BRS - York ASHP Performance Testing

Quality Assurance

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Justification Of Research

The report aims to outline the performance outcomes derived the YORK YKF05CNC Air Source Heat Pump installation in the Vector Home, a recently constructed cradle-to-cradle, sustainable, modular and affordable smart home constructed from recycled materials, situated within the Energy House 2.0 environmental climate chamber. It will report our findings from measured data throughout various climatic conditions and aim to represent a standard property model.

The research considers two different heating patterns – 24h Constant heating, and the SAP heating pattern of 07:00-09:00 and 16:00-23:00, found in Table 9 of SAP 10.2 [1]. The internal setpoint temperatures were based on SAP, with a single-zone heating setup, set to 21 °C.

Test scenarios

Table 1: Test conditions

Test Ref	Internal Setpoint Temperature [°C]	External Temperature [°C]	Heating Pattern
5 °C Constant	21	5	Constant
5 °C SAP	21	5	SAP
-5 °C Constant	21	-5	Constant
-5 °C SAP	21	-5	SAP
-10 °C Constant	21	-10	Constant

ASHP Overview:

The York YKF05CNC is an air-to-water monobloc air source heat pump manufactured for the domestic heating market. The unit is designed to be positioned outside the property and houses the evaporator, fan assembly, compressor, condenser, and circulator.

York YFK ASHP Control Strategy:

York delegated an approved engineer to install the unit and under floor heating (UFH) as well as to commission and configure the control strategy to their specifications. The heat pump has been installed with a remote York controller in the dwelling lounge. This controls using a predetermined weather curve set to deliver a specific flow temperature to the properties UFH, optimising the unit's ability to match a predetermined space heating flow temperature to match the outdoor temperature.

York YKF05CNC ASHP Installer Commissioning Parameters

Table 2. York YKF05CNC ASHP Installer Commissioning Parameters

Heat Curve	ODT	Expected Flow Temp	Presumed Indoor Temp.
Set Point A	-5 °C	35 °C	21 °C
Set Point B	7 °C	28 °C	21 °C
Set Point C	21 °C	20 °C	21 °C

Refrigerant

The unit uses a hydrofluorocarbon (HFC) refrigerant named R32, covered by the Kyoto Protocol. This chemical has the characteristics below.

Table 3. Refrigerant

Name	Class	Chemical Formula	Boil (0 bar (g))	Safety Group	Unit Capacity	GWP	CO_2eq
R32	HFC	CH2F21	-49.55 °C	A2L	1.25 kg	675	0.84 tons

Heat Transfer Medium & Frost Protection

Table 4. Heat transfer medium

Fluid Used	Freezing Point (°C)	Density (kg/m^3)	Kinematic Viscosity (m^2/s)	Specific Heat Capacity (J/kg.K)
Monopropylene Glycol HP – 15C (33%)	-15	1030.8	3.32E-06	3818.8

Fernox HP –15C Glycol has been used as the transfer medium for the heat pumps primary pipework as well as the UFH system; this will mitigate any risks around freezing and frost damage but may attribute to a lower overall system efficiency due to the lower specific heat capacity (SHC) and higher viscosity of glycol as opposed to water. This arrangement introduces additional system circulator power consumption, adding to the parasitic energy losses over the system.

Under Floor Heating

The property has been installed with a Frankishe low profile UFH solution, installed throughout the floor layout on an open loop, single zone design, designed by the manufacture.

Vector Home Fabric Performance Overview

The testing for this project was carried out in a recently constructed test dwelling known as the Vector Home. The building was aimed to be a low carbon, energy efficient home with low construction and running cost. The building has the following characteristics, which have been measured in-situ by the research team:

U Values		
Element	**Area (m^2)**	**As-built U-value (W/m^2K)**
Windows	5.01	1.21
GRP Composite Door	1.88	0.52
French door	2.54	1.23
Floor	40.51	0.38
External walls	50.53	0.32
Ceiling	40.51	0.15
Airtightness = 4.4 $m^3/h{\cdot}m^2$ @ 50 Pa		
Heat Transfer Coefficient = 59.1		

Experimental Setup

Test Conditions

The aim of this series of tests was to provide a series of steady state and dynamic tests of the heating system on the Vector V1 property. This was carried out to obtain the following metrics:

- Air temperatures
- Energy output of ASHP
- Energy consumption
- Coefficient of Performance (COP)
- Running costs
- System Energy Efficiency Indicator (SEEI)

Internal and chamber environments

The tests were split into two categories, "constant" heating pattern and "SAP" heating pattern.

- **Constant**: The test houses were heated continuously over each 24h period.
- **SAP**: The test houses were heated using the SAP pattern of 07:00-09:00 and 16:00-23:00.

The internal setpoint temperatures were based on SAP with a 21 °C setpoint in the single zone. The following test setup was followed for all tests:

- All external doors and windows were locked and shut throughout testing.
- All lighting and appliances were turned off for the duration of the tests.
- Measurement equipment was powered by an external source.
- The building was unoccupied.
- No curtains or blinds used.

Table U1 of SAP10.2 [1] was used to select external temperatures representative of the UK average during the winter months (December to February). All tests were conducted at both a constant 5 °C, constant -5 °C and constant -10 °C chamber temperature. The 5 °C was deemed typical of the UK average winter temperature, whereas the -5 °C was used to measure the heating system performance under more extreme UK winter conditions. The -10 °C was to test the performance of the system under extreme/atypical UK conditions. No solar, wind or rain was used through the testing.

Test duration

To minimise any thermal mass effects resulting from charging and discharging of the building fabric, each test was a minimum of 72 hours in duration. The initial 48-hour period allowed the test houses to reach a state of dynamic equilibrium[1]. The final 24-hour period for each test was the reporting period.

[1] Previous tests at the Energy House Labs have shown that 24-hour periods following the initial 48-hour stabilisation period produce repeatable results thereafter [2].

Measurement and analysis

Setpoints

The aim of the tests was to compare the experimental work with the setpoints (21 °C in a single zone) and schedules (07:00-09:00, 16:00-23:00) found in SAP [1].

Measurands

The following variables were monitored throughout each test at a one-minute time interval:

- House:
  - Air temperature in 4 locations as marked on Figure 1
  - Electrical energy consumption of the ASHP
  - Heat meter output on ASHP primary flow and return
- Chamber:
  - Air temperature at 36 points
  - Relative humidity at 36 points

It is worth noting that the building is elevated and is not in direct contact with the chamber soil.

