Evaluating Particle Sensors for IAQ Controls

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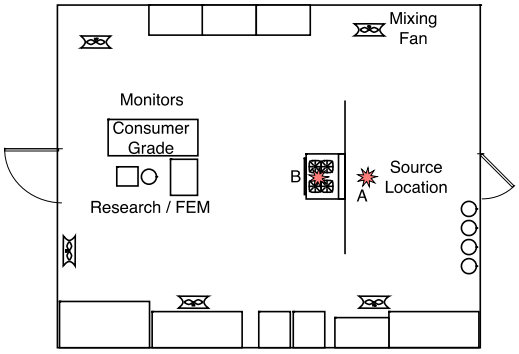
Sensing for control

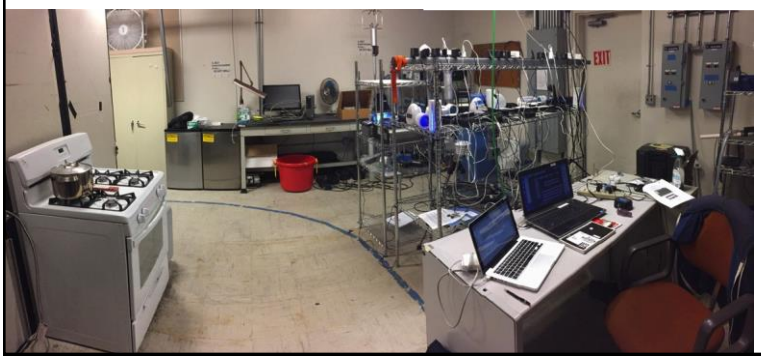
- ***Sensors*** packaged into IAQ ***monitors*** with power supply, display, internet connectivity (cloud storage)
  - Typically sensing: T, RH, PM, CO_2, VOCs
  - ***Monitor*** 250 USD/200 EUR
- ***Sensor*** 30 USD/25 EUR – light scattering (0.3 micron low limit)
- Current focus on particles – compare 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





