



State of Air Sensors

Where We Are, Where We're Going

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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.





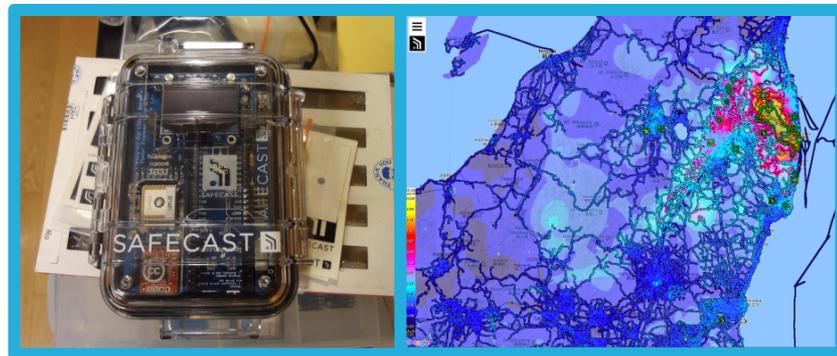
2008 - Air sensing pod used by communities

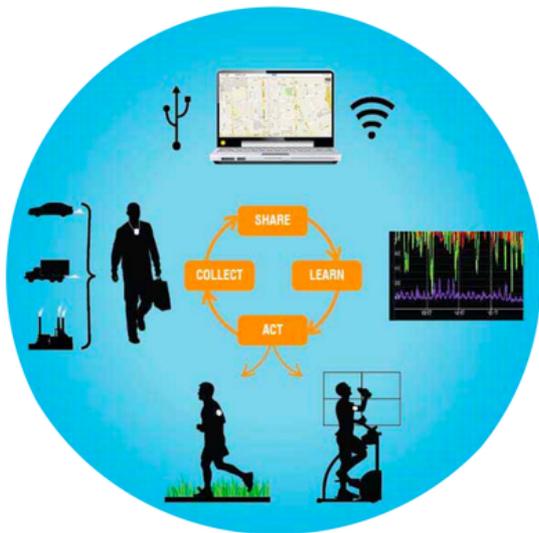


Common Sense program by Intel Berkeley built a mobile sensing pod that measured pollutants using low-cost sensors.

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

New York, NY Hardware

\$144,592
pledged of \$30,000 goal

927
backers

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 Sticker 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 (Model)	Type	Pollutant(s)	Approx. Cost (USD)	Field R ²	Lab R ²	Summary Report
	AethLabs (microLab)	Optical	BC (Black Carbon)	~\$6,500	R ² = 0.79 to 0.94		
	Air Quality Egg	Optical	PM	~\$200	R ² = 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.

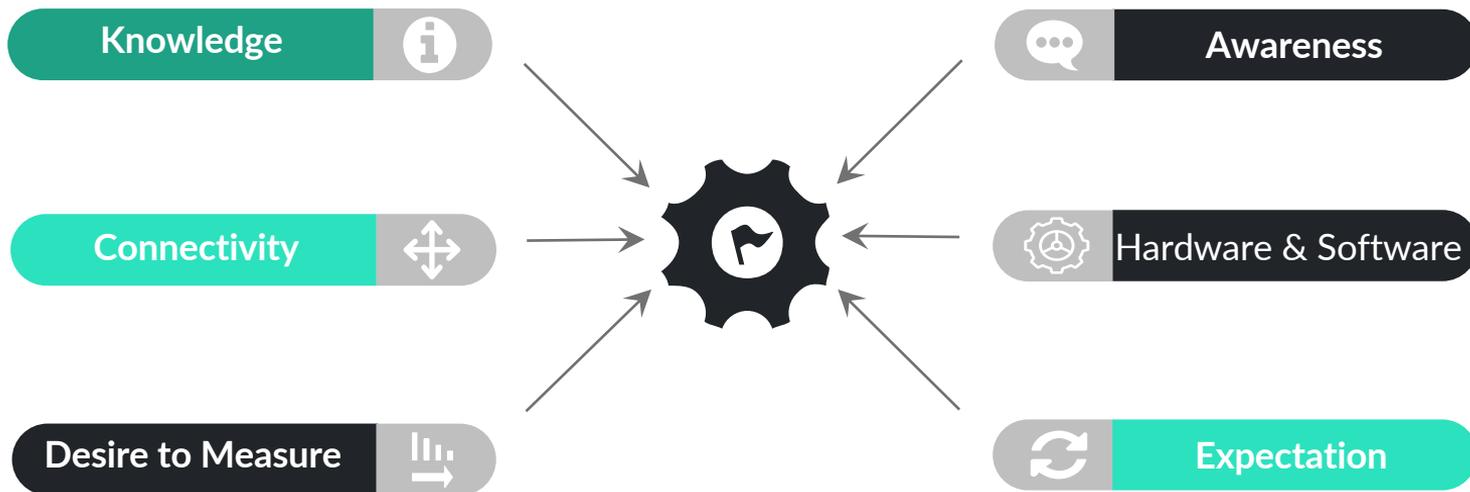
amazon Prime

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
 In Stock
 Prime
 This is a gift. Learn more
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- Awair: Know What's in the Air You Breathe - Air Quality Monitor** by Bitfiner **\$199.00**
 In Stock
 Prime
 Gift options not available. Learn more
 Delete Save for later
- 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**
 In Stock
 Shipped from: SainSmart Official
 Gift options not available. Learn more
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Tipping Point



State of the Market



Dominated by startups and small hardware/software companies



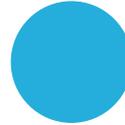
Large unknowns about sensor performance



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

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

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.

60+ companies

Solution Providers

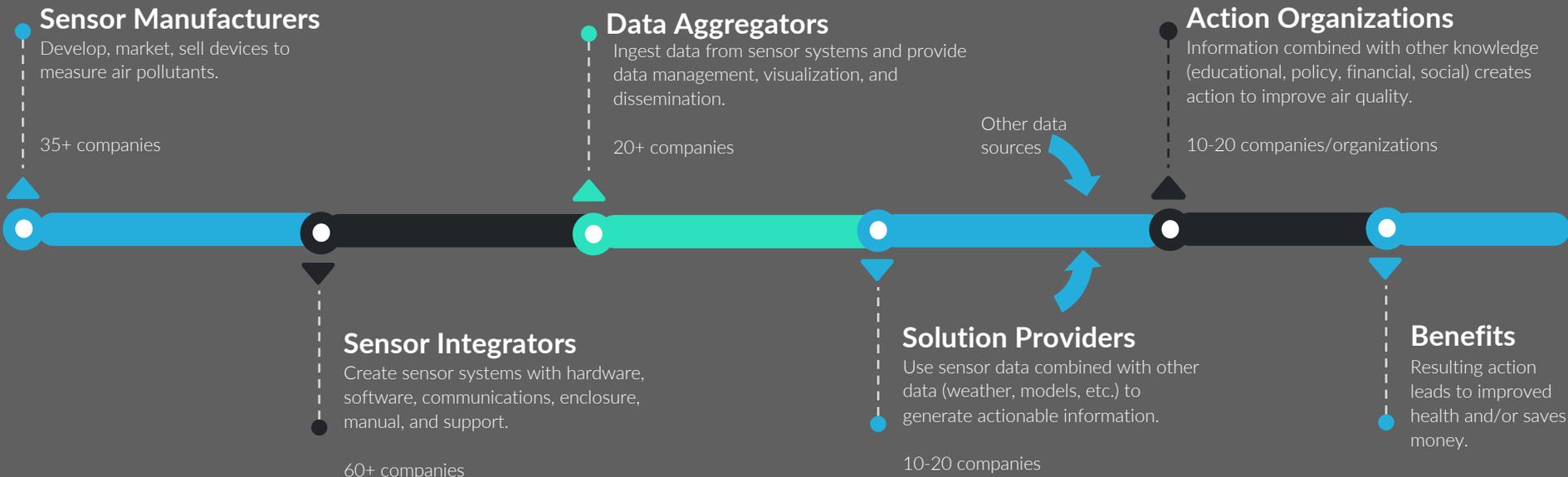
Use sensor data combined with other data (weather, models, etc.) to generate actionable information.

10-20 companies

Value Chain

Lots of work needed to create actions and benefits

Definition, Roles, and Current Status



Sample Project - Purple Air

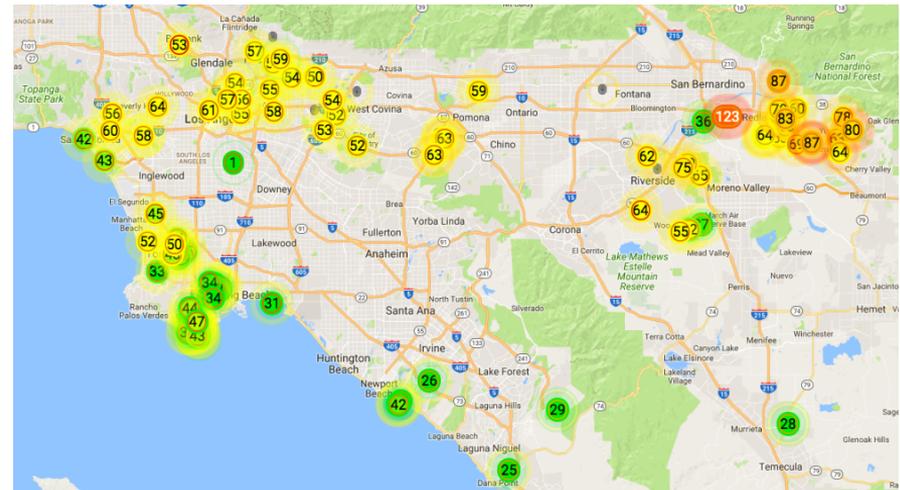
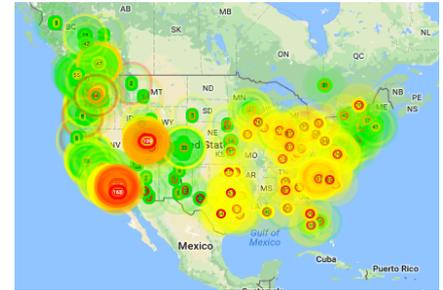
Organization: Purple Air

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

Organization: Minnesota Pollution Control Agency

Dates: 2017-2019

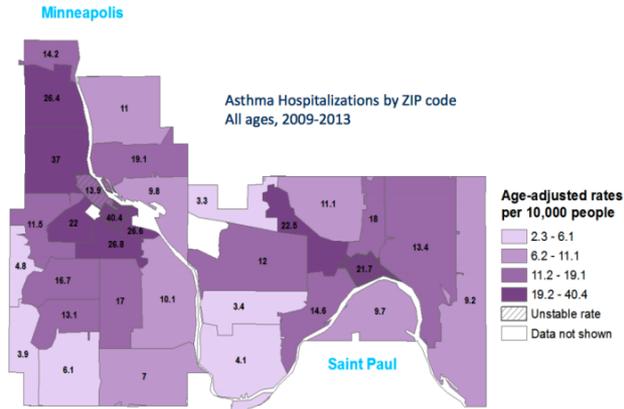
Objectives:

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



Pollutants:

- PM_{2.5}, Ozone, CO, SO₂, NO_x
- 50 sites (1 in each ZIP Code)



Sample Project - Taiwan

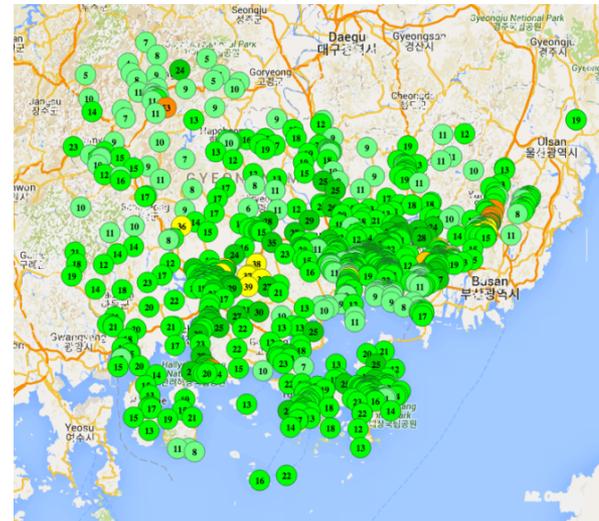
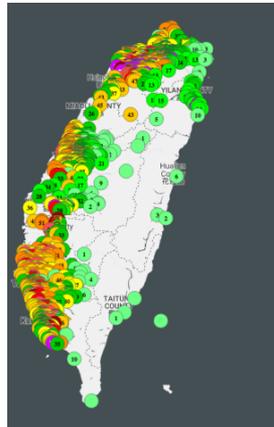
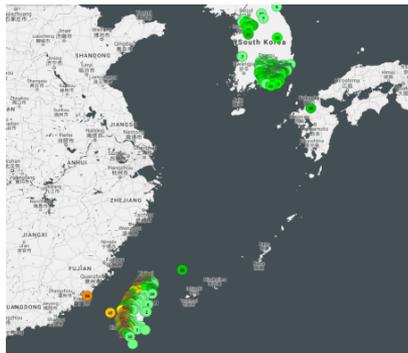
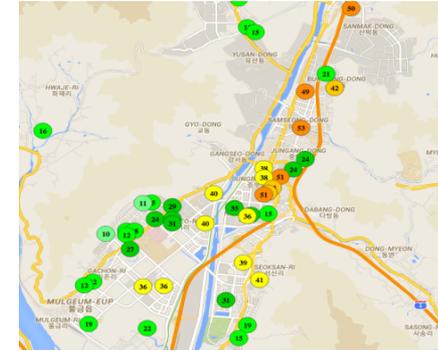
Organizations: Academia Sinica and National Taiwan Normal University

Dates: 2016+

Objective: Create a participatory urban sensing framework

Pollutants:

- PM_{2.5}
- 3000+ sites



Sample Project - Taiwan

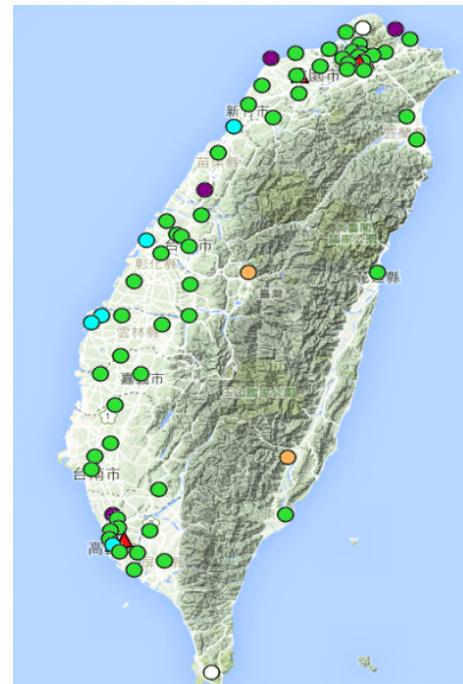
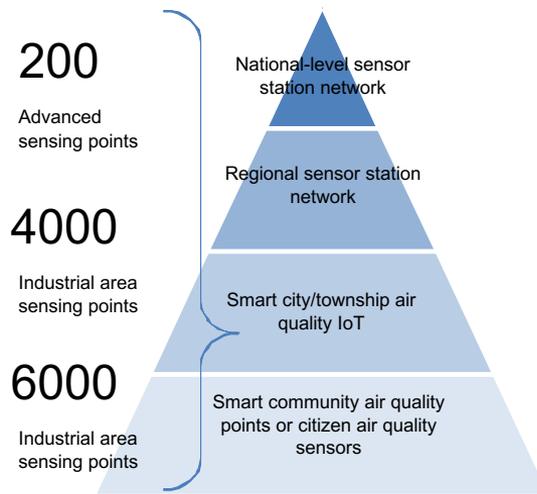
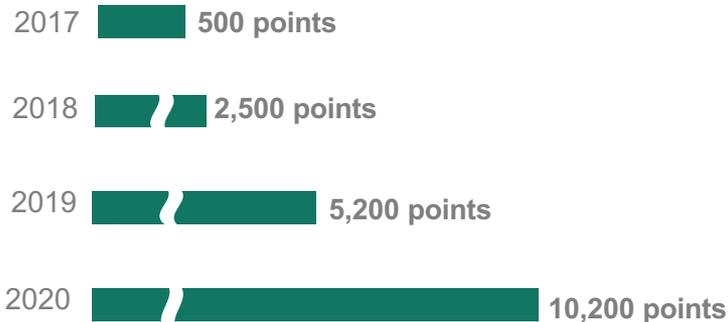
Organizations: Taiwan EPA and Industrial Technology Research Institute

Dates: 2017-2020

Objective: Deploy air sensors in major industrial areas, metropolitan areas, and townships

Pollutants:

- PM_{2.5}
- 10,200+ sites



Sample Analysis – Wine Country Fires

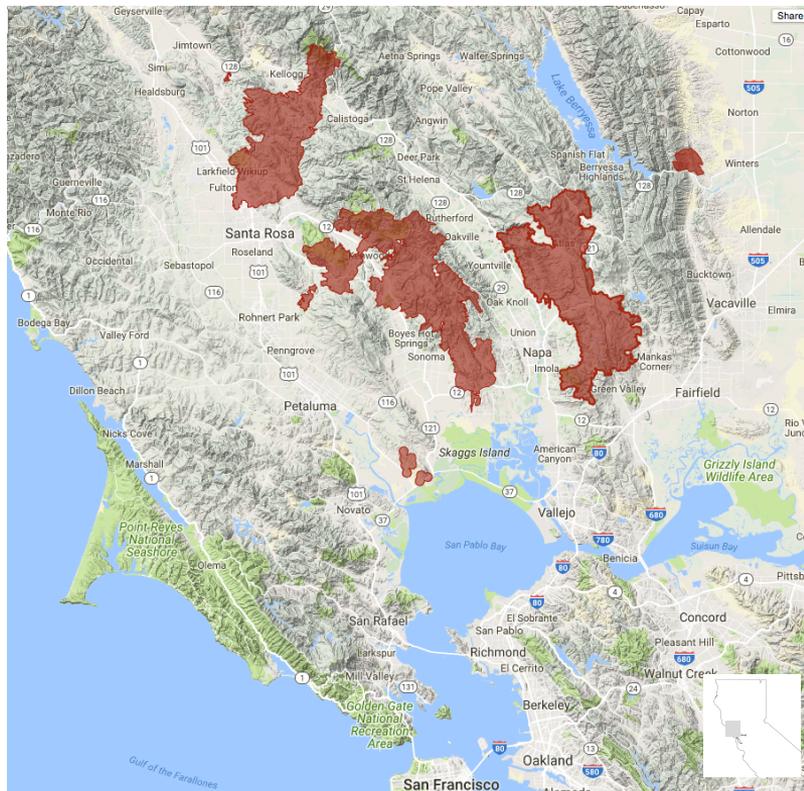
Location: San Francisco North Bay Counties

Dates: October 8-20, 2017

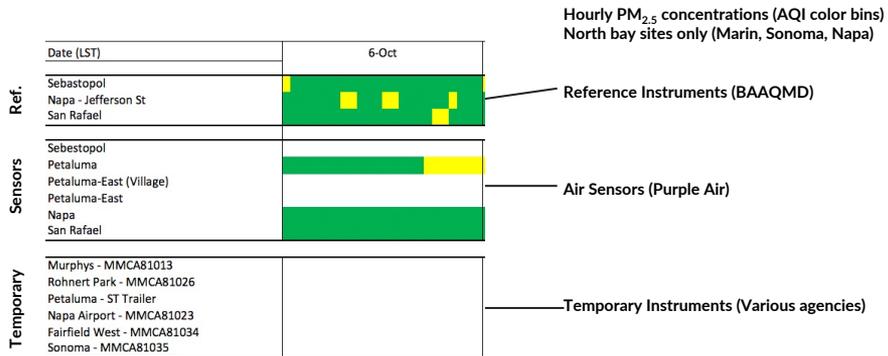
Issue: Smoke from fires ($PM_{2.5}$)

Statistics:

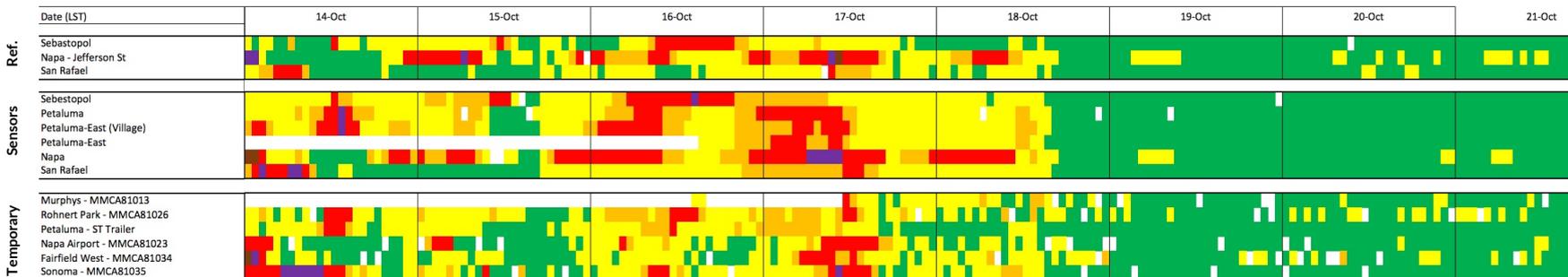
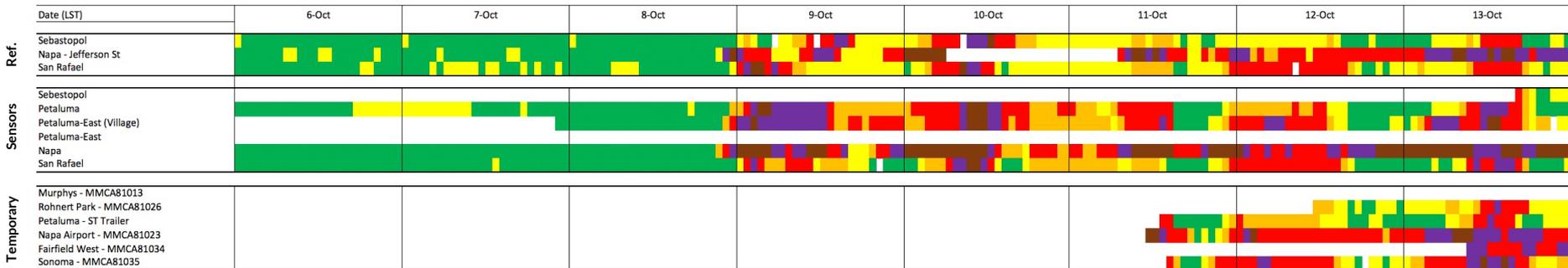
- 4 fires: Tubbs, Atlas, Nuns, Pocket
- 162,000 acres burned
- 8,900 houses and businesses destroyed
- 43 people killed
- Deadliest fires in California history



