



**State of Air Sensors**  
**Yesterday → Today → Tomorrow**

**Tim Dye**  
**TD Environmental Services**

# Brief History of Air Quality Sensors

It started long ago.



## 1800s to 1900s - Canaries save lives

Canaries in coal mines provided advance warning of toxic gases.

## 1974 - First PID for continuous sensing

Photoionization detector (PID) introduced as a hand-held instrument to detect leaks for Volatile Organic Compounds (VOCs). First introduced in 1974, early portable PIDs were bulky, heavy (9 lbs.), and had a separate hand-held probe and a controller carried by a shoulder strap.





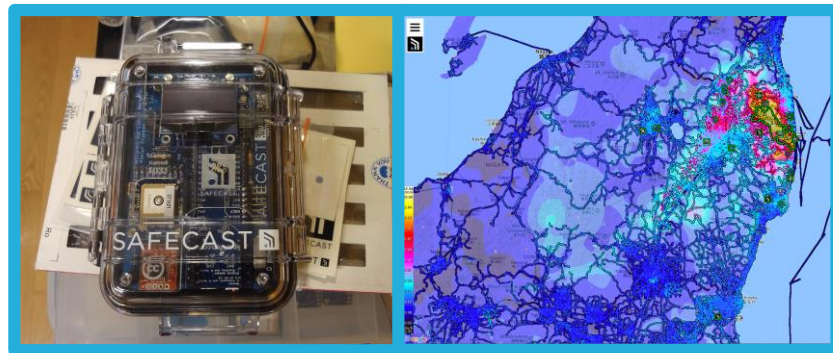
## 2008 - Air sensing pod used by communities

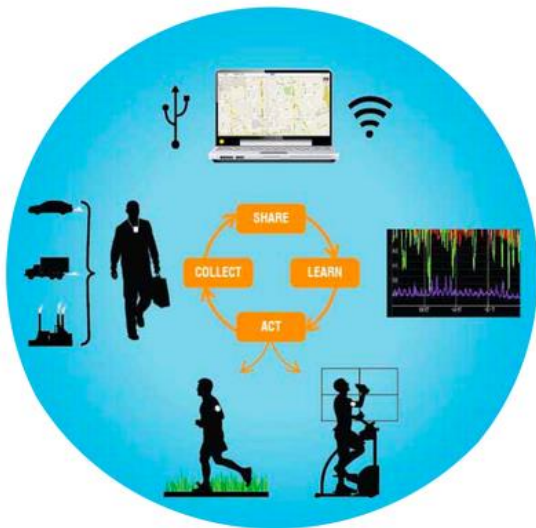


Common Sense program by Intel Berkeley built a mobile sensing pod that measured pollutants using low-cost sensors.

## 2011 Crowdsourced radiation data makes an impact

Safecast started in response to the meltdown of the Fukushima Daiichi Nuclear Power Plant in Japan. Where a group of volunteers quickly began monitoring, collecting, and openly sharing information on environmental radiation.





## 2012 - First U.S. meeting for low-cost air quality sensing

The U.S. EPA hosted the first comprehensive meeting on air quality sensors. The workshop helped set a path for EPA's low-cost air sensor program.



## 2012 - Low-cost sensor created by crowdfunding

Air Quality Egg funded via Kickstarter produced 800 air quality sensing eggs. The eggs measured carbon monoxide, nitrogen dioxide, temperature, and humidity using low-cost sensors, but poor accuracy of the eggs frustrated and soured many users.



About this project

Support this project

[Pledge \\$1 or more](#)

Application beta tester. Even if you don't collect your own data, you can still benefit from applications developed by the community that uses the aggregate open data from Air Quality Eggs around the world.

ESTIMATED DELIVERY  
Jul 2012

155 backers

[Pledge \\$30 or more](#)

Represent DIY air quality monitoring with a T-Shirt and Slicker set that we promise will not be lame. Shipping to US address included.

ESTIMATED DELIVERY  
May 2012

16 backers

## Air Sensor Guidebook



### 2013 - Good advice provided by U.S. EPA



Air Sensor Guidebook provided practical information on types of pollutants, what to consider when buying air sensors, steps to collect useful data, how to assess performance, and more.

### 2014 - Open-source PM sensor system launches

AirBeam, an open-source air sensor system, was released by HabitatMap for personal monitoring for  $PM_{2.5}$ . Users crowdsourced data on the AirCasting app and website to vividly show a region's particle levels.