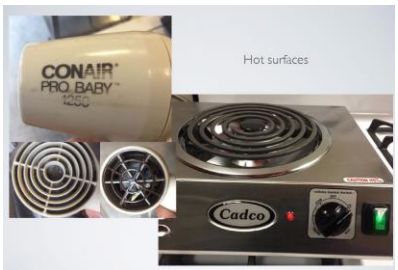
Particle Sources

General particles

Road dust, carpet, dust mop, and humidifier

Hot surfaces

Hair dryer, and electric burners



Cleaning products + ozone

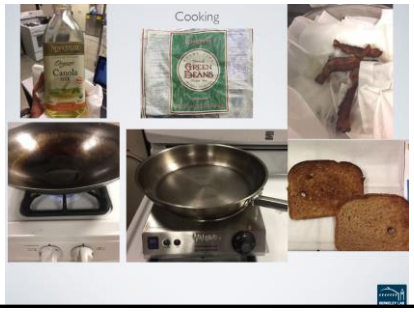
Particle Sources

Combustion

Gas burners, incense, candles, and cigarettes

Cooking

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



Reference Instruments ~ $35,000

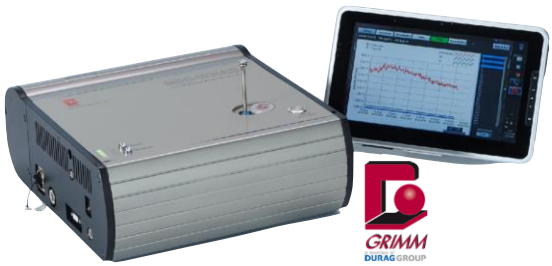
Thermo-Scientific TEOM-1405DF

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 35μm

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

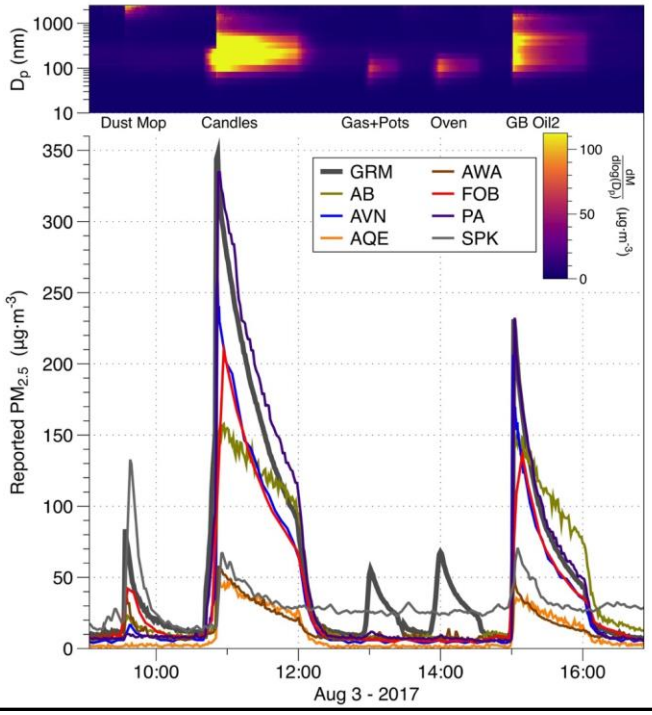
Event detection

- Some better than others

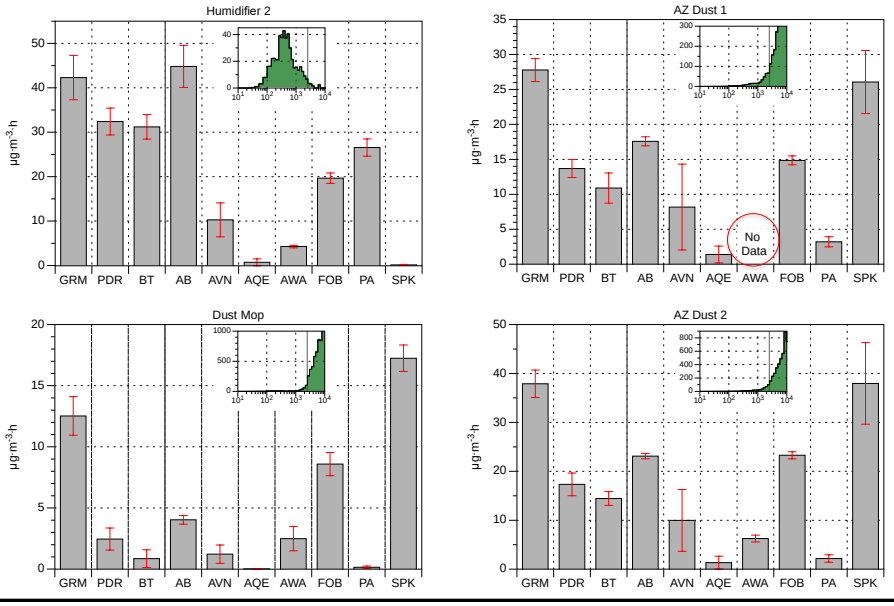
Magnitude

- Some better than others

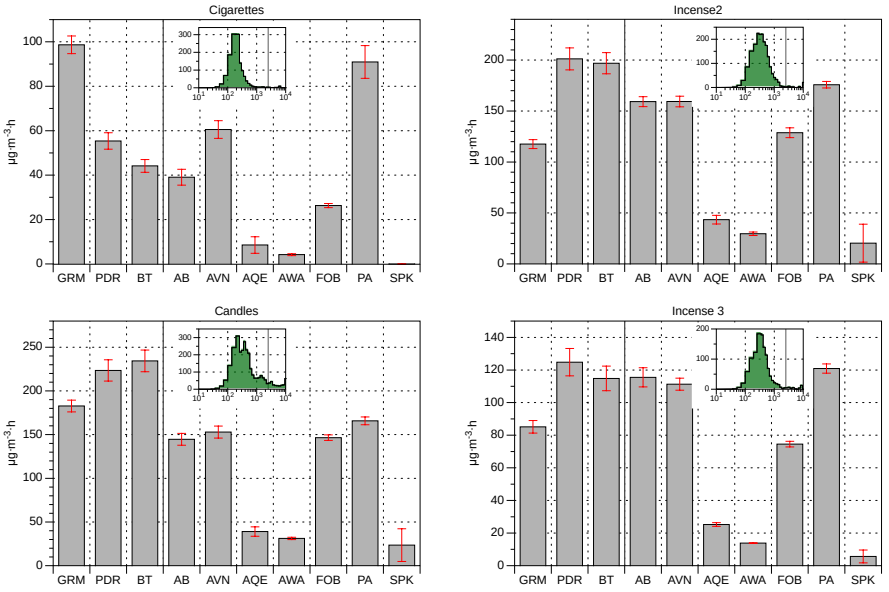
Depends on “event”
= depends on particle size distribution



