



RI4C2
Research & Innovation
For Cities & Citizens

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FACULDADE DE
CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE DE
COIMBRA

INICIATIVA ENERGIA PARA A SUSTENTABILIDADE

ENERGY FOR SUSTAINABILITY INITIATIVE • EFS | UC

Indoor Environmental Quality in School Buildings

Living Lab Experiences at the University of Coimbra

Manuel Gameiro da Silva

Living Labs-Pathways for Open Innovation Ecosystems - *RI4C2 Conference*
26 September, 2023, 10.00-13.00 CET

6 School Buildings Pilot Cases



Spain

Zubigune: conventional classrooms, mechanical manufacturing workshops, NZEB building and teacher rooms.

UPV/EHU (Donostia School of Architecture): collaborative teaching rooms for team learning and conventional classrooms.



France

UT3-PS: teaching rooms equipped with various sensors (brightness, temperature, energy, etc.) and interconnected with the campus data network. Open area for carrying out experiments. University with more than 30,000 students

CEREMA (working with a secondary school building in Gironde for up to 470 students): classrooms, offices, meeting rooms and school restaurant.



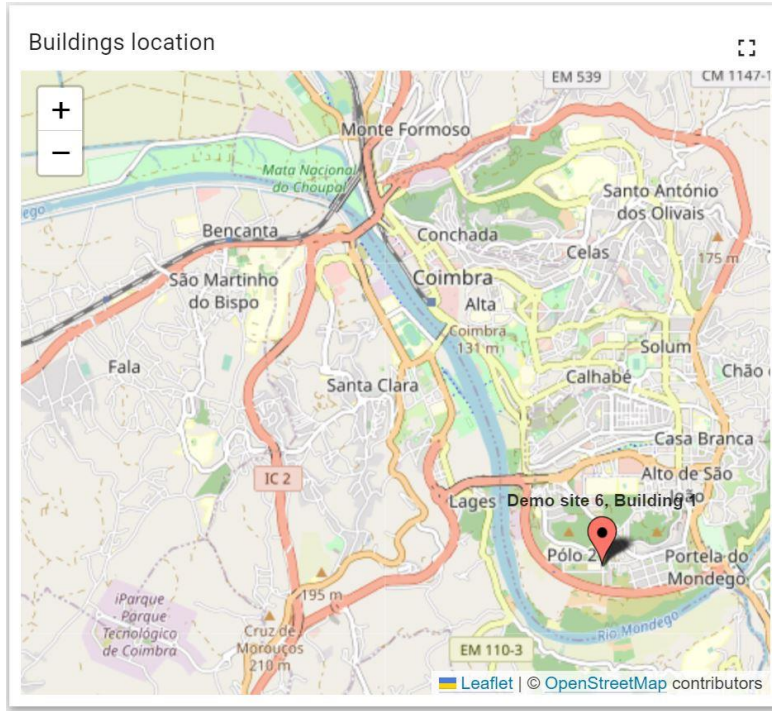
Portugal

IST Alameda Campus. University classrooms and kindergarten. Home to up to 9889 university students and 124 children.

FCTUC-DEM (Department of Mechanical Engineering). Classrooms, teacher offices and laboratory rooms. Up to 1000 students.

University of Coimbra Site Location

Departamento de Engenharia Mecânica
Rua Luís Reis Santos, Pólo II da Universidade de Coimbra
3030-788 Coimbra PORTUGAL
40° 11' 10" N; 08° 25' 06" W



DEM-UC Site Characteristics

University Building, located in Pólo II of UC, with a total area of 7 000 m², including laboratories, classrooms, offices, libray, bar/cafeteria, meeting rooms, and parking area.



