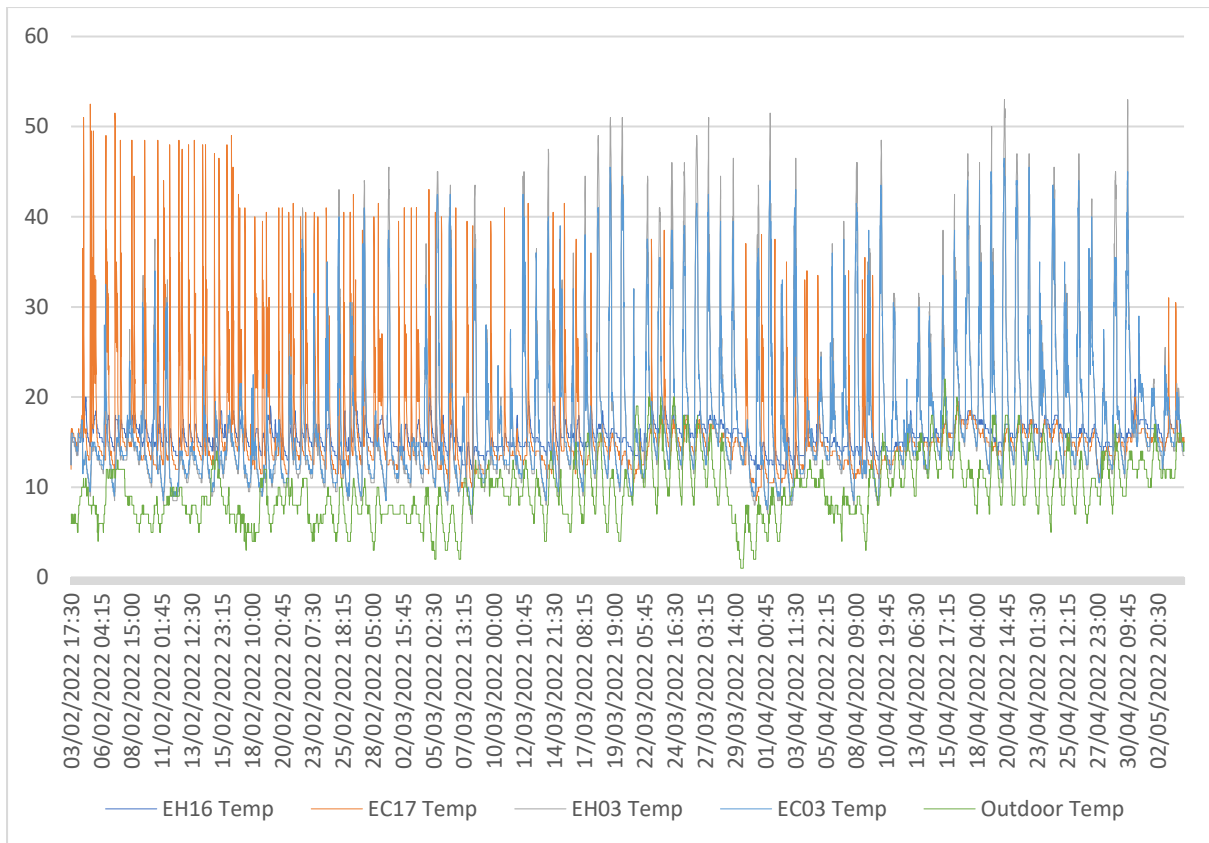
House #4 – Min Outside Temperature



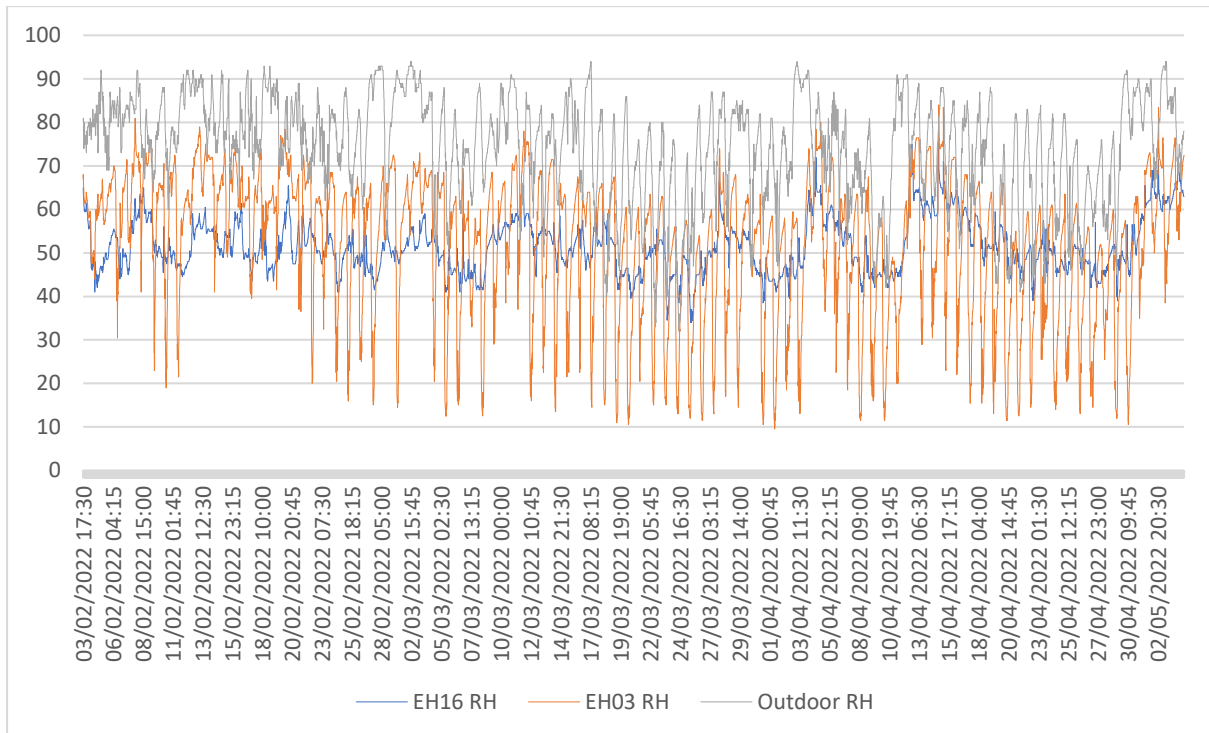
House #5

Temperature(°C)	Living room				Bedroom				Outdoor
	EC 03	EH 03	EC 17	EH 16	EC 04	EH 04	EC 18	EH 15	
Minimum	7.00	6.00	8.50	12.00	11.00	10.00	12.50	14.00	1.00
Maximum	46.50	53.00	52.50	22.00	45.00	49.00	58.50	21.50	22.00
Average	16.89	16.92	15.71	15.57	19.38	18.55	21.46	16.85	9.68
StdDev	7.15	8.19	5.07	1.41	6.17	5.58	10.25	1.08	3.37
Humidity(%)									
Minimum		9.50		34.00		12.50		34.00	32.00
Maximum		84.00		76.50		80.50		69.50	94.00
Average		52.11		51.53		48.60		50.39	74.39
StdDev		16.39		6.17		12.79		5.71	11.96

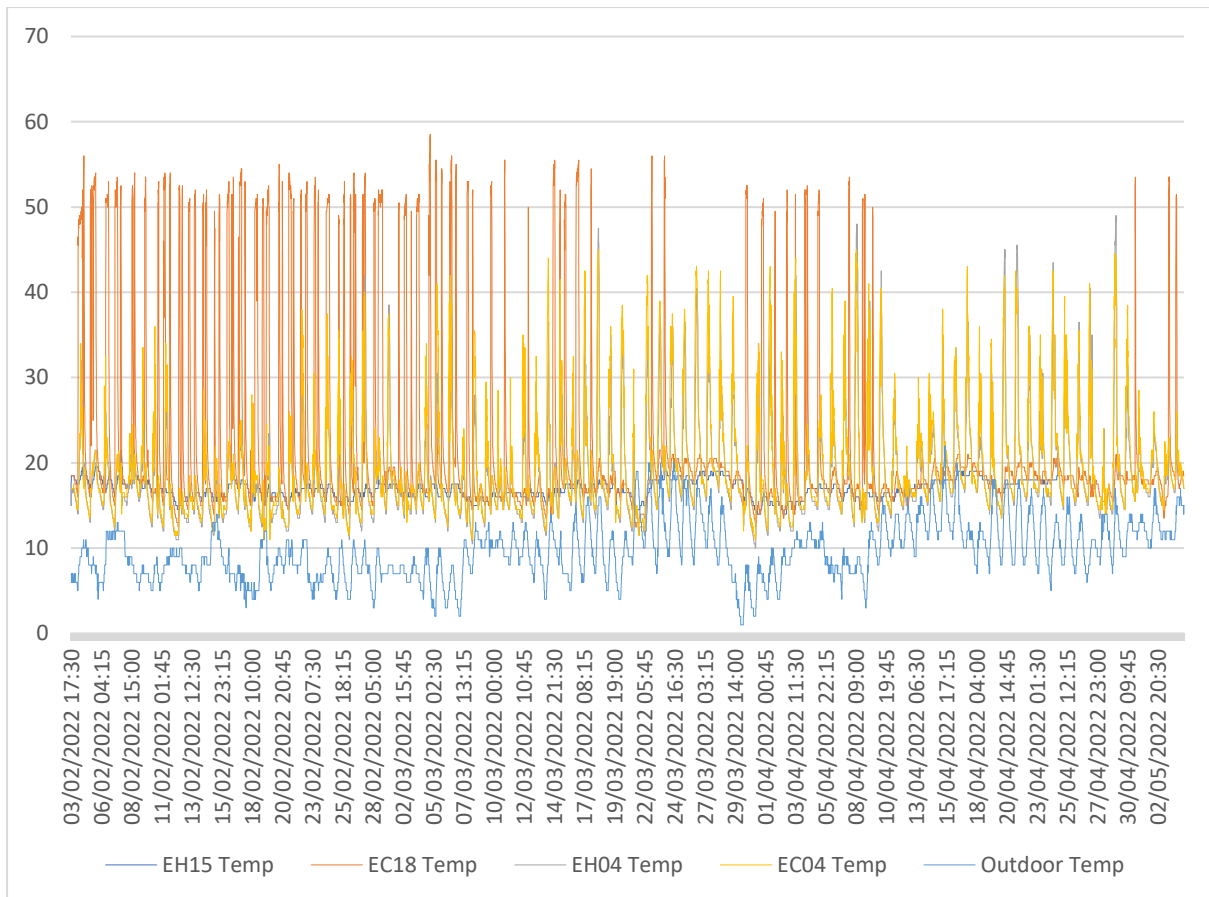
House #5 - Living room – Temperature



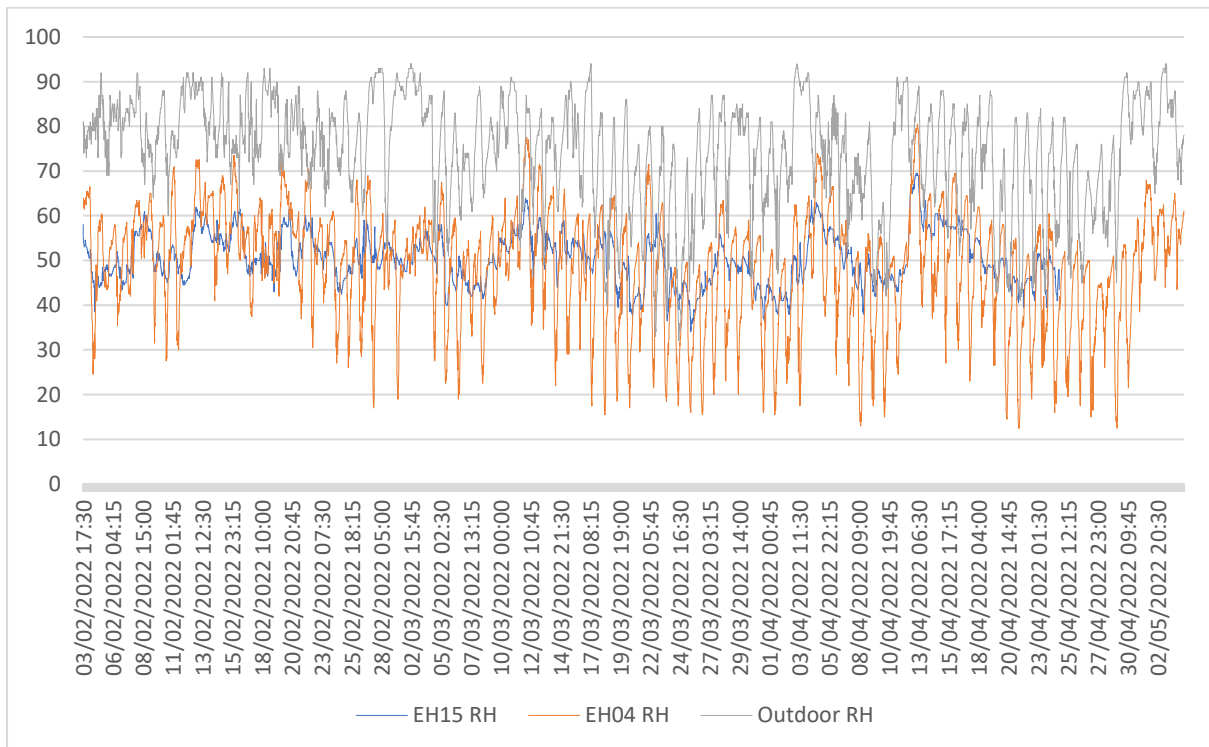
House #5 - Living room – Relative Humidity



