European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

COST Action TD1105

WGs & MC Meeting at SOFIA (BG), 16-18 December 2015

INDOOR AIR QUALITY ASSESSMENT IN A PUBLIC BUILDING USING MICROSENSORS AND CONVENTIONAL METHODS

Carlos Borrego

MC Member/ WG Member

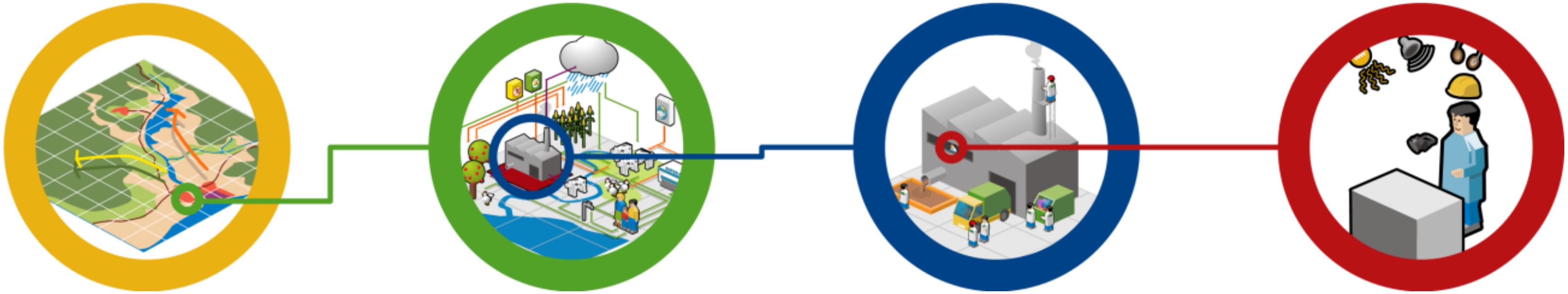
João Ginja and Clara Ribeiro

IDAD-Institute of Environment and Development / Portugal

COST is supported by the EU Framework Programme

ESF provides the COST Office through a European Commission contract

IDAD - Institute of Environment and Development



Air Pollution - IDAD carries out the following activities

- Stack emissions
- Ambient air quality
- Indoor air quality
- Odours assessment
- Inventories of air pollutants emissions
- Air quality modelling
- Air Quality Management

cost
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Impacts of Air Pollution – different scales

Global scale
- Climate change,…

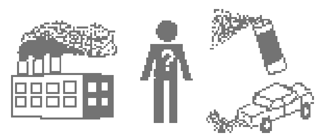
Local scale
- Exposure to traffic emissions,…

Micro-scale
- Impacts on indoor air quality!

We spend 80-90% of our time indoors!

Air Pollution - from sources to health effects

Emission sources → Ambient air concentrations → Exposure → Dose → Health effects

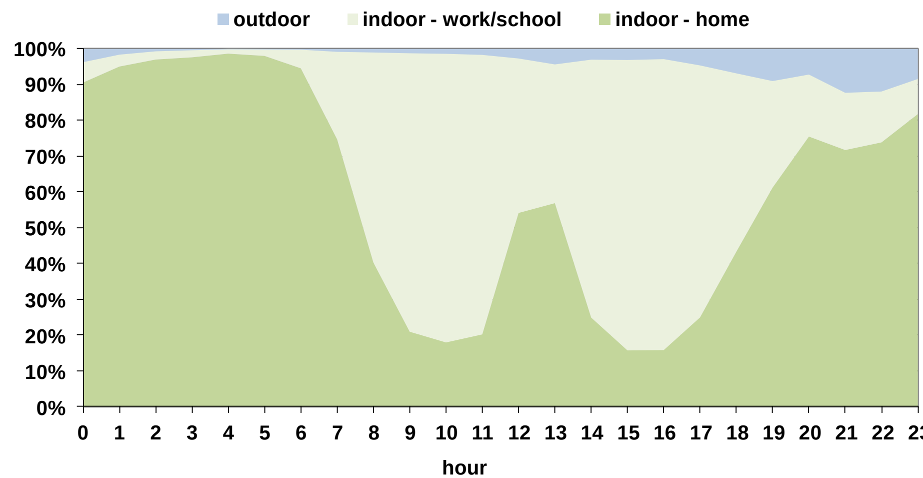


Emission
Quantity of a pollutant released to the atmosphere

Concentration
Physical characteristic of the environment in a given place and time

Exposure
Describes the interaction and contact with the pollutant

Dose
The amount of pollutant that crosses a specific barrier (skin, lung, digestive tract)



Example of time-activity pattern

INDOOR AIR QUALITY ASSESSMENT

Where?

- Homes
- School buildings
- Service buildings
- Hospitals
- Cultural/commercial areas
- Industrial buildings

What/how?

- Temperature, RH
- CO_2 , CO, O_3, PM, VOC, BTEX, formaldehyde, radon
- Bacteria and fungi
- **… (Indoor air may contain over 900 chemicals, particles, and biological materials with potential health effects)**

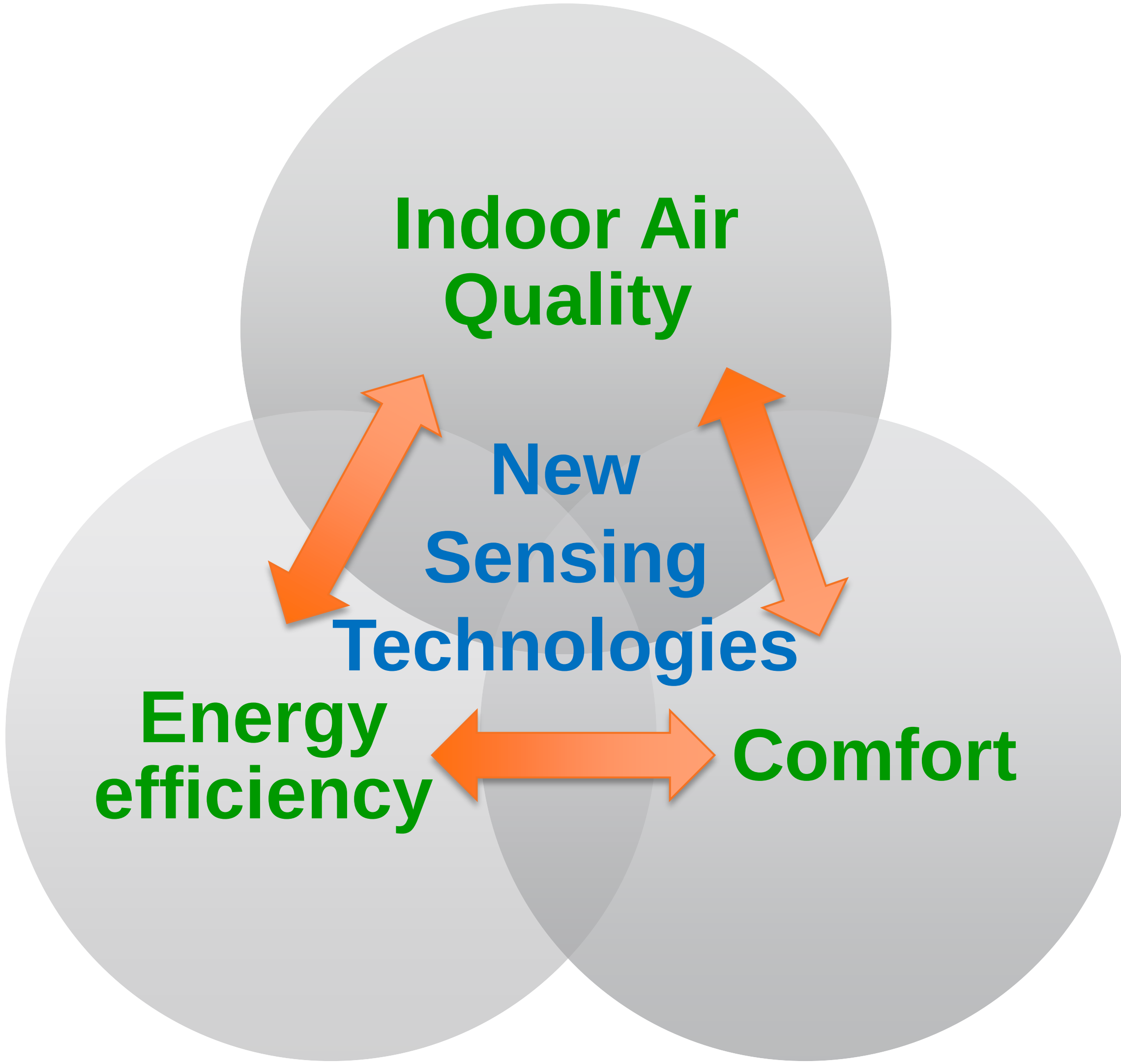
Why measure IAQ

- Occupants complaints
- Compliance with IAQ or ventilation standards
- Potential energy saving measures
- Research