DEM-UC Site Characteristics

Monitored Zones

Demo-site 6

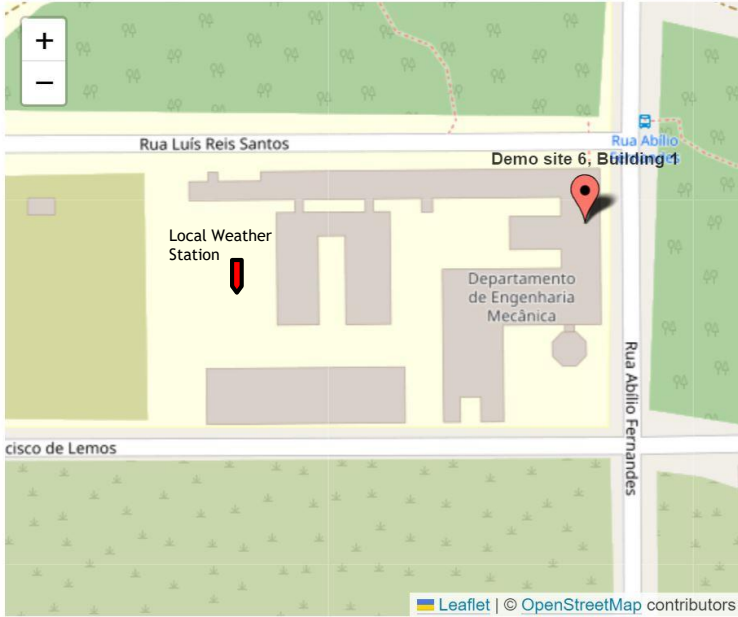
Overview ▾

Entities

Realtime - last 7 days



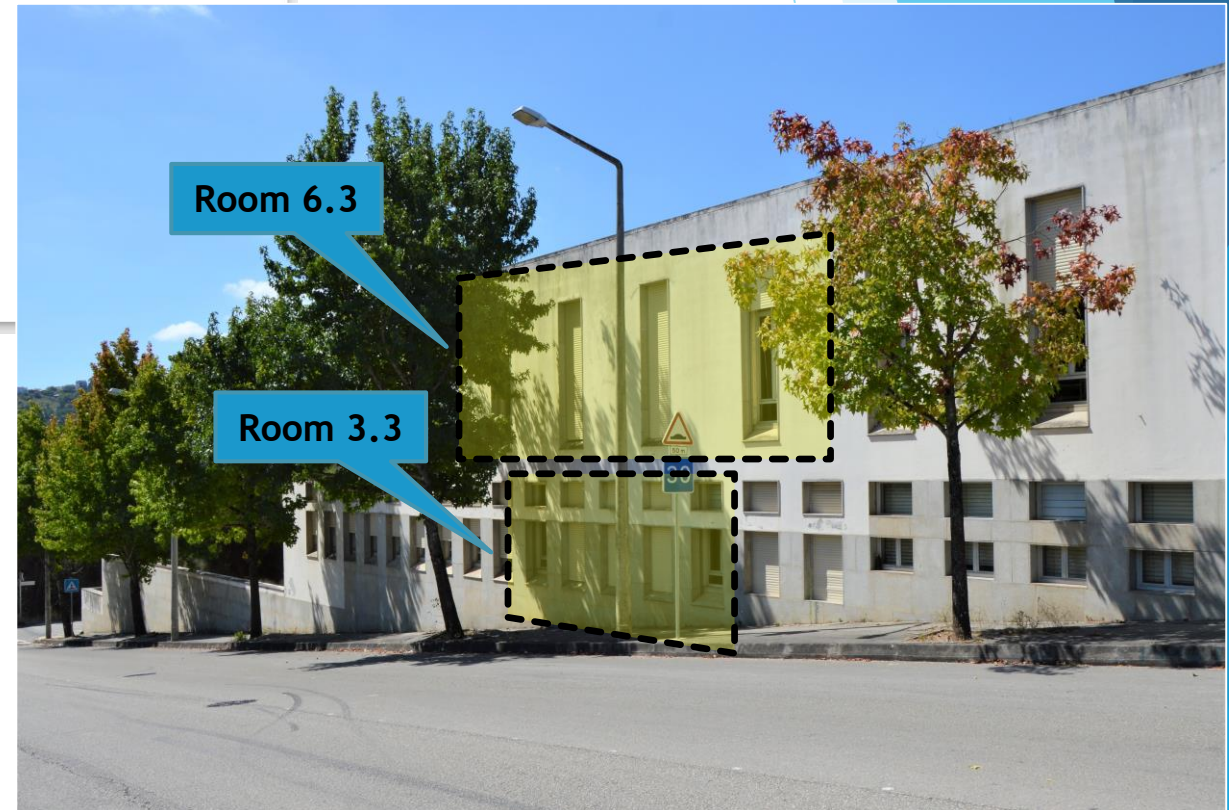
Buildings location



Sensors location



- Demo site 6, Building 1
 - Demo site 6, Building 1, Classroom 3.3
 - Cube 42
 - Measurement System 7
 - Demo site 6, Building 1, Classroom 6.3
 - Cube 35
 - Measurement System 5
 - Measurement System 6
 - Demo site 6, Building 1, Corridor
 - Measurement System 8
- Local Weather Station



DEM-UC Site Characteristics

Monitored Parameters



1 Local Weather Station

| |
|-------------------------------------|
| Air Temperature (°C) |
| Dew Point Temperature (°C) |
| Relative Humidity (%) |
| Wind Direction (°) |
| Wind Speed Avg (km/h) |
| Wind Speed Gust (km/h) |
| Atmospheric Pressure (hPa) |
| Precipitation Rate (mm) |
| Precipitation Acumulated (mm) |
| UV Radiation (W/m ²) |
| Solar Radiation (W/m ²) |



3 Indoor Meas Stations

| |
|--|
| Air Temperature (°C) |
| Relative Humidity (%) |
| Atmospheric Pressure (hPa) |
| CO2 Concentration (ppm) |
| TVOC Concentration (ppb) |
| Formaldehyde Concentration (ppb) |
| PM10 Concentration (µg/m ³) |
| PM4 Concentration (µg/m ³) |
| PM2.5 Concentration (µg/m ³) |
| PM1 Concentration (µg/m ³) |
| NO2 Concentration |

