CREST - Centre for Renewable Energy and Sustainable Technologies

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Abstract

CREST – Centre for Renewable Energy and Sustainable Technologies at South West College is one of the most sustainable buildings in the UK and Ireland. This building achieves the Passive House, BREEAM Excellent, and net Carbon Zero building standards. This paper presents an overview of the post occupancy performance data since completion in 2014. The key findings that are presented include:

- Monitoring data of the space heating demand to date.
- Overview of the indoor air quality (IAQ) and ventilation performance to date.
- Generation data of the solar photovoltaic technology.

Introduction

CREST – Centre for Renewable Energy and Sustainable Technologies is led by South West College which is a Further and Higher Education College, located in the south west region of Northern Ireland. The college currently is developing into becoming the Passive House Centre of Excellence for the Northern Ireland region. This is being achieved through the operation of the centre, which provides passive house demonstration and offers the designers and tradesperson courses to the local construction industry.

The Passive House Certified CREST Pavilion in Figure 1 was completed in November 2014 with the purpose of being a demonstration building for passive house design principles and renewable technologies. It is the first educational building in Northern Ireland to have Passive House Certification. The building is distinguished by three key building standards:

1) Passive House Certified.
2) Building Research Establishment Environmental Assessment Method (BREEAM) Excellent.
3) Net Carbon Zero.

Whilst a combination of two of these sustainable criteria has been carried out in other parts of the UK, this was the first example of a combination of all three.

Figure 1: The CREST Pavilion with design featured solar control in brise-soleil and large overhangs.

Climate in Northern Ireland versus South Pacific Region

It is important to outline that the CREST Pavilion is located in the cool temperate climate of Northern Europe. This is in contrast to the warm / tropical climate of the South Pacific region. The local climate has a significant impact on the performance of a passive house building, most notably the average temperatures and solar radiation. Climate data is used to help calculate the space heating/cooling demand and the heating/cooling load within the Passive House Planning Package (PHPP). The climate data sets for Northern Ireland (GB0022a – Belfast-Aldergrove) along with climate data sets for Melbourne (AU0001a Melbourne), Christchurch (NZ0003a-Christchurch) and Auckland (NZ0001a-Auckland) are presented in order to capture the contrast between the regions.

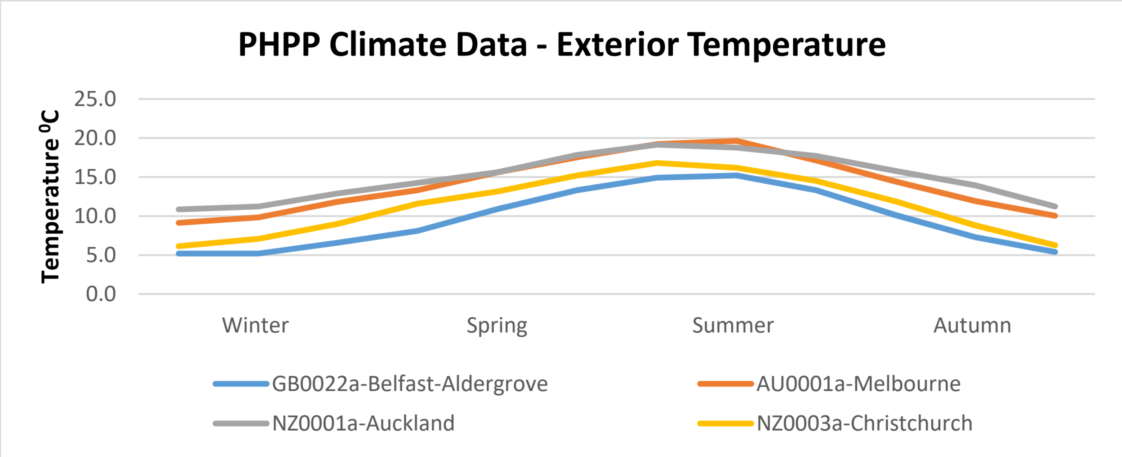

Figure 2: PHPP Climate Data of the Exterior Temperatures across the Seasons for the four locations.

Figure 2 presents the four sets of outdoor temperature climate data across the four seasons. There is a similar pattern between the four locations. However, annual average temperatures show that Auckland and Melbourne are warmer with similar averages of 14.1°C and 14.9°C, respectively. The annual average temperatures between Belfast and Christchurch are comparable at 9.6°C and 11.4°C, respectively.

