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Air Quality Sensor Bootcamp

Implementation

Best Practices for Air Sensor Network Design

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Air Quality Sensor Bootcamp
Air Sensor Network Design

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Agenda

01 Brief Review of Previous Sessions

02 Air Sensor Network Design Framework

03 Network Design in Action

04 Q&A

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AIR POLLUTION HUMAN HEALTH IMPACTS

EYES

Because there is a high flow of blood in the eyes, they are especially sensitive to small pollution particles like those found in PM2.5. Conditions such as dry eye syndrome, retinopathy, glaucoma, and cataracts have been connected to high air pollution exposure.

BRAIN

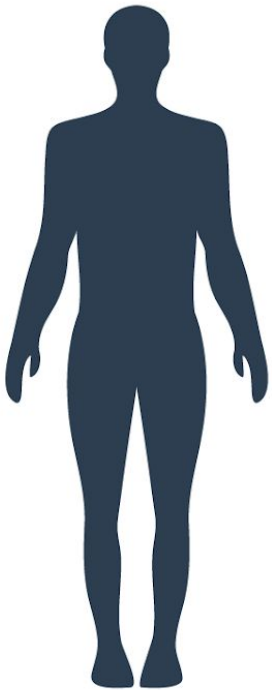
Air pollution exposure has been linked to a variety of neurological and cognitive impacts, including memory impairment, learning disabilities, anxiety, depression, schizophrenia, ADHD, and neurological conditions including dementia, Alzheimer's disease, Parkinson's disease, and stroke. Studies have even linked precise air pollution decreases to lowered dementia risk.

LUNGS

A slew of respiratory impacts are attributed to dirty air, from respiratory inflammation to asthma development to chronic loss of pulmonary function. Because most air pollutants are breathed in, the respiratory system is often the place where air pollution-related disease is most readily observed.

HEART

Cardiovascular disease and death are closely linked to air pollution, with outcomes of heart disease, heart failure, cardiac arrest, and arrhythmias. Some studies have even shown a stronger correlation between cardiovascular damage and death after air pollution exposure than oberved with respiratory diseases.



STOMACH

Studies have demonstrated a link between poor air quality and gastrointestinal diseases, including inflammatory bowel disease (IBD), irritable bowel syndrome (IBS), and appendicitis, as the inhalation of air pollution is associated with changes to the gut microbiota. Long-term exposure to high concentrations of NO2 and PM has been linked to the early onset of Crohn's Disease.

LIVER

Animal studies find that long-term exposure to ambient air pollution is associated with metabolic-associated fatty liver disease, a disease that affects a quarter of the global population. The disease can progress to liver cancer and liver-related death.

