Report on the air quality factors of floors H-3F and H-4F for January 23rd to February 19th 2023

Maintaining a comfortable air quality (temperature, humidity and CO2 level) in an office building is very important for the health and productivity of its users.

Summary:

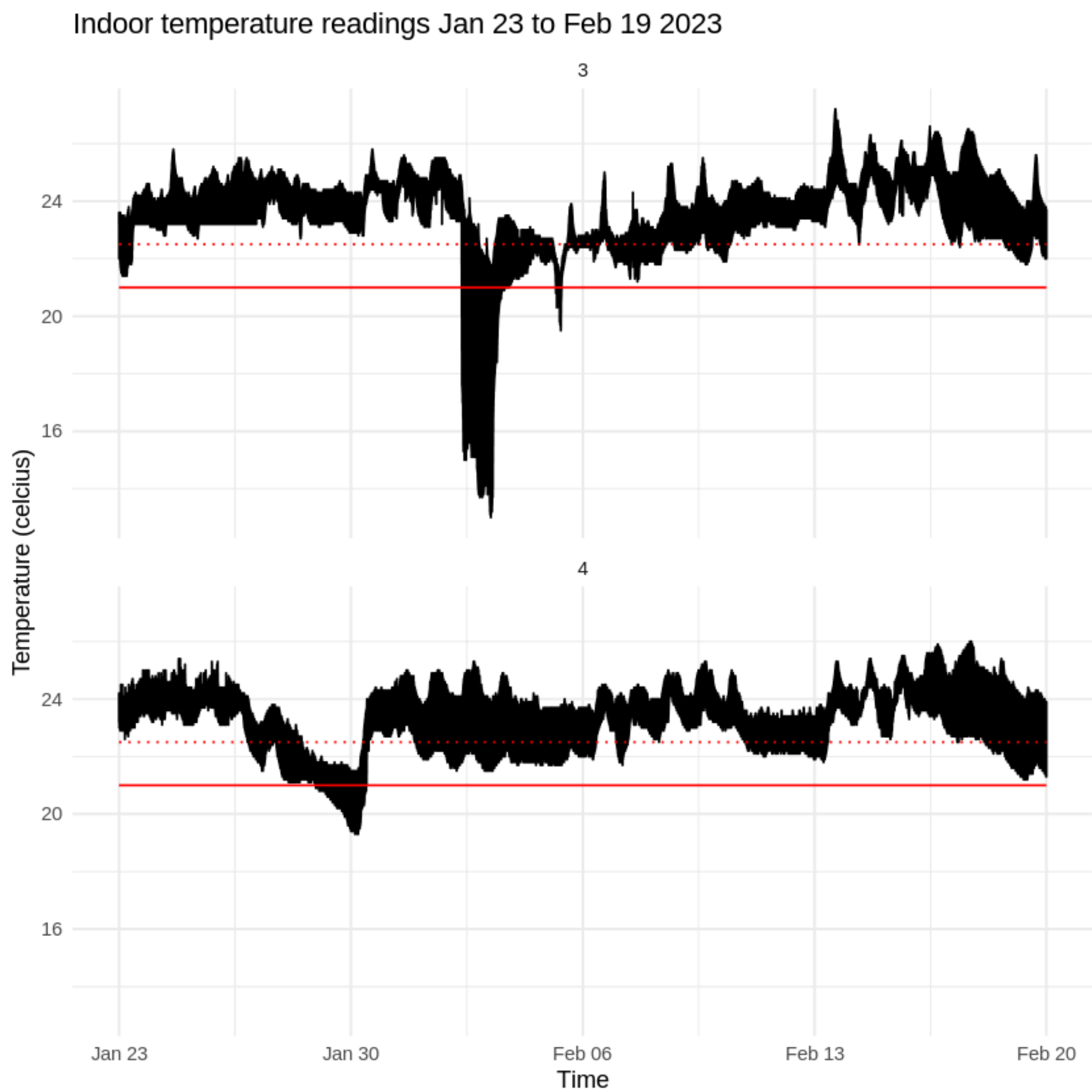
From January 23rd 2023 to February 19th 2023 the temperature, CO2 and humidity levels on floors H-3F (floor 3) and H-4F (floor 4) are consistently within the required operational values.

There are short periods on both floors where the temperature reading drops below the required operational value of 21 degrees. On floor 3 this occurs in early February. On floor 4 this occurs in late January. (See figure 1)

The CO2 readings peak at over 1000ppm 6 times on floor 3 and 10 times on floor 4. These peaks are only for short periods and are still within a safe range for humans (less than 1500ppm). (See figure 2)

The humidity readings are always above the desired rate of 20% over this time period. (See figure 3)

Figure 1:
The red line represents the lowest desired temperature, 21 degrees. The dashed red line represents the estimated lowest temperature at the sensor level (on the ceiling) when the temperature is adjusted to desk level. This adjustment accounts for the ceiling temperature being approximately 1.5 degrees higher than desk level temperature and provides for better representation of users' experience.