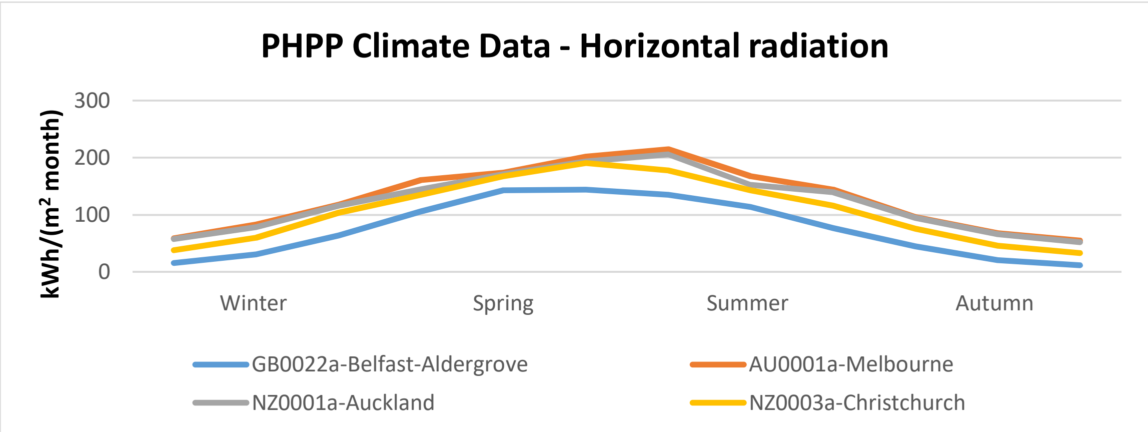

Figure 3: PHPP Climate Data of the Horizontal radiation across the Seasons for the four locations.

Figure 3 shows the average monthly horizontal radiation figures from the PHPP for the four locations across the seasons. Again, there is a general pattern between the four locations. However, this time there is a clear difference between the Northern Ireland and the southern hemisphere locations. The gap between Belfast and Christchurch is again closer than Belfast and the others for horizontal radiation.

As outlined in a relevant paper that focused on building passive houses in sub tropical climates by [Leardini 2013] *"A myth concerning New Zealand is its 'tropical' climate and the consequent low performance required for residential buildings. Lying midway between Antarctica and the tropics (34°-47° latitude South), New Zealand's climate has a wide variation from the 'winterless North' to the deep South with chilled winters approaching those of European regions of similar latitude."* (Ireland 51°-56° latitude North)

Location	Belfast	Melbourne	Auckland	Christchurch
Annual Average Temp	9.6°C	14.1°C	14.9°C	11.4°C
Annual High Temp	15.2°C	19.6°C	19.1°C	16.8°C
Annual Low Temp	5.2°C	9.1°C	11.2°C	6.1°C
Dew Point Temp	6.6°C	8.7°C	11.2°C	6.8°C
Summer Average Temp	12.6°C	18.8°C	18.5°C	16.0°C
Winter Average Temp	6.6°C	9.6°C	11.1°C	6.5°C
Global Horizontal Radiation	908 kWh/m²/a	1543 kWh/m²/a	1474 kWh/m²/a	1288 kWh/m²/a
Heating Degree Hours	70kKH	34kKH	22kKH	56kKH

Figure 4: Includes various PHPP Temperatures, Heating degree hours and Annual Horizontal radiation figures for the four locations.

Figure 4 presents various temperatures, the heating degree hours and the annual global horizontal radiation data for the four locations. This again underlines comparable figures between Belfast and Christchurch and in particular average winter temperature, dew points, and annual high and annual low. This corresponds with research examining the Planning Criteria for Passive Houses in New Zealand. *"The potential of solar radiation for passive heating in winter, combined with the mild temperatures, forms a good basis for implementing the Passive House concept."* [Grove-Smith & Schnieders 2010]

The important differences of the four climates can be summarised as follows:

I. The monthly mean outside temperatures are 4.5 – 5.3 °C higher in Melbourne and Auckland than in Belfast throughout the whole year. The average monthly mean outside temperature in Christchurch is only 1.76 °C higher than in Belfast.
II. The global horizontal radiation is similarly high at all four locations during summer. Melbourne receives the most solar radiation with a figure of 1543 kWh/ (m²a), followed by Auckland 1474 kWh/ (m²a) and Christchurch 1288 kWh/ (m²a). Belfast has a lower figure for solar radiation of 908 kWh/ (m²a).
III. The heating degree hours in kilo Kelvin hours (kKH) are highest for Belfast at 70kkH followed by Christchurch at 56 kKH, with Melbourne and Auckland being lower again with figures of 34kkH and 22kKH.
IV. Average winter temperatures in Belfast and Christchurch are almost identical at 6.6°C and 6.5°C with Melbourne and Auckland again providing a contrast with higher winter average temperature figures of 9.6°C and 11.1°C.
V. The Dew point temperatures also follow at pattern with Belfast and Christchurch being 6.6°C and 6.8°C, Melbourne and Auckland has again higher figures of 8.7°C and 11.2°C.

Building Performance

Space heating Demand

Heating for the building is provided via an air to water heat pump, with under floor heating distribution. The Passive House Planning Package (PHPP) calculates the annual heating demand using both the annual method and the monthly method.

- Monthly method 13.0 kWh/ (m^2a) or 5,902 kWh/a.
- Annual method 11.3 kWh/ (m^2a) or 5,138 kWh/a.

The calculated total annual space heating demand is thus 13.0 kWh/ (m^2a). Assuming current standard electricity rates in Northern Ireland £0.15/kWh, then the predicted annual cost of heating the building excluding standard charges should be in the region of £885 for a building with a floor area of 455m^2. This compares very favourably with the South West College (SWC) estate average of 103kWh/ (m^2a), which for a building of the same size would imply annual space heating costs of approximately £7,030. That represents an 87% saving on heating.

Monitoring data via the Building Management System (BMS):

- Year 1 recorded 11.6 kWh/ (m^2a) or 5,283 kWh/a.
- Year 2 recorded 12.1 kWh/ (m^2a) or 5,488 kWh/a.

The recorded performance of the space heating for Year 1 was 5,283 kWh/a. Again, assuming current standard electricity rates of £0.15/kWh [Power NI], then the annual cost of heating the building excluding standard charges in Year 1 was £792.45. The recorded performance of the space heating for Year 2 was 5,488 kWh/a. Therefore, annual cost of heating the building excluding standard charges in Year 2 was £823.20.

This was a slightly better than expected performance in contrast to the predicted annual heating demand calculated in the PHPP. In addition to the monitoring, we know the corridor under floor heating zone is rarely active due to the full length south facing glazing running the length of the corridor. This was suggested as the main reason for the monitored heat demand being less than the designed heat demand.

Ventilation

The Building Management System (BMS) optimises the performance of the building. It controls and monitors the key services including ventilation, windows, and indoor air quality. It constantly gathers data from internal monitors (e.g. temperature, carbon dioxide, relative humidity), responding according to user settings and preferences. It is also linked to an on-site weather station which measures external temperature, wind speed and rainfall similar to a previous paper [Clarke 2015]. User experience of the BMS controlled motorised windows is negative. They have been prone to faults with two actuator brackets needing to be replaced at CREST. The programmed controls prevent opening during periods of low external temperature and rain, thus causing problems for the facility management team.

Ventilation is provided by two passive house certified Mechanical Ventilation Heat Recovery (MVHR) units in the building. The auxiliary electricity consumption of the MVHR was monitored since the completion of the building. In Year 1 the total recorded was 415 kWh/a. In Year 2 the total recorded was 399 kWh/a. This was again slightly better than the PHPP calculated auxiliary electric demand for the ventilation system which is 431 kWh/a; however, it was within 10% of this predicted figure.

