

Webinar – IAQ sensors for smart ventilation of buildings

Peter Wouters – Operating Agent AIVC

Tuesday 6 March 2018



The screenshot shows the AIVC website homepage. At the top, there is a navigation bar with the AIVC logo and the text 'Air Infiltration and Ventilation Centre'. Below this is a search bar and a 'Search' button. The main content area is divided into several sections: 'Recent News', 'Highlighted News', 'Top events', and 'AIRBASE'. The 'Highlighted News' section features three items: 'AIVC 2018 Conference - Abstract submission...', 'Register now for the AIVC webinar on smart...', and '23 Mar-18 - AIVC Workshop "Ventilation for...'. The 'Top events' section lists three events: '6 March 2018, Webinar – IAQ sensors for smart ventilation of buildings', '19-20 March 2018, Workshop, Wellington (NZ) - Towards higher-performing buildings: The role of airtightness...', and '18-19 September 2018, Conference, Juan-les-Pins, 39th AIVC conference'. The 'AIRBASE' section provides a link to search in a database of 22279 publications with 15778 pdf documents. On the right side, there is a 'Did you know?' section with a red-bordered box containing the text 'AIVC is the information centre of the International Energy Agency on energy efficient ventilation'. The bottom of the page features social media icons for LinkedIn, Twitter, YouTube, and Facebook.

EBC Energy in Buildings and Communities Programme

AIVC Air Infiltration and Ventilation Centre

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Airbase | AIVC Newsletters | AIVC Publications | AIVC Events

Recent News

AIRBASE Click here for searching in a database of 22279 publications with 15778 pdf documents

Did you know?

AIVC is the information centre of the International Energy Agency on energy efficient ventilation

Highlighted News

- AIVC 2018 Conference - Abstract submission...**
New deadline is 20 March, 2018
> 02 March 2018 **MORE**
- Register now for the AIVC webinar on smart...**
6-March-2018, 15:00-16:30 (CET)
> 01 February 2018 **MORE**
- 23 Mar-18 - AIVC Workshop "Ventilation for..."**
Sydney, Australia
> 15 January 2018 **MORE**

Top events

- 6 March 2018, Webinar – IAQ sensors for smart ventilation of buildings**
AIVC defines smart ventilation as a process to continually adjust the ventilation system of a building in order to provide the desired Indoor Air Quality (IAQ) benefits while minimizing energy consumption, u
MORE
- 19-20 March 2018, Workshop, Wellington (NZ) - Towards higher-performing buildings: The role of airtightness...**
The objective of this AIVC workshop is to discuss and identify ways to improve the quality of our homes with respect to airtightness and ventilation, as well as discussing the impact suboptimal performance h
MORE
- 18-19 September 2018, Conference, Juan-les-Pins, 39th AIVC conference**
The 39th AIVC conference: "Smart ventilation for buildings" will be held on 18 and 19 September 2018 in Juan-les-Pins, France
MORE

VIP 37: Impact of Energy Policies on...
This Ventilation Information Paper analyses both the policy instruments used (...
> Valérie Leprince, Maria Kapsalaki, Rémi Carrié, EU
MORE

VIP 36: Metrics of Health Risks from...
In a recent review of 31 green building certification schemes used around the...



Welcome to the International Energy Agency's Energy in Buildings and Communities Programme

The IEA-EBC Programme is an international energy research and innovation programme in the buildings and communities field. It enables collaborative R&D projects among its 24 member countries. We provide:

- High quality scientific reports
- Summary information for policy makers

High Priority Research Themes

1. Integrated planning and building design
2. Building energy systems
3. Building envelope
4. Community scale methods
5. Real building energy use

www.iea-ebc.org



ANNUAL REPORT

The Annual Report provides an overview of progress made by the EBC Programme, including summaries of new, ongoing and recently completed projects.

PDF (14.3 MB)

CONTACT

EBC Secretariat (ESSU)

Mr. Malcolm Orme
+44 (0)121 262 1920
Email

AIVC is the information centre of the International Energy Agency on energy efficient ventilation

LATEST NEWS

SSB 2018

The 10th International Conference on System Simulation in Buildings will be held in Liège, Belgium, between 10th - 12th December 2018.

AIVC Annual Conference

The 39th AIVC Annual Conference will be held in Juan-les-Pins, France, between 18th - 19th September 2018.

QUEST2017 - Smart Energy Communities on the Hill

The November 2017 EBC Meeting was held in conjunction with the QUEST2017



AIVC Member countries

- Belgium
- China
- Denmark
- France
- Germany
- Italy
- Japan
- Korea
- Netherlands
- New Zealand
- Norway
- Spain
- Sweden
- United Kingdom
- United States

→ Interest from several other countries



More focusing on knowledge generation aspects



BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM



More focusing on market implementation



Towards better quality and compliance



the international platform for ventilative cooling

IEQ Global Alliance

For better indoor environment quality



HOME ADVOCACY EVENTS RESEARCH ABOUT CONTACT

Search Site



Mission of the IEQ Global Alliance

The mission of IEQ-GA is to provide an acceptable indoor environmental quality (thermal environment-indoor air quality-lighting-acoustic) to occupants in buildings and places of work around the world and to make sure the knowledge from research on IEQ get to be implemented in practice. >> Read more...

Keynote speakers at the 38th AIVC – 4th venticool – 6th TightVent joint conference



The keynote speakers for the 38th AIVC – 6th TightVent – 4th venticool conference: "Ventilating healthy low-energy buildings" have been announced. The joint conference, co-organized by the International Network on Ventilation and Energy Performance (INVE), on behalf of the AIVC ...

Continue reading →

User's Manual for 2016 IAQ Standard Published by ASHRAE



ATLANTA – A manual to help users navigate the changes in ASHRAE's 2016 ventilation standard is now available. The User's Manual for ANSI/ASHRAE Standard 62.1-2016, Ventilation for Acceptable Indoor Air Quality, provides information on the requirements of the standard and ...

Continue reading →

REHVA Journal issue 6 / December 2016



The REHVA Journal December issue on EPB Standards Published for Formal Vote & Energy Efficient Renovations is now available online @ www.rehva.eu

AIVC Newsletter



Foreword

The members of the Air Infiltration and Ventilation Centre (AIVC) are pleased to inform you and to the dissemination of the research projects in the field of air infiltration and ventilation. These projects have just been reviewed for the 2017-2020 operating period at our first board meeting. AQI, IEQ-GA, and other research, will be reviewed during a performance of the 'technical center' board, and the research are no longer addressed in these projects.