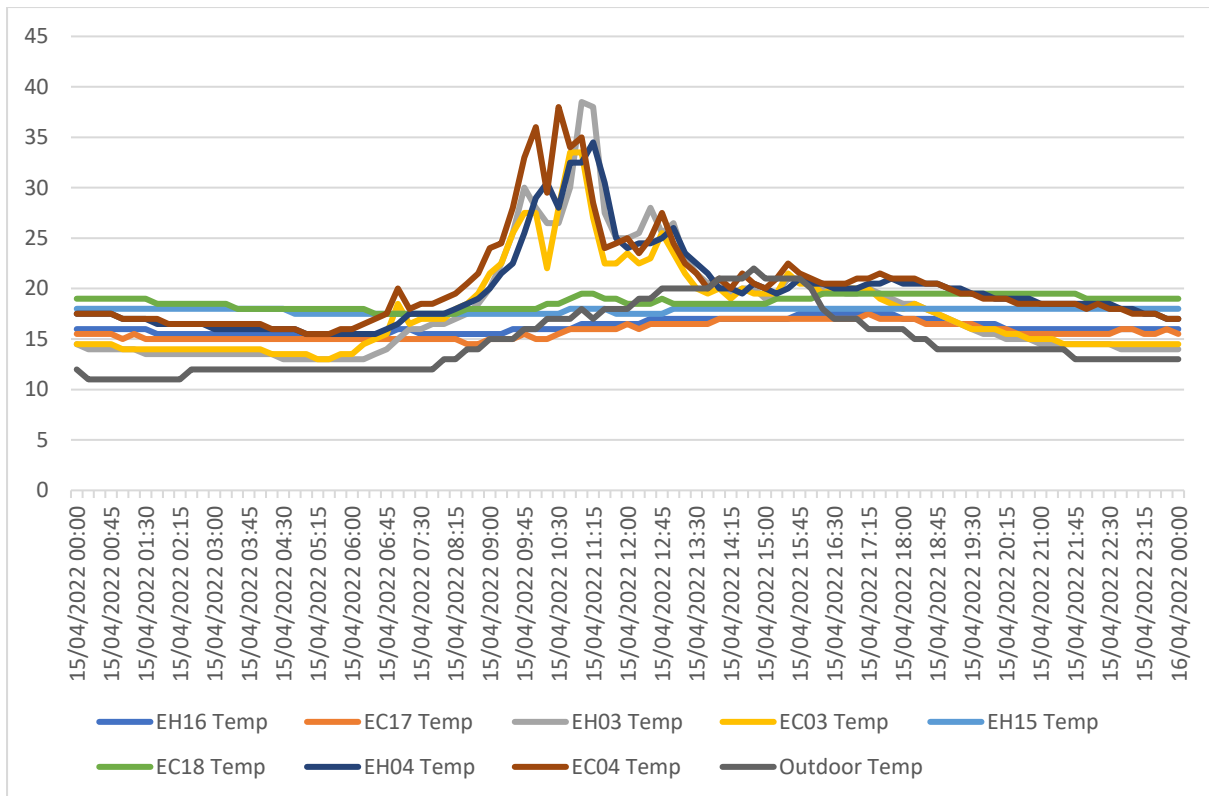
House #5 – Bedroom – Temperature



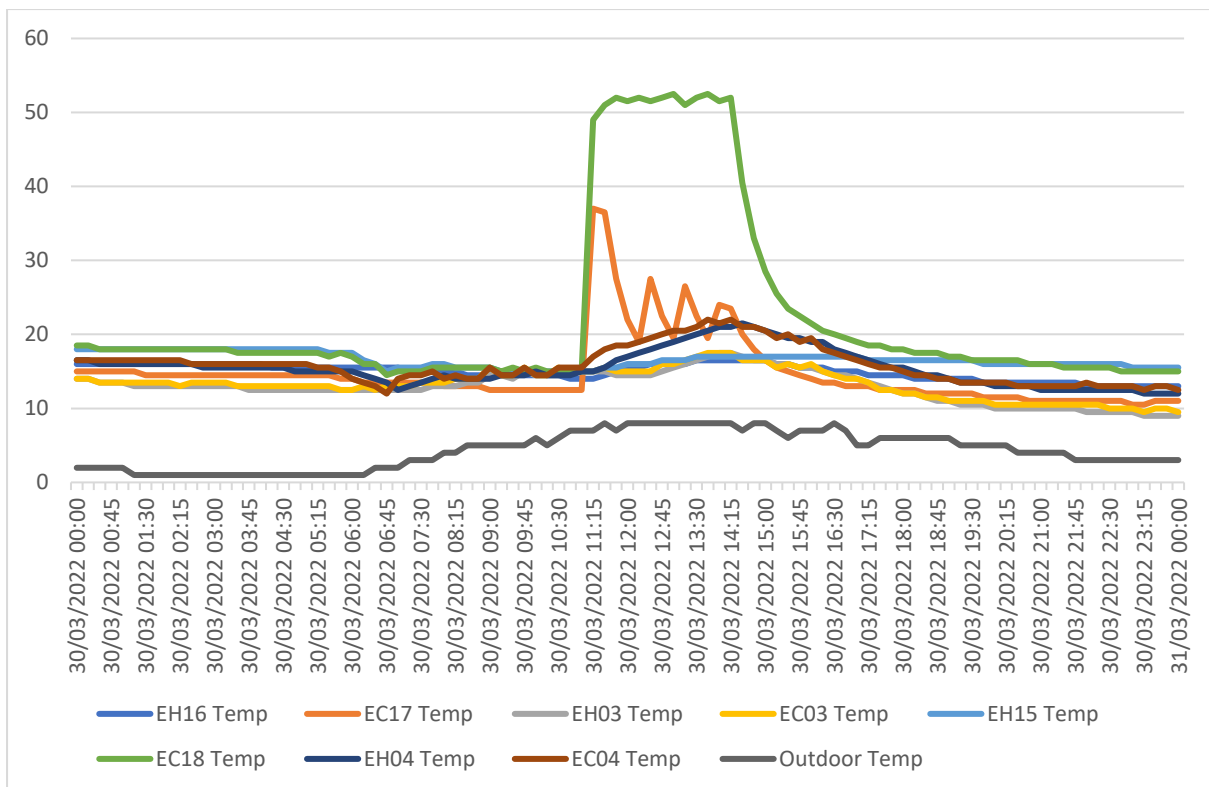
House #5 – Bedroom – Relative Humidity



House #5 – Max Outside Temperature

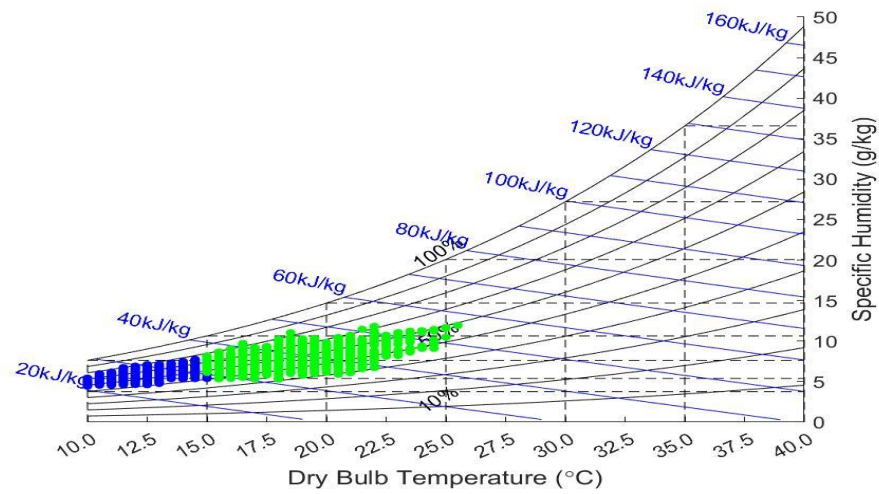


House #5 – Min Outside Temperature

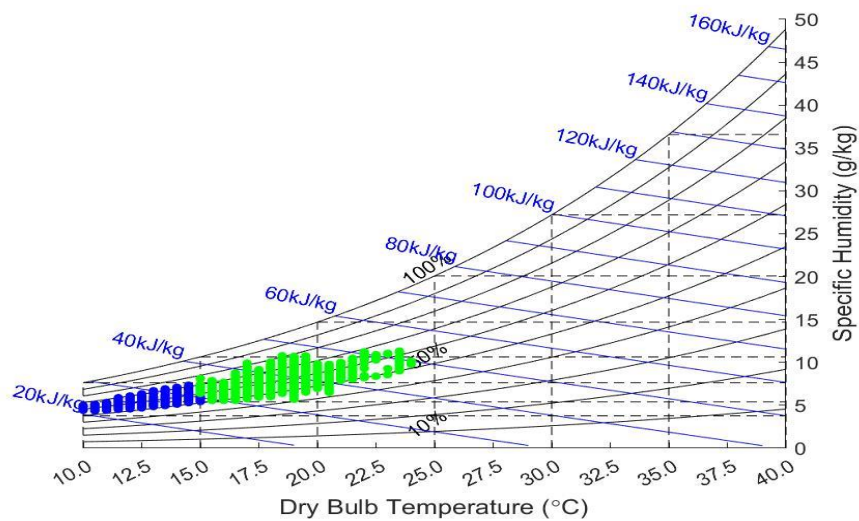


The comfort map from Artificial Intelligence Model Output

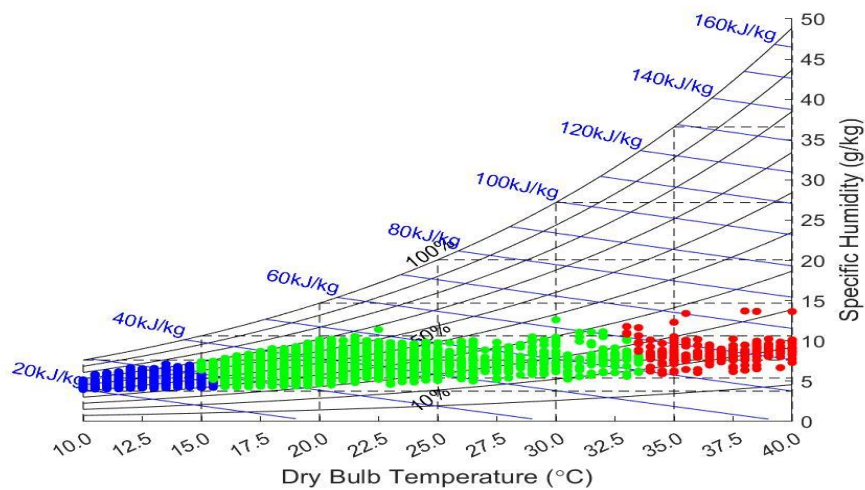
H1RoomEH05 = 66.17% Comfort



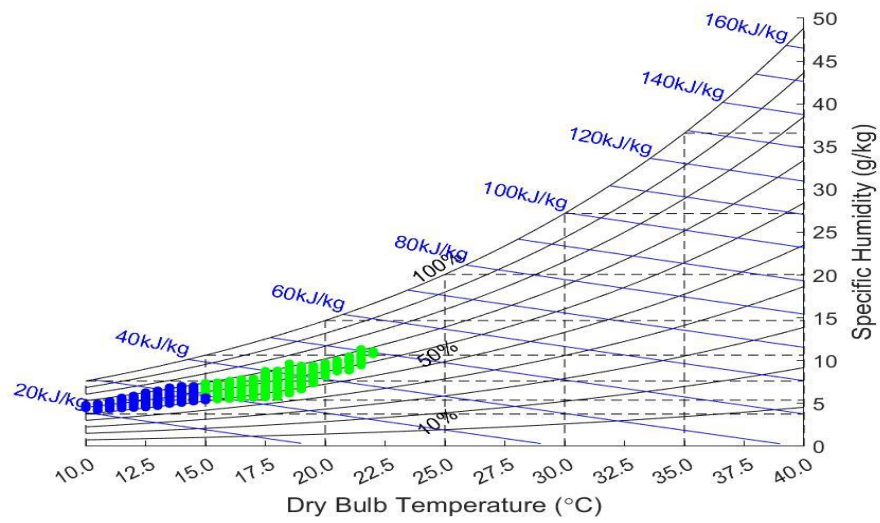
H1RoomEH14 = 75.17% Comfort



