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

COST Action TD1105

WGs and MC Meeting at ISTANBUL, 3-5 December 2014

Action Start date: 01/07/2012 - Action End date: 30/06/2016

Year 3: 1 July 2014 - 30 June 2015 (*Ongoing Action*)

ACTIVE AND PASSIVE MEASURES TO ASSESS AND IMPROVE INDOOR ENVIRONMENT QUALITY – THE EU-PROJECT CETIEB

CETIEB

Jürgen Frick

Chair Indoor Environment Quality cluster

Materials Testing institute (MPA)

University of Stuttgart / Germany

cost EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

EuNetAir

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

COST is supported by the EU Framework Programme

ESF provides the COST Office through a European Commission contract

CETIEB

Cost-Effective Tools for Better Indoor Environment in Retrofitted Energy Efficient Buildings

Key facts

Project No.:	285623
Total budget:	3.6 million Euro (funding 2.5 million + 130,000 Taiwan)
Start date:	1st October 2011
Duration:	36 months
Partner:	15
Coordinator:	Dr. Jürgen Frick Materials Testing Institute University of Stuttgart
Homepage:	www.cetieb.eu

Motivation CETIEB

In future:

- Increase of energy efficient buildings
- If retrofitted, change of indoor environment
  - Tight building envelope and insulation
  - Low air exchange or HVAC systems
  - Use of new materials with potential of emissions
- Influence on health and comfort
  - “Sick building syndrome”
- Need
  - for assessment of indoor environments
  - for improvement
  - for cost-effectiveness

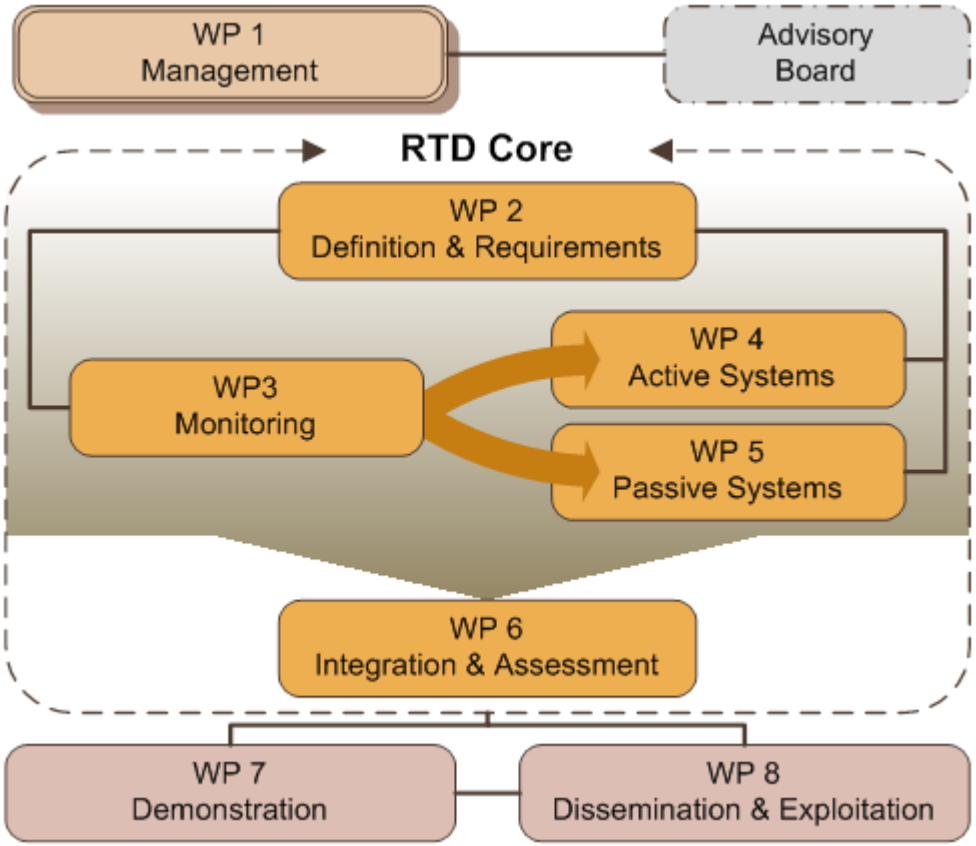
Objectives

- Development of tools to assess and improve indoor environments
  - **Monitoring** with advanced sensors
    - VOC, thermal surface, light spectra, CO_2, climate
  - **Active control**
    - intelligent control platforms and methodologies for HVAC, lighting, and plant based air quality control
  - **Passive systems** based on advanced materials
    - Lightweight mineral insulation plasters with photo catalytic and thermal storage abilities
- Cost-effectiveness
  - Wireless monitoring based on low cost solutions (MEMS)
  - Adapted solutions for different markets based on the same system
    - End-users, experts, facility managers
  - Effective use of active materials
- Focus: Retrofitted energy efficient buildings

Consortium

Universität Stuttgart (MPA (coord.), IGE, IFK)	RTD
Delap & Waller EcoCo Ltd., Dublin	SME
S&B Industrial Minerals S.A., Athens	Industry
Solintel M&P S.L., Madrid	SME
Università Politecnica delle Marche, Ancona	RTD
R.E.D. SRL, Padova	SME
TTI GmbH - TGU Smartmote, Stuttgart	SME
Fraunhofer-Gesellschaft, IPM Freiburg	RTD
InfraTec GmbH, Dresden	SME
CEA INES, Grenoble	RTD
STAM SRL, Genova	SME
Schwenk Putztechnik GmbH, Ulm	Industry
Consorzio TRE, Napoli	RTD
FCCCO Construccion SA, Madrid	Industry
National Taiwan University of S&T, Taipei	RTD

Project structure



Wireless Monitoring

- Small and portable
- cost-effective
- Wireless and autonomous
- Different sensors
- Cloud based data analysis

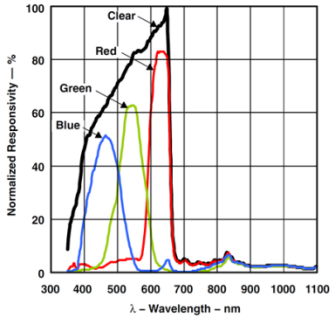
Principle sketch of a monitoring system in use (TTI Smartmote)

Available sensors

- RH/T (50 €)

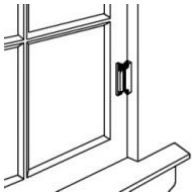
- T (Pt100/Pt1000; < 20€)

- Light
  - Intensity and colour(< 5€)
  - Visible and IR (< 5€)



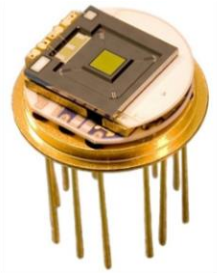
  - Calibrated pyranometer, UV-sensor (< 200€)
- CO_2 (0-2000 ppm; < 200€)
- VOC (CO_2 – equivalent)

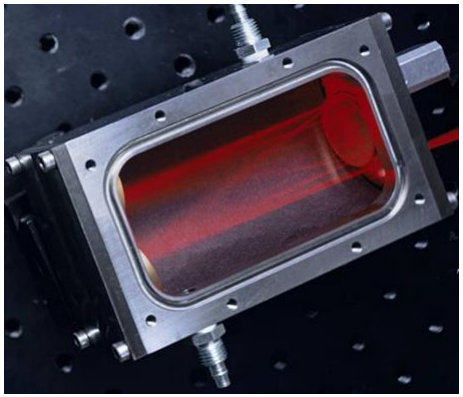
- Window/door opening (several magnetic; < 20€)



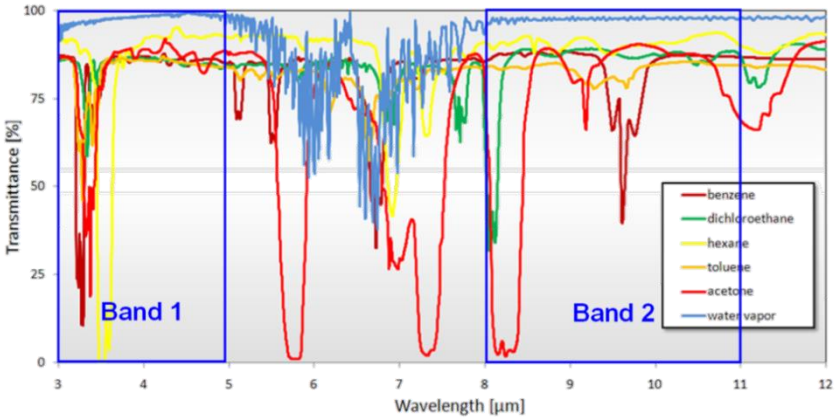
- Wind- and air-flow (indoor/outdoor)

VOC sensor

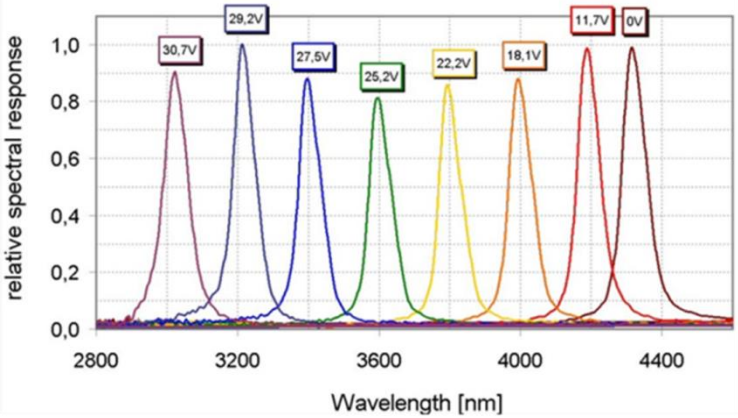




Micro spectrometer module (InfraTec) and multi-reflection cell (Fraunhofer IPM)



