



Low-cost sensors

*Claudio Belis, Laurent Spinelle and Michel Gerboles
European Commission Joint Research Centre, Ispra, Italy
Unit Air and Climate*

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Online

Joint
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RoadMap



- 1- What is a gaseous sensor?**
- 2- Different technologies...**
- 3- One main obstacle !!!**
- 4- Sensors based applications**



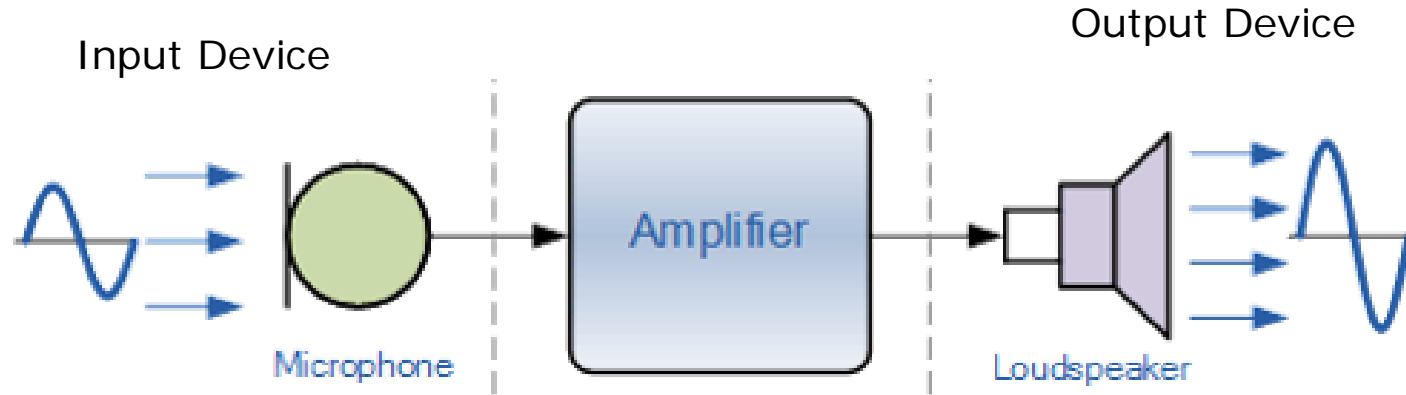
1- What is a gaseous sensor?

2- Different technologies...

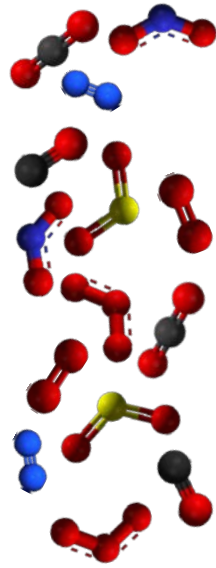
3- One main obstacle !!!

4- Sensors based applications

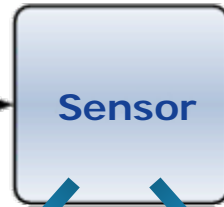
1- What is a gaseous sensor?



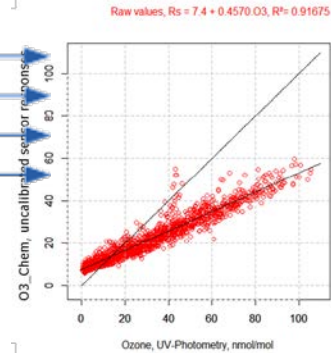
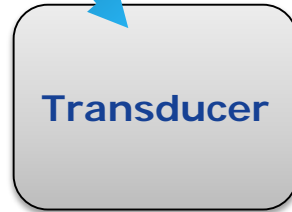
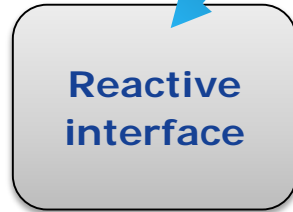
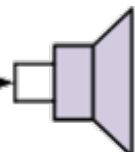
1- What is a gaseous sensor?



