Assessment of CO_2 sensors for ventilation control

Julie SORIANO

CETIAT Project PR39 « IAQ sensors » team :
Benoît GOLAZ (Engineer)
Jérémy ALLIMAN (Technician)
Gilles COUDERC (Technical support)
Julien SAVARY (IT support)

cetiat
ensemble, innover et valider

AIVC workshop Madrid April 2026

1

Context

IEQ + **Energy consumption**

European regulations (EPBD, ERP)

Increase of ventilation systems using CO_2 sensors

Ongoing work on common testing framework for CO_2 sensors

How to test the drift ?

At european level (CEN\TC 247)
At french level (GS14)

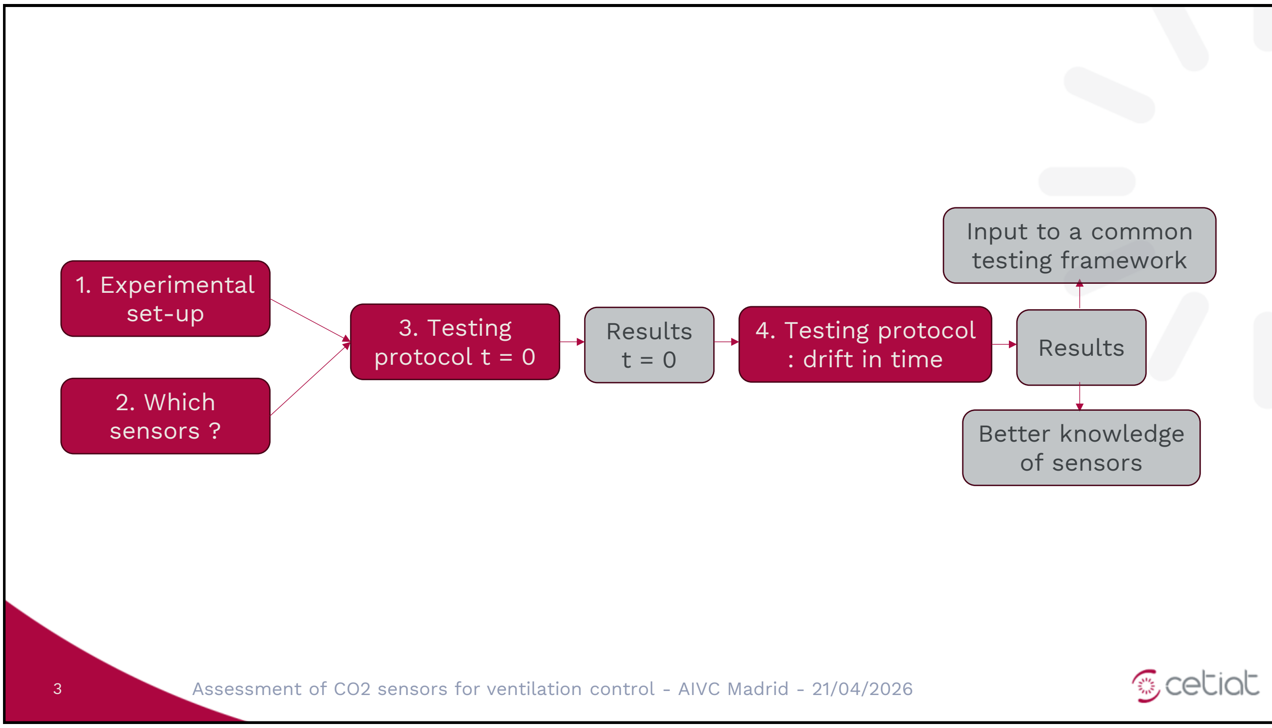
CETIAT research project « PR 39 - IAQ sensors »

Objectives :