Infrared absorption spectra of typical VOCs and water vapour

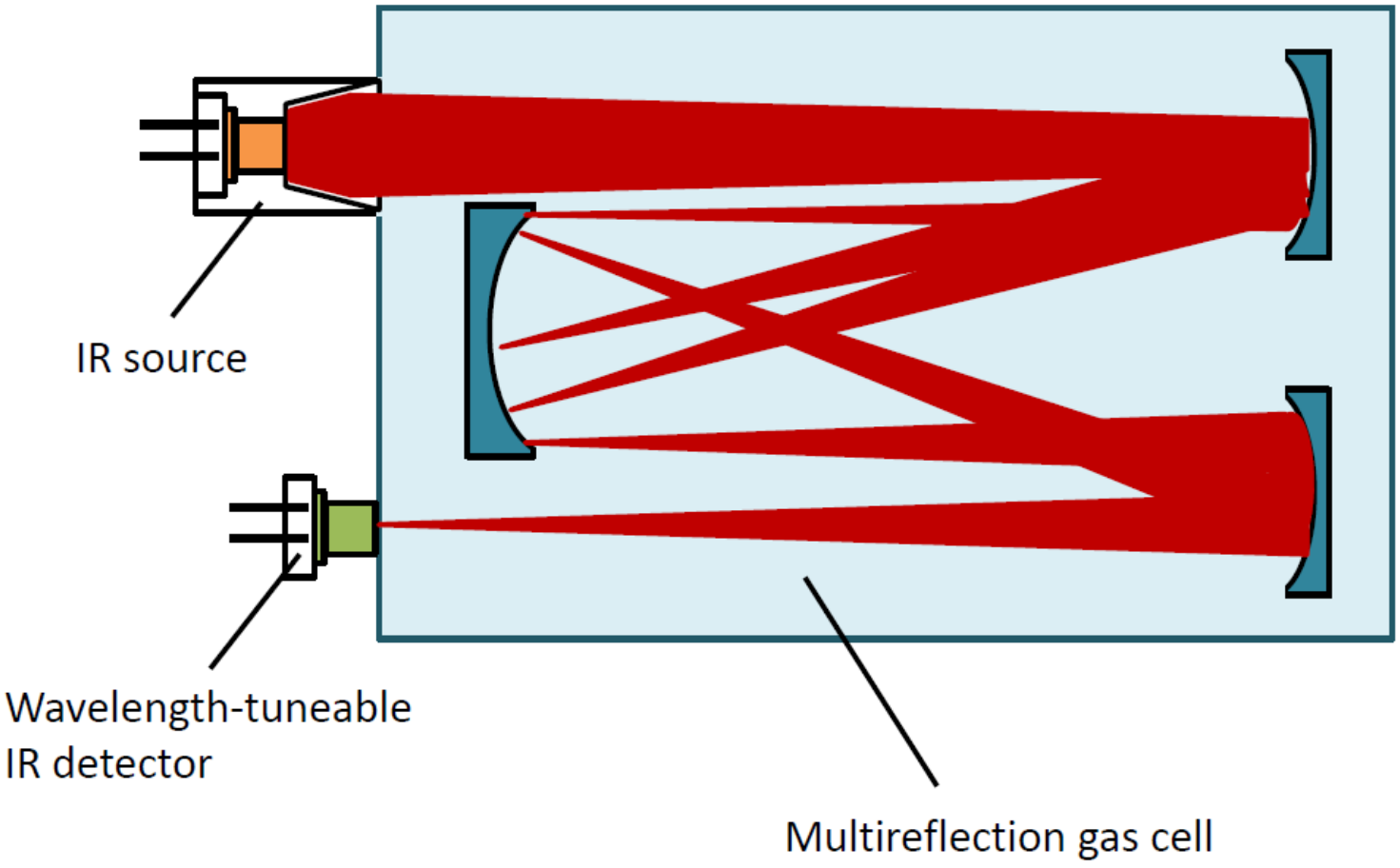


- spectrometric (IR)
- selective
- „Spectral tunable infrared detector with micro-mechanical Fabry-Perot-Filter“
- InfraTec GmbH

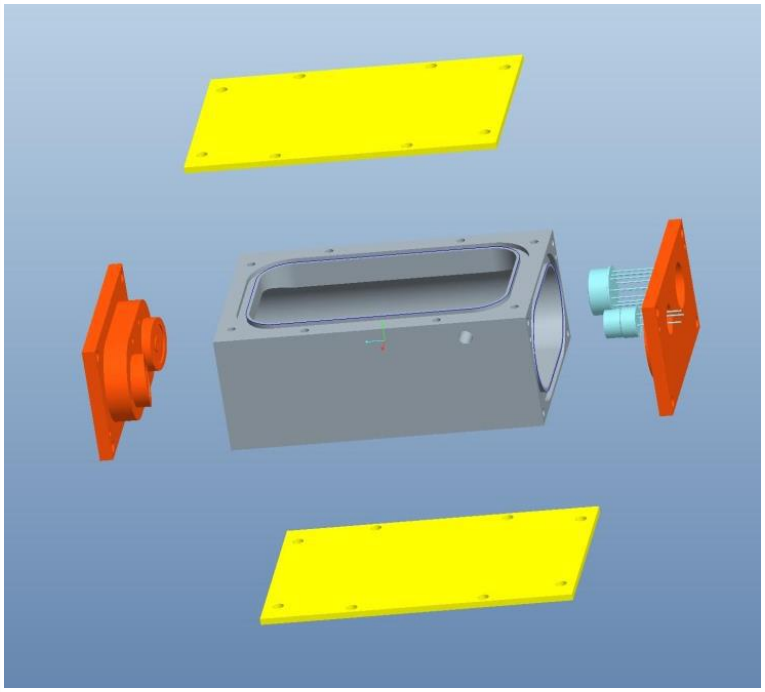
AMA SENSOR Innovation Award 2008

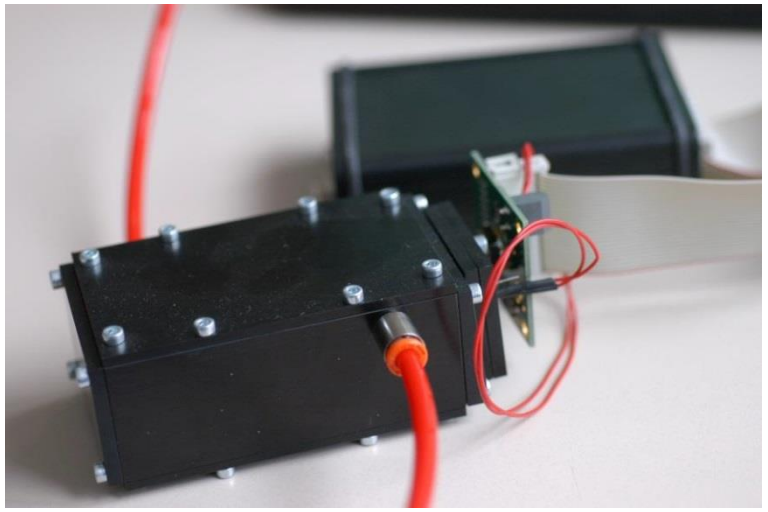
SPIE 2009 Prism Award for Photonics Innovation