↓

- Indoor air quality assessment
- Identification of pollutant sources or critical areas
- Suggestion/implementation of best practices

Sustainable building



Pollutants and standards – international guidelines

- There are no specific regulation or binding resolutions from EU related with IAQ (standardized EU framework);
- Some countries have legislation/guidelines for indoor air quality;
- **France** - <u>**mandatory to monitor IAQ**</u> - the monitoring of IAQ in public buildings must be implemented gradually, particularly for establishments accommodating children (formaldehyde, benzene, and CO_2)

Germany
Austria
Slovenia
Finland
France
Holland
Lithuania
Norway
Portugal
Romania
Sweden

Australia
Canada
Hong Kong
Sweden
WHO

Pollutants and standards – international policies

Poluente	Período	Alemanha	Austrália	Áustria	Canadá	Eslovénia	Finlândia	França	Holanda	Hong Kong	Lituânia	Noruega	Portugal	Roménia	Suécia	OMS
Amónia µg.m^{-3}	ND					50					40					
Amónia e aminas µg.m^{-3}	ND						20									
Bactérias UFC.m^{-3}	ND									1000			<(ext+350)			
Benzeno µg.m^{-3}	ND	3						10 (1) 5 (2) 2 (3)	20				5			
CH_2O µg.m^{-3}	Inst		120*													
	30 min			100								100		35		100
	1 hora				123											
	8 horas				50					100			100			
	24 horas			60												
	ND	30				100	50	100 (4) 30 (5) 10 (6)	1.2		10				50	
CO mg.m^{-3}	15 min								100				100			100
	30 min	60							60					6		
	1 hora				25 ppm				30				35			35
	8 horas	15	10*		11 ppm				10	10		10	10			10
	24 horas				10 ppm								7			7
	ND					10	8	10-50 ppm			3				2	
CO_2 ppm	8 horas									1000			1250			
	ND					1670	1200	(7)				1000				
Fungos UFC.m^{-3}	ND												<exterior			
NO_2 µg.m^{-3}	30 min	350														
	1 hora				480				200			100				200
	8 horas									150						
	1 ano								40							40
	ND										40				40	
O_3 µg.m^{-3}	1 hora		210*		240											
	4 horas		170*													
	8 horas				40				100	120						
	ND					100		110 (8) 240 (9)			30				50	
PM10 µg.m^{-3}	8 horas									180			50			
	24 horas								50							
	1 ano								20							
	ND					100	50				50				40	
PM2.5 µg.m^{-3}	1 hora				100											
	8 horas												25			
	24 horas								25							
	1 ano								10							
	ND														15	
Radão Bq.m^{-3}	inst													140		
	8 horas									200			400			
	3 meses				200											
	1 a		200*				200									
	ND					400		400				100			100	
COV Totais µg.m^{-3}	1 hora		500*													
	8 horas									600			600			
	ND	1000														

Pollutants and standards – international policies

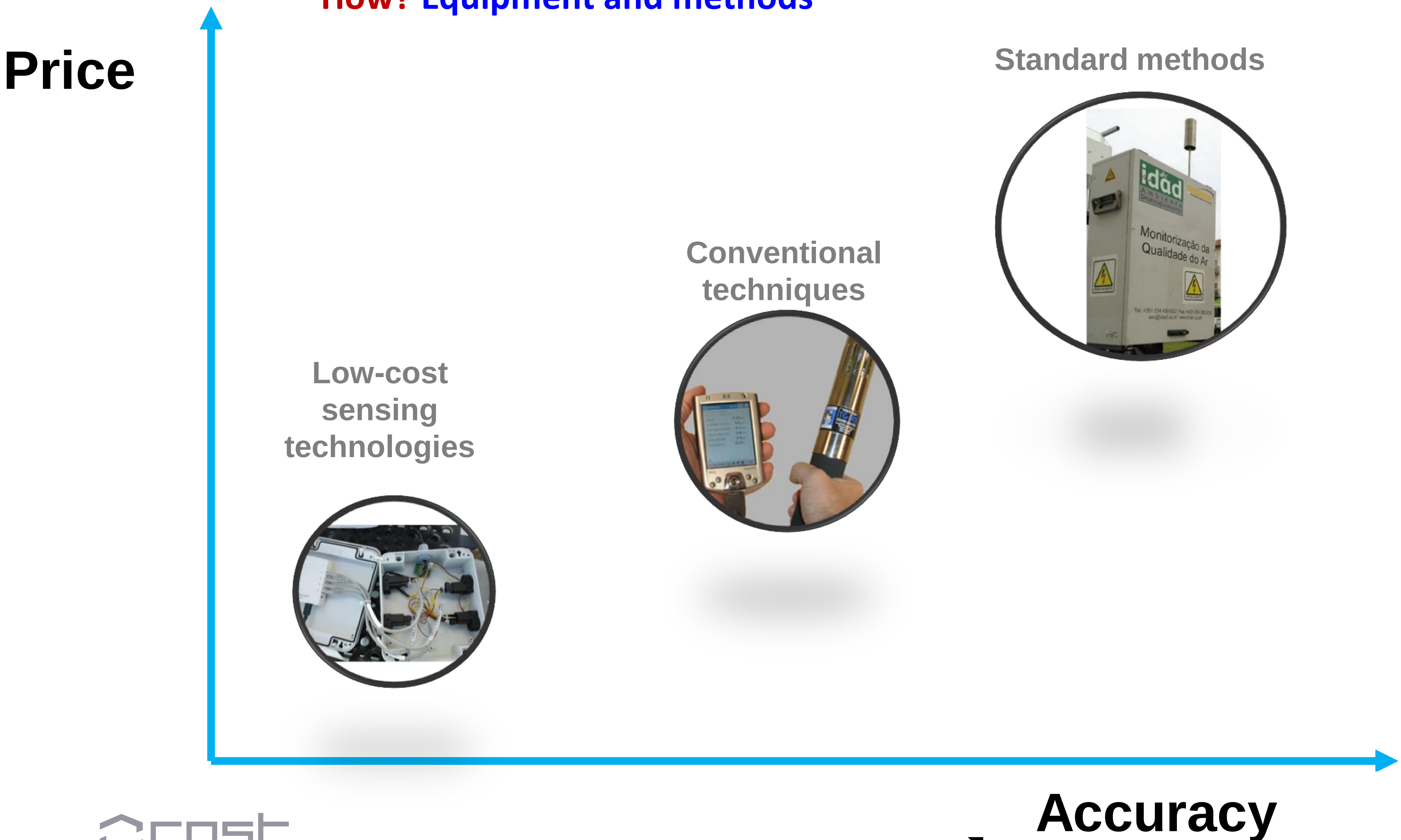
Poluente	Período	Alemanha	Austrália	Áustria	Canadá	Eslovénia	Finlândia	França	Holanda	Hong Kong	Lituânia	Noruega	Portugal	Roménia	Suécia	OMS
Amónia µg.m^{-3}	ND					50					40					
Amónia e aminas µg.m^{-3}	ND						20									

