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Smart IAQ Sensor Networks and Living-Lab Monitoring Strategies

Manuel Gameiro da Silva

*Cohort-Based Training 3 – Modelling of the hospital indoor environment
19-23 Jan 2026, KTH, Stockholm*

HumanIC project has received funding from the European Union's Horizon Europe research and innovation program under the Marie Skłodowska-Curie (HORIZON-MSCA-2022-DN-01, project no 101119726)



Funded by
the European Union

Part 1

- ▶ **Assessment and Visualization of IEQ data collected with Smart Multiprobes**

ASHRAE 2020 Virtual Conference ►

Low Cost Sensor System for the Assessment
of Indoor Environmental Quality

Seminar 39 - Low Cost Sensing Technologies
for Grid-Interactive Efficient Buildings

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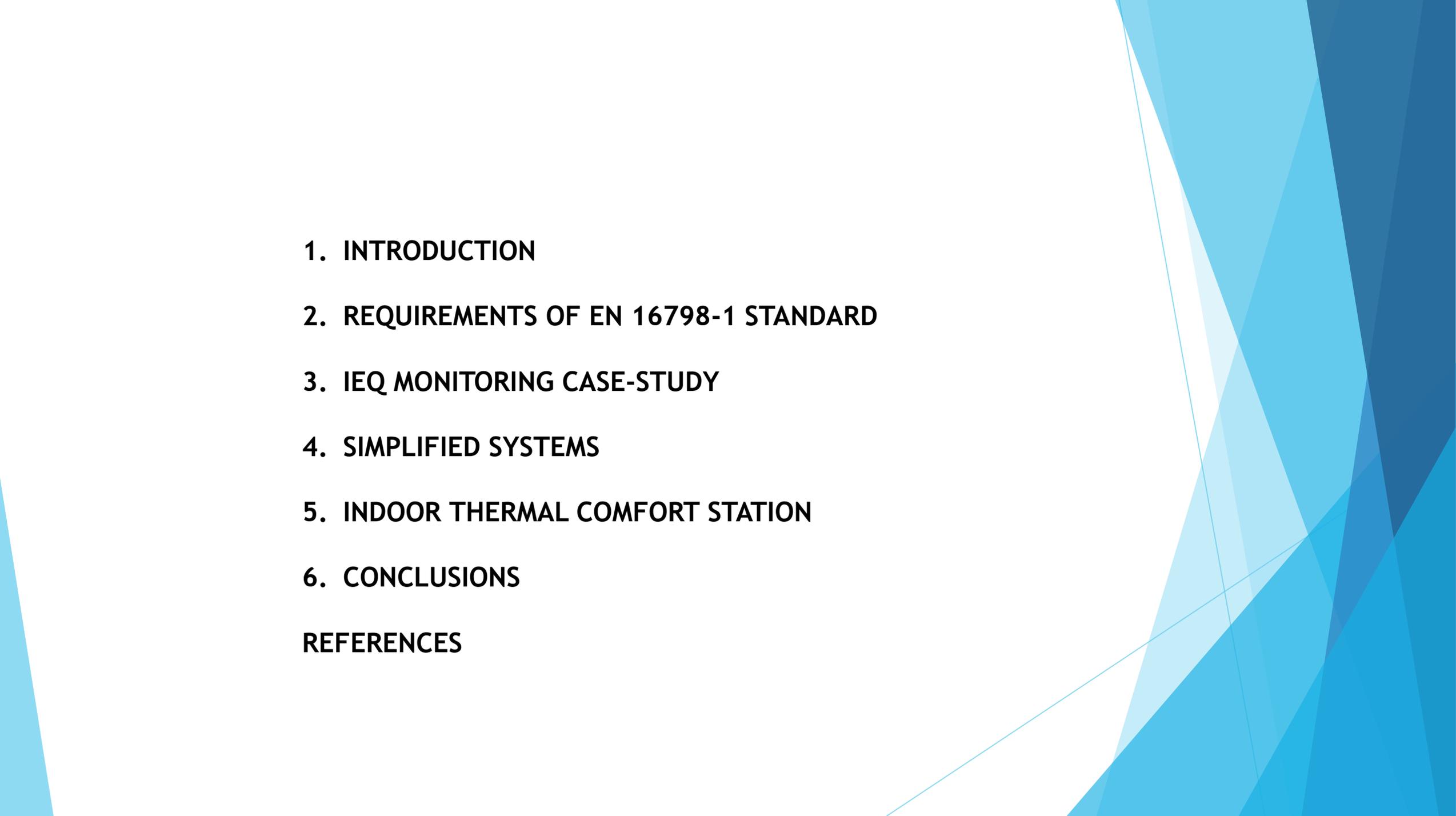
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1. Explain the impact of sensor performance and cost on GEB control and performance measurement
2. Acquire the competency to assess and communicate the main indicators related to building energy and indoor environment quality
3. Understand key technologies that have the potential to reduce sensor cost
4. Describe how to implement low-cost sensor and sensor system for building-grid integration, energy efficiency and indoor environment measurement and improvement

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The presented work was carried out in the framework of the Project RETROSYM POCI-01-0145-FEDER-032503 granted by the Portuguese Science and Technology Foundation and Programa Operacional do Centro

The background features abstract, overlapping geometric shapes in various shades of blue, ranging from light sky blue to deep navy blue. The shapes are primarily triangles and polygons, creating a modern, layered effect. The text is positioned on the left side of the slide, set against a plain white background.

1. INTRODUCTION

2. REQUIREMENTS OF EN 16798-1 STANDARD

3. IEQ MONITORING CASE-STUDY

4. SIMPLIFIED SYSTEMS

5. INDOOR THERMAL COMFORT STATION

6. CONCLUSIONS

REFERENCES

How has it started?

Model for the calculation of thermal comfort indices PMV and PPD (ISO 7730 - Fanger's method)

Input Data	
M (met)	1,2
W (met)	0
I cl (clo)	0,9
Ta (°C)	22,0
Tr (°C)	22,0
pa (Pascal)	1400
Va (m/s)	0,10
M (W/m ²)	69,8
W (W/m ²)	0
Icl (m ² °C/W)	0,1395

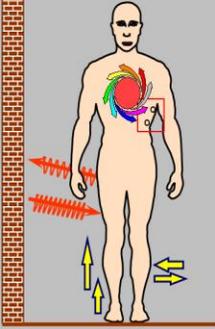
Control of Iterative Method
(Tcl - T_{cl,m}) = 0,00

Enable Macros
After introducing data,
Press Run Button.
After calculation, (Tcl - T_{cl,m}) must
be equal to 0.

Run

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manuel.gameiro@dem.uc.pt

Intermediate Calculations	
T skin =	33,7 °C
hc natural conv =	3,589
max hc =	3,826 (W/m ² °C)
hc forced conv =	3,826
Tcl =	27,2 °C
fcl (Icl < 0,5 clo) =	1,180
min fcl =	1,140 (m ² °C/W)
fcl (Icl > 0,5 clo) =	1,140



Heat Fluxes	
perspiration	11,73 (W/m ²)
sweating	4,88 (W/m ²)
breathing (latent)	5,30 (W/m ²)
breathing (sensible)	1,17 (W/m ²)
radiation	24,60 (W/m ²)
convection	22,55 (W/m ²)
Total Flux (Q)	70,23 (W/m ²)
Balance [(M-W) - Q]	-0,45 (W/m ²)

Output Data	
PMV =	-0,02
PPD (%) =	5,0



https://www.researchgate.net/publication/255971260_SPREADSHEETS_FOR_THE_CALCULATION_OF_THERMAL_COMFORT_INDICES_PMV_AND_PPD [1]

https://www.researchgate.net/publication/255971362_PMV_PPD_MC_english_prot [2]

Comfort Categories in EN16798-1

Category	Explanation
I	High level of expectation and is recommended for spaces occupied by very sensitive and fragile persons with special requirements like handicapped, sick, very young children and elderly persons
II	Normal level of expectation and should be used for new buildings and renovations
III	An acceptable, moderate level of expectation and may be used for existing buildings
IV	Values outside the criteria for the above categories. This category should only be accepted for a limited part of the year

NOTE In other standards like EN 13779 and EN ISO 7730 categories are also used; but may be named different (A, B, C or 1, 2, 3 etc.)

IEQ Monitoring Case Study

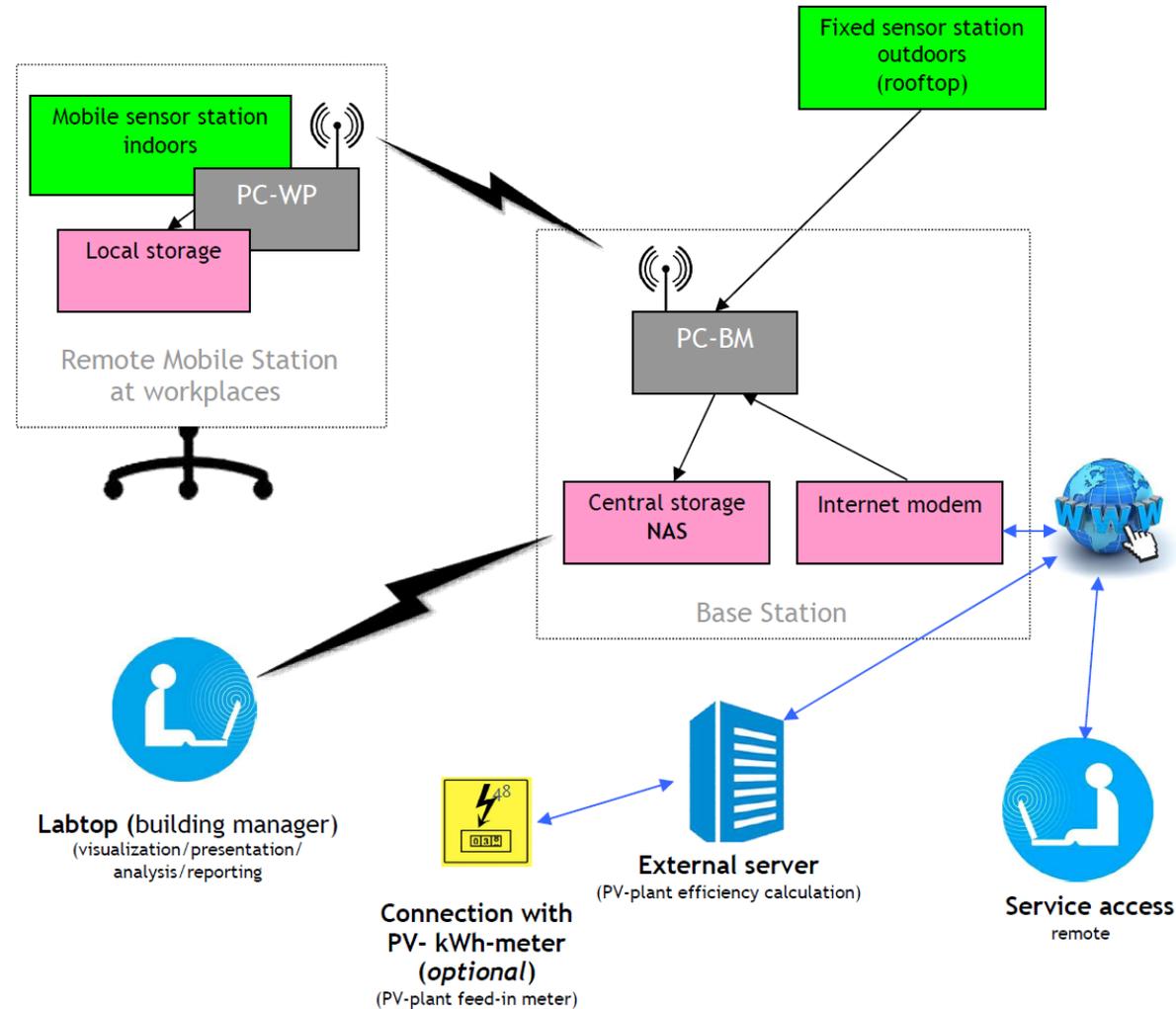
Gemeentehuis Horst aan de Maas

A Case of Excellence in Indoor Environmental Quality Monitoring



IEQ Monitoring Case Study

Monitoring System Architecture



IEQ Monitoring Case Study

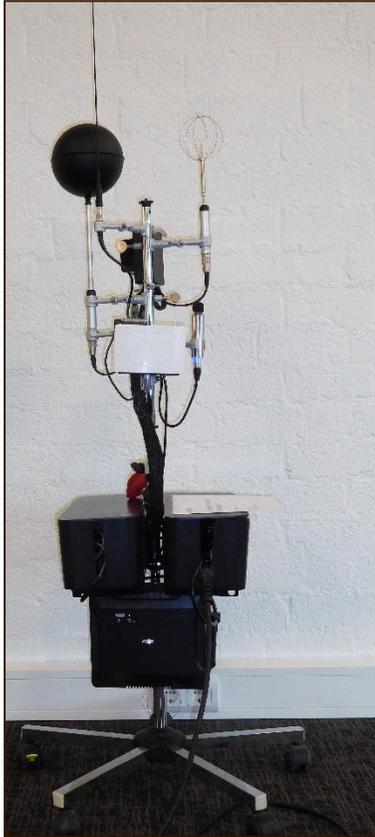


Table of WP variables

Nr	Parameter	Unit
1	Indoor Operative Temperature	(°C)
2	Predicted Mean Vote - PMV 1	---
3	Predicted Mean Vote - PMV 2	---
4	Predicted Percentage of Dissatisfied	(%)
5	Predicted Percentage of Dissatisfied	(%)
6	Draught Rate	(%)
7	Indoor Dew Point Temperature	(°C)
8	Air Temperature Fluctuation	(°C/h)
9	Indoor Air Pressure (hPa)	(hPa)
10	Indoor Humidity Ratio	(g/Kg of air)
11	Indoor Operative Temperature 2	(°C)
12	Indoor Air Temperature	(°C)
13	Indoor Relative Humidity	(%)
14	Indoor Concentration of CO2	(ppm)
15	Indoor Concentration of CO2	(ppm)
16	Indoor Concentration of VOCs	(100*ppb)
17	Indoor Concentration of PM10	(ug/m3)
18	Indoor Concentration of PM2.5	(ug/m3)
19	Indoor Concentration of PM1	(ug/m3)
20	Illuminance level (lux)	(lux)
21	Air Temperature Neck Level	(°C)
22	Air Temperature Anckle Level	(°C)
23	Air Velocity Neck Level	(m/s)
24	Air Velocity Anckle Level	(m/s)
25	Noise Equivalent Level 5 min	(dBA)

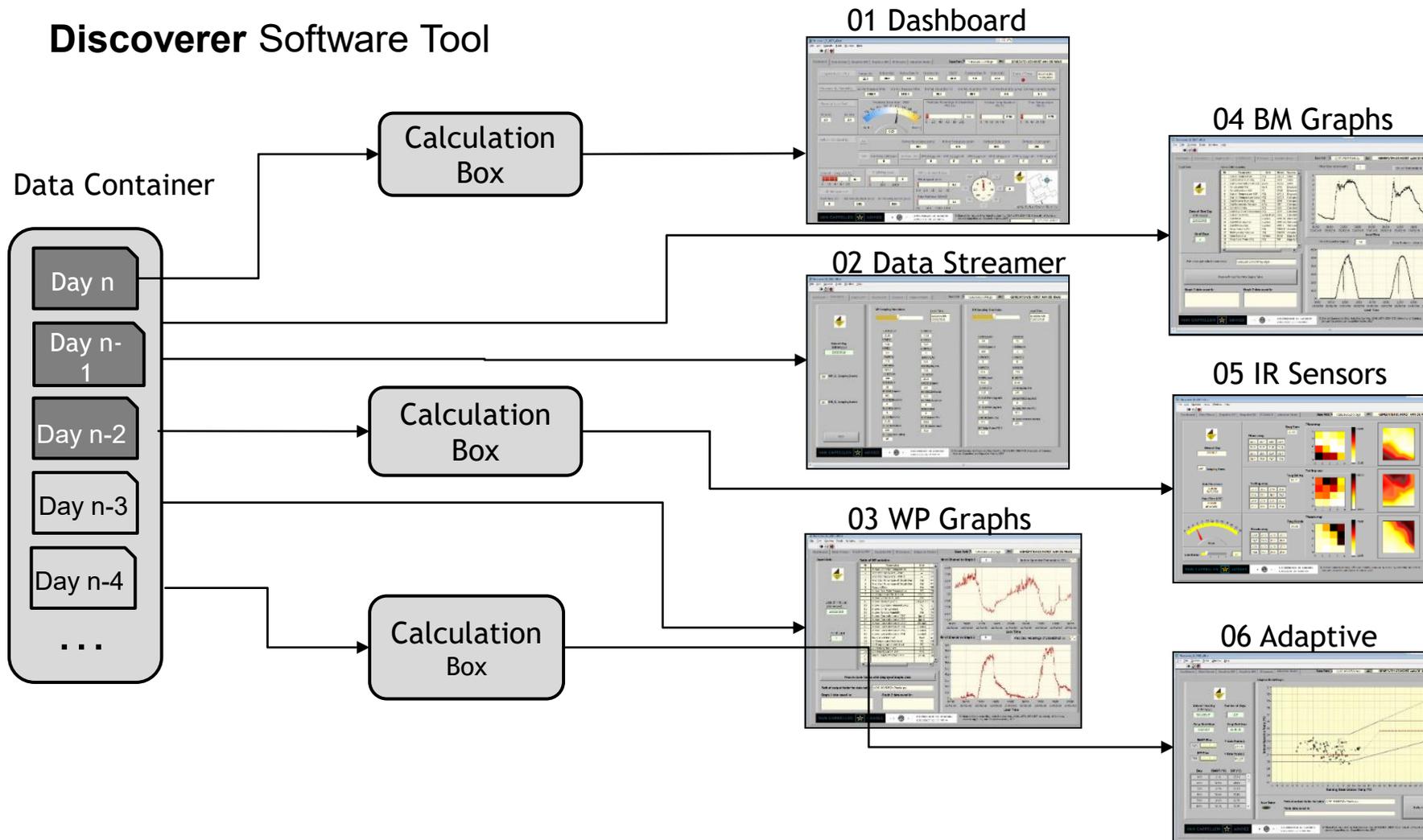


Table of BM Variables

Chanel	Parameter, Units
1	Outdoor Air Temperature (°C)
2	Outdoor Relative Humidity (%)
3	Outdoor Concentration of CO2 (ppm)
4	Wind Speed WST (m/s)
5	Wind Direction WST (°)
6	Outdoor Air Temperature WST(°C)
7	Outdoor Air Temperature Yocto(°C)
8	Outdoor Relative Humidity (%)
9	Outdoor Barometric Pressure (mbar)
10	Windchill Index (°C)
11	Outdoor Dew Point Temperature (°C)
12	Outdoor Air Humidity (g/kg of dry air)
13	Outdoor Concentration of PM10 (ug/m3)
14	Outdoor Concentration of PM2.5 (ug/m3)
15	Outdoor Concentration of PM1 (ug/m3)