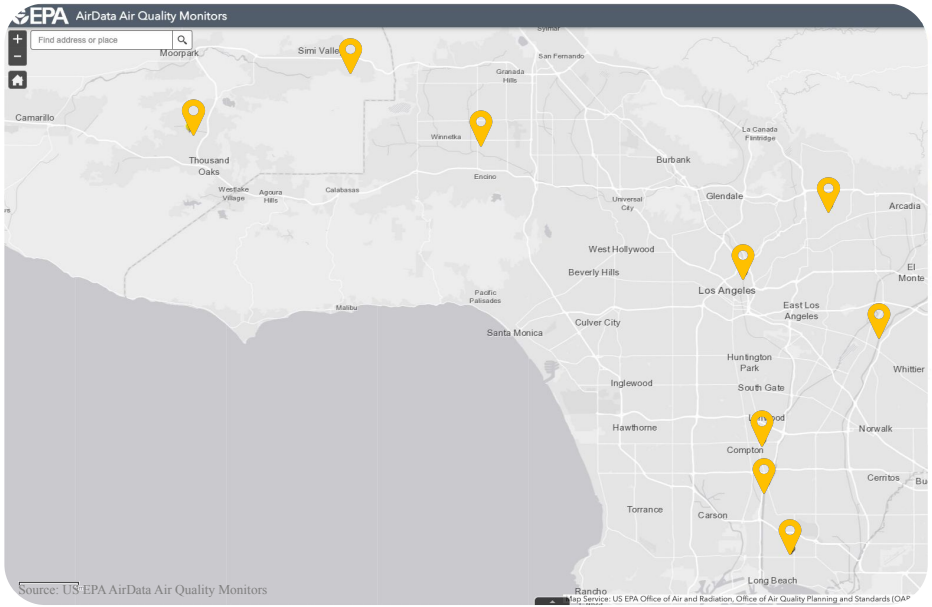
BONES

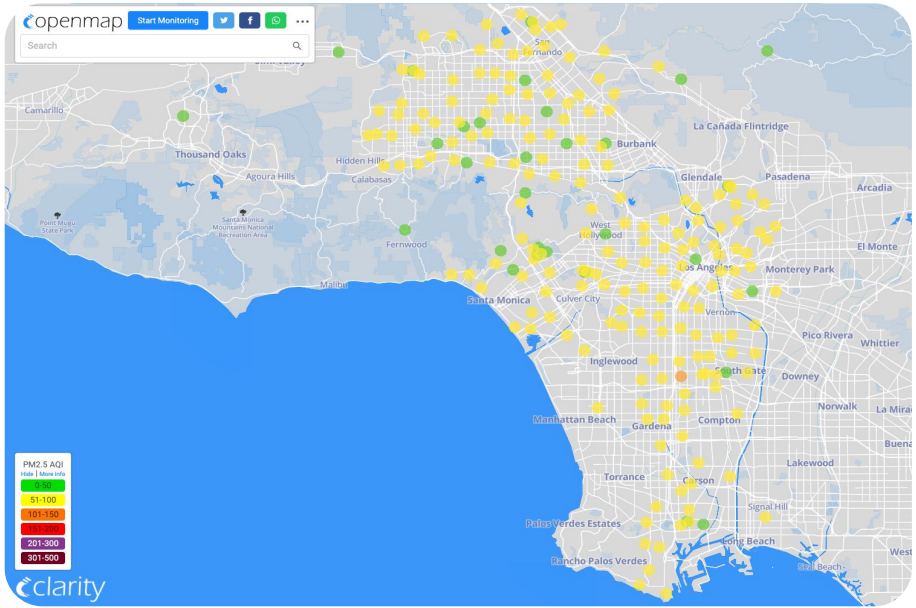
A 2020 study found that ambient air pollution exposure is linked to lower bone mass. Other studies have found that air pollution may act as a risk factor for osteoporosis and be linked to higher rates of hospitalization for bone fractures, though research is limited.

REPRODUCTION

Though the mechanisms behind it are not yet understood, exposure to higher levels of air pollution has been associated with lower levels of fertility and more difficulty in conceiving, including in those undergoing in vitro fertilization, as well as in a variety of sperm quality parameters. Further research is needed to investigate how exactly air pollution acts on the reproductive system.

Regulatory vs. Hybrid Monitoring in Los Angeles, CA





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Low-cost Air Sensors : US EPA Recommendations

US EPA recommends sensors for:

- Science education and research
- Conducting air monitoring projects
- Supplementing regulatory air quality measurements
- Measuring local air quality to better understand sources of pollution

Air pollution hotspots

Short-term changes in air quality

Air quality data for rural areas

The **United States Government Accountability Office has** stated that low-cost sensors have the potential to help meet some monitoring information in additional locations and/or more real-time data.

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Other US Agencies' Air Sensor projects

- **California Air Resources Board - Community Air Monitoring Systems Utilizing Low-Cost Sensors**

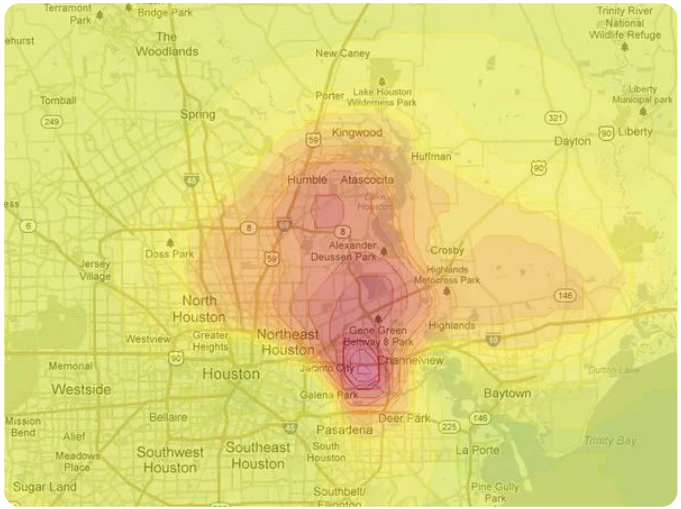
  Assembly Bill 617 - Community Air Protection Program allows communities to incorporate the use of Low-Cost sensors into their community driven air monitoring plans