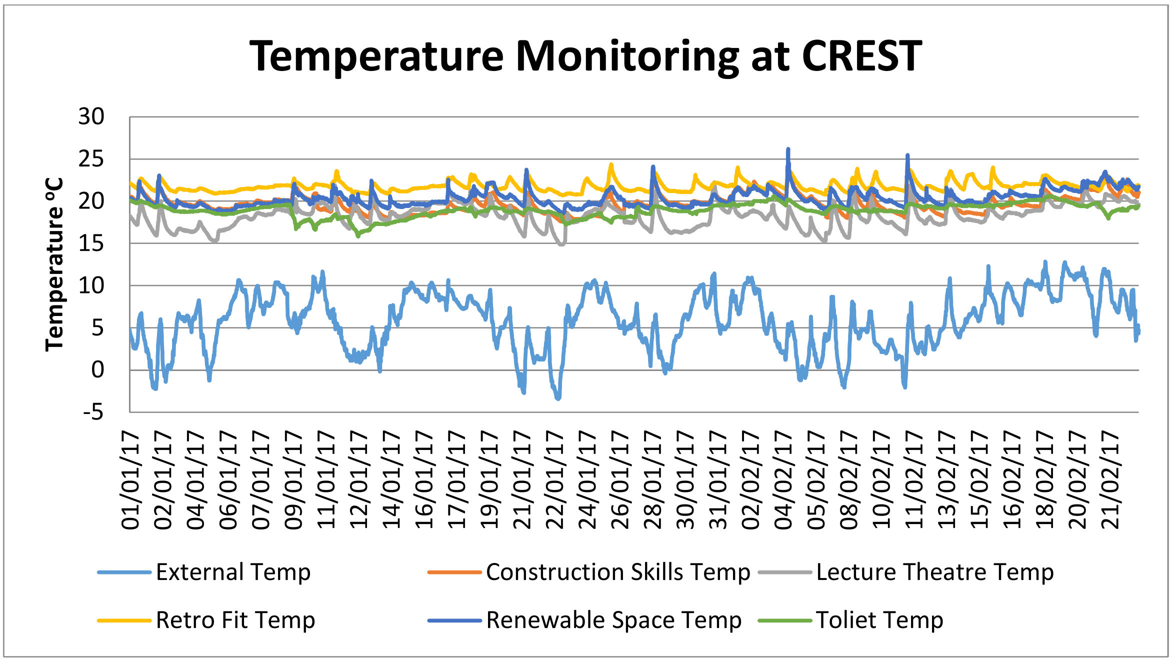

Figure 5: Temperature monitoring data from the CREST Pavilion along with the external temperature.

Early reports of overheating caused some alarm but this turned out to be due to a combination of control set points and higher than required heat pump flow temperature set points. We can see from Figure 5 that the indoor thermal comfort temperature range (16°C – 26°C) was maintained during this period despite some sub-zero external temperatures.

Figure 6 presents monitoring data of carbon dioxide (CO_2) concentrations in parts per million (ppm) from the four sensors inside the CREST Pavilion. We can see that the ventilation rates maintained moderate indoor air quality of 1,000 ppm with peaks typically below 1,200ppm [EN 13779:2007].