<u>Figure 2</u>:
The red line represents the highest operational level of CO_2 at 1000ppm.

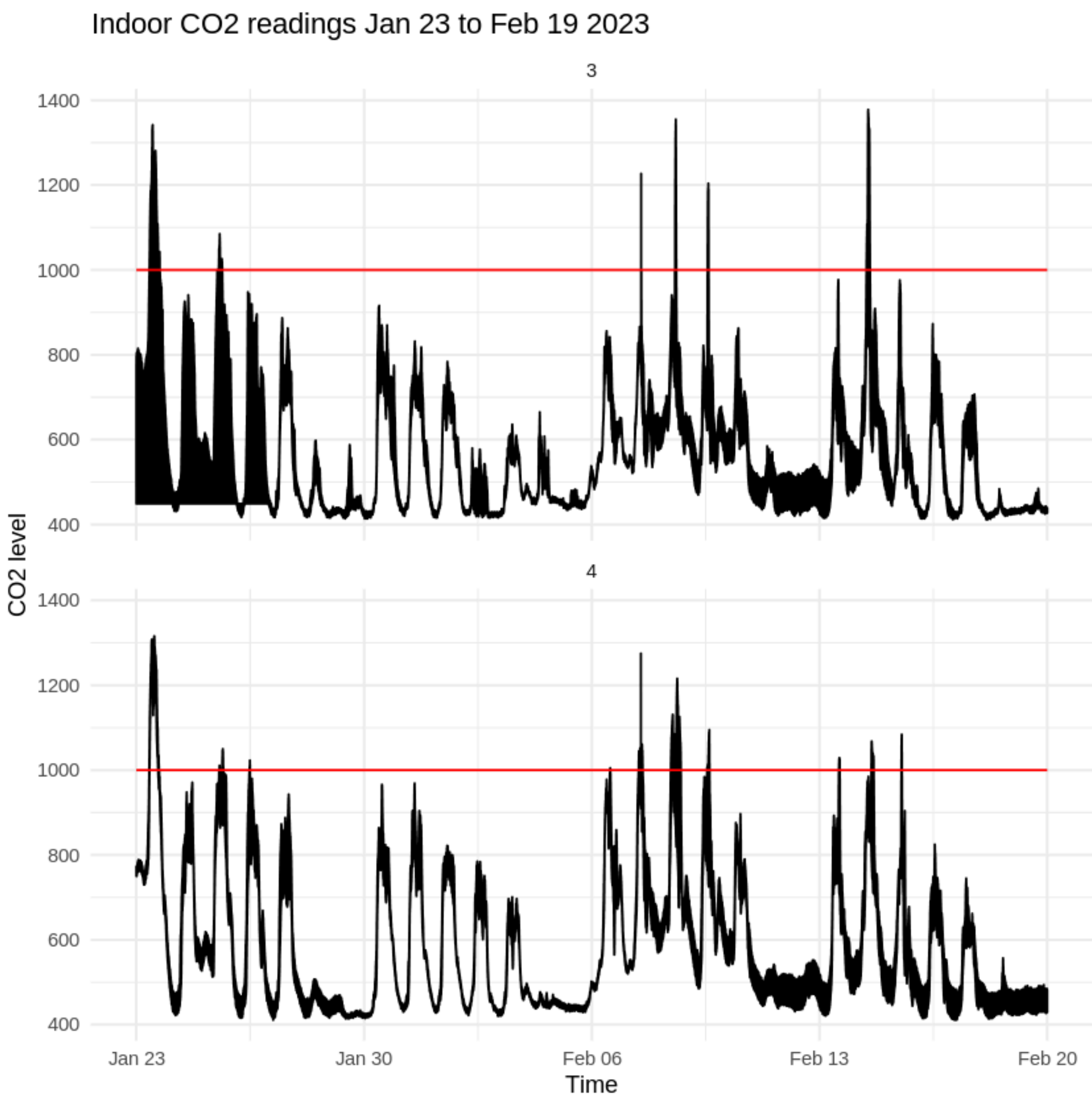
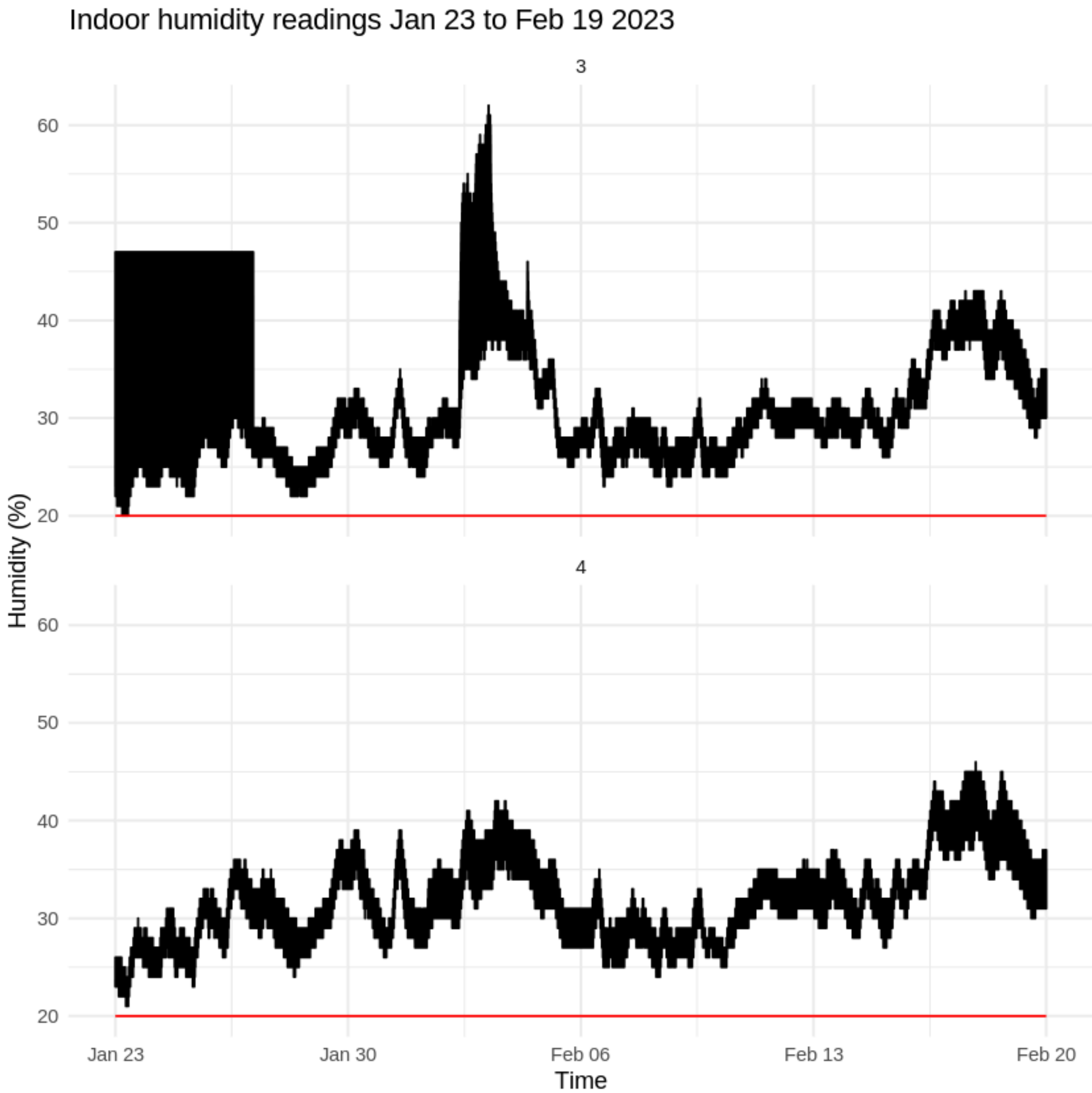