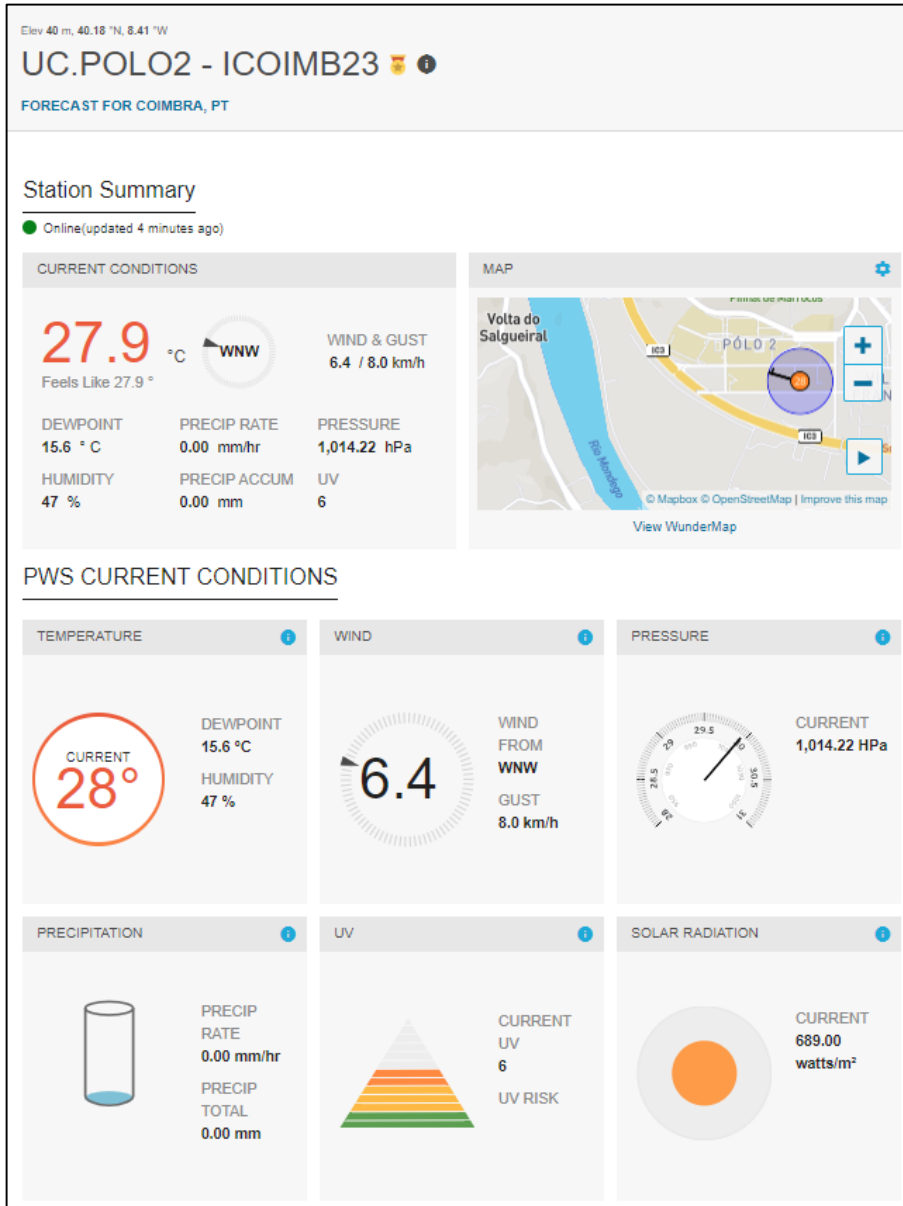


2 Cubes

| |
|--------------------------|
| Air Temperature (°C) |
| Relative Humidity (%) |
| CO2 Concentration (ppm) |
| TVOC Concentration (ppb) |
| Illuminance (lux) |
| White Level |
| Light Color |
| Light Flicker index |
| Leq 10min (dBA) |
| |
| |

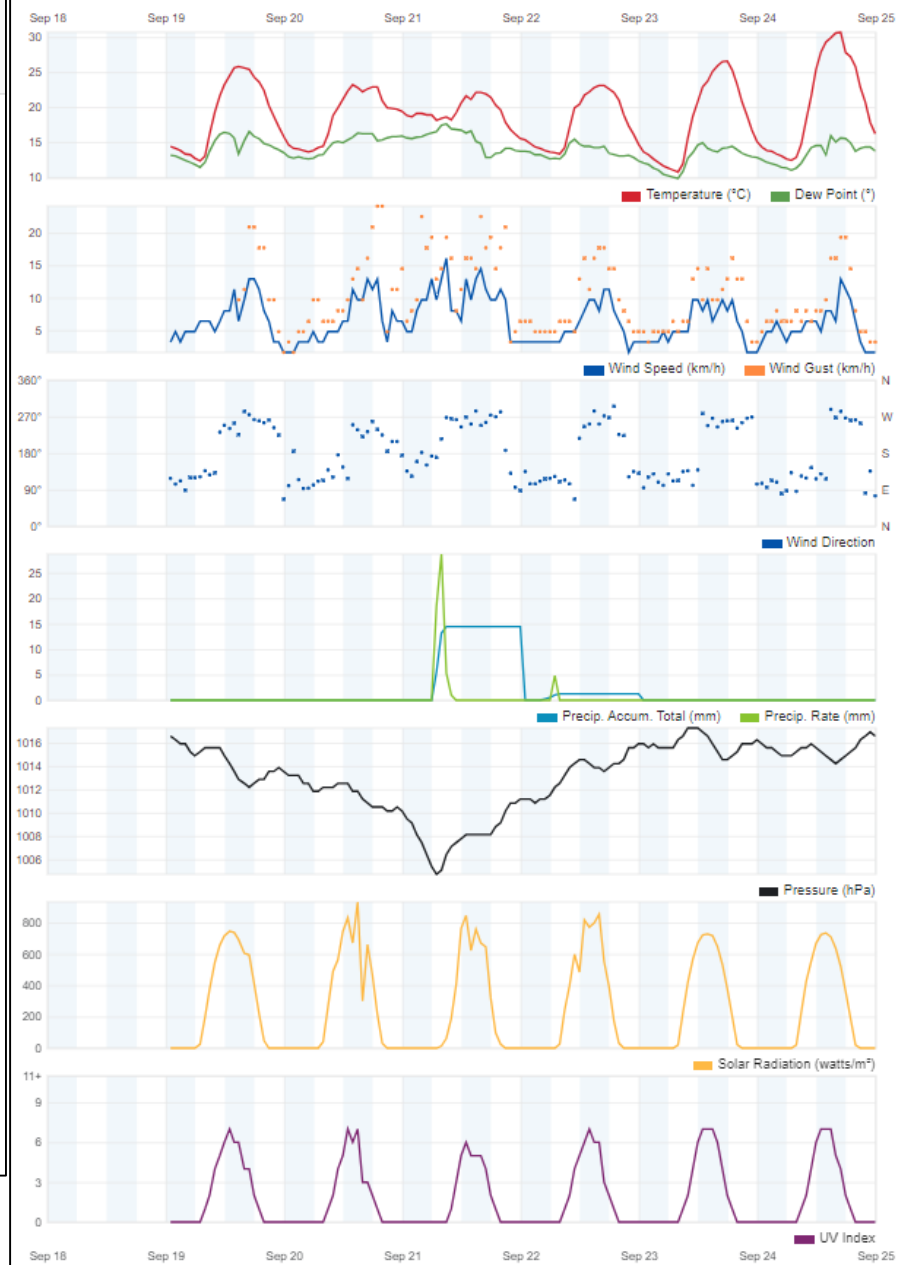
DEM-UC Site Characteristics

Local Weather Station



<https://www.wunderground.com/dashboard/pws/ICOIMB23/graph/2023-09-20/2023-09-20/weekly>

September 18, 2023 - September 24, 2023



DEM-UC Site Characteristics

Monitored Zones - Room 3.3 (MS 7)

Located in the ground-floor of the Didactic Block, ($6.5 \times 6.5 = 42 \text{ m}^2$); Entrance door facing West located in the clauster corridor, five windows facing East in the external facade of the Building, total glazed area of 8 m^2 , Mechanical Ventilation System and an All-Air HVAC System.