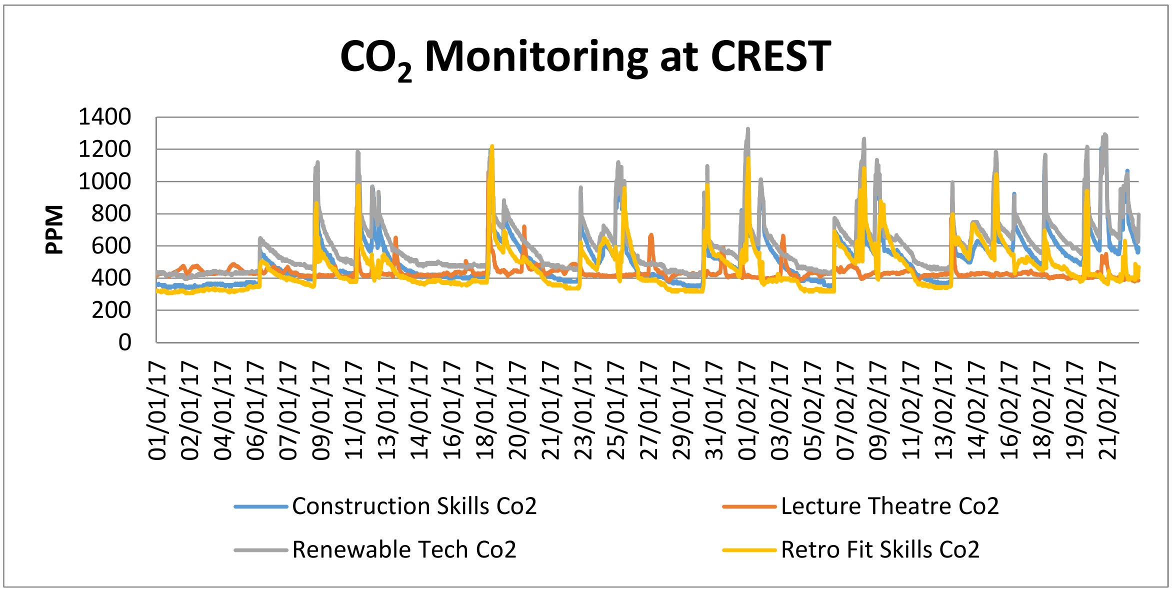

Figure 6: CO_2 monitoring data from the CREST Pavilion.

Figure 7 shows the relative humidity (rH%) monitoring data from the five sensors inside the CREST Pavilion. The monitoring data for relative humidity percentages was maintained within the recommended range of 35% -55% [Kaufmann 2016].

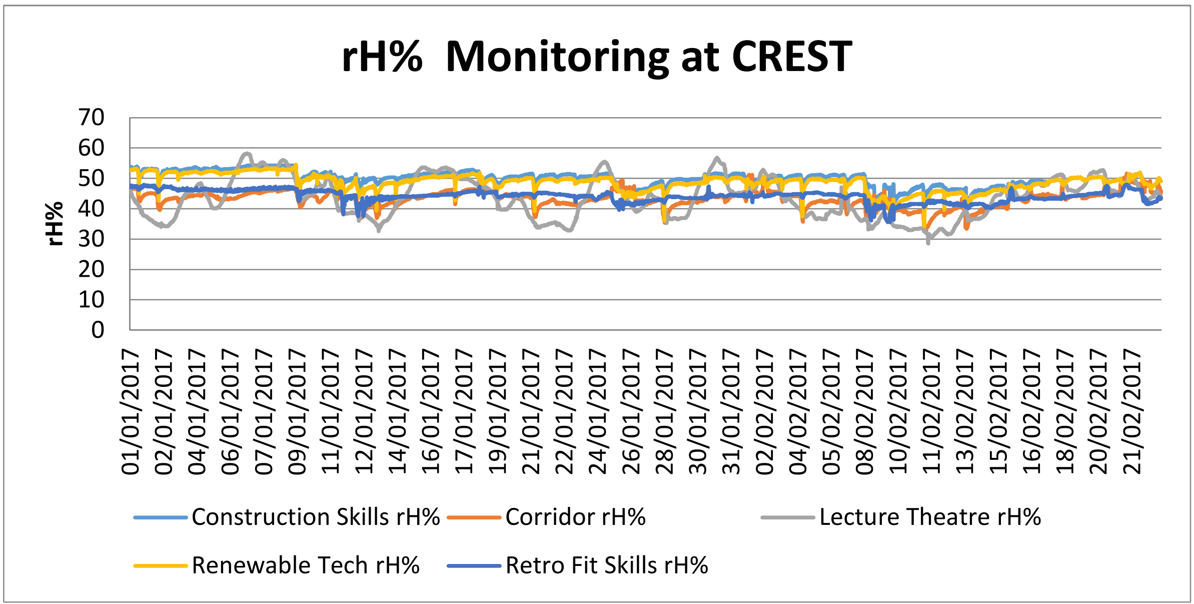

Figure 7: rH% monitoring data from the CREST Pavilion.

Energy

At CREST we embraced Net Carbon Zero as a logical step to achieve due to our low energy consumption as a result of achieving the Passive House standard. Others posed the question 'Is net Zero the right target for buildings?' [Grant 2012]. It is an excellent question however for CREST as we felt it was a good target for us with the nature and purpose of the building along with the backdrop of the future Energy Performance of Buildings Directive requiring all new buildings to be nearly zero energy buildings. Net Carbon Zero was achieved by virtue of the low energy demand and renewable energy generation from an installation of 49kW of solar photovoltaic (PV) panels installed at the Pavilion. This is comprised of a 45kW robotic solar tracker and 4kW of static wall mounted panels.