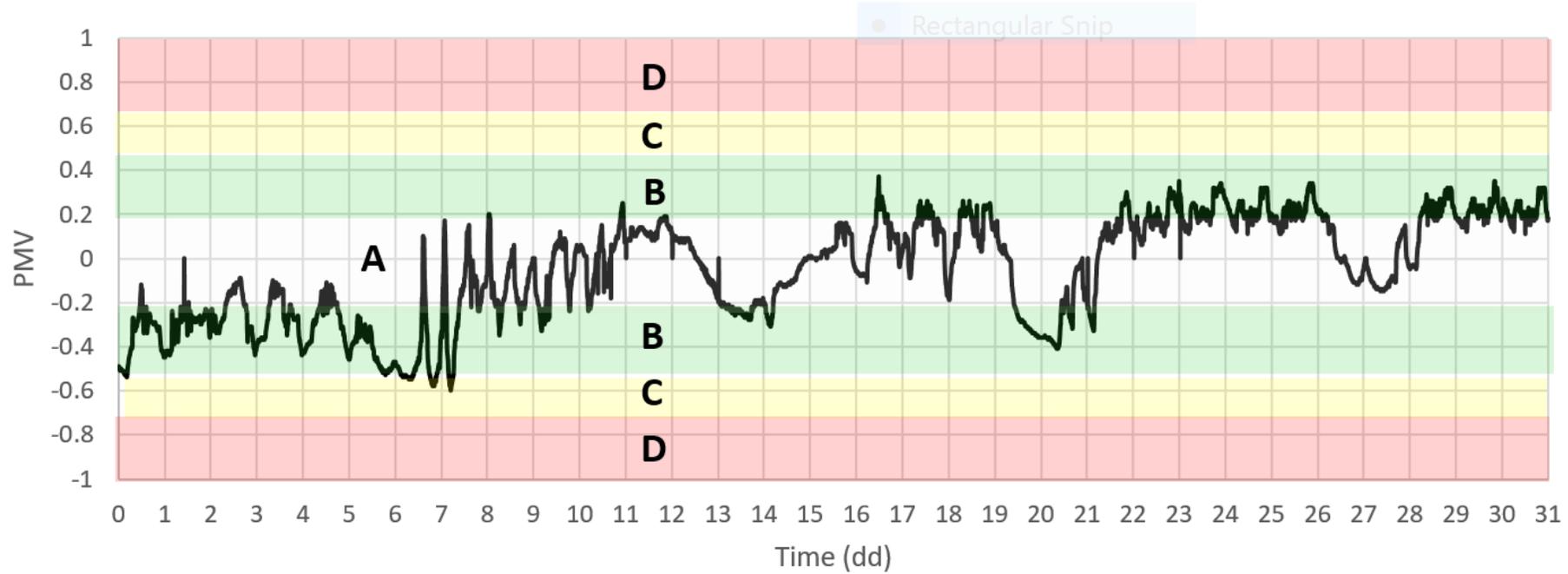
IEQ Monitoring Case Study

Discoverer Software Tool

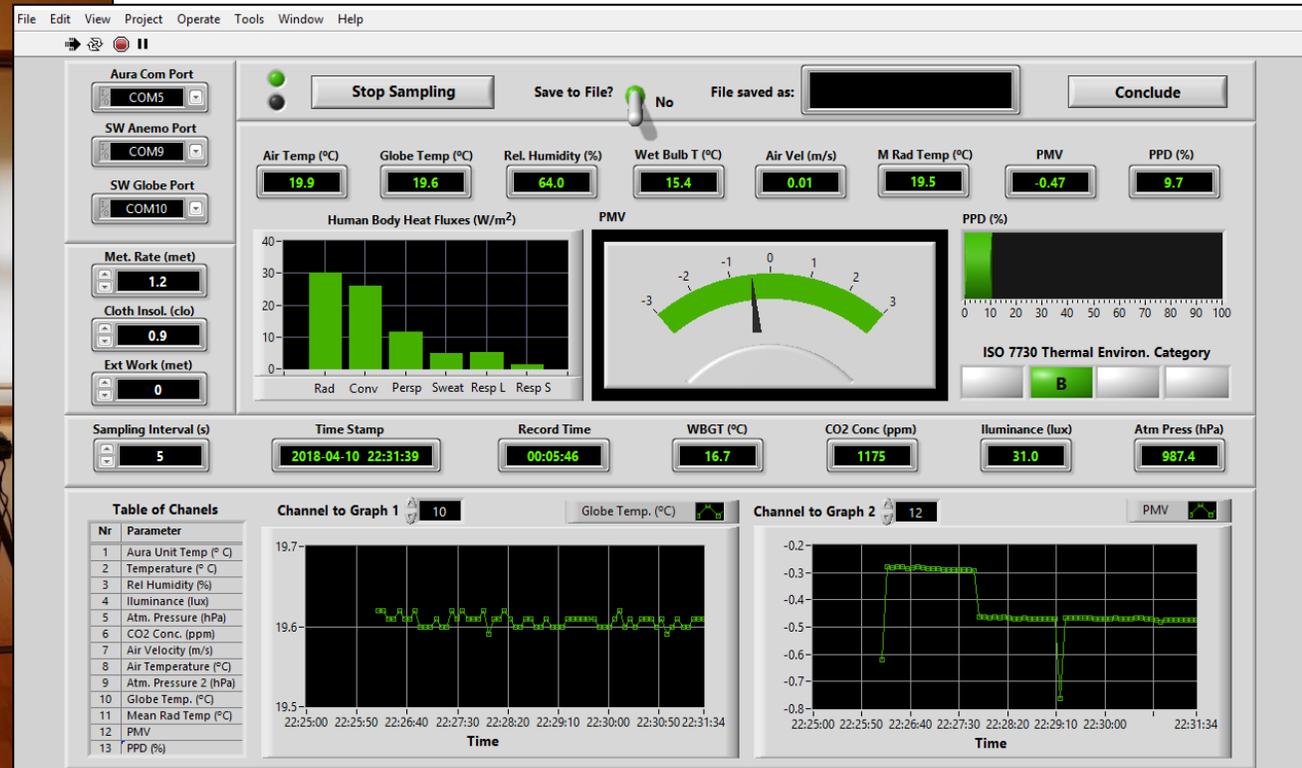
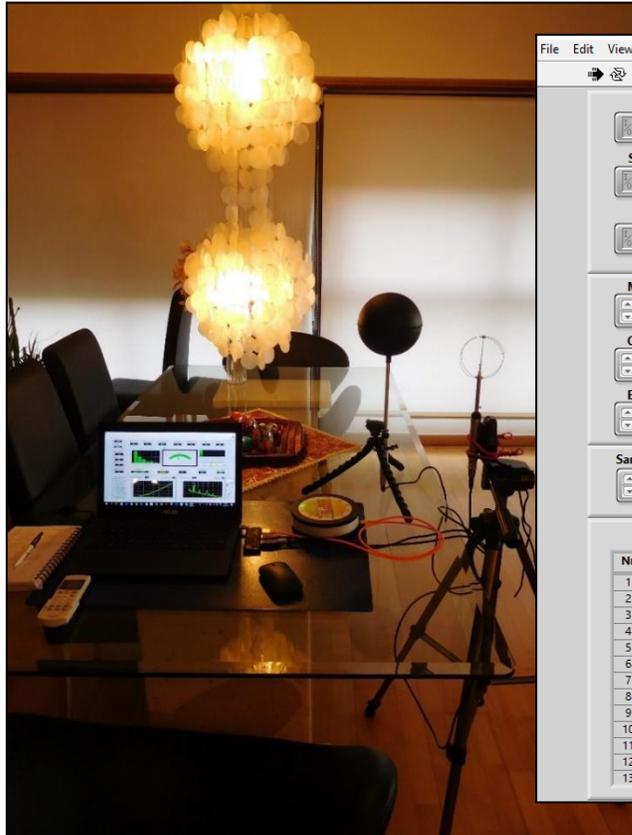


Long-term Evaluation of Thermal Comfort

Horst Gemeentehuis Horst aan de Maas, January 2018 - PMV

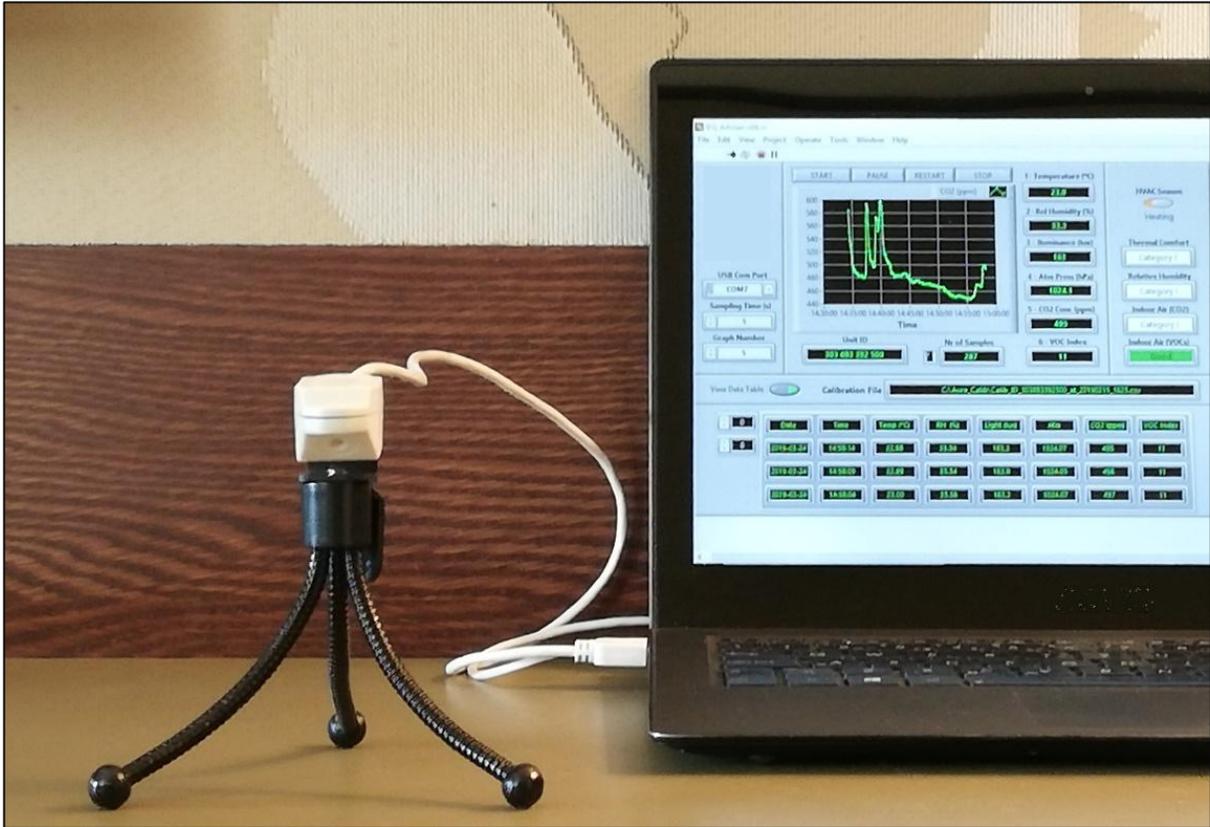
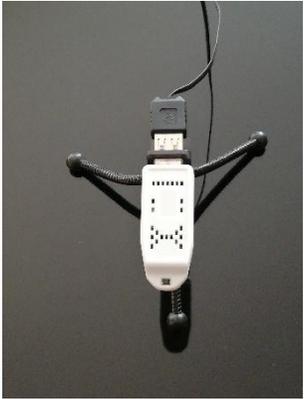