Site Characteristics

Monitored Zones - Room 3.3

Scada Interface of Building Management System

- Main →
- VC0-Sala 3.0
- VC1-Sala 3.1
- VC2-Sala 3.2
- VC3-Sala 3.3**
- VC4-Sala 3.4
- VC5-Sala 3.5
- VC6-ANF-2

Temperatura

Setpoint GTC: 22.0 °C

Setpoint Local: 22.0 °C

Setpoint Atual: 22.0 °C

Temperatura de Retorno: 23.3 °C

Funcionamento: ON

Modo de Controle: ON

Horário: [Clock Icon]

CO2

Limite Máximo CO2: 1250 ppm

Limite Mínimo CO2: 500 ppm

CO2 no Retorno: 501 ppm

Abertura Mínima (%): 100%

Abertura Máxima (%): 0%

Tempo de Ciclo (min): 0 min

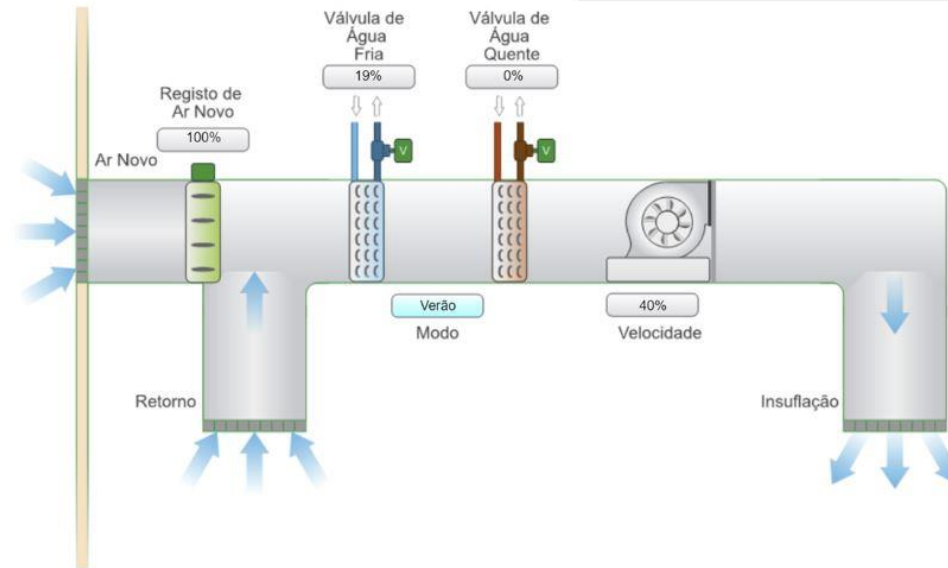
Ocupação

Ocupação Efetiva: Desocupado

Temperatura

Limite Máximo Setpoint: 24.0 °C

Limite Mínimo Setpoint: 18.0 °C



Site Characteristics

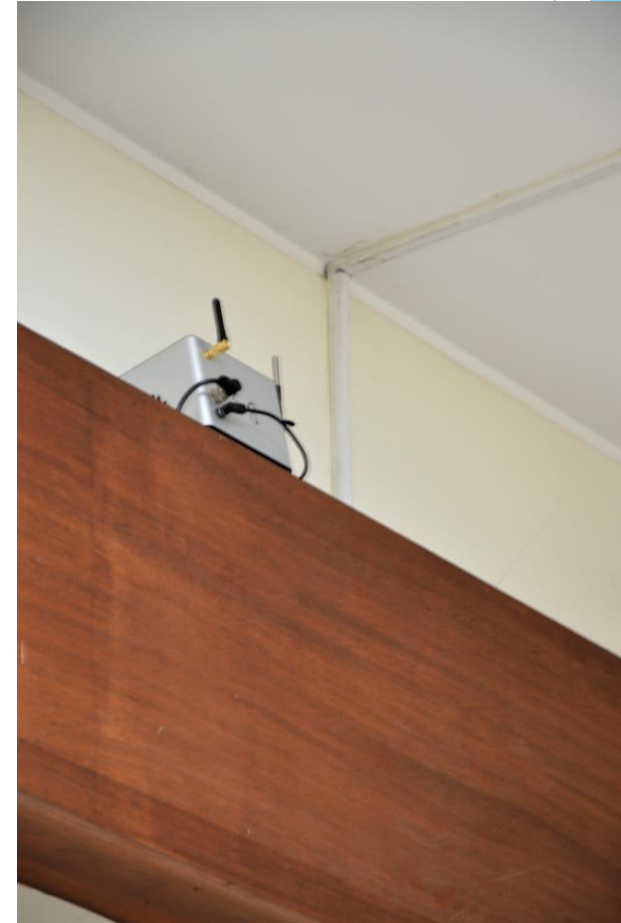
Monitored Zones - Room 6.3 (MS 5 and MS 6)

Located in the first-floor of the Didactic Block, (6 x 10 = 60 m²); Entrance door facing West located in the clauster corridor, four windows facing East in the external facade of the Building, total glazed area of 10 m², Natural Ventilation System, Total Recirculating HVAC Split System and a Heating System based on warm water radiators supplied by a central natural gas boiler