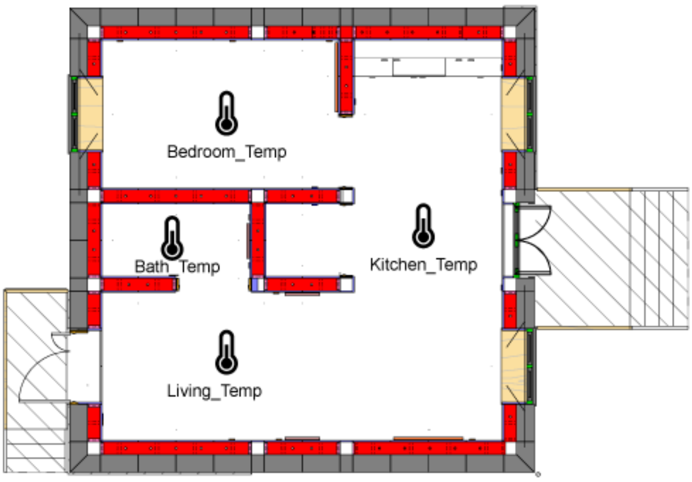

Figure 1. Internal temperature sensor locations

Table 5: Measurement equipment used in the Energy House 2.0 York ASHP performance tests.

Measurement	Equipment	Uncertainty[2]
Room air temperatures	hygroVUE 10 (20 to 60 °C) [3]	±0.1 °C
Chamber air temperatures	hygroVUE 10 (–40 to 70 °C) [3]	±0.2 °C
Relative humidity	Campbell Scientific HygroVUE10 [3]	±1.5%
Electrical energy monitor	ABB EQ B21 (MID class b) [4]	±1%
Heat Meter	Sontex Superstatic 749 [5]	±1%

[2] uncertainties were taken from supplier data sheet.
[3] [3]
[4] [4]
[5] [5]

Measurement Technique

All measurements were taken at one minute time intervals.

Internal Conditions

All temperature measurements within the homes were conducted as follows:

Air Temperature:

- 24-hour (Daily), seven-hour (Evening heating period), two-hour (Morning heating period) Averages
    - One minute temperature data averaged over the above period used in plotting and calculation of SEEI

Electrical Energy Consumption:

- ELVACO
    - measured at one-minute intervals for the ASHP
    - Summed over 24h for daily figures

Heat Meter output:
Heat meter energy output only increased per kWh, so was calculated for better resolution as follows:

- 1 minute flow temperature, return temperature, volume per min, and specific heat capacity value was obtained
    - Specific heat capacity value was measured at 20 °C using a refractometer and compared to manufacturers charts
- The following equation was used:

$$Q = \frac{(\dot{m} \cdot 1000) \cdot C \cdot (T_{Flow} - T_{Return})}{3600000}$$

- Where:
    - Q is heat meter energy in Wh
    - $\dot{m}$ is volume flow per minute in m^3/min
    - C is the measured specific heat capacity in J/(kg.K)
    - T_{Flow} is the flow temperature in °C
    - T_{Return} is the return temperature in °C

Coefficient of Performance (COP):
The COP was based on the boundary conditions defined in the Electrification of Heat Demonstration Project report [6]. All COP's considered within this report are defined as COP_{H4}, including the ASHP unit and circulation pump and represents the performance of the entire space heating system.

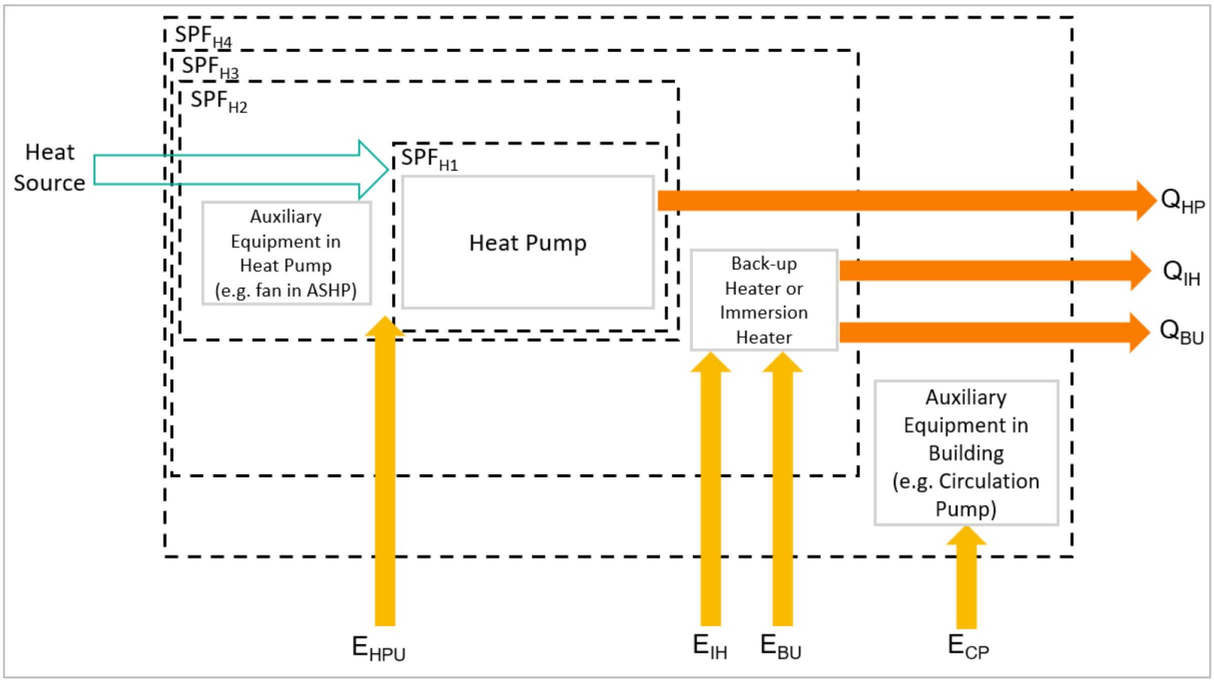

Figure 2: SPF system boundaries used to calculate coefficient of performance (COP) values. Test conditions meant that the immersion heater (E_{IH} and Q_{IH}) was not used in this test [6].

The COP was therefore calculated as:

$$COP = \frac{24h\ Heat\ Meter\ Output\ [kWh]}{24h\ System\ Electrical\ Energy\ Consumption\ [kWh]}$$

[6]Diagram Source: [6]

System Energy Efficiency Indicator (SEEI):

The SEEI is a metric created by the research team to attempt to compare heating systems performance, accounting both the energy consumption of the system, and the system's ability to heat the property. It indicates how much the average internal temperature of the property will increase per unit energy consumption.