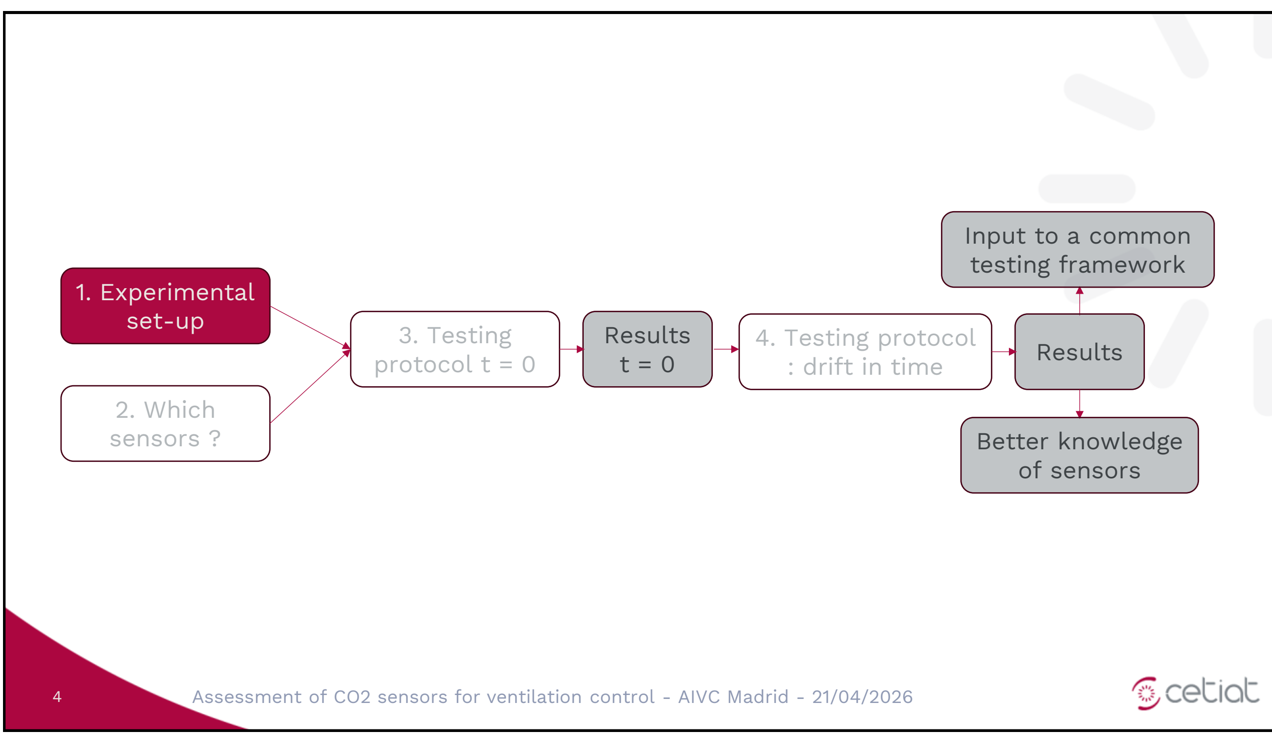
1. Develop a **protocol** for characterising **CO_2** sensors
2. Identify the **strengths** and **weaknesses** of these sensors.

Project co-financed by **Eurovent Certita Certification** and followed by **15 manufacturers** (ventilation, flitration, air cleaner)

2


1. Experimental set-up
2. Which sensors ?
3. Testing protocol t = 0
Results t = 0
4. Testing protocol : drift in time
Results
Input to a common testing framework
Better knowledge of sensors
3
Assessment of CO2 sensors for ventilation control - AIVC Madrid - 21/04/2026
cetiat

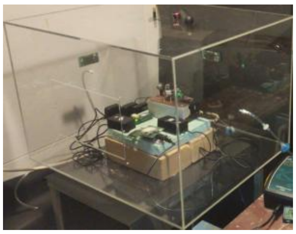
3


1. Experimental set-up
2. Which sensors ?
3. Testing protocol t = 0
Results t = 0
4. Testing protocol : drift in time
Results
Input to a common testing framework
Better knowledge of sensors
4
Assessment of CO2 sensors for ventilation control - AIVC Madrid - 21/04/2026
cetiat

4

Experimental setup : literature review

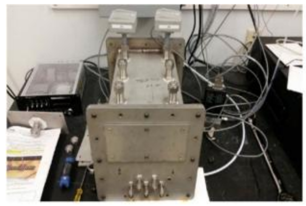
« **Batch** » : airtight space and one-shot CO_2 injection



Pereira 2022

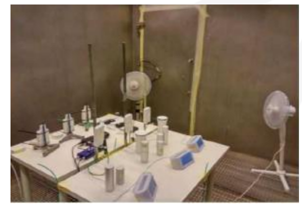
« Continuous » : continuous CO_2 injection compensate the air change