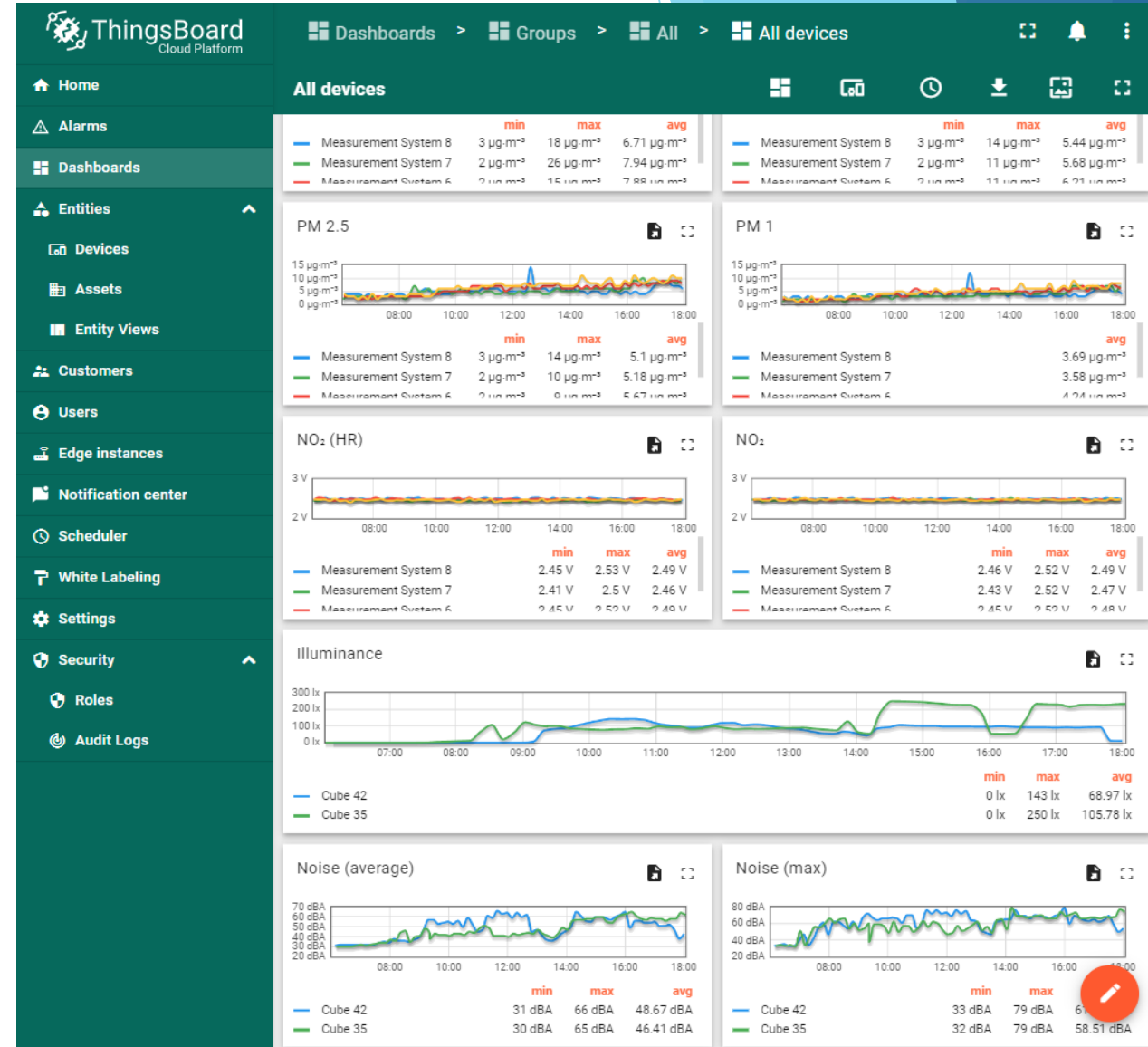
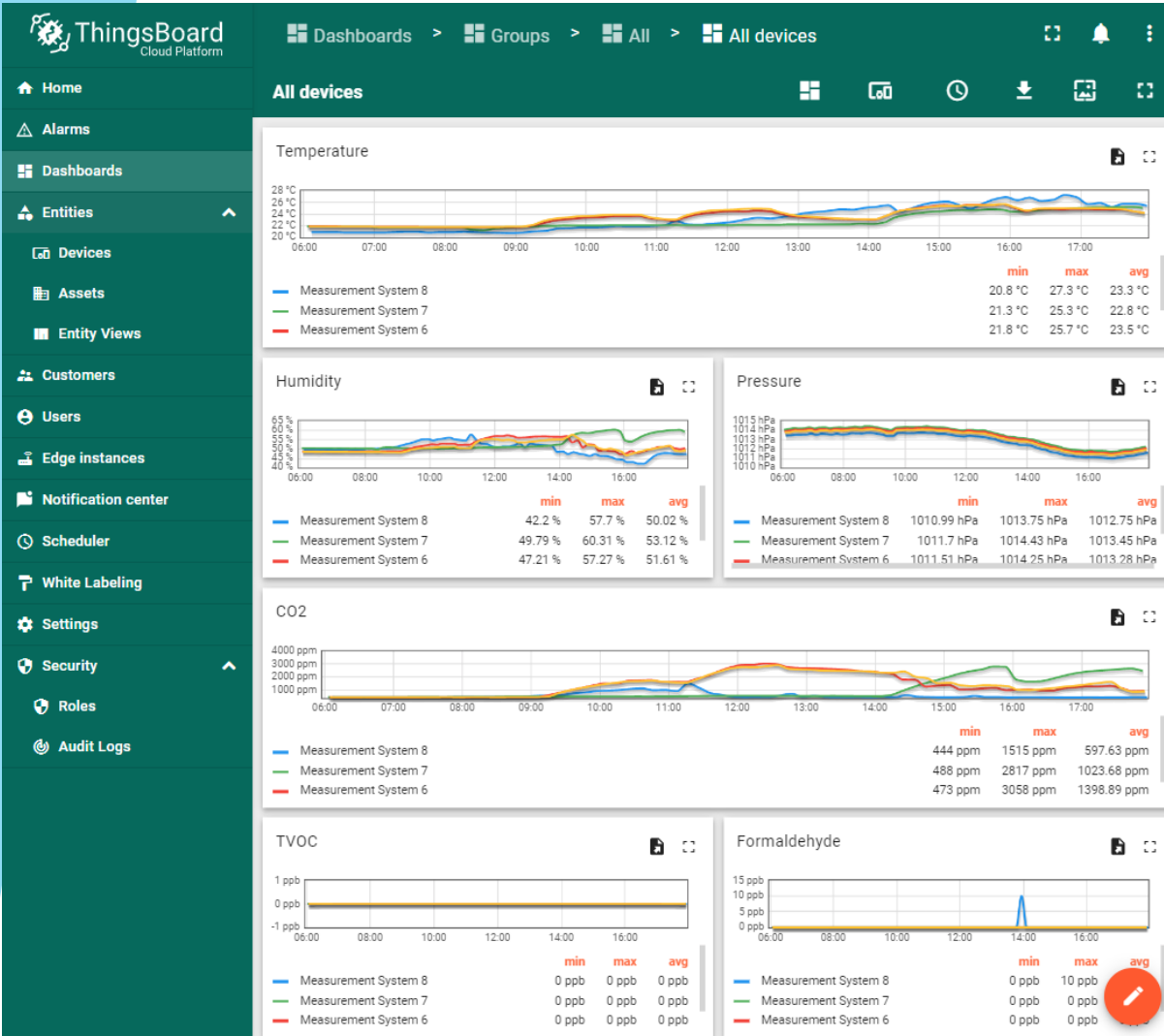