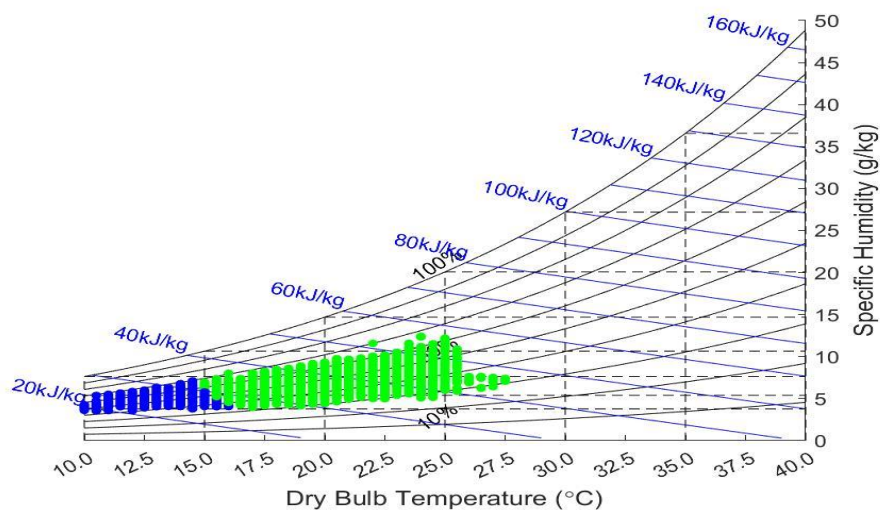
H1RoomEH06 = 57.43 % Comfort



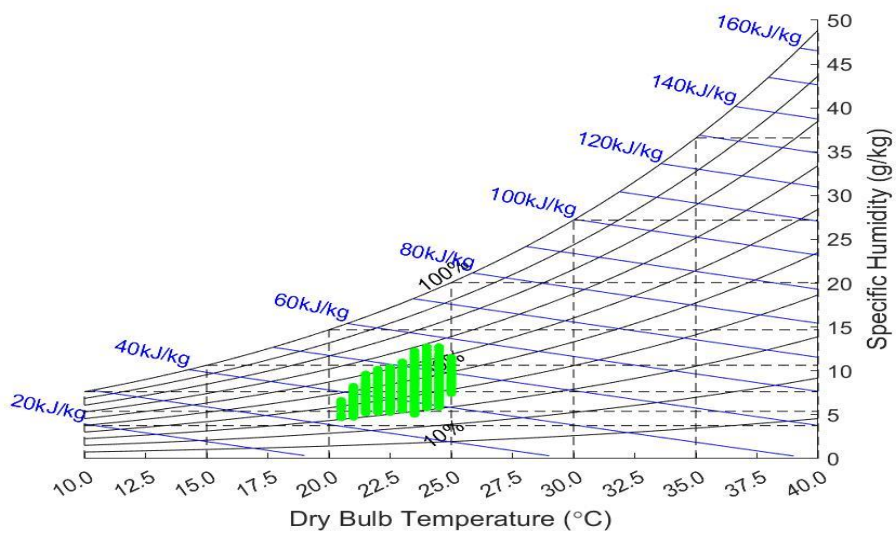
H1RoomEH13 = 68.83% Comfort



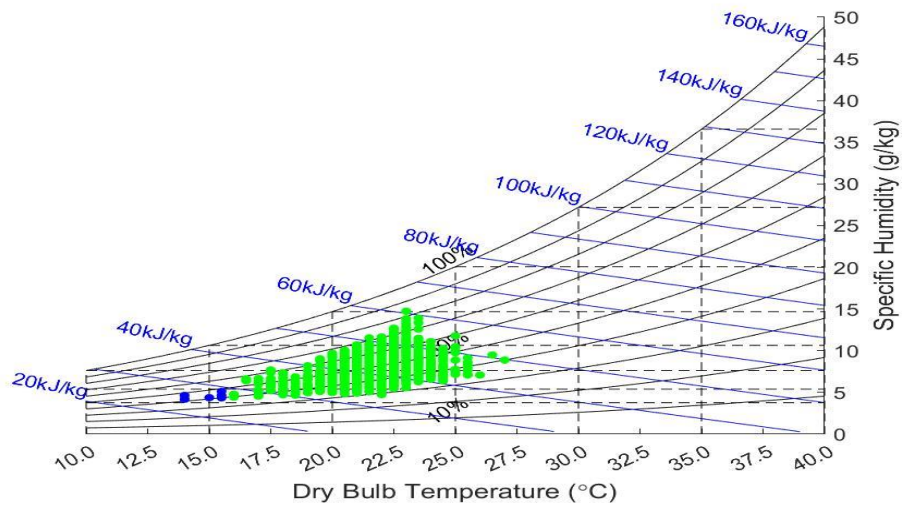
H3RoomEH09= 79.12% Comfort



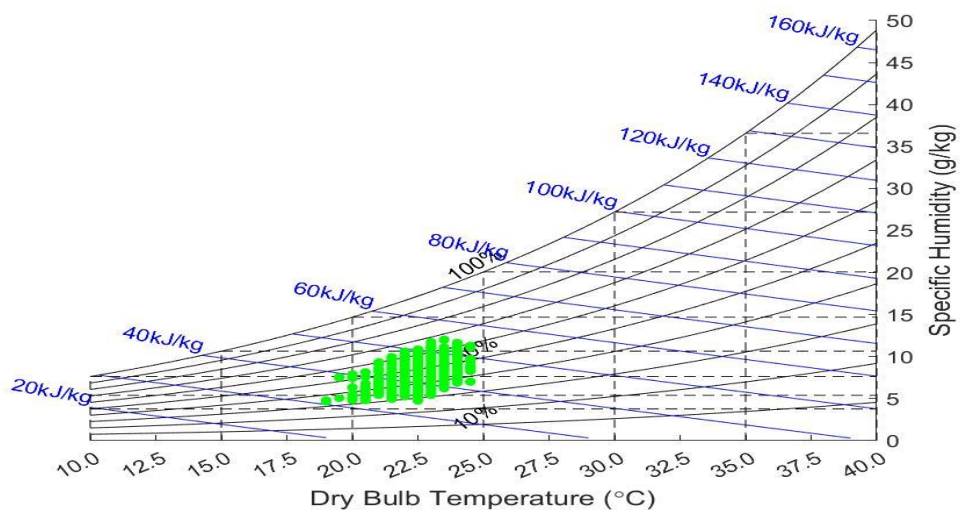
H3RoomEH20=100% Comfort



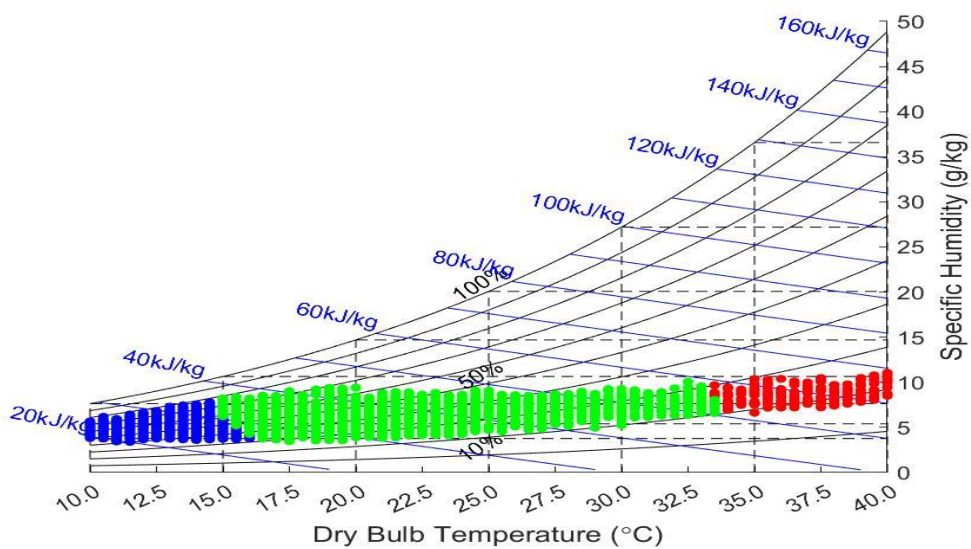
H3RoomEH10= 99.93% Comfort



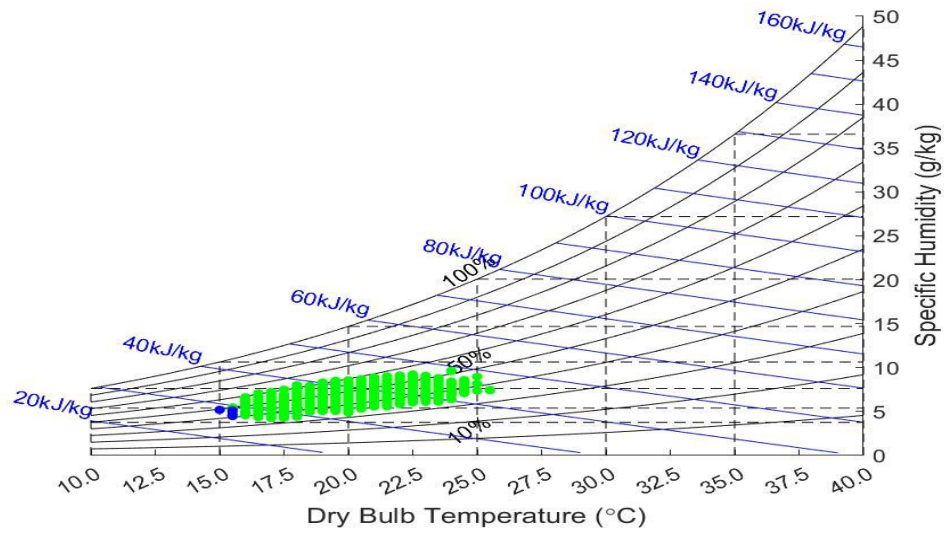
H3RoomEH17= 100% Comfort



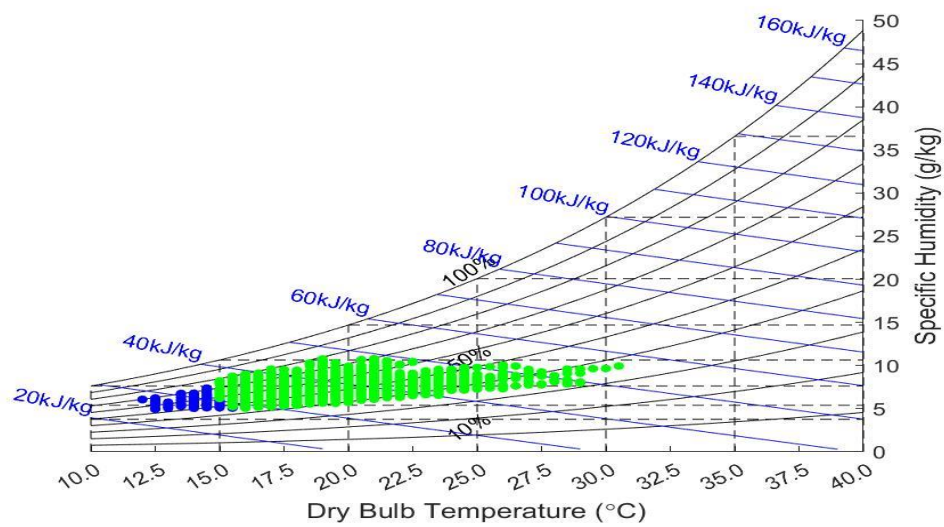
H4RoomEH01= 52.61% Comfort