**AQ-SPEC**  
Air Quality Sensor Performance Evaluation Center

**Evaluations**

SCAQMD's AQ-SPEC program aims at being the testing center for low cost air monitoring sensors to establish performance standards by which sensors are evaluated. The program evaluates sensors in both controlled laboratory conditions and in the field. In the field, sensors are tested alongside one or more of SCAQMD's existing air monitoring stations using traditional Federal reference or equivalence methods to gauge overall performance. Sensors demonstrating acceptable performance in the field are then brought to the AQ-SPEC laboratory for more detailed testing in an atmospheric chamber under controlled conditions.

**Summary Tables & Reports**

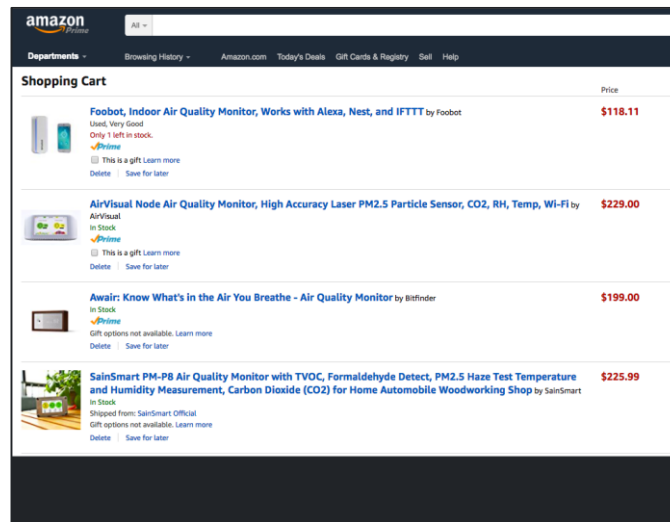
PM Sensors							
Sensor Image	Manufacturer (Picoc)	Type	Pollutant(s)	Approx. Cost (USD)	*Field R <sup>2</sup>	*Lab R <sup>2</sup>	Summary Report
	AethLabs (microAeth)	Optical	BC (Black Carbon)	~\$6,500	R <sup>2</sup> = 0.79 to 0.94		
	Air Quality Egg	Optical	PM	~\$200	R <sup>2</sup> = 0.0		

## 2014 – Game-changing evaluation center launches

The South Coast Air Quality Management District in Los Angeles set up a comprehensive evaluation center for air sensors. It evaluated the accuracy and usability of commercially available, low-cost air quality sensors.

## 2016 - Startup and more startups

At a pace of almost one new company per week, startups seek to develop air quality sensor for the consumer market. You can buy air sensor systems for around \$200 on Amazon. Many devices look beautiful with flashy apps, videos, and websites. While many of them look interesting, the accuracy and quality of the data often remains elusive.



**amazon** Prime

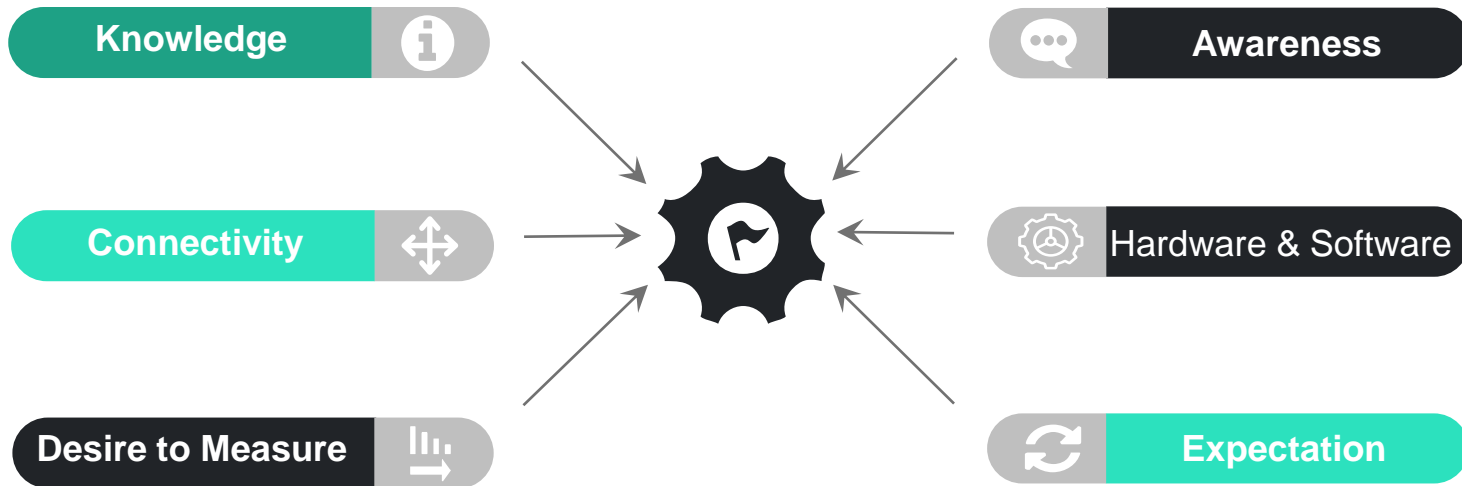
Departments - Browsing History - Amazon.com Today's Deals Gift Cards & Registry Sell Help