Poluente	Período	Alemanha	Austrália	Áustria	Eslovénia	Finlândia	França	Holanda	Lituânia	Noruega	Portugal	Roménia	Suécia	OMS
Benzeno µg.m^{-3}	ND	3					10 (1) 5 (2) 2 (3)	20			5			
CO mg.m^{-3}	15 min							100			100			100
	30 min	60						60				6		
	1 hora							30			35			35
	8 horas	15	10*					10		10	10			10
	24 horas										7			7
	ND				10	8	10-50 ppm		3				2	
CO_2 ppm	8 horas										1250			
	ND				1670	1200	(7)			1000				
PM10 µg.m^{-3}	8 horas										50			
	24 horas							50						
	1 ano							20						
	ND				100	50			50				40	

Poluente	Período	Alemanha	Austrália	Áustria	Canadá	Eslovénia	Finlândia	França	Holanda	Hong Kong	Lituânia	Noruega	Portugal	Roménia	Suécia	OMS
O_3 µg.m^{-3}	4 horas		170*													
	8 horas				40				100	120						
	ND					100		110 (8) 240 (9)			30				50	
PM10 µg.m^{-3}	8 horas									180			50			
	24 horas								50							
	1 ano								20							
	ND					100	50				50				40	
PM2.5 µg.m^{-3}	1 hora				100											
	8 horas												25			
	24 horas								25							
	1 ano								10							
	ND														15	
Radão Bq.m^{-3}	inst													140		
	8 horas									200			400			
	3 meses				200											
	1 a		200*				200									
	ND					400		400				100			100	
COV Totais µg.m^{-3}	1 hora		500*													
	8 horas									600			600			
	ND	1000														

Indoor air quality monitoring

How? Equipment and methods

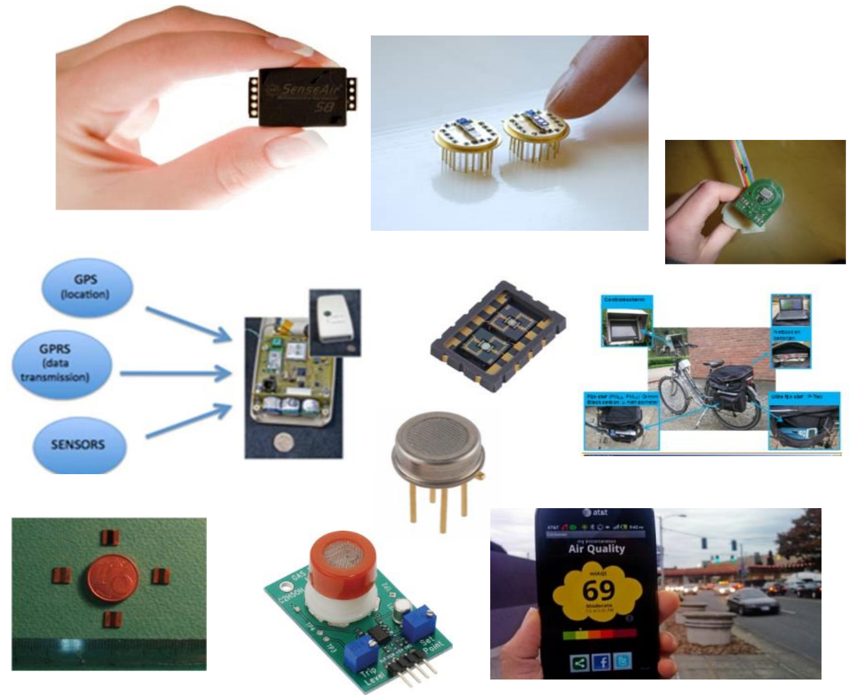


New sensing technologies for air pollution control

Low-cost sensing technologies

Their use can be particularly valuable to have highly spatially and temporally resolved air quality data and to improve exposure assessment

The raising of awareness in indoor air quality issues leads to other potential utilizations of monitoring data



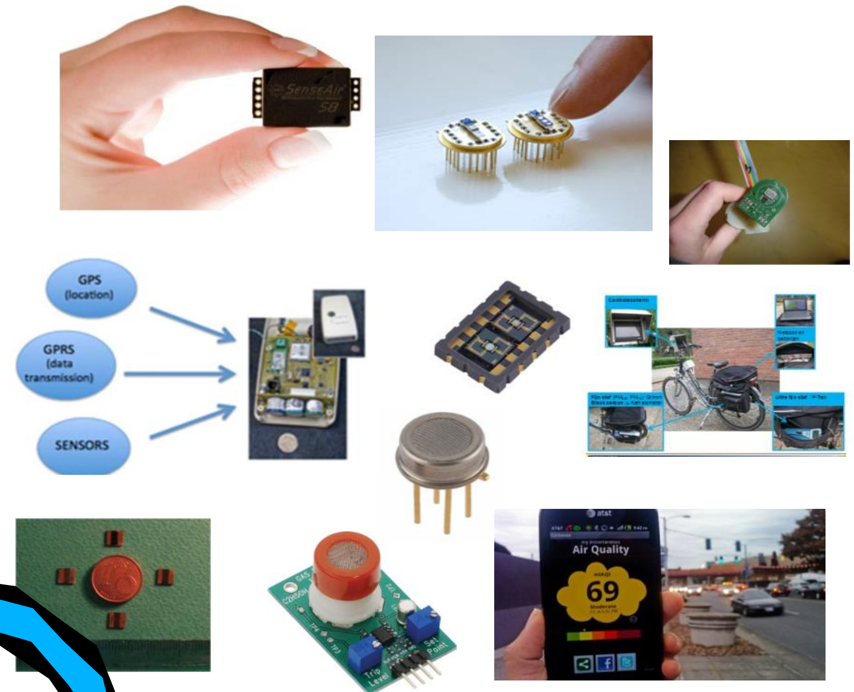
Qualitative or Quantitative data?

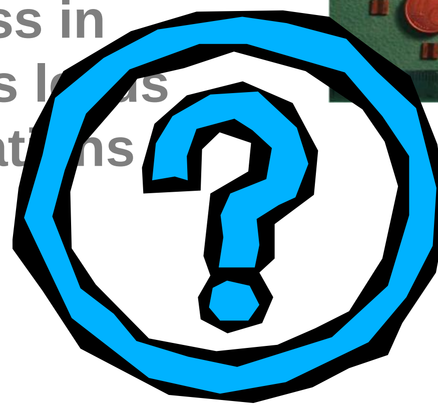
New sensing technologies for air pollution control

Low-cost sensing technologies

Their use can be particularly valuable to have highly spatially and temporally resolved air quality data and to improve exposure assessment

The raising of awareness in indoor air quality issues leads to other potential utilizations monitoring data