Site Characteristics

Monitored Zones - Corridor

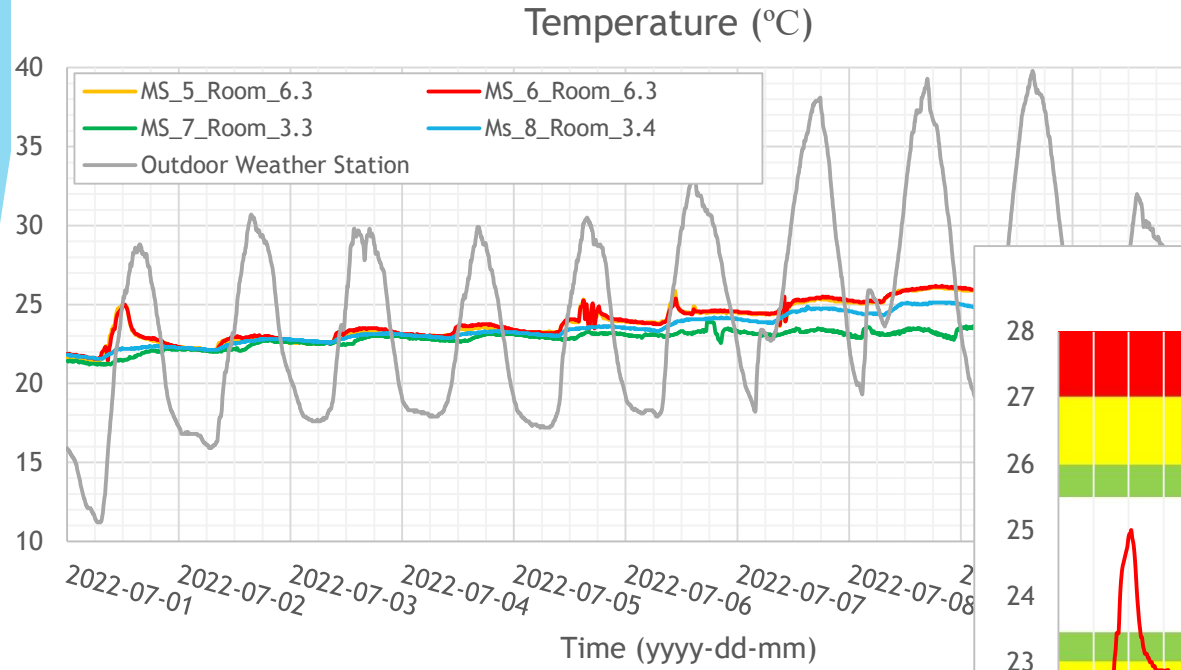


Web Platform Interface

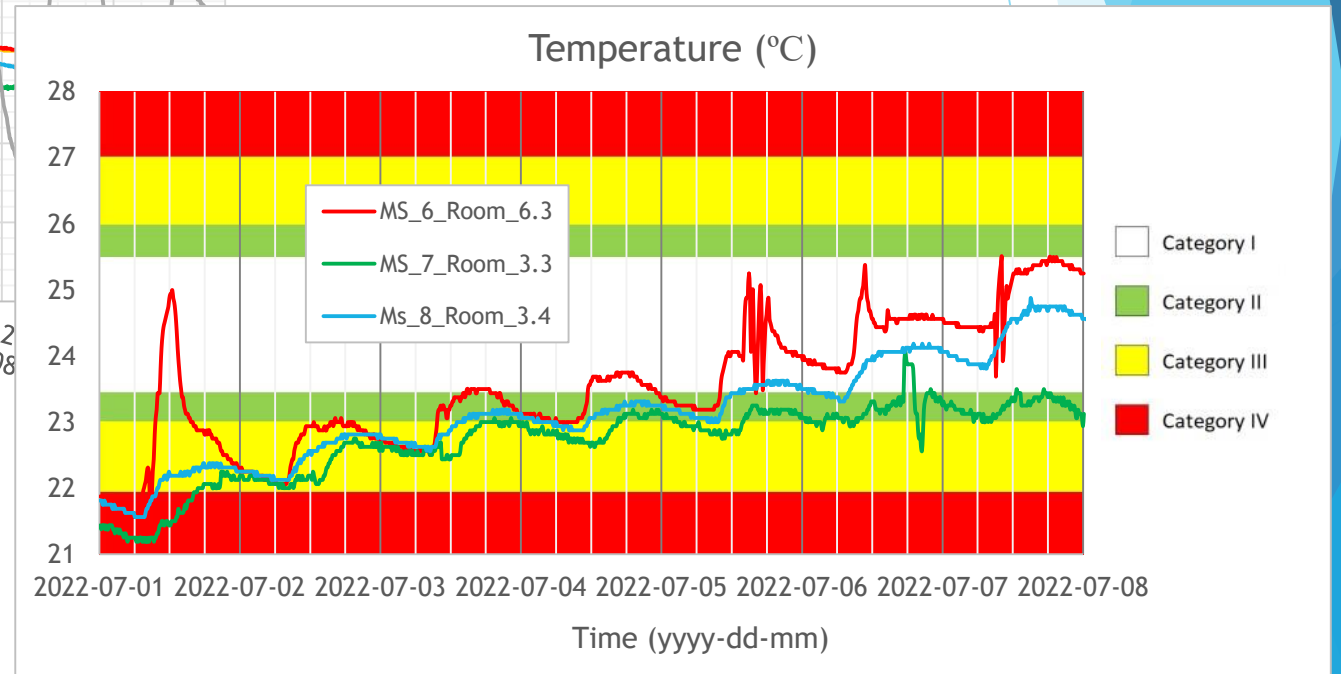


First Monitoring Period

Processed data from 2022-07-01 to 2022-07-08



Categories of EN 16 798 -1