Figure 3:
The red line represents the lowest desired humidity level of 20%.



Sensor breakdown
On each floor there are 7 sensors that read temperature, humidity and CO_2. When analysing the data by sensor we can see that the trend across the sensors is very similar for all three air quality factors with a few anomalies.

<u>Floor 3:</u>

Temperature (See figure 4)
The overall drop in temperature for floor 3 in early February appears to be most prevalent in sensors 1792 and 1882. The other sensors also show a less significant drop. If we look at the locations of these sensors on the floor plan we can see that these sensors are both on the north side of the building (see figure 7). There are a range of factors that could have contributed to this significant difference in temperatures. This area of the building could have had less people working in it on this day, it could be in a more draughty area of the building, or perhaps on this day the windows on this side of the building could have been opened. As

the temperature is consistently above the 21 degree level for the rest of the time period it is likely this drop was caused by a one off event rather than a recurring issue with the temperature control.

It is important to note that sensor 1856 has unusually flat results for the first half of the time period. This could be due to an issue with the sensor but is more likely due to the fact this sensor is in a sealed room and therefore the temperature was much more regulated. It is likely the doors to this room were kept closed during this period.

If we look at the estimated desk height temperature (approximately 1.5 degrees lower than the sensors as these are at ceiling height) we can see that there are a few more instances where the temperature is lower than desirable. However, overall the average temperature across all sensors is at or above the recommended threshold.

CO2 (See figure 5)
When analysing the CO2 readings we can see a spike across all sensors (excl. 1856) at the very start of the time period. When looking closer it is apparent this spike occurred at midday on the 23rd of January. This could be due to an influx of people into the spaces at this time, i.e. more people in the office than usual, or possibly a delay or issue in the ventilation system. The spike is still under 1500ppm so is still considered safe for humans. Sensor 1856 also recorded another 4 major spikes. This sensor is located in a separate room so these spikes likely occurred when there were multiple people in the room with the doors closed. This is a common cause of CO2 readings spiking. These four spikes all occur around midday so it is possible there is a scheduled meeting in this room around this time.