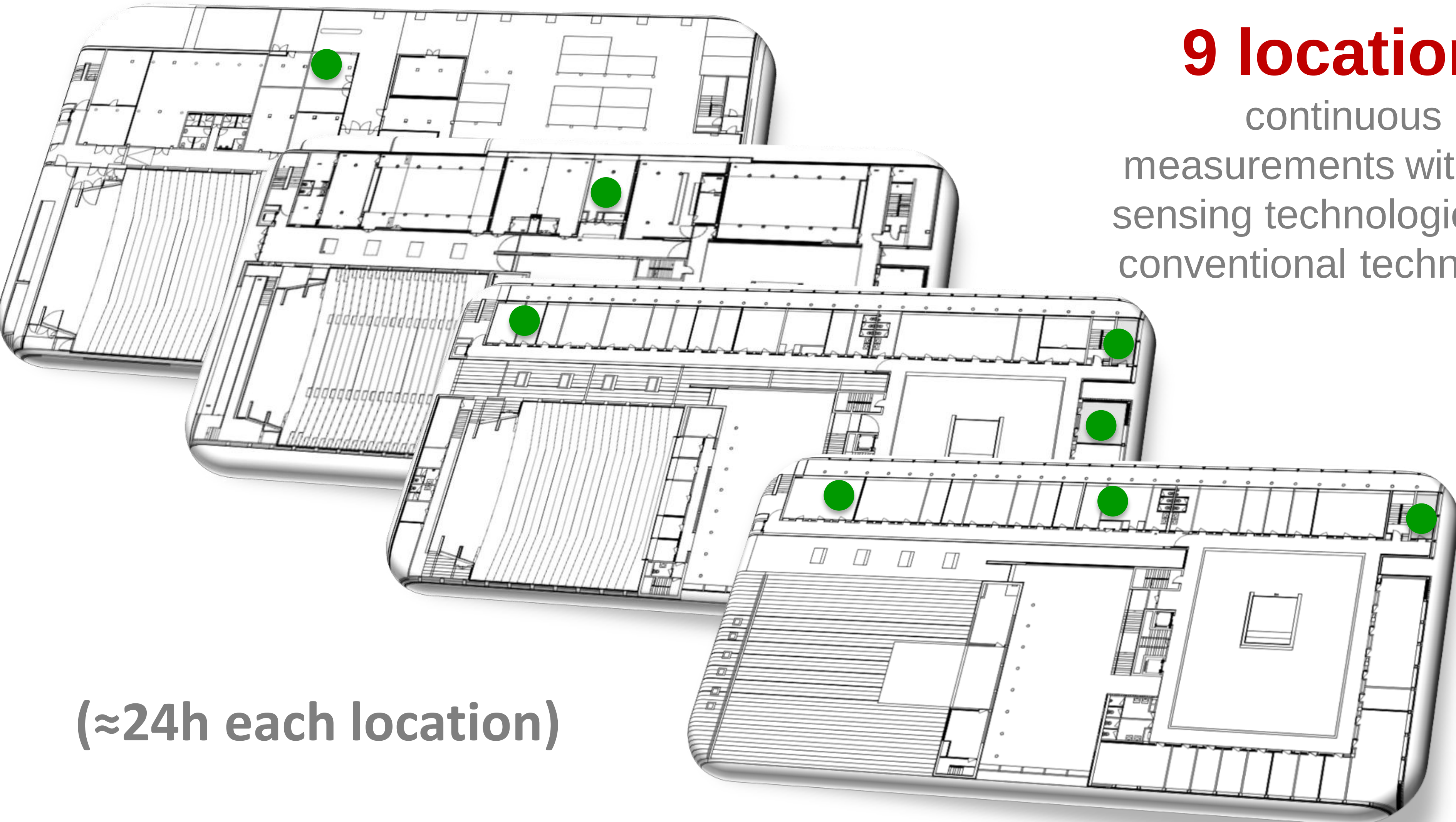
Sensitivity? ppb-ppm?

Stability? lifetime/maintenance?

Selectivity? interferents?

Qualitative or Quantitative data?

Case study - PUBLIC BUILDING



9 locations

continuous measurements with new sensing technologies and conventional techniques.

(≈24h each location)

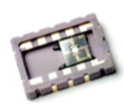
Case study - PUBLIC BUILDING

Pollutant	Sensor	
PM10	light scattering photometer/ gravimetric	 Thermo pDR1200
PM2.5		
CO_2 - Carbon dioxide	**NDIR** - nondispersive infrared sensor	 Graywolf IQ604
VOC - Volatile Organic compounds	**PID** - Photo Ionization Detector	
CO - Carbon Monoxide	Electrochemical sensor	
O_3 - Ozone		
Bacteria and fungi	Impaction principle	MERCK MAS 100 

IAQ assessment with **conventional sensors/techniques**

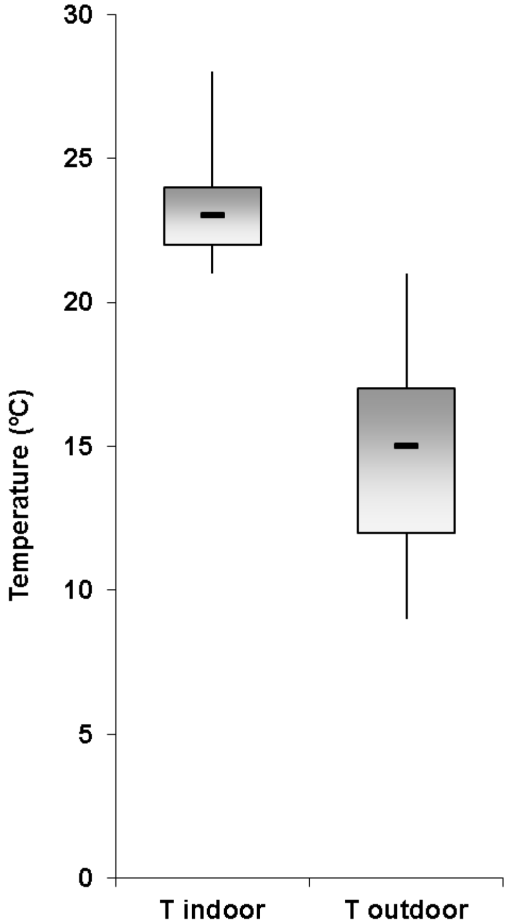
Preliminary analysis for PM, CO_2 and VOC data

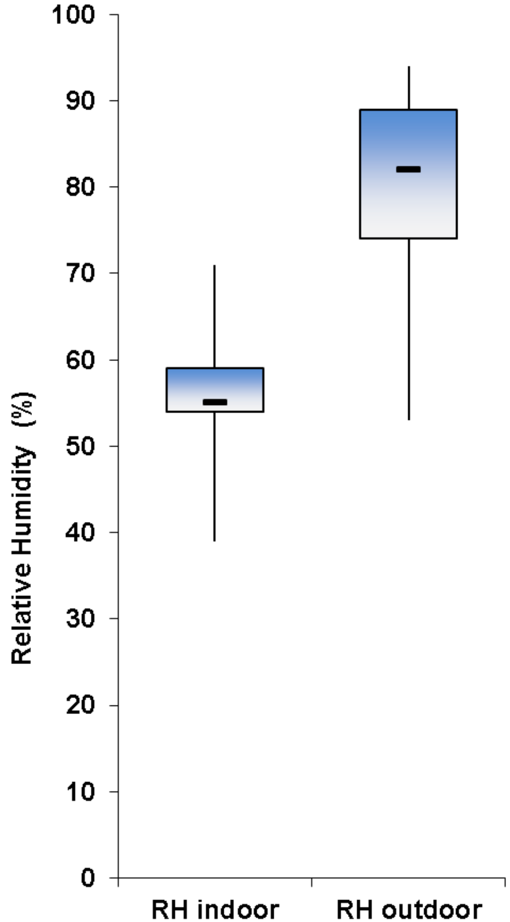
Case study - PUBLIC BUILDING

Pollutant	Sensor	
PM10	light scattering method	 PPD42NS
PM2.5		
CO_2 - Carbon dioxide	NDIR - nondispersive infrared sensor	 SensAir Engine K30
CO - Carbon Monoxide	Electrochemical sensor	 Nemoto NAP-505R
VOC - Volatile Organic compounds	<u>MOS sensors</u> Metal Oxide Semiconductor sensors	 MiCS5524 MiCS2614 MiCS2714 
O_3 - Ozone		
NO_2 - nitrogen dioxide		