- **South Coast Air Quality Management District/US EPA STAR Grant**

  Air Quality Sensor Performance Evaluation Center (AQ-SPEC) - funds the deployment of low-cost sensors to characterize and evaluate their performance

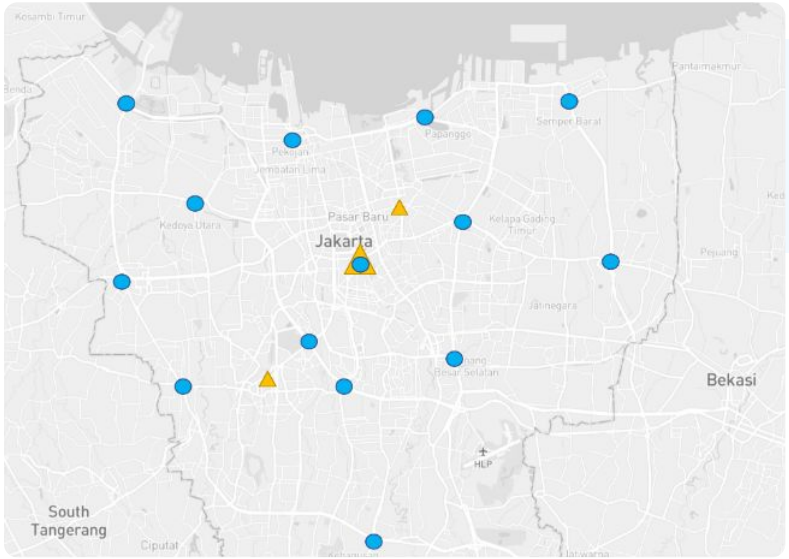
- **Houston, Texas**

  - Data sharing between community based organizations, the City of Houston, and Harris County
  - Community monitoring using Clarity Nodes influenced placement of a US EPA regulatory monitor



[Houston Clean Air Network: Check out the story on NPR!]

How to Approach Designing a Sensor Network?



: (14x) Clarity Node-S air monitors

: Existing reference sites (PM2.5)

Sensor Network Design Research

- There is limited research and guidance on designing a low-cost sensor network
- The variety in project scopes makes it challenging to create a sensor network design framework that will serve every project

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Sensor Network Design Definition

The process used to determine the **optimal placement of individual air quality sensors** to measure pollutant concentrations and **answer specific project goals.**