Small test cell



Banister 2019

Room size test cell

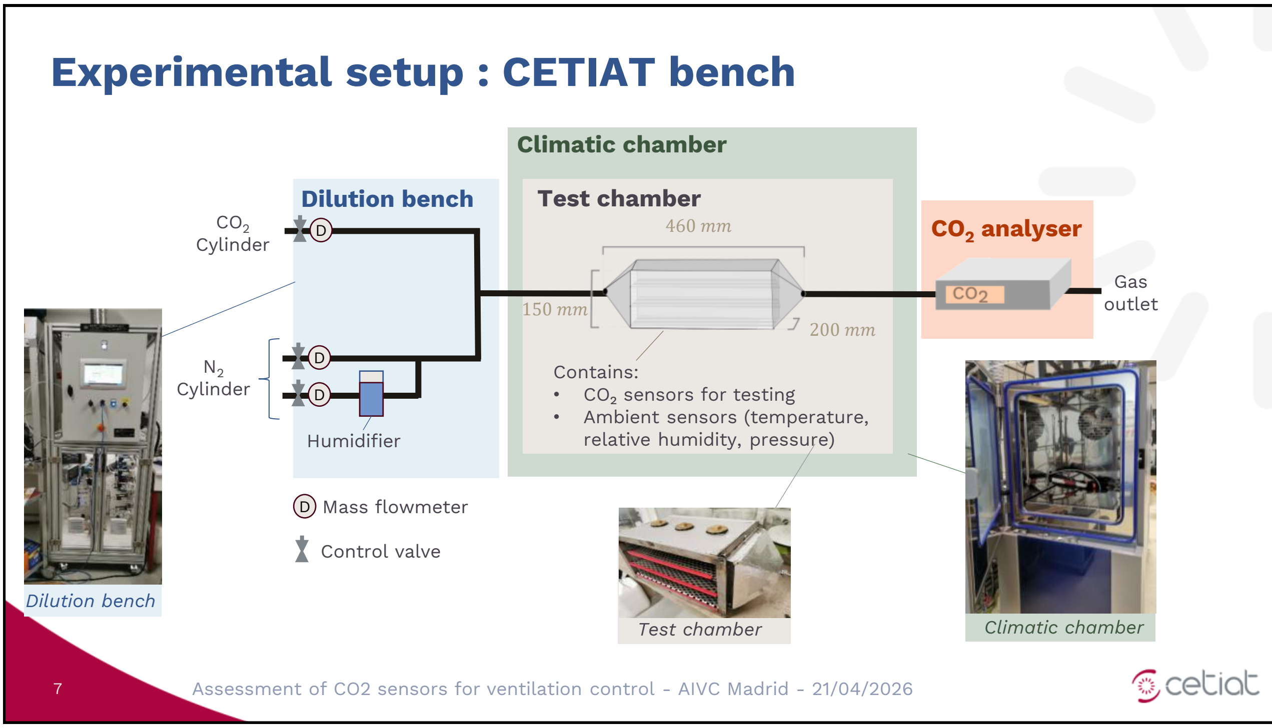


Mylonas 2019

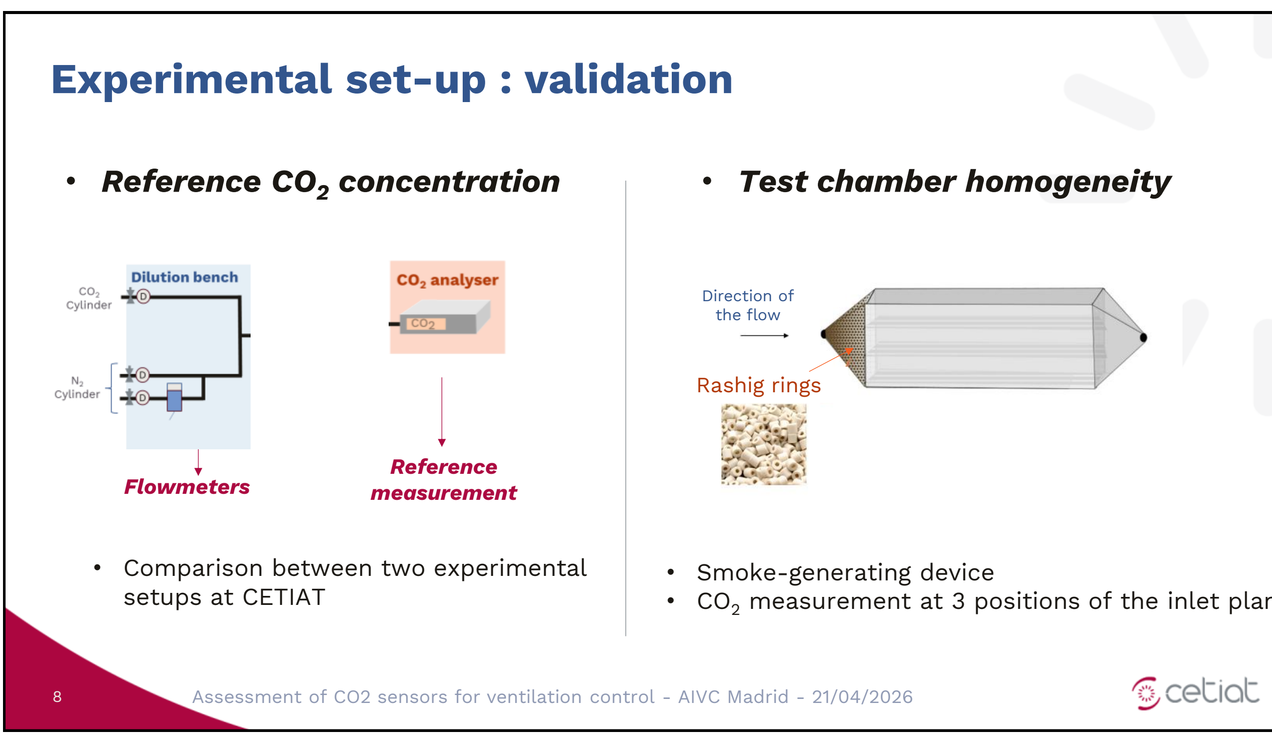
Experimental setup : literature review

	For Indoor / Outdoor	Batch / Continuous	Temperature	Humidity	Pressure
Othman 2025	indoor	No steady state (pattern)	Measured	Measured	Neither controled nor measured
Banister 2019	indoor	Continuous	Neither controled nor measured	Neither controled nor measured	Neither controled nor measured
Baldelli 2021	indoor	Continuous	Neither controled nor measured	Neither controled nor measured	Neither controled nor measured
Mylonas 2019	indoor	Continuous	Controled	Measured	Neither controled nor measured