Input Device



Output Device



RoadMap



1- What is a gaseous sensor?

2- Different technologies...

3- One main obstacle !!!

4- Sensors based applications

2- Different technologies...



Main types:

- Metal oxide sensors (MOx) = variable resistor
- Electrochemical sensors: amperometric or potentiometric

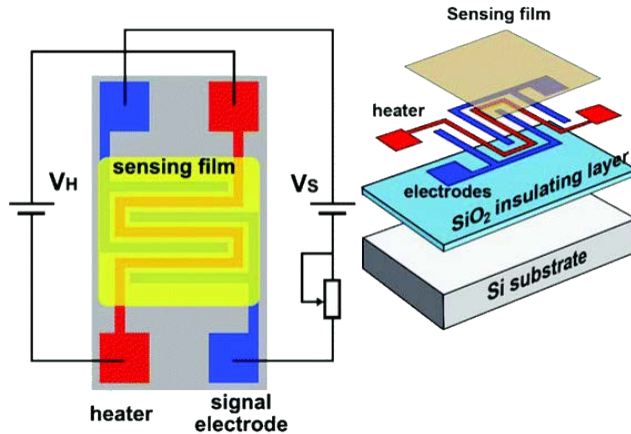
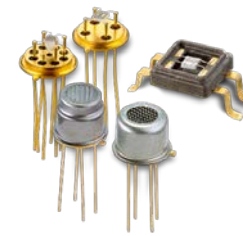
More specific:

- Photo Ionization Detectors (PID)
- Electronic nose and sensors arrays
- Optical particle counter

Characteristics:

Sensitivity	Response time
Selectivity	Recovery time
Stability	Hysteresis
Limit of detection	Life cycle
Resolution	Working temperature (Mox)
Linearity	

2- Different technologies: -> Resistive sensors



- Metal oxide layer act as a variable resistor
- Most used MOx : SnO₂ (wide reactivity and strong changes on resistance)

+ Lower cost: around 10 ~ 15 €
+ Range of concentration: from ppm to ppb
+ Affected by temperature and relative humidity variation

- Slow response time
- Not selective: react to nearly any reducing, oxidizing, toxic gases or volatile organic compounds (VOC)
- Concentration hysteresis

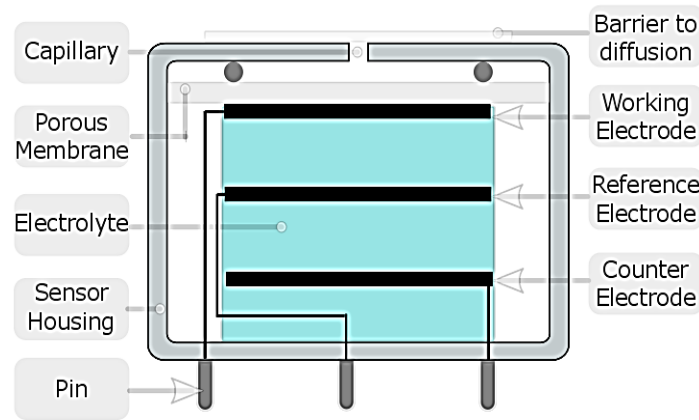
2- Different technologies: -> Electrochemical sensors



RedOX reaction of gaseous molecules at the sensor working electrode generates current which is measured.