Prototype System for IEQ Analysis

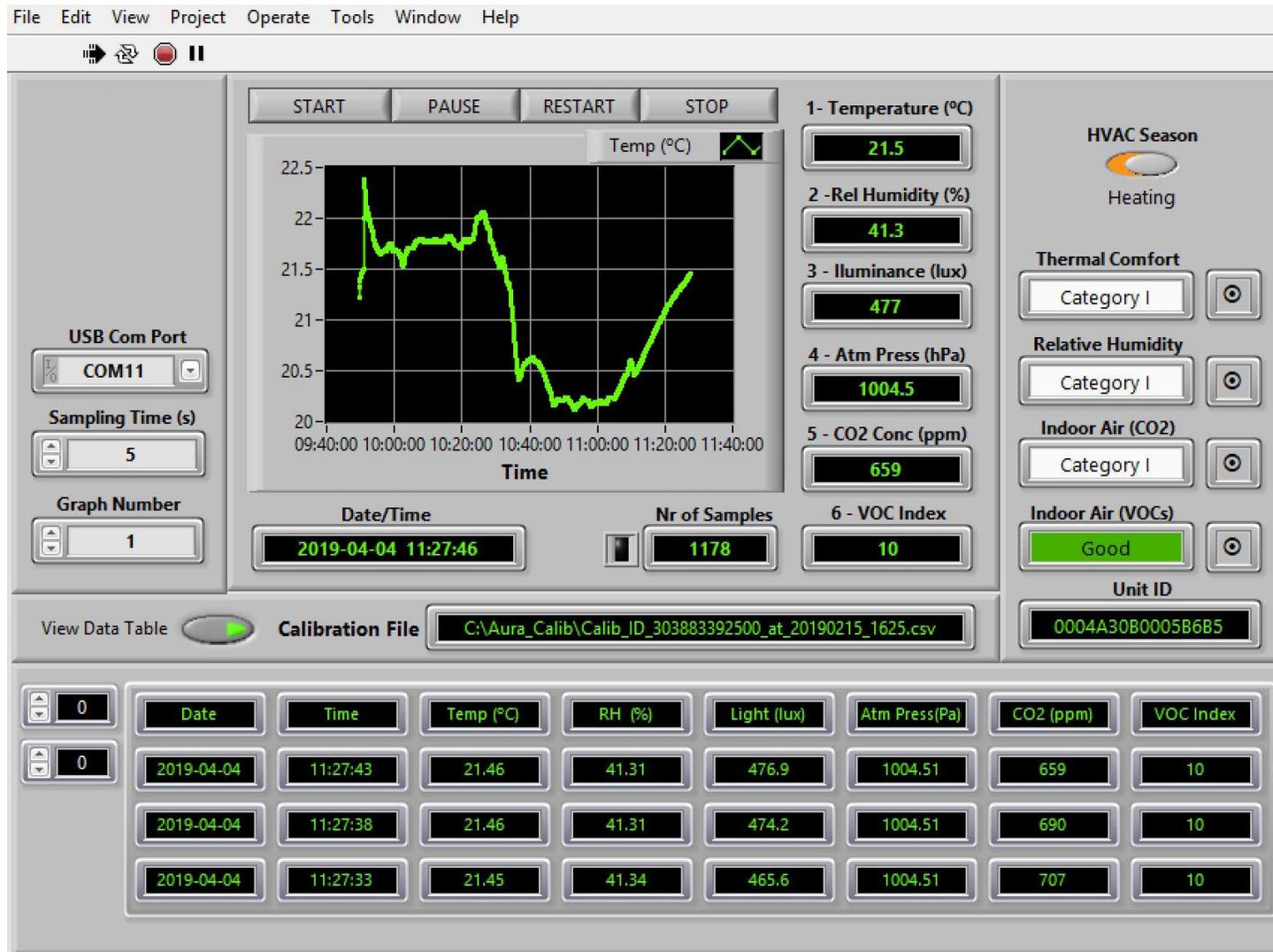


Miniaturized IEQ Monitoring System

IEQ MULTIPROBE + IEQ Discoverer App



IEQ Monitoring & Categorization Software



IEQ Categorization Scheme

HVAC Season

Heating

Thermal Comfort
Category I 

Relative Humidity
Category I 

Indoor Air (CO2)
Category I 

Indoor Air (VOCs)
Good 

Unit ID
0004A30B0005B6B5

HVAC Season

Cooling

Thermal Comfort
Category IV 

Relative Humidity
Category I 

Indoor Air (CO2)
Category I 

Indoor Air (VOCs)
Good 

Unit ID
0004A30B0005B6B5

HVAC Season

Cooling

Thermal Comfort
Category III 

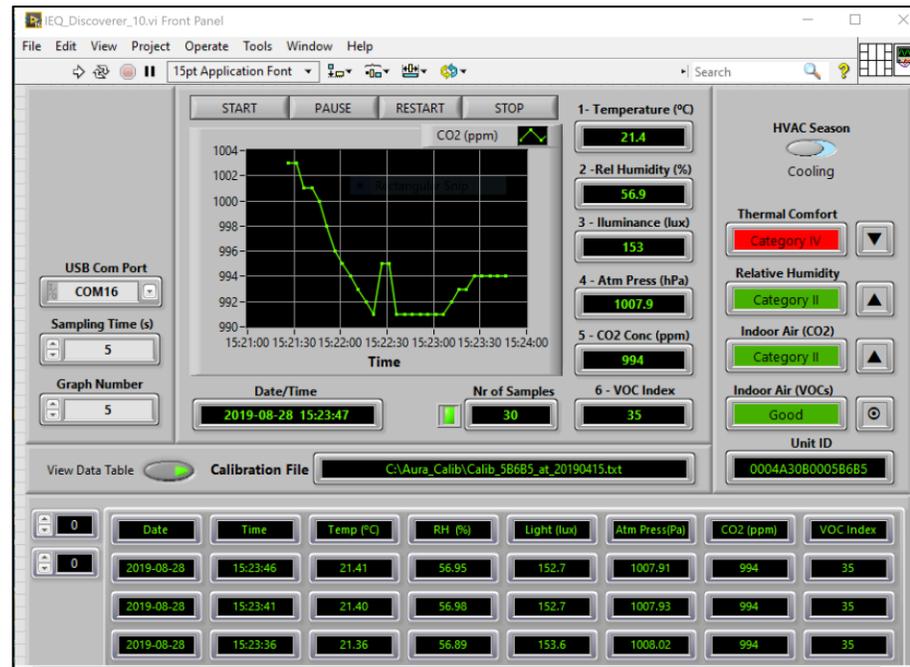
Relative Humidity
Category I 

Indoor Air (CO2)
Category III 

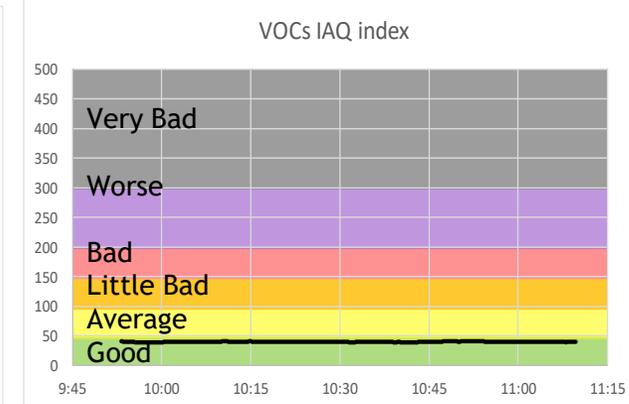
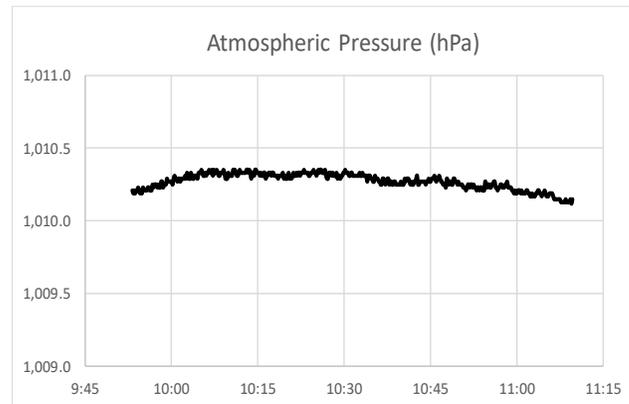
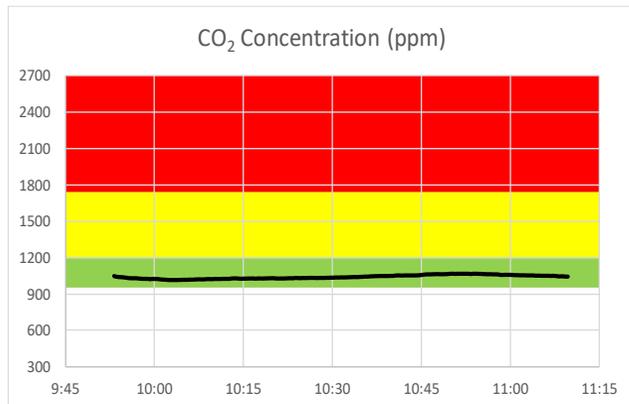
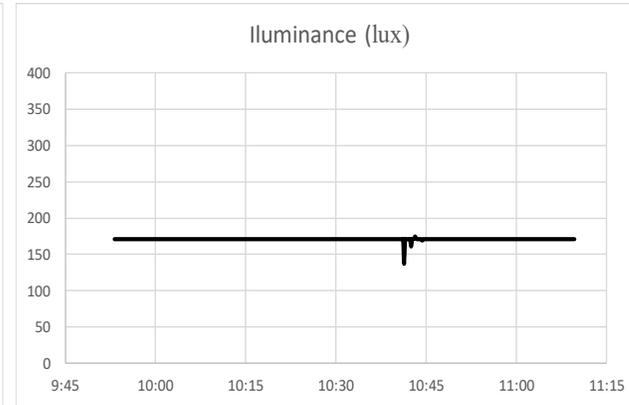
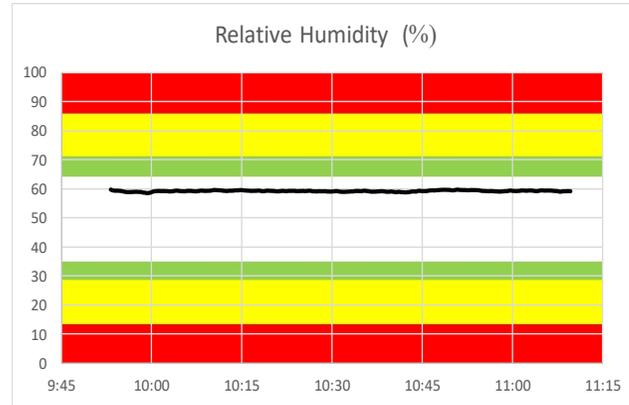
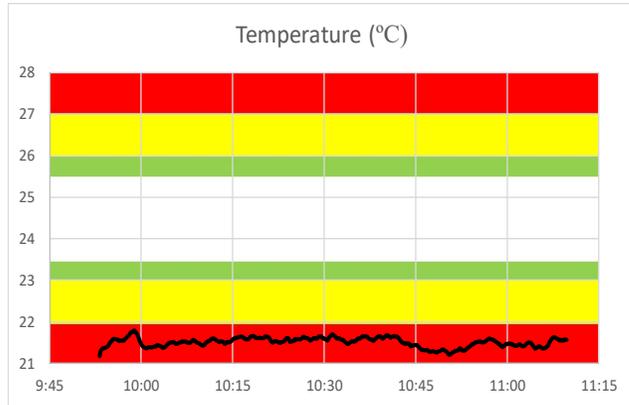
Indoor Air (VOCs)
Good 

Unit ID
0004A30B0005B6B5

IEQ Monitoring in a Auditorium

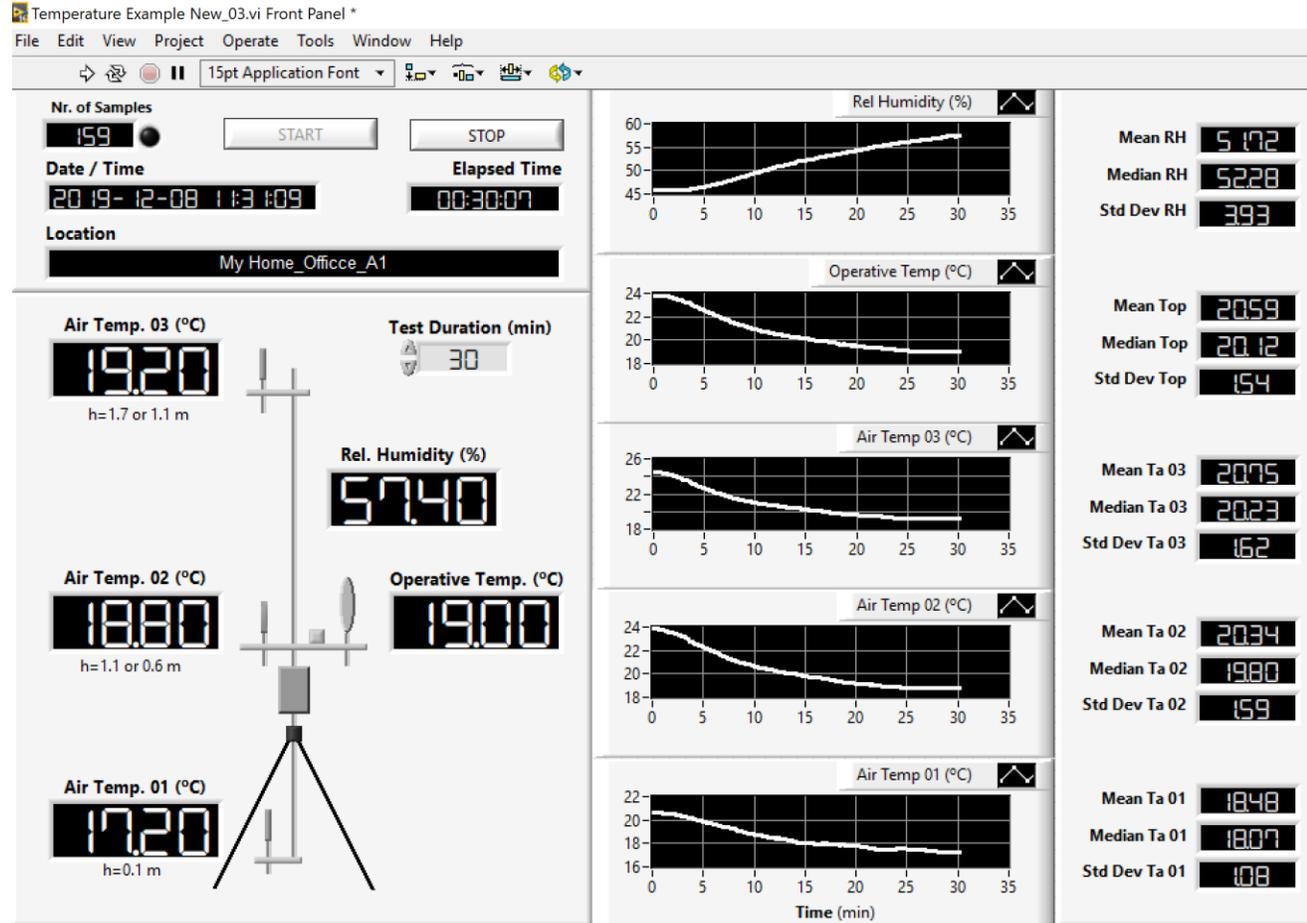


Categorized Data Presentation



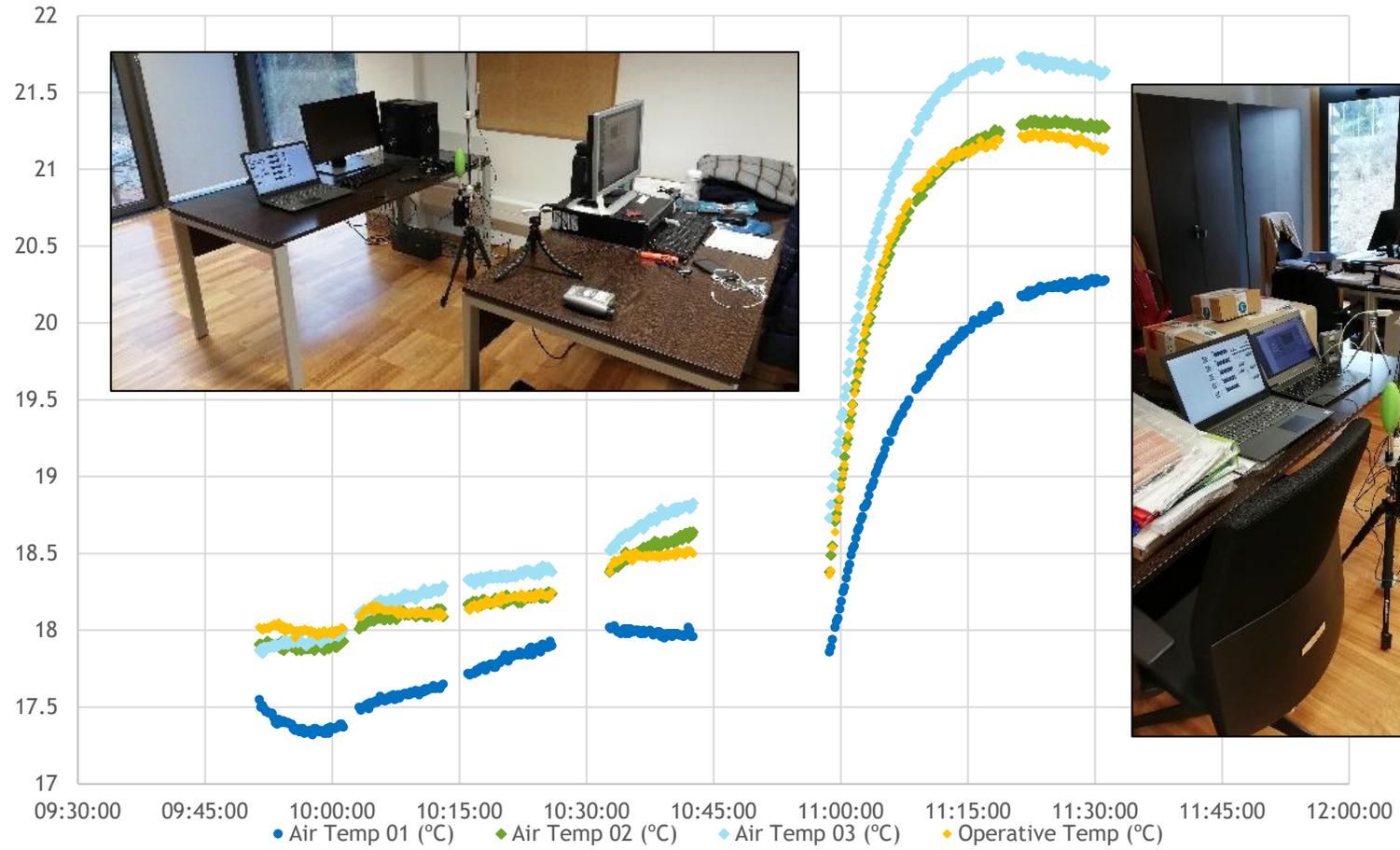
- Category IV
- Category III
- Category II
- Category I