The SEEI has been calculated as follows:

$$SEEI\ \left[\frac{K}{kWh}\right] = \frac{T_{Internal}\ [°C] - T_{Chamber}\ [°C]}{E_{Electric}\ [kWh]} \equiv \frac{\Delta T\ [K]}{E_{Electric}\ [kWh]}$$

Chamber Conditions

- Air Temperature, Relative Humidity
    - Plotting 24h plots
    - Averaged over 24h period for use in SEEI calculation.

Results

The results detailed in this section are taken from the final 24h period of a minimum 72h test. This is to ensure that stable conditions have been met.

Vector 5 °C York UFH Constant

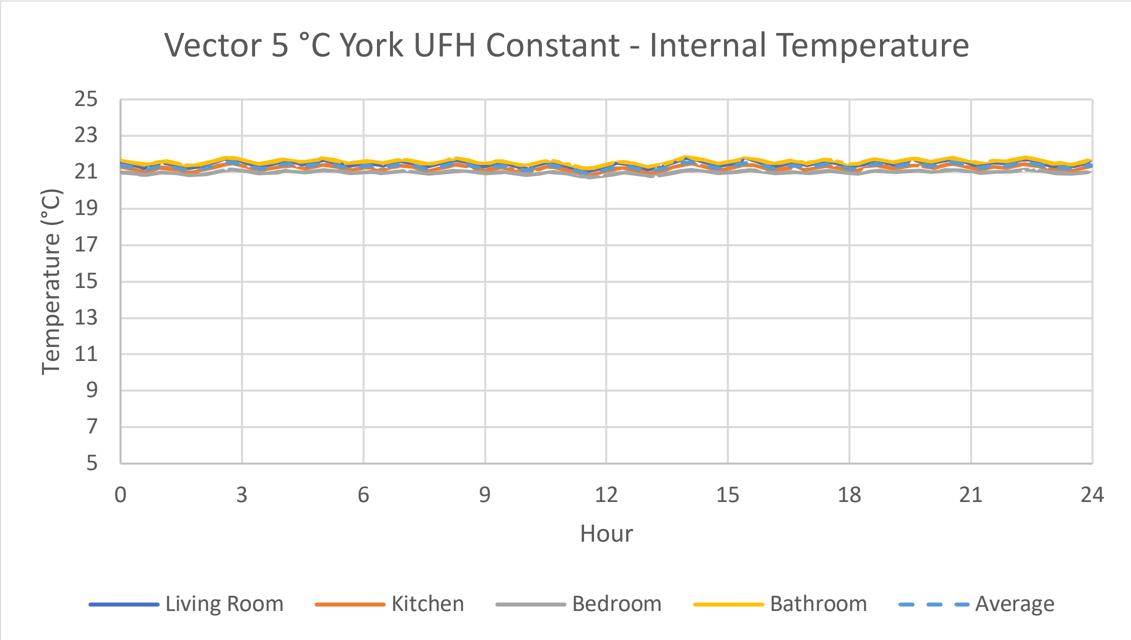

Figure 3. Vector 5 °C York UFH Constant - Internal Temperature

- Good temperature control, all values withing ±1 °C of setpoint temperature.