The members give you a series of our latest achievements and in return, we encourage you to visit our website and to use our newsletter and to help us find out more and of course to make your opinion for the upcoming 2018-2021 AIVC Conference on 13-14 September 2017, in Nottingham, UK, with which you present 'making a look forward to seeing you in our future meeting'.

From November, Operating Agents & V...



no 11
March 2017

13-14 September 2017 - 38th AIVC Conference in Nottingham, UK

The 38th AIVC, both 14th and 4th International Conference on Air Infiltration and Ventilation, will be held on 13 and 14 September 2017 in Nottingham, UK. The event will focus on:

- the state of the art in the field of air infiltration and ventilation
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The conference will consist of a series of workshops, a keynote conference, a plenary session, a series of presentations and a series of presentations.

The conference is organized by the International Network for Information and Research on Air Infiltration and Ventilation (INIVE).

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In this issue

13-14 September 2017 - 38th AIVC & 5th International Conference on Air Infiltration and Ventilation, Nottingham, UK

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<http://subscriptions.inive.org/>

Energy Efficiency and Indoor Climate in Buildings

... with specific information on AIVC, IEQ-GA and the platforms QUALICheck, Dynastee, venticool and TightVent

News.inive.org



Workshop details



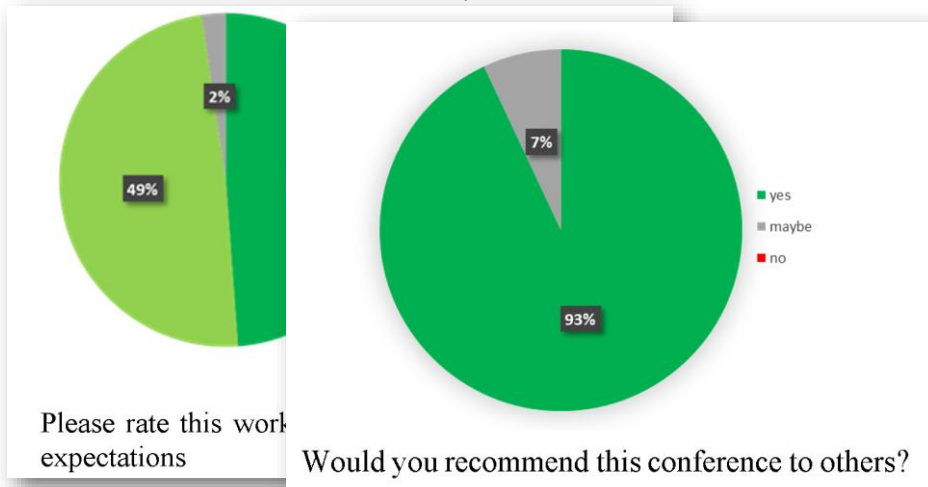
14-15 March 2017, Workshop, Brussels - Is ventilation the answer to indoor air quality control in buildings? Do we need performance-based approaches?

Brussels, Belgium 03/14/2017 - 09:15

Indoor exposure to contaminants should be minimized to avoid adverse health and comfort effects. Experience shows that this qualitative statement is difficult to translate into measurable terms, such as performance indicators or metrics, which can be used as a basis for defining and assessing requirements in regulations and standards while holistically reflecting indoor air quality. The simplest and most commonly used approaches rely on ventilation airflow rates determined by experts or codes. These approaches have fundamental shortcomings in practice for systems that do not have steady contaminant sources or do not provide a constant airflow rate, such as natural, hybrid, or demand-controlled ventilation. More sophisticated approaches can be based on health damage, pollutant exposures, or perceived air quality but they generally entail a number of assumptions about the pollutants of concern and occupant scenarios. Such methods could lead to useful metrics. However, as of today, there is no clear set of metrics that can be used to assess the overall ventilation performance of a building with regard to its indoor air quality, or used in standards or regulations.

This workshop aims to identify the pros and cons of performance-based approaches and metrics that can be considered to assess the IAQ performance of ventilation systems, as well as to draft guidelines for their use in standards and regulations.

Brussels March 2017 workshop on IAQ metrics



ABOUT - SUBMISSIONS - REGISTRATION - PROGRAMME - COMMITTEES - VENUE - ACCOMMODATION & TRAVEL - SPONSORSHIP - GALLERY - CONTACT

AIVC 2017

38th AIVC - 6th TightVent & 4th venticool Conference, 2017
 Ventilating healthy low-energy buildings
 13-14 September 2017, University Of Nottingham, Nottingham, UK

95 14 45 22
DAYS HOURS MINUTES SECONDS

The University of Nottingham
 UNITED KINGDOM · CHINA · MALAYSIA

Ventilating healthy low-energy buildings

ABOUT - SUBMISSIONS - REGISTRATION - COMMITTEES - VENUE - ACCOMMODATION & TRAVEL -

DEADLINE FOR ABSTRACTS: MARCH 20

AIVC 2018

39th AIVC - 7th TightVent & 5th venticool Conference
 Smart ventilation for buildings
 18-19 September 2018, Antibes Juan-Les-Pins Conference Centre,
 Antibes Juan-Les-Pins, France

195 17 36 34
DAYS HOURS MINUTES SECONDS

Smart ventilation for buildings

Topical sessions at 2018 conference ...

1. IAQ metrics
2. **Smart ventilation control**
3. **Sensors for smart ventilation**
4. Rationale behind ventilation requirements and regulations
5. Utilization of heat recovery
6. Integrating uncertainties due to wind and stack effect in declared airtightness results
7. Ductwork airtightness
8. Residential cooker hoods
9. French initiatives for indoor air quality
10. **Demand controlled ventilation in French buildings – 35 years of wide scale experience**
11. Commissioning of ventilation systems – Improving quality of installed ventilation systems
12. Measurement Accuracy of air flow and pressure difference
13. Air cleaning as supplement for ventilation
14. New annex on resilient cooling
15. BIM and Construction 4.0 opportunities in relation to ventilation and airtightness

Workshops in Wellington and Sydney



19-20 March 2018, Workshop, Wellington (NZ) Towards higher-performing buildings: The role of airtightness and ventilation

Wellington, New Zealand 03/19/2018 - 08:00



23 March 2018 Workshop Sydney (Australia) – Ventilation for IAQ and cooling



Energy in Buildings and
Communities Programme

www.iea-ebc.org

Invitation to IEA EBC Annex Definition Workshop on
Resilient Cooling
for Residential and Small Office Buildings

The workshop will be held on Friday, **27th April 2018**, 10:00 to
17:00 at Vienna International Airport, Office Park 1.