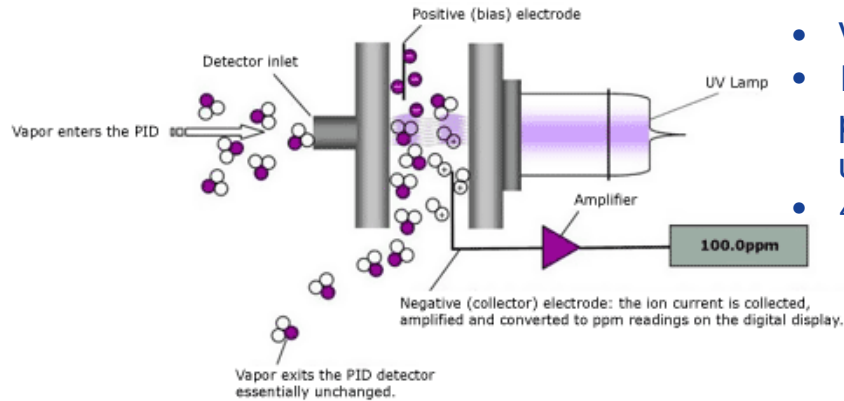
- + Medium cost: around 50 ~ 180 €
- + Range of concentration: from ppm to ppb
- + Fast response time
- + Low detection limits

- Highly affected by temperature and relative humidity variation
- Partial Selectivity: cross-reactivity within the same type of molecule
- Sensitive to meteorological effect: temperature, humidity



2- Different technologies:

-> Photo Ionization Detector

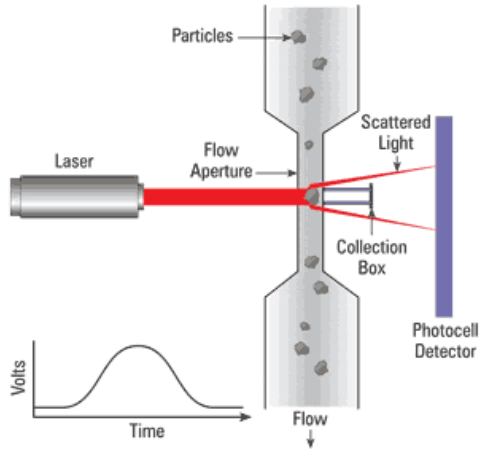


- VOCs measurements
- Ion detection of high-energy photons, typically in the ultraviolet (UV) range
- 4 main PID lamp used:
 - Xenon = 9.6 eV
 - Deuterium = 10.2 eV
 - **Krypton = 10.6 eV**
 - Argon = 11.7 eV

- + Small temperature and humidity dependence
- + Fast response time
- + High sensitivity

- Range of concentration: down to ppm, few down to ppb
- Linearity deviations between high and low concentration
- ***Not selective: react to nearly any volatile organic compounds (VOC) with ionization potential lower than lamp energy***
- Important short term drift, need re-calibration adjustment

2- Different technologies: -> Optical particle counter



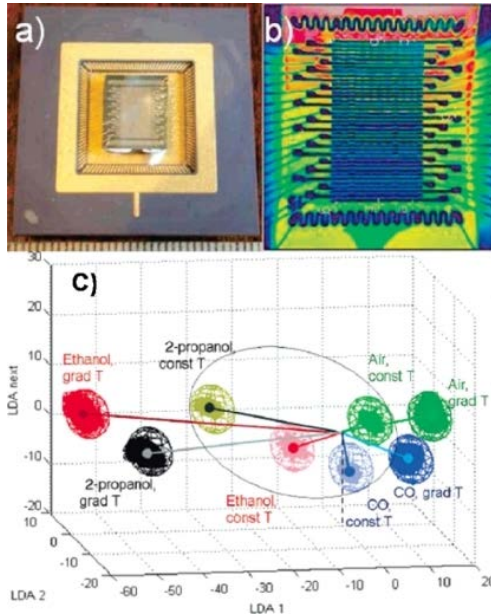
- Particle size counting
- Laser diode as the light source
- Laser light is scattered by particles



- + Fast response time
- + Sensitivity in the range of $1 \mu\text{g}/\text{m}^3$
- + Can derive the size of the particle (PM10, PM2.5,..)
- Converts from particle counts to PM mass using statistical coefficients
- The light scattering depends on unknown and uncontrolled parameters such as particle shape, colour and density, humidity,..