Humidity (See figure 6)
The humidity percentage for the floor is above the threshold of 20% humidity across the entire time period. There are some spikes in humidity, one of significance is recorded by sensor 1882. This spike aligns with a significant drop in temperature recorded on the same sensor. We also see some unusual readings from sensor 1856 but as this sensor is located in a separate room where the doors can be closed this is likely due to the doors being left closed over this period.

<u>Floor 4</u>
Note: there are no readings from sensor 1935 before February 7th.

Temperature (See figure 4)
The temperature on floor 4 is above the desired threshold the majority of the time. There is a dip in temperature on the 30th of January but it drops to only approximately 1.5 degrees lower than the 21 degree threshold. The drop is the most significant for sensors 1884, 1883 and 1958 which are all found on the northern side of the floor. This indicates that something occurred on the north side of the floor to cause this drop. The northern side of the building is a more open space and therefore may be harder to keep at a regulated temperature. The northern side of the building is also likely to get less sun which may be a factor.

Overall at desk height the estimated temperature is stable and above the threshold at the estimated desk height temperature. However, there are a few occurrences where the temperature drops below the desired level of 21 degrees (at sensor level this would register at 22.5 degrees). The temperature is sitting much closer to the minimum desired temperature than is initially clear. The drops are still only minor and are only by a degree or so.

CO_2 (See figure 5)
The CO_2 levels on floor 3 spike at the beginning of the time period across all the sensors. Aside from this spike there is only one sensor that records another major spike, sensor 1935. This sensor is located in a separate enclosed room, rather than in open plan areas like the other sensors. As such, this spike is likely attributed to a higher density of people in the space, most likely with the doors closed, therefore increasing CO_2 production and reducing ventilation. The spike is still well under 1500ppm so is safe for humans.

There is a clear trend in the data where there are very low readings for 2 days, followed by higher readings for 5 days which is most likely due to people not being in the office on weekends. There is also a small spike recorded in all the sensors on the 8th of February but this is quite minor and peaks at 1135ppm which is still safe for humans.

Humidity (See figure 6)
As with floor 3, the humidity readings are all within a desirable range. The readings are at their lowest at the start of the time period and show an upwards trend as time passes.

Figure 4:

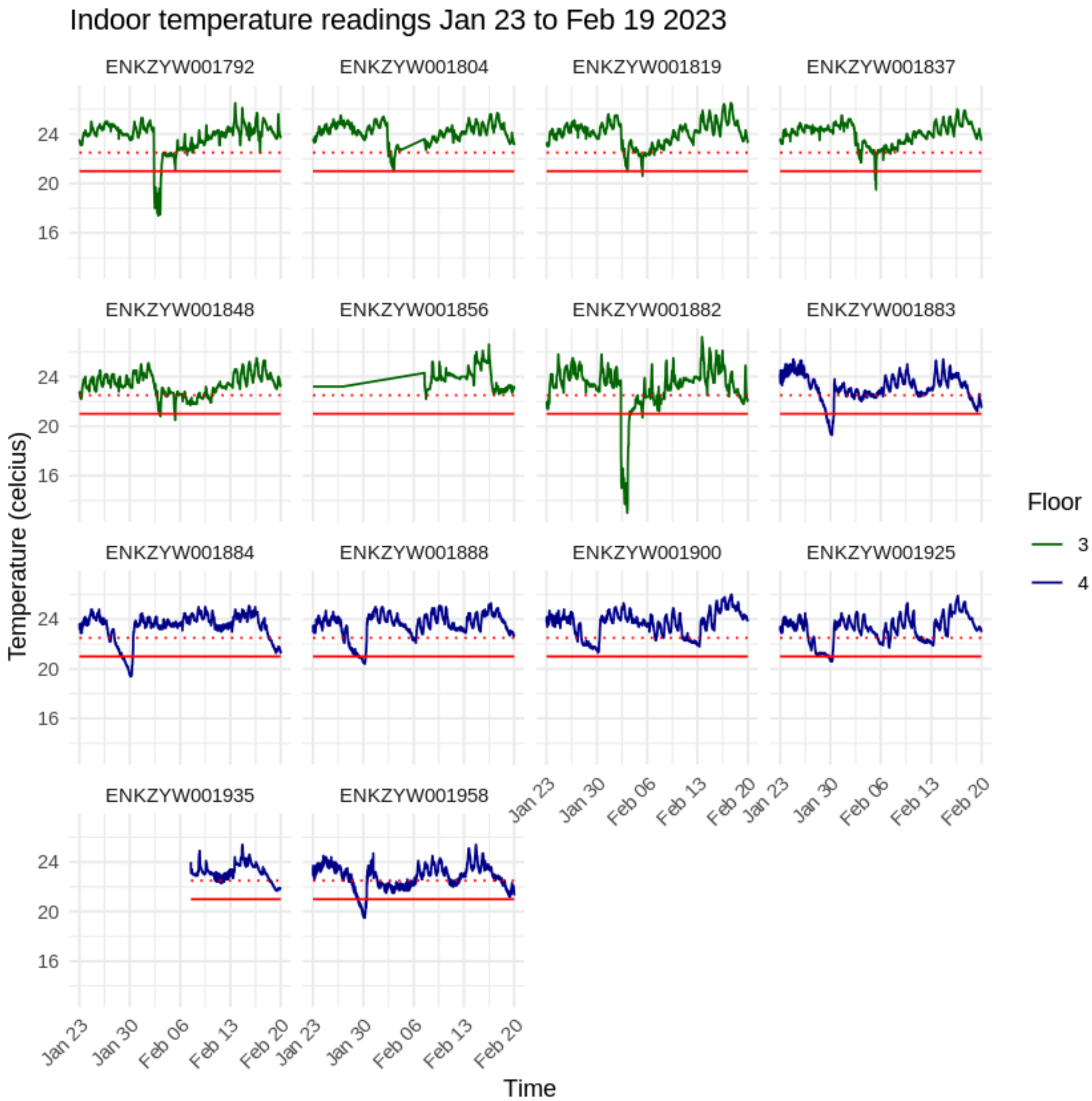
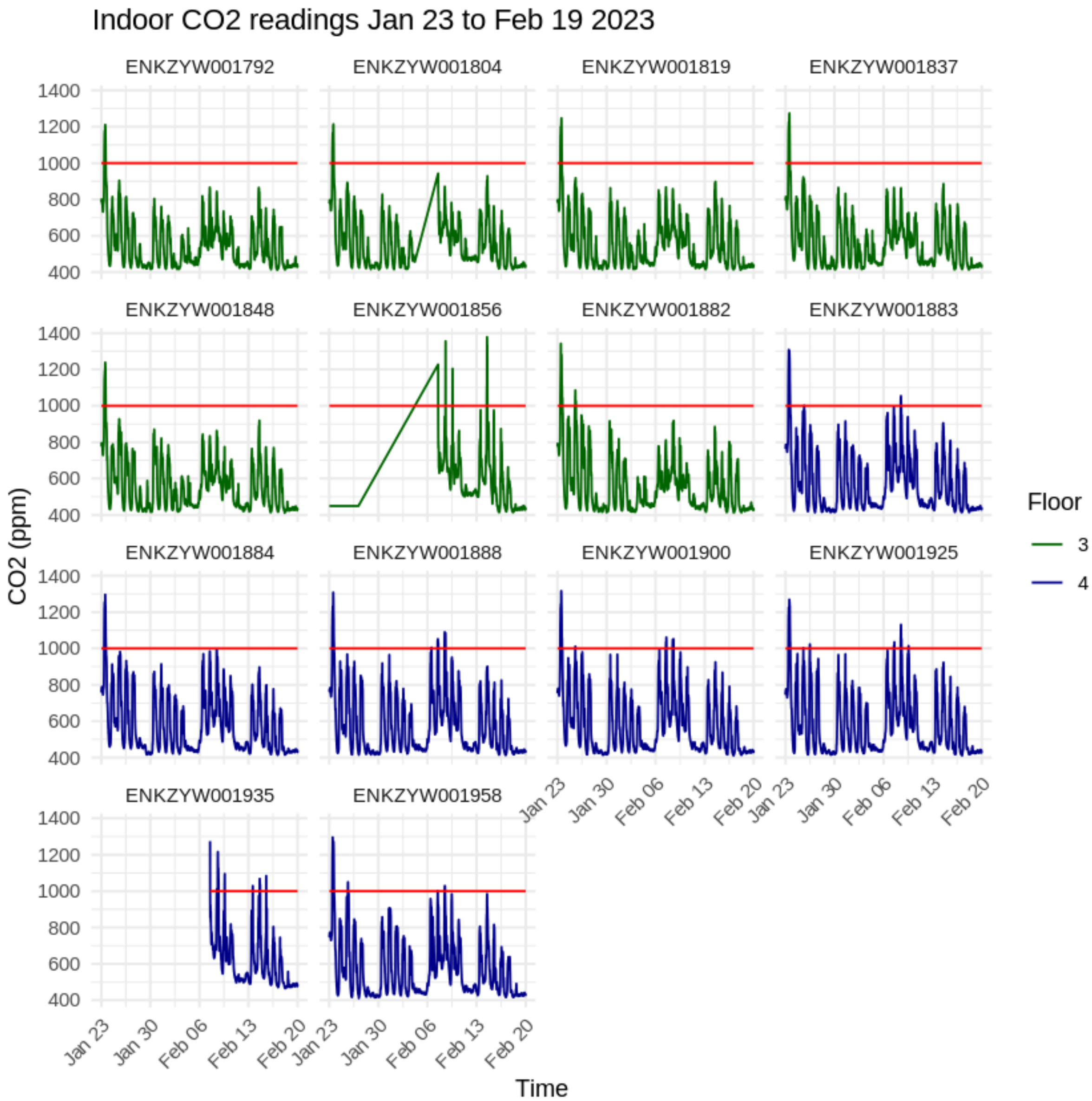