Petersen 2018	indoor	Continuous	Controled	Neither controled nor measured	Neither controled nor measured
Pereira 2022	indoor	Batch	Controled	Controled	Neither controled nor measured
Marinov 2018	indoor	Batch	Controled	Controled	Controled
Janke 2023	Indoor specific	Batch	Neither controled nor measured	Neither controled nor measured	Neither controled nor measured
Dubey 2024	outdoor	No steady state	/	/	/
Rivero 2023	outdoor	Batch	Neither controled nor measured	Neither controled nor measured	Neither controled nor measured
Müller 2020	outdoor	Continuous	Controled	Neither controled nor measured	Controled

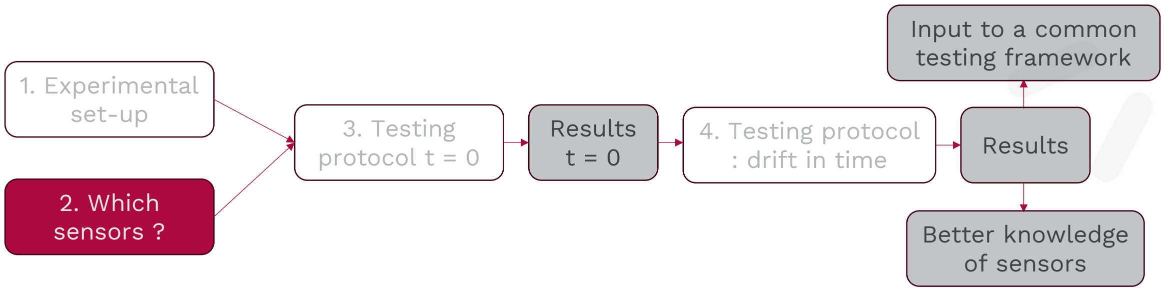
Controled	Measured	Neither controled nor measured