2- Different technologies...

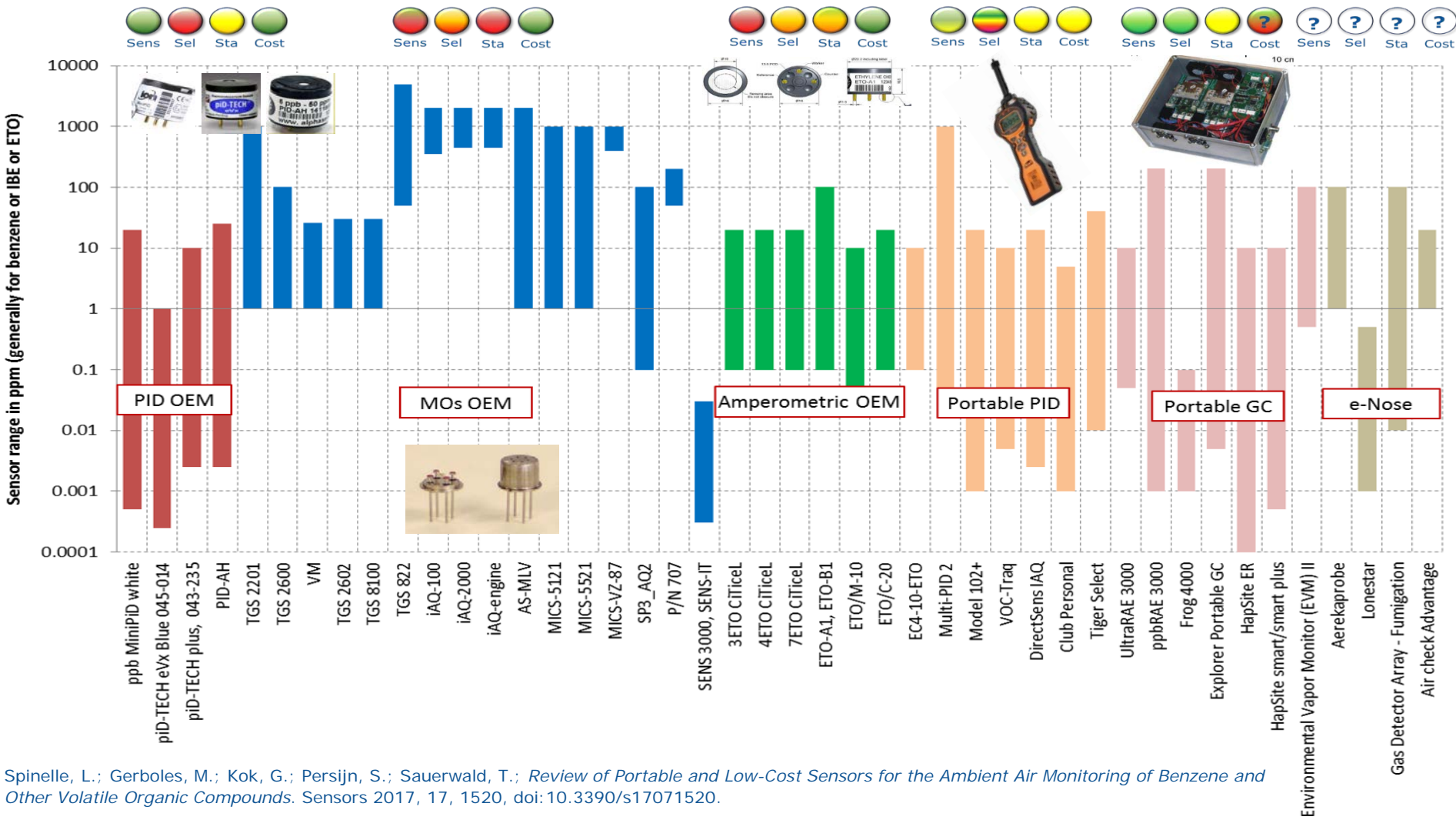
-> Electronic nose/sensors arrays



- Arrays of several simple sensors of different type
- Smart pattern recognition (neural networks)