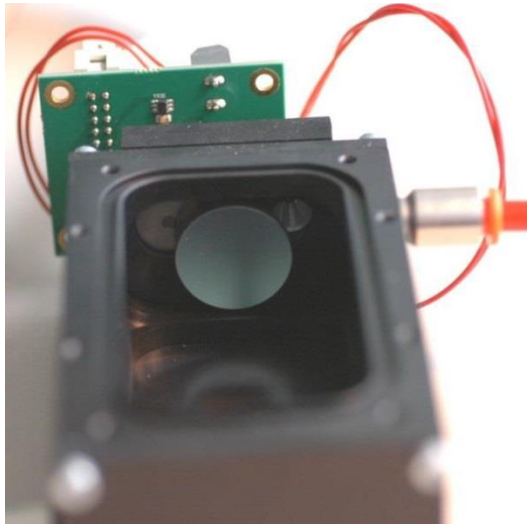
VOC micro spectrometer



VOC sensor development





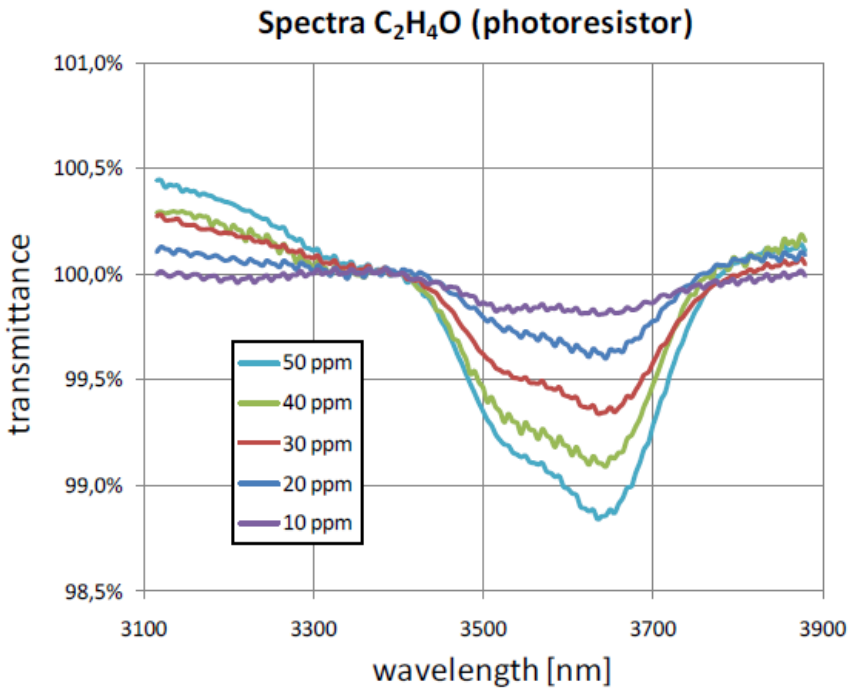


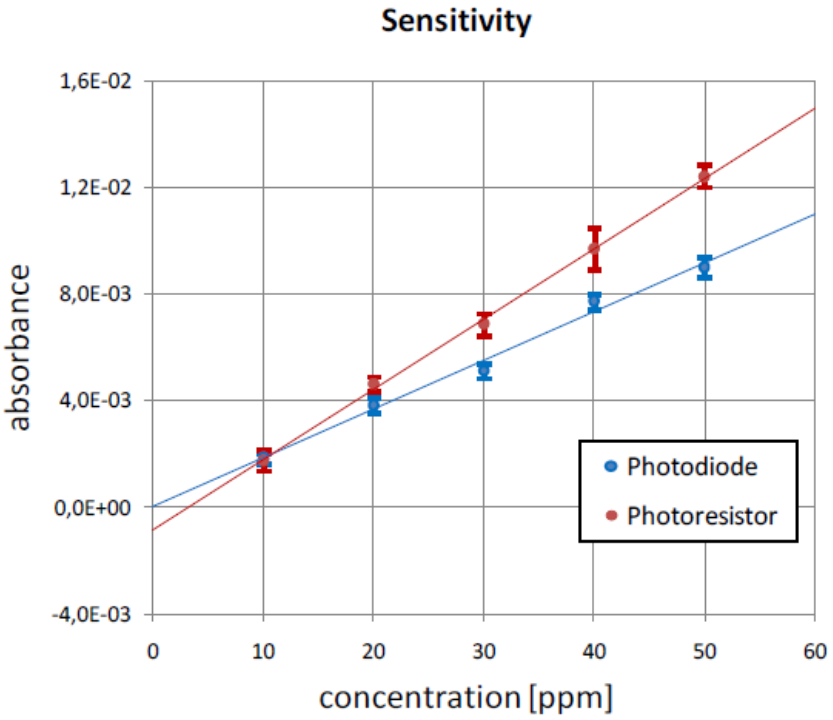
Laboratory evaluation

- Variations of sensing detectors
  - Pyro-electric
  - PbSe – photoresistor
  - PbSe – photodiode

	Pyroelectric	Photoresistor	Photodiode
Recording time	~ 5 min	~ 1 min	~ 1 min
Chopping frequency	10 Hz pulsed	63 Hz mechanical chopper	25 Hz pulsed
Sensitivity (C_2H_4O)	10 ppm	5…10 ppm	2…5 ppm
Spectral resolution	50…70 nm	50…70 nm	25…35 nm

VOC-sensor laboratory results





Next step: thermal stabilisation

On site use at St. Salvator

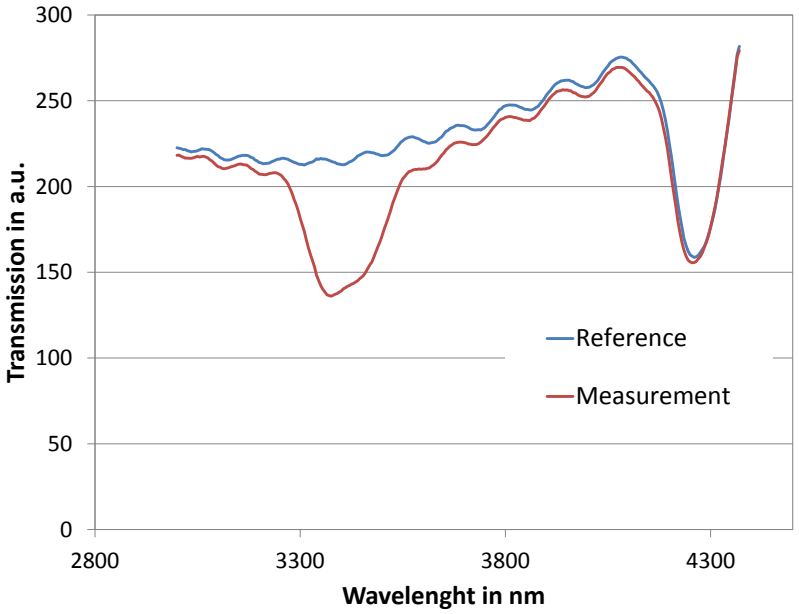
funded by

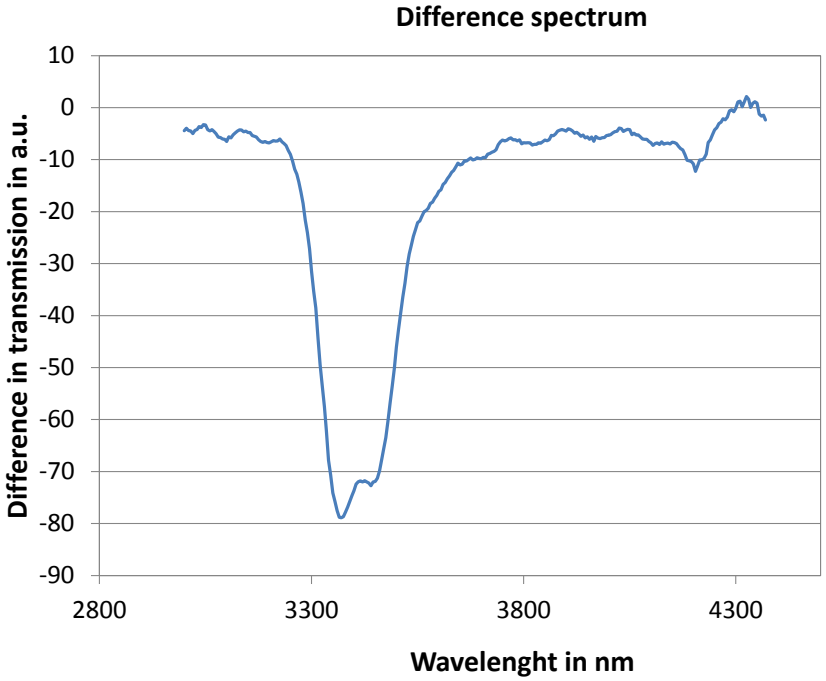
DBU
Deutsche Bundesstiftung Umwelt

- Consolidation product produces ethanol at reaction
- Amount could be dangerous
- After laboratory validation use of VOC sensor to detect ethanol

Measurement results

- Raw data, not treated
- Ethanol band clearly visible





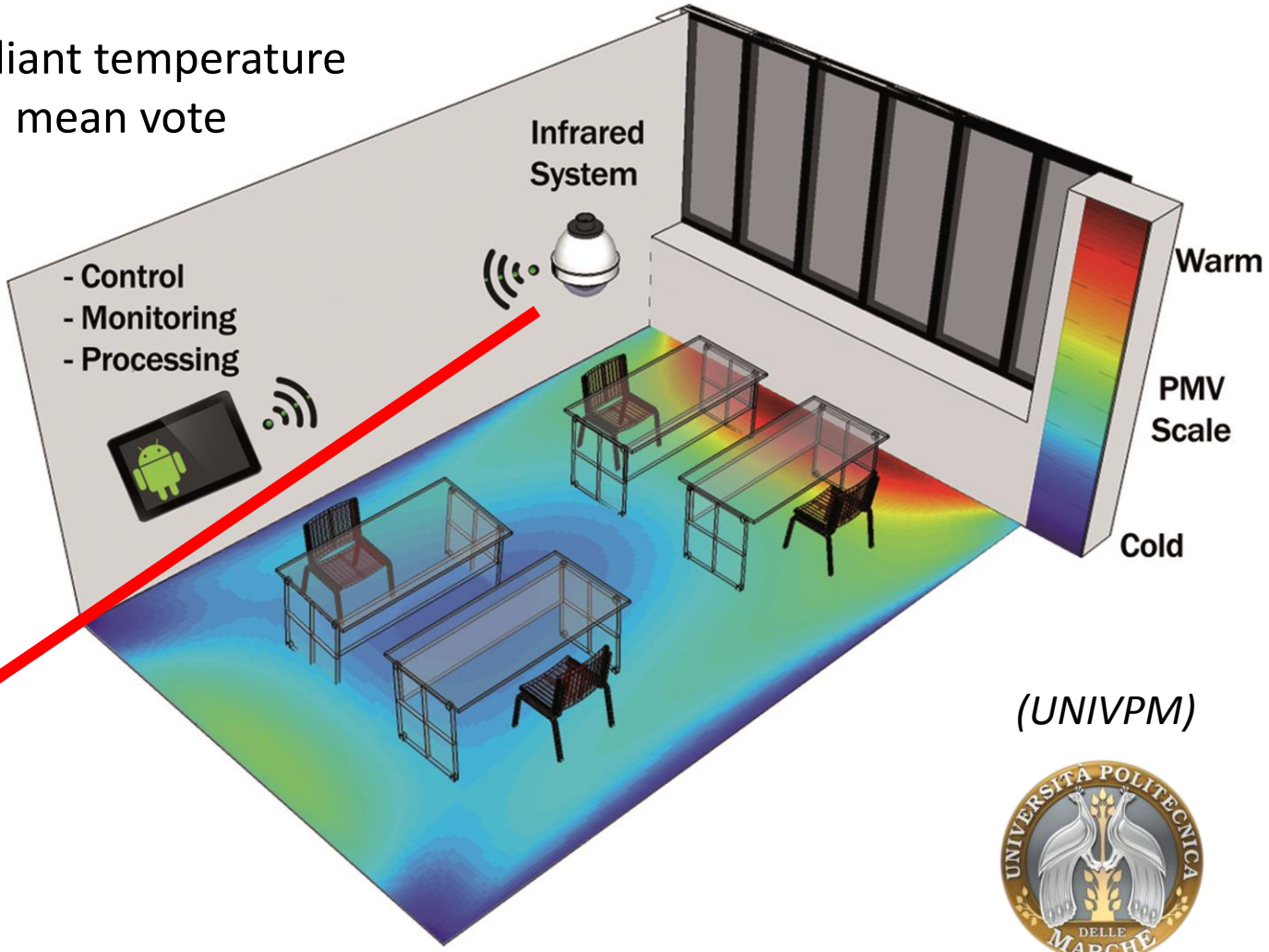
TVOC sensor array

Open MOX-sensor node with 4 different MOX-sensors, PCB-board and microcontroller (Fraunhofer-IPM)

