Air Pollution Sensor Technology: State of the Science and Related US EPA Activities

National Association of Clean Air Agencies
2013 Fall Membership Meeting

Baltimore, MD
September 23-25, 2013

Tim Watkins
US EPA/Office of Research and Development

The Changing Paradigm of Air Monitoring

The Role of Sensor Technology in the Changing Paradigm

Sensor Technology

How data is collected?		
Who Collects the data?	Limited Mostly to Governments, Industry, and Researchers	Expanded Use by Communities and Individuals
Why data is collected?	Compliance Monitoring, Enforcement, Trends, Research	New Applications and Enhancement of Existing Applications
How data is accessed?	Government Websites, Permit Records, Research Databases	Increased Data Availability and Access

Snyder et al., 2013

Convergence of Technologies and Cultural Change

Miniaturized environmental sensors

e.g., CairClip

e.g., Arduino microprocessor

Introduction of low cost controls and communications

Emerging data-viewing/ communication apps

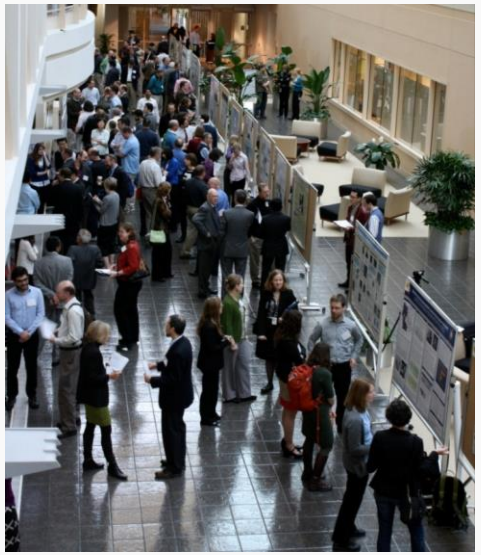
AirCasting App

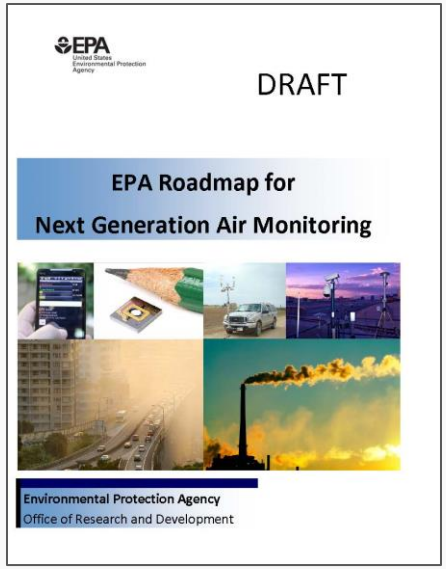
Smartphone / Tablet generation

e.g., fitbit activity tracker

What is EPA doing?

- Stimulating collaboration and conversation
- Assessing emerging technology
  - Literature review of sensor technology
  - Sensor evaluation through laboratory and field analyses
- Thinking big picture about these developments and implications





http://www.epa.gov/research/airscience/docs/roadmap-20130308.pdf

EPA Technology Review
(Available Soon)

- Scope
  - Real time/continuous monitoring technologies of gases and particulates
  - Only lower-cost (<10 K) systems
  - Gas sensors: electrochemical, metal oxide, spectroscopic sensing principles
  - PM sensors: light scattering or light absorption sensing principles

- Pollutants
  - Criteria Air Pollutants - CO, SO2, NO2, PM
  - HAPs - formaldehyde, acetaldehyde, benzene, 1,3-butadiene
  - Other Pollutants - ammonia, total VOCs, hydrogen sulfide, and methane

- Gaps
  - Many sensors that were reviewed do not have the detection limits required to measure ambient levels of these pollutants
  - Many of the sensors suffer from selectivity issues and/or impacts of high RH
  - There are no direct mass PM sensors and the light scattering sensors do not measure ultrafine PM
  - Very few of these systems have been rigorously tested