Revision of Energy Performance of Buildings Directive

New aspect:

“Smart Readiness Indicator”

Aspects which can be included:

- Energy efficiency improvement
- Indoor climate control
- Smart grid
- ...



**Ventilation
Information
Paper
n° 38**

March 2018

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International Energy Agency
Energy Conservation in Buildings
and Community Systems Programme



Air Infiltration and Ventilation Centre

What is smart ventilation?

François Durier, CETIAT, France
Rémi Carrié, ICEE, France
Max Sherman, LBNL, USA

Agenda of today...

• Introduction

- *Peter Wouters (AIVC, Belgium)*

Now the 2 key presentations which **focus on two emerging technologies: particulate and VOC sensors:**

Evaluating particulate sensors for IAQ controls

- *Iain Walker (LBNL, USA)*

Assessment of low-cost particulate and VOC sensors

- *Laure Mouradian (CETIAT, France)*

Evaluating Particle Sensors for IAQ Controls

Iain Walker

Lawrence Berkeley National Laboratory

AIVC Webinar, March 6th 2018



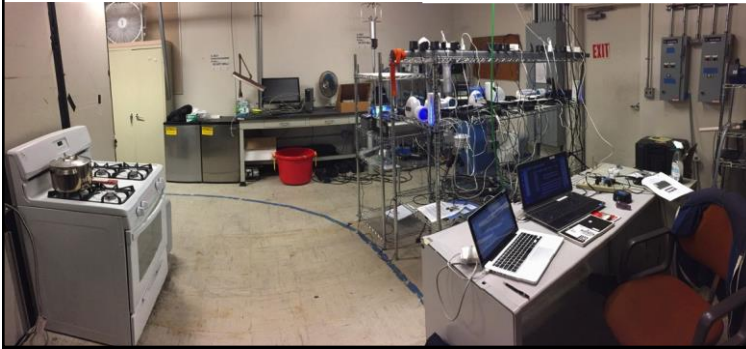
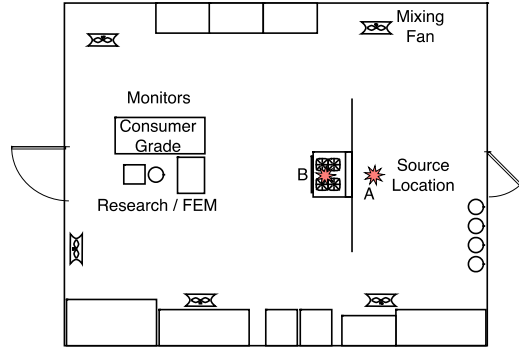
Sensing for control

- **Sensors** packaged into IAQ **monitors** with power supply, display, internet connectivity (cloud storage)
 - Typically sensing: T, RH, PM, CO₂, VOCs
 - **Monitor** 250 USD/200 EUR
- **Sensor** 30 USD/25 EUR – light scattering (0.3 micron low limit)
- Current focus on particles – compare to reference & research grade monitors
 - Event detection
 - Is magnitude correct?
 - Impact of size distribution? What sizes are monitors sensitive to vs. what are sizes created by indoor events
 - Good enough for on/off decision for ventilation/filtration control?

Testing

Compare low-cost monitors to research and reference systems

Controlled testing in Lab
Extra tests in home



Particle Sources

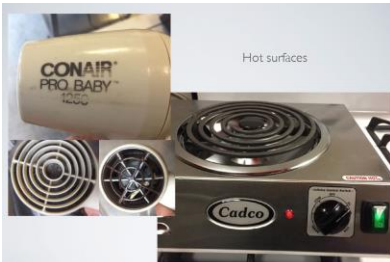
General particles

Road dust, carpet, dust mop, and humidifier



Hot surfaces

Hair dryer, and electric burners



Cleaning products + ozone



Particle Sources

Combustion

Gas burners, incense, candles, and cigarettes



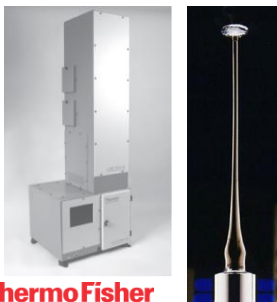
Cooking

Stir fry, pancakes, bacon, heated oil, boiled water, toast, and frozen pizza



Reference Instruments ~ \$35,000

Thermo-Scientific TEOM-1405DF

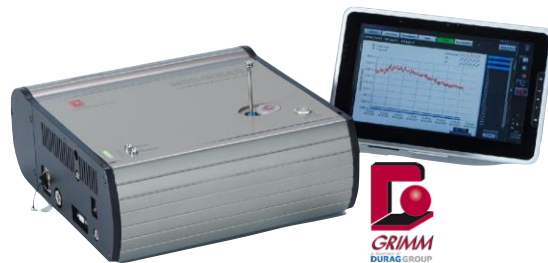


ThermoFisher
SCIENTIFIC

Direct Mass readings
PM_{2.5}, PM_{Coarse}

TEOM = Tapered Element Oscillating
Mass-Balance

Grimm miniWRAS



Aerosol Spectrometer
Particle size distribution in 41 channels from
10nm up to 35 μ m