**Shopping Cart** Price

- Foobot, Indoor Air Quality Monitor, Works with Alexa, Nest, and IFTTT** by Foobot **\$118.11**  
 Used, Very Good  
 Only 1 left in stock.  
 Prime  
 This is a gift Learn more  
 Delete Save for later
- AirVisual Node Air Quality Monitor, High Accuracy Laser PM2.5 Particle Sensor, CO2, RH, Temp, Wi-Fi** by **\$229.00**  
 AirVisual  
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- SainSmart PM-P8 Air Quality Monitor with TVOC, Formaldehyde Detect, PM2.5 Haze Test Temperature and Humidity Measurement, Carbon Dioxide (CO2) for Home Automobile Woodworking Shop** by SainSmart **\$225.99**  
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# Tipping Point

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# State of the Market

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**Dominated by startups and small hardware/software companies**



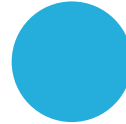
**Large unknowns about sensor performance**



**Few standards exist, no regulations accepting of sensors**



**Lots of interest in monitoring local air quality**



**Funding for demonstration and proof-of-concept projects**



**Some early results are promising**



# Value Chain

Lots of work needed to create actions and benefits

## Definition, Roles, and Current Status

### Sensor Manufacturers

Develop, market, sell devices to measure air pollutants.

35+ companies

### Sensor Integrators

Create sensor systems with hardware, software, communications, enclosure, manual, and support.

60+ companies

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### Data Aggregators

Ingest data from sensor systems and provide data management, visualization, and dissemination.

20+ companies

Other data sources

### Sensor Integrators

Create sensor systems with hardware, software, communications, enclosure, manual, and support.

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### Solution Providers

Use sensor data combined with other data (weather, models, etc.) to generate actionable information.

10-20 companies

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### Action Organizations

Information combined with other knowledge (educational, policy, financial, social) creates action to improve air quality.

10-20 companies/organizations

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Create sensor systems with hardware, software, communications, enclosure, manual, and support.

60+ companies

### Solution Providers

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### Benefits

Resulting action leads to improved health and/or saves money.

Other data sources

# Sample Project

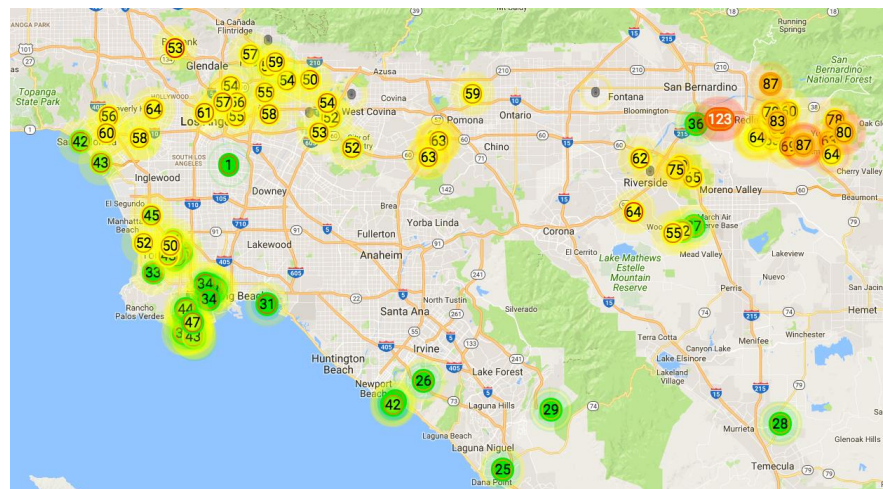
Organization: Purple Air

Dates: 2015+

Objectives: Helping others monitor air quality

Pollutants:

- $PM_1$ ,  $PM_{2.5}$ ,  $PM_{10}$ ,
- 550 sites
- Growing rapidly (200+ per month)



“People really care. They want to monitor PM for their health, exercising, when to open windows, buying a house, wildfire smoke, and more”. - Adrian Dybwad, Founder of PurpleAir