Sample Analysis – Wine Country Fires



Sample Analysis – Wine Country Fires



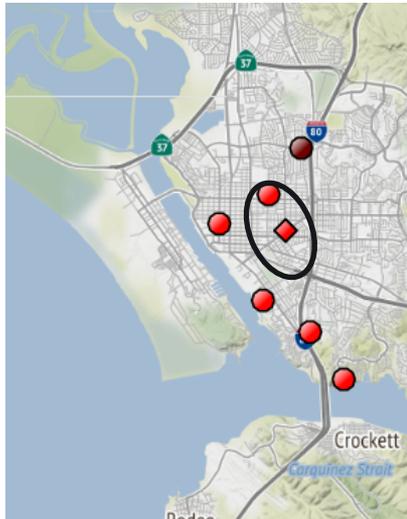
Sample Analysis – Wine Country Fires

Compare Sensors to FEM

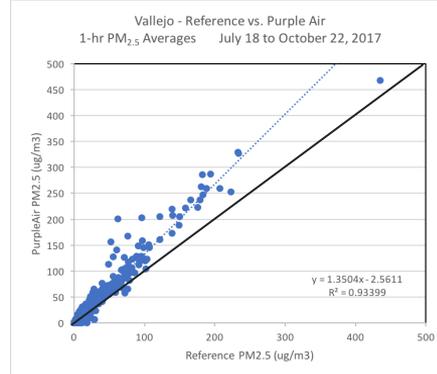
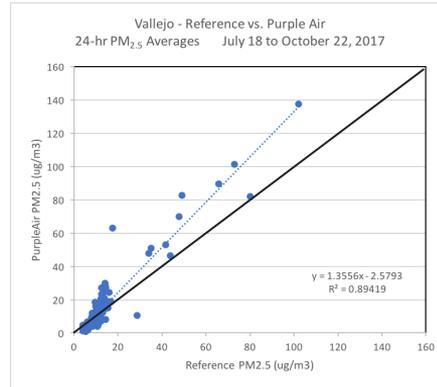
Location: Vallejo, CA

Instrument: BAM 1020

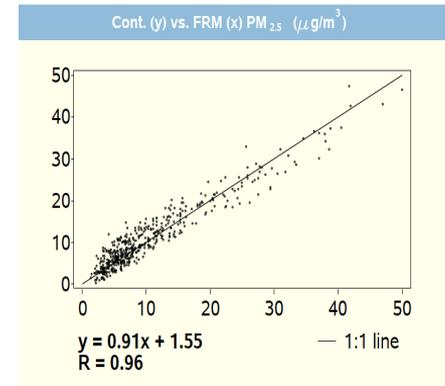
Sensor: Purple Air



Purple Air vs. FEM (2017)

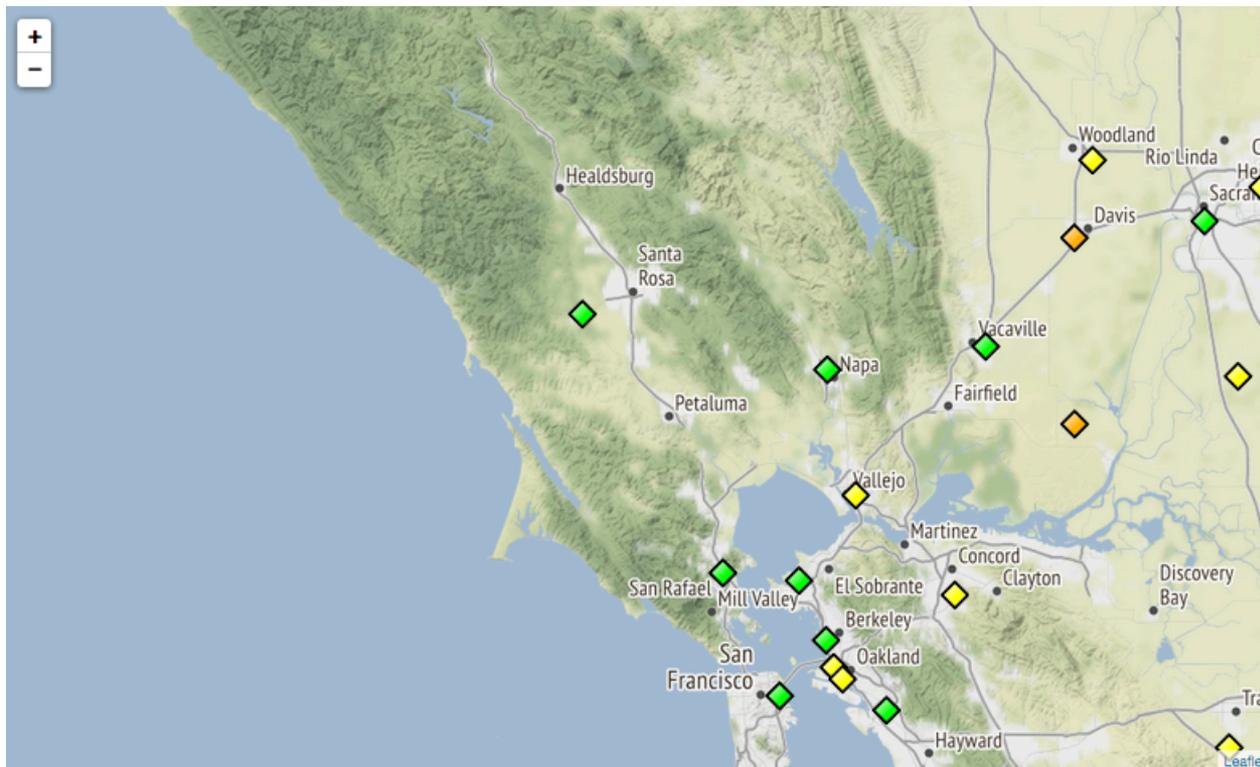


FEM vs. FRM (2008-2010)