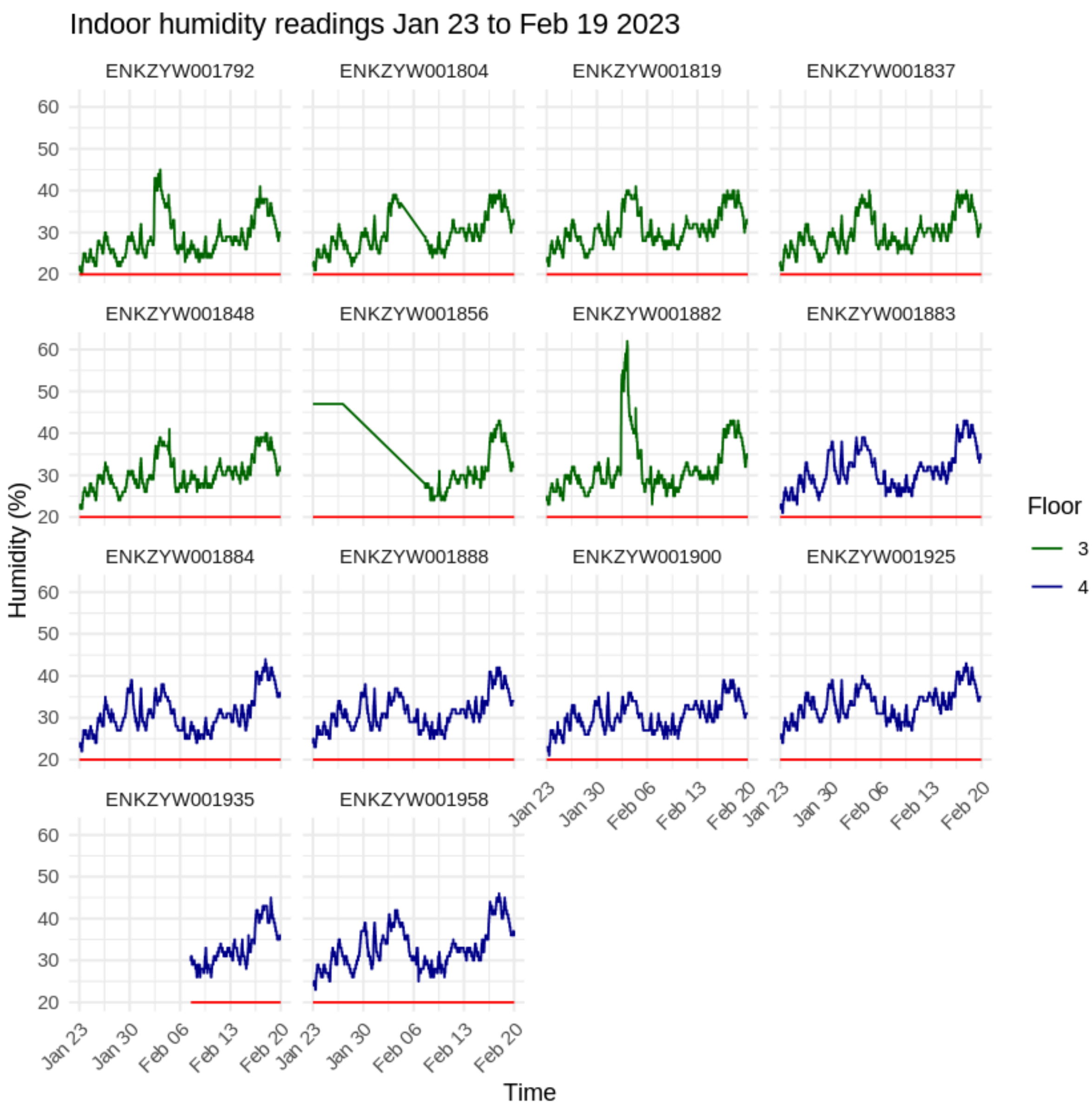