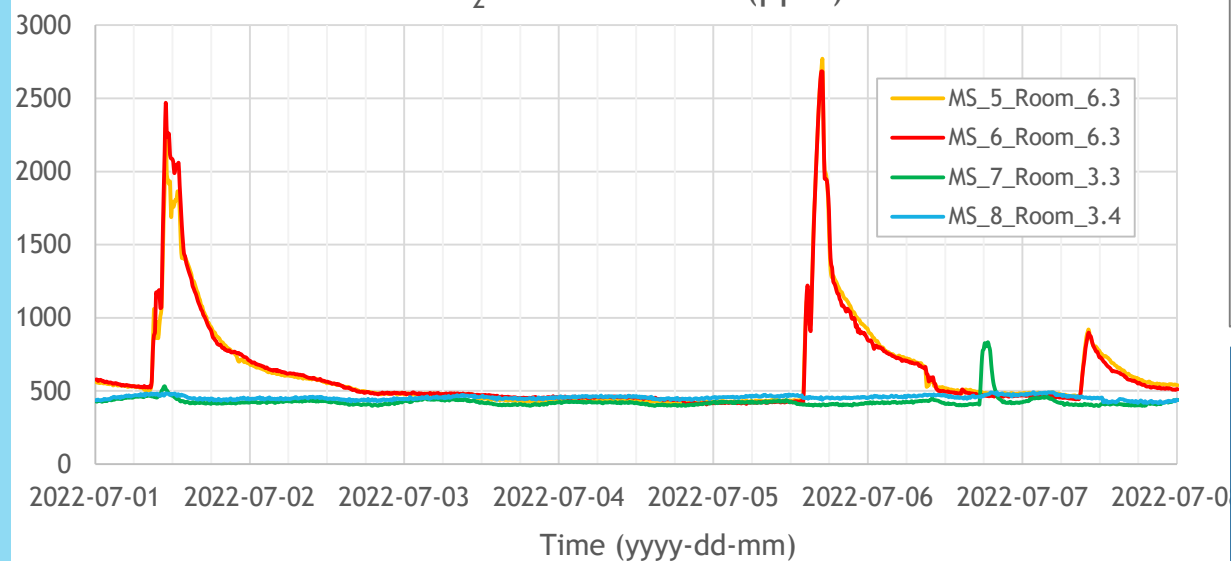


First Monitoring Period

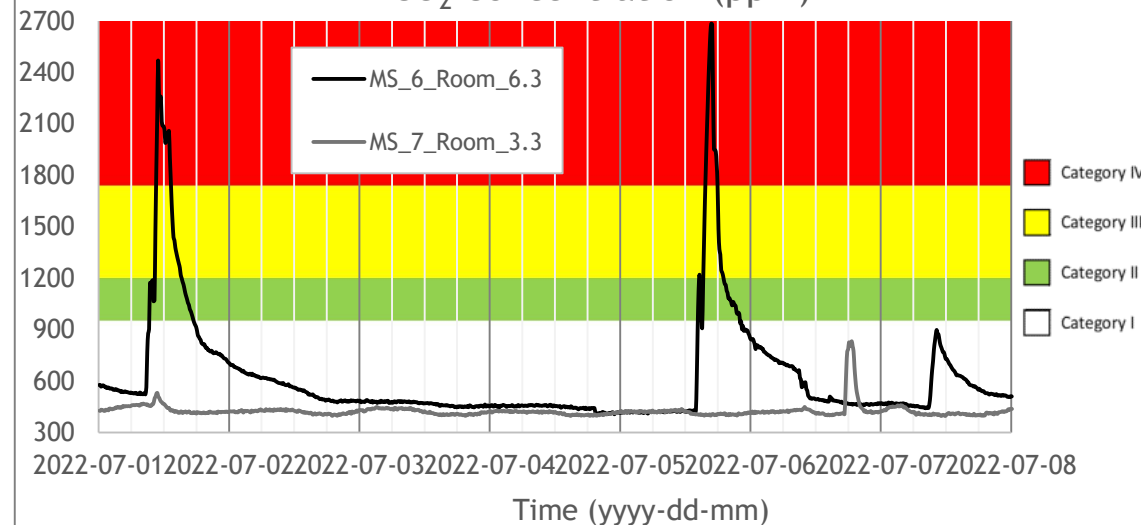
Processed data from 2022-07-01 to 2022-07-08

Categories of EN 16 798 -1

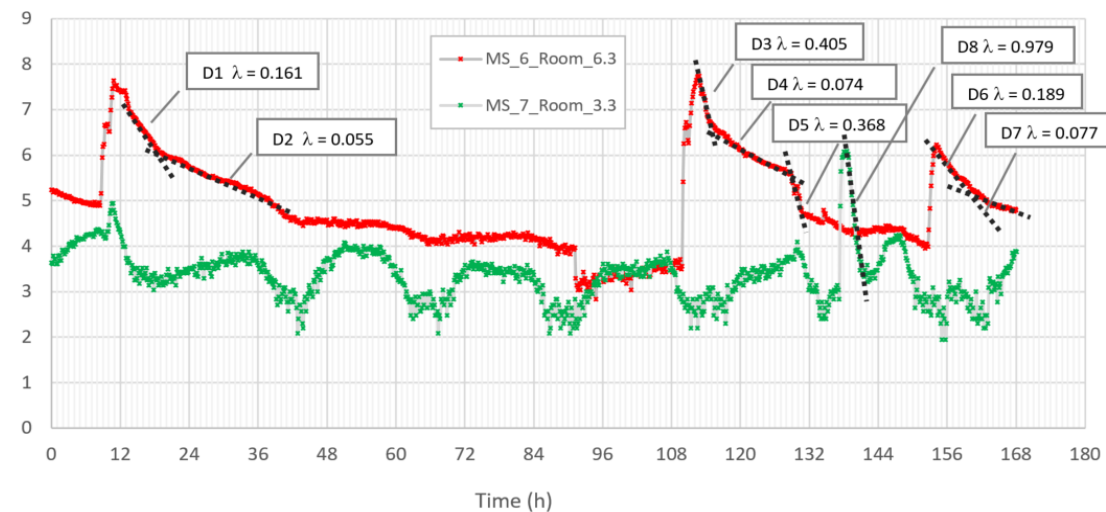
CO₂ Concentration (ppm)



CO₂ Concentration (ppm)