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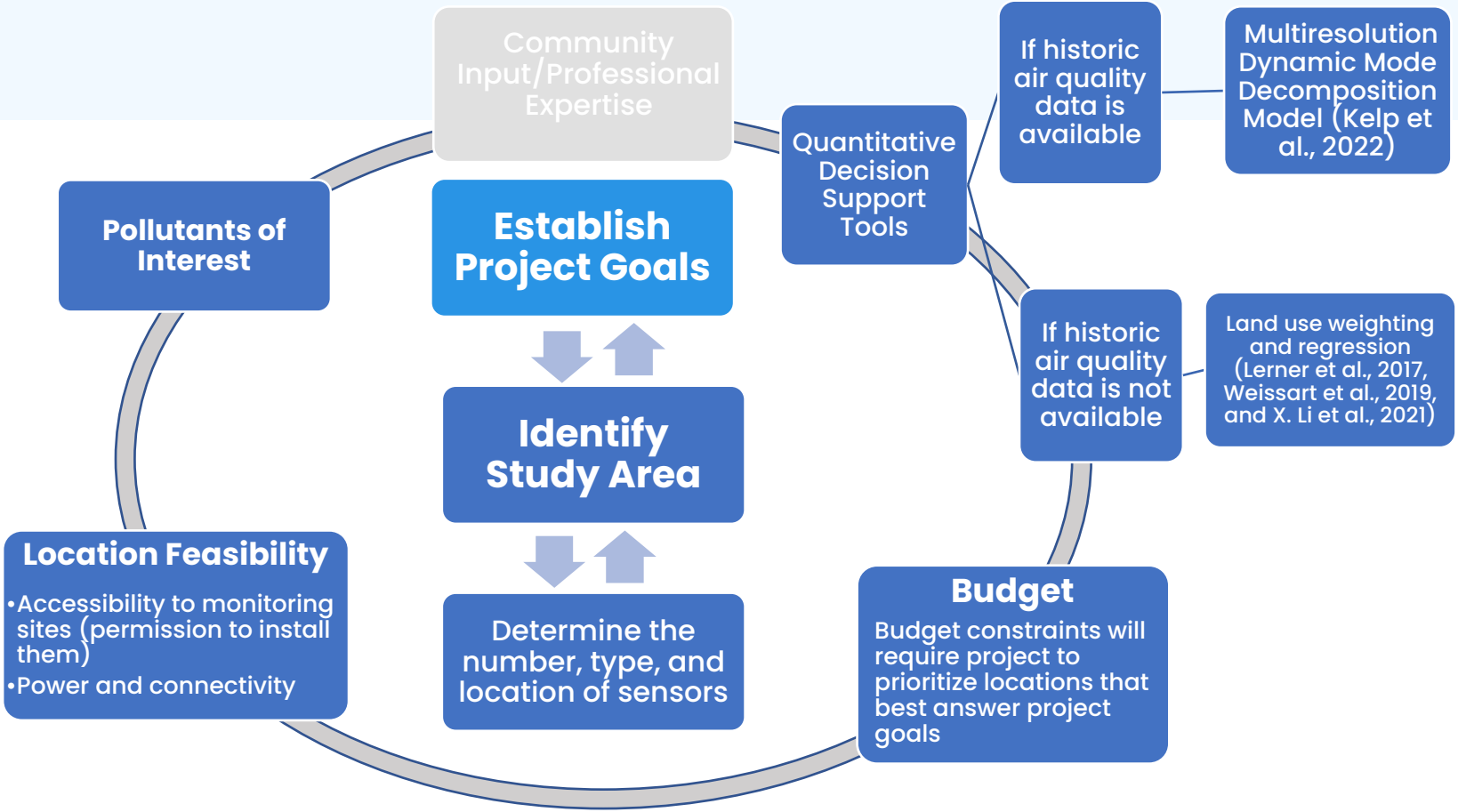
Common Literature Themes

Literature Review

- Project goals
- Project budget
- Air quality knowledge
- Air pollution sources
- Community experience
- Locations for sensor placement

Check out Maggie's PhD dissertation here!

Sensor Network Design Decision Framework



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Example of a Quantitative Decision Support Tool

- US EPA-funded pilot study by Kelp et al. used a **multi resolution dynamic mode decomposition to identify the optimal placement of PM2.5 sensors**
- Obtained PM2.5 data from regulatory monitors between 2000 to 2016 over the contiguous United States to **study the variation of PM2.5 concentrations over one day to identify high-priority sensor locations**
- Research suggests that there are **gaps in the current EPA monitoring network** in certain areas of the United States