Indoor temperature readings Jan 23 to Feb 19 2023
ENKZYW001792
ENKZYW001804
ENKZYW001819
ENKZYW001837
ENKZYW001848
ENKZYW001856
ENKZYW001882
ENKZYW001883
ENKZYW001884
ENKZYW001888
ENKZYW001900
ENKZYW001925
ENKZYW001935
ENKZYW001958
24
20
16
Temperature (celcius)
Jan 23
Jan 30
Feb 06
Feb 13
Feb 20
Time
Floor
3
4

Figure 5:



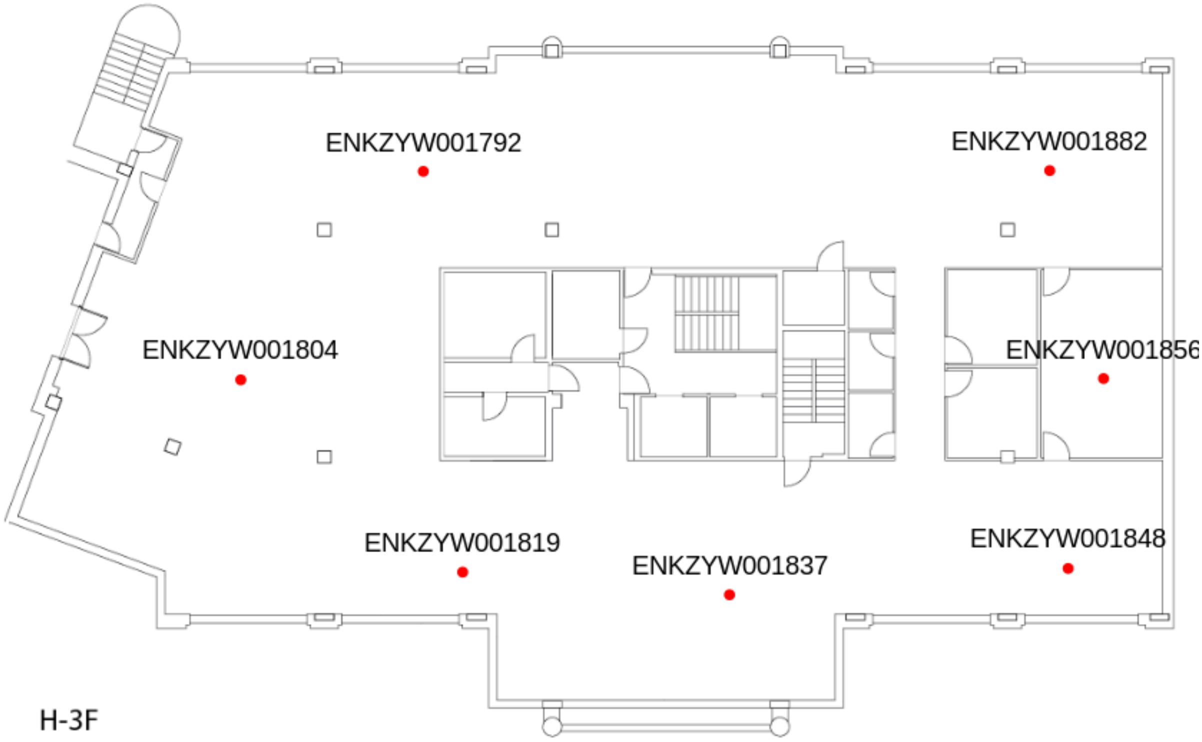
Indoor CO2 readings Jan 23 to Feb 19 2023
ENKZYW001792
ENKZYW001804
ENKZYW001819
ENKZYW001837
ENKZYW001848
ENKZYW001856
ENKZYW001882
ENKZYW001883
ENKZYW001884
ENKZYW001888
ENKZYW001900
ENKZYW001925
ENKZYW001935
ENKZYW001958
1400
1200
1000
800
600
400
CO2 (ppm)
Jan 23
Jan 30
Feb 06
Feb 13
Feb 20
Time
Floor
3
4

Figure 6:



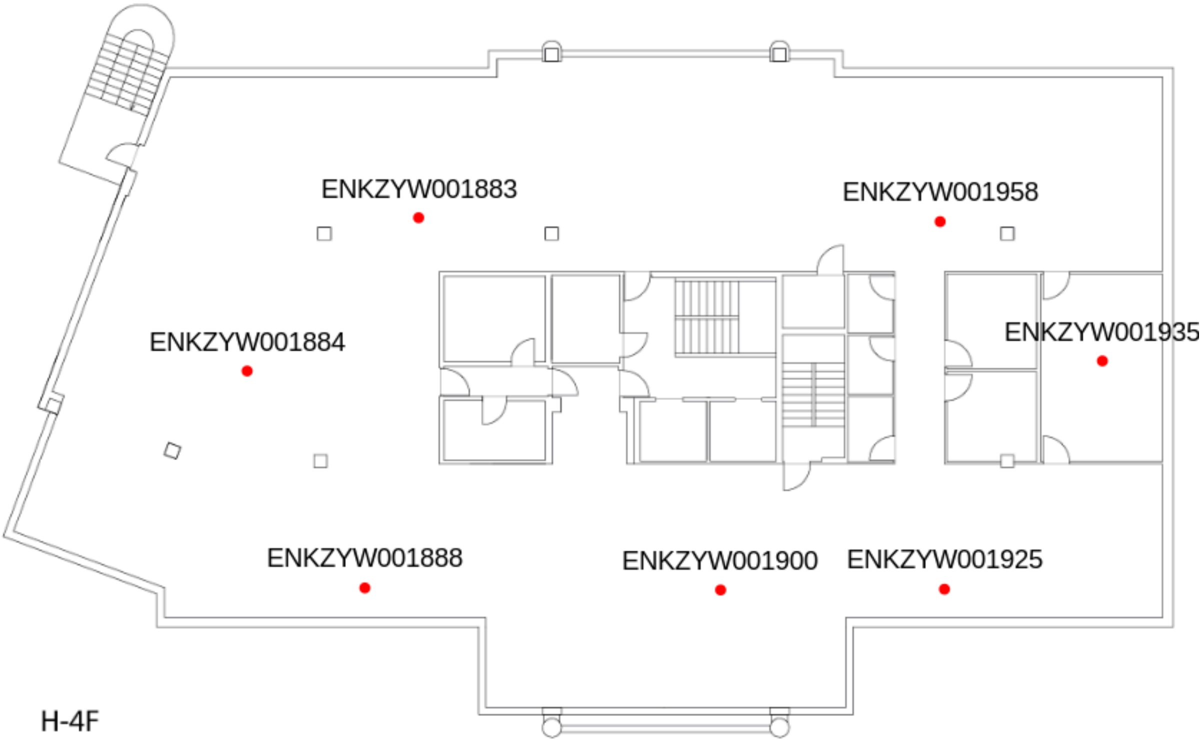
Indoor humidity readings Jan 23 to Feb 19 2023
ENKZYW001792
ENKZYW001804
ENKZYW001819
ENKZYW001837
ENKZYW001848
ENKZYW001856
ENKZYW001882
ENKZYW001883
ENKZYW001884
ENKZYW001888
ENKZYW001900
ENKZYW001925
ENKZYW001935
ENKZYW001958
Humidity (%)
60
50
40
30
20
Jan 23
Jan 30
Feb 06
Feb 13
Feb 20
Time
Floor
3
4