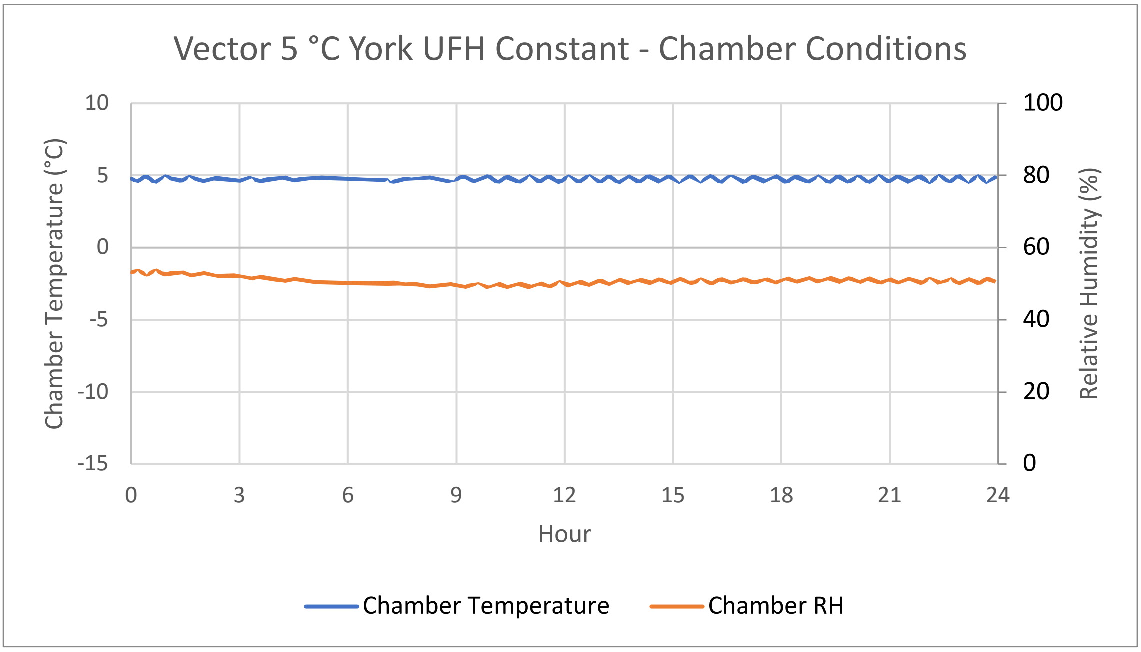

Figure 4. Vector 5 °C York UFH Constant- Chamber Conditions

Vector 5 °C York UFH SAP

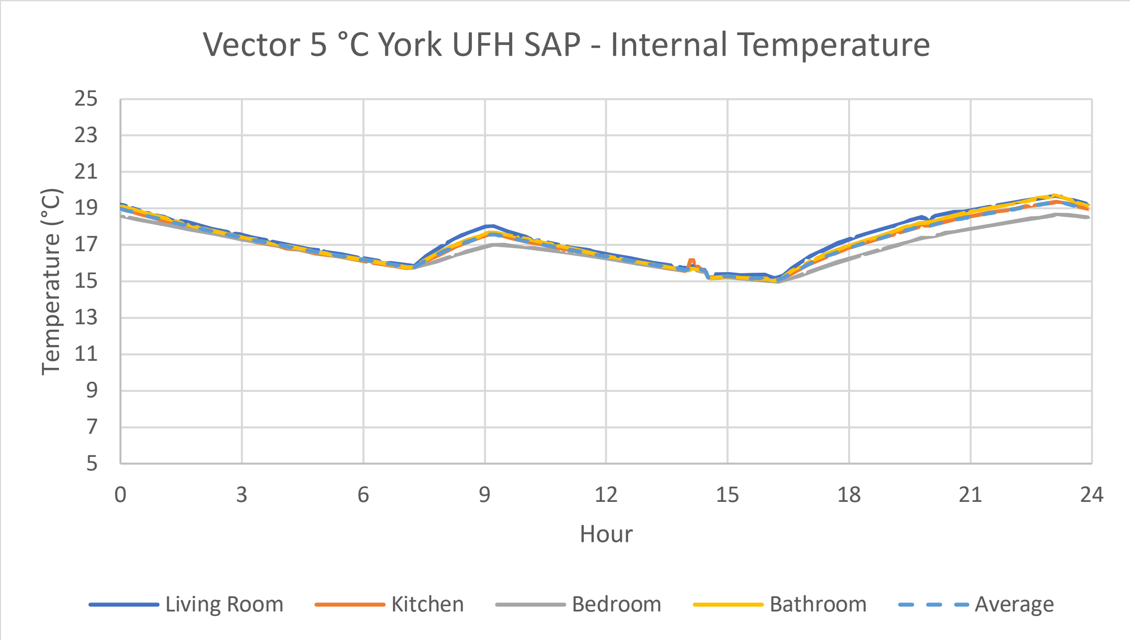

Figure 5. Vector 5 °C York UFH SAP - Internal Temperature

- Did not achieve setpoint in either the morning or evening heating period
- Reached a minimum temperature of ~15 °C
- Maximum temperature AM: ~18 °C, PM: ~19.5 °C

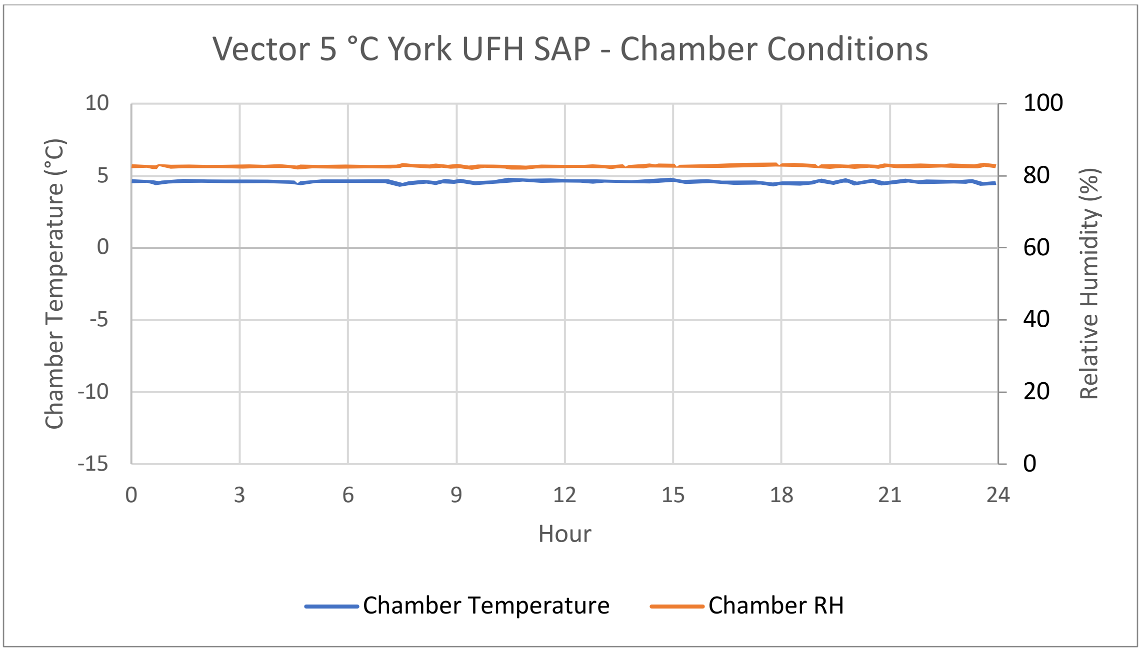

Figure 6. Vector 5 °C York UFH SAP - Chamber Conditions

Vector-5 °C York UFH Constant

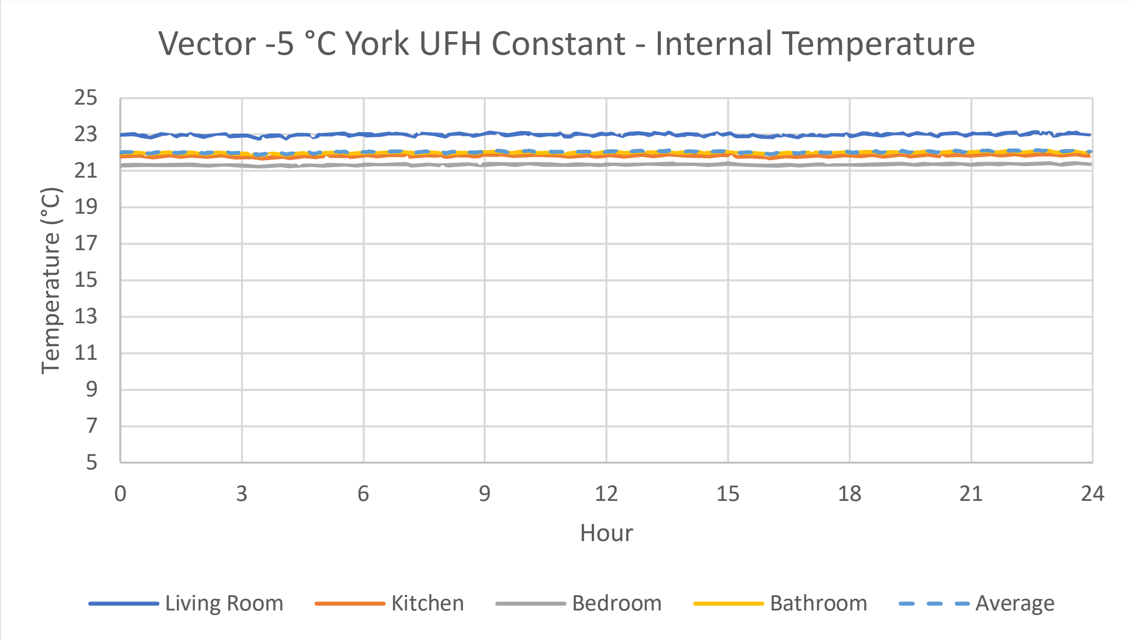

Figure 7. Vector -5 °C York UFH Constant - Internal Temperature

- Low levels of hysteresis
- All zones achieved setpoint, with good control (±1 °C), Living Room overshot the setpoint by ~2 °C