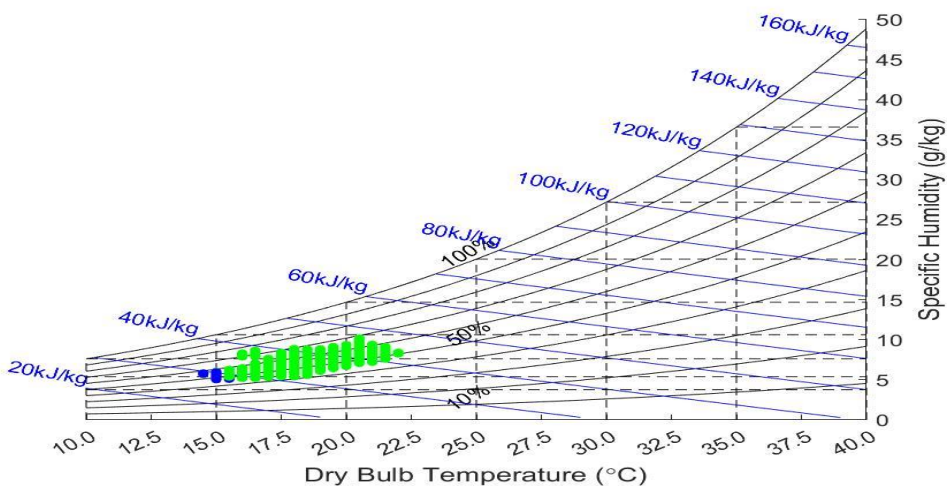
H4RoomEH19= 99.83% Comfort



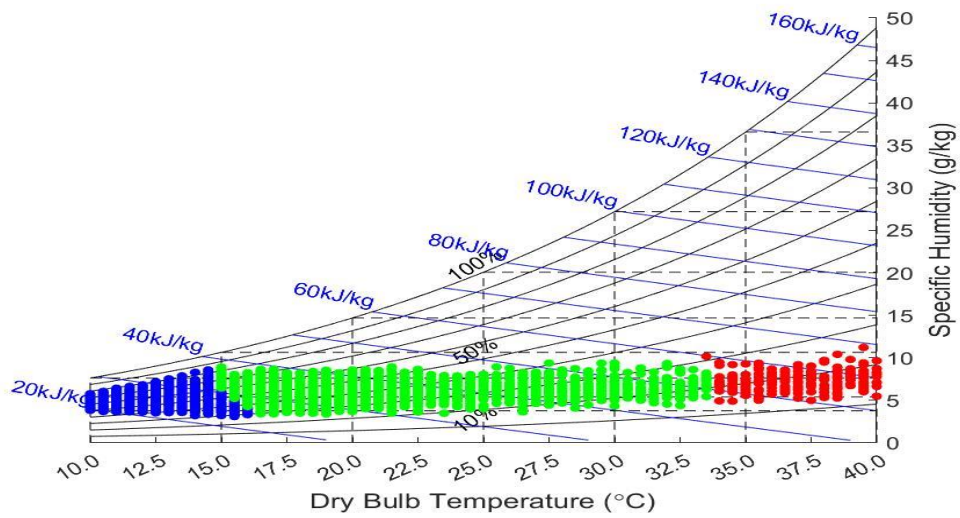
H4RoomEH08= 92.95% Comfort



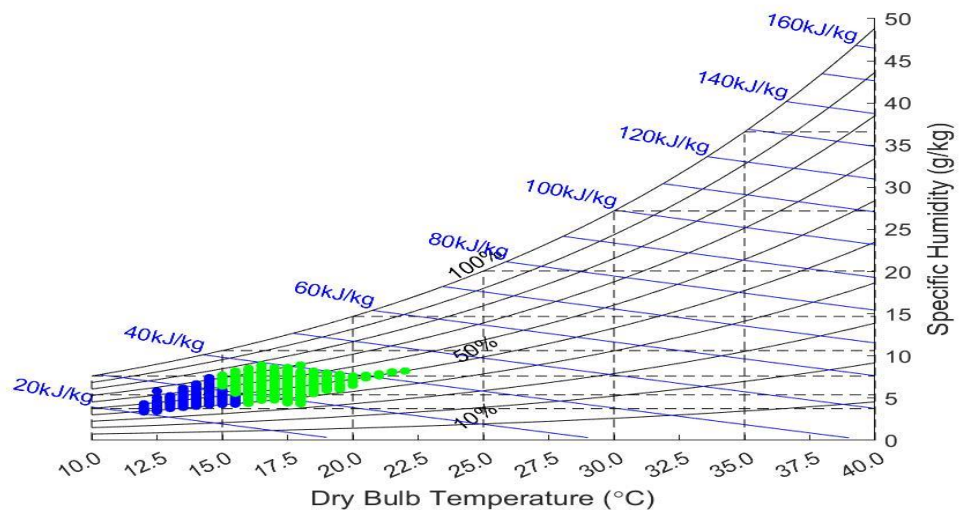
H4RoomEH11= 99.02% Comfort



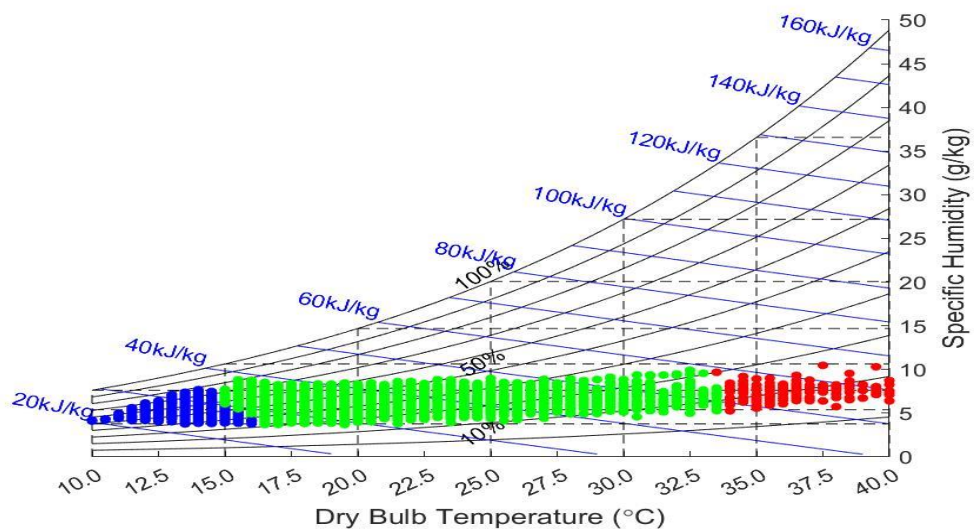
H5RoomEH03= 34.46% Comfort



H5RoomEH16= 57.25% Comfort

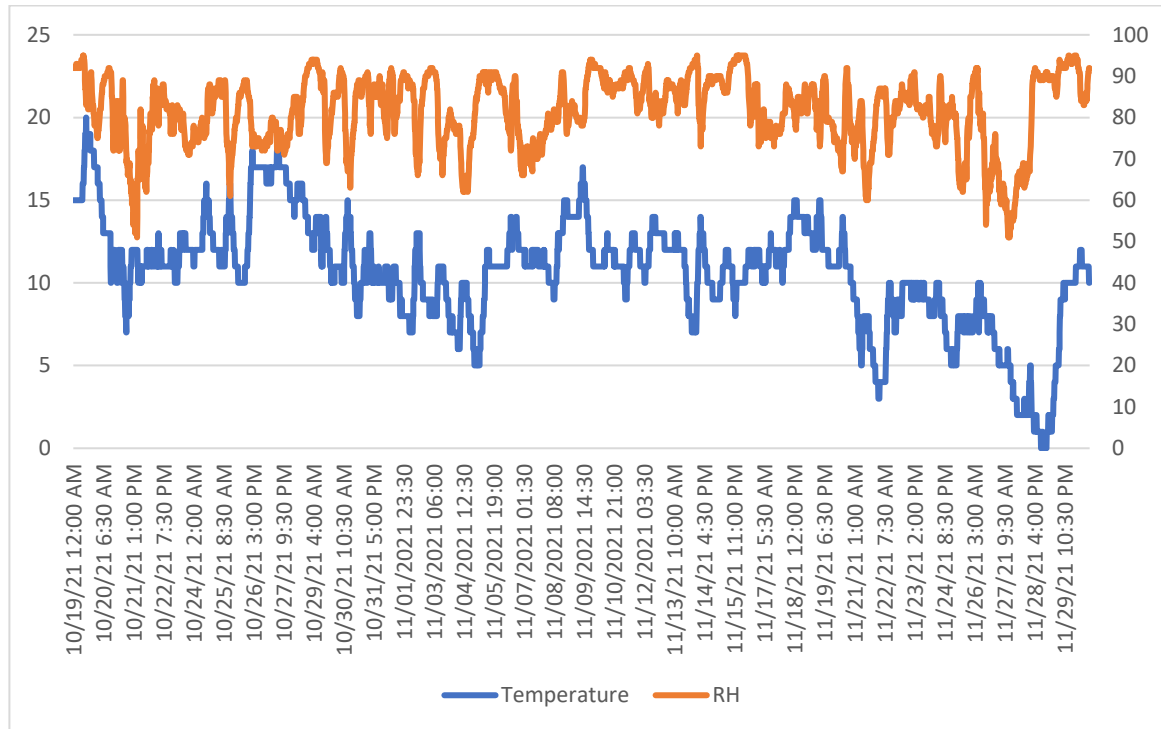


H5RoomEH04= 70.32% Comfort

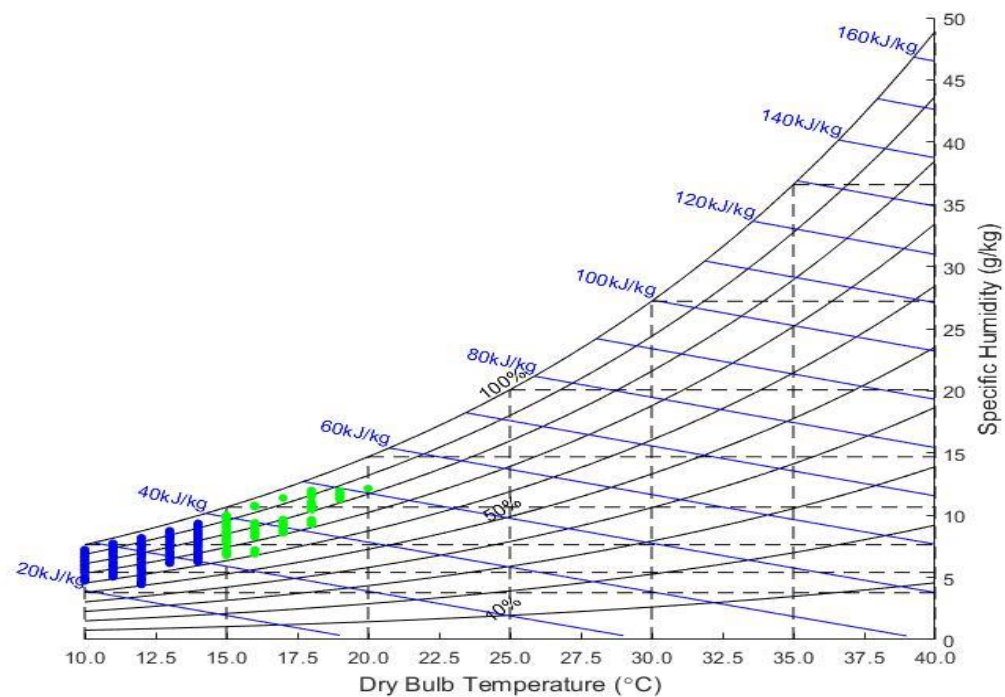


The New Modular House with Advanced Heating Controls

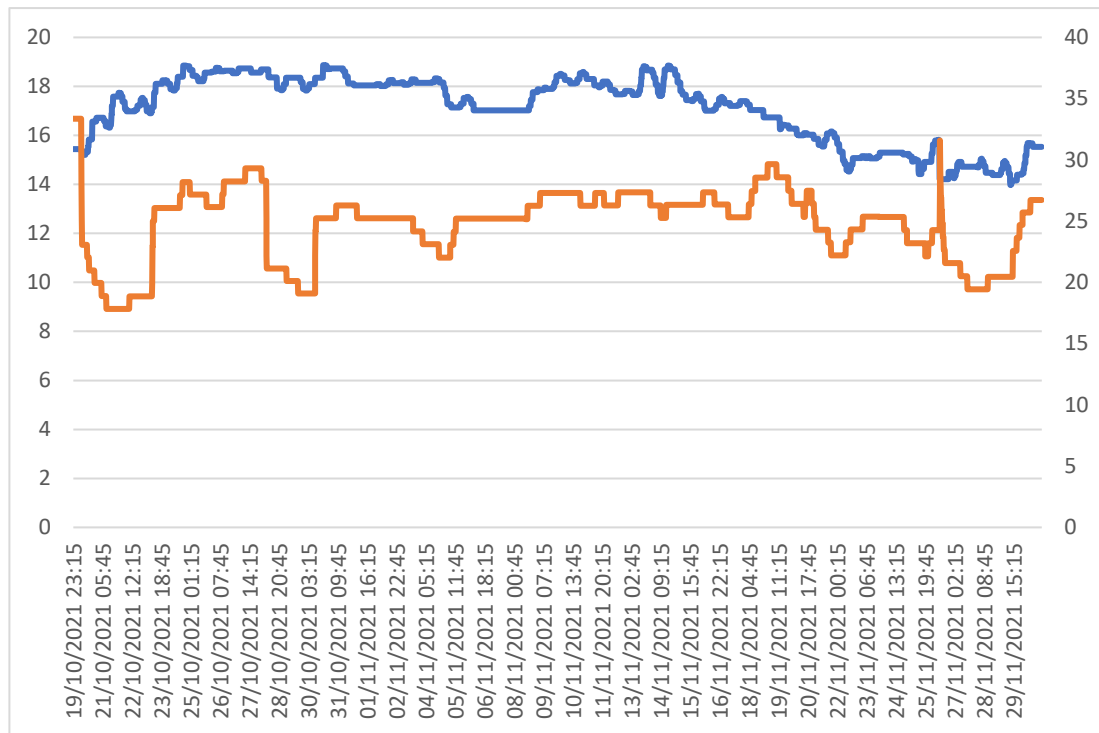