# Sample Project

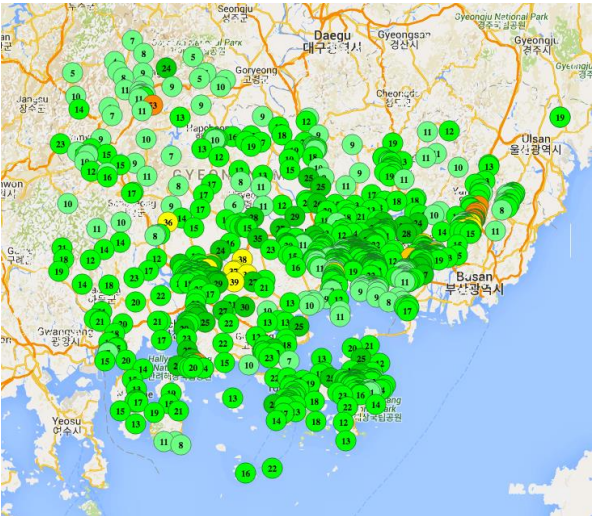
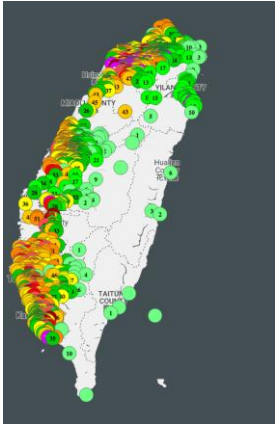
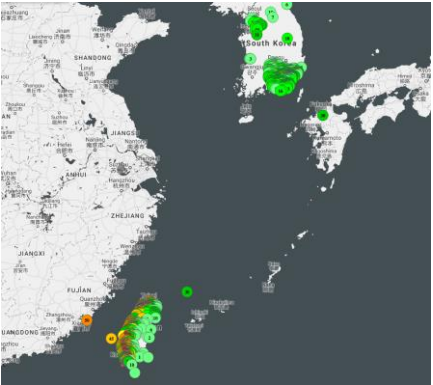
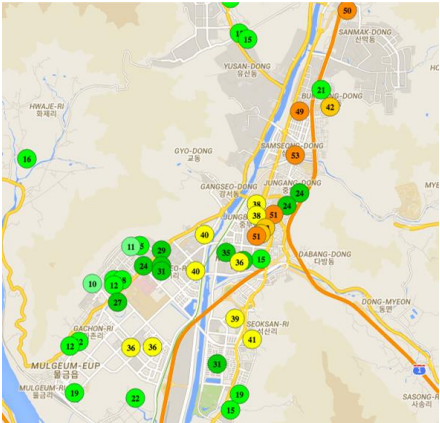
Organizations: Academia Sinica and National Taiwan Normal University

Dates: 2016+

Objective: Create a participatory urban sensing framework

Pollutants:

- PM<sub>2.5</sub>



# Sample Project

Organization: Minnesota Pollution Control Agency

Dates: 2017-2019

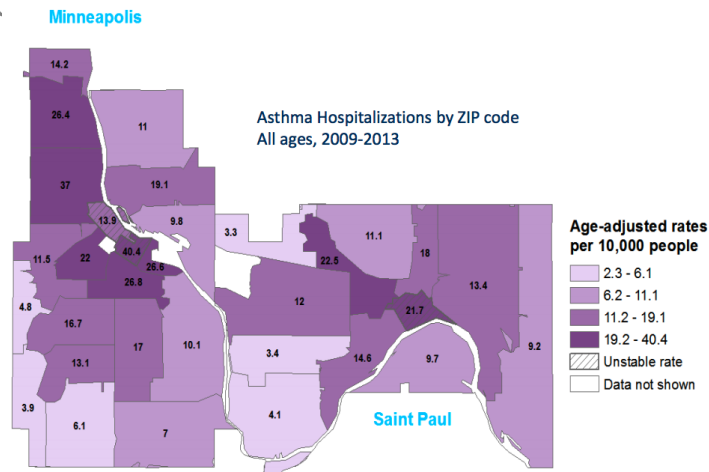
Objectives:

- Better understand small-scale differences in urban air quality
- Evaluate new sensor technology to monitor air quality