- gas sensor array
- low cost
- semi selective

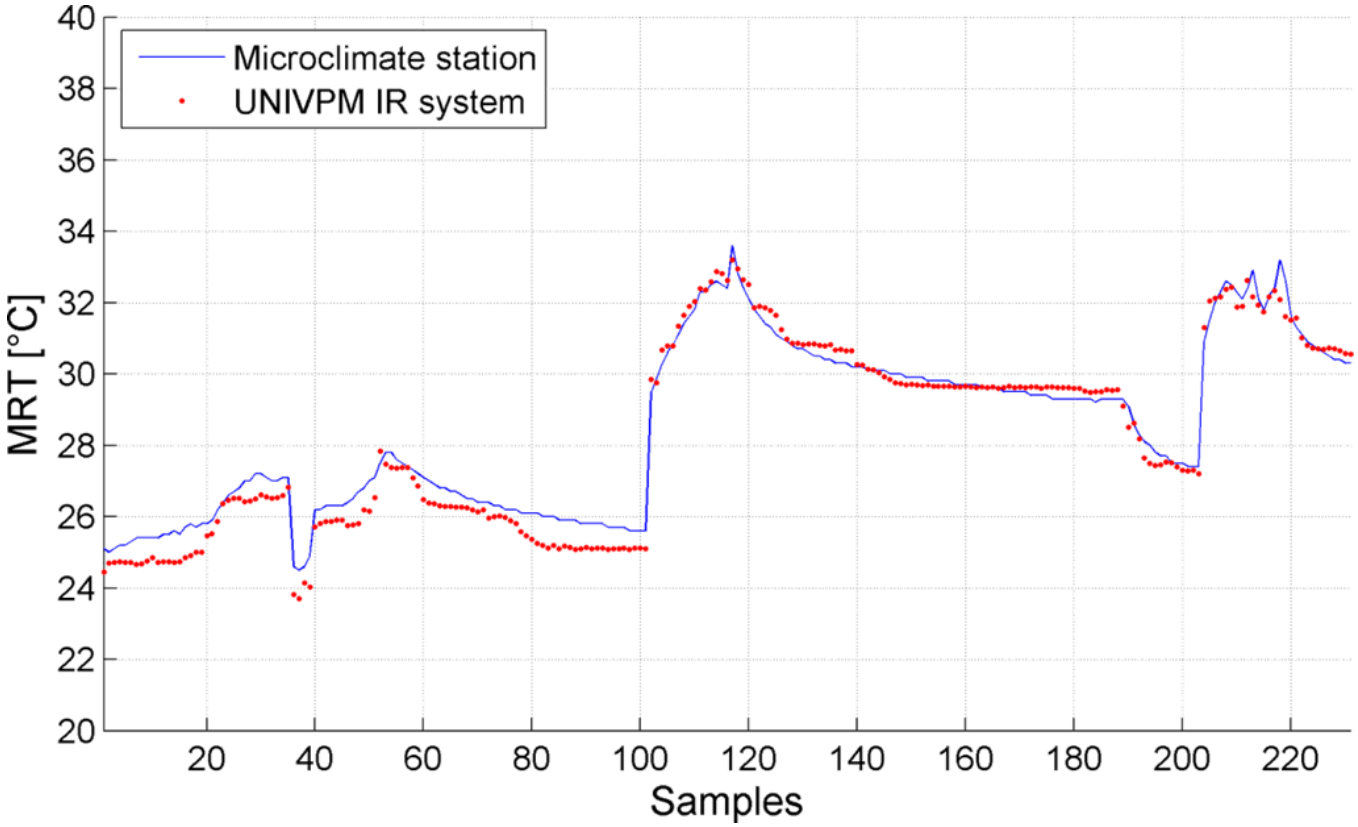
Thermal comfort detection in real time

- Mean radiant temperature
- Predicted mean vote



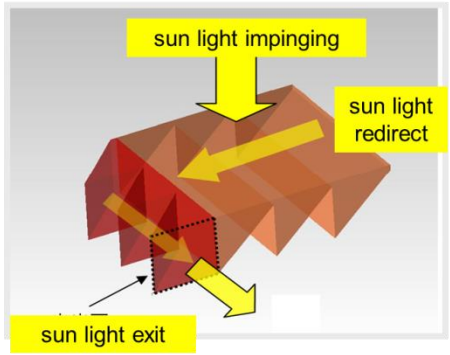
(UNIVPM)

Accuracy


Microclimate station
UNIVPM IR system
MRT [°C]
Samples
40
38
36
34
32
30
28
26
24
22
20
20
40
60
80
100
120
140
160
180
200
220

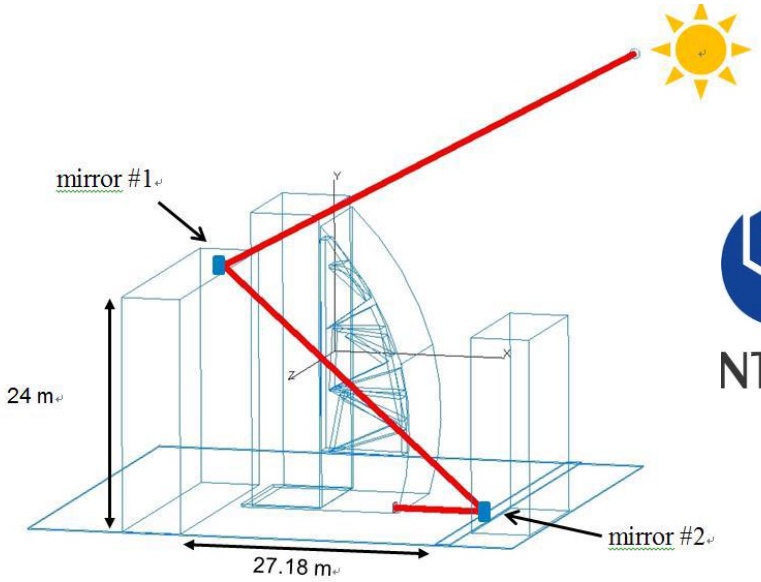
Natural light illumination system

Example from our partner NTUST in Taiwan

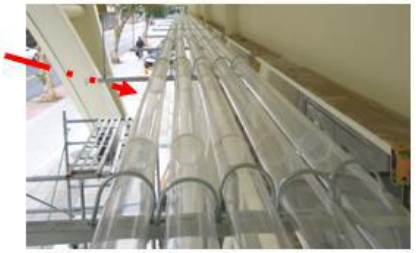


SunLego® Prototype

Demonstration at university building in Taipei



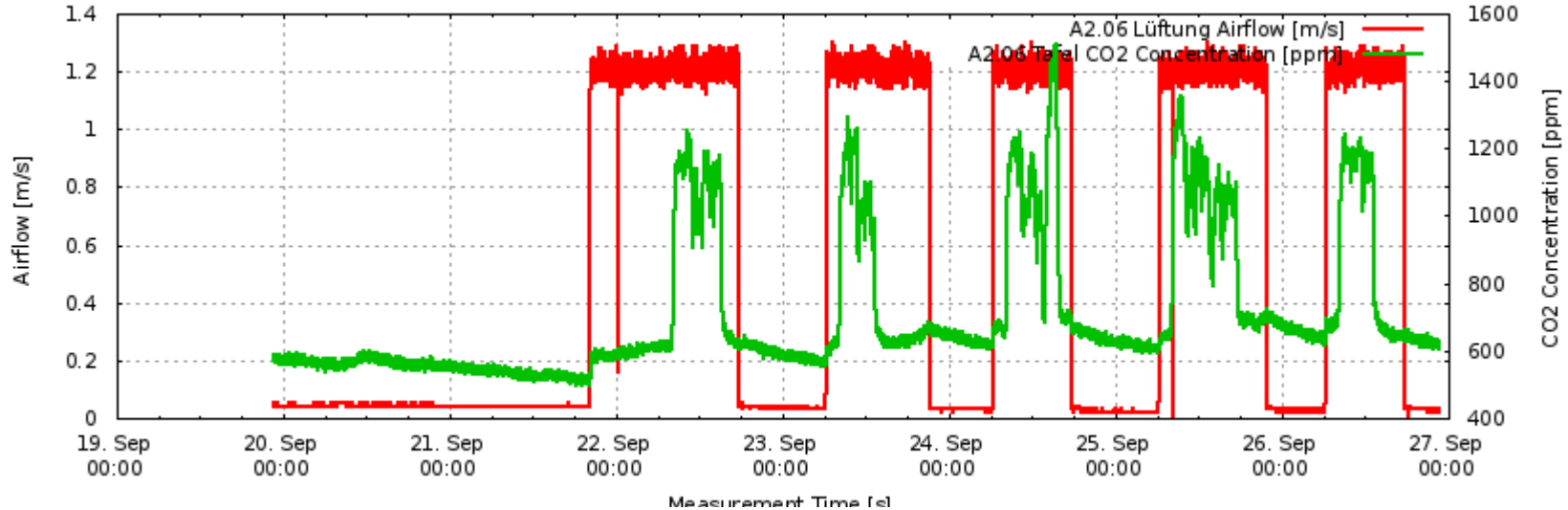
Demonstration at university building in Taipei