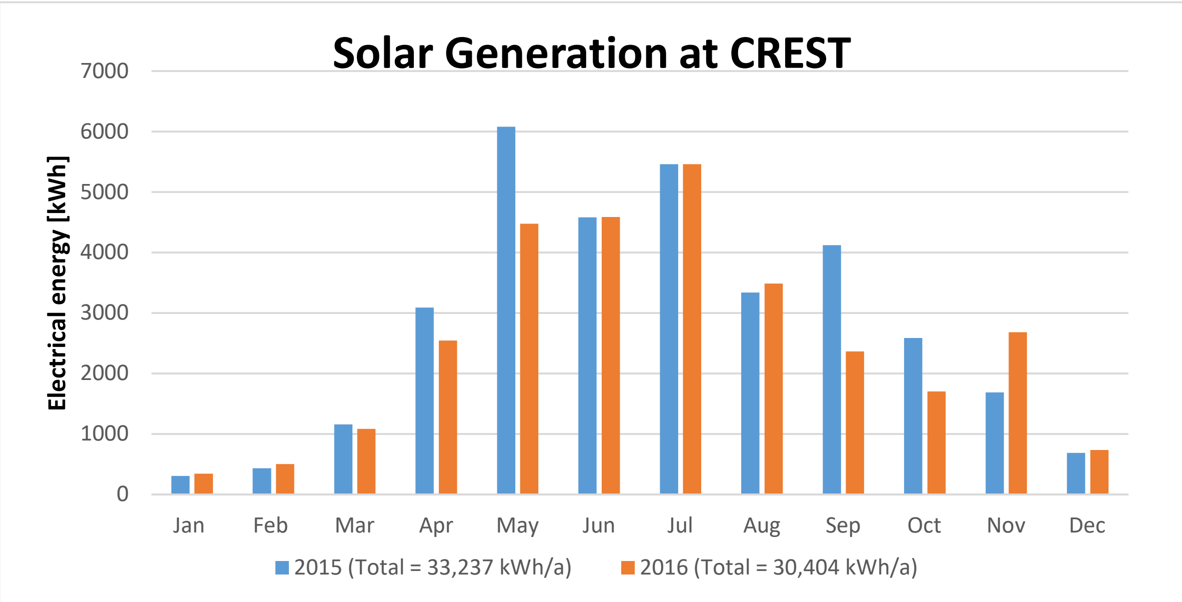

Figure 8: Annual monthly distribution of solar generation data from the CREST Pavilion

The PHPP has calculated the Primary Energy requirement to be 66 kWh/(m^2a) for heating (air to water heat pump), domestic hot water, household electricity and auxiliary electricity. Primary Energy at 66 kWh/(m^2a) equates to a total of 30,030 kWh/a. The monitored generation data for the robotic solar PV system and the static system at the CREST Pavilion in Year 1 was a total 33,237 kWh/a which offset the total primary energy demand and left a surplus of 3,207 kWh. In Year 2, the monitored generation data was 30,404 kWh/a which again offset the total primary energy demand and left a surplus of 374 kWh. This monitoring has demonstrated that the building can be considered to be net carbon zero because the actual annual generation output of the solar panels exceeds the total annual primary energy demand of the building [Grant 2012].

Conclusion

This paper focused on the CREST Pavilion performance data to date. These initial results of monitoring data have indicated the building is as calculated by the PHPP, if not performing slightly better than the calculated specific heating demand but within the range of the monthly and annual methods within the PHPP. This demonstrates that PHPP provides a robust design tool for accurate design and prediction of energy performance in the UK and adds to the growing body of evidence that the Passive House standard does not produce a significant performance gap between design and actual performance.

This post occupancy research also has demonstrated that good indoor air quality was maintained within the recommended ranges for temperature, CO_2 and relative humidity. The BMS system recorded internal air quality every 15 minutes over each 24 hour period. This data was held for 10 days on the internal memory. This limited the recording of data and user experience has found the BMS system to be problematic, and in particular the automatic windows. Similarly to [Bretzke 2012] and [Clarke 2015] we would advocate less sophisticated controls.

This research also highlights that the Passive House standard with the combination of excellent building fabric to reduce the heating demand coupled with renewable energy micro generation is an excellent vehicle for achieving zero carbon and near zero energy buildings.

The research for this paper has uncovered the need for some improvements in data collection and this will be addressed going forward with the PhD research. The BMS will be reconfigured to improve the collection of data and increased capacity added to record higher volumes of data including the IAQ and temperature profiling.

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