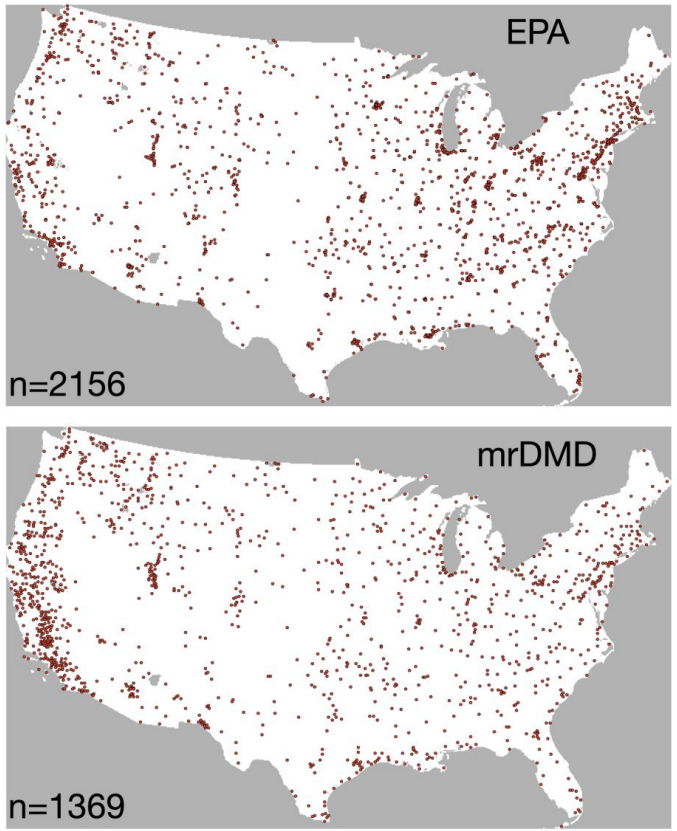
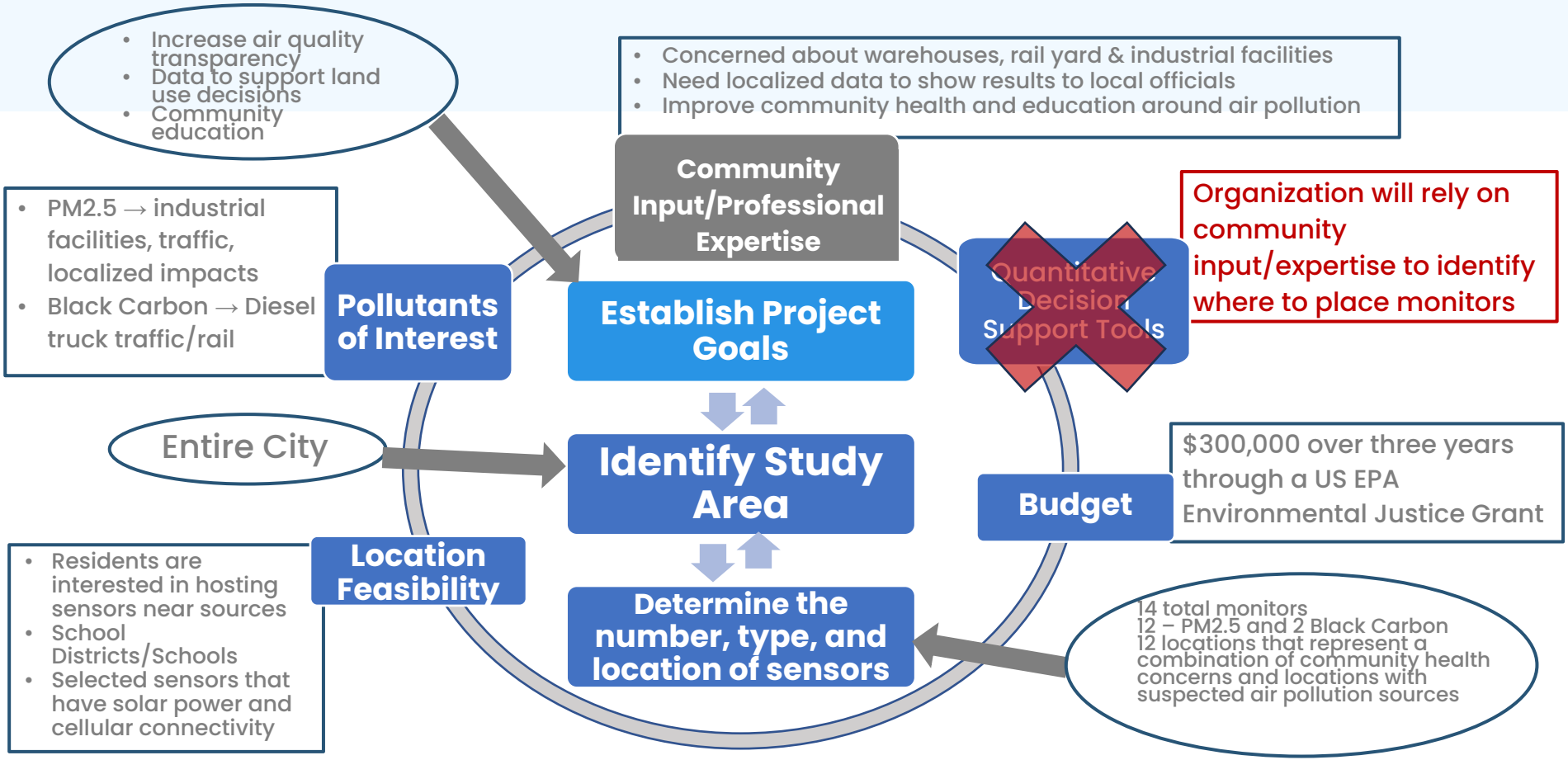