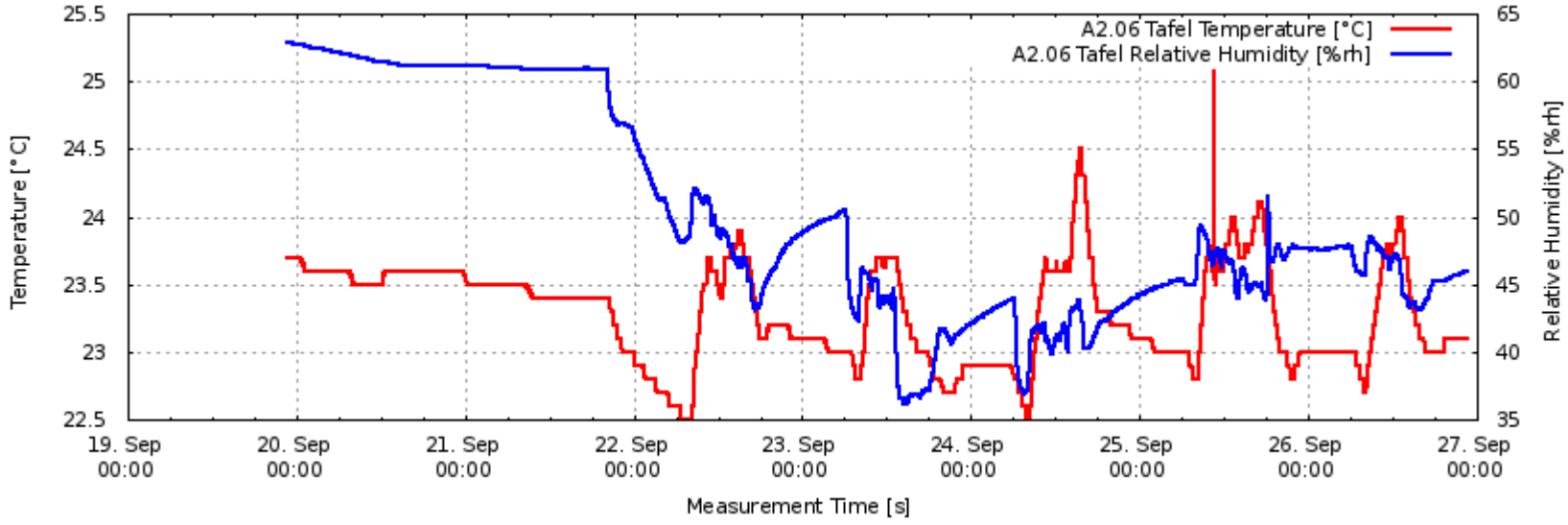


NTUST

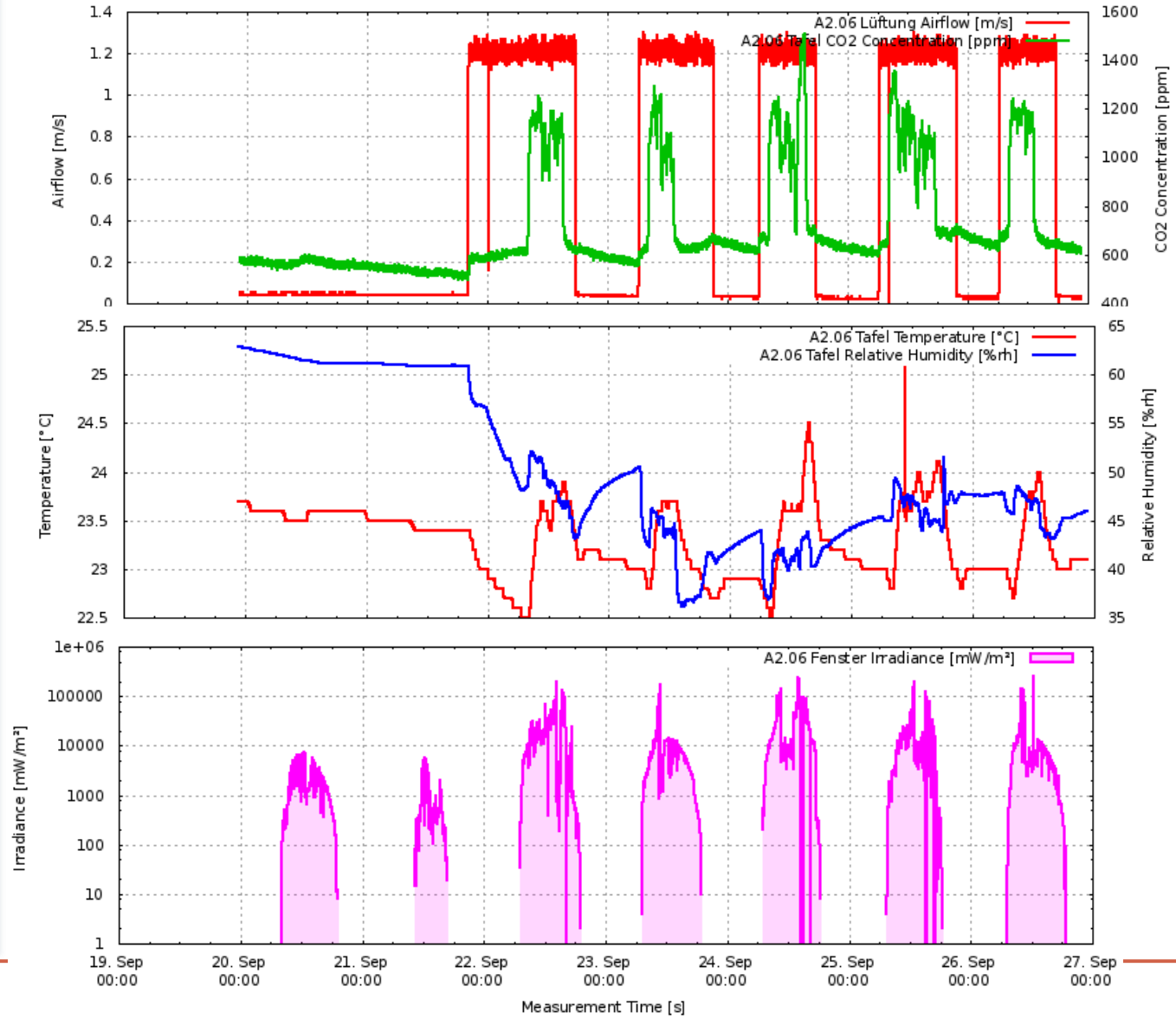
Richard-von Weizsäcker school, Öhringen

Monitoring data: (RH, T, Vent., CO_2)