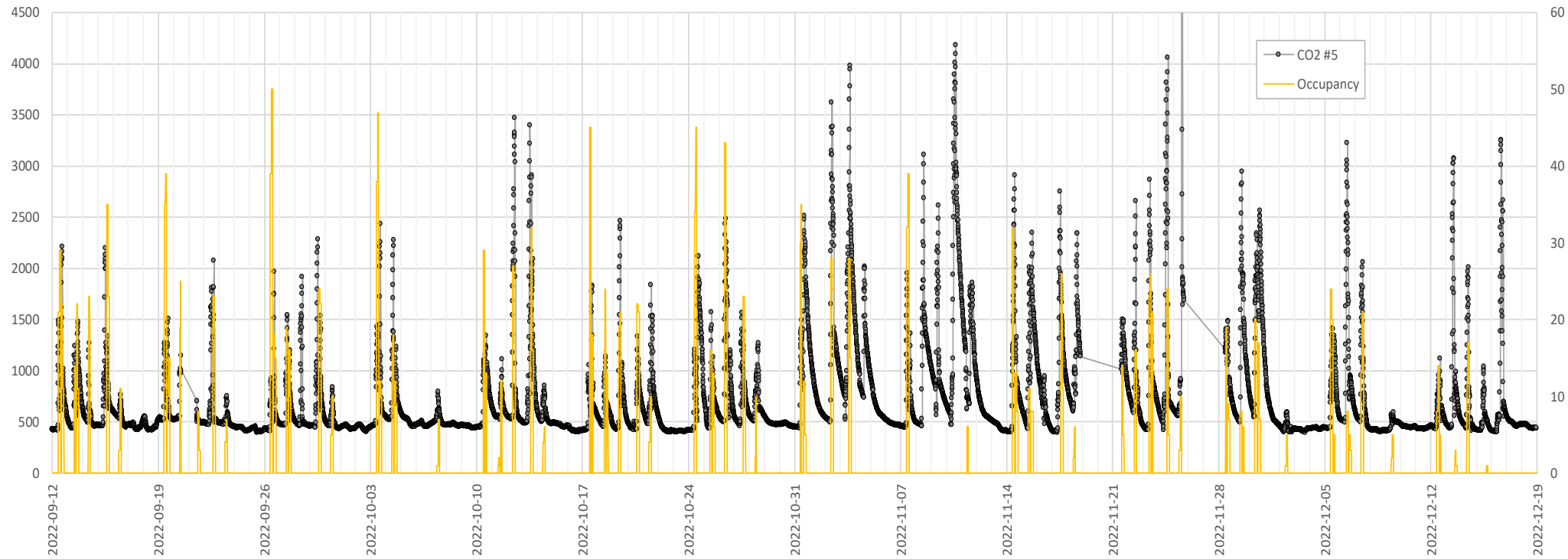
Ln(C-C_{out}) CO₂ (ppm)



First Semester 2022/2023

2022-09-12 to 2022-12-19
(Business as Usual Situation)

CO2 (ppm)



Quiz for Subjective Assessment

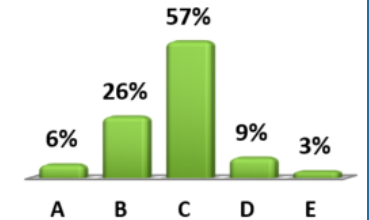


21 Questions about IEQ perception

3/14/2023 10:37 AM

6. Como gostarias que a sala estivesse agora?

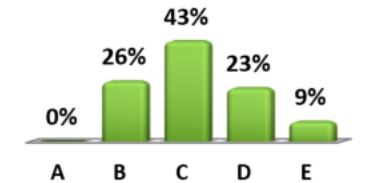
| | | | |
|---|----------------------|-----------|-------------|
| A | Mais Quente | 2 | 6% |
| B | Um Pouco Mais Quente | 9 | 26% |
| C | Como Está | 20 | 57% |
| D | Um Pouco Mais Fria | 3 | 9% |
| E | Mais Fria | 1 | 3% |
| | | 35 | 100% |



3/14/2023 10:40 AM

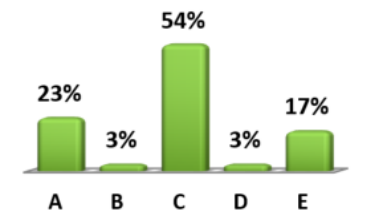
9. Como consideras a iluminação na tua secretária?

| | | | |
|---|-----------|-----------|-------------|
| A | Péssima | 0 | 0% |
| B | Má | 9 | 26% |
| C | Ok/Neutra | 15 | 43% |
| D | Boa | 8 | 23% |
| E | Excelente | 3 | 9% |
| | | 35 | 100% |



21. Qual a fonte de ruído que mais te incomoda?

| | | | |
|---|--------------------------------|-----------|-------------|
| A | Ruído De Trânsito Automóvel | 8 | 23% |
| B | Ruído De Outras Salas de Aulas | 1 | 3% |
| C | Corredores | 19 | 54% |
| D | Recreio | 1 | 3% |
| E | Não Incomoda/Não Se Aplica | 6 | 17% |
| | | 35 | 100% |



Global Strategy Approach

Creation of IEQ Work Team at the School

Diagnosis of the Existing Situation

Definition of Goals and Objectives

Education & Training

- Make population aware
- Streamline team building
- Implement questionnaires, studies, events and analyzes

Implementation & Monitoring

- Define indicators
- Mount monitoring system
- Analyze data evolution
- Prepare summary reports

Policies

- Review progress and implement best practices
- Increase vigilance
- Implement corrective measures

Communicate
Present Results
Disseminate Strategy

Corrective Measures

| Room 6.3 (Natural Ventilation) | Room 3.3 (Mechanical ventilation) |
|--|---|
| IAQ Awareness Campaign | Commissioning Process of the Installed Ventilation System |
| Subjective Perception of Occupants | Replacement of the Programmer |
| Assessment of Influence of Window Opening on the Air Exchange Rate | Calibration of CO ₂ Sensors of the DCV System |
| Use of CO ₂ Traffic Light Meters | Vigilance Phase of the Retrofitted System |



CONCLUSIONS

The DEM-UC IEQ Living Lab is a powerful tool, with very positive impact on the various vectors of activity of High Education Institutions

Generates meaningful data that is used for research, teaching and knowledge transfer activities

Provides very good conditions for project-based learning, promoting an easy contact of the students with their surrounding environment data

Allows benchmarking with other similar case studies



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Vă mulțumim pentru atenție

Kiitos huomiostasi

Danke für Ihre Aufmerksamkeit

Merci pour votre attention

Grazie per l'attenzione

Gracias por su atención

Obrigado pela vossa atenção



QUESTIONS

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www.uc.pt/efs