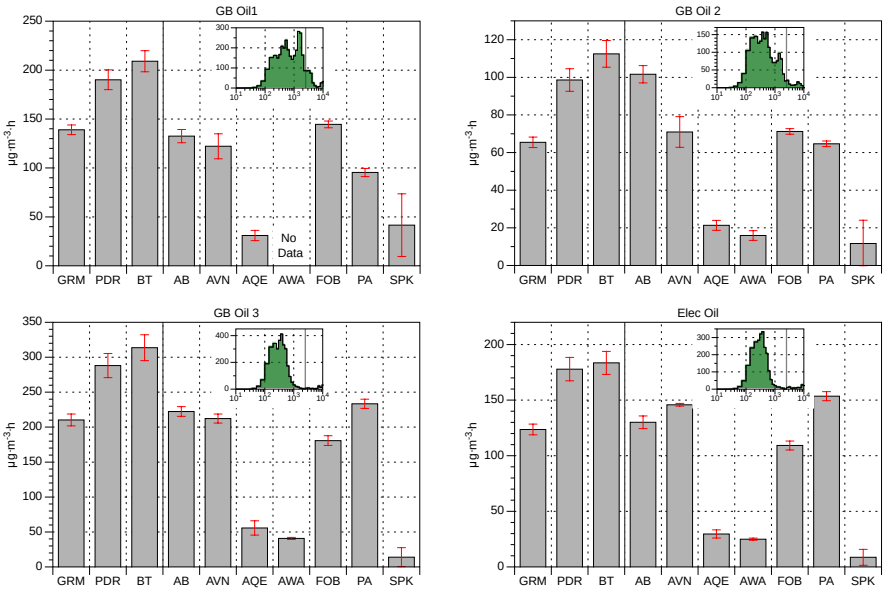
Humidifier and Dust



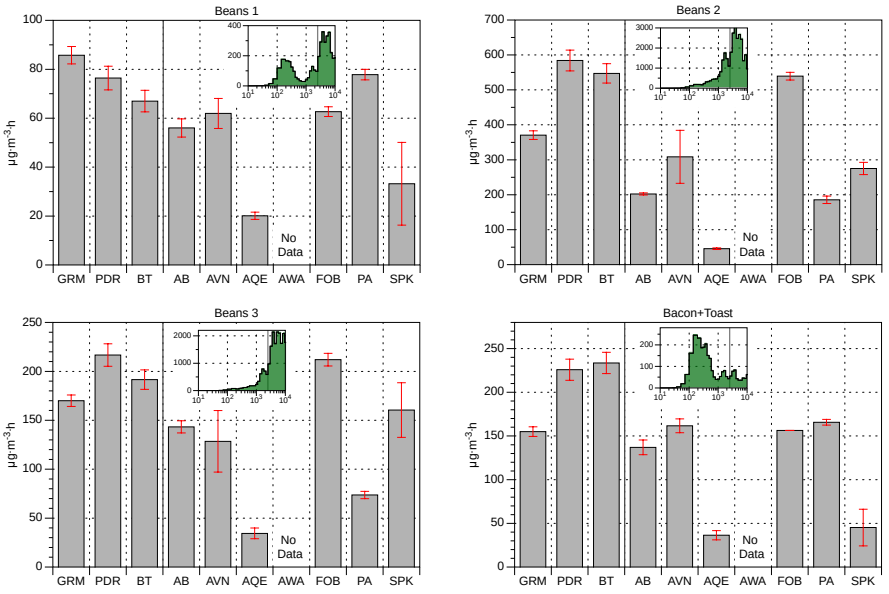
Recreational Combustion



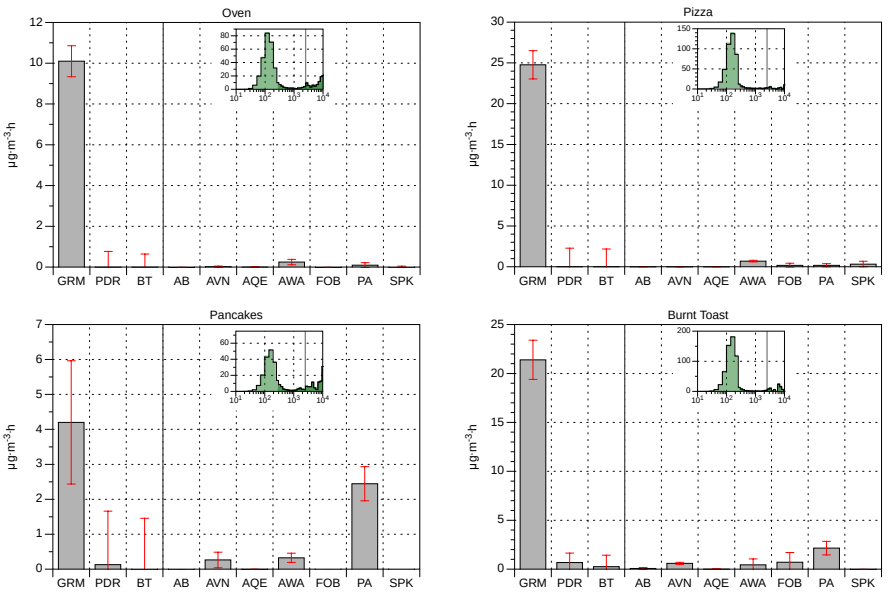
Heating Oil on Gas or Electric Burners



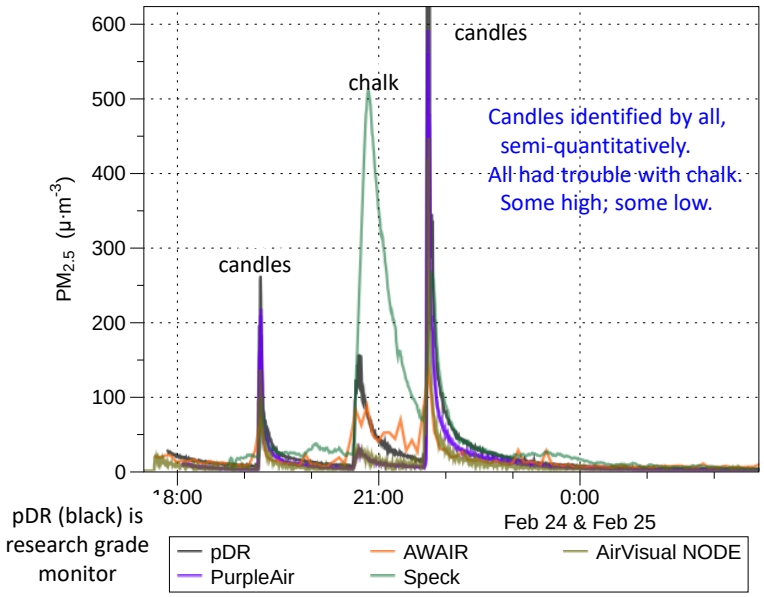
Stir-Frying and Frying + Toasting



Cooking that Emits Mostly <0.3 um Particles

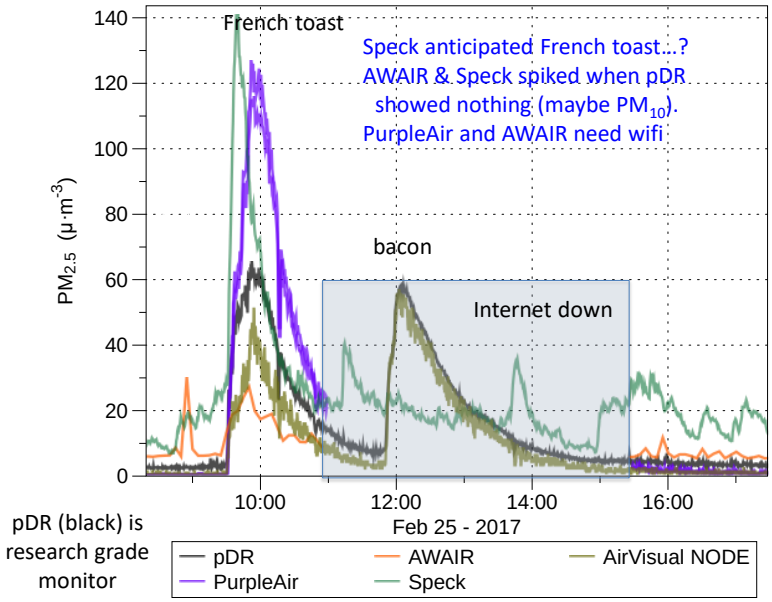


In-Home Test