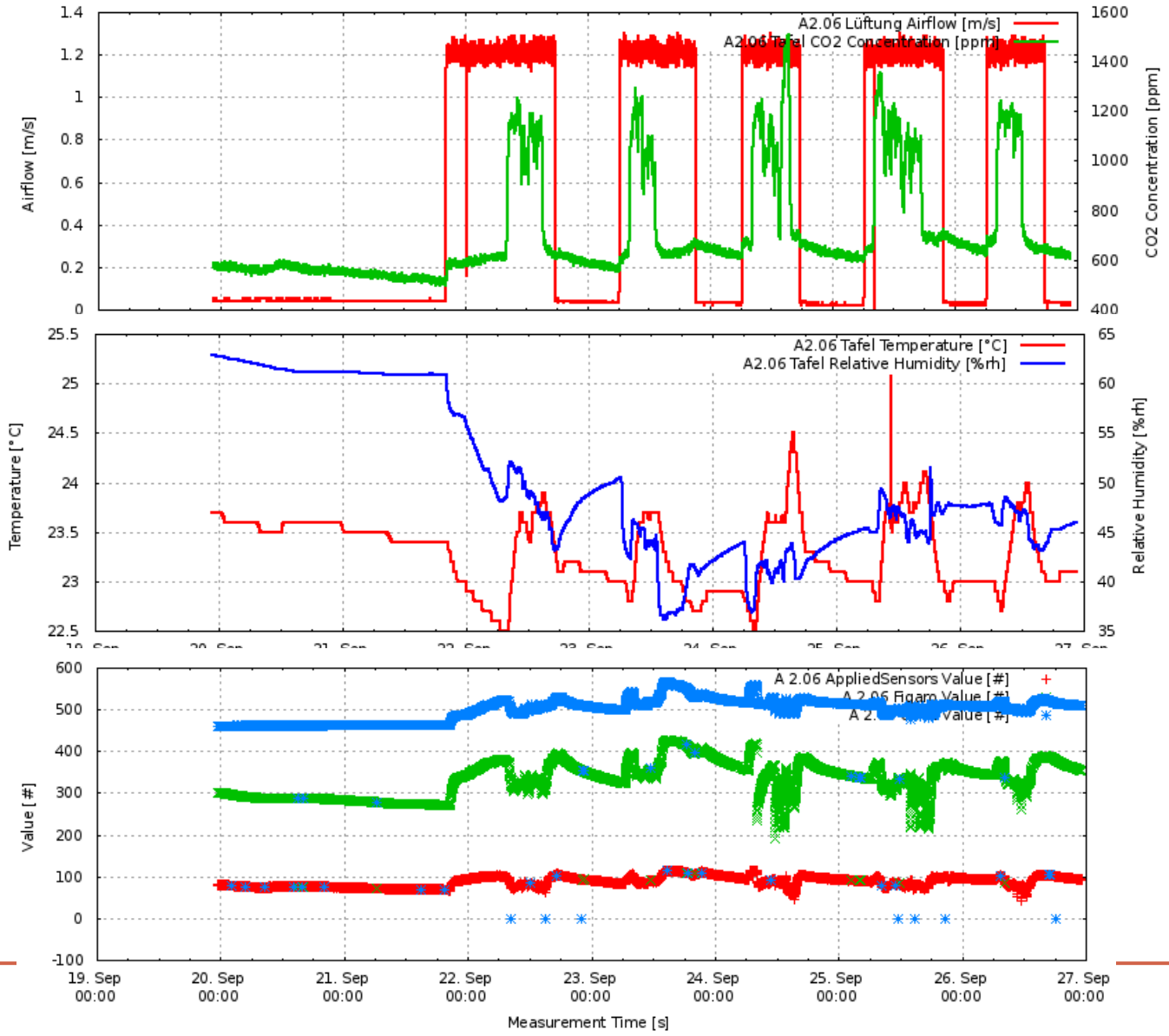




Monitoring data: (RH, T, Vent., CO_2, sunlight)

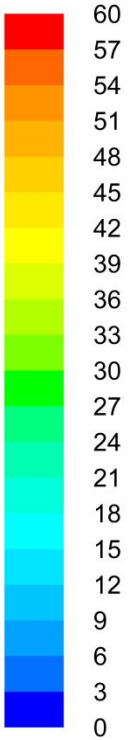


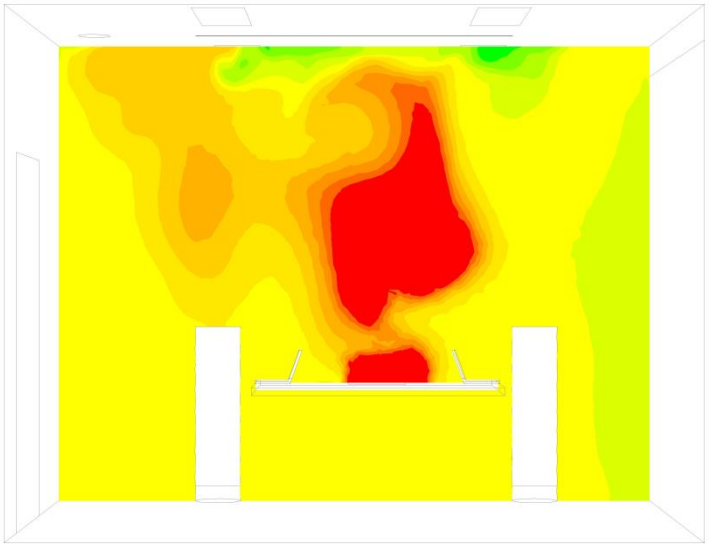
Monitoring data: (RH, T, Vent., CO_2, TVOC)



Active control and modelling

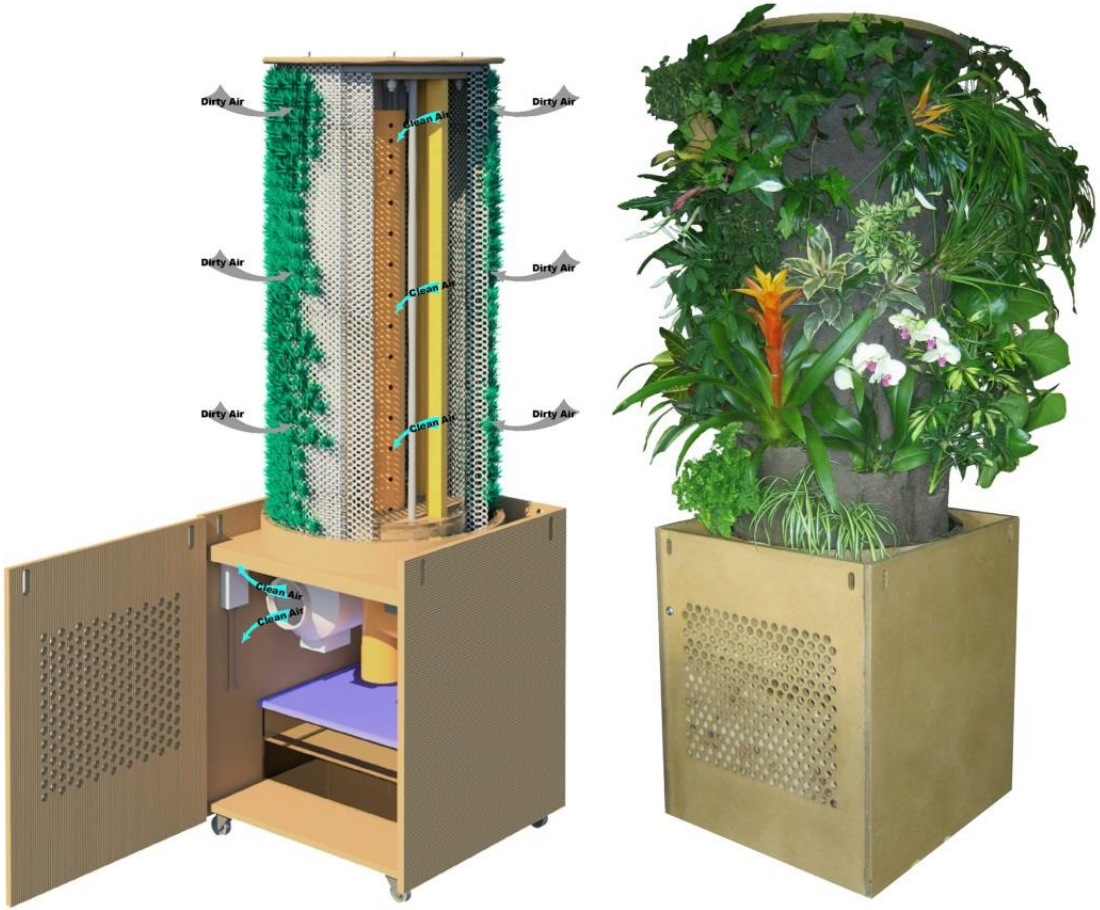
- **Optimal operational methodologies and control algorithms** for
  - lighting,
  - HVAC systems, and
  - plant based air quality control
- **Intelligent control platforms** able to implement
  - operation methods and
  - control algorithms
- **Modelling of indoor environment**
  - Assessment and validation of monitored data to optimise control parameters and systems

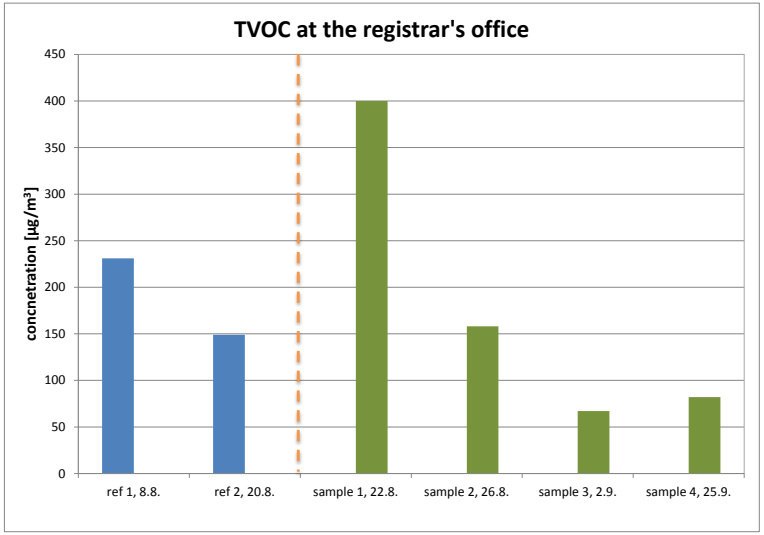




Emission of pollutants in an office situation (USTUTT IGE)