Summary of Gas-Phase Sensors

Sensor Type	Pollutants Measured from List	Range	Selectivity	Response times, seconds	Range of operating conditions	Other Considerations
Electochemical Sensors	Benzene*, H2S, NH3, CO, SO2, NO2, O3	single ppb /1 ppm to up to 10 /1200 ppm	Not selective but characterized	1-70	15 -90 % RH (some have lower upper RH tolerances), 0 to 40 °C	Short sensor lifetimes (1-2 years)*
Metal Oxide Sensors	non-methane hydrocarbons, benzene, methane, CO, NO_2, NH_3, SO_2, total VOCs, NOx	typically single ppb/0.1 ppm to 25 - 100 ppm.	Not selective and not well characterized	60-180	10-90% RH, -10°C to +50°C, sensitive to changes in RH, T, and P	Issues with sensor drift
Spectroscopic Sensors	NO (chemiluminscence), CH_4, VOCs (NDIR)	DL is 9 ppb for NO, NDIR 1-100 % range	Selective for chemiluminscence	20-60	-40/-20°C to +50/55 °C and 0/10 % RH - 95%RH	Limitations on ability to make selective sensors inexpensive

* Determined through EPA sensor evaluation studies.

Sensor Evaluation Open House

www.epa.gov/airscience

AIR CLIMATE & ENERGY RESEARCH PROGRAM
BUILDING A SCIENTIFIC FOUNDATION FOR SOUND ENVIRONMENTAL DECISIONS

Sensor and Apps Evaluation Opportunity

WHAT: EPA offers technology developers the opportunity to send in your sensor for evaluation in a controlled laboratory setting.

WHEN: Nominate your device by June 30, 2012
Testing to occur July – September, 2012

HOW: Device developers should submit a statement of interest to EPA by June 30, 2012 providing basic information about their device. Due to capacity constraints, EPA will accept a limited number (~10) devices for evaluation over a range of pollutant concentrations and environmental conditions (e.g. humidity and potential interferences). Participants will be invited to visit the EPA lab in early July to discuss their instruments, the evaluation protocol, and receive a tour of the facility. Following the completion of the evaluation each participant will receive information on the performance of their device under known environmental conditions.

QUESTIONS or Point of Contact: Ron Williams, 919-541-2957, williams.ronald@epa.gov

SELECTION CRITERIA: Devices receiving the highest consideration:

- have the technical feasibility to measure NO_2 and/or O_3 at environmentally relevant concentrations,
- have some preliminary data on expected performance characteristics,
- have not previously undergone standardized evaluations under known challenge test conditions by any party, and
- represent highly portable sensor and smart phone type applications featuring continuous measurement capabilities.

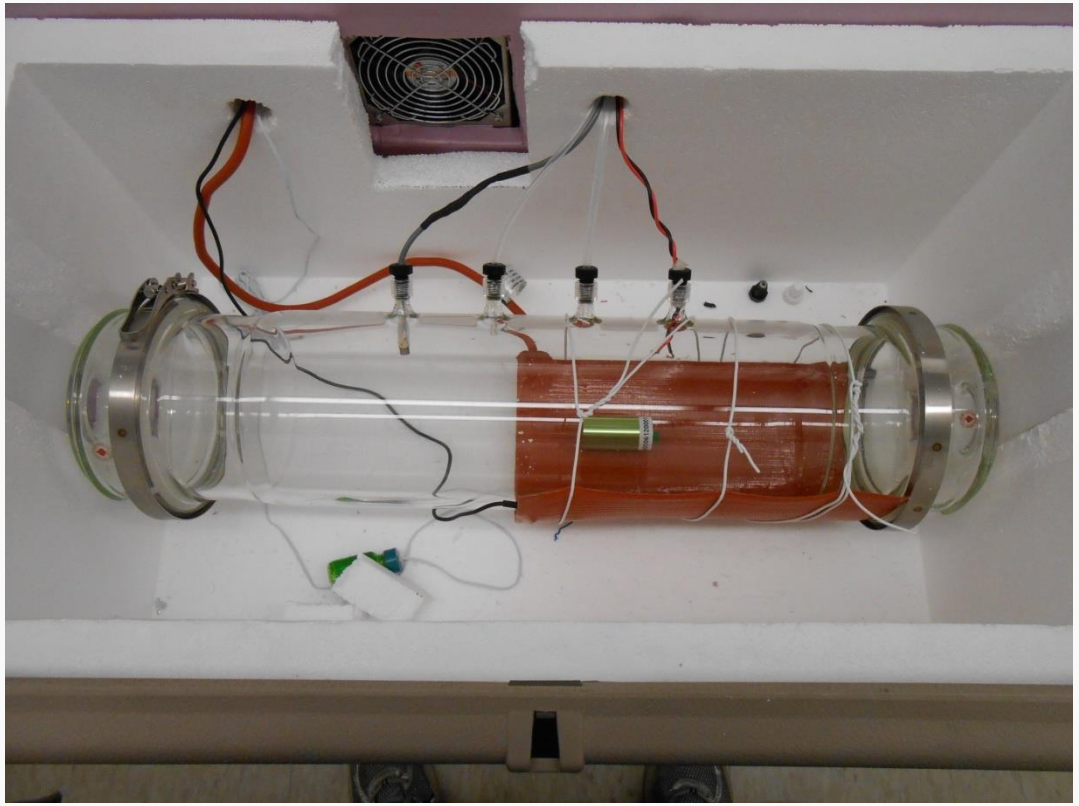
Description:

- Open call for potential collaboration
- O_3 and NO_2 focus
- A total of 9 research groups nominated devices for evaluation
- Variety of devices
- Formal cooperative agreements established
- Not FRM/FEM Evaluations

Feedback Provided to Sensor Developers:

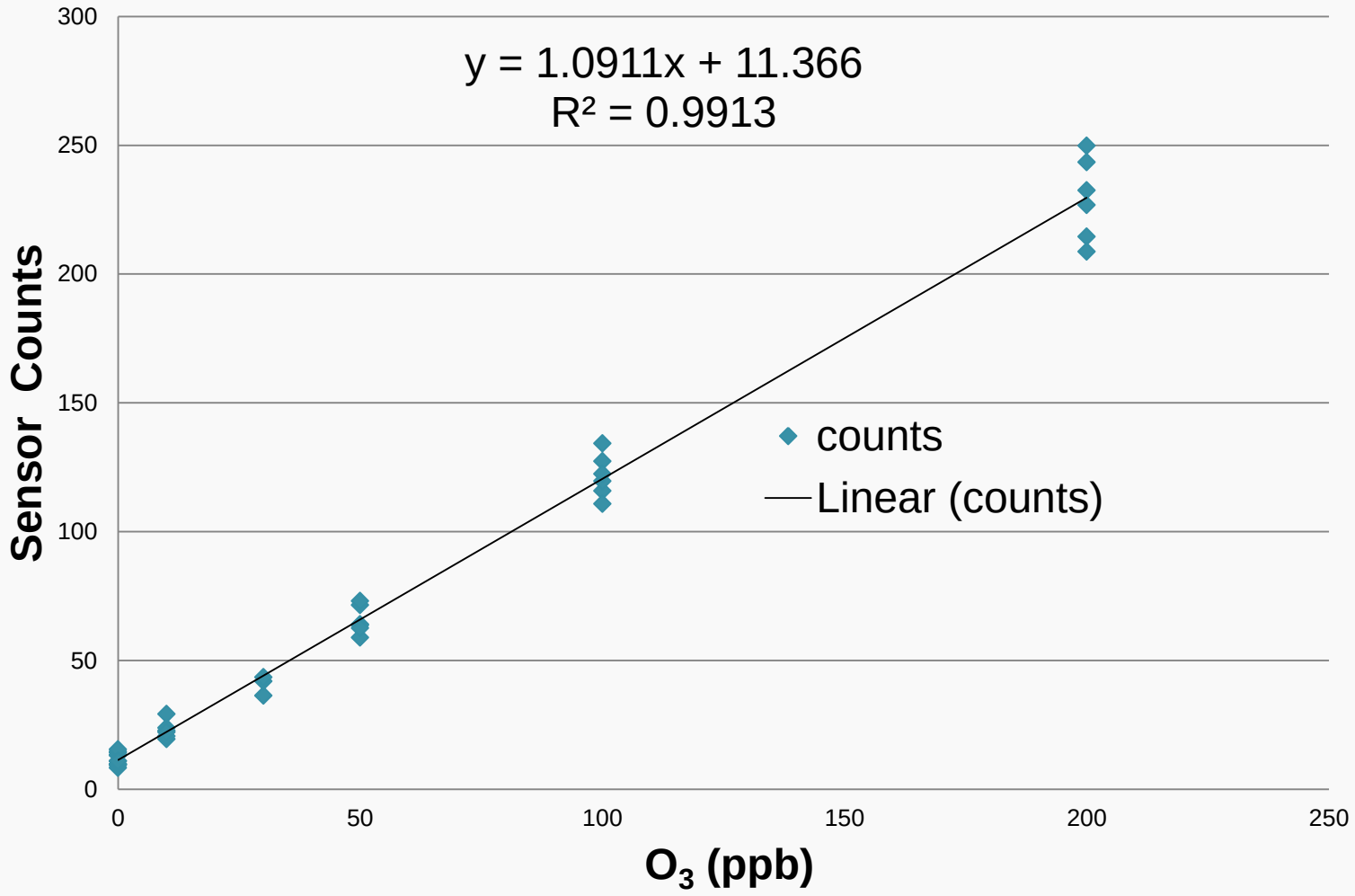
- General performance of the device
- Observations on operation
- Validated non-summarized data
- EPA's intent was not to compare one specific device with another
- EPA recognized the confidential nature of the technologies being evaluated