Thermal Comfort Indoor Station

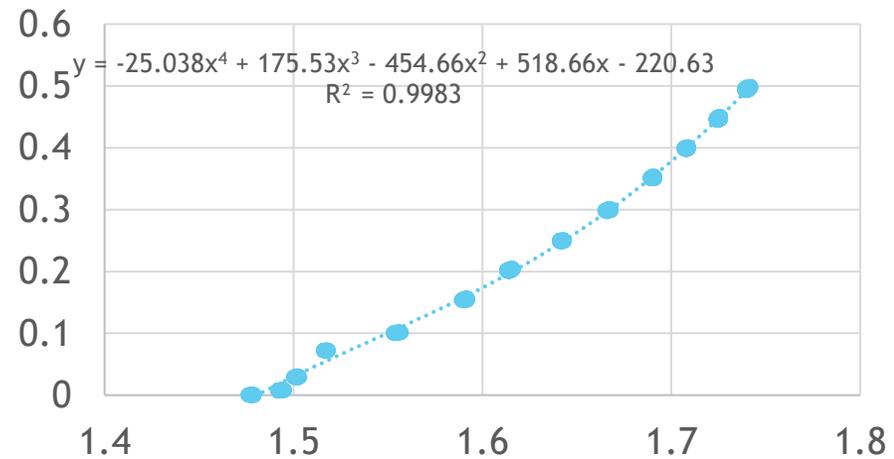
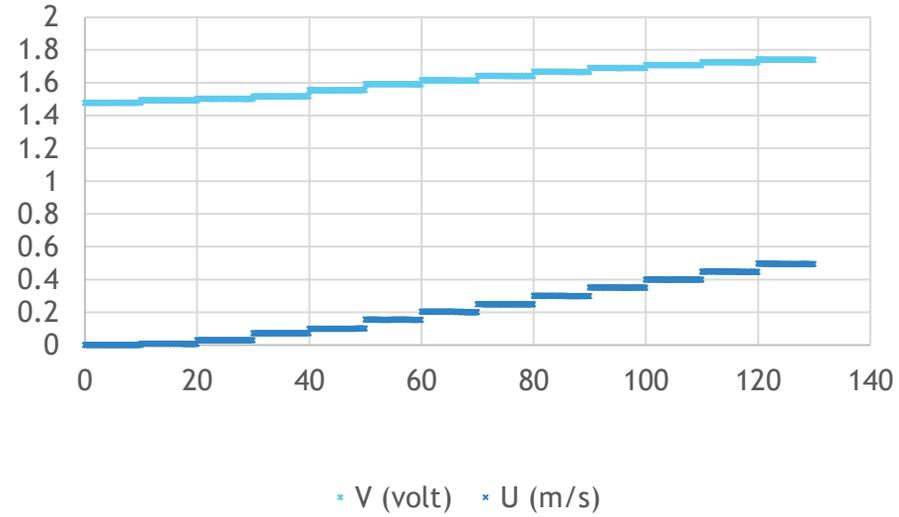
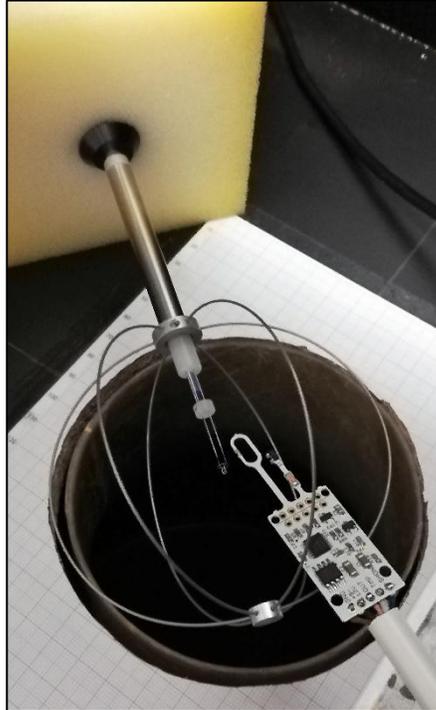


Thermal Comfort Indoor Station

Two Rooms Measurements



Calibration of low-speed affordable thermal anemometer



Conclusions

- The concept initially defined for the IEQ monitoring systems has been successfully implemented.
- The systems are an attempt to allow a better spread of the use of IEQ assessments, due to the integration of different probes in only one measuring device and to the innovative communication strategy.
- It is expected that a larger number of users will have access and easily understand the different dimensions of the evaluation of IEQ, with positive impacts in terms of well-being, health, safety and productivity of people in buildings and other indoor environments

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- [1] https://www.researchgate.net/publication/255971260_SPREADSHEETS_FOR_THE_CALCULATION_OF_THERMAL_COMFORT_INDICES_PMV_AND_PPD
- [2] https://www.researchgate.net/publication/255971362_PMV_PPD_MC_english_prot
- [3] Gameiro da Silva, Manuel, Dias Carrilho, João, van Cappellen, Leo, van Putten, John, Smid, Bart, “Gemeentehuis Horst aan de Maas: a case of excellence in indoor environmental quality”, *Rehva Journal*, Volume 55, Issue 4, August 2018, pp40-50
- [4] Gameiro da Silva, Manuel, van Cappellen, Leo, Sanjuanello, Eduardo, “Assessing and Communicating Indoor Environmental Quality”, *Rehva Journal*, Volume 56, Issue 2, April 2019, pp 14-18, also published in *Magyar Épületgépészet*, LXVIII, évfolyam, 2019/6

Part 2

▶ **Processing IAQ Data Collected in Monitored Buildings**

Presentation Outline

- Particularities of Nearly Zero Energy Buildings
- Time Evolution of the Concentration of a Pollutant
- Step Change Input Based Methods
- Periodic Input Based Methods
- Conclusions

Particularities of Nearly Zero Energy Buildings

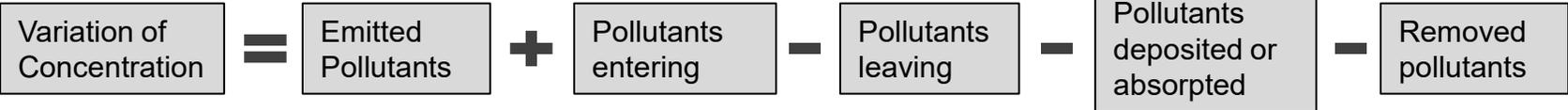
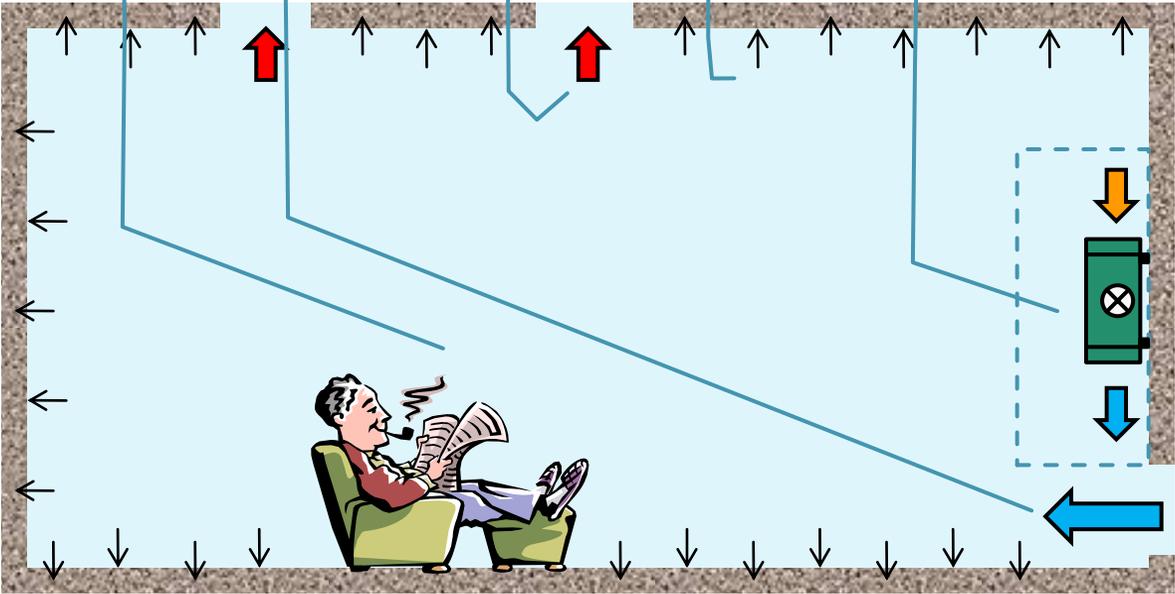
Energy Performance of Buildings Directive Recast (EPBD 2010) launched a target to the EU Member States regarding NZEBs

NZEBs are reached with self energy production, reduction of energy losses and better management of energy consumption

The management of ventilation/infiltration processes becomes very important in buildings with a much better insulation

Time Evolution of the Concentration of a Pollutant

$$\frac{dC}{dt} = \frac{G}{V} + \lambda_v C_{ext} - \lambda_v C(t) - v_d \frac{S}{V} - \frac{Q_{ac}}{V} C \varepsilon_{ac}$$



Time Evolution of the Concentration of a Pollutant

$$\frac{dC}{dt} = \frac{G}{V} + \lambda_v C_{ext} - \lambda_v C(t) - v_d \frac{S}{V} - \frac{Q_{ac}}{V} C \varepsilon_{ac}$$

C , mean instantaneous concentration of the pollutant (mg/m³)

G , generation of pollutants inside the compartment (mg/h)

V , room volume (m³)

λ_v , air exchange rate (h⁻¹)

C_{ext} , outdoor concentration (mg/m³)

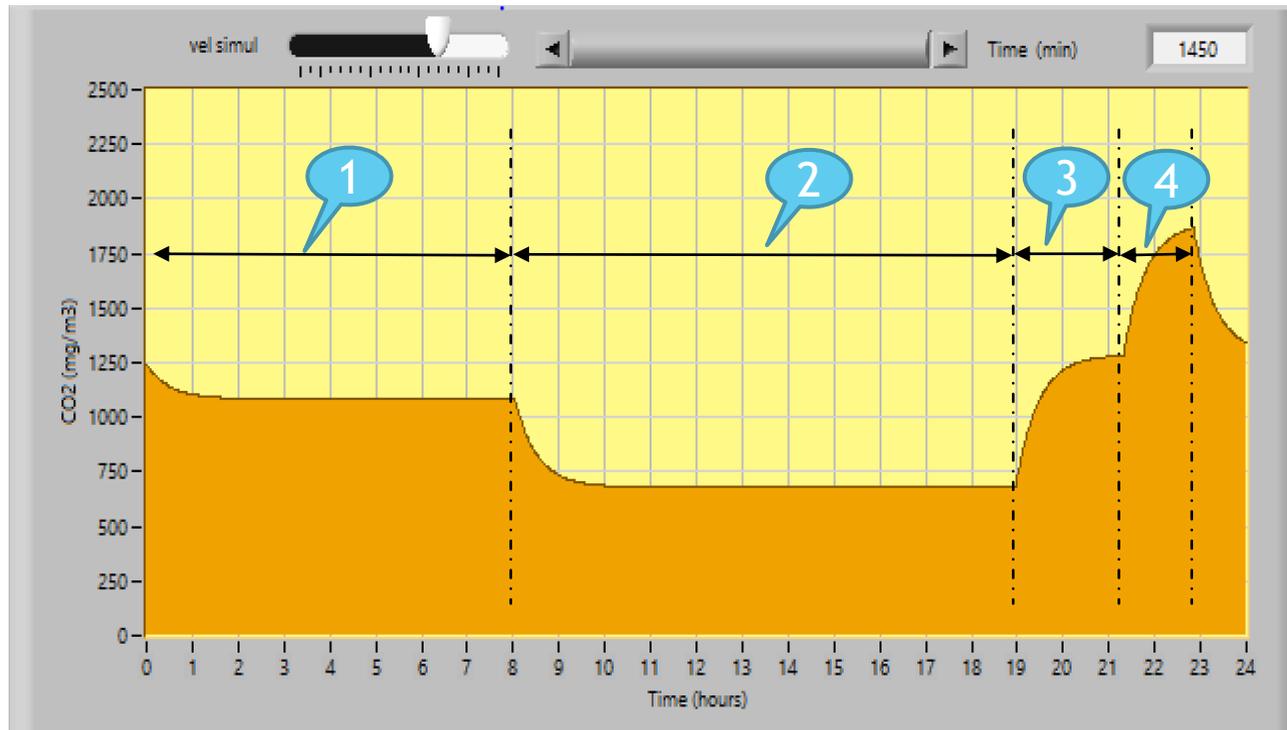
v_d , rate of deposition of pollutant (mg/(m²h))

S , area of deposition surface (m²)

Q_{ac} , flow rate through the air purifier (m³/h)

ε_{ac} , efficiency of air purifier (dimensionless)

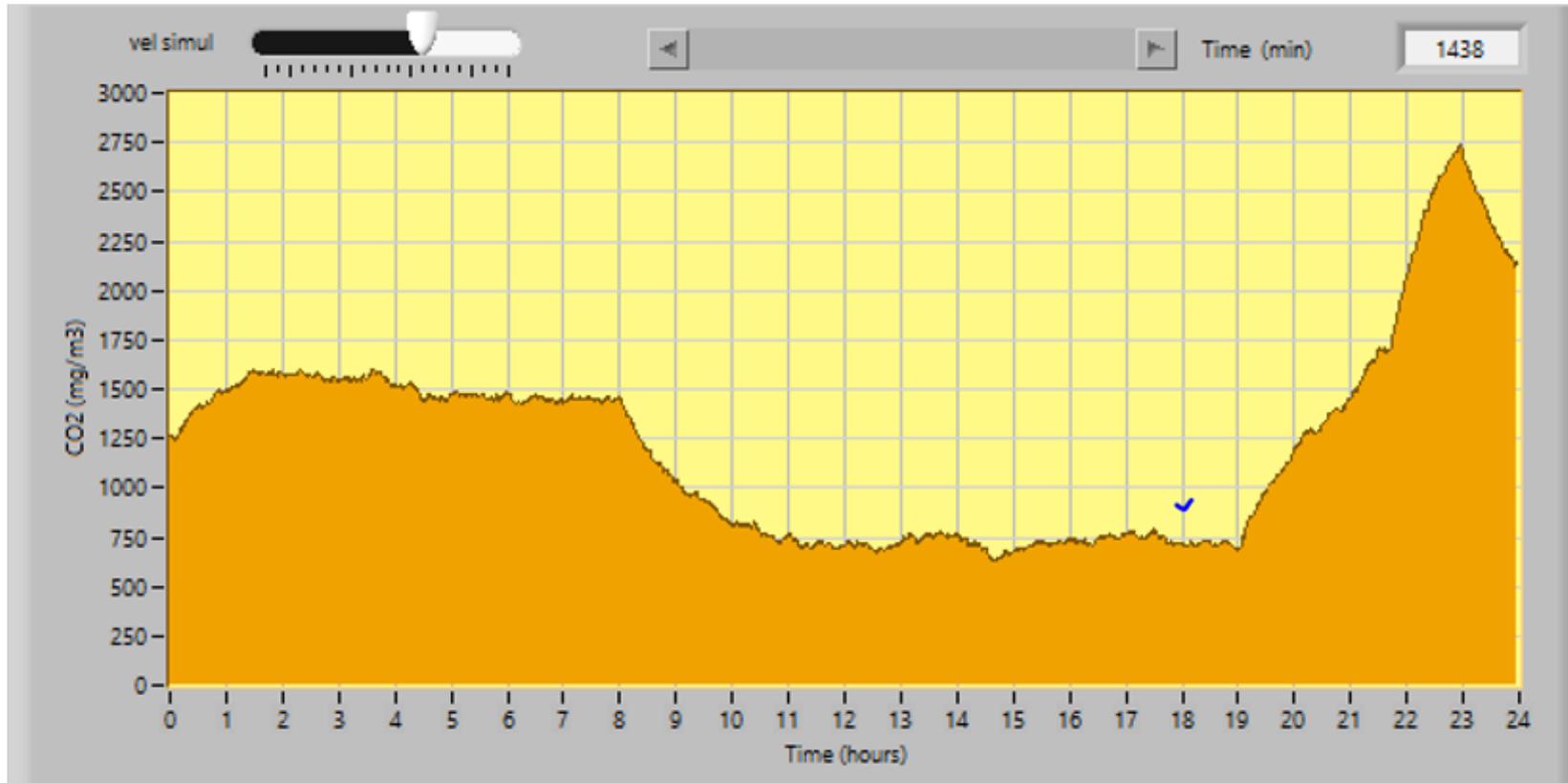
A typical theoretical evolution in a residential compartment



$$\frac{dC}{dt} = \frac{G}{V} + \lambda C_{ext} - \lambda C$$

A sequence of phases defined by step changes, occurring, for instances, due to variation of the rate of emission, the speed of the fan, or the velocity of the wind

An actual evolution in a residential compartment



The effect of wind perturbations and the uncertainty in the measurement of the gas concentration are main reasons for the differences.