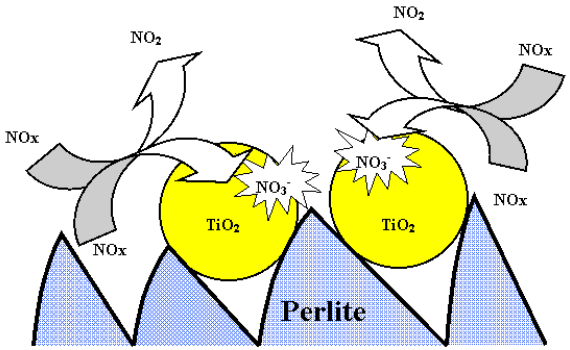
Demonstration Air Biofilter



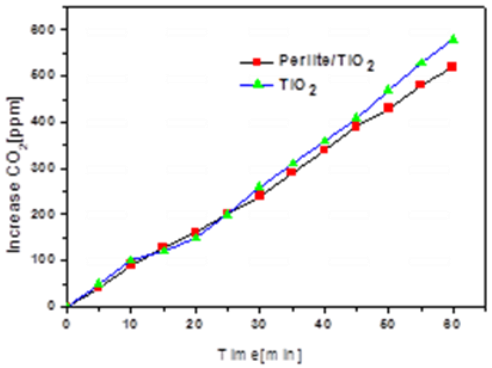


Passive systems

- photo catalytic material

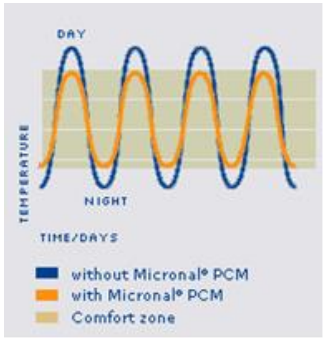


TiO_2 / perlite system: degradation of NOx, VOC, …



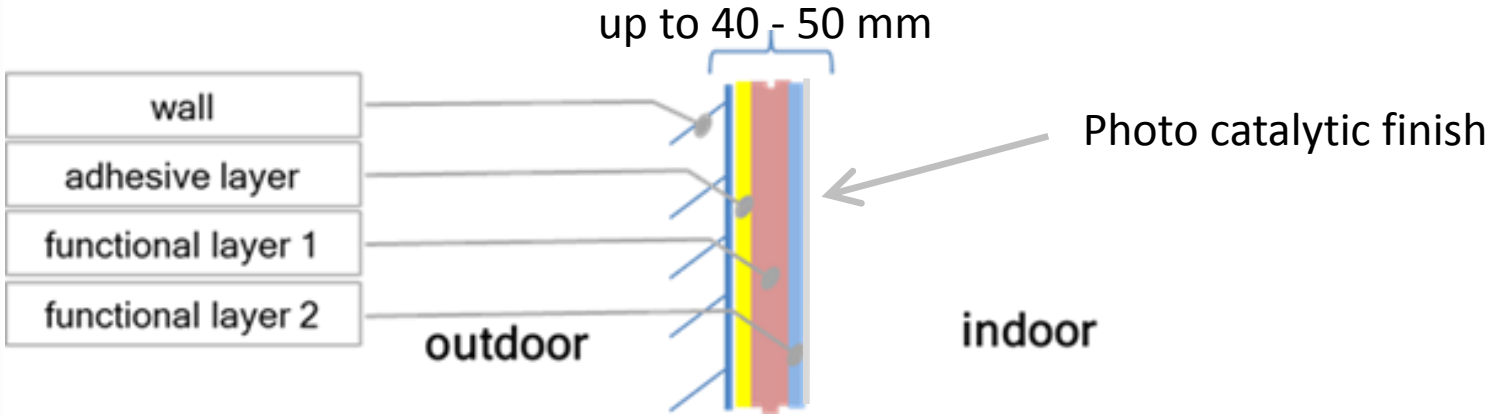
- Similar effect with lower amount of active material
- Cost reduction of 50% intended

- phase change material



- lightweight mineral plaster
- phase change materials
- improved heat storage capacity
- keeping room temperature within human comfort range

Passive systems layout



Adhesive mortar:

- compatible with sulphate, limestone or cement substrates

Insulation plaster:

- lightweight, special sulphate and cement resistant binder, machine workable

Storage plaster:

- Insulation plaster with phase change materials (PCM)

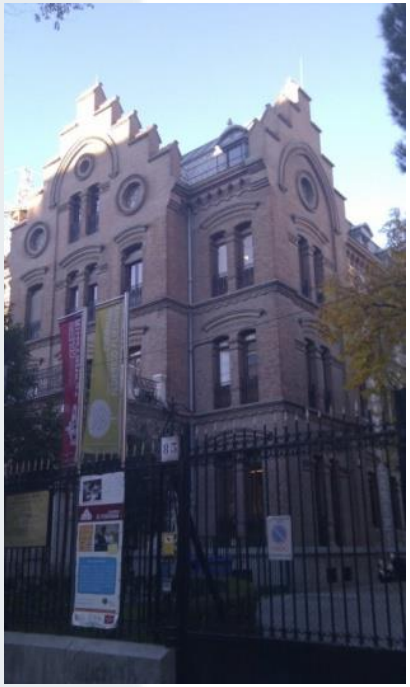
Photocatalytic finish

- Overcoat, special sulphate and cement resistant white binder with nano-TiO_2

Technical parameters

Parameter	Insulation render	Storage render
Dry density [g/dm^3]	360	435
Compressive strength [N/mm^2]		
after7 days	0.71	1.90
after 28 days	1.04	1.83
Thermal conductivity [W/(m^2 K)]	**0.067**	**0.074**
Shrinkage after 28 days [mm/m]	1.2	1.4
Water vapour diffusion equi-valent air layer thickness [cm]	15.8	25.6
Water vapour diffusion resistence ratio	5.0	7.9