pDR (black) is research grade monitor

In-Home Test



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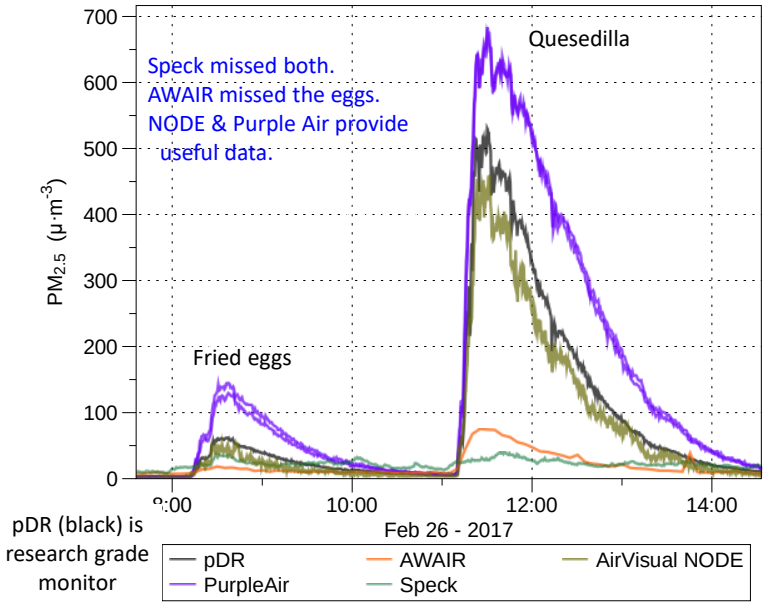


Other Studies – Similar Results

- 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/

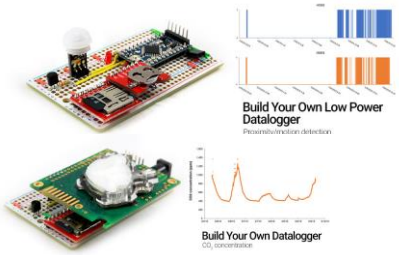
T, RH, PM, CO_2, O_3, NO_2; slots for 4 e2v MOx sensors

Open Source Building Science Sensors

Illinois Institute of Technology

http://www.osbss.com/