Time Evolution of the Concentration of a Pollutant

The solution of the simplified differential equation,

$$\frac{dC}{dt} = \frac{G}{V} + \lambda C_{ext} - \lambda C$$

for the case of a step change, is:

$$\frac{C(t) - C_{equi}}{C_0 - C_{equi}} = e^{-\lambda t}$$

where

$$C_{equi} = C_{ext} + \frac{G}{Q}$$

being

$$\lambda_v = \frac{Q}{V}$$

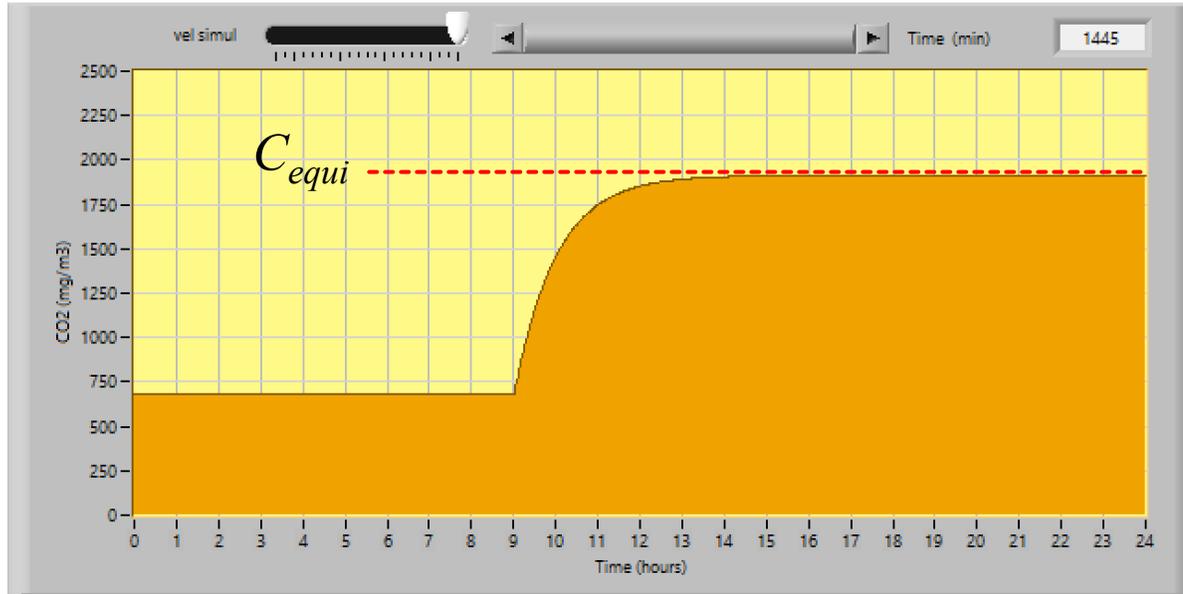
The air exchange rate (h⁻¹)

$$\tau = \frac{1}{\lambda_v} = \frac{V}{Q}$$

The mean age of air (h)

Step Change Input Based Methods

Method 1 - C_{equi} based



$$C_{equi} = C_{ext} + \frac{G}{Q}$$

$$Q = \frac{G}{(C_{equi} - C_{ext})}$$

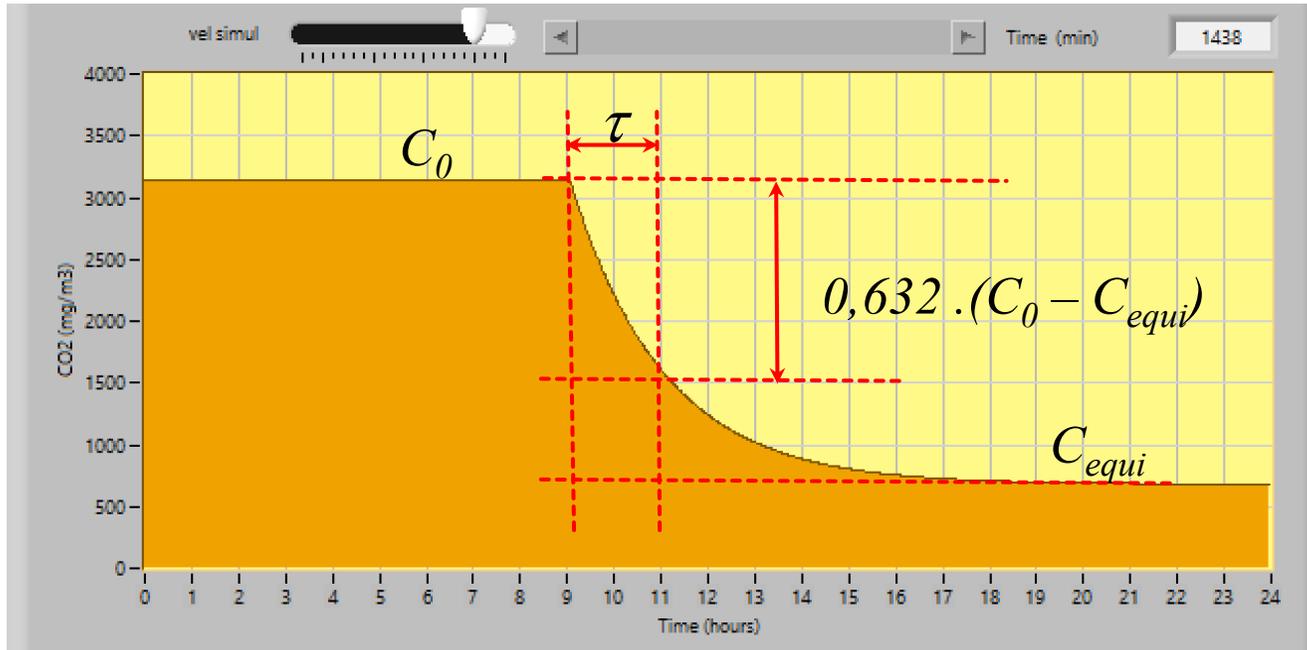
$$\lambda_v = \frac{Q}{V}$$

$$Q = \frac{37000}{(1913 - 680)} = 30 \text{ m}^3/\text{h} \quad \lambda_v = \frac{30}{30} = 1 \text{ h}^{-1}$$

Requirements: The emission rate G and room volume should be known. One step non-disturbed rising signal

Step Change Input Based Methods

Method 2 - Time constant (τ)



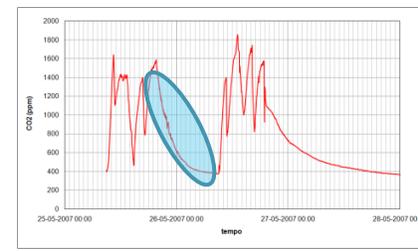
In the response of a first order system to a step change, the time constant τ is the time needed to reach 63.2% of the total response. The air exchange rate is the inverse of the time constant.

Pros: Very easy and fast to implement

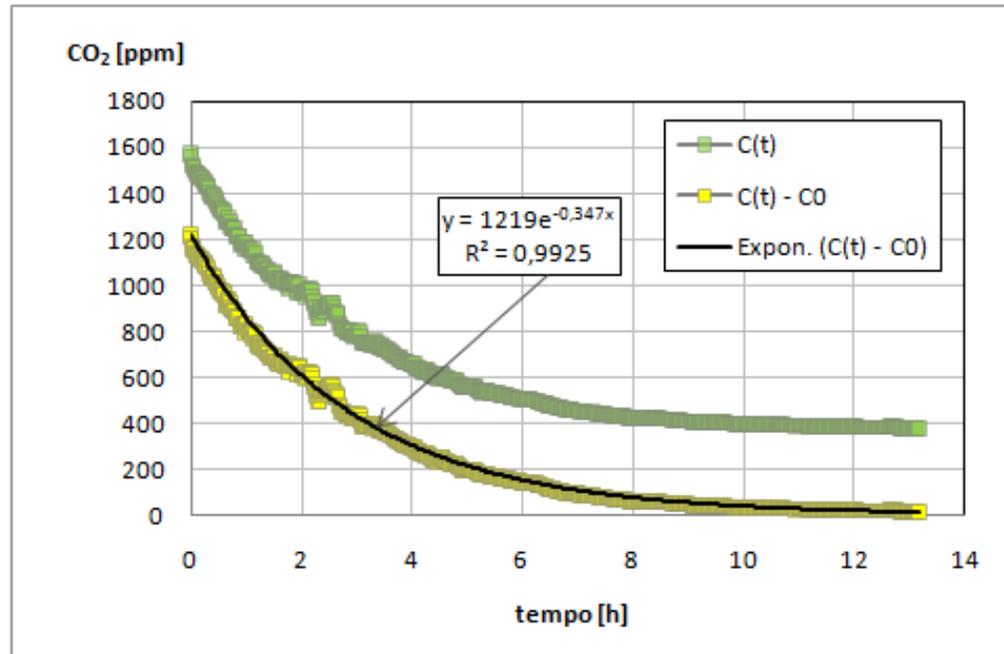
Cons: The precise localization of τ may be difficult if the signal is noisy

$$\frac{C(t) - C_{equi}}{C_0 - C_{equi}} = e^{-\lambda t} = e^{-\frac{t}{\tau}}$$

Step Change Input Based Methods



Method 3 - Fitting of the decay points with an exponential line



Pros: Better accuracy since when taking into account all the measuring points, the signal noise is somehow filtered

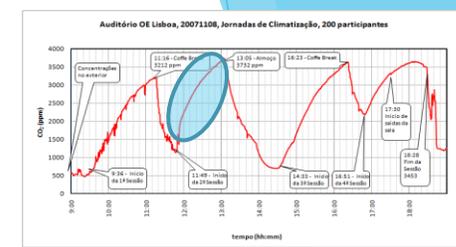
Cons: A computer software with a fitting algorithm is needed

Tip : Time should be expressed in hours. What is the unit of a Microsoft time stamp?

$$\underbrace{C(t) - C_{equi}}_Y = \underbrace{(C_0 - C_{equi})}_k \cdot e^{-\lambda t}$$

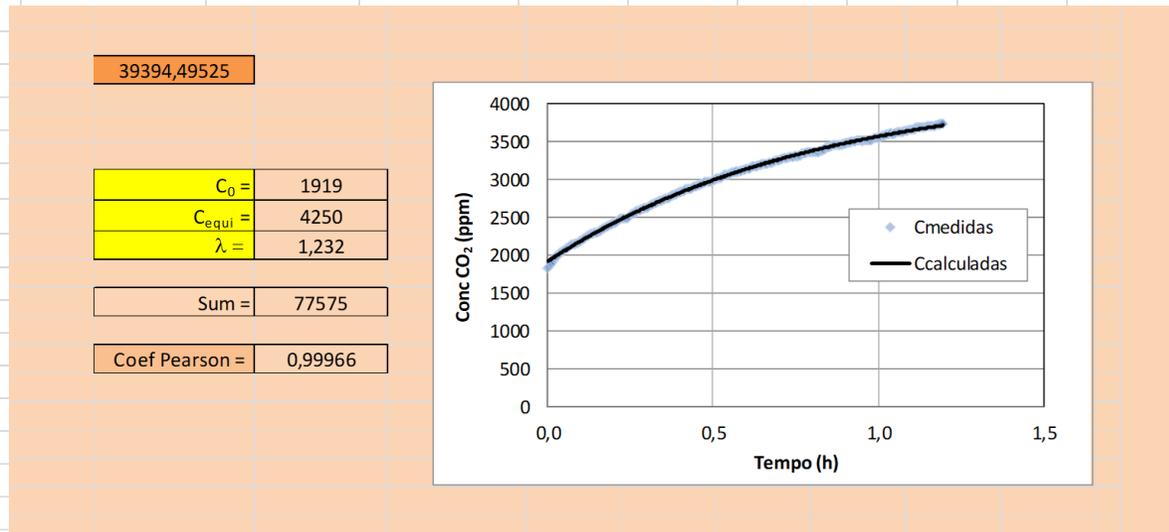
$$Y = k \cdot e^{-\lambda x}$$

Step Change Input Based Methods



Method 4 - Fitting of the rising points with an exponential line

Tempo	C _{medidas}	C _{calculadas}	Δ ²
h	ppm	ppm	
0,00	1839	1900	3721
0,00	1853	1906	2791
0,01	1868	1912	1904
0,01	1885	1917	1052
0,01	1897	1923	687
0,01	1910	1929	360
0,02	1930	1935	22
0,02	1951	1940	112
0,02	1968	1946	477
0,02	1981	1952	850
0,03	1992	1958	1188
0,03	2003	1963	1584
0,03	2016	1969	2223
0,04	2029	1974	2972
0,04	2042	1980	3832
0,04	2051	1986	4264
0,04	2053	1991	3808
0,05	2059	1997	3861
0,05	2068	2002	4301
0,05	2079	2008	5047



$$C(t) = C_{equi} + (C_0 - C_{equi}) \cdot e^{-\lambda t}$$

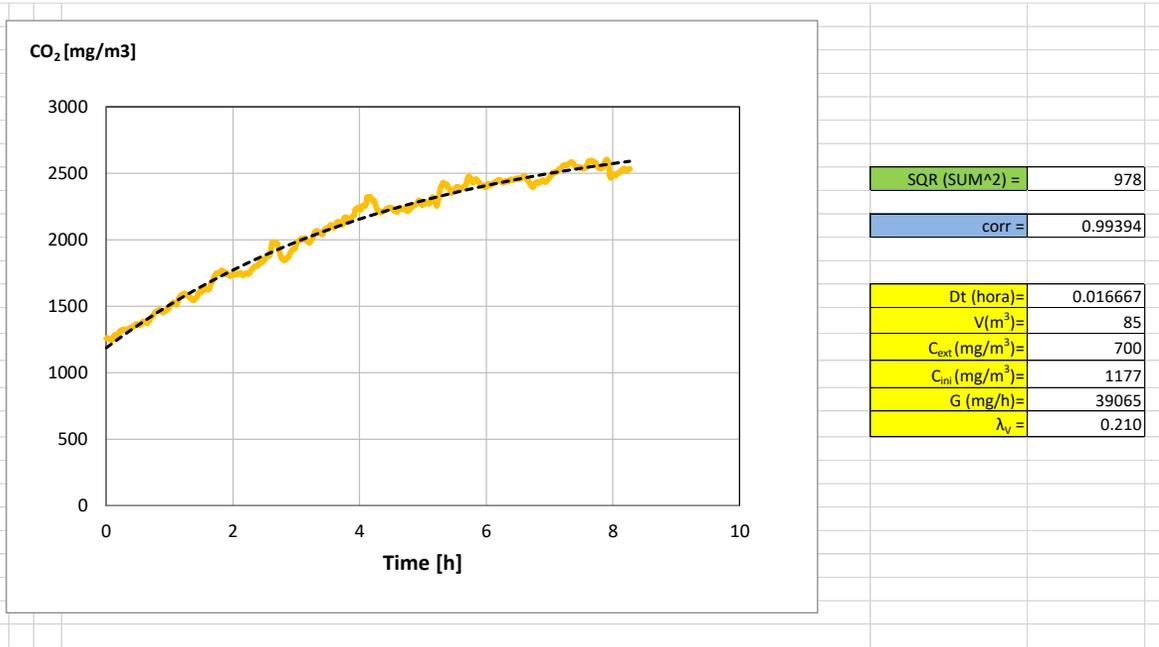
Cons: Need to implement “by hand” the Least Squares Method for the exponential curve fitting (Solver complement function of Excel is used)

Pros: The same as the previous method)

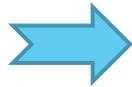
Step Change Input Based Methods

Method 5 - Fitting with a finite differences equation

Nr	t (h)	T * 10	CO2 ppm	CO2 real	CO2	Delta
0	0	305	701	1261.8	1186.853	5617.060
1	0.016667	304	700	1260	1192.81	4514.445
2	0.033333	302	698	1256.4	1198.747	3323.871
3	0.05	302	698	1256.4	1204.663	2676.736
4	0.066667	299	695	1251	1210.558	1635.557
5	0.083333	297	693	1247.4	1216.433	958.985
6	0.1	300	696	1252.8	1222.287	931.073
7	0.116667	310	706	1270.8	1228.12	1821.579
8	0.133333	318	714	1285.2	1233.933	2628.288
9	0.15	318	714	1285.2	1239.726	2067.887
10	0.166667	317	713	1283.4	1245.499	1436.522
11	0.183333	317	713	1283.4	1251.251	1033.566
12	0.2	325	721	1297.8	1256.983	1666.017
13	0.216667	334	730	1314	1262.695	2632.170
14	0.233333	336	732	1317.6	1268.388	2421.865
15	0.25	338	734	1321.2	1274.06	2222.191
16	0.266667	341	737	1326.6	1279.712	2198.450
17	0.283333	340	736	1324.8	1285.345	1556.690
18	0.3	339	735	1323	1290.958	1026.683
19	0.316667	339	735	1323	1296.552	699.523
20	0.333333	340	736	1324.8	1302.125	514.140
21	0.35	344	740	1332	1307.68	591.477
22	0.366667	346	742	1335.6	1313.215	501.105
23	0.383333	348	744	1339.2	1318.73	419.013
24	0.4	350	746	1342.8	1324.226	344.976
25	0.416667	351	747	1344.6	1329.704	221.904



$$\frac{dC}{dt} = \frac{G}{V} + \lambda C_{ext} - \lambda C$$



$$\Delta C = \Delta t \times \left(\frac{G}{V} + \lambda C_{ext} - \lambda C \right)$$

$$C_i = C_{i-1} + \Delta C$$

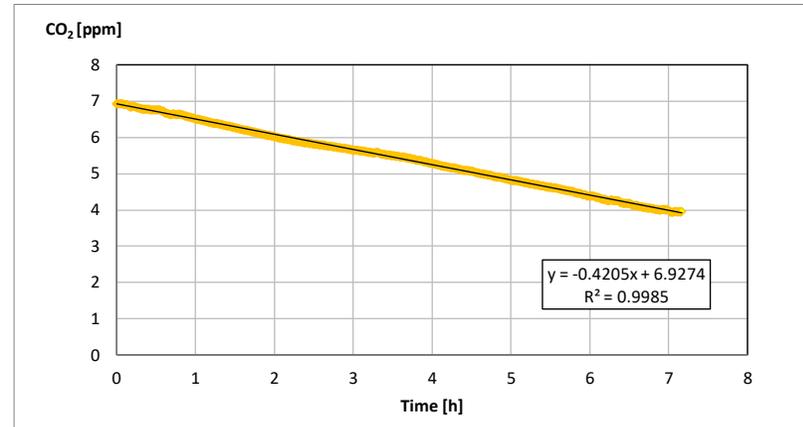
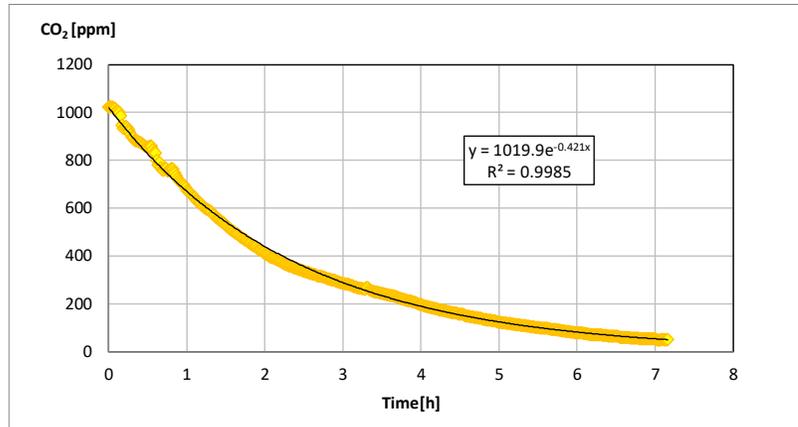
Pros: it is quite general. May be used for any part of the time evolution of the signal