Source: EPA's Air Data

Sample Analysis – Wine Country Fires



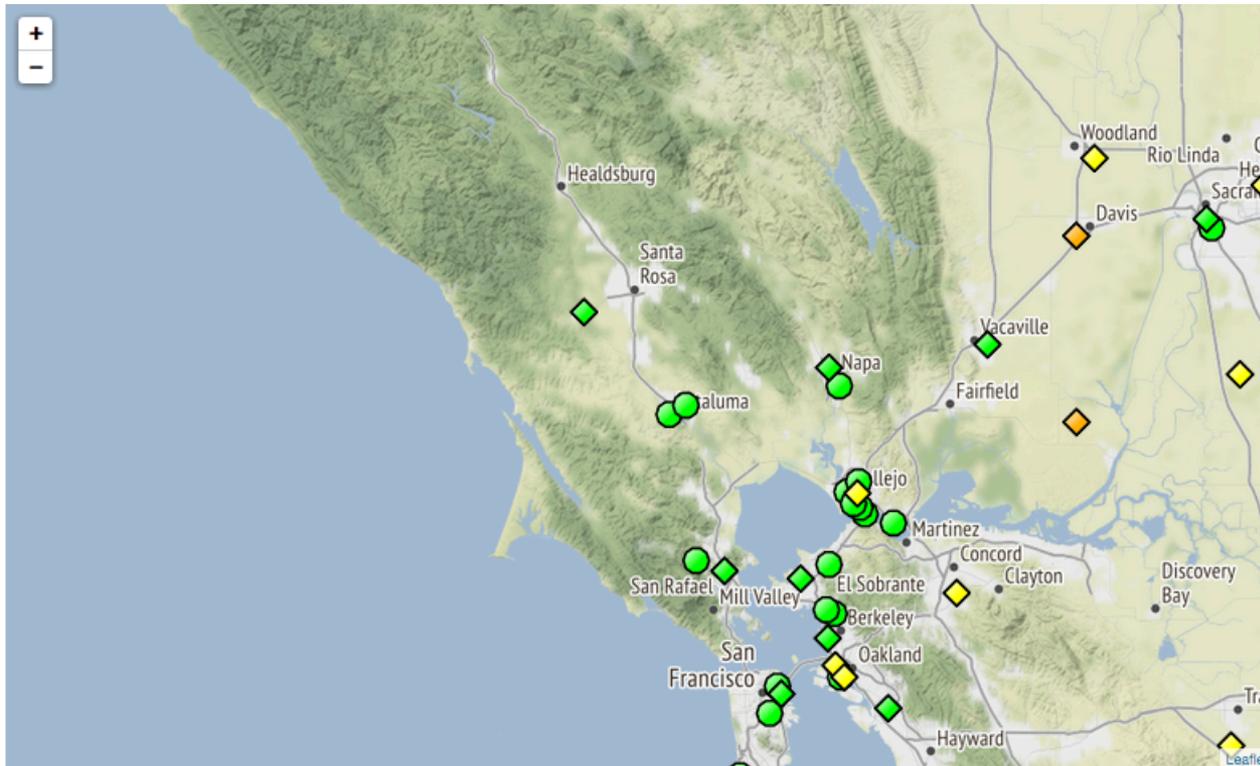
Reference 19

Sensors

Temporary 0

October 8, 2017 1200 LST

Sample Analysis – Wine Country Fires



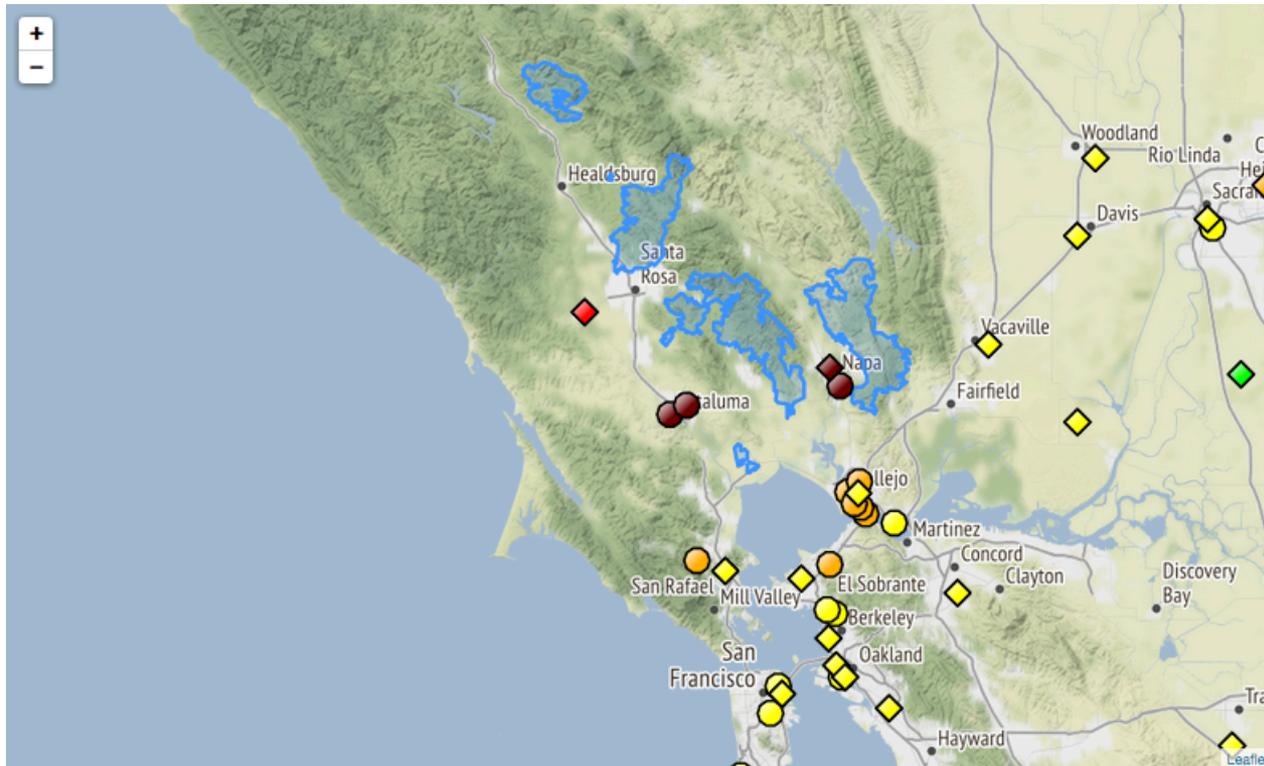
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Sensors 18

Temporary 0

October 8, 2017 1200 LST

Sample Analysis – Wine Country Fires



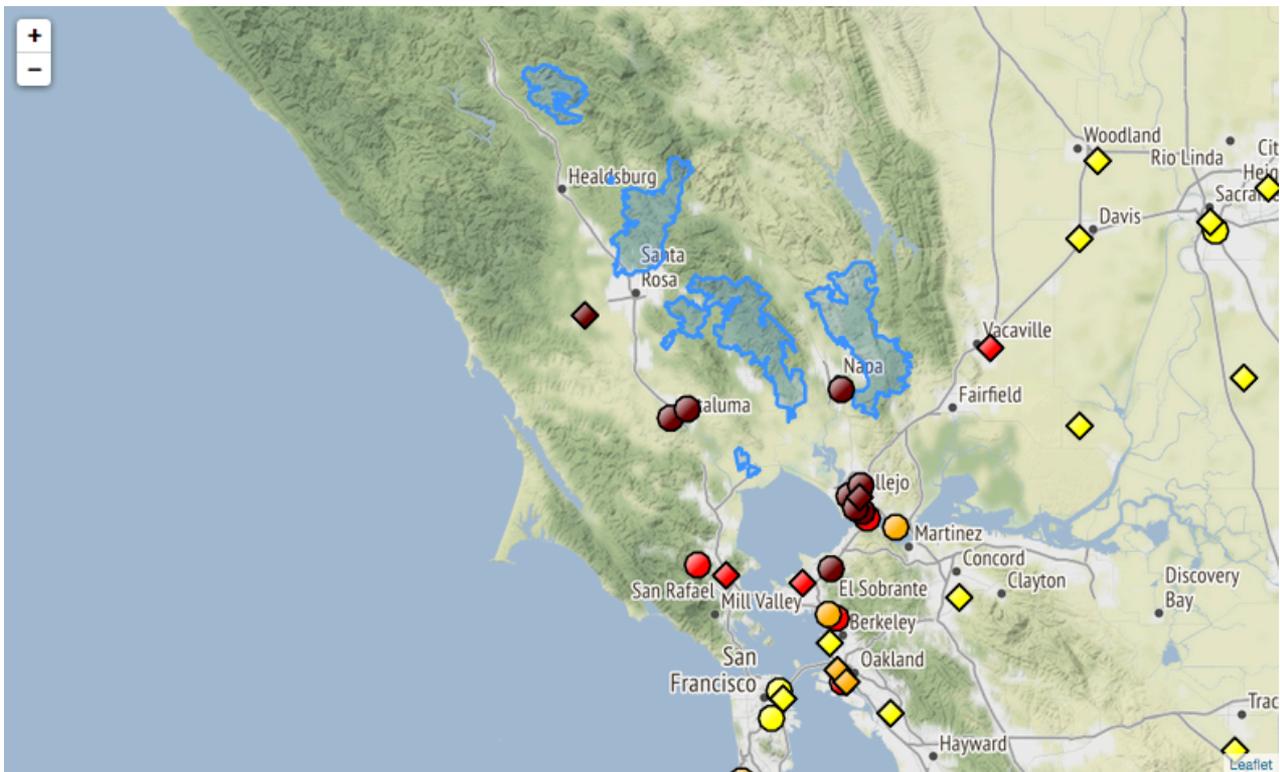
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Sensors 18

Temporary 0

October 9, 2017 1200 LST

Sample Analysis – Wine Country Fires



Reference 

19

Sensors 

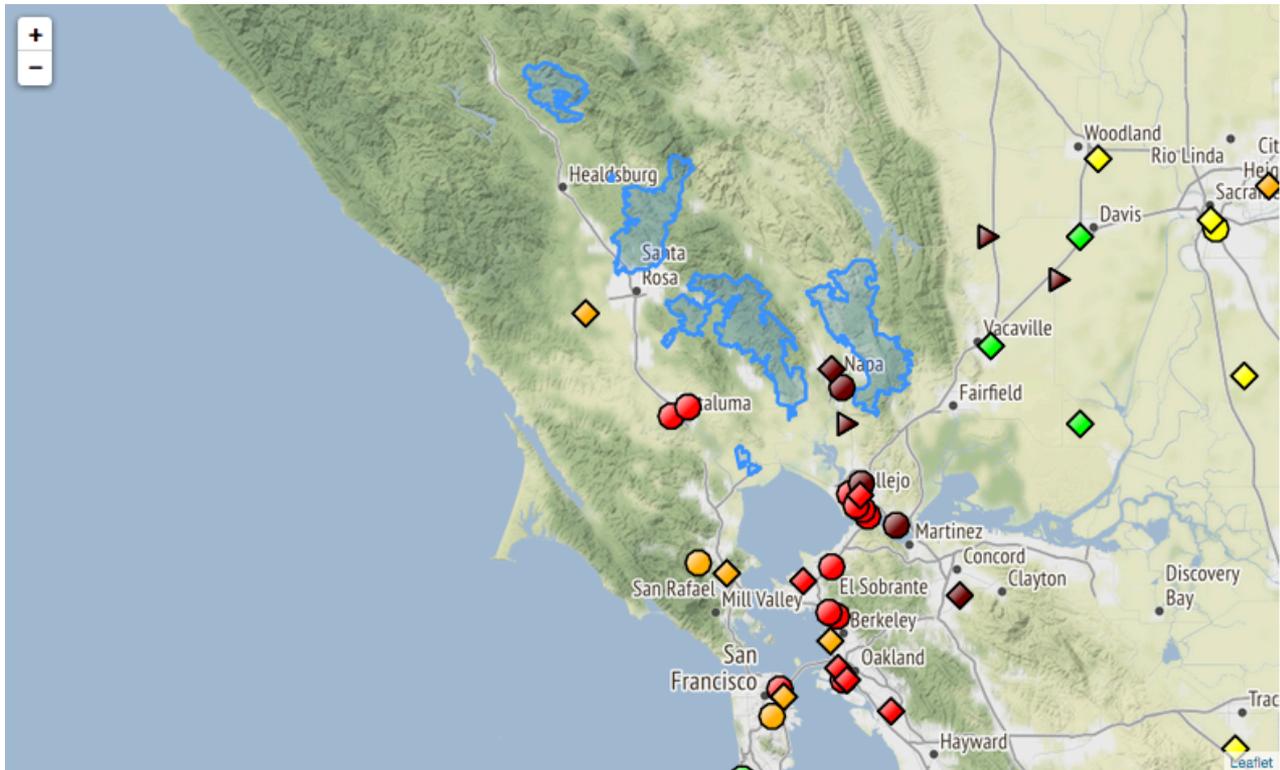
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Temporary 

0

October 10, 2017 1200 LST

Sample Analysis – Wine Country Fires



Reference 

19

Sensors 

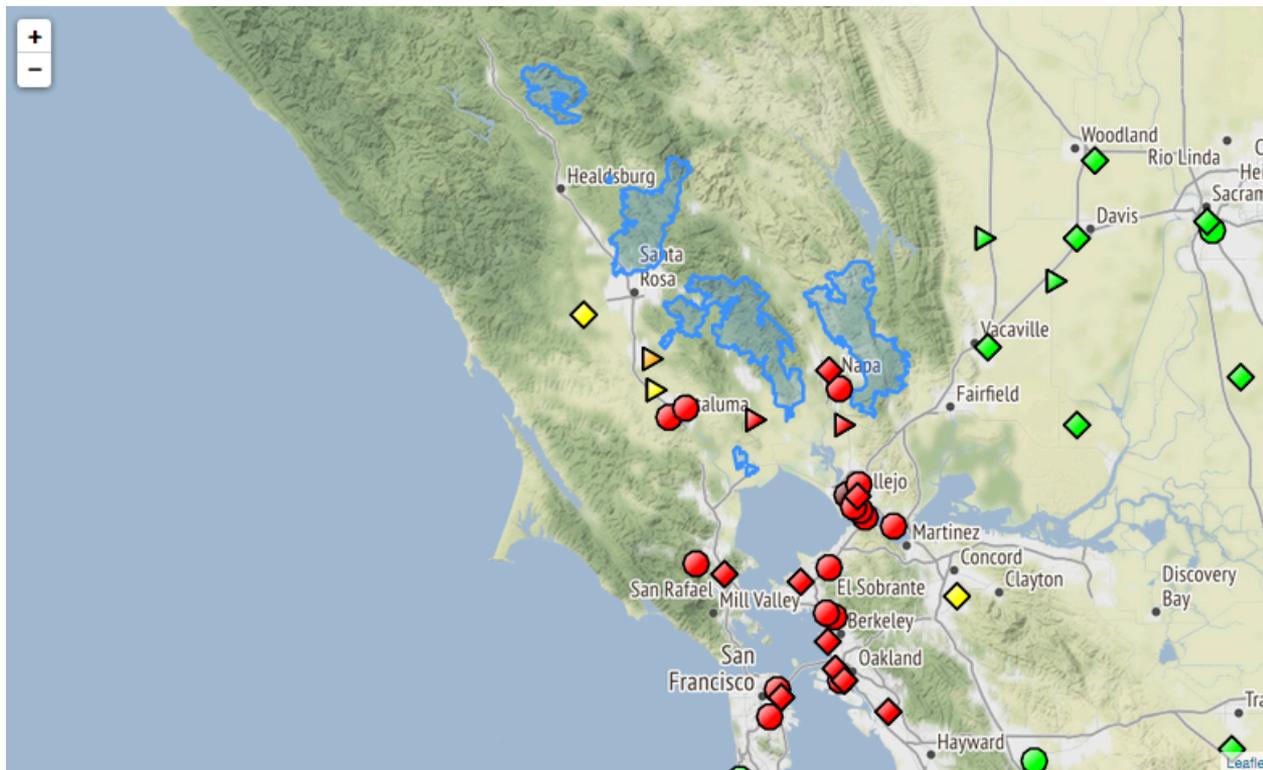
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Temporary 