Evaluating Personal Sensors



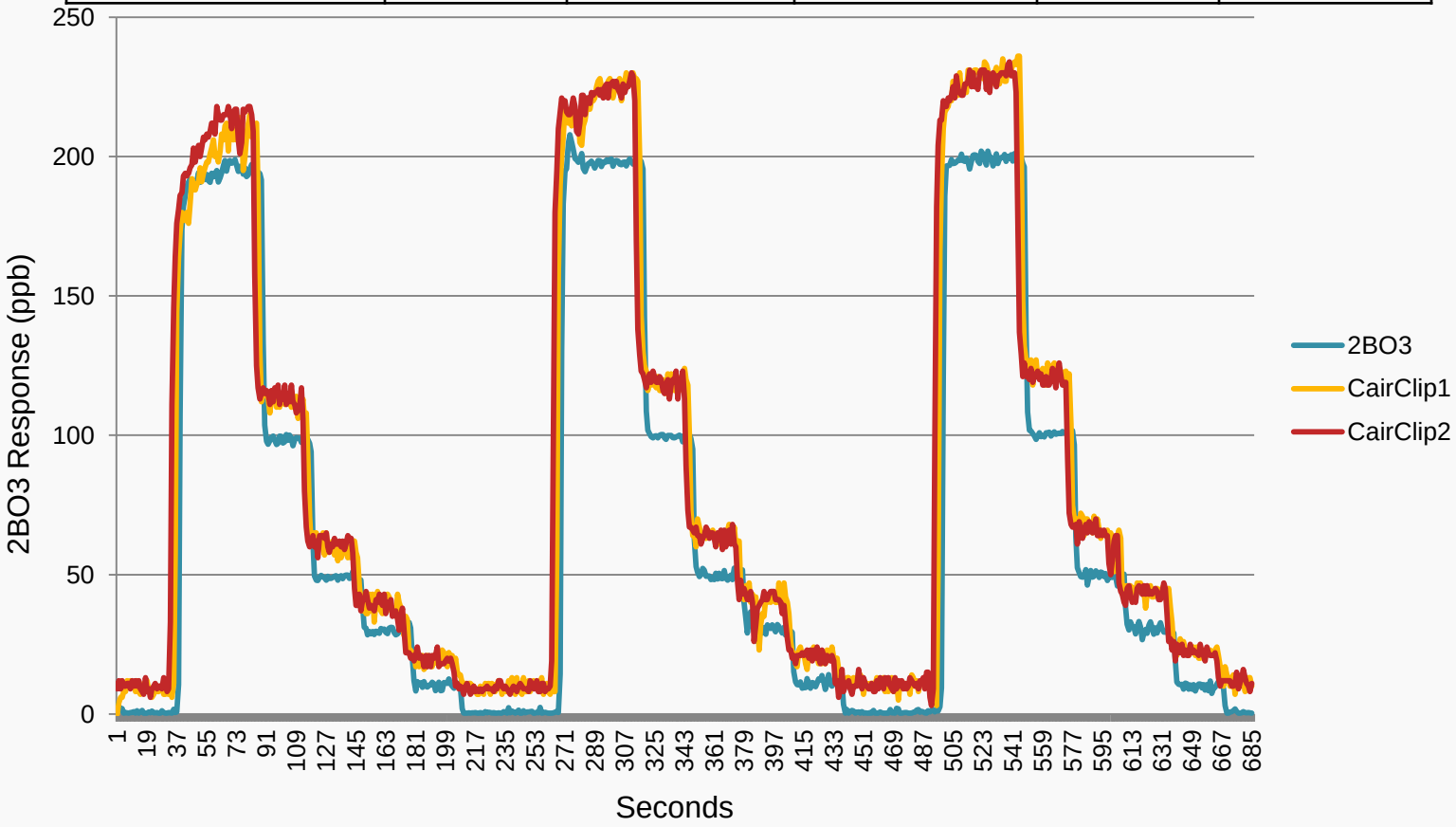
CairClip electrochemical sensor evaluated under the Air Sensors Project