Step Change Input Based Methods

Method 6 - Logarithmizing the excess of concentration and fitting with a linear equation

$$C(t) - C_{equi} = (C_0 - C_{equi})e^{-\lambda t}$$

$$\ln(C(t) - C_{equi}) = -\lambda t + \ln(C_0 - C_{equi})$$



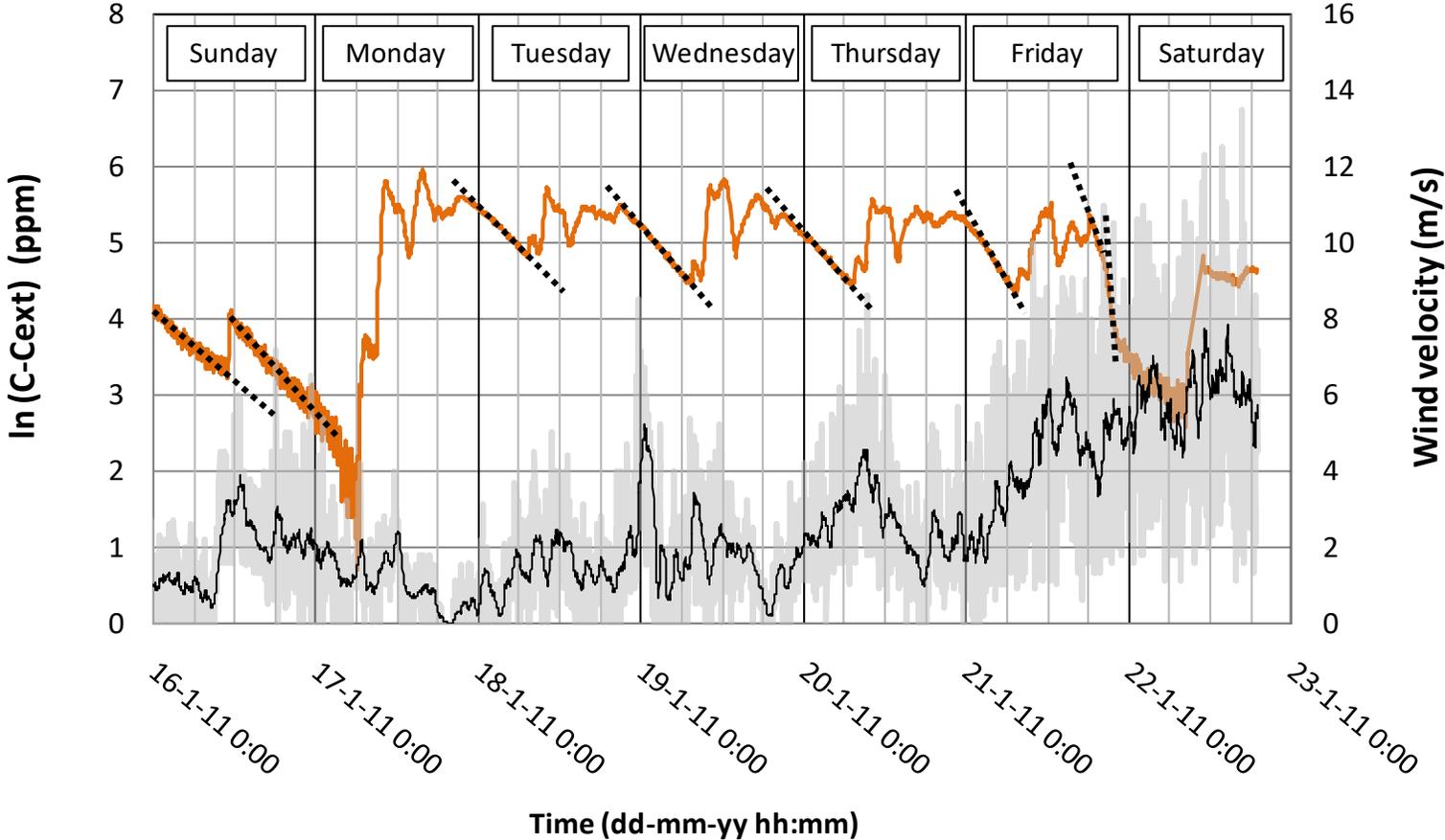
$$Y = Ke^{-\lambda X}$$

$$Y = mX + b$$

Pros: it allows a better identification of the transition of phases

Step Change Input Based Methods

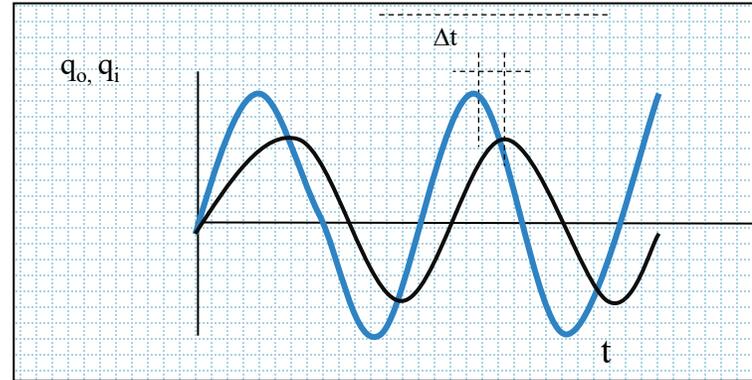
Method 6 - Logarithmizing the excess of concentration and fitting with a linear equation



Periodic Input Based Methods

Response of a 1st order system to a periodic input

$$\tau \frac{\partial x}{\partial t} + x = A \sin \omega t$$



The solution of the differential equation is:

$$x(t) = C e^{-\left(\frac{t}{\tau}\right)} + \frac{A/a_0}{\sqrt{1+(\omega\tau)^2}} \sin(\omega t - \phi(\omega)).$$

Where:

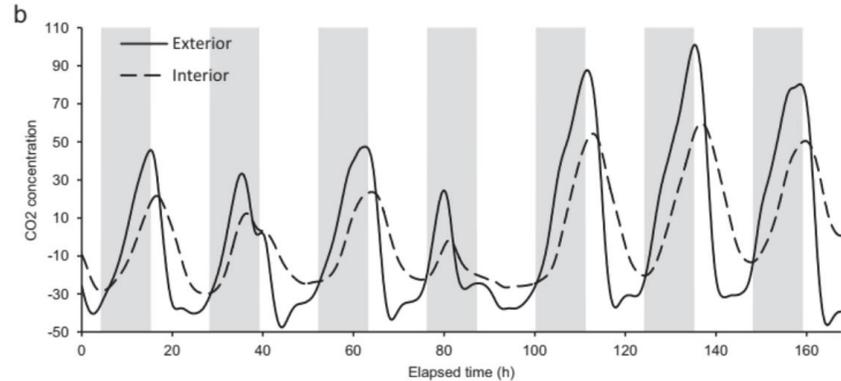
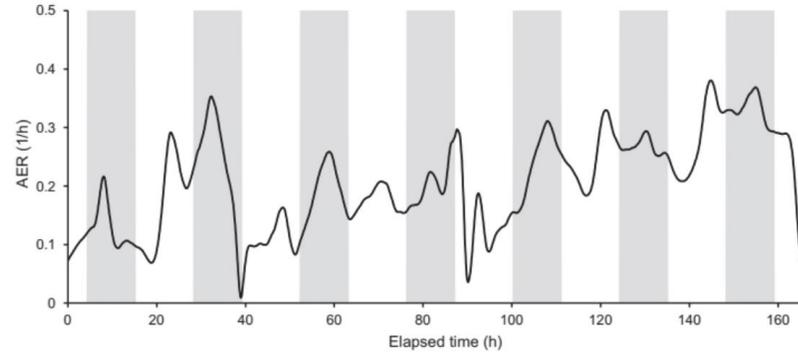
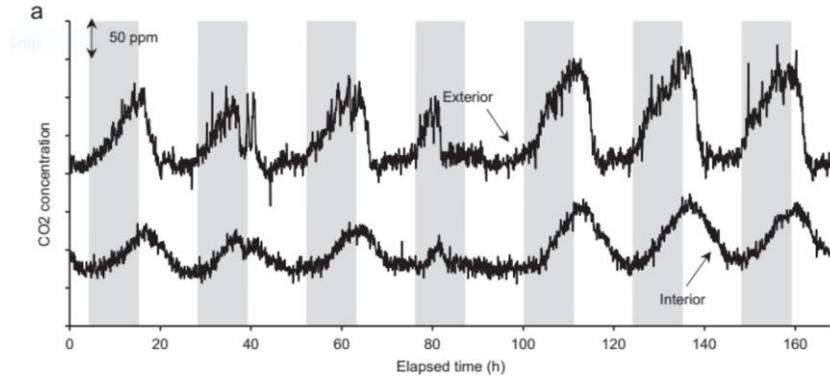
$\phi(\omega) = -\tan^{-1}(\omega\tau)$ is the phase angle

$\Delta t = \frac{\phi(\omega)}{\omega}$ is the time delay

$\frac{1}{\sqrt{1+(\omega\tau)^2}}$ is the amplitude ratio

Periodic Input Based Methods

Method 7 - Response of a 1st order system to a periodic input



Pros: The method allows the assessment of a short-term evaluation of air exchange rate

Cons: To apply it with CO₂ as a tracer gas, the building must be unoccupied

Conclusions

- ▶ Different Methods are available to estimate AER from the monitoring of CO₂ concentration in buildings
- ▶ The accuracy of assessment and the time resolution of AER data depend on the sophistication of the method
- ▶ A recent approach based upon the response to a periodic input signal has been addressed

References

- ▶ M C Gameiro da Silva - Indoor Air Quality Simulation Tools, *Rehva Journal - European Journal of Heating, Ventilation and Air-Conditioning Technology*, Volume 46, Issue 4, August 2009, pp 30-32
- ▶ M. C. Gameiro da Silva, “Virtual Laboratories for a Course about Indoor Environmental Quality”, *Special Issue of International Journal on Emerging Technologies in Learning*, November 2009 doi:10.3991/ijoe.v5s2.1107
- ▶ João Dias Carrilho, Mário Mateus, Stuart Battermann, Manuel Gameiro da Silva, “Air Exchange Rates from Atmospheric CO2 Daily Cycle””, *Energy and Buildings* 92, 1: 188 - 194. doi: 10.1016/j.enbuild.2015.01.062
- ▶ João Dias Carrilho, Maria Rocheta Gomes, Mário Mateus, Stuart Batterman, Manuel Gameiro da Silva - “Measurement of Infiltration Rates from Daily Cycle of Ambient CO2” *International Journal of Ventilation* ISSN 1473-3315 Volume 14 No 4 March 2016 : <http://www.tandfonline.com/loi/tjov20>

Part 3

▶ **Living Lab Experiences at the University of Coimbra**

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

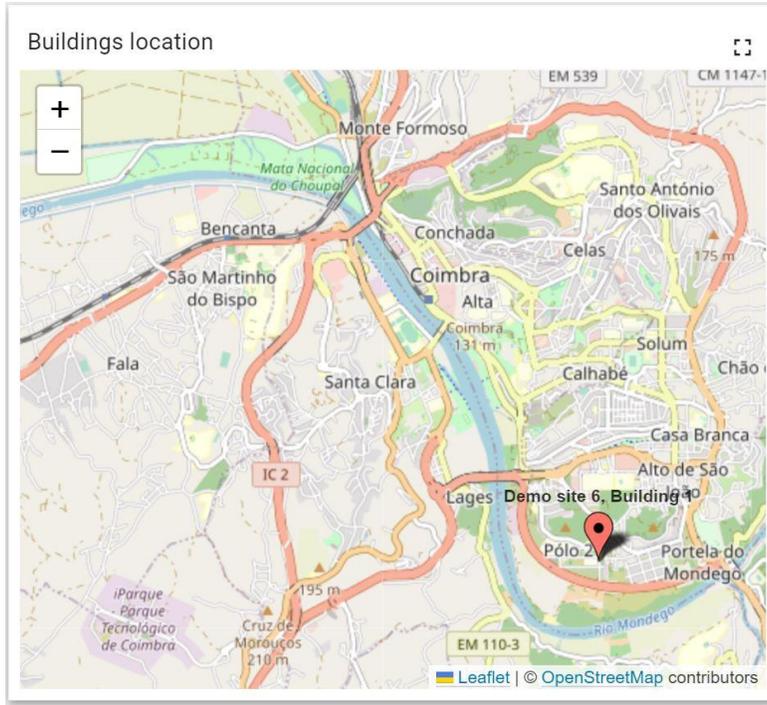
IST Alameda Campus. University classrooms and kindergarten. Home to up to 9889 university students and 124 children.

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

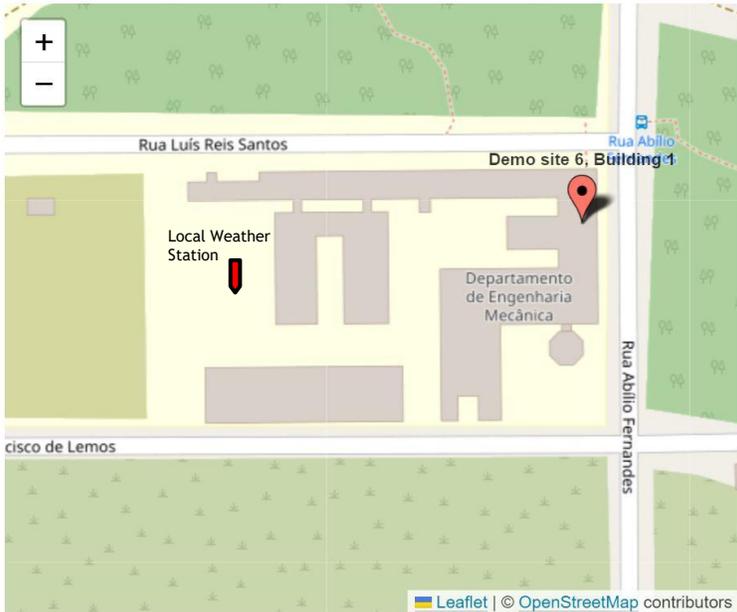
Overview ▾

Entities

Realtime - last 7 days



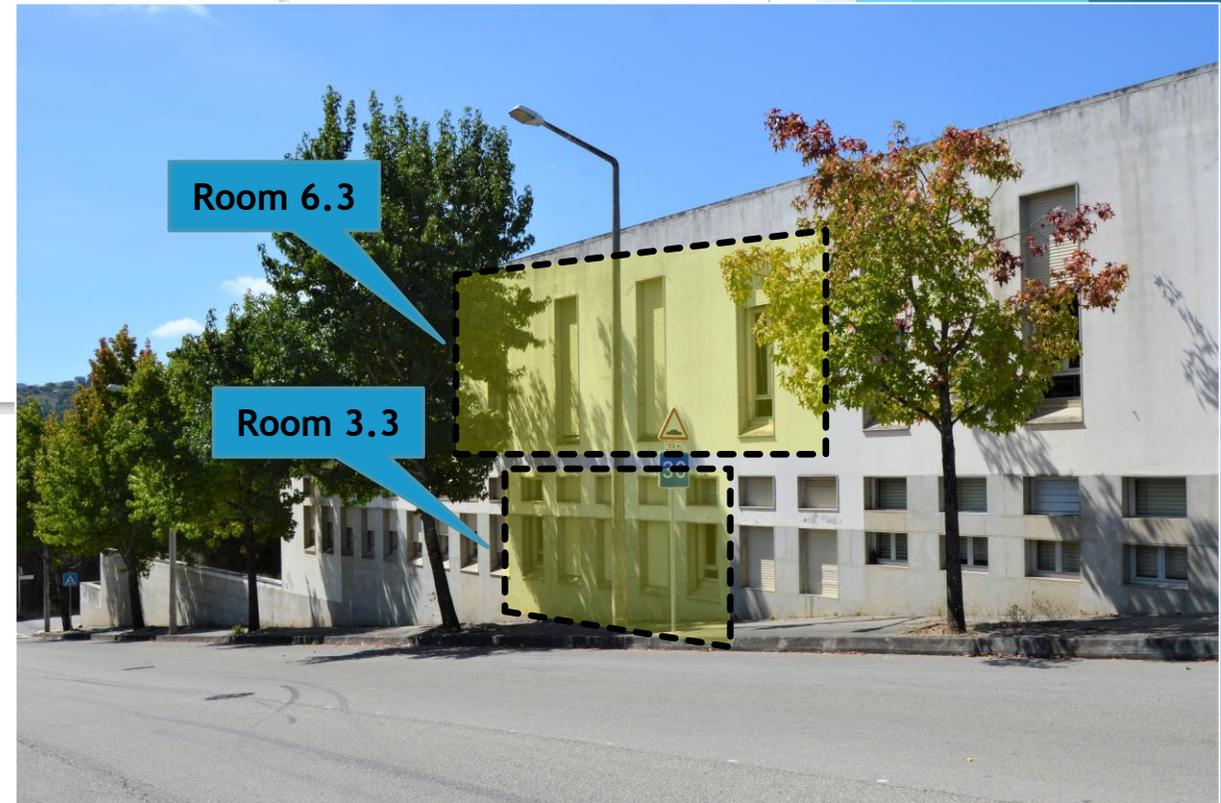
Buildings location



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 Accumulated (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