Parallel measurement with **low cost sensors**

Environmental conditions





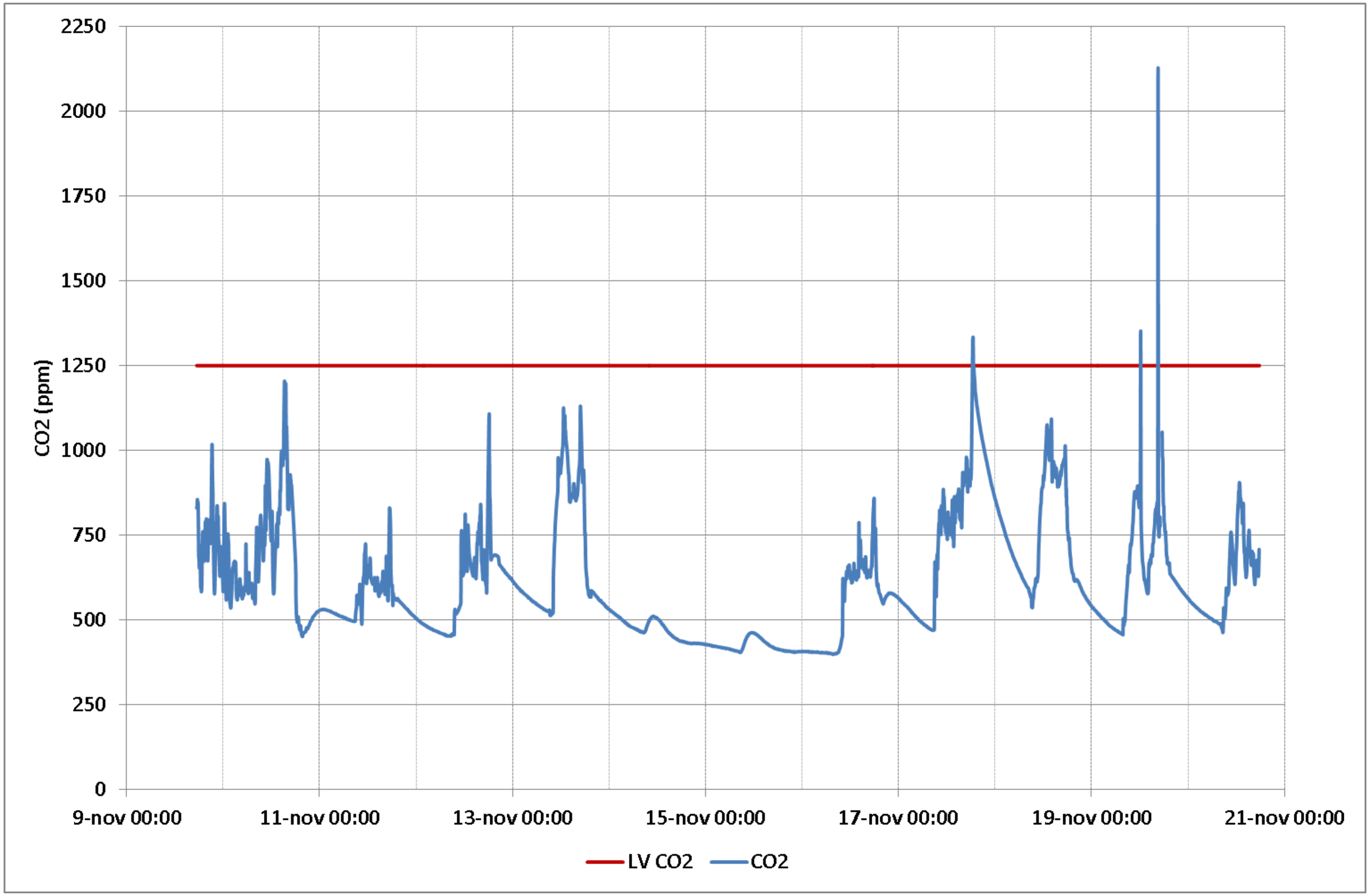
Relatively stable conditions for indoor temperature and relative humidity.

Average during measurement campaign:

T_{indoor}=23 ºC
RH_{indoor}=55%

$T_{outdoor}$=15 ºC
$RH_{outdoor}$=82%

Results – CO_2



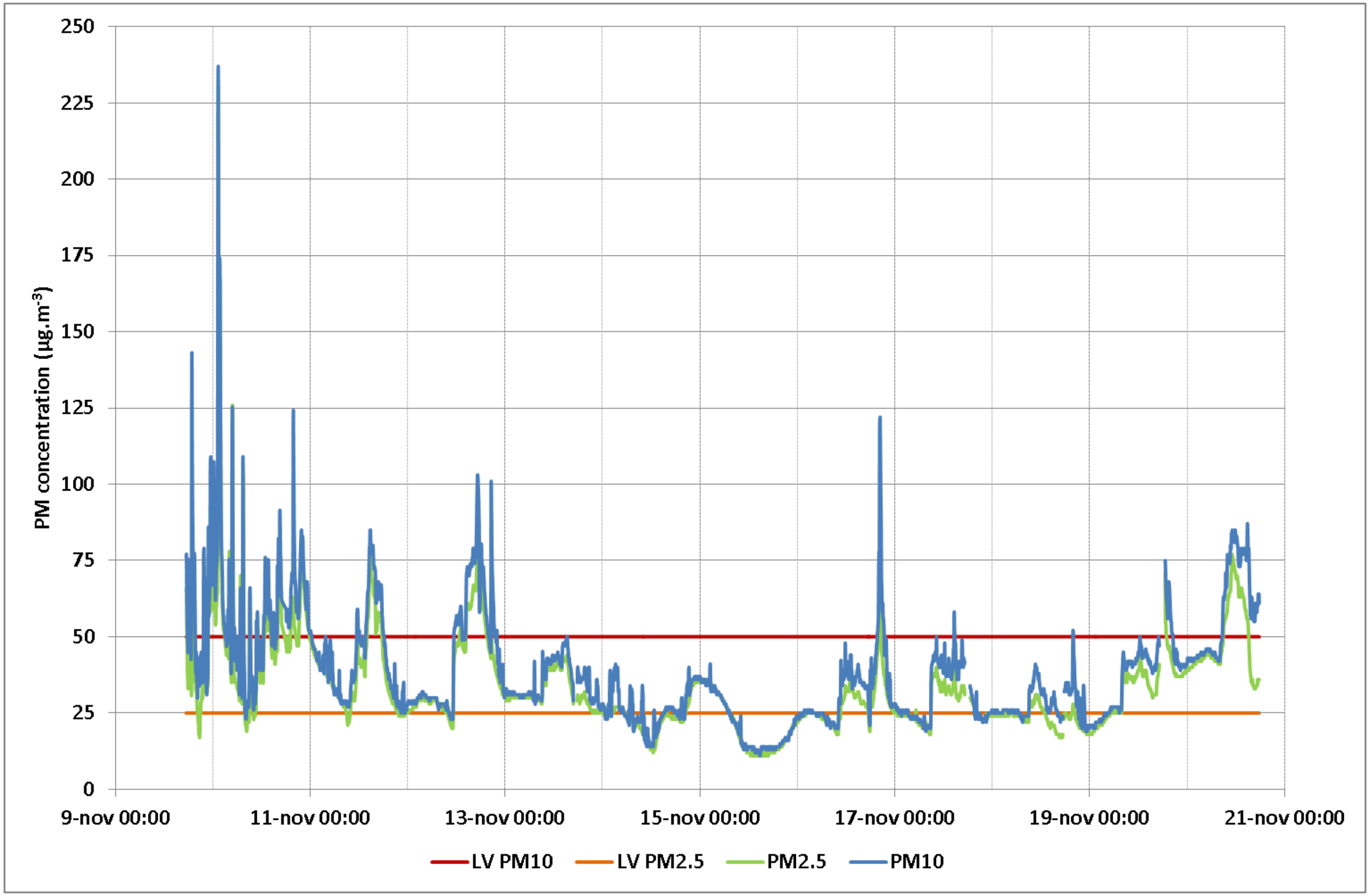
HVAC system off (natural ventilation).

Offices with 1 to 6 persons.