Cairclip performance against reference analyzer



Example of Basic Performance Characteristics

Calibration #	2BO3 (minutes rise time)	CairClip 1 (minutes rise time)	CairClip 2 (minutes rise time)	CairClip 1 (final rise time)	CairClip 2 (final rise time)
1	5	19	17	14	12
2	3	5	5	2	2
3	4	4	5	<1	1



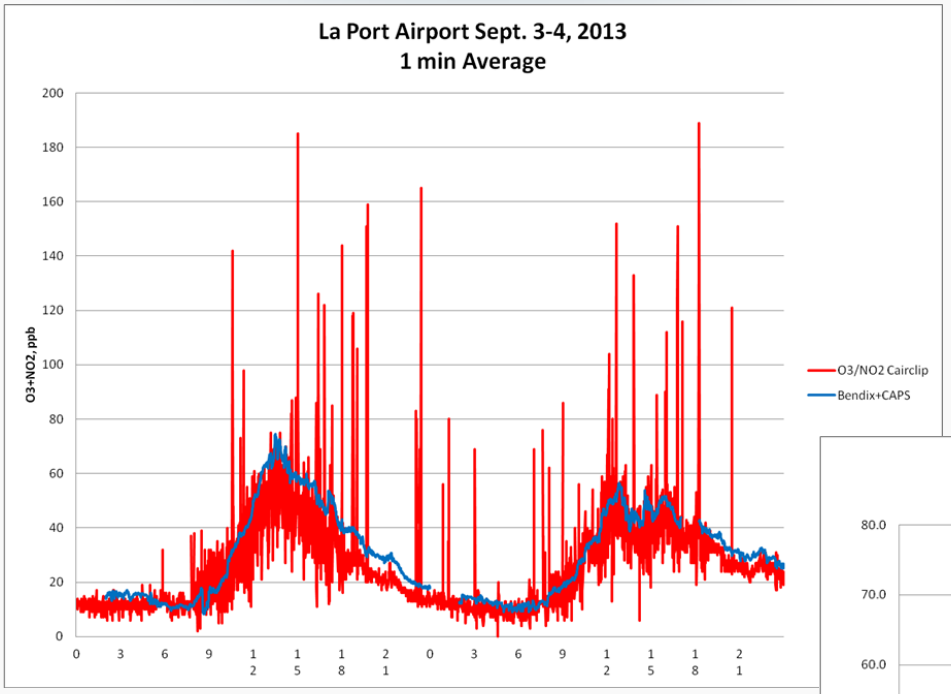
Sensor Evaluation in Collaboration with NASA (Houston, TX Sept 2013)