T, RH, CO_2, Particles, δελτα–P, equilibrium RH, light state, proximity, occupancy



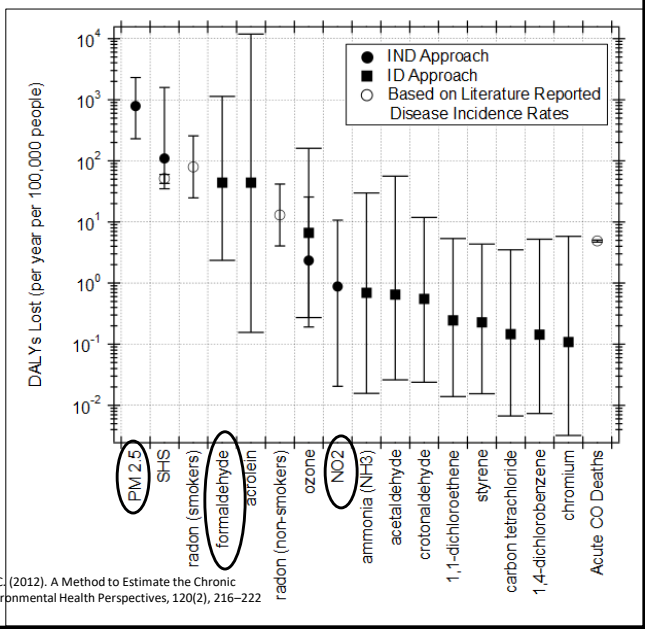
DIY / Maker offerings

- Sensor + parts kit: using same sensor as monitors
- EPA kit for schools: https://www3.epa.gov/airnow/teachers/gh_pmsensorkit_handoutandinstructions.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



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