+ Highly improved sensitivity

- Need an exhaustive calibration set of compounds
- High cost



Spinelle, L.; Gerboles, M.; Kok, G.; Persijn, S.; Sauerwald, T.; *Review of Portable and Low-Cost Sensors for the Ambient Air Monitoring of Benzene and Other Volatile Organic Compounds*. *Sensors* 2017, 17, 1520, doi:10.3390/s17071520.

RoadMap



- 1- What is a gaseous sensor?
- 2- Different technologies...
- 3- One main obstacle !!!**
- 4- Sensors based applications

3- One main obstacle !!!

-> Calibration

Linear regression and multilinear regression

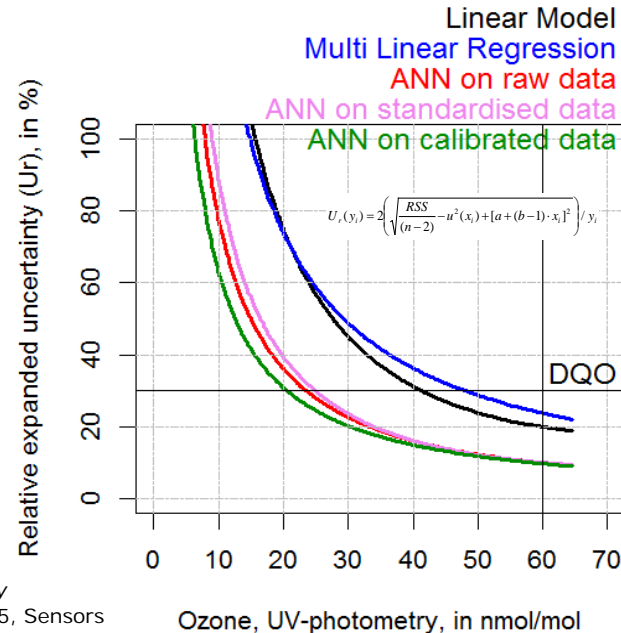
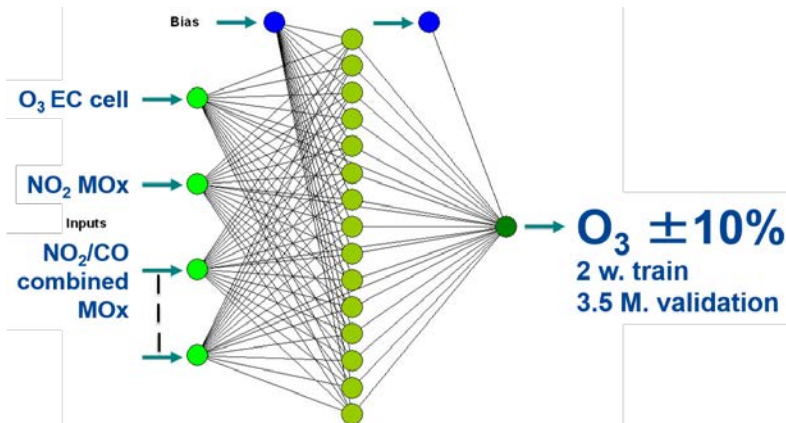
Linear regression

- ≠ sensors
- depend on the exposure conditions
- include all interfering effects

Multilinear regression based on laboratory experiments

- improve the quality of the data
- needs other variables (gaseous compounds, temperature, humidity...)

Artificial Neural Network



Field calibration of a cluster of low-cost available sensors for air quality monitoring. Part A: Ozone and nitrogen dioxide, Spinelle L. et al., 2015, Sensors and Actuators B: Chemical, 2015, 215, p. 249-257

RoadMap



- 1- What is a gaseous sensor?
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- 4- **Sensors based applications**

4- Sensors based activities.