3

October 11, 2017 1200 LST

Sample Analysis – Wine Country Fires



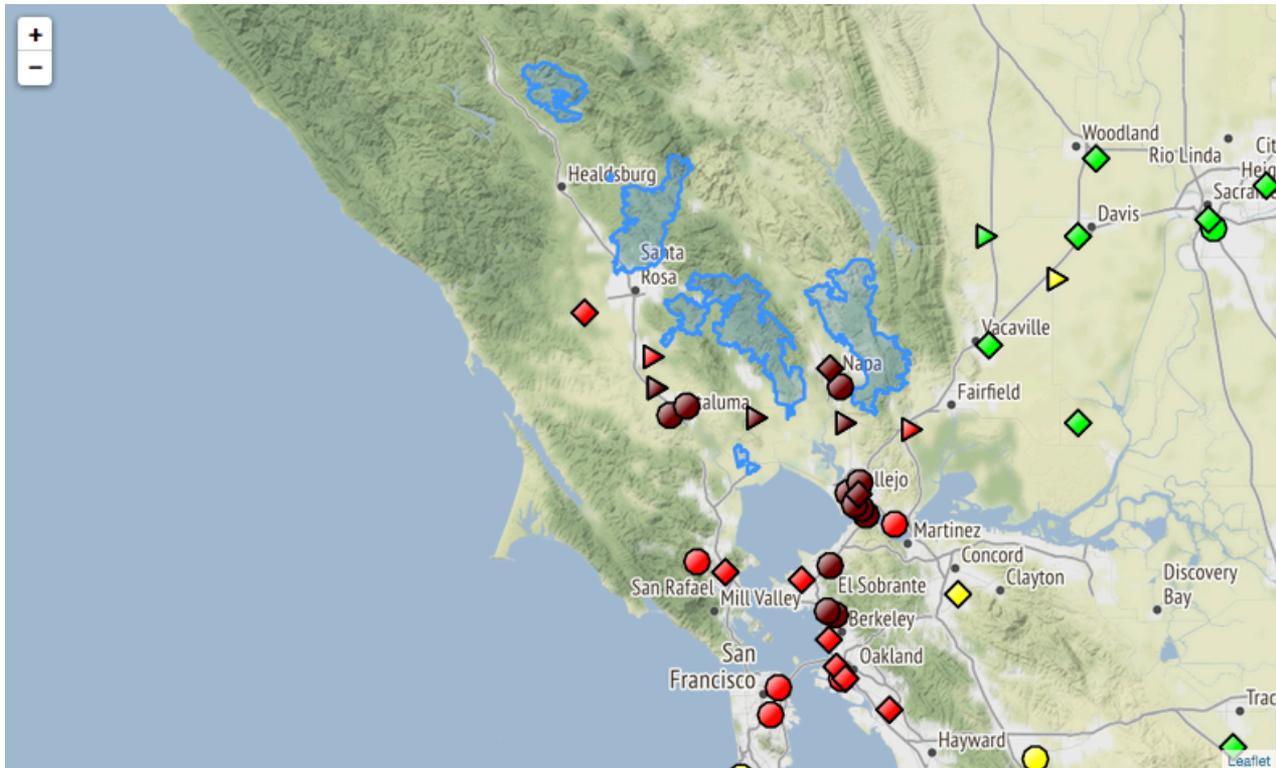
Reference 19

Sensors 18

Temporary 6

October 12, 2017 1200 LST

Sample Analysis – Wine Country Fires



Reference 

19

Sensors 

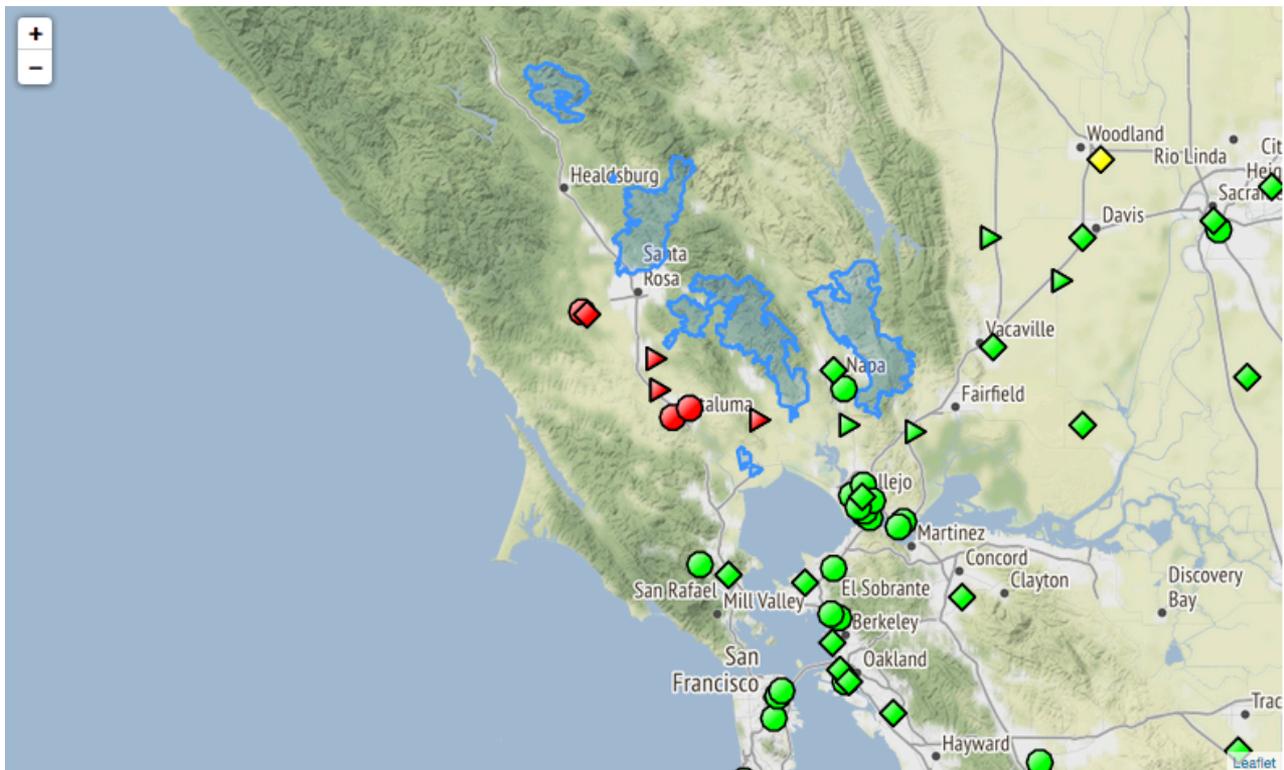
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Temporary 