School El Porvenir, Madrid



SCHWENK Putz- und Mörtelsysteme

Baustoffe fürs Leben

Installation
Thermal insulation
Plaster system with
Thermal storage

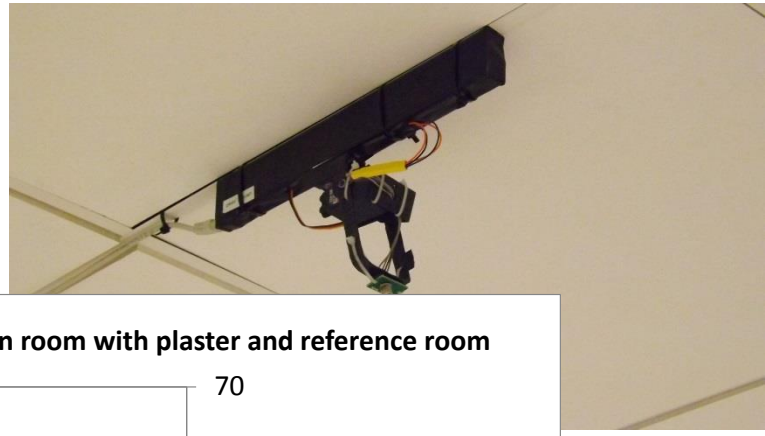
Old building

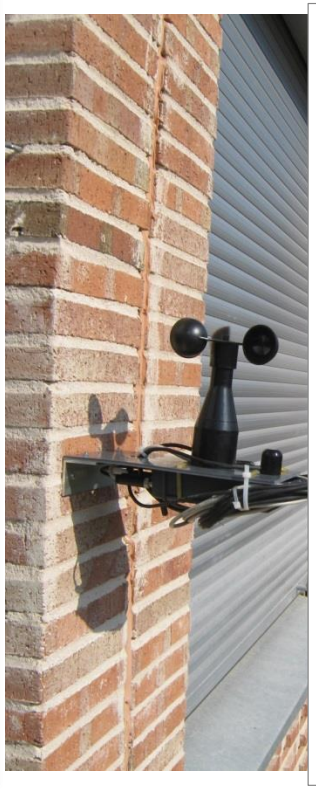
new building

FCC CONSTRUCCION

Monitoring at El Porvenir in Madrid

- CO_2
- Temperature
- rel. humidity
- Light
- Thermal comfort
- Wind





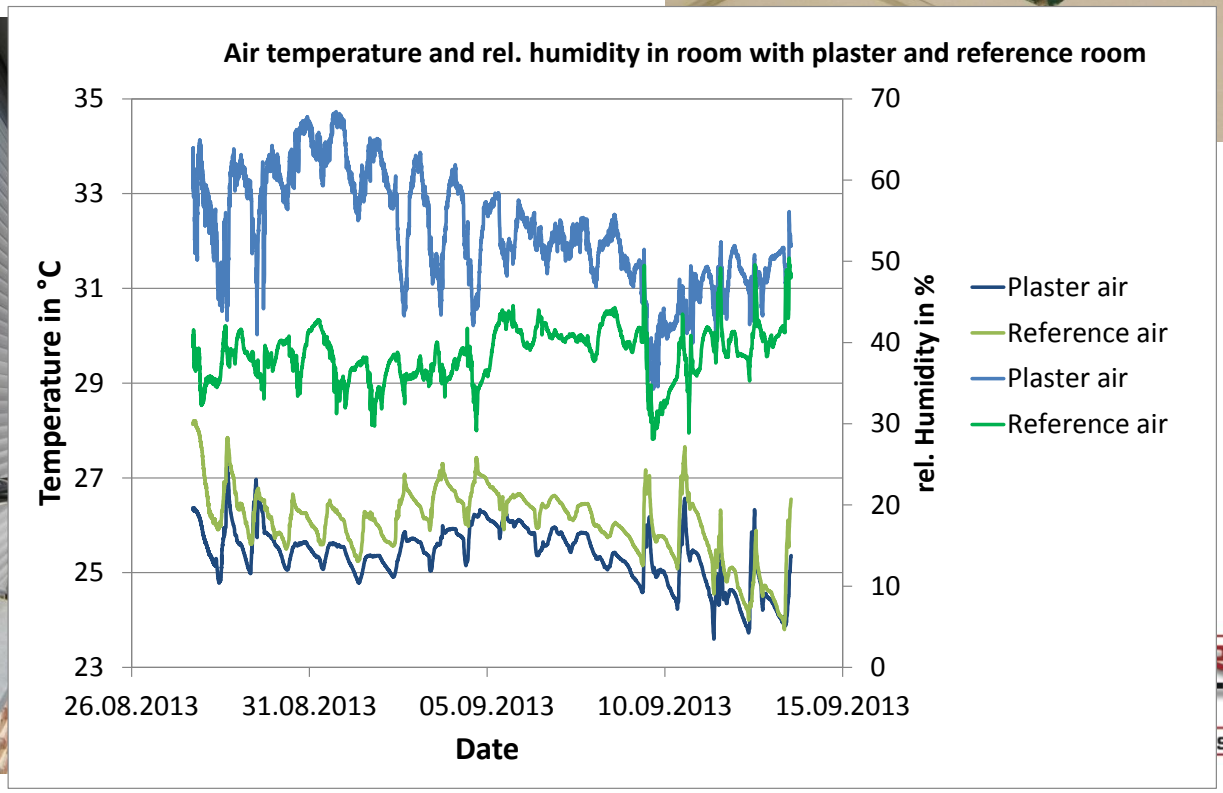
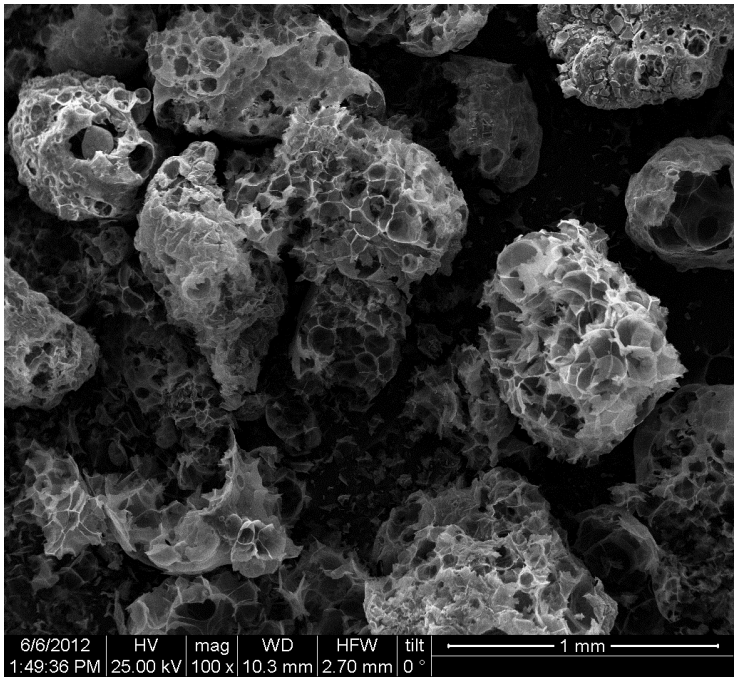
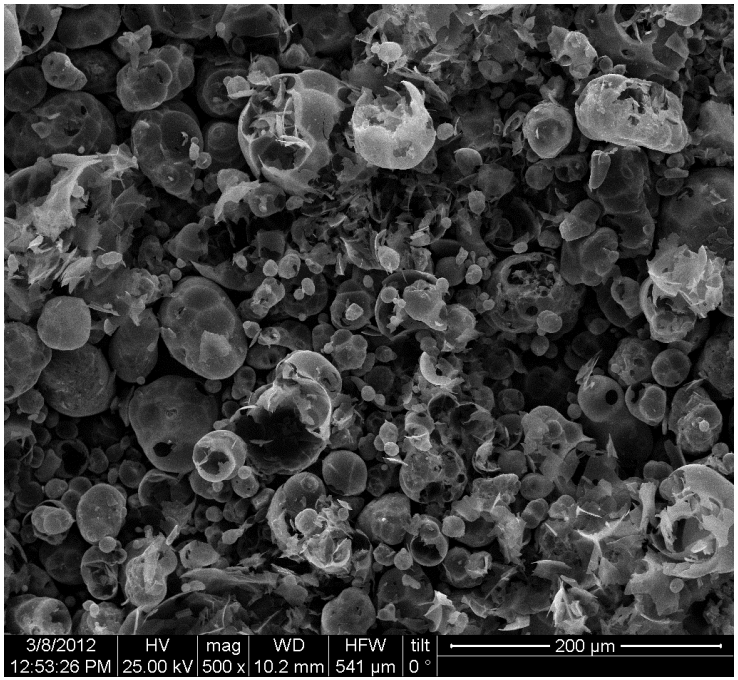


Photo catalytic finish

Expanded Perlite Variations SEM pictures

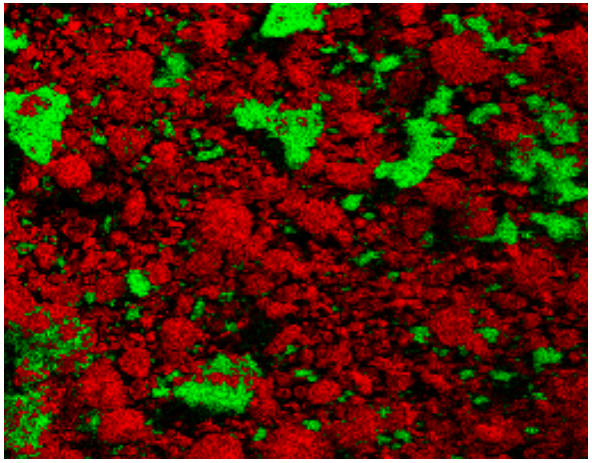


conventionally expanded perlite

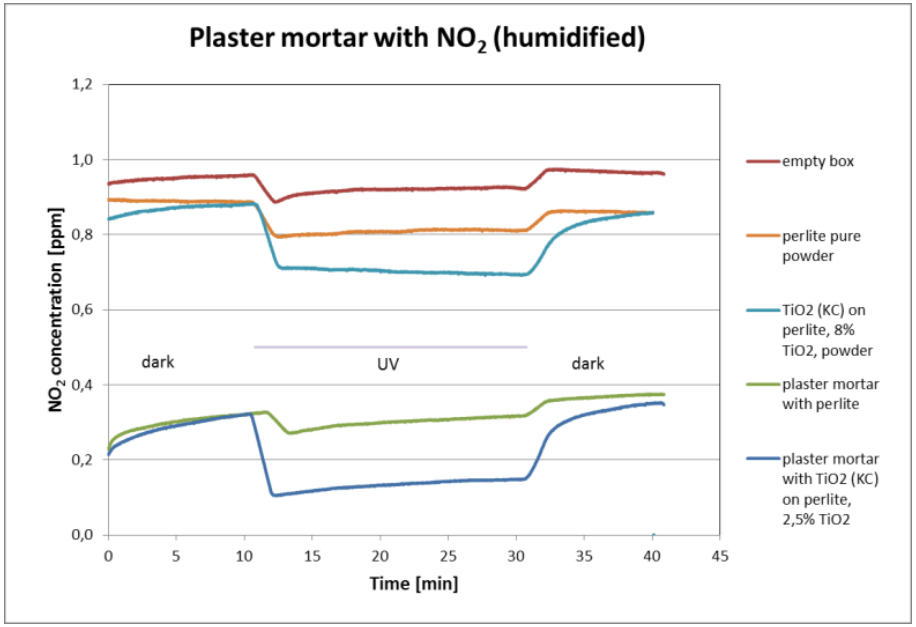


expanded perlite µ-spheres

Photo catalytic finish



Expanded perlite µ-spheres with TiO_2; deposition route via Ti-Isopropoxide



Results with VOC-Overflow

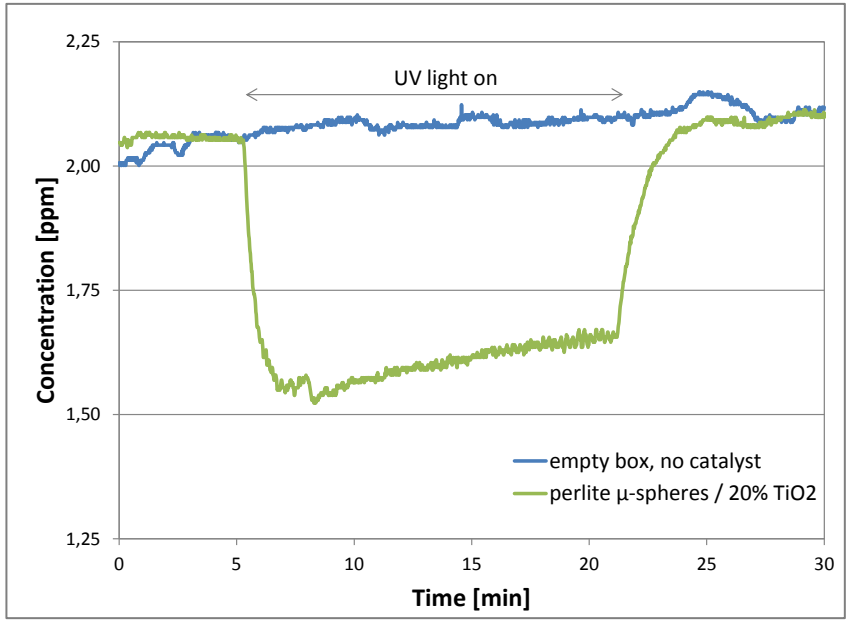


Photo catalytic powder sample

Conclusions

- Monitoring
  - Monitoring platform open for advanced sensors (CO_2, thermal comfort, light, climate, etc.)
  - VOC sensors available (< 5 ppm detection limit)
  - TVOC in ppb range
- Active control and modelling
  - Intelligent control platforms and methodologies developed and tested
  - Plant based Air Biofilter demonstrated
  - Modelling of complex office situations with sources and sinks available
- Passive systems
  - Mineral thermal insulation and thermal storage plaster (PCM)
  - Photo catalytic finish

Acknowledgement

The CETIEB project is supported by the European Commission under the 7th Framework Programme, Grant Agreement No. 285623.

Thank you for your attention!