Experimental setup : CETIAT bench
Climatic chamber
Dilution bench
Test chamber
460 mm
150 mm
200 mm
CO2 analyser
CO2
Gas outlet
CO2 Cylinder
N2 Cylinder
Humidifier
Contains:
• CO2 sensors for testing
• Ambient sensors (temperature, relative humidity, pressure)
Mass flowmeter
Control valve
Dilution bench
Test chamber
Climatic chamber
7
Assessment of CO2 sensors for ventilation control - AIVC Madrid - 21/04/2026
cetiat

7


Experimental set-up : validation
• Reference CO2 concentration
• Test chamber homogeneity
Dilution bench
CO2 Cylinder
N2 Cylinder
CO2 analyser
CO2
Flowmeters
Reference measurement
• Comparison between two experimental setups at CETIAT
Direction of the flow
Rashig rings
• Smoke-generating device
• CO2 measurement at 3 positions of the inlet plan
8
Assessment of CO2 sensors for ventilation control - AIVC Madrid - 21/04/2026
cetiat

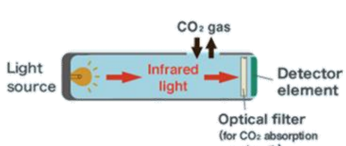
8



Low-cost CO_2 sensors : overview

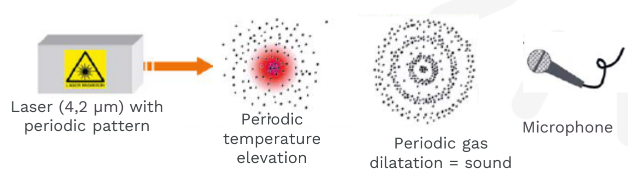
Two technologies based on CO_2 **infrared absorption** at 4,2 µm

Non Dispersive Infrared (*NDIR*)



(Figaro website : https://www.figarosensor.com/product/feature/cdm7162.html)

Photoacoustic Spectroscopy (*PAS*)



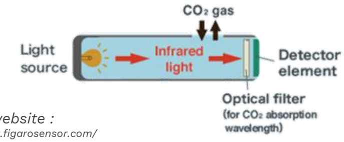
(Duquesnoy et al., 2018)

Other technologies :

- Electrochemical (EC) : less stable and accurate than infrared (Dubey, 2024)
- Metal oxide Semiconductor (MOx or MOS) : « eCO_2 » low performance (Demenaga, 2021; Moreno-Rangel, 2018)
- Thermal conductivity (new technology) : need oxygen in the test gas

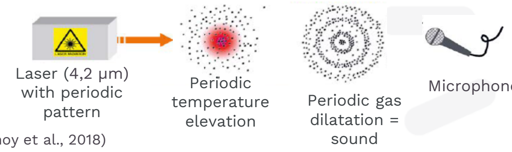
Low-cost CO_2 sensors : overview

Non Dispersive Infrared (*NDIR*)



(*Figaro website : https://www.figarosensor.com/product/feature/cdm7162.html*)

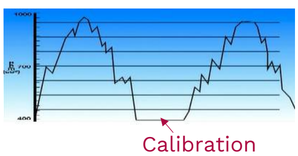
Photoacoustic Spectroscopy (*PAS*)



(Duquesnoy et al., 2018)

Two automatic calibration methods

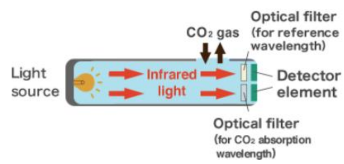
Automatic Baseline Calibration (ABC)



(Senseair website : https://senseair.com/the-senseair-abc-algorithm/)