6

October 13, 2017 1200 LST

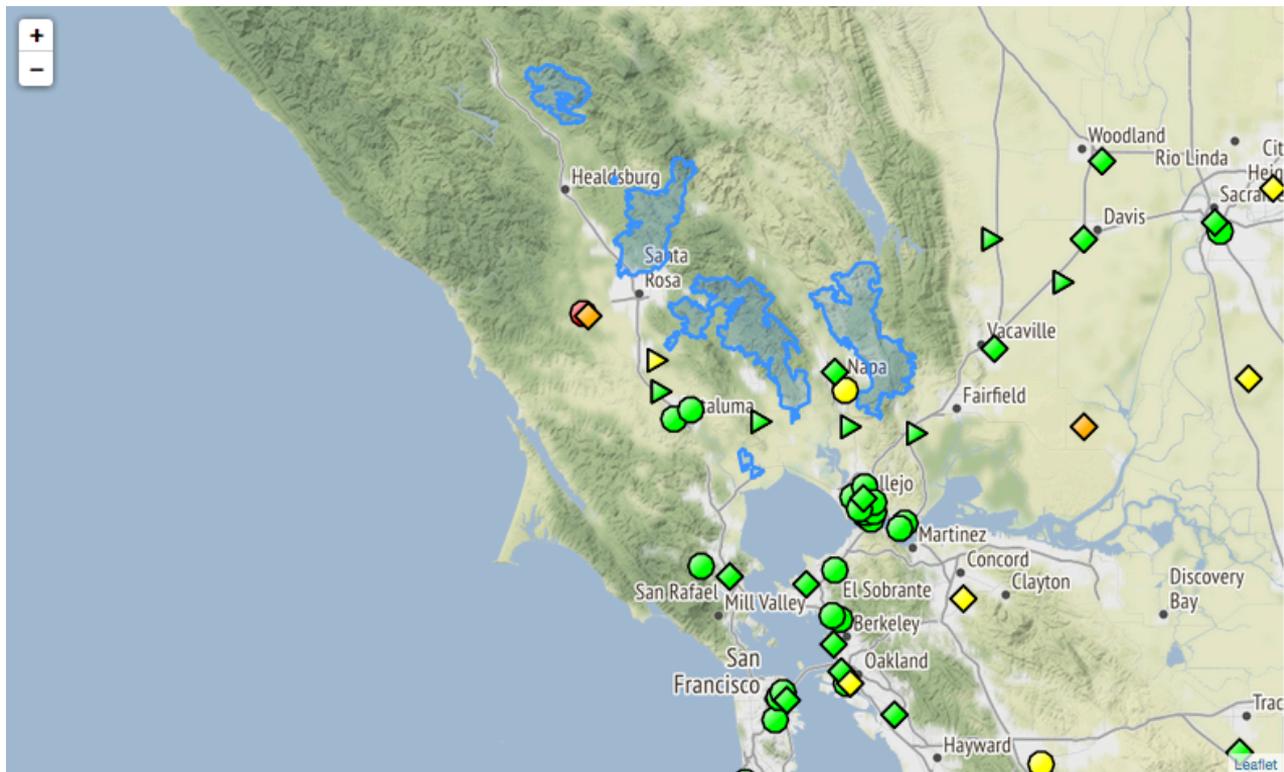
Sample Analysis – Wine Country Fires



October 14, 2017 1200 LST

- Reference 19 
- Sensors 21 
- Temporary 6 

Sample Analysis – Wine Country Fires



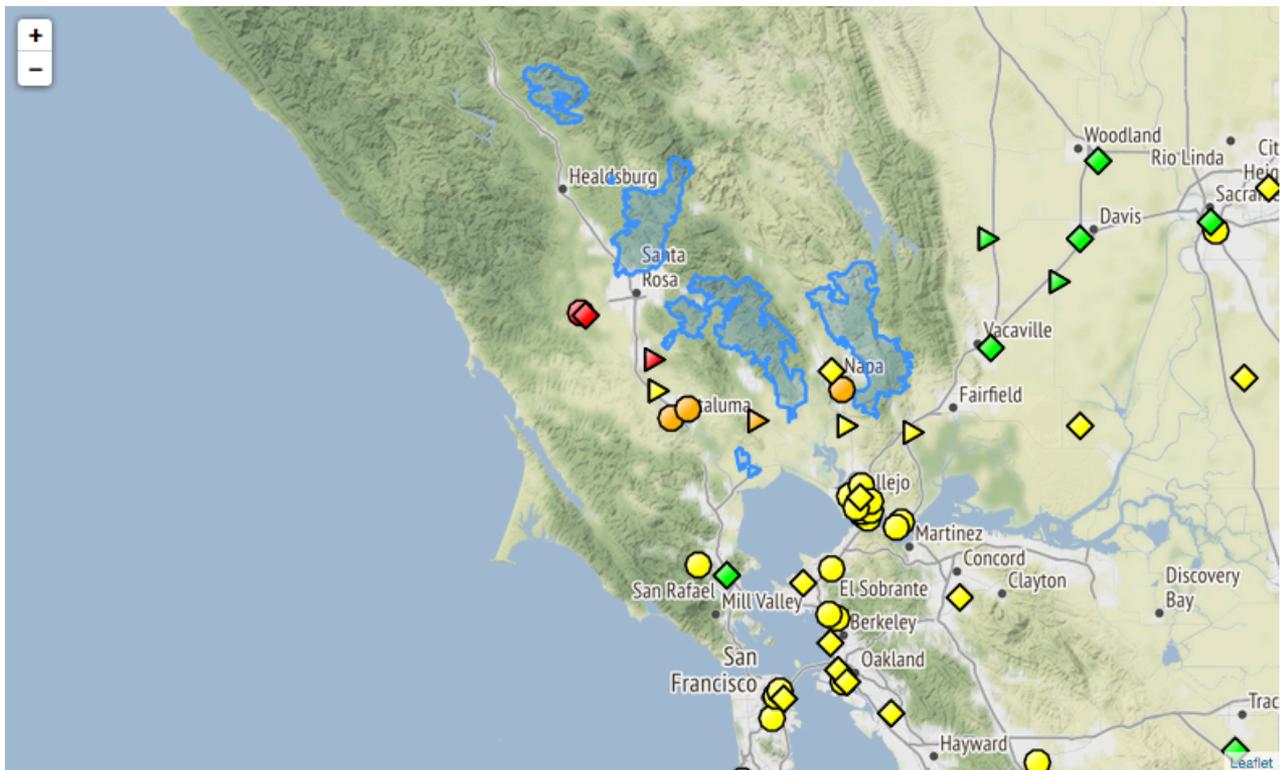
Reference 19

Sensors 21

Temporary 6

October 15, 2017 1200 LST

Sample Analysis – Wine Country Fires



Reference 

19

Sensors 

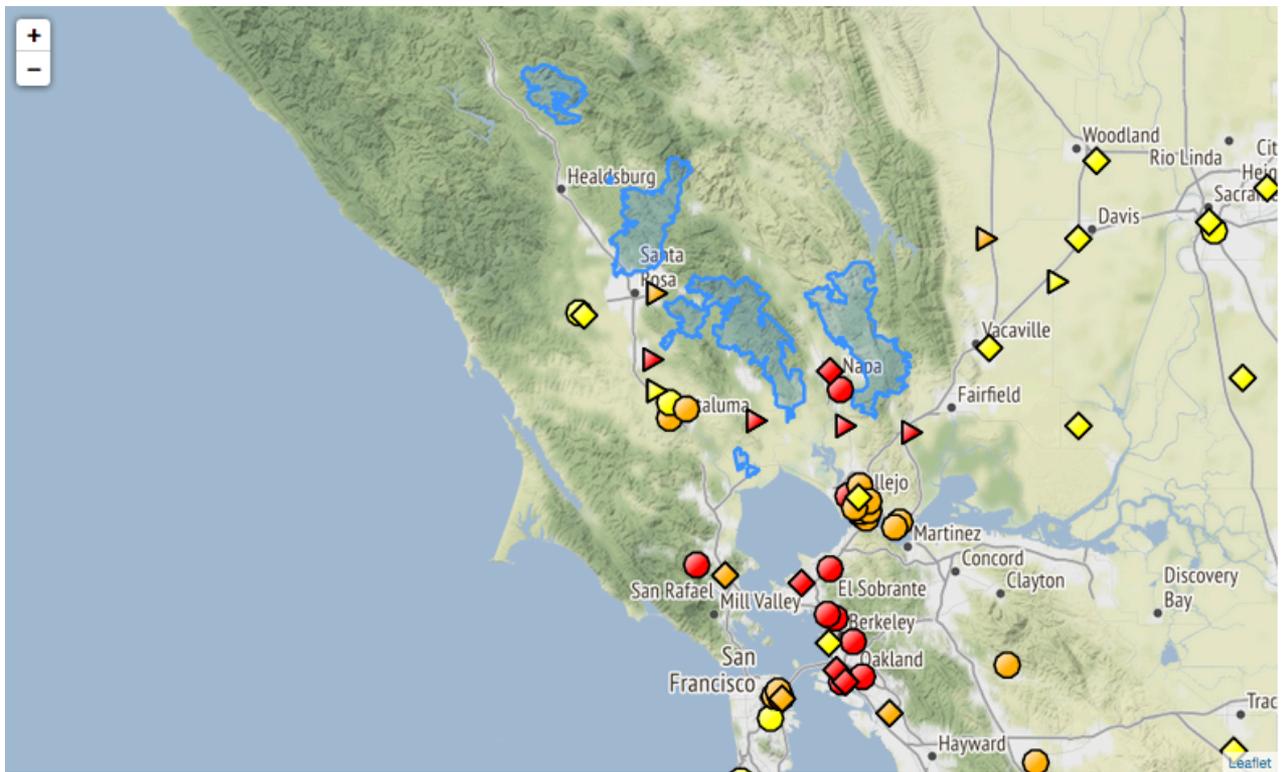
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Temporary 

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October 16, 2017 1200 LST

Sample Analysis – Wine Country Fires



Reference 

19

Sensors 

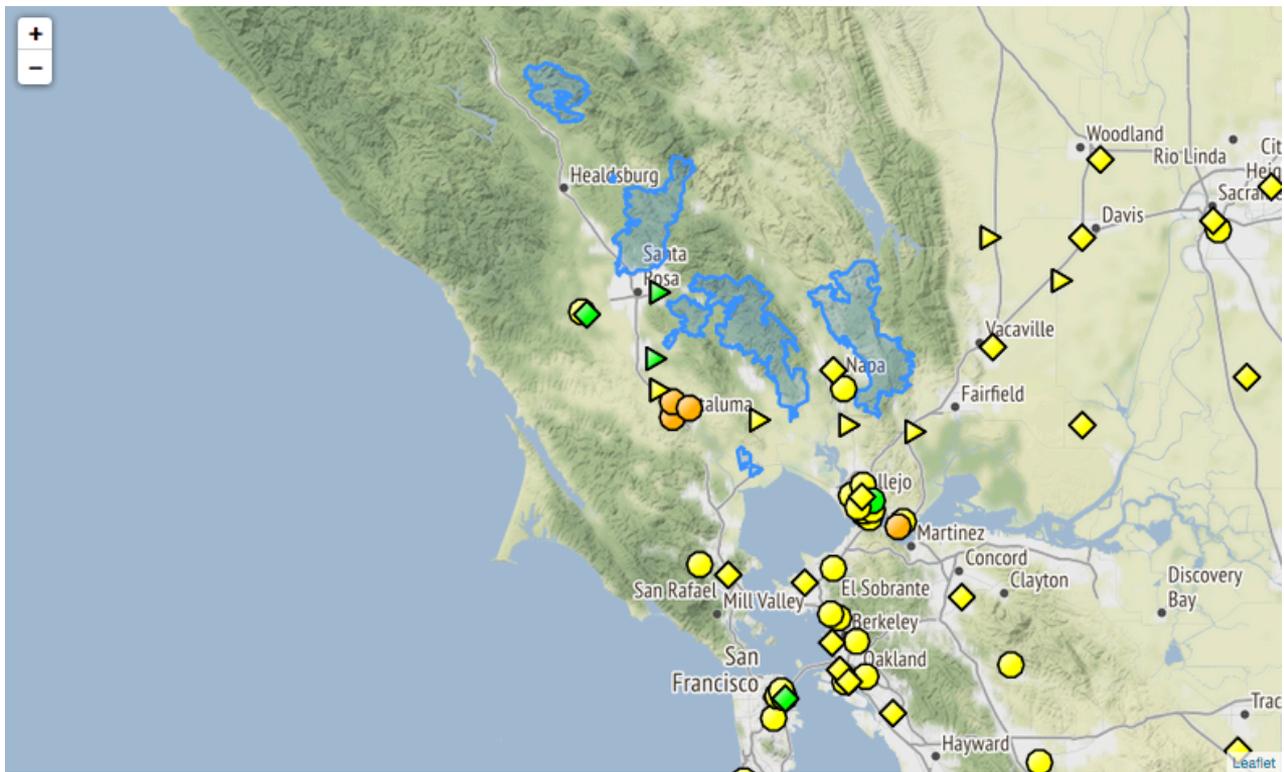
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Temporary 