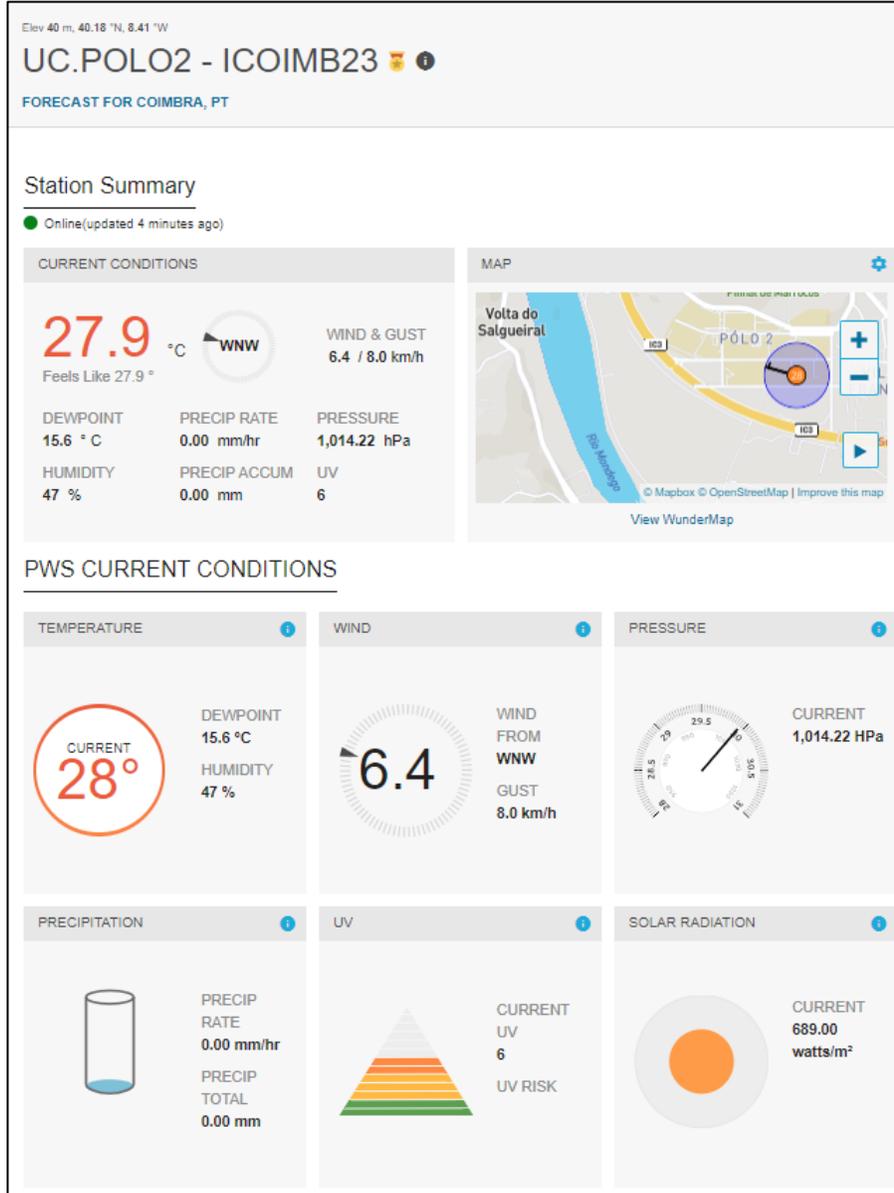
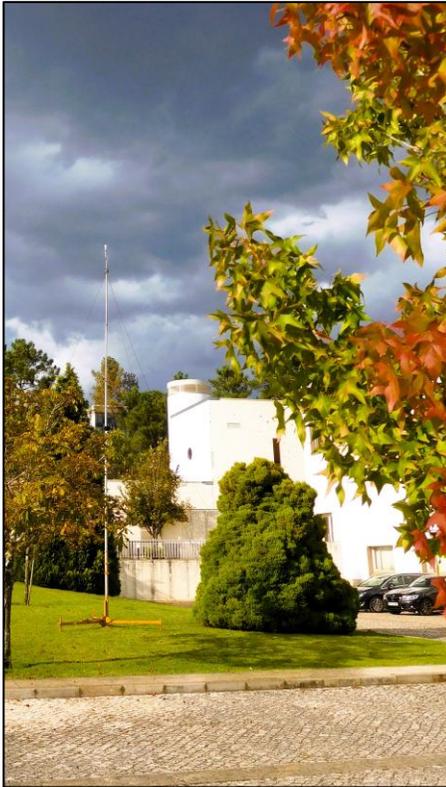


2 Cubes

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

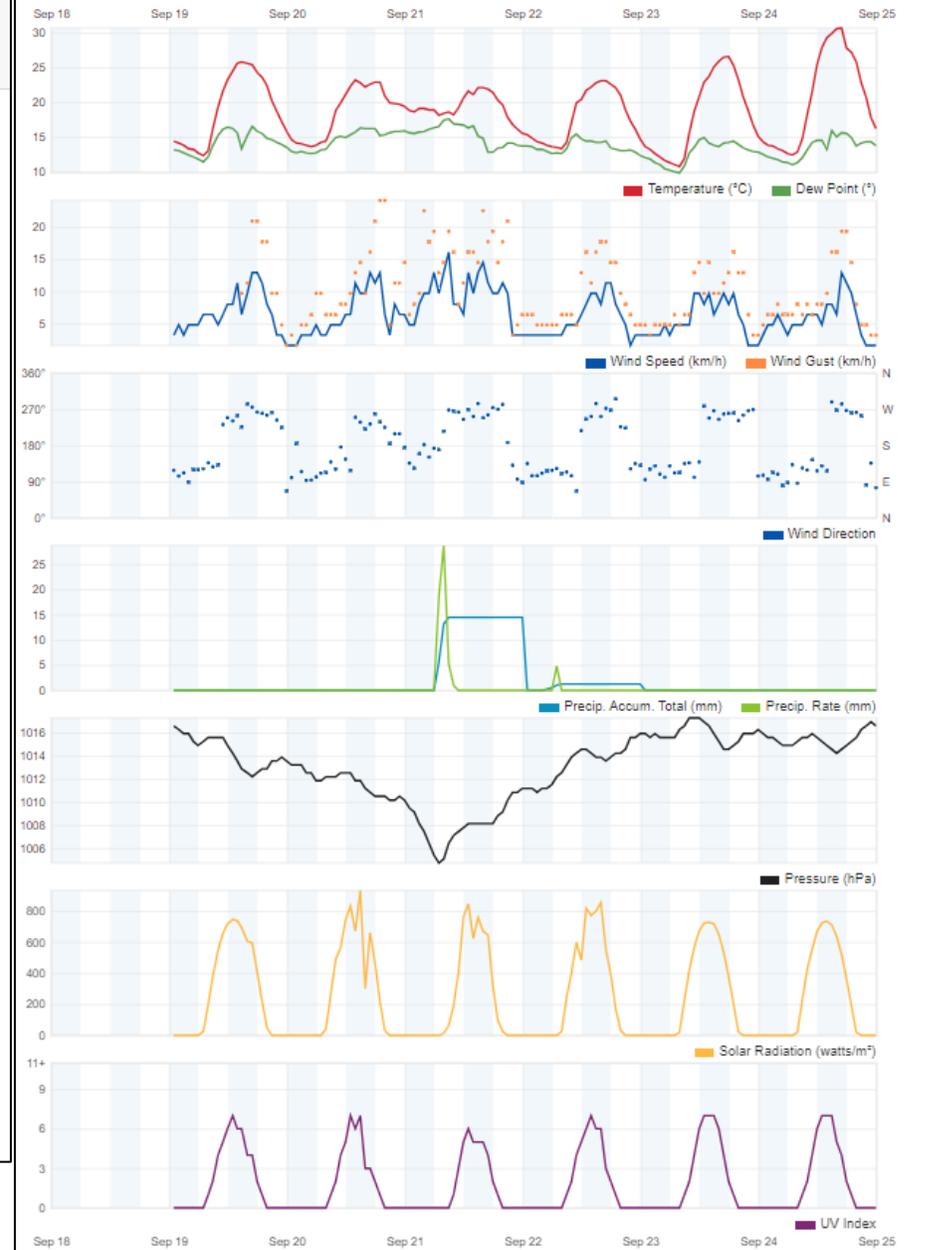
DEM-UC Site Characteristics

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

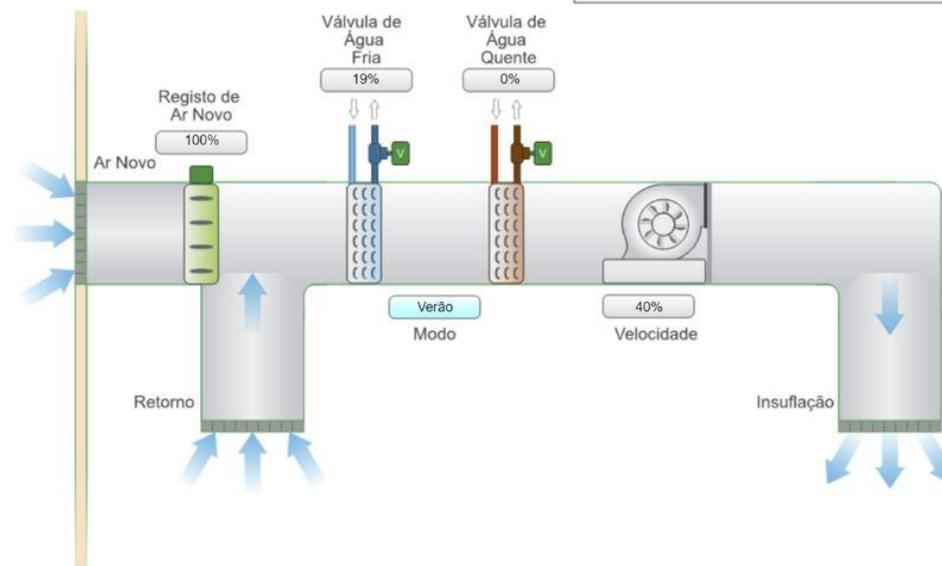
Ocupação

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

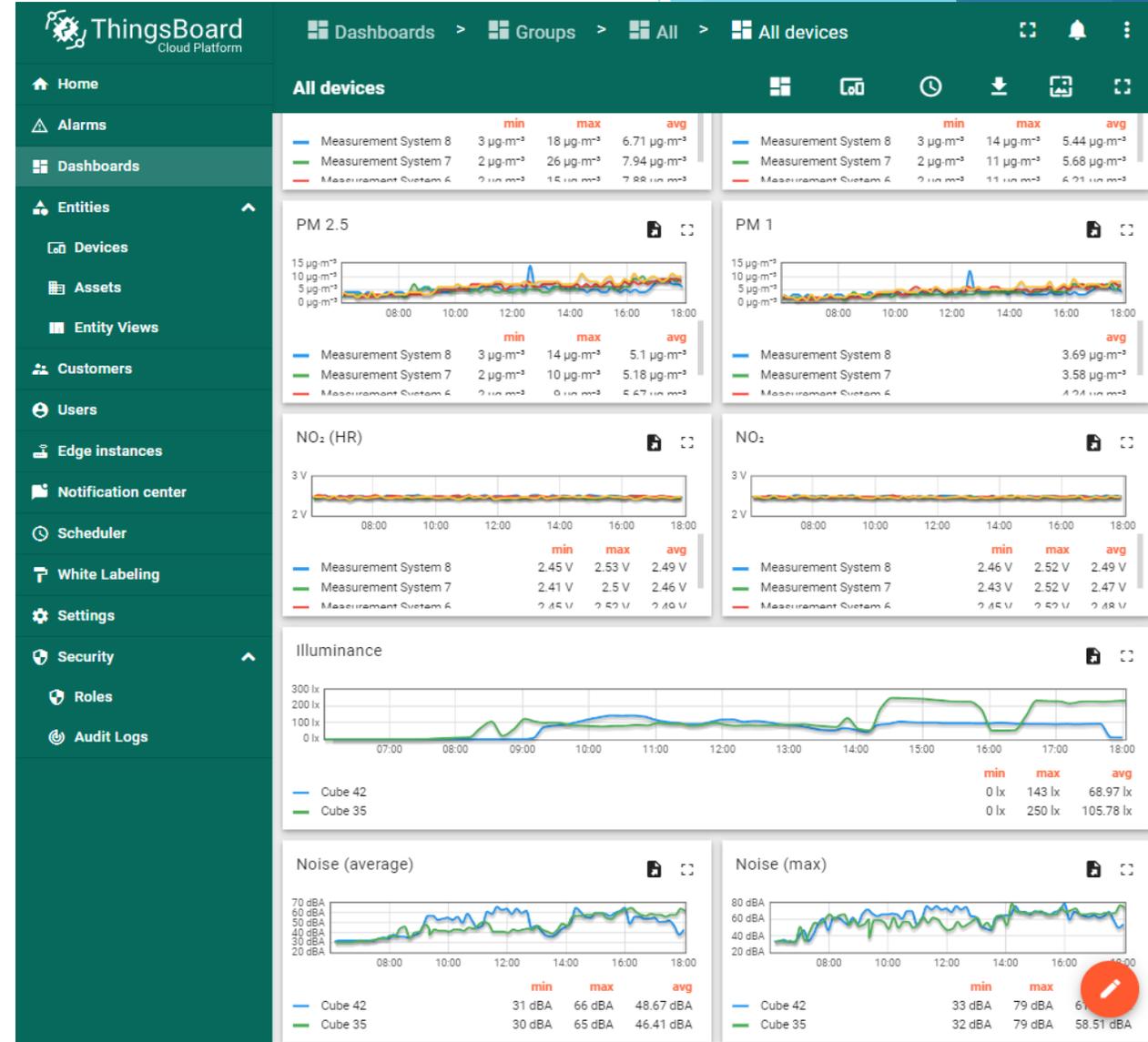
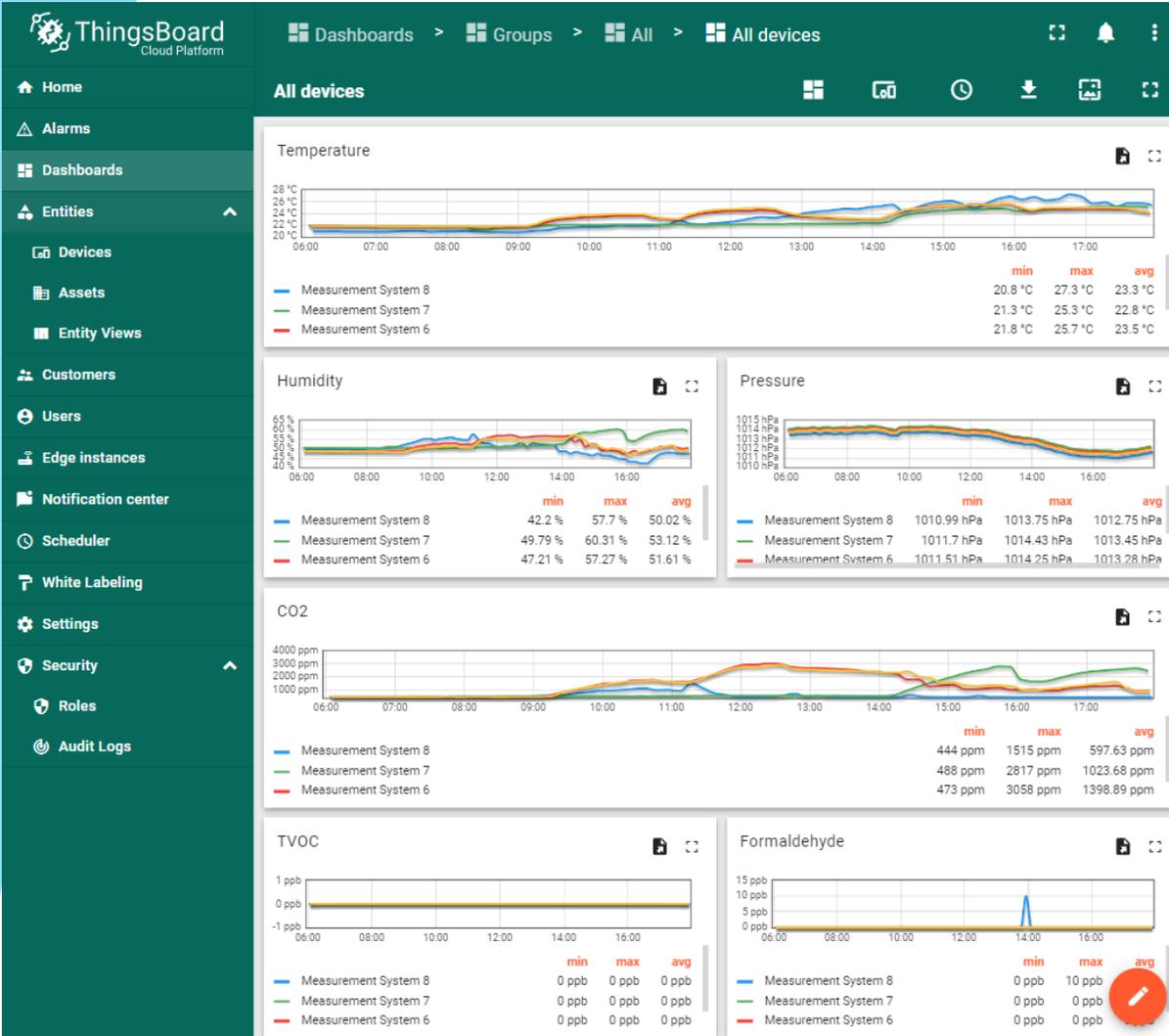