CO_2 (8h average) **bellow the limit value** (1250 ppm) in all locations.

Correspondence with time-activity pattern.

Results - PM10 and PM2.5

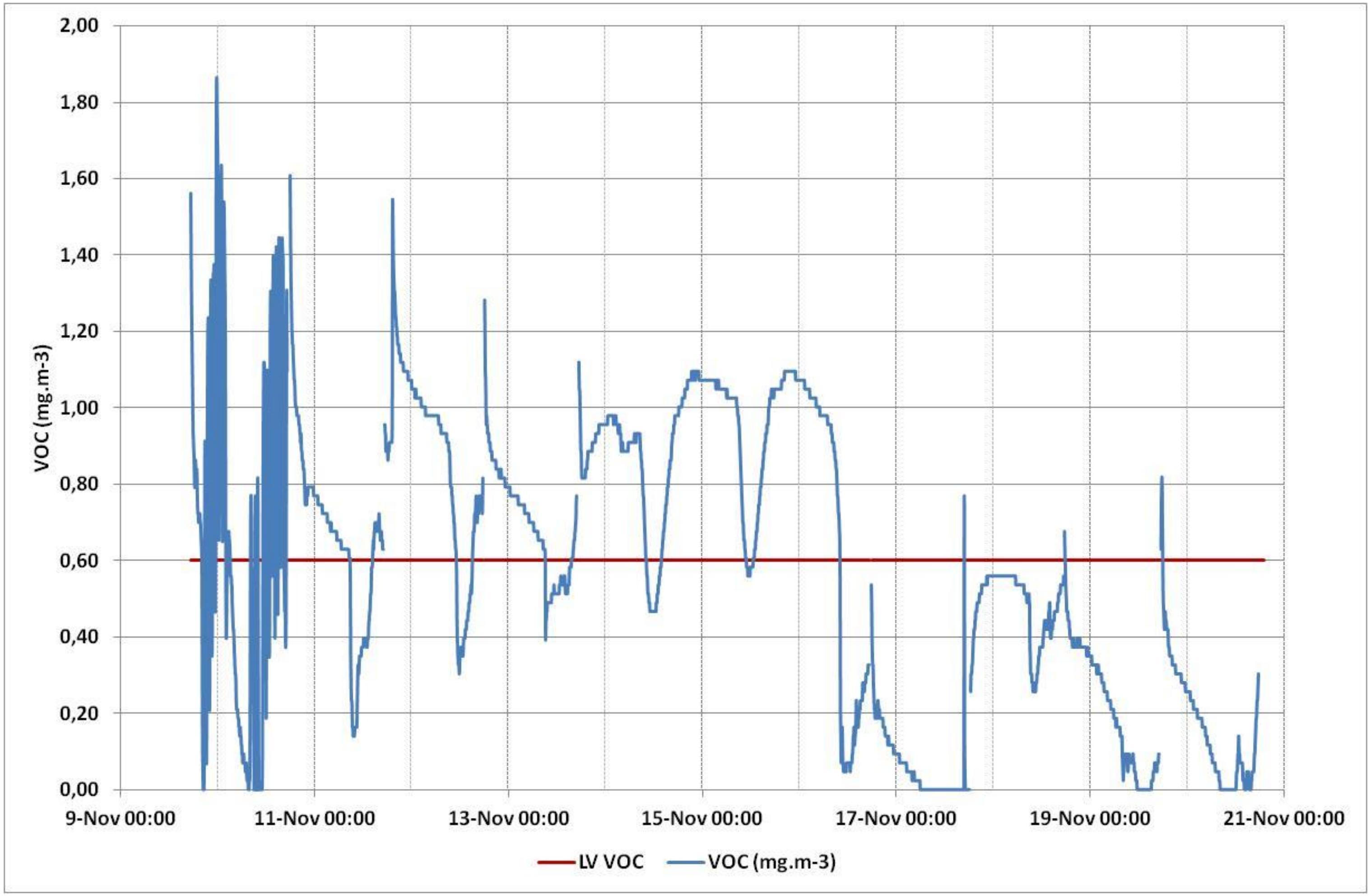


PM10 (8h average) **above the limit value** in 5 locations.

PM2.5 (8h average) **above the limit value** in 8 locations.

Exceedances related with indoor sources (particle resuspension, cleaning activities,…), proximity to car garage and tobacco smoke, and outdoor air.

Results - VOC

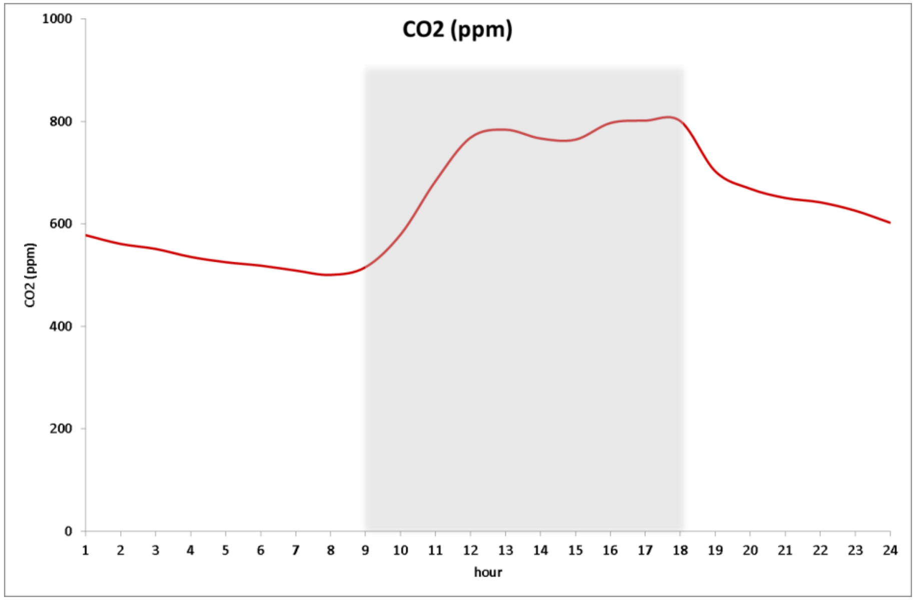


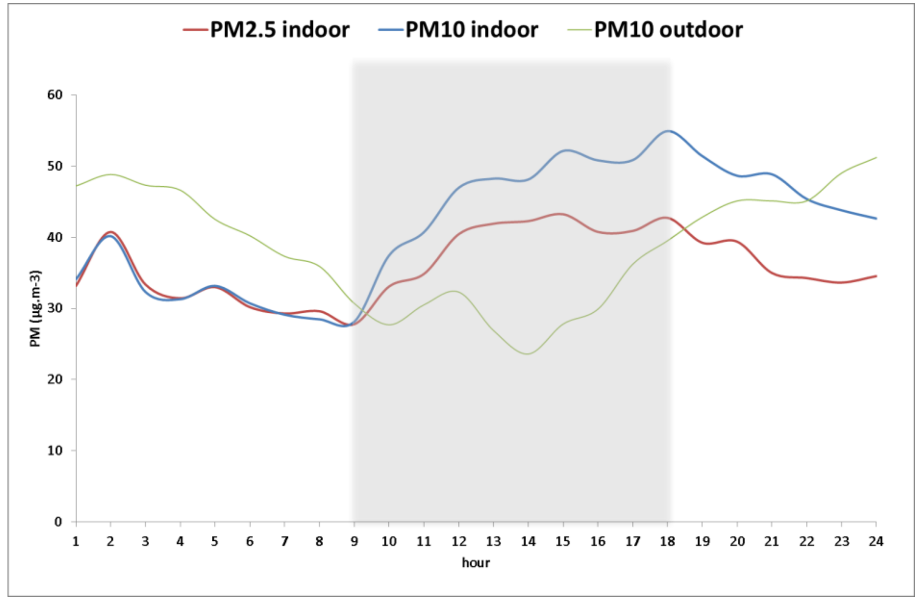
VOC (8h average) **above the limit value** in 1 location.