Figure 7:



ENKZYW001792
ENKZYW001882
ENKZYW001804
ENKZYW001856
ENKZYW001819
ENKZYW001837
ENKZYW001848
H-3F

Figure 8:



Outdoor air quality

The outdoor temperature has a moderate positive correlation with the indoor temperature. Which indicates the higher the outdoor temperature, the higher the indoor temperature. This will need to be accounted for appropriately as the seasons change.

The outdoor temperature has a moderate positive correlation with the indoor humidity percentage and wind speed also has a slightly positive correlation with indoor humidity percentage.

Table 1: Pearson's Correlation Matrix Floor 3

	avg_ind_temp	avg_ind_humidity	avg_ind_co2	out_temp	out_humidity	windSpeed
avg_ind_temp	1.00000000	-0.1417528	0.36090966	0.18670855	-0.09321688	-0.01587671
avg_ind_humidity	-0.14175283	1.0000000	-0.18095362	0.65004099	0.18477390	0.37419845
avg_ind_co2	0.36090966	-0.1809536	1.00000000	-0.01998358	-0.22843812	-0.13871694
out_temp	0.18670855	0.6500410	-0.01998358	1.00000000	-0.36707927	0.33956041
out_humidity	-0.09321688	0.1847739	-0.22843812	-0.36707927	1.00000000	-0.06791138
windSpeed	-0.01587671	0.3741985	-0.13871694	0.33956041	-0.06791138	1.00000000

Table 2: Pearson's Correlation Matrix Floor 4

	avg_ind_temp	avg_ind_humidity	avg_ind_co2	out_temp	out_humidity	windSpeed
avg_ind_temp	1.00000000	0.1210252	0.5506270991	0.2649544241	-0.09341795	0.03354528
avg_ind_humidity	0.12102516	1.0000000	-0.2108242832	0.7340685732	0.10408045	0.38921529
avg_ind_co2	0.55062710	-0.2108243	1.0000000000	0.0007047967	-0.28489870	-0.05637408
out_temp	0.26495442	0.7340686	0.0007047967	1.0000000000	-0.36707927	0.33956041
out_humidity	-0.09341795	0.1040805	-0.2848987001	-0.3670792709	1.00000000	-0.06791138
windSpeed	0.03354528	0.3892153	-0.0563740774	0.3395604115	-0.06791138	1.00000000

Note: This correlation matrix indicates that the indoor temperature has a slightly positive correlation with the CO2 levels. This is expected as when it is hotter people are breathing out more CO2 due to the warmer air expanding lung capacity and hence more air is exhaled containing more CO2.

Recommendations:

1. The overall temperature base could be lifted, it is consistently above 21 degrees at ceiling height but when you account for the estimated desk height temperature it is often nearer this threshold. Increasing the overall temperature for this time period could be effective in increasing user comfort.
2. Improve the ventilation in the 2 rooms on the eastern side of the building. There are often CO2 build ups in these rooms, most likely following or during meetings. This would also help to keep the overall floor temperature more consistent. It would be beneficial to leave the doors to this room open when possible to enable better air quality regulation or install better ventilation.
3. The insulation/ventilation on the northern side of the building could be improved as this is the part of the building that experiences the most dramatic drops in temperature.
4. Investigate what the issue is with sensor 1935 as we don't want sensors missing large periods of data going forward.
5. As there is a correlation between outdoor and indoor temperature the forecast could be used to predict the amount of strain that is going to be put on the HVAC system on a given day as colder days will require more effort from the HVAC system to heat.
6. When measuring air quality factors consider an appropriate upper limit for temperature and humidity. These being too high can lead to user discomfort so an upper limit might also be useful.