Research Instruments ~ \$5,000-7,000



BT-645

 **Met One Instruments, Inc.**



ThermoFisher
SCIENTIFIC pDR-1500

Used as reference for in-home measurements

Low Cost IAQ Monitors ~ 250 USD/200 EUR

AirBeam



PM, T, RH
1 sec

AirVisual Node



PM2.5, PM10,
T, RH, CO2
10 sec- 15 min

AirQualityEgg V2



PM, T, RH
1 min

AWAIR



PM, T, RH,
CO2, VOC
10 sec-5 min

Foobot



PM, T, RH,
CO2, VOC
5 min

PurpleAir V2



PM1, PM2.5,
PM10, T, RH
80 sec

Speck V2



Count, PM, T,
RH
1 min

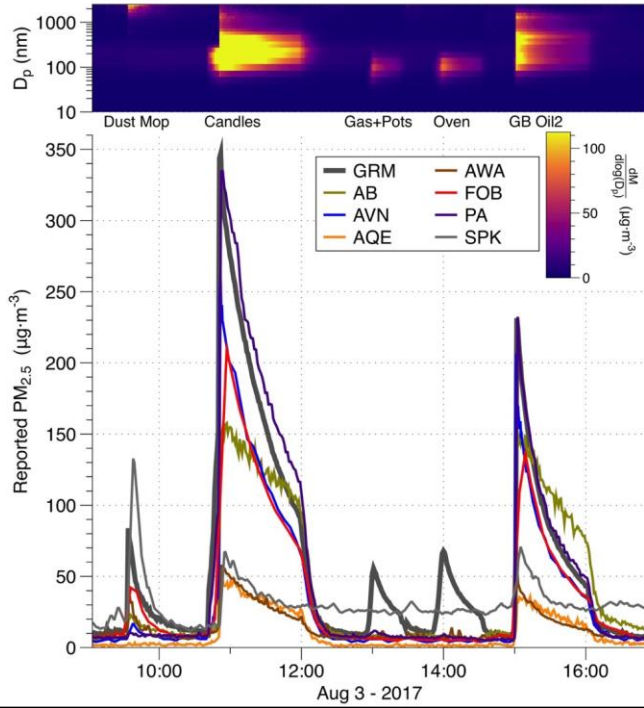
Event detection

- Some better than others

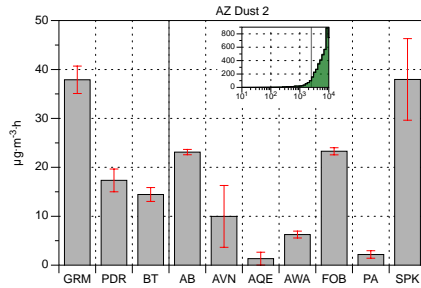
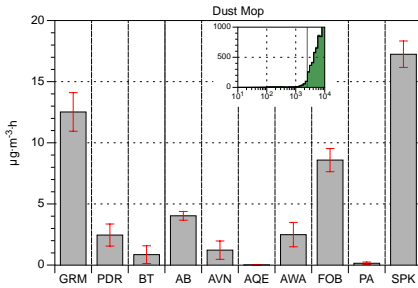
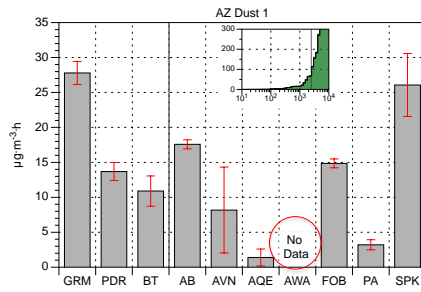
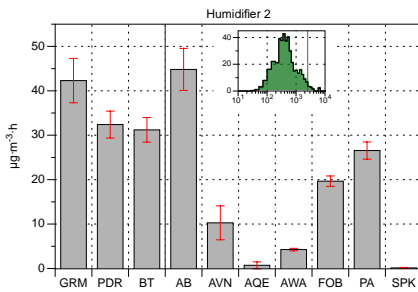
Magnitude

- Some better than others

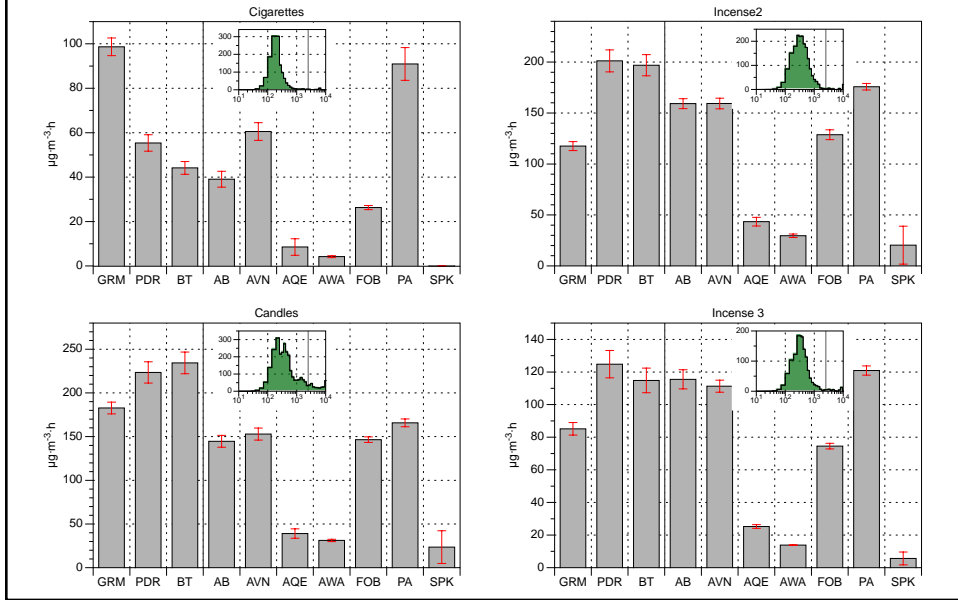
Depends on "event"
= depends on particle size distribution