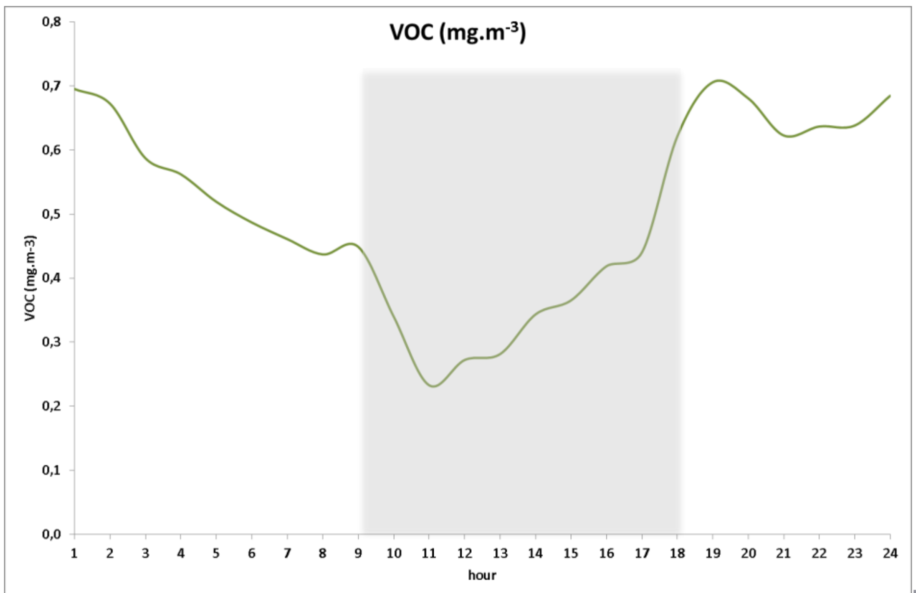
Concentrations related with indoor sources (occupants, air fresheners, cleaning activities, proximity to car garage and tobacco smoke).

Daily profile with higher concentrations during the night. Decrease in concentrations after opening / occupation of spaces at the beginning of the day.

Results – average daily profile





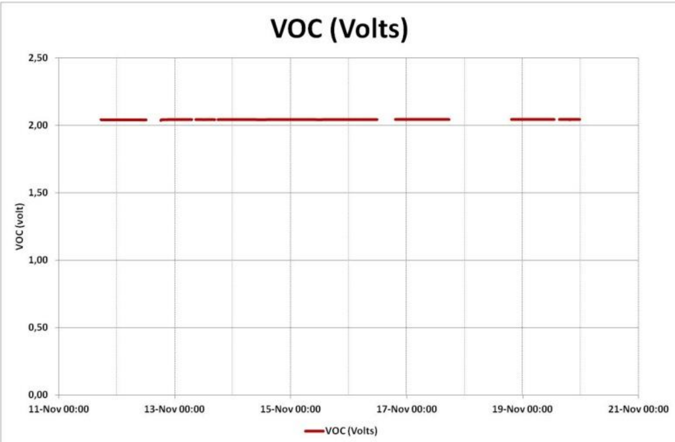


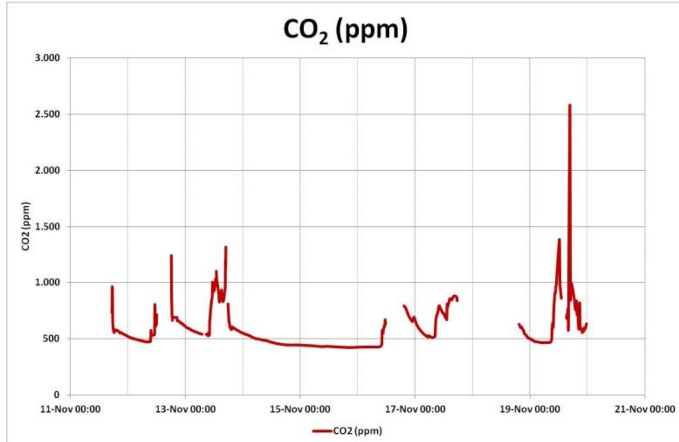
CO_2 - correlation with building occupancy. Relatively high average baseline (low ventilation).

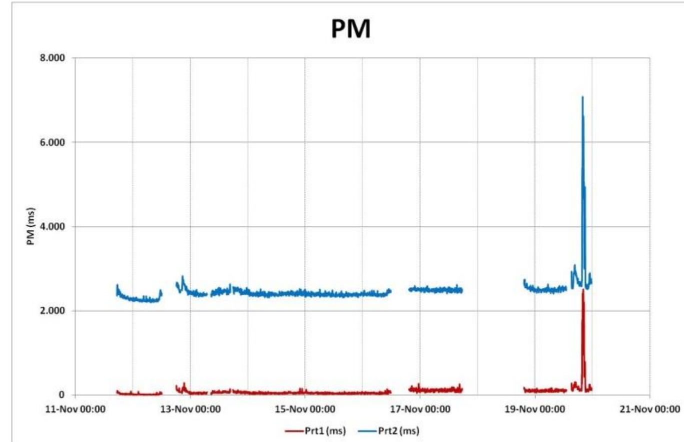
VOC - higher concentrations during the night, after cleaning the spaces. Decrease after opening at the beginning of the day.

PM - different indoor and outdoor profile. Importance of indoor sources for the PM concentration.

Results - Raw data (low cost sensor)

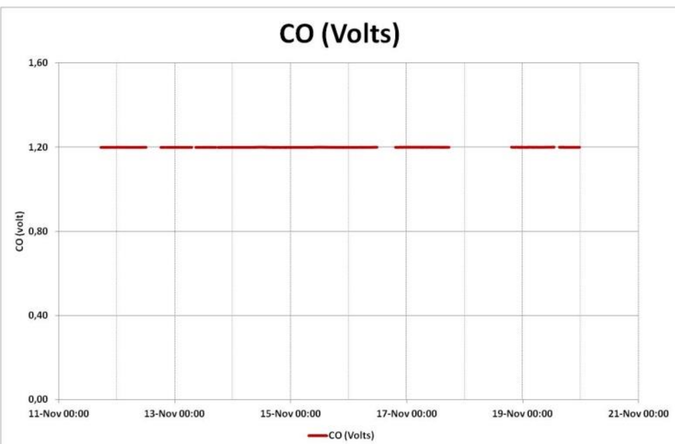


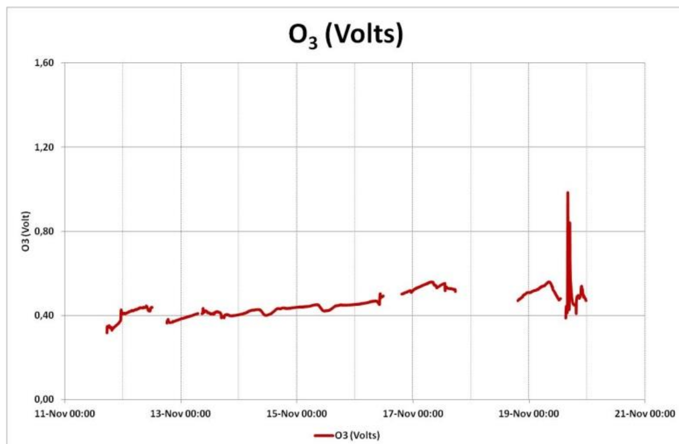


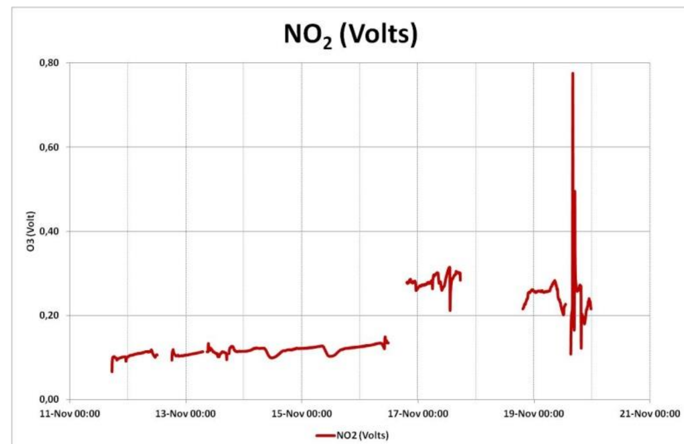


Sensor signal without variation

Sensors signal with variation and possible correlation with conventional equipment and time-activity pattern