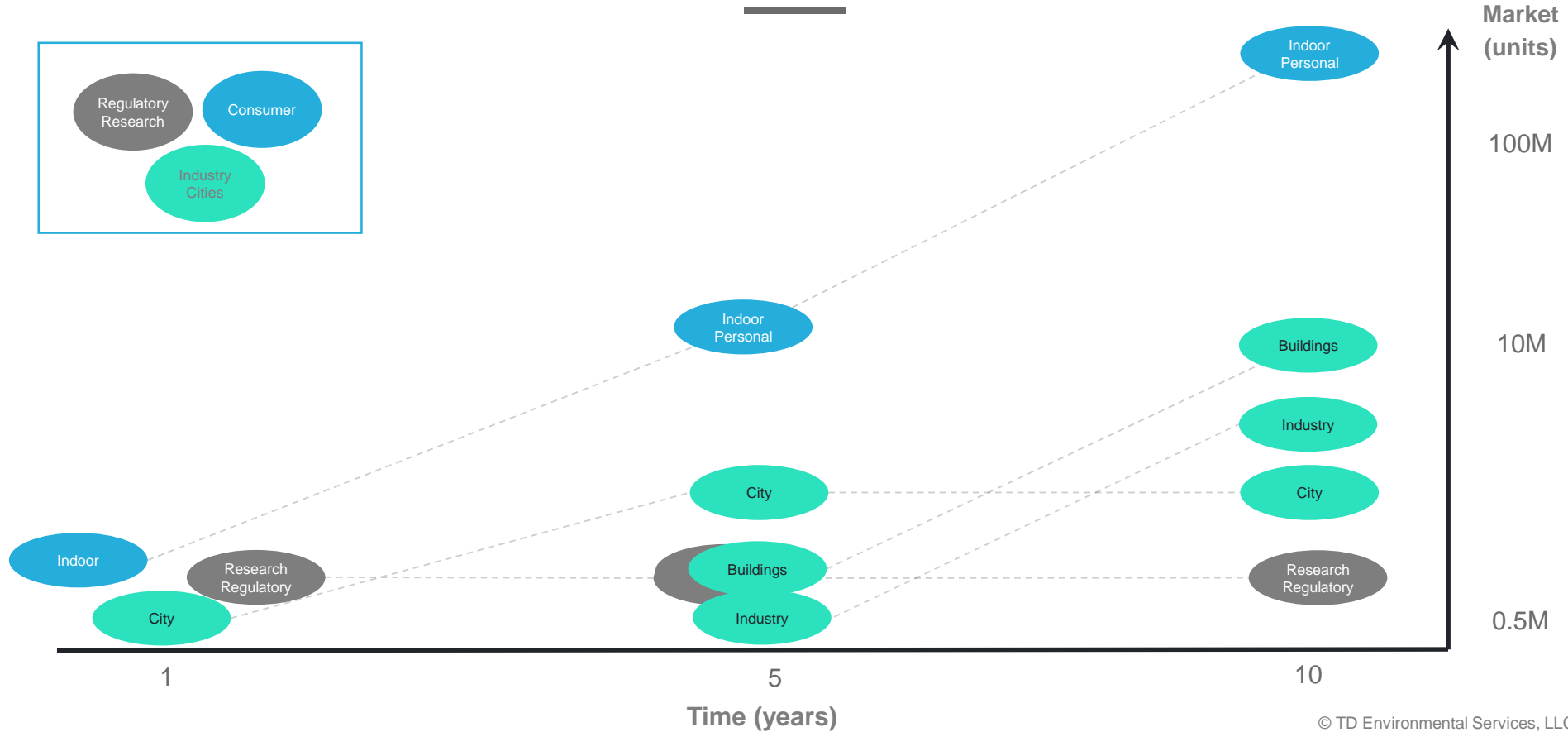
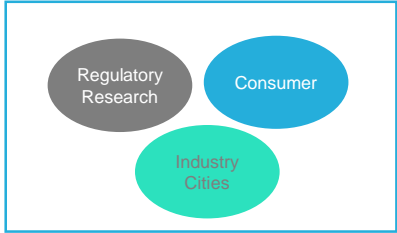
Pollutants:

- PM<sub>2.5</sub>, Ozone, CO, SO<sub>2</sub>, NO<sub>x</sub>
- 50 sites (1 in each ZIP Code)



# Market Evolution

Market growth in next 10 years



# What's Needed?

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## Sensor Performance

Need to increase quality, durability, and longevity of air sensors (both gas and PM)



## Successful Proof-of-Concepts

This new technology requires demonstration of the benefits.



## Standards

Long-term business growth for regulatory, industry, and buildings will result from regulations and codes incorporating this new technology.



## Ecosystem – Users & Suppliers

Ultimately create a market with users and businesses meeting their near- and long-term needs



# Contact **information**

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