Outdoor data:



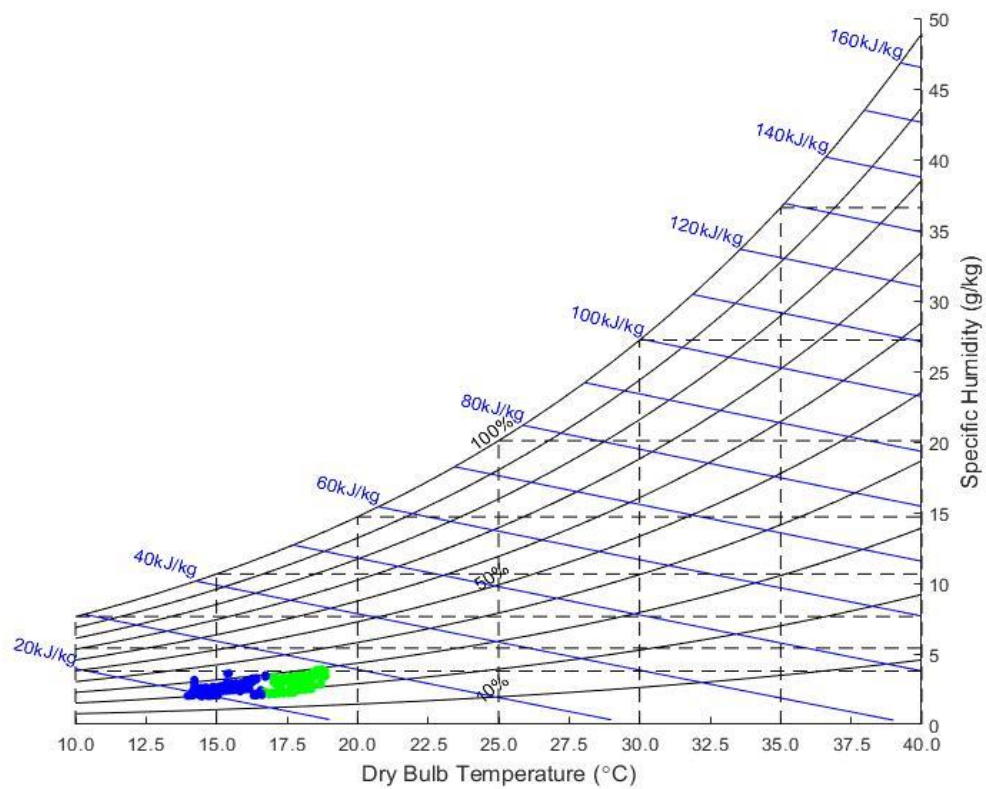
Outdoor comfort map output from the AI Model (Assumption Clothing value 1 clo, Activity 1.5 met, age 30 years); 10.27% in comfort condition



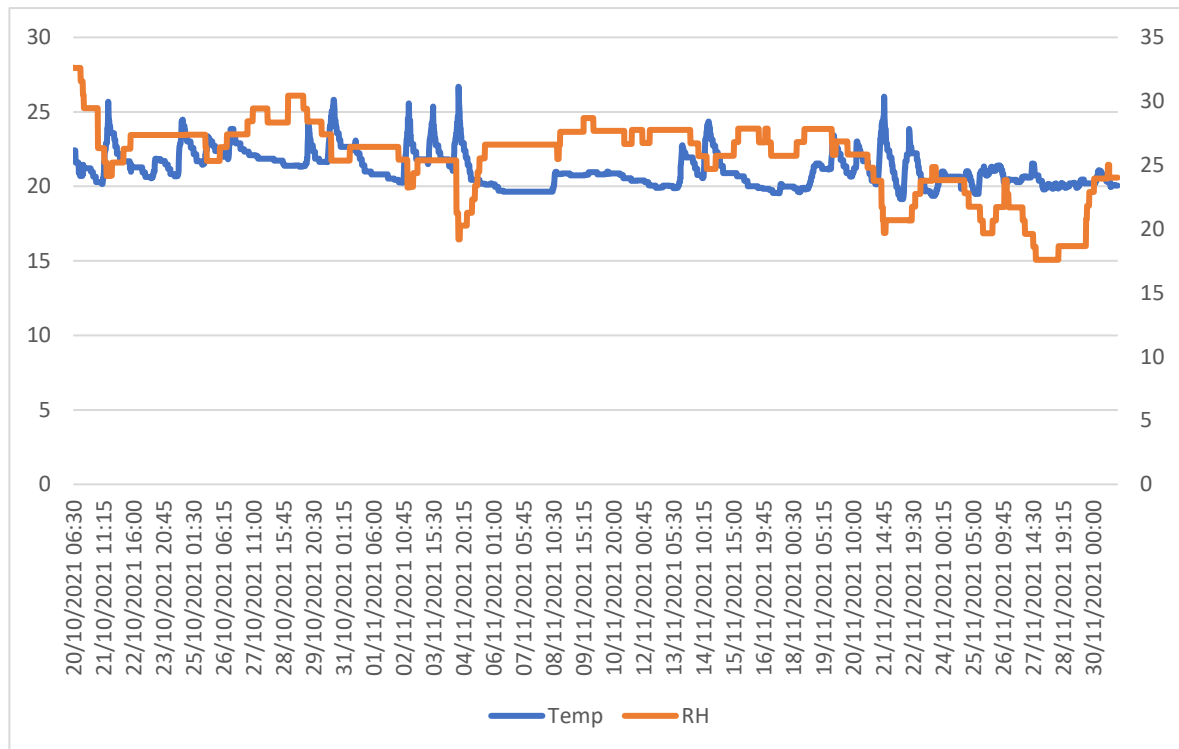
Backdoor data:



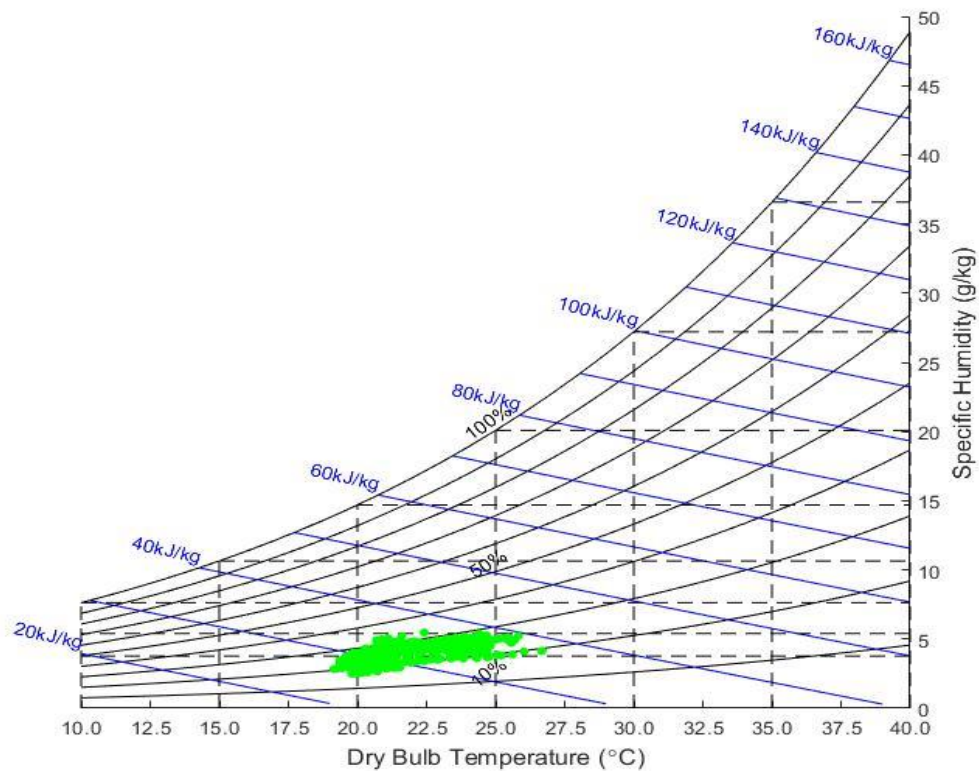
Backdoor comfort map output from the AI Model (Assumption Clothing value 1 clo, Activity 1.5 met, age 30 years); 68.08% in comfort condition



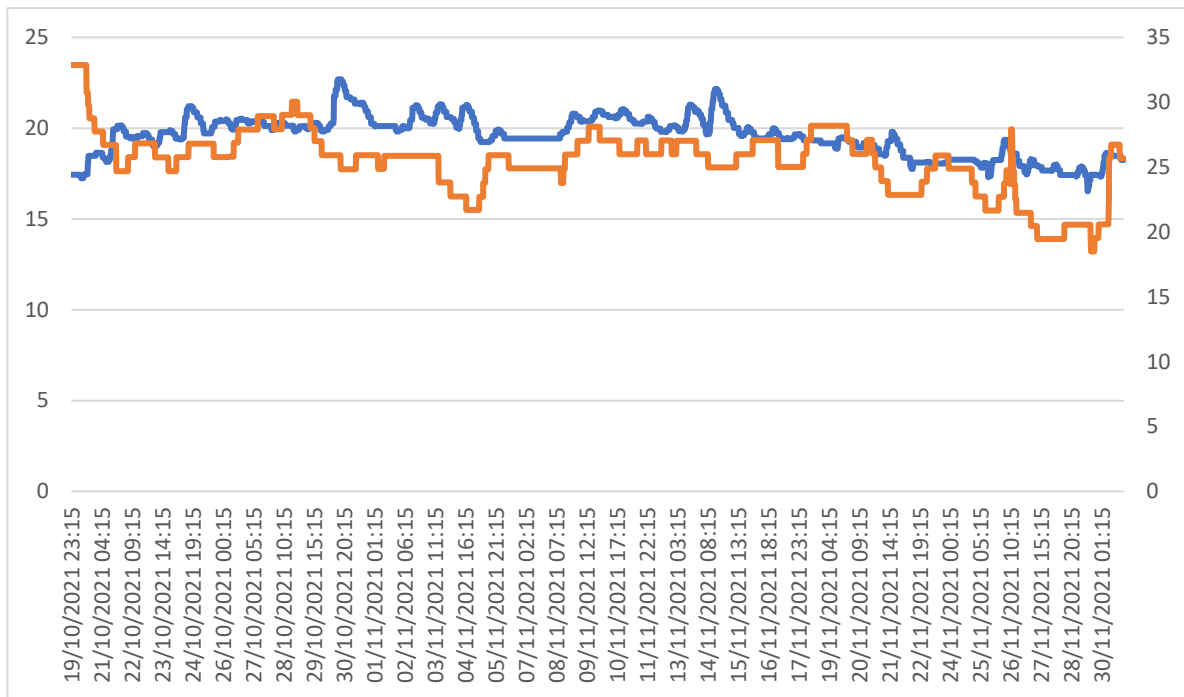
Master Bedroom data:



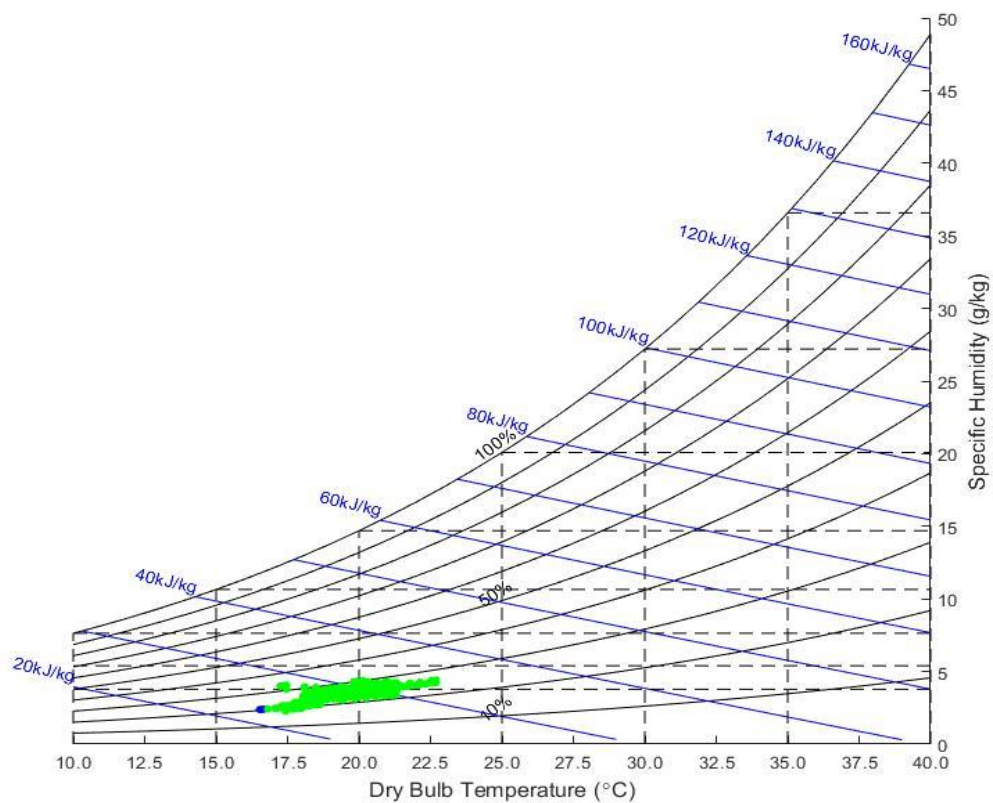
Master Bedroom comfort map output from the AI Model (Assumption Clothing value 1 clo, Activity 1.5 met, age 30 years); 100% in comfort condition



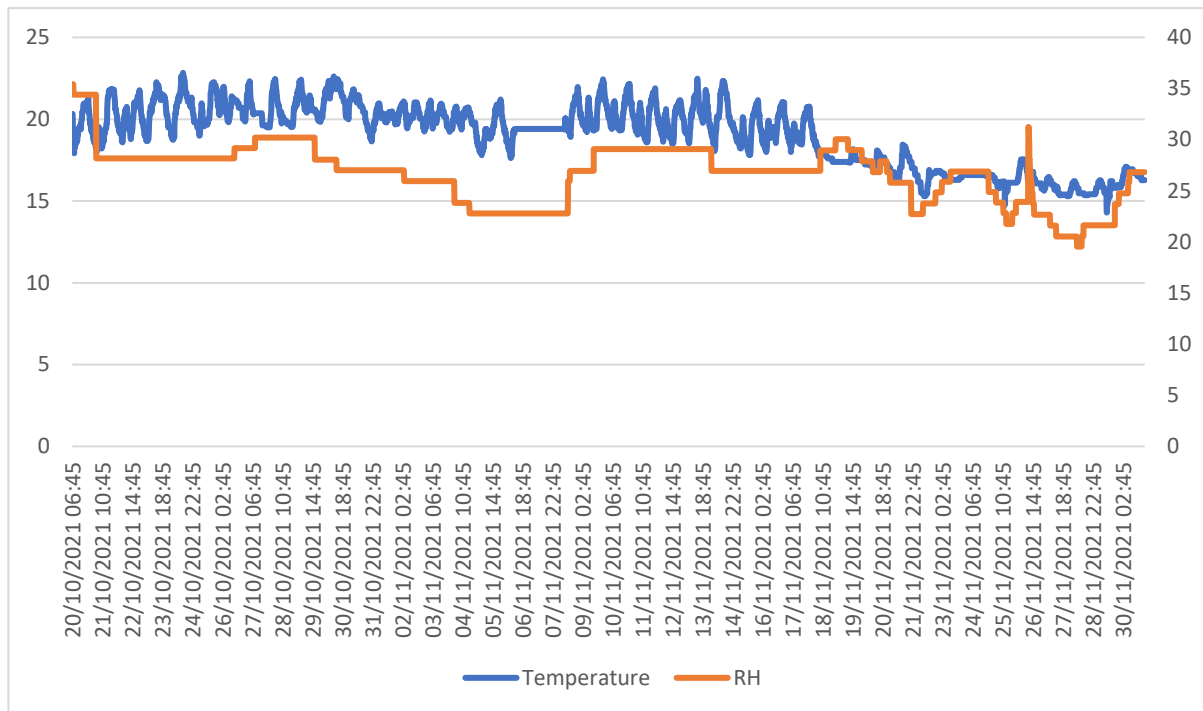
Living room data:



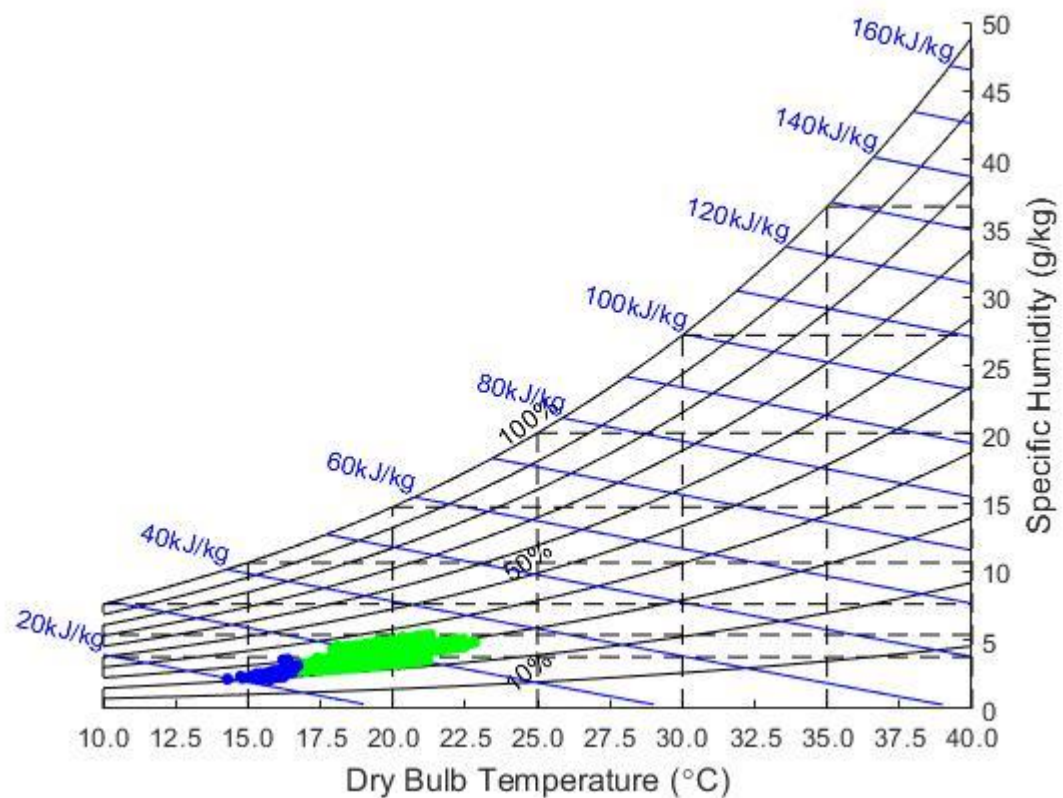
Living room comfort map output from the AI Model (Assumption Clothing value 1 clo, Activity 1.5 met, age 30 years); 99.90% in comfort condition



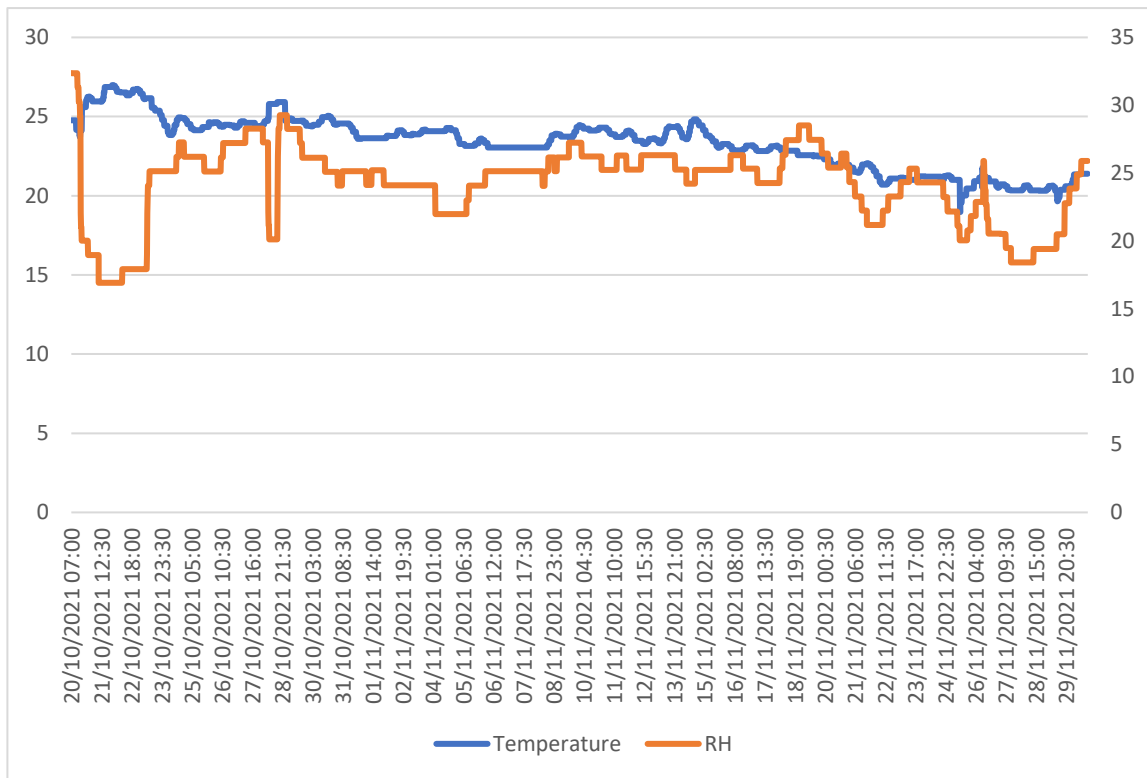
Stair's data:



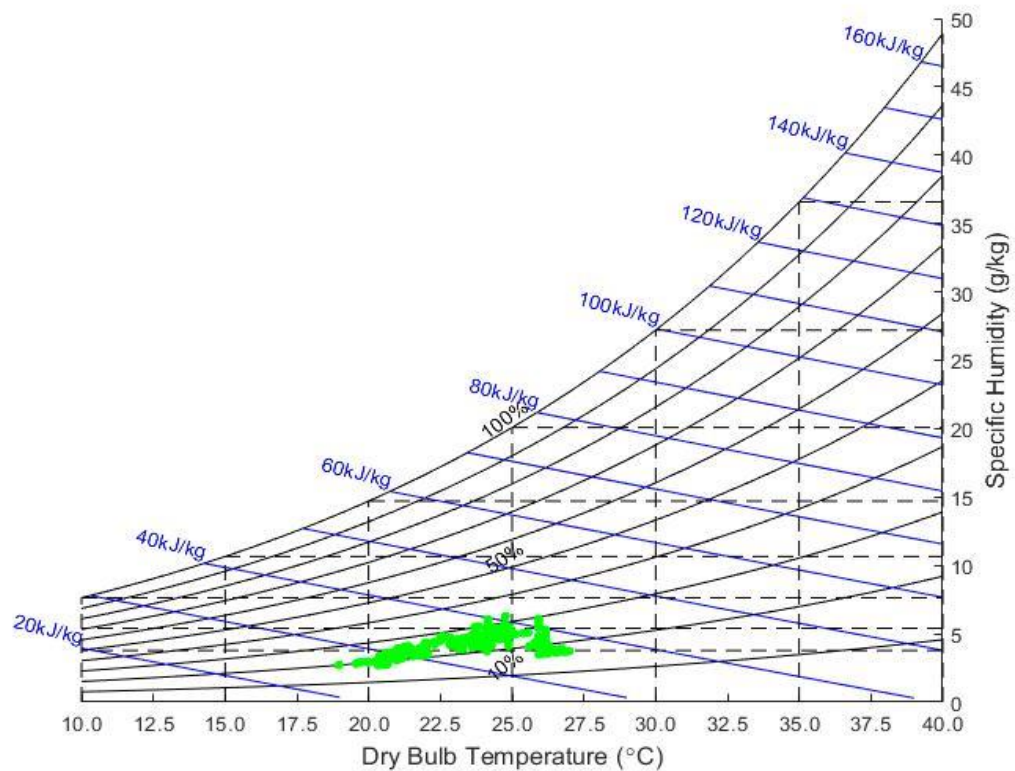
Stairs comfort map output from the AI Model (Assumption Clothing value 1 clo, Activity 1.5 met, age 30 years); 80.07% in comfort condition



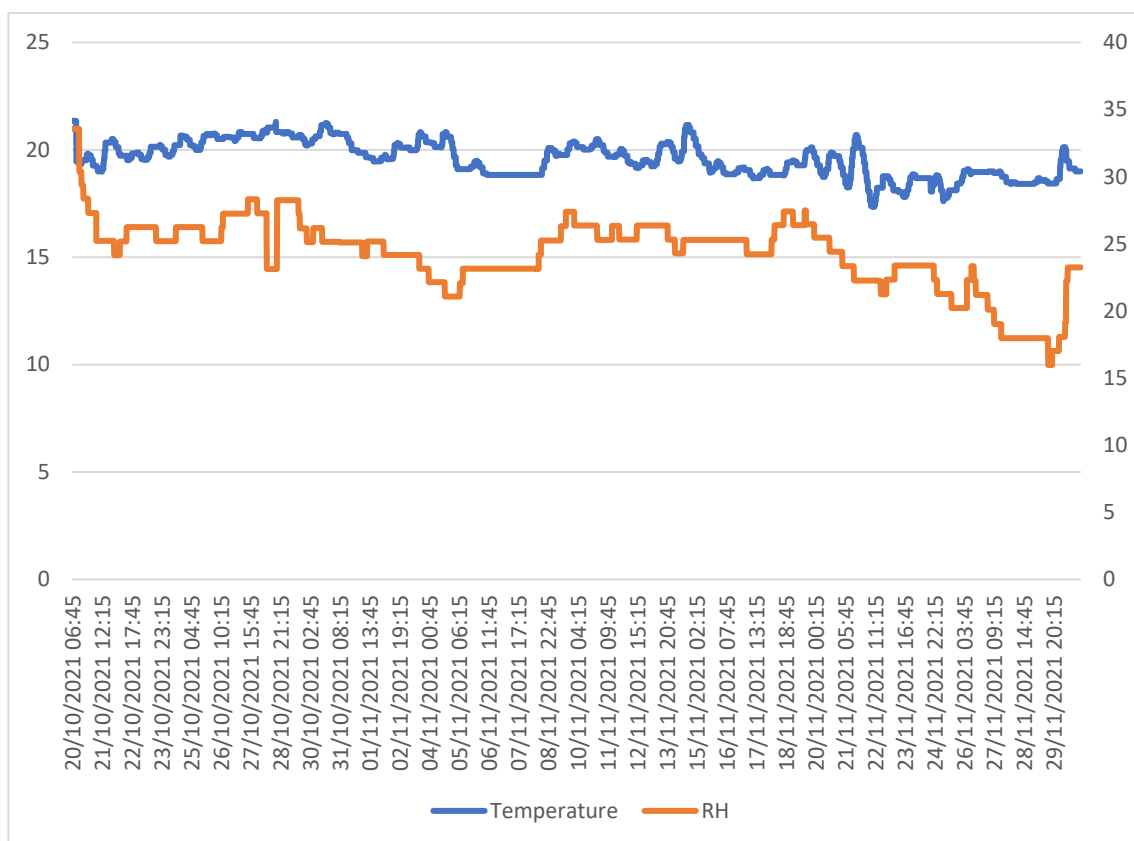
Kitchen data:



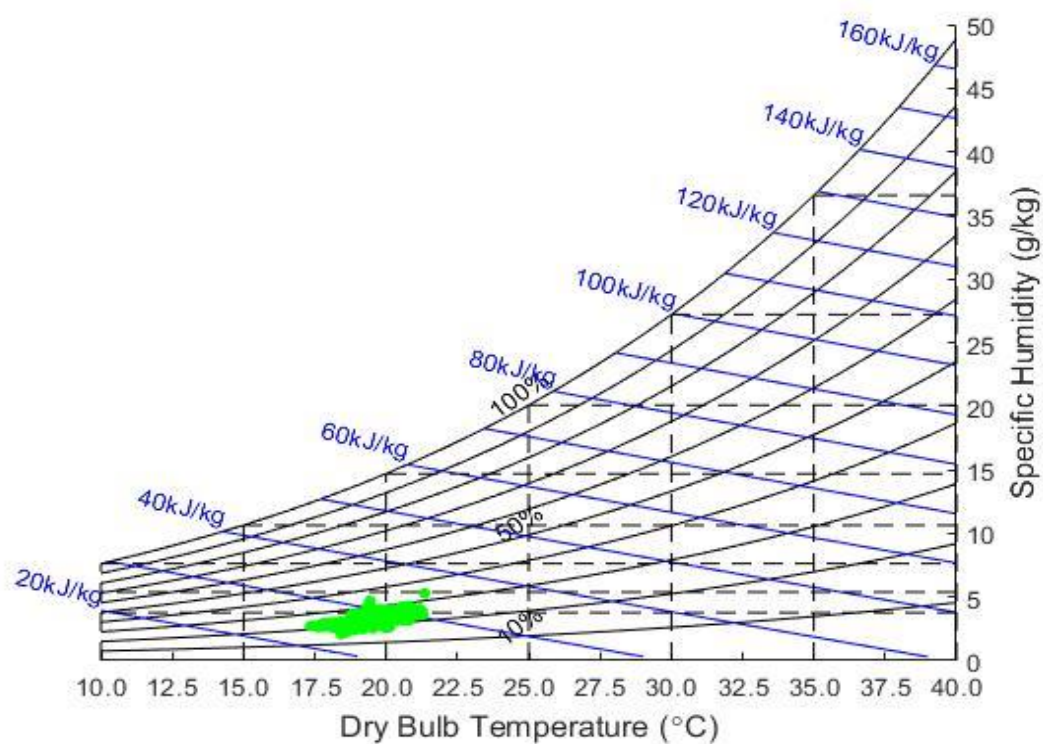
Kitchen comfort map output from the AI Model (Assumption Clothing value 1 clo, Activity 1.5 met, age 30 years); 100% in comfort condition



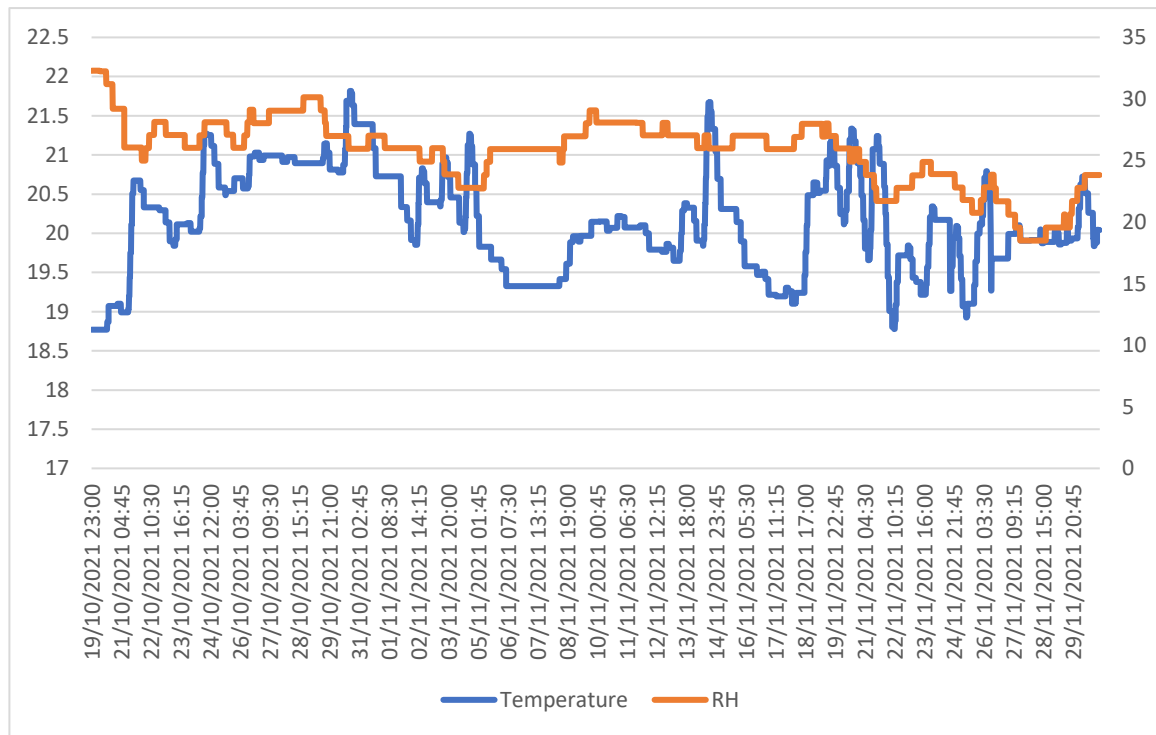
Landing data:



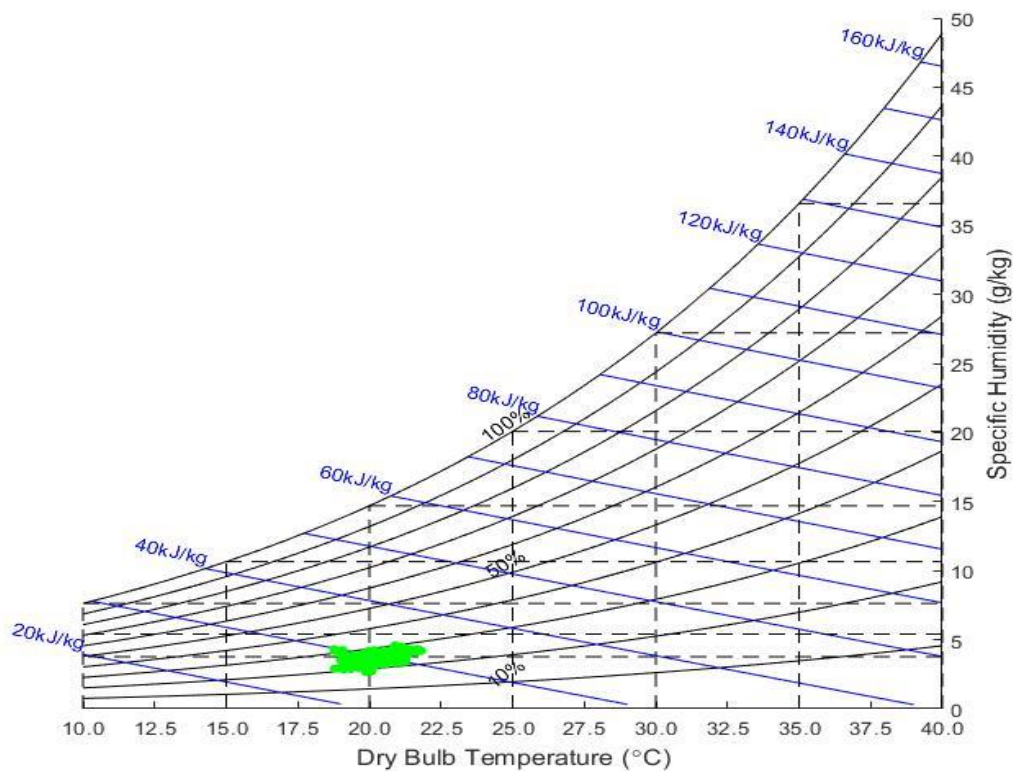
Landing comfort map output from the AI Model (Assumption Clothing value 1 clo, Activity 1.5 met, age 30 years); 100% in comfort condition