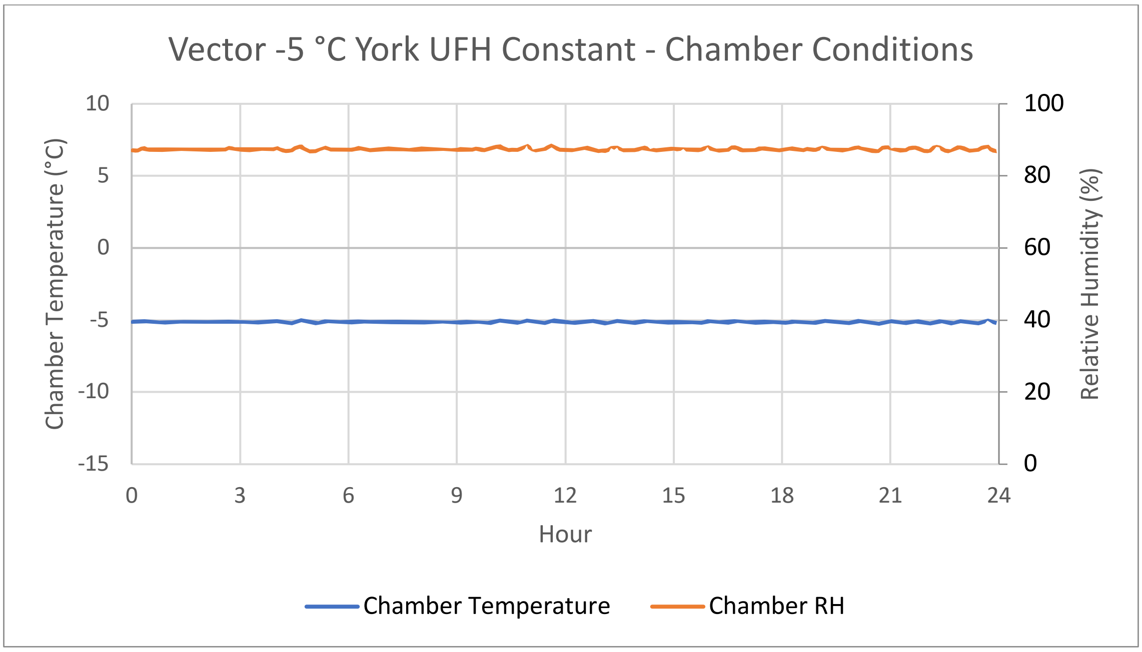

Figure 8. Vector -5 °C York UFH Constant - Chamber Conditions

Vector-5 °C York UFH SAP

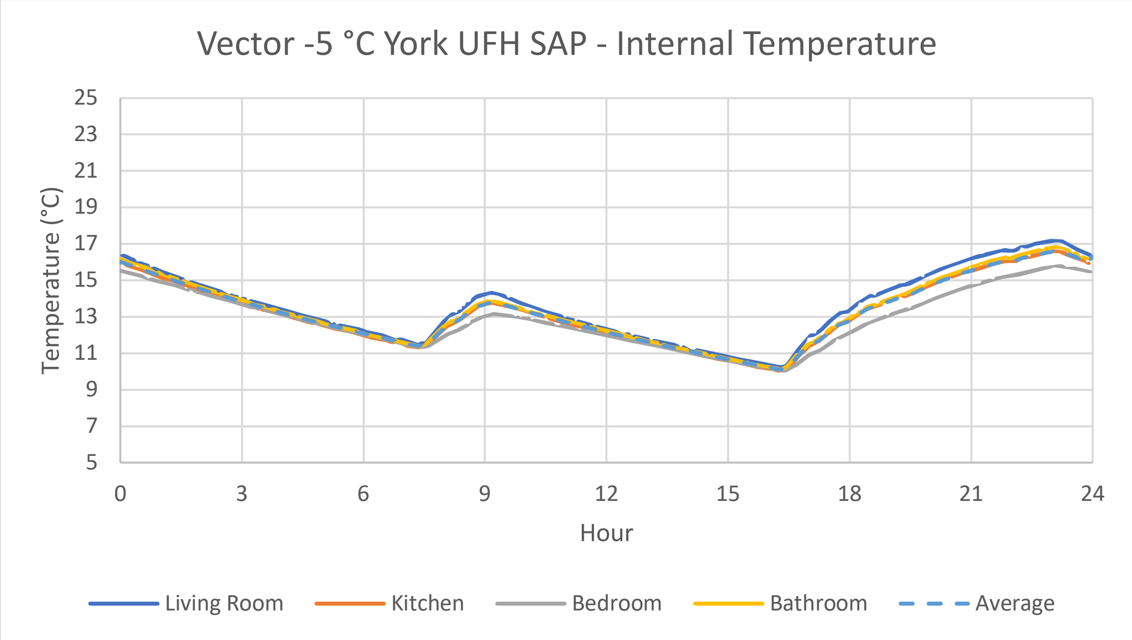

Figure 9. Vector -5 °C York UFH SAP - Internal Temperature

- Did not achieve setpoint in either the morning or evening heating period
- Reached a minimum temperature of ~10 °C
- Maximum temperature AM: ~14 °C, PM: ~17 °C