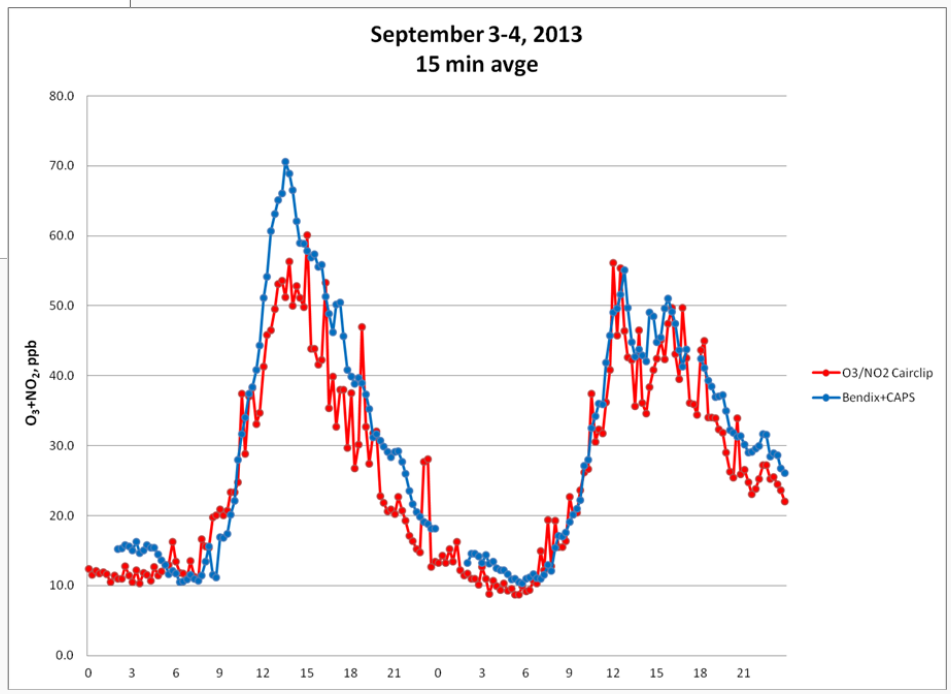
- EPA deploying sensor technology (CairClip) for NO2 and O3 that performed well during the EPA Sensor Evaluation Open House.
- NASA deploying sensor technology (Geotech AQMesh-5) to measure O3, NO, NO2, CO, SO2.
- Sampling with sensors will be used to evaluate air craft and remote measurements as well as air quality models.
- Provides EPA with additional insights and experience with the use of sensor technologies in the field for future applications.

CairClip

Geotech AQMesh-5

Preliminary Results from Houston: Integrated O_3 and NO_2

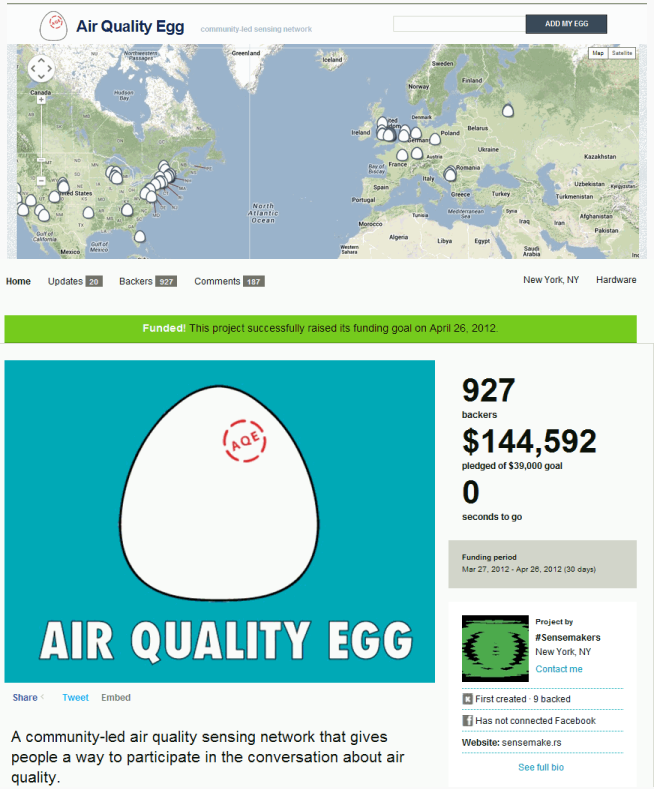




Sensor Technology is Enabling Citizen Science

Citizen Science for a variety of interests:

- Individual Health
- Community Exposures
- Research
- Education
- Technology



My Air My Health

U.S. Department of Health and Human Services
U.S. Environmental Protection Agency

Ongoing and Future EPA Sensor Evaluation Activities

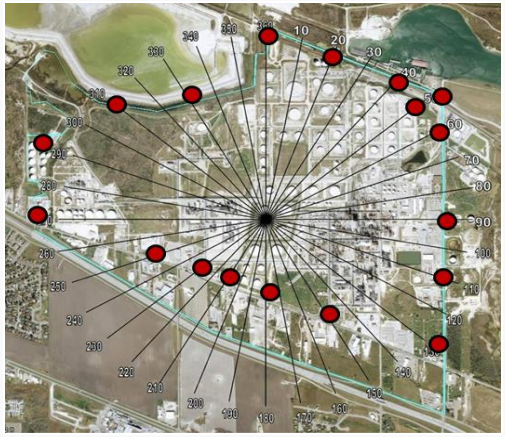
- PM and VOC Sensor Evaluations
  - A host of low cost (<$2500) PM2.5 and VOC sensors purchased or acquired for laboratory and/or field evaluation
  - Field work to be completed in CY 2013
  - Results available in CY 2014

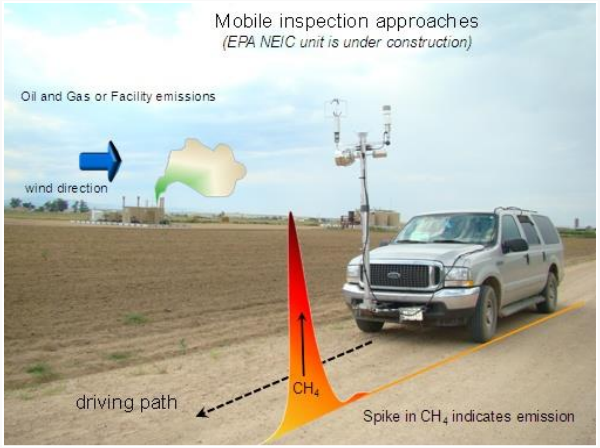
- Discussing potential sensor related projects in EPA Regions 2 and 4

Next Generation Air Monitoring Research at EPA

- Sensor Evaluations
  - Ozone, NO_2, PM, and VOCs
- Village Green Project
- Facility Fenceline and Sensor Networks
- Geospatial Mapping of Air Pollution (GMAP)