7

October 17, 2017 1200 LST

Sample Analysis – Wine Country Fires



Reference 

19

Sensors 

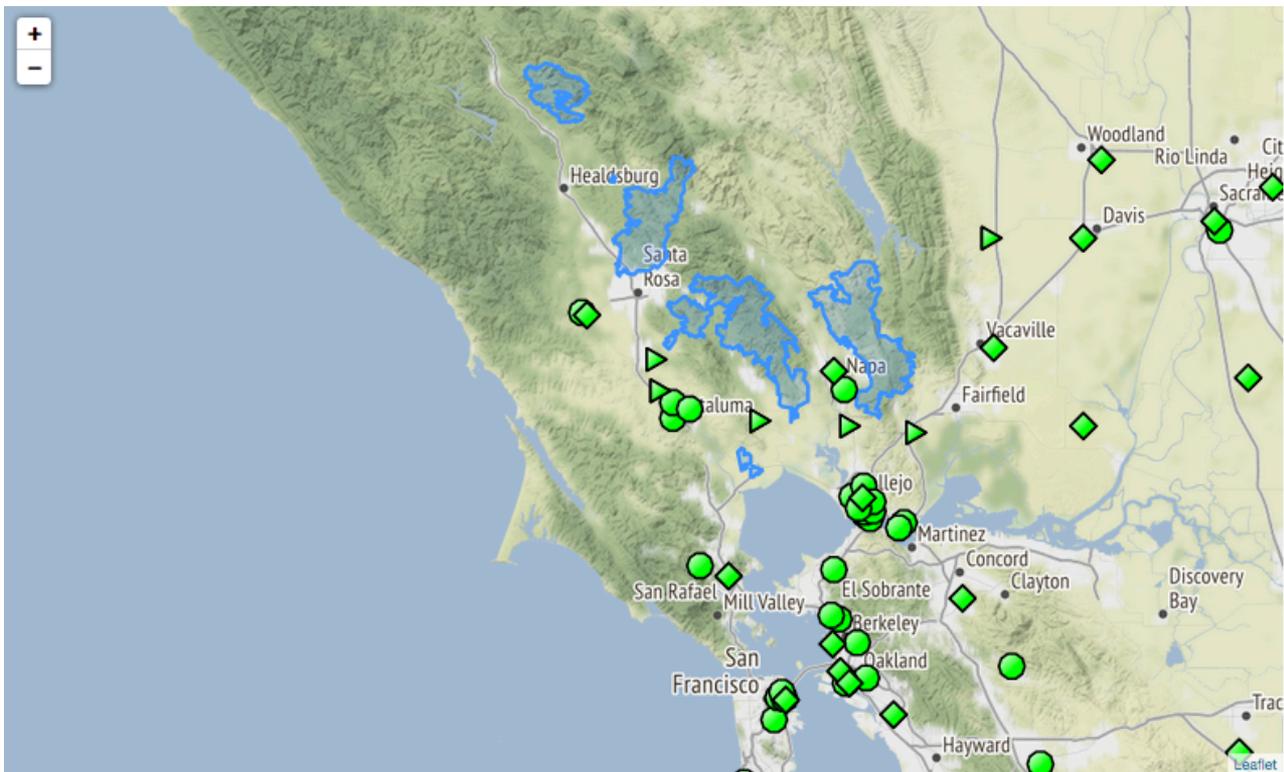
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Temporary 