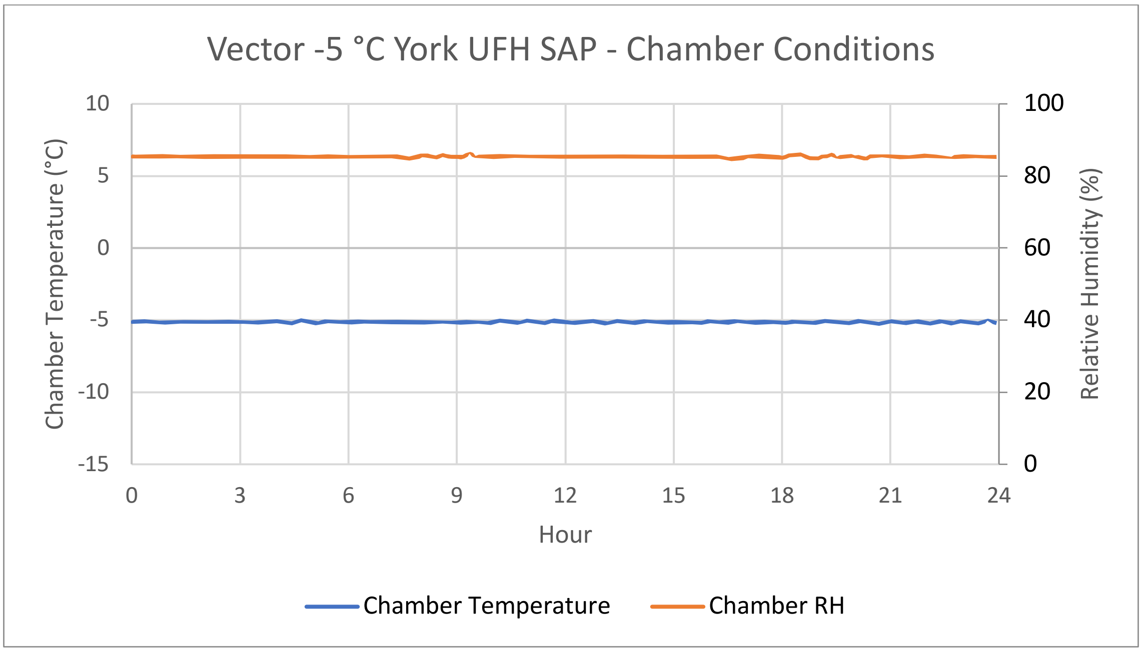

Figure 10. Vector -5 °C York UFH SAP - Chamber Conditions

Vector-10 °C York UFH Constant

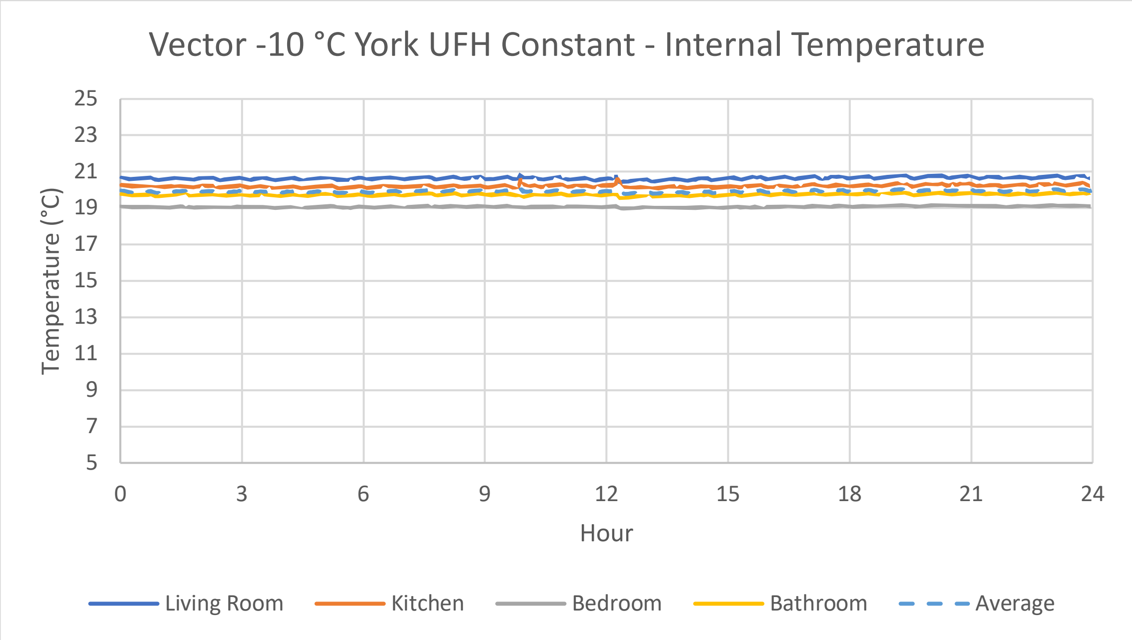

Figure 11. Vector -10 °C York UFH Constant - Internal Temperature

- Low levels of hysteresis
- Temperatures ranging between approx. 19-21 °C
- All areas just below the setpoint

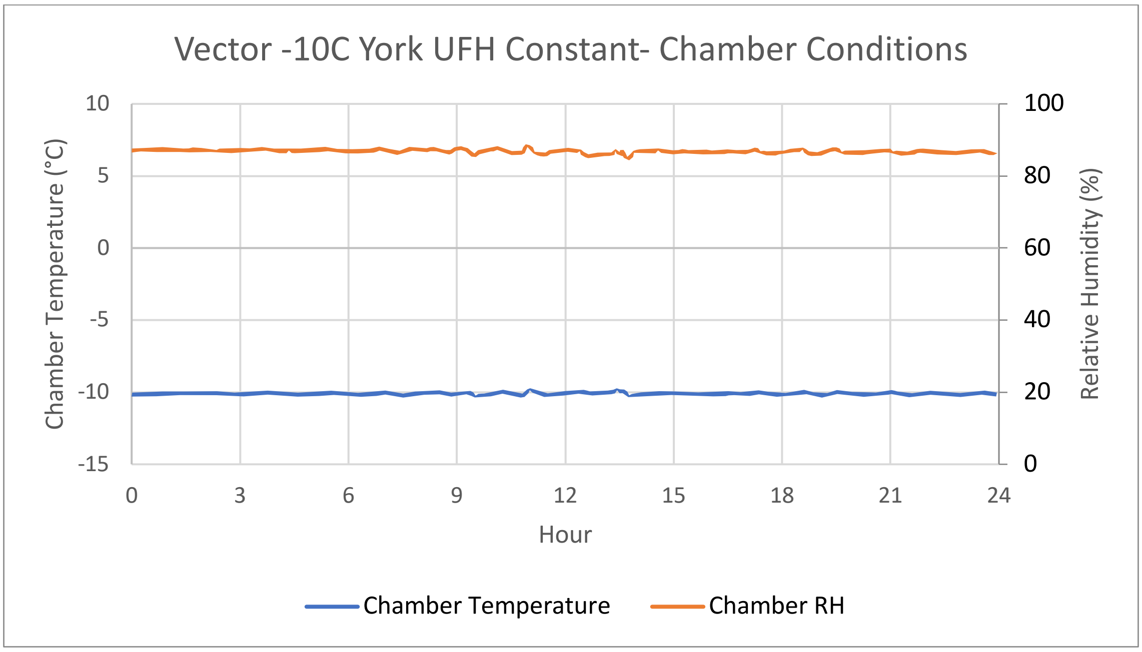

Figure 12. Vector -10 °C York UFH Constant- Chamber Conditions

Results Summary

The following section presents a comparison across all test scenarios. Figure 13 shows the COP for all tests. The greatest COPs were achieved during the 5 °C tests. Although better COP's were achieved during SAP heating patterns compared to constant, it should be noted that the setpoint temperature was never achieved during the SAP heating pattern.