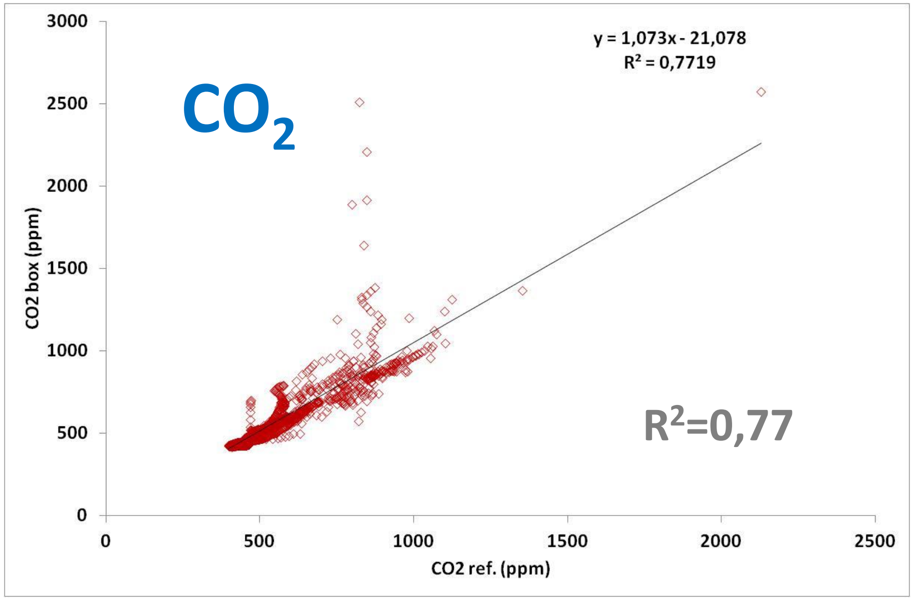


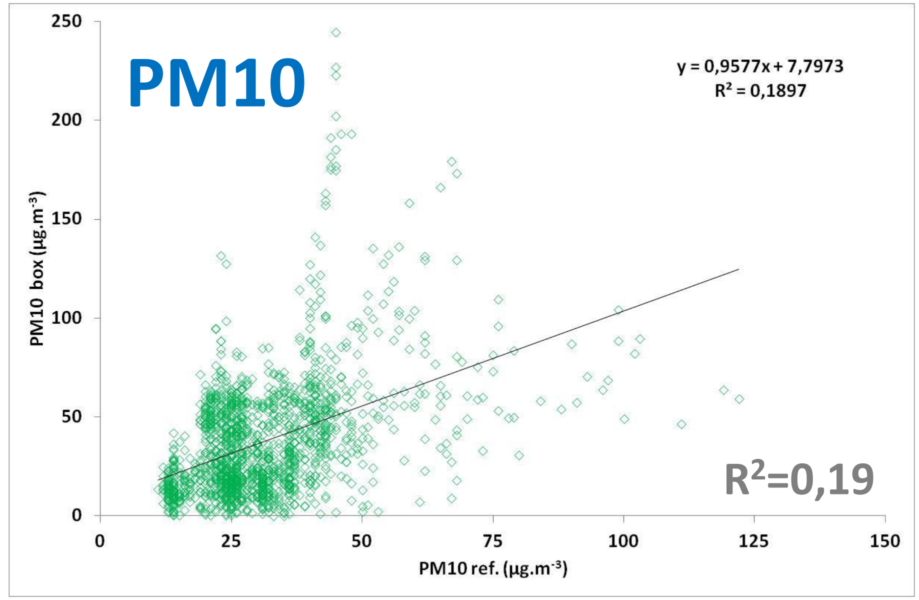
Sensor signal without variation

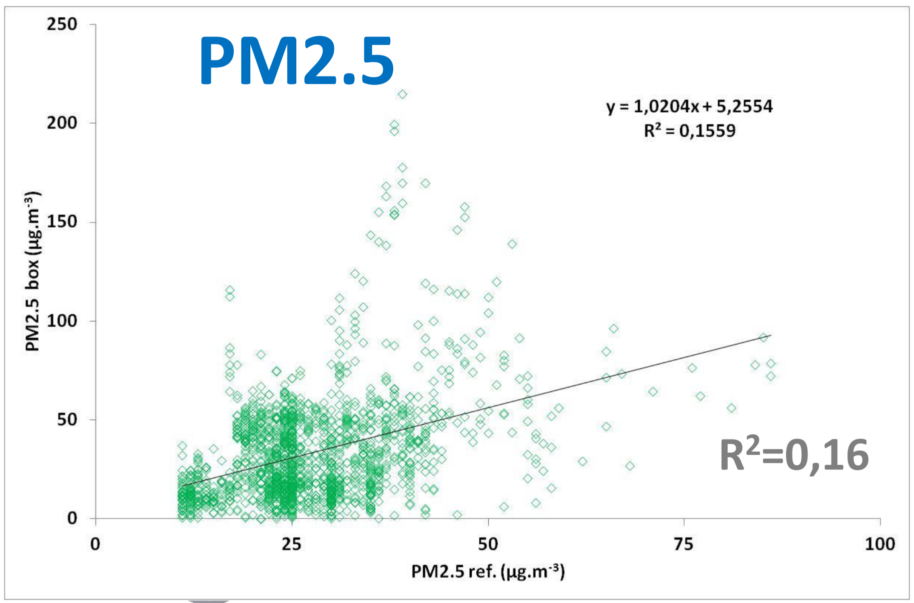
Sensors with the same variation profile (possible cross sensitivity) R^2=0,8

cost
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Results – correlations







CO_2 - strong correlation between micro-sensors and reference equipment (R^2=0,77)

PM10/PM2.5 - poor correlation between micro-sensors and reference equipment (R^2=0,2)

VOC – sensor with no data/correlation (possible saturation)

CONCLUSIONS

- Confirmation of the importance of some sources with relevant contribution to indoor air quality such as:
  - materials, cleaning, indoor activities;
  - strategies of **ventilation**;
  - tobacco smoke / car garage;
  - and **ambient air quality**.
- Good correlation in part of the measurements, between micro-sensors and reference methods (CO_2).
- Result: CO_2 levels should be considered with precaution as an indicator of indoor air quality.
- An intervention in indoor air quality based on the concentration of CO_2 disregard possible exceedance for PM10 and VOC.

CONCLUSIONS

- The **raise of awareness on IAQ issues** combined with the **development of low-cost sensing technologies** allowed to look to other potential utilizations of monitoring data.

- The real-time collected data can be used to **inform occupants** in addition to security or HVAC control purposes.

- The use of **new sensing technologies** for IAQ assessment could be seen as a valuable contribution to create **healthy** and **comfortable** living environments**!**

CONCLUSIONS and CHALLENGES

- IAQ constitutes a **complex case for risk assessment** and management due to a wide variety of pollutants, exposure levels, different possible health outcomes.

- Need for **more research** in the effects due to **combined exposure** to indoor air pollutants and need of unbiased methods for their evaluation, including development of validated monitoring and modelling tools.

- **Climate change** and rise of **energy costs** may have important effects in indoor air quality (e.g. extreme weather conditions, need to additional thermal insulation and decreased ventilation).