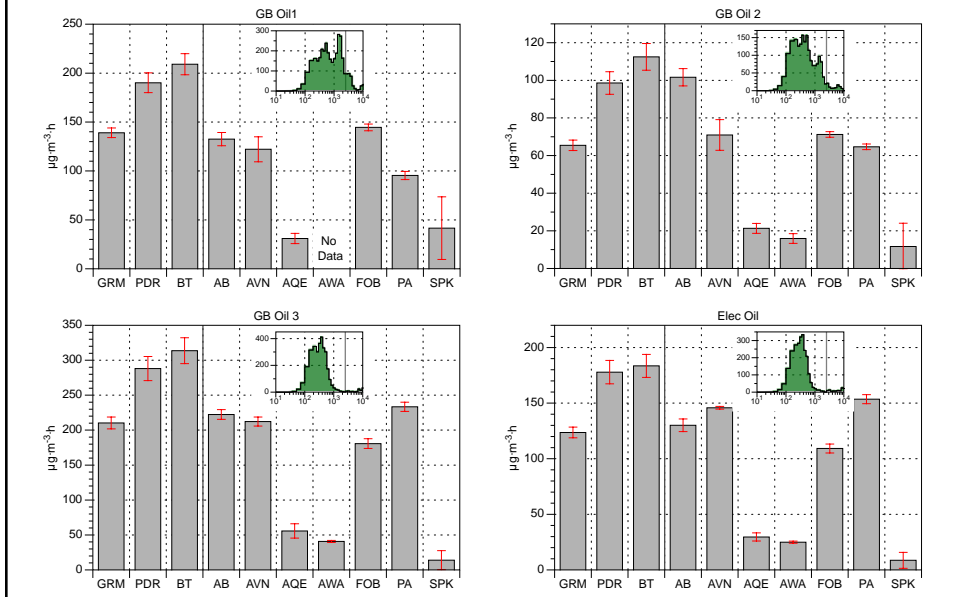
Humidifier and Dust



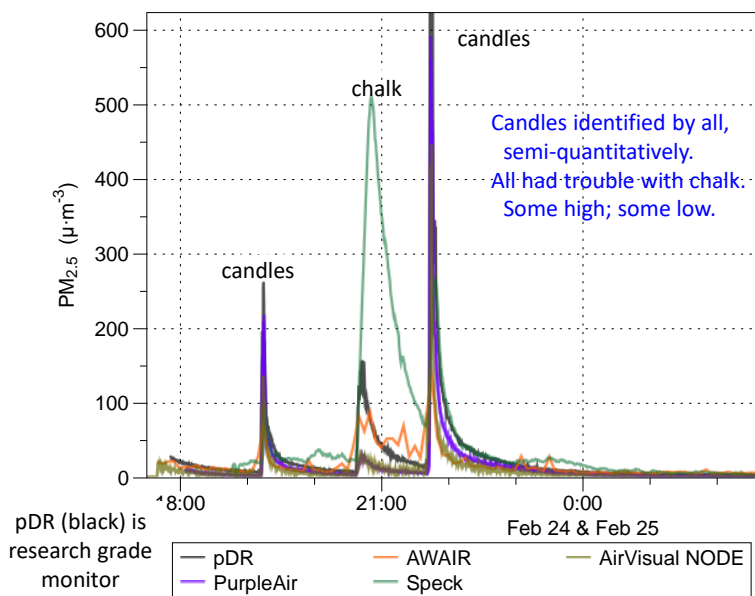
Recreational Combustion



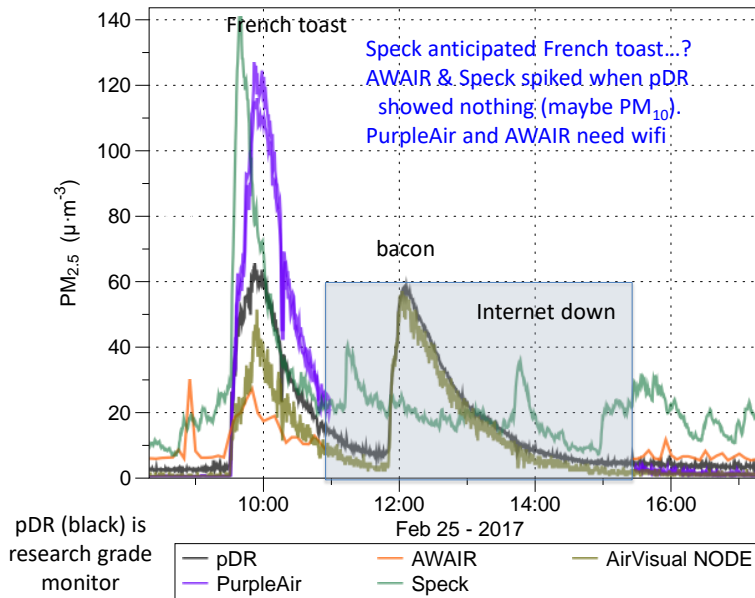
Heating Oil on Gas or Electric Burners



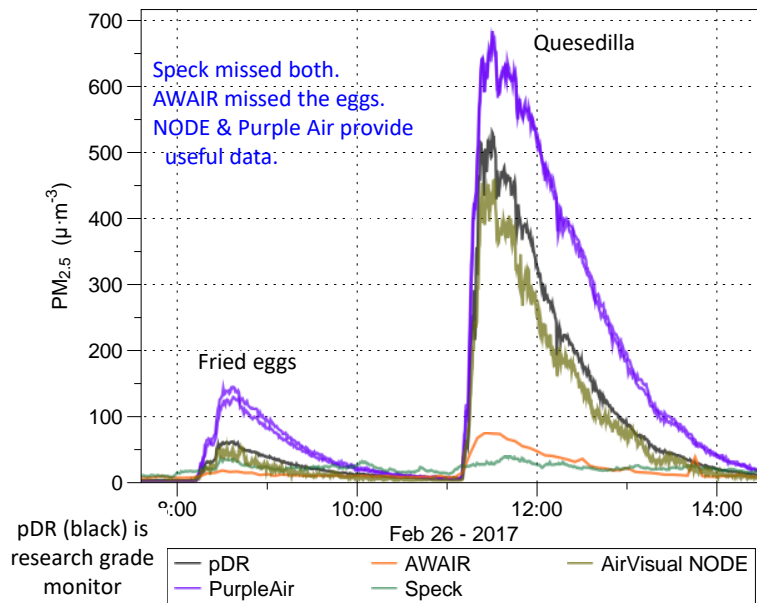
In-Home Test



In-Home Test



In-Home Test



Other Studies – Similar Results

- EPA has done some work focusing on outdoors
<https://www.epa.gov/air-sensor-toolbox>
- South Coast AQMD is working on outdoor and chamber tests
<http://www.aqmd.gov/aq-spec/home>
- Carnegie Mellon has done some work and developed the SPECK
<https://explorables.cmucreatelab.org/explorables/air-quality-monitor-tests/>
- Air quality in China
<http://aqicn.org/sensor/>



Are these monitors/sensors “good enough”?