-> Low cost monitoring station

Fixed monitoring station



Unitec srl, ETL3000
multi sensor station



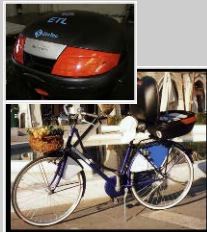
Aeroqual, AQM 60
Air Quality station



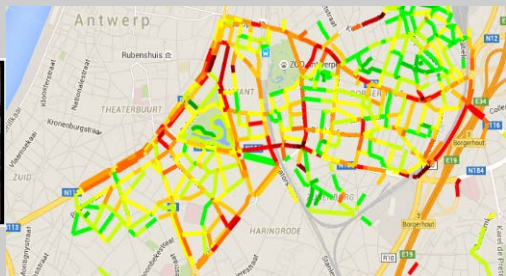
AQMesh

- Multi-component ambient air quality monitoring:
 - NO, NO₂, O₃, CO, SO₂
 - Optical particle counter
- MOx/Electrochemical Sensors
- 15' or hourly averages
- Built-in data logger
- GSM data transfer to Server in charge of data treatment (black-box)

Sensors on bike for road profiles

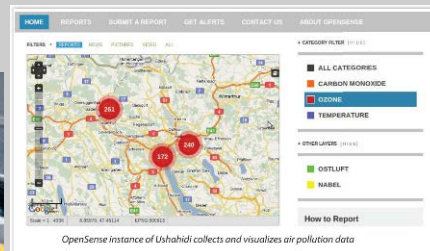
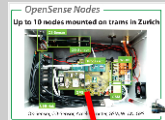


Unitec srl
ETLbike



AIR MAP, Antwerpen - BC
<http://www.airqmap.com/cityGuards.html>

Sensors on bus for real time



OpenSense (ETH-CH)
<http://www.opensense.ethz.ch>

4- Sensors based activities.

-> Personal exposure monitoring

Common sense, INTEL Lab, Berkley - USA



COPE: Characterisation of Chronic Obstructive Pulmonary Disease Exacerbations using Environmental Exposure Modelling, King's College London, UK



Linking e-health records, patient-reported symptoms and environmental exposure data to characterise and model COPD exacerbations: protocol for the COPE study, Moore L. et al., 2016, BMJ Open, 2016

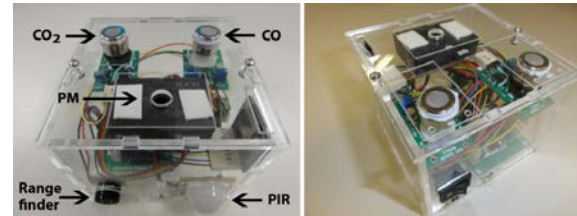
CITY-SENSE: Development of sensor-based Citizens' Observatory Community, NILU, NO

- Little Environmental Observatory (LEO)
- CITI-SENSE Citizens' Observatories Toolbox



<http://co.citi-sense.eu>

PACMAN: Particles, Activity and Context Monitoring Autonomous Node, NIWA,



<https://www.niwa.co.nz/atmosphere/research-projects/pacman>

4- Sensors based activities.

-> Open source platforms

Waspnote with Sensor board, Libellium, SP

<http://www.libellium.com/products/waspnote/>



Smart citizen kit, Fab Lab Barcelona at the Institute for Advanced Architecture of Catalonia, SP

<https://smartcitizen.me/>

- 4 Collaborators
- 9 Partners
- 2 Community Founding
 - Goteo 2012
 - Kickstarter 2013



AirQualityEgg, New York, USA

- Kickstarter Founding 2012

<http://airqualityegg.com/>



AirSensEUR: An open platform for air quality monitoring, JRC, EC

- Collaboration between the Air and Climate (C05) and Digital Economy (B06) Units



European
Commission

Thank you and keep in touch




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