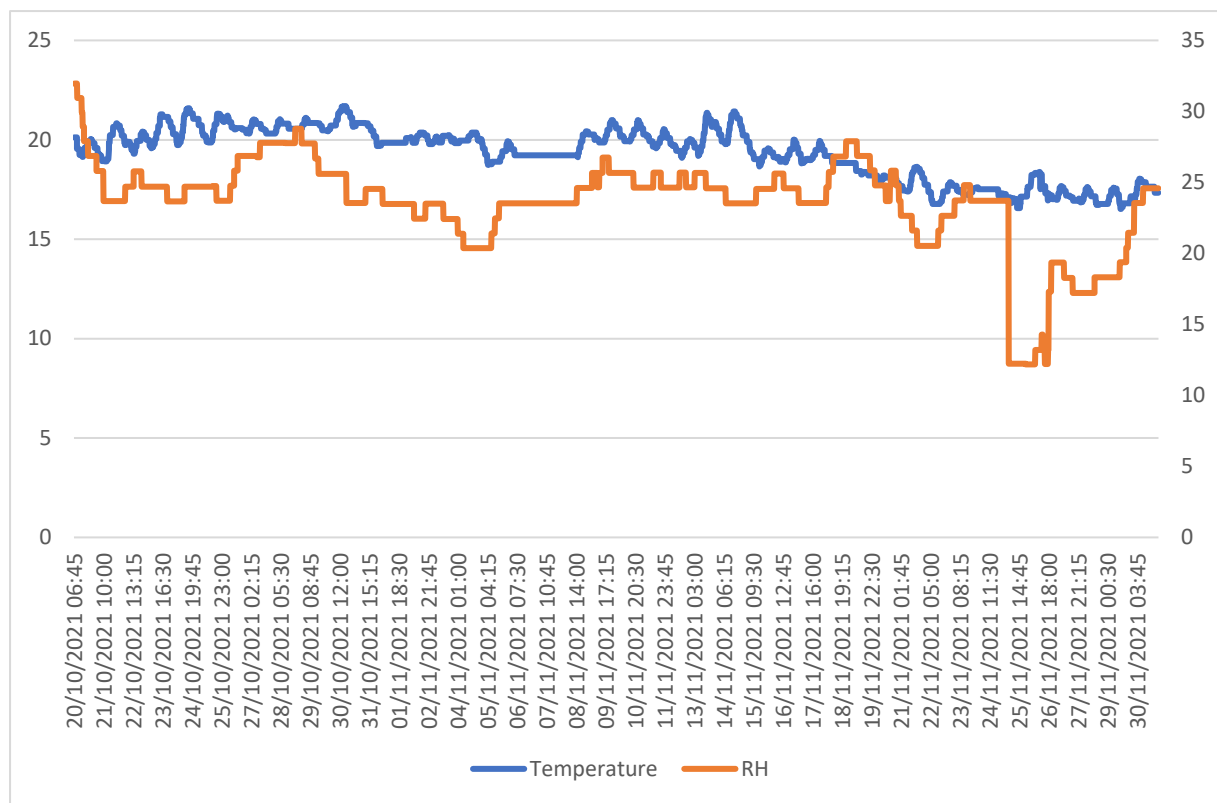
Bedroom data:



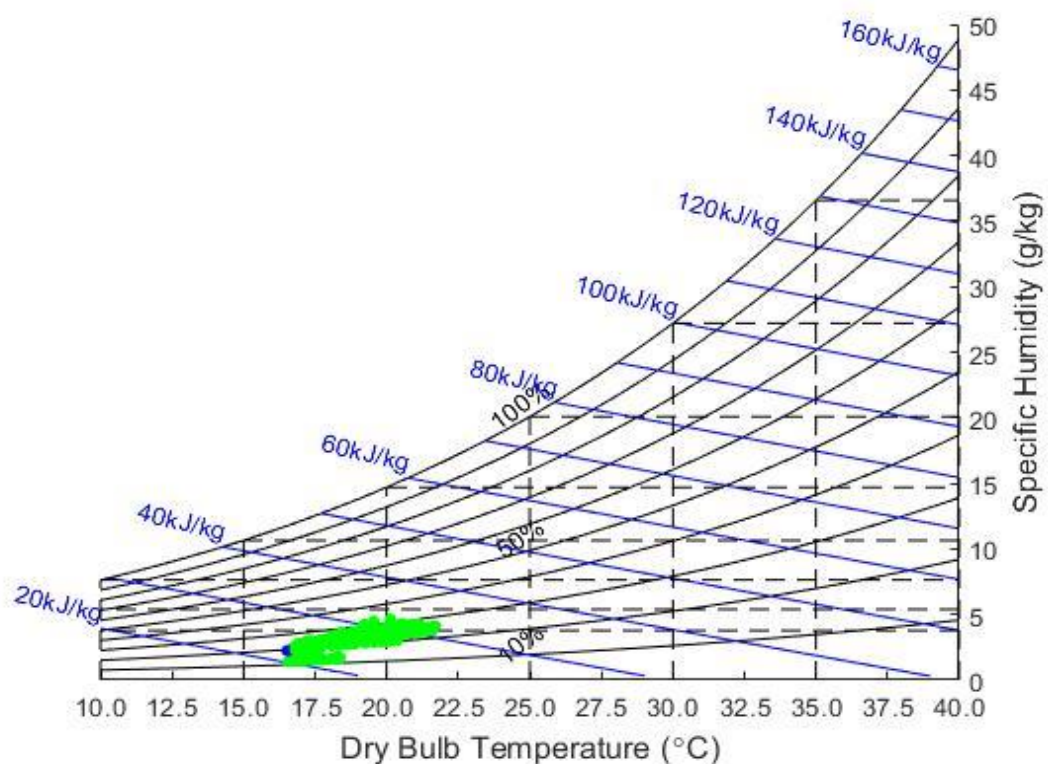
Bedroom comfort map output from the AI Model (Assumption Clothing value 1 clo, Activity 1.5 met, age 30 years); 100% in comfort condition



Dining room data:



Dining room comfort map output from the AI Model (Assumption Clothing value 1 clo, Activity 1.5 met, age 30 years); 99.78% in comfort condition



Appendix 11. The Example of the Questionnaire

Tennant Questionnaire

Name :

Date: /.../20...

Address:

House typology:

Heating system : (Please tick where applicable)

☐ boiler – type: ☐ gas ☐ oil ☐ electric ☐ other :

water heater: ☐ combi boiler ☐ Conventional ☐ other:

☐ furnace

☐ heat pump

Windows: (Please tick where applicable)

☐ single glazed ☐ double-glazed ☐ triple glazed ☐ roof window ☐ skylight

With ☐ Curtain ☐ Blinds

Ventilations: (Please tick where applicable)

☐ trickle ventilators in window frames ☐ passive stack ventilation ☐ extractor fans

☐ air bricks (external walls) ☐ other:

I. Heating and occupants' behaviour

- What was your thermostat temperature setting during the seasons?
 Spring : °C
 Summer : °C
 Autumn : °C
 Winter : °C
- Do you regularly adjust your thermostat depending on whether you are present in your home?

- If you also have other controls (e.g., thermostatic radiator valve and/or boiler controls) are these used often?

- Do you lower heating controls in certain rooms that are less inhabited to save on costs?

- Do you have any additional direct heating systems? If so, how many and how often do you use them?

- When you enter/leave a room in your home do you close internal doors?

7. Please complete the following tables to show at what hours you switch on/off your heating through the changing seasons. (We understand these are rough estimates, so please use memory and knowledge of daily habits to be as thorough as you can)

Spring:

Weekday		Weekend	
Switch ON	Switch OFF	Switch ON	Switch OFF

Summer:

Weekday		Weekend	
Switch ON	Switch OFF	Switch ON	Switch OFF

Autumn:

Weekday		Weekend	
Switch ON	Switch OFF	Switch ON	Switch OFF

Winter:

Weekday		Weekend	
Switch ON	Switch OFF	Switch ON	Switch OFF

8. How often are external doors (e.g., front/back door) kept open? Please specify changes in behaviour during the seasons.

Spring	
Summer	
Autumn	

Winter	

9. Please describe your window opening behaviour (e.g., how often do you open your windows and for what reason do you open them? Please specify any changes of behaviour during the seasonal changes)

Spring	
Summer	
Autumn	
Winter	

II. Occupancy

- How many people live in your home?
- Describe your family dynamic (e.g., retired couple, working couple, couple with young family and/or teenagers, single occupant etc.)
.....
.....
- Were there any significant changes in the household occupants during the testing period?
.....
- Can you identify typical working patterns in which occupants are away from your home (e.g., Mon - Fri 9 to 5, working 3 days per week, 25 hrs per week etc.)
.....
.....
.....
- During the testing time frame, have you had any extended periods (e.g., 2 days or more) when you have been away from your home?
.....

III. Moisture Generation, Humidity and Draught

1. How frequent is the bath and/or shower?
.....
2. How frequent are cooking appliances used if present? (e.g., hob, oven)
.....
.....
3. How frequent is an indoor clothes washer and/or dryer appliance used if present?
.....
.....
4. Do you find mould to be a problem in your home? (e.g., any surface condensation or mould growth on ceilings, wall-ceiling joints, around window bays, around wall-floor joints, on walls behind furniture, against external walls etc.)
.....
.....
.....
5. Is there frequently moisture/ice on windowpanes?
.....
.....
.....
6. Do you find draught to be a problem in your home? This is inclusive of draughts around windows, doors, from suspended floor (if present), service entry pipes, air bricks etc.
.....
.....
.....
7. How significant of a problem is the draught? (e.g., how does it affect the comfortability of your home?)
.....
.....
.....
8. Is there a notable difference in the draught depending on weather conditions? If so, please specify.
.....
.....
.....
9. Is there anything that you have done in an attempt to address the issue of draught?
.....

10. What is the frequency of operating blinds and/or curtains?

11. How do you use the ventilations? (e.g., are trickle vents always kept open? Have air bricks been blocked to reduce draughts etc? Are extract fans used during cooking and bathing etc?)

IV. Thermal Comfort

1. How do you feel about the temperature in your home at this moment? (Please tick the applicable.)

☐	Cold
☐	Slightly Warm

☐	Cool
☐	Warm

☐	Slightly Cool
☐	Hot

☐	Neutral
--------------------------	---------

2. Do you feel that the current temperature of your home is comfortable for you? (Please tick the applicable.)

☐	Much too Cool
☐	Comfortably Warm

☐	Too Cool
☐	Too Warm

☐	Comfortably Cool
☐	Much too Warm

☐	Comfortable
--------------------------	-------------

3. What would you like the temperature in your home to be? (Please tick the applicable.)

☐	Cooler
--------------------------	--------

☐	No Change
--------------------------	-----------

☐	Warmer
--------------------------	--------

4. How would you rate the overall acceptability of the temperature of your home at this moment? (Please tick the applicable.)

☐	Acceptable
--------------------------	------------

☐	Not Acceptable
--------------------------	----------------

5. How do you feel about the air movement in your home at this moment? Please (tick the applicable.)

☐	Too Still
☐	Slightly breezy

☐	Slightly still
☐	Too breezy

☐	Just Right
--------------------------	------------

6. What would you like the air movement in your home to be? (Please tick the applicable.)

☐	Increase movement
--------------------------	-------------------

☐	No change
--------------------------	-----------

☐	Decrease movement
--------------------------	-------------------

7. How do you feel about the humidity in your home at this moment? (Please tick the applicable.)

☐	Much too humid
☐	Slightly dry

☐	Too humid
☐	Too dry

☐	Slightly humid
☐	Much too dry

☐	Just Right
--------------------------	------------

8. What would you like the humidity in your home to be? (Please tick the applicable.)

☐	Increase humidity
--------------------------	-------------------

☐	No change
--------------------------	-----------

☐	Decrease humidity
--------------------------	-------------------

Thank you for your participation.