Yes?

- Purple Air & Foobot: detected almost all sources and had enough magnitude for control

Maybe

- AirVisual & Air Beam & AWAIR: detected most sources

No

- Air Quality Egg & Speck not reliable enough
- Issues are particle size sensitivity and possibly composition
 - Nothing below 0.3 micrometers – problem for cooking!
- Need a standardized way to compare devices
- Need to check performance again after a couple of years

Connectivity

Almost all require an internet connection for cloud storage or data retrieval

- ALWAYS confirm upload otherwise data can be overwritten and lost

Almost all have an app for data viewing – particularly if they have no built-in display

Foobot & AWAIR already set up for IFTTT protocols for communicating with other devices: ifttt.com

Other devices would require custom applications to read cloud data

Build your own monitor (BYOM)

UPOD: Open source platform for mobile air quality monitoring

University of Colorado, Boulder

<http://mobilesensingtechnology.com/>

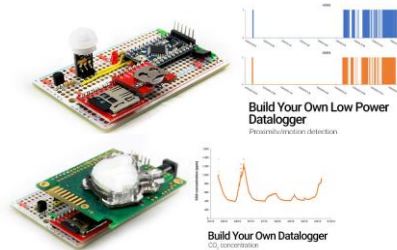
T, RH, PM, CO₂, O₃, NO₂; slots for 4 e2v MOx sensors

Open Source Building Science Sensors

Illinois Institute of Technology

<http://www.osbss.com/>

T, RH, CO₂, Particles,
 $\delta\epsilon\lambda\tau\alpha$ -P, equilibrium RH, light
state, proximity, occupancy



DIY / Maker offerings

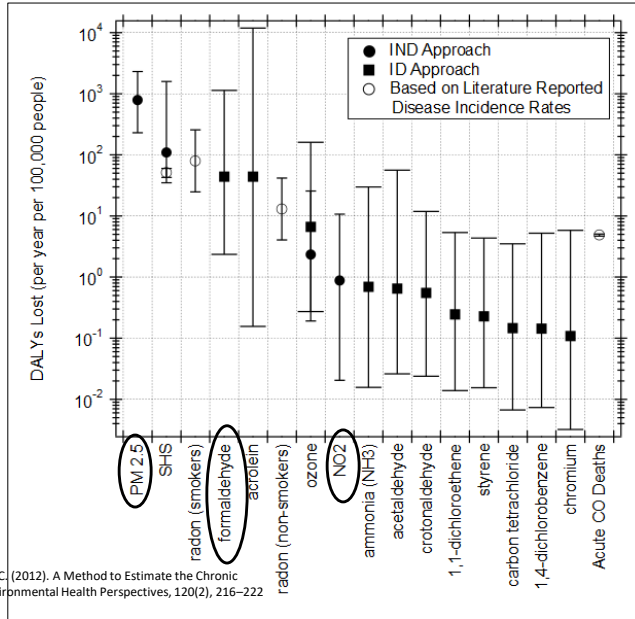
- Sensor + parts kit: using same sensor as monitors
- EPA kit for schools:
https://www3.epa.gov/airnow/teachers/gh_pmsc_parts_kit_box_doutandinstructions.pdf
- ~\$50/50 EUR



Why Particles?

We live in a complex soup of many agents - which ones have the biggest health impact?

Disability Adjusted Life Years: DALYs



Logue, J. M., Price, P. N., Sherman, M. H., & Singer, B. C. (2012). A Method to Estimate the Chronic Health Impact of Air Pollutants in U.S. Residences. *Environmental Health Perspectives*, 120(2), 216-222

6 March
2018

Assessment of low-cost particulate matter and VOC sensors

Laure MOURADIAN

Purpose of the study

Assessment of « new » IAQ sensors

- Low cost stand-alone sensors for consumers
- Compact and internet-connected
- Measuring :
 - Particulate matter
 - VOCs
- Assessment of sensitivity, response time
 - On site and in laboratory
 - Regarding the nature of pollutant

Sensors tested at CETIAT



AWAIR
PM, VOCs, CO₂



FOOBOT
PM, VOCs



LASER EGG
PM

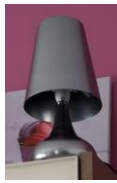


6 March 2018

SPECK
PM



AERECO
PM



UNI-T
PM, VOCs



Assessment of low-cost particulate matter and VOC sensors

3



Few / heterogeneous information on sensors characteristics

Information available on manufacturers' technical specifications for particles measurements

A	B	C	D	E	F
<ul style="list-style-type: none"> Sensitivity: 0,3 – 10 µm PM2.5, PM10 PM 2.5 ±10% Response time 10-100 ms 	<ul style="list-style-type: none"> Sensitivity: 0,3 - 2,5 µm ± 4 µg/m³ or ± 20 % Range: 0-1300 µg/m³ 	<ul style="list-style-type: none"> Resolution 1µg/m³ Range: 0-500 µg/m³ 	<ul style="list-style-type: none"> Range: 0-500 µg/m³ 	<ul style="list-style-type: none"> Sensitivity: 0,5 - 3 µm Count of particles : ppL Transposition n µg/m³ 	<ul style="list-style-type: none"> Count of particles /size PM2,5 PM10

Difficulty connecting sensors to the network or recovering data...