✔ *NDIR* ✔ *PAS*

Dual wavelength



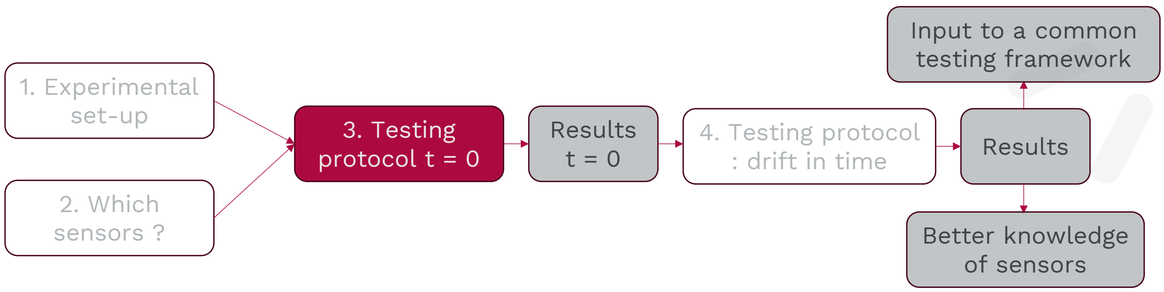
(*Figaro website : https://www.figarosensor.com/product/feature/cdm7162.html*)

✔ *NDIR* ✘ *PAS*

Choice of sensors for testing

Manufacturer	Technology	Automatic calibration method	Price (€)*
Senseair	NDIR	Automatic Baseline Calibration	57
Sciosense	NDIR	Automatic Baseline Calibration	17
Winson	NDIR	Automatic Baseline Calibration	11
Sensirion	NDIR	Automatic Baseline Calibration + Dual wavelength	31
Amphenol	NDIR	Dual wavelength	86
Sensirion	PAS	Automatic Baseline Calibration	62

* Indicative prices with distributors



Testing protocole t = 0 (without drift)

Method in 2 paths

Litterature review

- Scientific articles (6 articles)
- Standards:
  1. CEN/TS 17660-1:2021 " Air quality - Performance evaluation of air quality sensor systems" (outdoor)
  2. ASTM D8624 – 25 "Standard Test Method for Evaluating CO_2 Sensors or Sensor Systems Used in Indoor Applications"

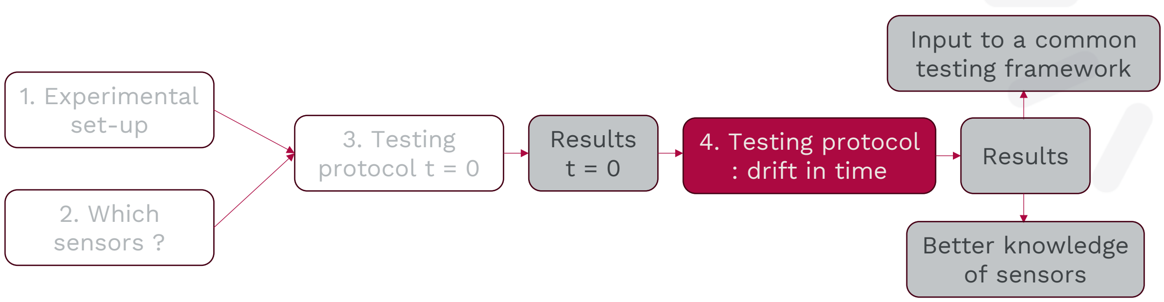
Discussions

- Ventilation experts
- Sensors manufacturers experts (Sensirion, Sciosense, Senseair, Amphenol, Belimo, Altra, Siemens)

Testing protocole t = 0 (without drift)

	Steady state conditions : CO2 , temperature (T°), humidity (RH)	Uniformity	Hysteresis	Repeatability	Response time
Level 1 : simple – easily repeatable to evaluate drift (next step)	CO_2 : 400, 800, 1100,1800 T° = 20 °C HR = 50% *16 pts*	6 sensors	Up and down	X2	1 step up
Level 2 : T° / HR	T° : 15, 20, 25, 30 °C for CO2 800 and 1800 ppm, HR 50 % HR : 20, 40, 60, 80% for CO2 800 and 1800 ppm, T° 20°C *16 pts*	6 sensors	/	/	/

Sensor manufacturers alert point !



Drift evaluation protocole

Test t = 0 → Cycles HR /T° → Test 1 → 1 year of use → Test 2 → Dirtying → Test 3

Cycles HR /T°:

Climatic chamber

What cycles ?
How many ?

Test 1: *Forced calibration*

1 year of use: Office? Dwelling ?