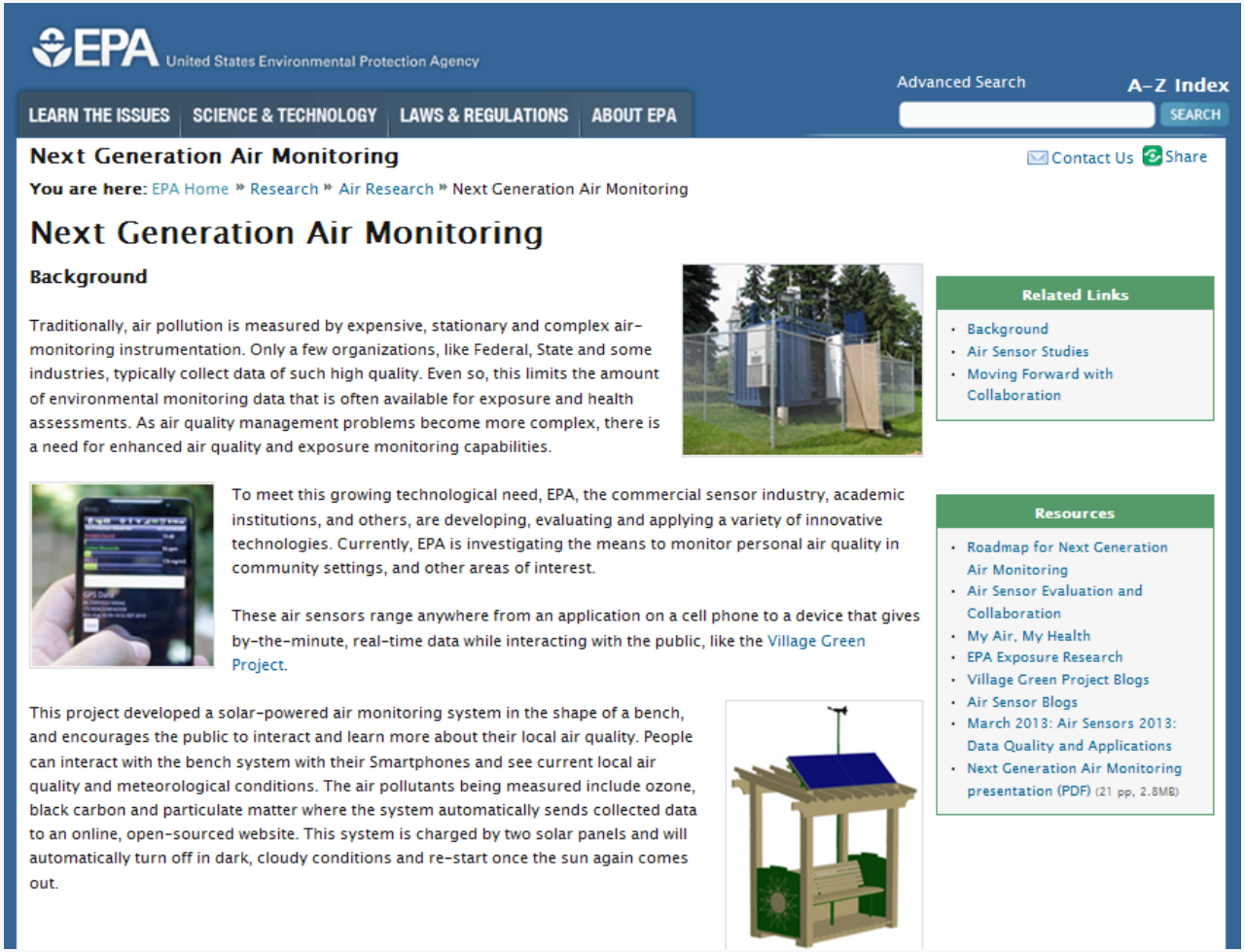
CairClip
(O3 & NO2)





EPA Next Generation Air Monitoring Site

For More Information:



EPA United States Environmental Protection Agency

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Next Generation Air Monitoring

Background

Traditionally, air pollution is measured by expensive, stationary and complex air-monitoring instrumentation. Only a few organizations, like Federal, State and some industries, typically collect data of such high quality. Even so, this limits the amount of environmental monitoring data that is often available for exposure and health assessments. As air quality management problems become more complex, there is a need for enhanced air quality and exposure monitoring capabilities.

To meet this growing technological need, EPA, the commercial sensor industry, academic institutions, and others, are developing, evaluating and applying a variety of innovative technologies. Currently, EPA is investigating the means to monitor personal air quality in community settings, and other areas of interest.

These air sensors range anywhere from an application on a cell phone to a device that gives by-the-minute, real-time data while interacting with the public, like the Village Green Project.

This project developed a solar-powered air monitoring system in the shape of a bench, and encourages the public to interact and learn more about their local air quality. People can interact with the bench system with their Smartphones and see current local air quality and meteorological conditions. The air pollutants being measured include ozone, black carbon and particulate matter where the system automatically sends collected data to an online, open-sourced website. This system is charged by two solar panels and will automatically turn off in dark, cloudy conditions and re-start once the sun again comes out.

Related Links

- Background
- Air Sensor Studies
- Moving Forward with Collaboration

Resources

- Roadmap for Next Generation Air Monitoring
- Air Sensor Evaluation and Collaboration
- My Air, My Health
- EPA Exposure Research
- Village Green Project Blogs
- Air Sensor Blogs
- March 2013: Air Sensors 2013: Data Quality and Applications
- Next Generation Air Monitoring presentation (PDF) (21 pp, 2.8MB)

http://www.epa.gov/research/airscience/air-sensor-research.htm