7

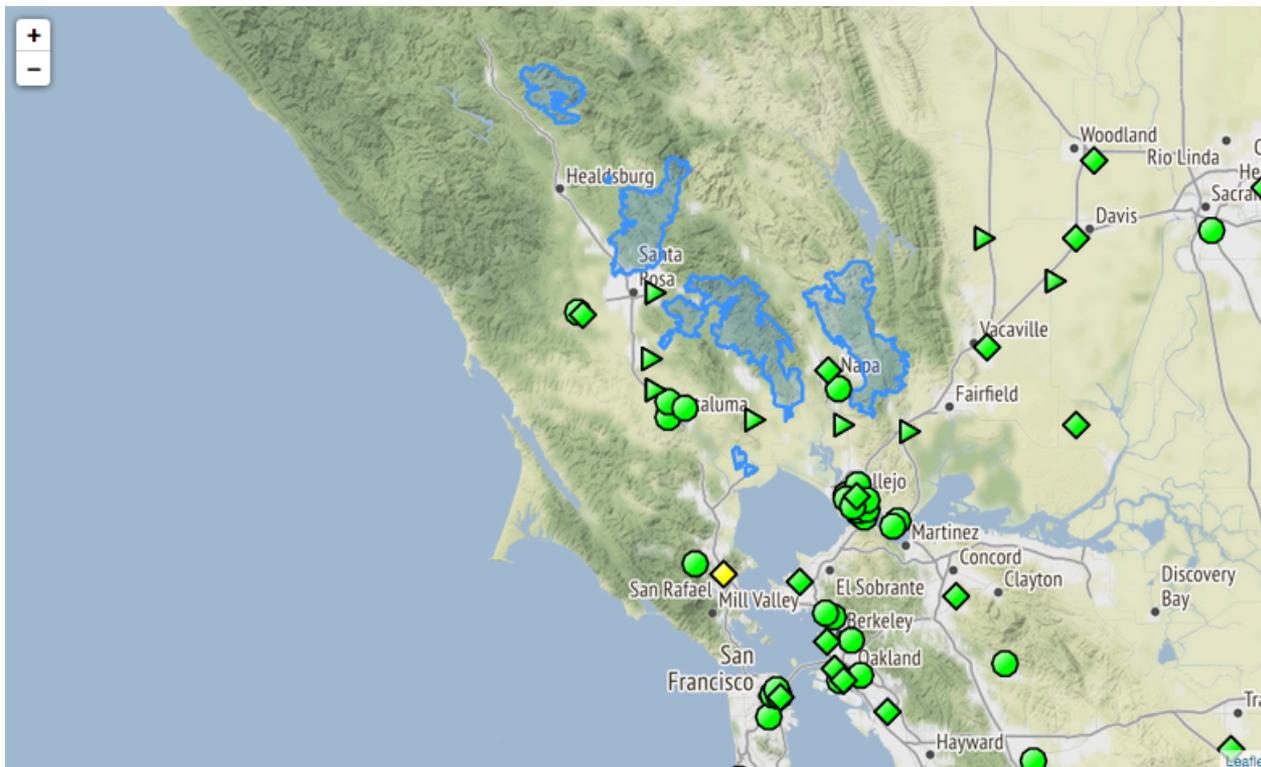
October 18, 2017 1200 LST

Sample Analysis – Wine Country Fires



October 19, 2017 1200 LST

Sample Analysis – Wine Country Fires



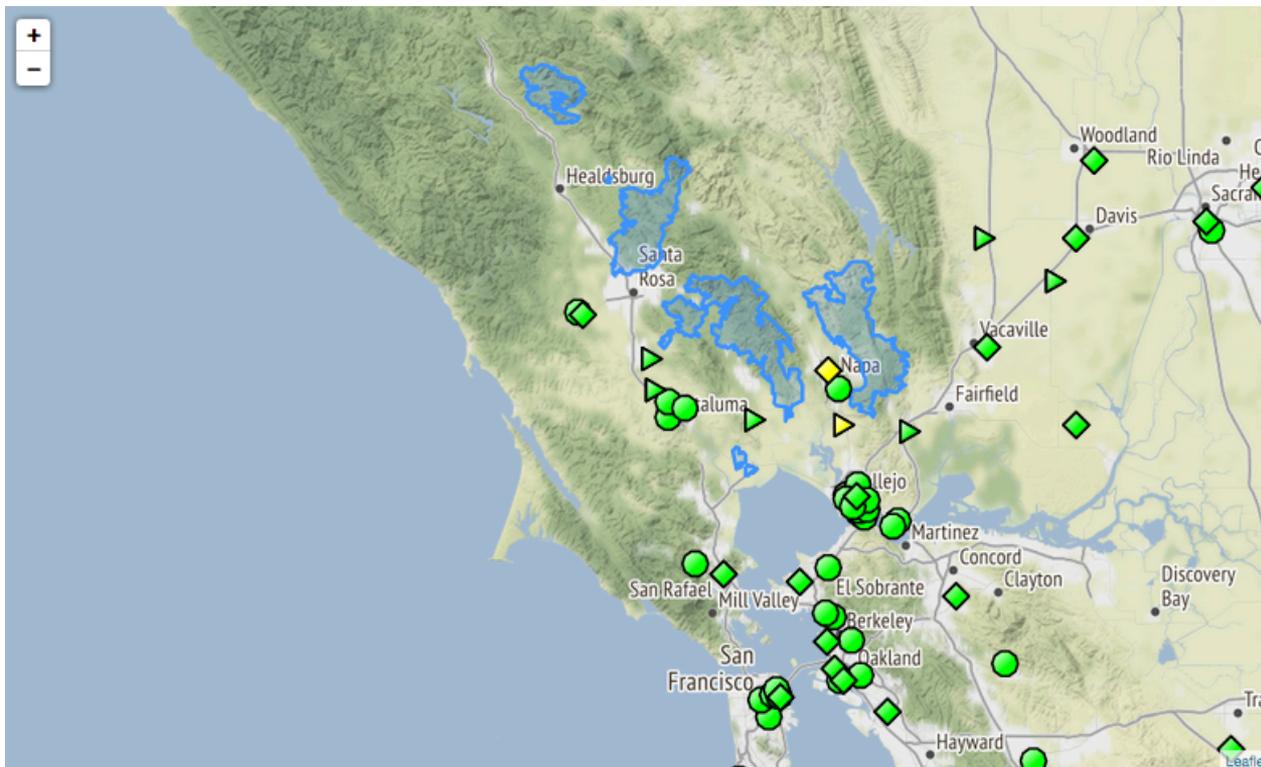
Reference 19

Sensors 25

Temporary 7

October 20, 2017 1200 LST

Sample Analysis – Wine Country Fires



Reference 19 

Sensors 25 

Temporary 7 

October 21, 2017 1200 LST

An Idea: School Monitoring Network

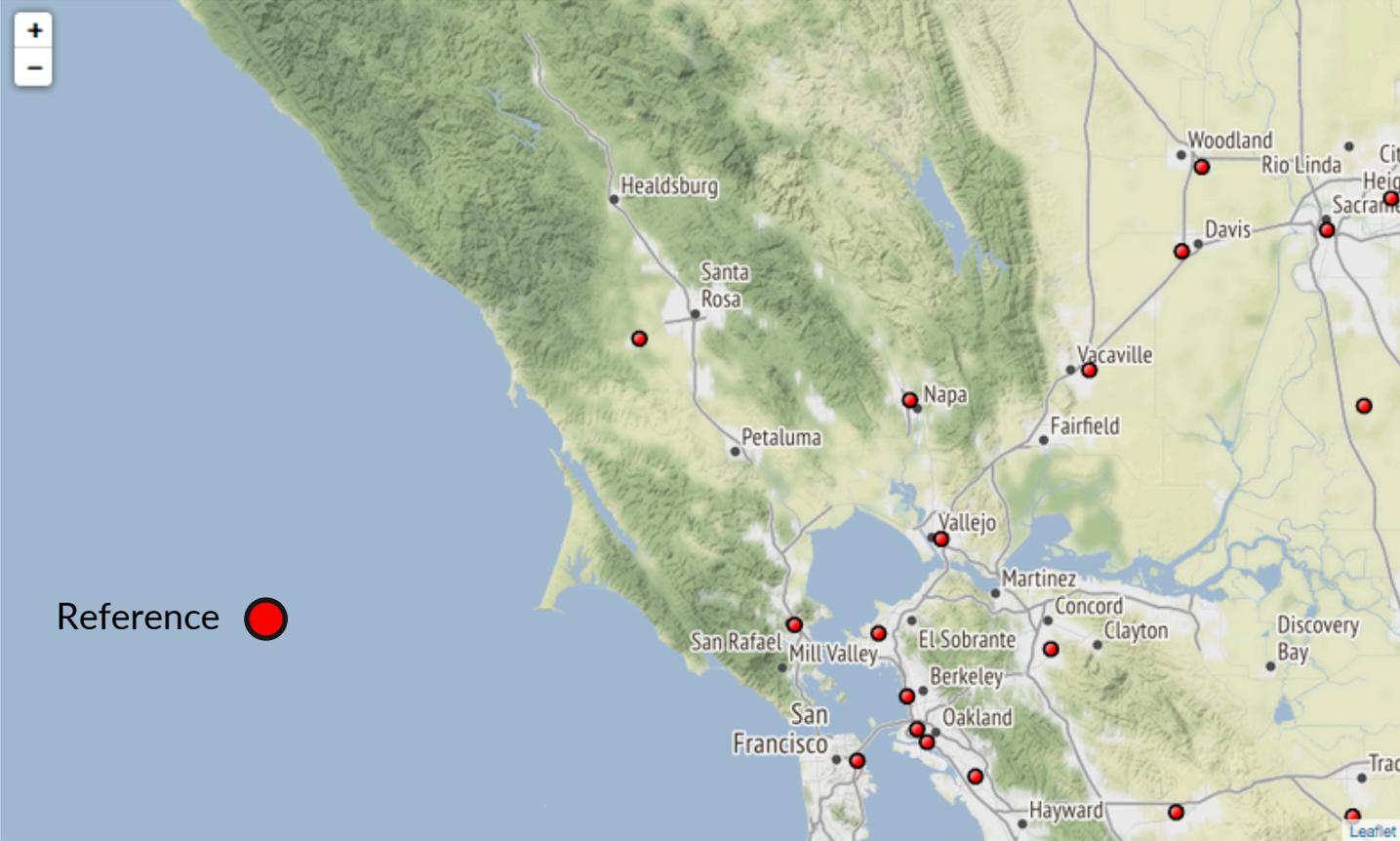
What:

- A PM_{2.5} and weather station at all California High Schools
- Air quality curriculum
- Data system to manage and ensure quality
- 4,000+ high schools

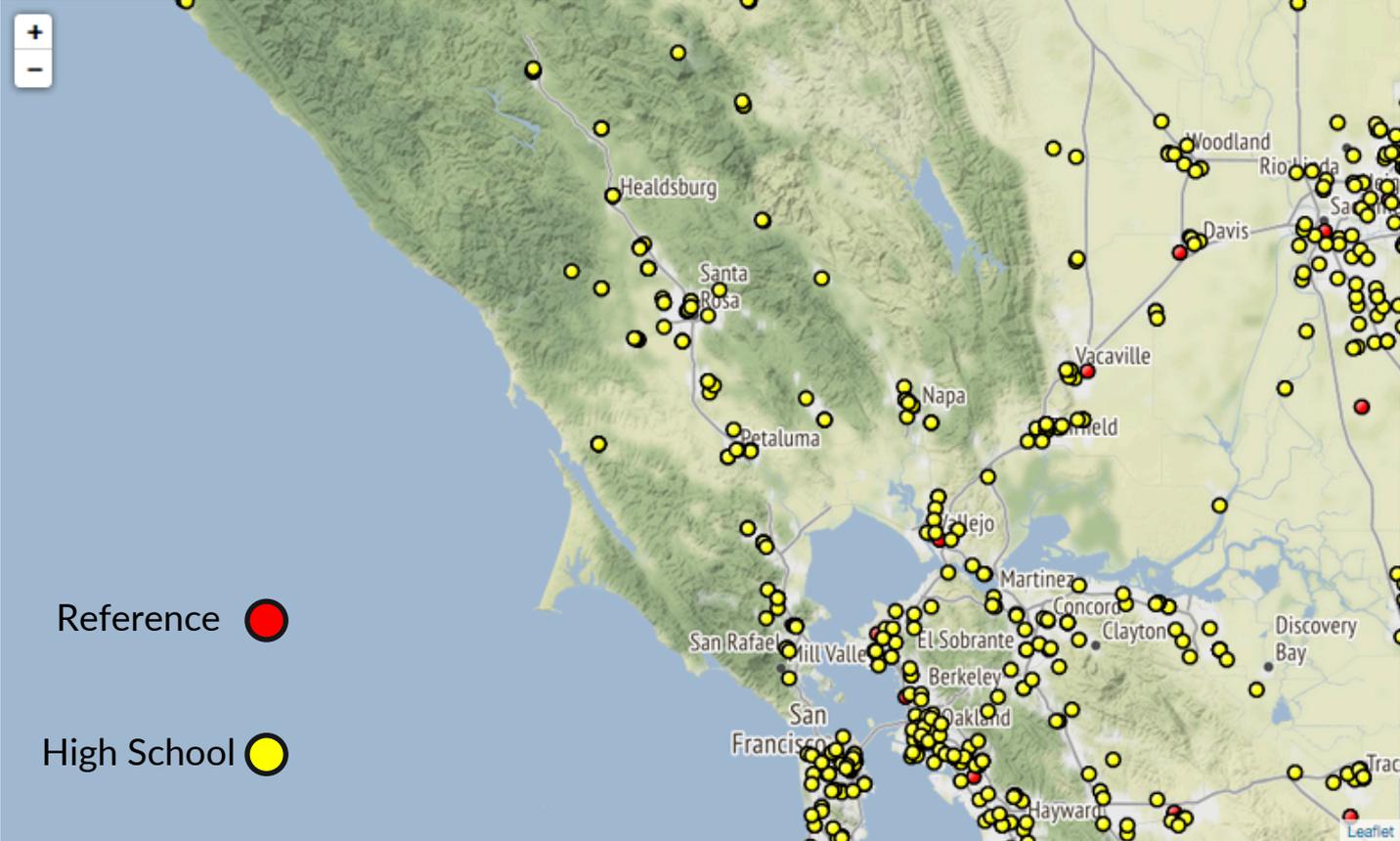
Why:

- Creates a base network that is geographically representative
- Provides timely warnings and real-time situational awareness
- Supplements reference PM_{2.5} network
- Curriculum engages future consumers

An Idea: School Monitoring Network



An Idea: School Monitoring Network



What's Needed?



Sensor Performance

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



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.

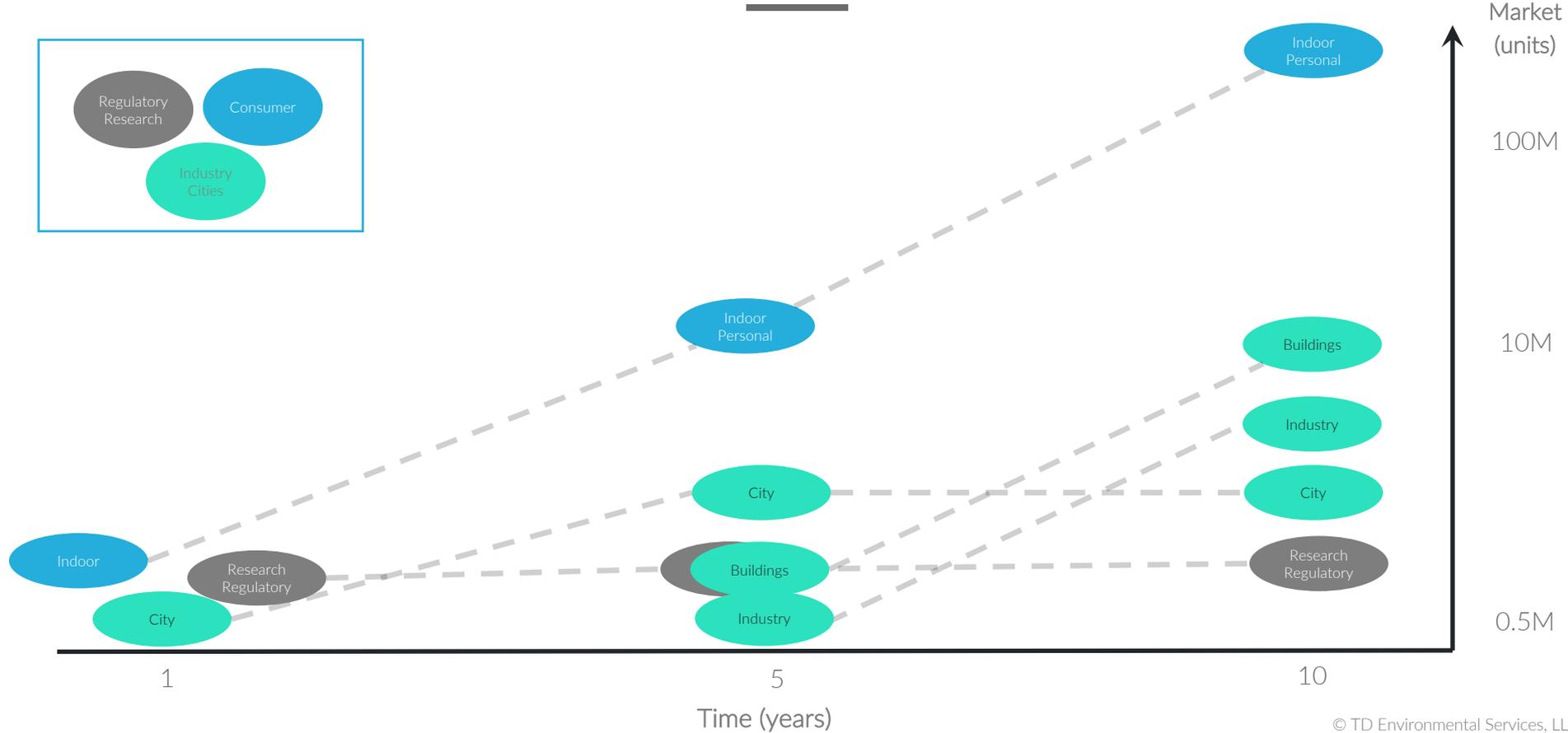
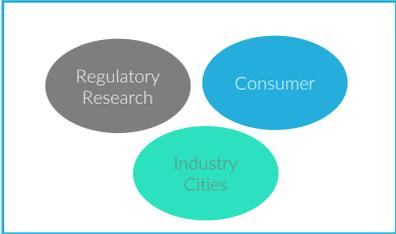


Ecosystem – Users & Suppliers

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

Market Evolution

Market growth in next 10 years



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