Test 2: *Forced calibration*

Dirtying: Oil mist ? (filter dirtying inspiration)

Next steps

1. Experimental set-up
2. Which sensors ?

→ 3. Testing protocol t = 0 → Results t = 0 → 4. Testing protocol : drift in time → Results → Input to a common testing framework / Better knowledge of sensors

- July 2026 : Sensor testing (t = 0) planned
- 26-27 August 2026 : CEN/TC247 Workshop for CO_2 sensors testing

Thank you for your attention

Assessment of CO_2 sensors for ventilation control

Julie SORIANO

CETIAT Project PR39 « IAQ sensors » team :
Benoît GOLAZ (Engineer)
Jérémy ALLIMAN (Technician)
Gilles COUDERC (Technical support)
Julien SAVARY (IT support)

cetiat
ensemble, innover et valider

Références

Baldelli, A. (2021). Evaluation of a low-cost multi-channel monitor for indoor air quality. *Measurement: Sensors*.

Dubey, R., Telles, A., Nikkel, J., Cao, C., Gewirtzman, J., Raymond, P. A., & Lee, X. (2024a). Low-Cost CO2 NDIR Sensors: Performance Evaluation and Calibration Using Machine Learning Techniques. *Sensors*, *24*(17). https://doi.org/10.3390/s24175675

González Rivero, R. A., Morera Hernández, L. E., Schalm, O., Hernández Rodríguez, E., Alejo Sánchez, D., Morales Pérez, M. C., Nuñez Caraballo, V., Jacobs, W., & Martinez Laguardia, A. (2023). A Low-Cost Calibration Method for Temperature, Relative Humidity, and Carbon Dioxide Sensors Used in Air Quality Monitoring Systems. *Atmosphere*, *14*(2). https://doi.org/10.3390/atmos14020191

Marin B. Marinov, N. D. (2018). Performance Evaluation of Low-cost Carbon Dioxide Sensors. *XXVII International Scientific Conference Electronics.*

Müller, M., Graf, P., Meyer, J., Pentina, A., Brunner, D., Perez-Cruz, F., Hüglin, C., & Emmenegger, L. (2020). Integration and calibration of non-dispersive infrared (NDIR) CO2 low-cost sensors and their operation in a sensor network covering Switzerland. *Atmospheric Measurement Techniques*, *13*(7), 3815–3834. https://doi.org/10.5194/amt-13-3815-2020

Duquesnoy, M., Melkonian, J.-M., Levy, R., Raybaut, M., Dherbecourt, J.-B., & Godard, A. (2018). Comprendre. Détection de gaz par spectroscopie photoacoustique : principe et mise en œuvre. Photoniques, 94, 38–44. https://doi.org/10.1051/photon/20189438

Références

Mylonas, A., Kazanci, O. B., Andersen, R. K., & Olesen, B. W. (2019). Capabilities and limitations of wireless CO 2 , temperature and relative humidity sensors. Building and Environment, 154, 362–374. https://doi.org/10.1016/j.buildenv.2019.03.012

Hanin Othman, G. S. (2026). A calibration chamber framework for low-cost indoor air quality. Building and Environment.

Pereira, P. F., & Ramos, N. M. M. (2022). Low-cost Arduino-based temperature, relative humidity and CO2 sensors - An assessment of their suitability for indoor built environments. Journal of Building Engineering, 60. https://doi.org/10.1016/j.jobe.2022.105151

Petersen, J. ;, Kristensen, J. ;, Elarga, H. ;, Andersen, R. K. ;, Midtstraum, A., Petersen, J., Andersen, J., Midtstraum, R. K., Kristensen, J., Elarga, H., & Andersen, R. (2025). Sensors: An Experimental Investigation (Vol. 21).

Dubey, R., Telles, A., Nikkel, J., Cao, C., Gewirtzman, J., Raymond, P. A., & Lee, X. (2024). Low-Cost CO2 NDIR Sensors: Performance Evaluation and Calibration Using Machine Learning Techniques. Sensors, 24(17). https://doi.org/10.3390/s24175675

Demanega, I., Mujan, I., Singer, B. C., Anđelković, A. S., Babich, F., & Licina, D. (2021). Performance assessment of low-cost environmental monitors and single sensors under variable indoor air quality and thermal conditions. Building and Environment, 187. https://doi.org/10.1016/j.buildenv.2020.107415

Moreno-Rangel, A., Sharpe, T., Musau, F., & McGill, G. (2018). Field evaluation of a low-cost indoor air quality monitor to quantify exposure to pollutants in residential environments. Journal of Sensors and Sensor Systems, 7(1), 373–388. https://doi.org/10.5194/jsss-7-373-2018