Site Characteristics

Monitored Zones - Corridor

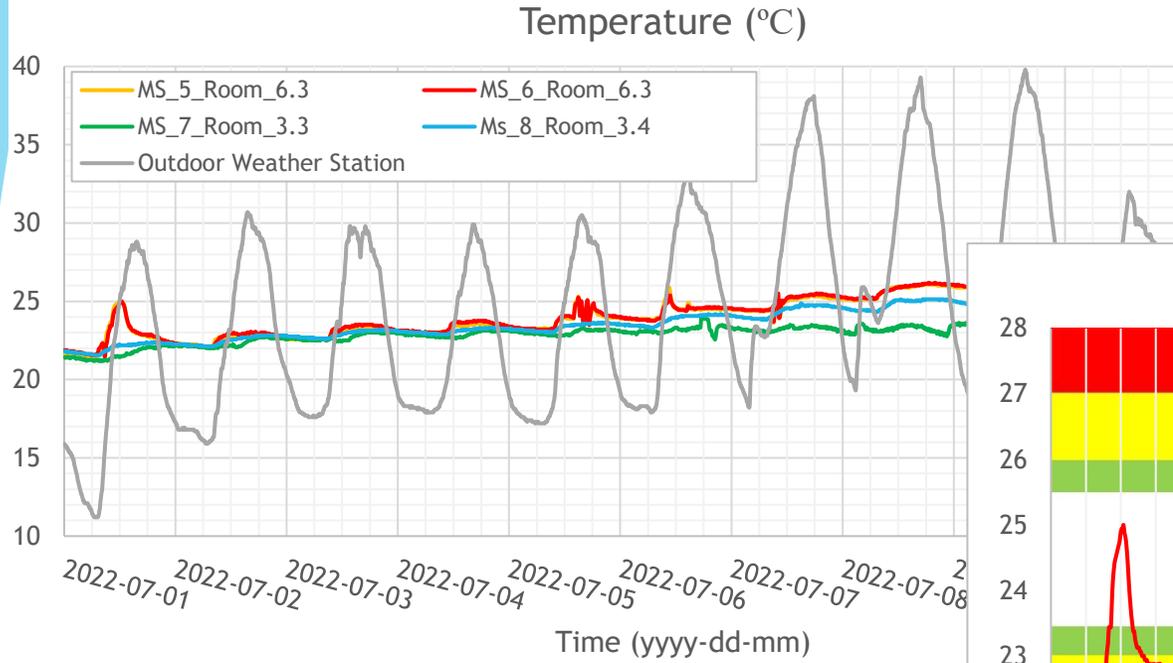


Web Platform Interface

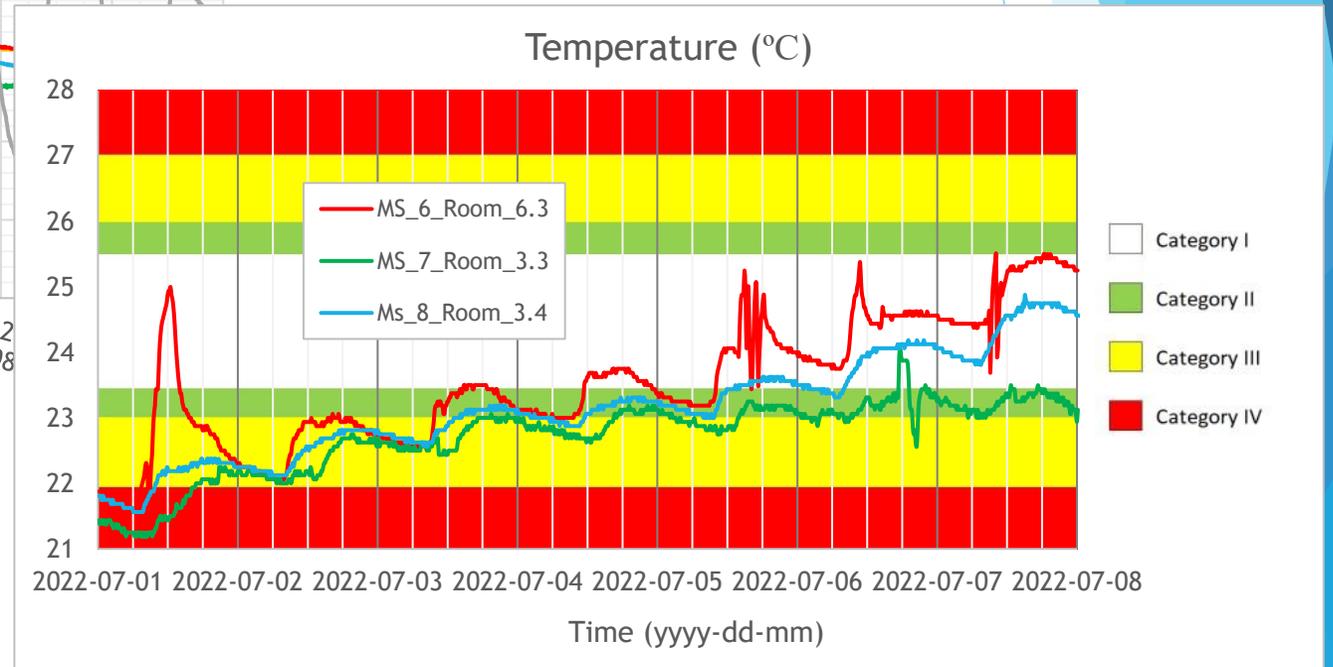


First Monitoring Period

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



Categories of EN 16 798 -1

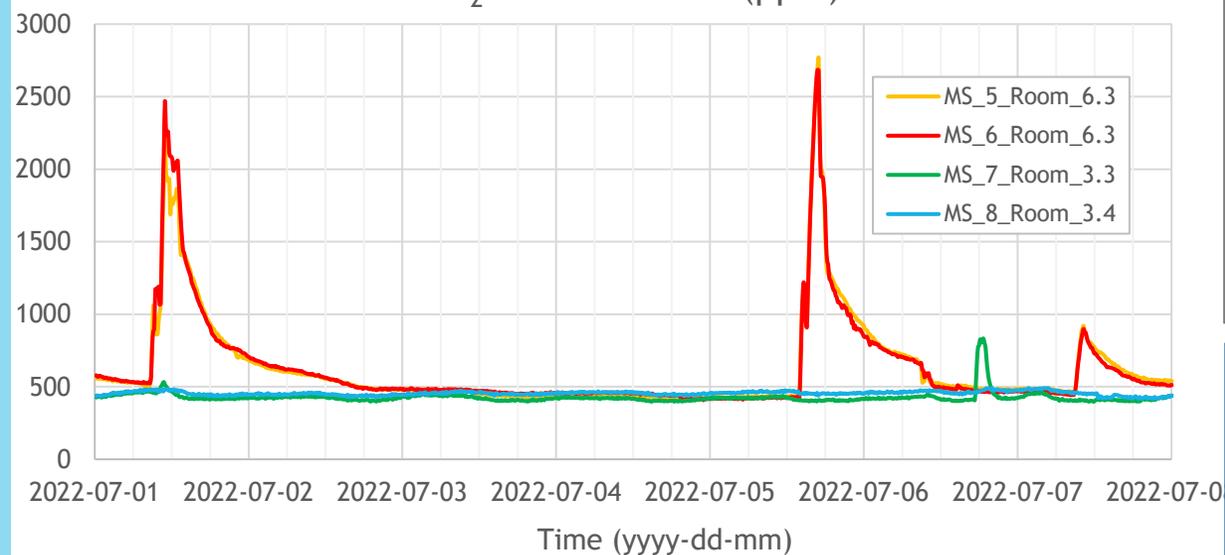


First Monitoring Period

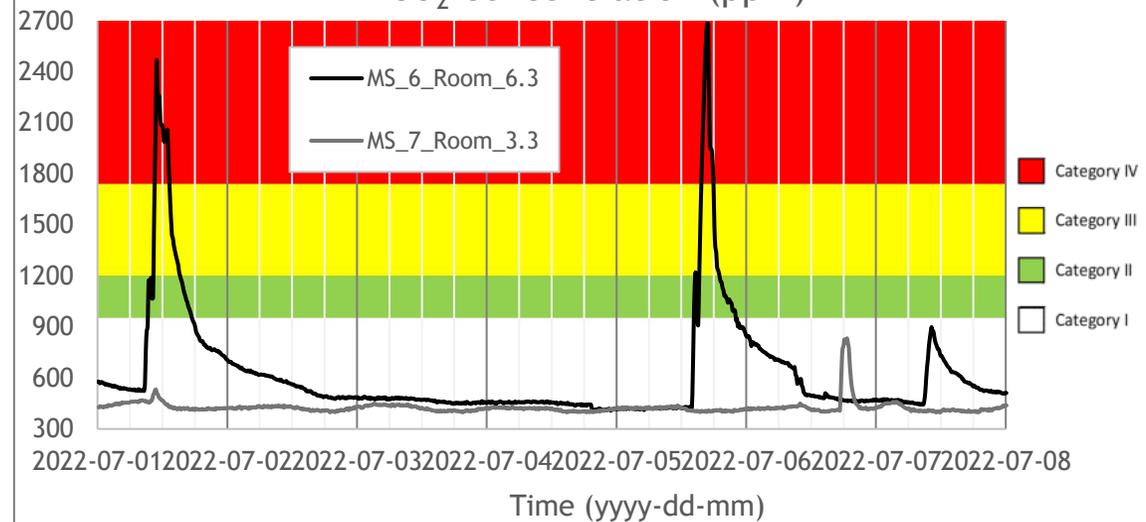
Processed data from 2022-07-01 to 2022-07-08

Categories of EN 16 798 -1

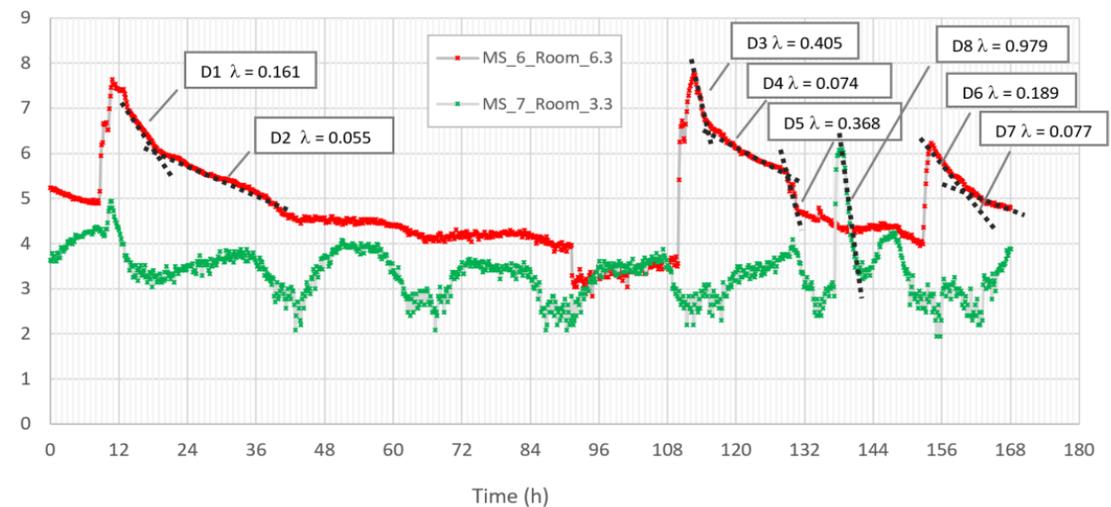
CO₂ Concentration (ppm)



CO₂ Concentration (ppm)



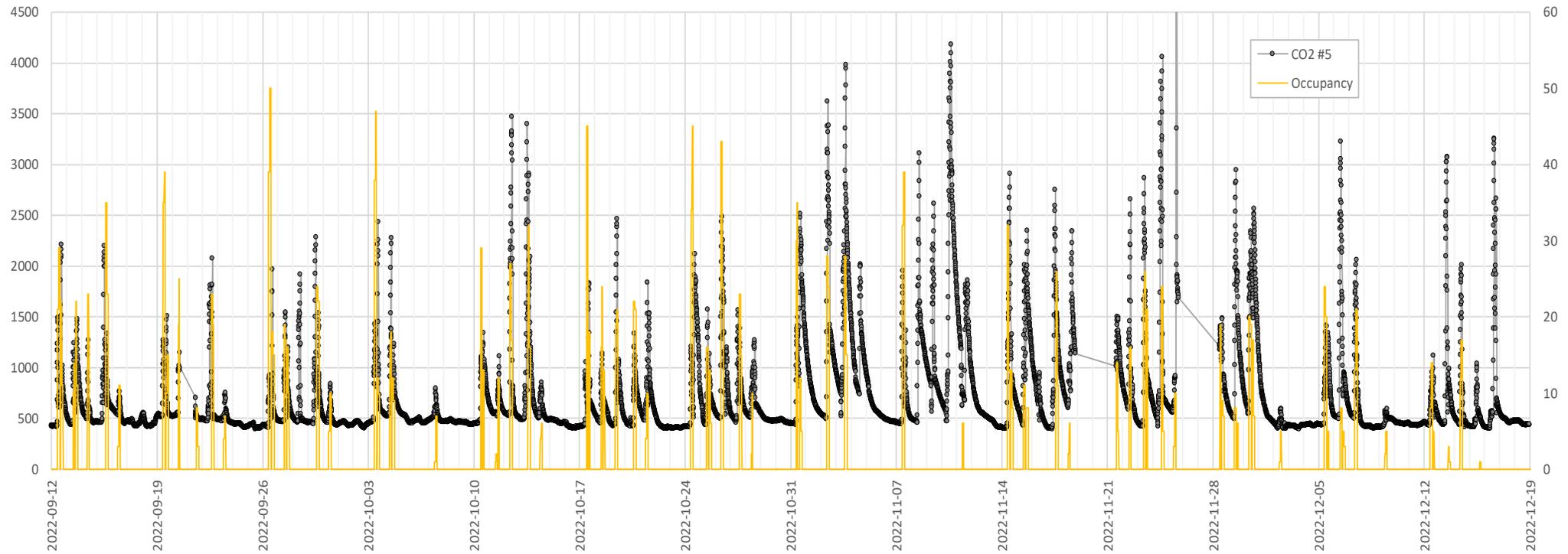
Ln(C-C_{out}) CO₂ (ppm)



First Semester 2022/2023

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

CO2 (ppm)



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



Thank you for your attention

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<https://orcid.org/0000-0003-0739-9811>