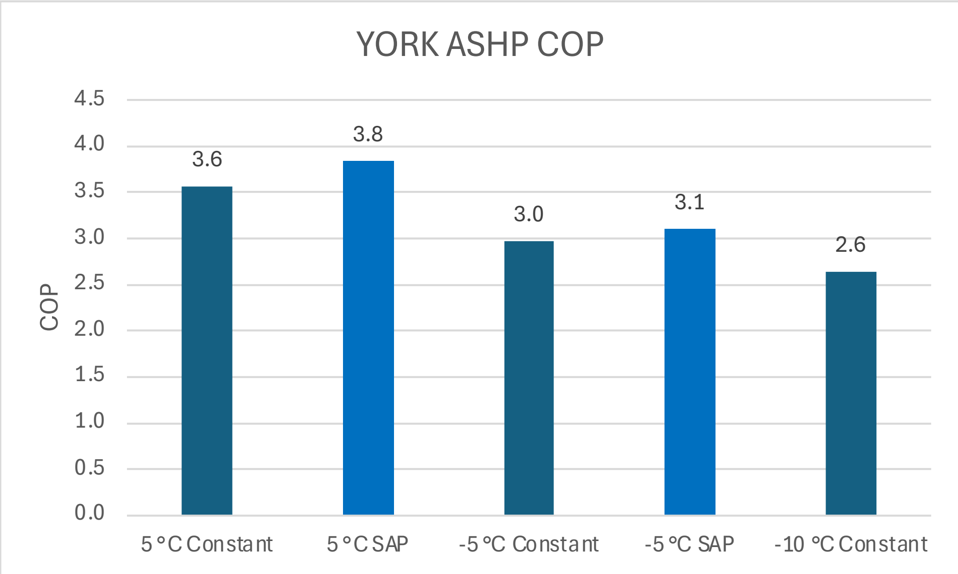

Figure 13: Comparison of all COPs

The same pattern is observed in the system energy efficiency indicator (SEEI) (Figure 14). The system achieves a greater SEEI at higher chamber temperatures, and SAP tests achieving greater indicators than their respective constant tests.

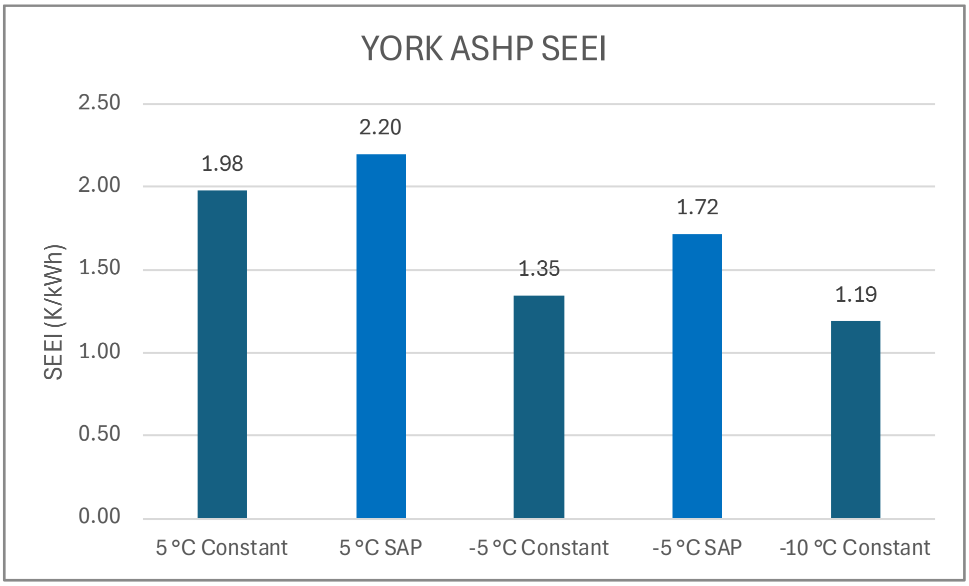

Figure 14. System Energy Efficiency Indicator

Energy running costs were calculated using the Ofgem electric energy price cap of 24.50p/kWh for the period 1st October to 31th December 2024 [7].

When considering a typical UK winter day, it would cost £2.05 per day to run the York ASHP in a constant heating pattern (Figure 15). Energy consumption, and therefore running cost, increases as chamber temperature decreases. SAP heating profiles consume less energy than their respective constant tests, however this is at the expense of internal comfort levels.

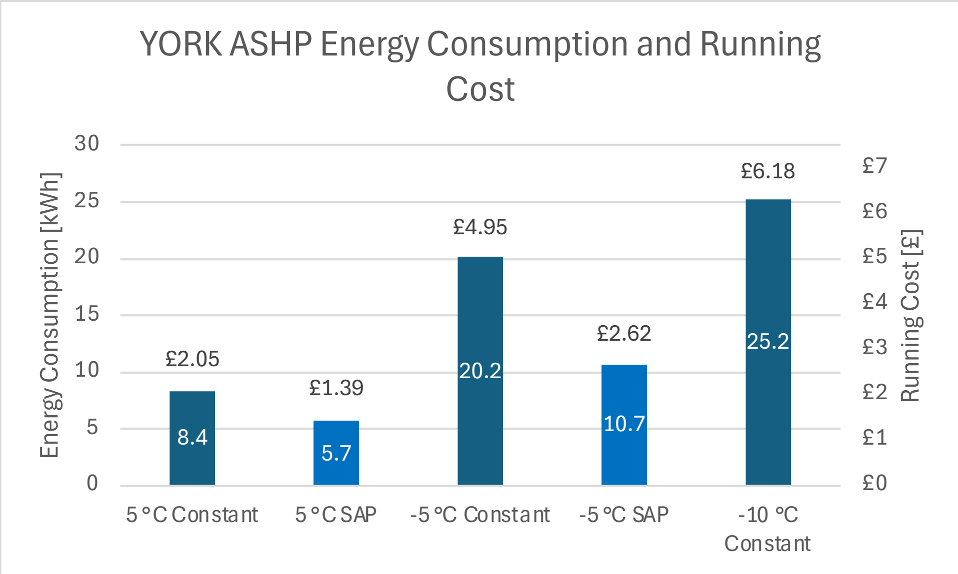

Figure 15. Energy consumption and running costs

Figure 16 shows all constant heating patterns tests were within ±1 °C of the 21 °C setpoint, with the -10 °C chamber temperature test achieving ~20 °C internally. All SAP tests did not achieve the 21 °C setpoint, noticeably in the -5 °C SAP test.