6 March 2018

Assessment of low-cost particulate matter and VOC sensors

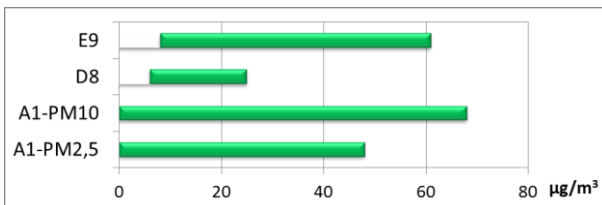
4



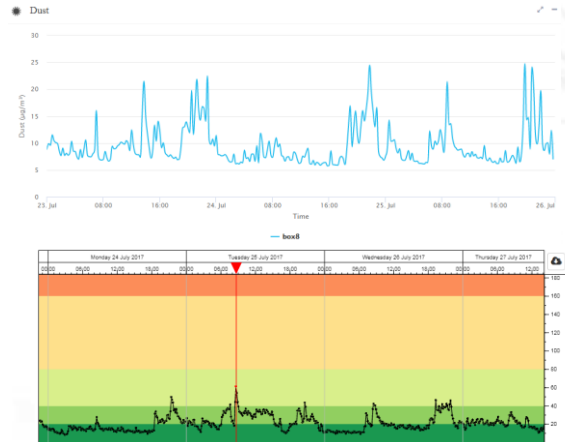
On-Site measurements

Sensors installed in a house, in the countryside

- Range of measured indoor particulate matter during 1 month



→ Disparity of values (Min – Max)



Tests at CETIAT

Testing room – 8 m³

- External supply fan + high efficiency filter
- Injection of pollutant + indoor comfort fan
- Sensors in central zone

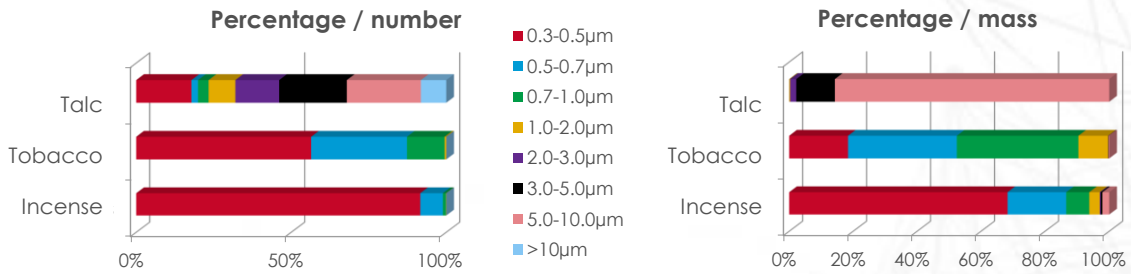
Reference measurement/particles:

- Counter of Particules (COP) TSI 3330
- 7 channels 0,3 to 10 µm
- Transition from number to µg/m³ by calculation + hypothesis on particles density (2.8)

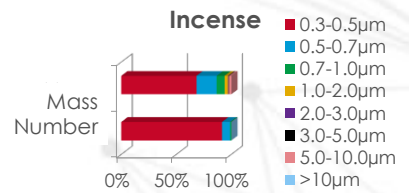
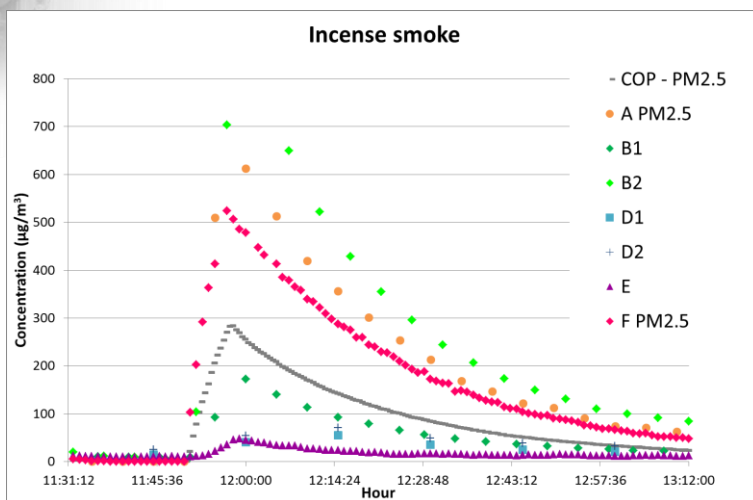


Particles generated

Talcum powder, tobacco smoke and incense smoke were injected in the test room



Sensor response to incense smoke



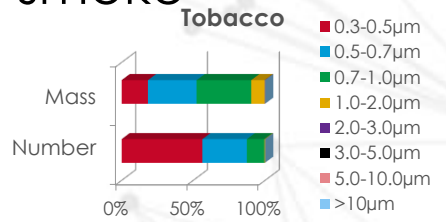
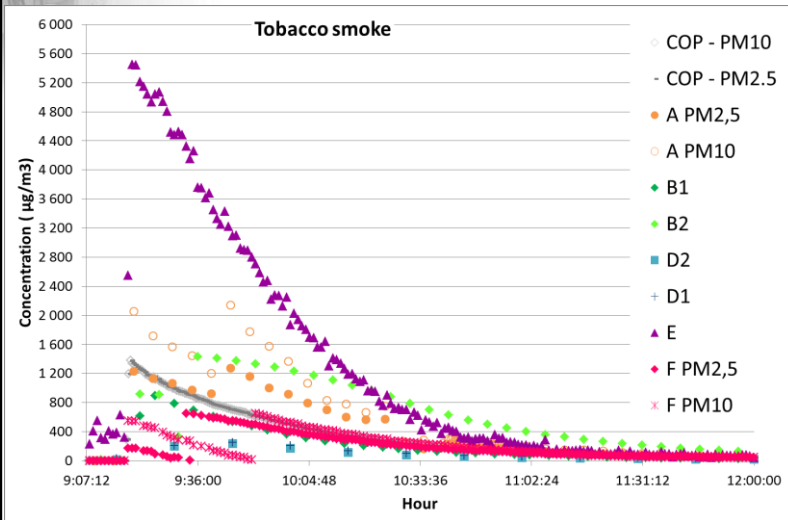
Incense smoke is mainly composed of very small particles

$$B_2 > A > F > B_1 > D_{1-2} > E$$

→ Differences due to:

- Sampling
- Average values
- Sensitivity

Sensor response to tobacco smoke

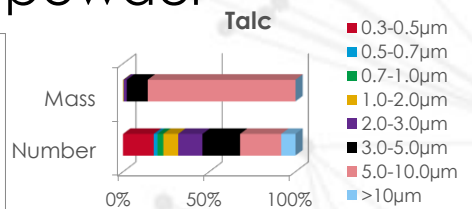
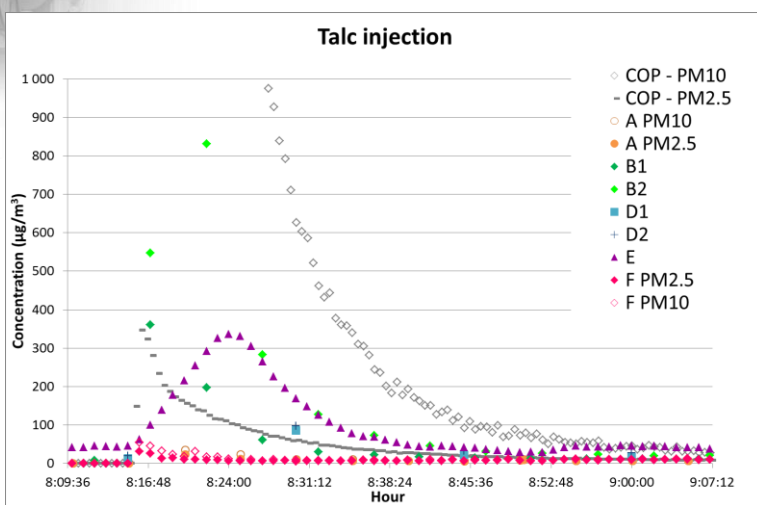


Tobacco smoke is mainly composed of fine particles

$$E > A_{PM10} > B_2 > A_{PM2.5} > F > B_2 > D_{1-2}$$

→ the orders of magnitude of the responses differ with another particle composition

Sensor response to talcum powder

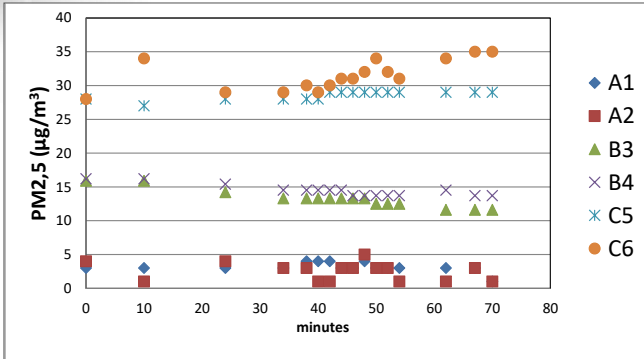


Talcum powder is heavier and deposits more quickly

$$B_1 > B_2 > E > D_{1-2} > A > F$$

→ Some sensors react very little to talcum dispersion

Measurement at low level of particles



Indoor concentration of PM2.5
No particle generation

Basic level : ~5 / 15 / 30 µg/m³

Disparity of values even with no particle generation

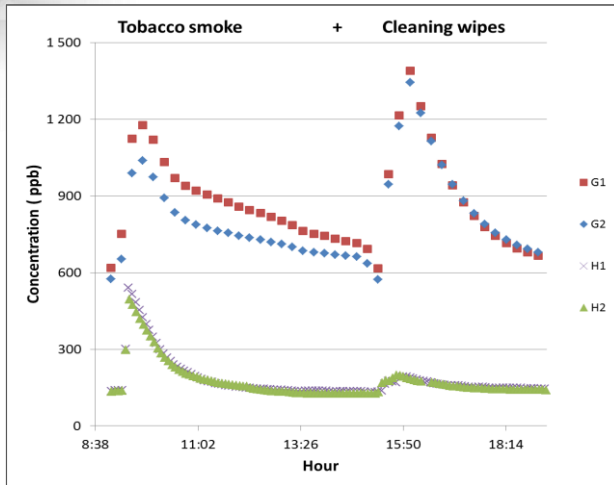
VOCs measurements

Information available on manufacturers' technical specifications for particles measurements

G	H	I
<ul style="list-style-type: none"> Sensitivity: hydrogen gas, hydrogen sulfide, ammonia, ethanol, toluene, and formaldehyde Value in ppb 	<ul style="list-style-type: none"> Sensitivity: Formaldehyde, iso-butane, toluene, methane, ammoniac, benzene, etc. (*) Range: 100-1000 ppb 	<ul style="list-style-type: none"> Range : 0-9,9 mg/m³ Resolution 1mg/m³

- 2 sensors give ppb values
- 1 sensor give mg/m³ value (which hypothesis for gas density ?)

Sensor response to VOCs

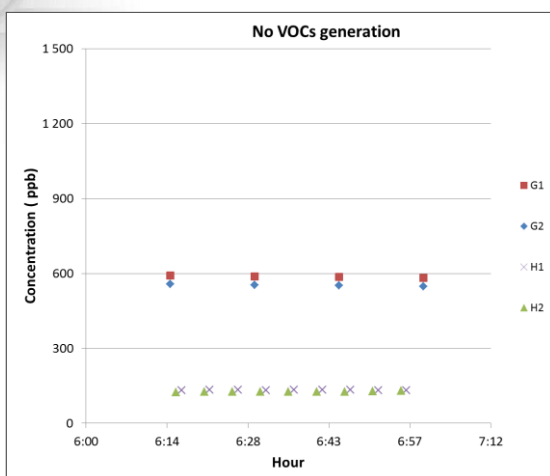


Comparison of two sensors
With two different sources of VOCs

→ Values differ between sensors G and H

→ the order of magnitude of the responses differ
Tobacco/cleaning wipes

Measurement at low level of VOCs



Indoor concentration of VOCs for 2 sensors in the CETIAT testing room

No VOCs generation

Basic level : 130 / 600 ppb

Disparity of values even with no VOCs generation

Conclusions

Measurement results

- High disparity between sensors
- Impact of data sampling and average
 - Time lag
 - Lower peak value
- Impact of the pollutant composition
 - Sensor responses are different / nature of pollutant
 - Particles: incense, tobacco, talc
 - VOCs : tobacco, incense, cleaning wipes
- Few informations available
 - Sensitivity /selectivity
 - Data processing
 - Ambient conditions influence

Assessment of IAQ Sensors

- Need to characterize the generated pollutant
 - Nature and Composition
 - Properties (density, ...)
- Periodic calibration is needed
 - Complex pollutant
 - Not only one gas for VOCs
 - Several Particles generations (fine, very small, ...)
 - On-site ?

Which use of « low-cost » sensors (PM · VOCs) ?

For individual use

- OK for information purposes only
- What is the influence of residents activities (cooking, cleaning, ...) on some IAQ metrics

Not ready for fine DCV use

- reliability of data and connexion, durability, calibration, ...

6 March
2018

Thank you for your attention