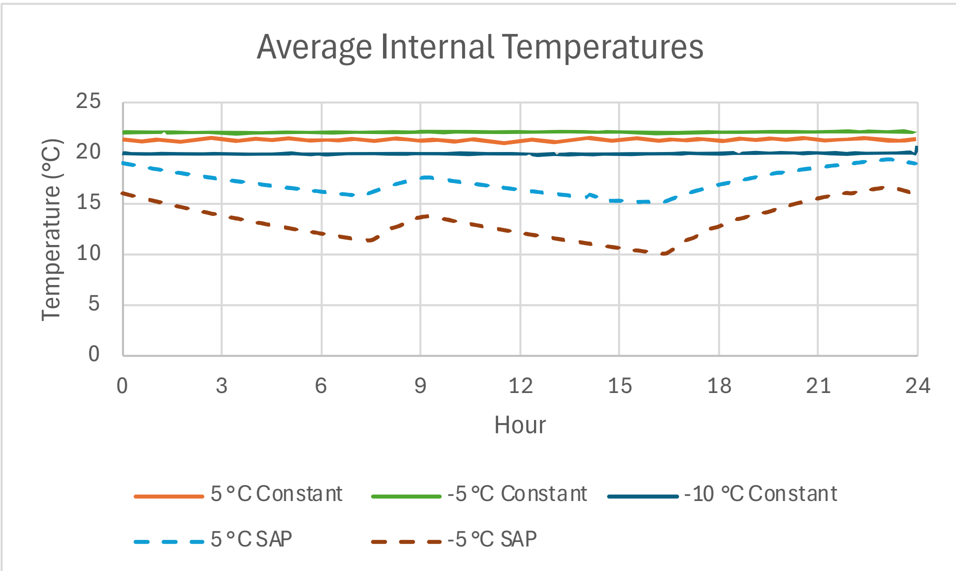

Figure 16. Average internal temperature time series

Table 6 presents all energy related metrics across all tests of the York ASHP.

Table 6: Summary of all tests

Test Ref	**ASHP Consumption (kWh)**	**COP**	**24h Running Cost**	**SEEI (K/kWh)**
5 °C Constant	8.4	3.6	£2.05	1.98
5 °C SAP	5.7	3.8	£1.39	2.20
-5 °C Constant	20.2	3.0	£4.95	1.35
-5 °C SAP	10.7	3.1	£2.62	1.72
-10 °C Constant	25.2	2.6	£6.18	1.19

Figure 17 presents a scatter plot showing the relation between the York ASHP COP under a constant heating pattern and the chamber temperature. A linear regression through the three points shows that the COP increases by 0.06 for every 1 °C increase in chamber temperature.

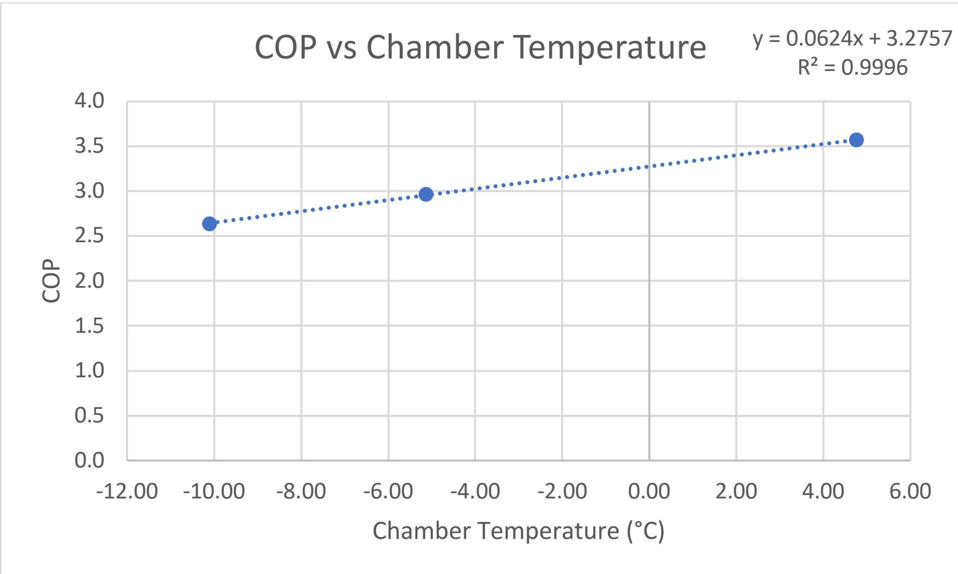

Figure 17. Scatter plot of COP vs chamber temperature

Conclusion

The York ASHP was tested under a variety of chamber conditions and external temperatures. It is worth noting that ASHP's are not advised to be run under a SAP heating pattern without the introduction of a setback temperature, to allow for the system to be able to achieve the setpoint within the morning/evening heating periods, however, the SAP heating pattern is what is currently used for the UK energy model.

In terms of both COP and SEEI, the system performed best under a SAP heating pattern, at a 5 °C chamber temperature (COP = 3.8; SEEI = 2.20 K/kWh). However, it must be noted that when operating under an SAP pattern, the internal environment did not achieve the 21 °C Setpoint temperature.

When subjected to a constant heating pattern, the internal environment achieved the setpoint temperature, with minimal hysteresis, for **all** chamber temperatures (5 °C, -5 °C and -10 °C). Again, the greatest COP and SEEI was observed during the 5 °C chamber temperature (COP = 3.6; SEEI = 1.98 K/kWh).

Further research may focus on the use of setback setpoints between SAP heating periods to assess impact on ASHP heating provision and energy use.

References

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