Figure 2. $PM_{2.5}$ sensor locations. Distribution of sensor locations in the EPA monitoring network compared to those identified as optimal by the mrDMD algorithm. The EPA sites are shown at original scale while mrDMD locations are projected on a 10 km × 10 km grid. Small gray patches in the Southwest and Pacific Northwest reflect grid cells with missing or corrupted data that were discarded from this analysis.

Kelp, M. M., Lin, S., Kutz, J. N., & Mickley, L. J. (2022). A new approach for determining optimal placement of PM2.5 air quality sensors: case study for the contiguous United States. *Environmental Research Letters*, *17*(3), 034034. https://doi.org/10.1088/1748-9326/AC548F

Sensor Network Design: Case Study



Hybrid Networks in Action: London

London, United Kingdom

Number of Clarity Nodes:

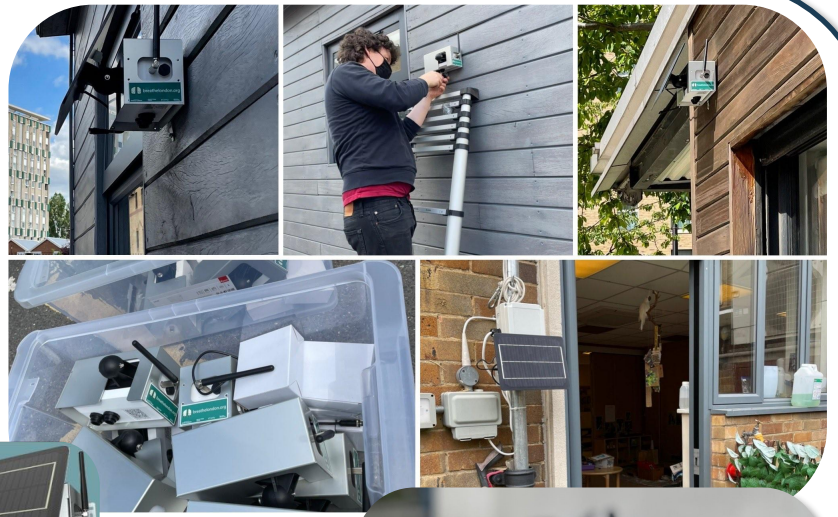
195 March 2021 → **500+** June 2023

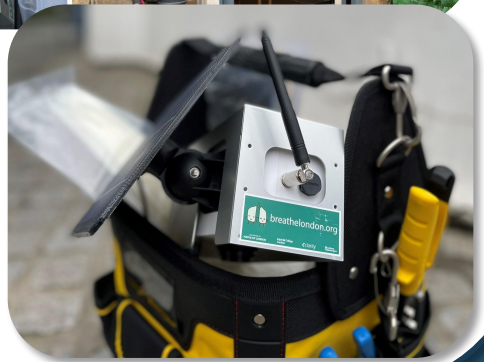
"I am delighted that Londoners will now have access to real-time, accurate air quality data for their area from more than 300 monitoring sites. This will improve awareness and help people reduce their exposure to polluted air. and better target efforts on improving air quality at a local level."

Sadiq Khan
Mayor of London

Action Enabled:

Improve air quality with targeted policies





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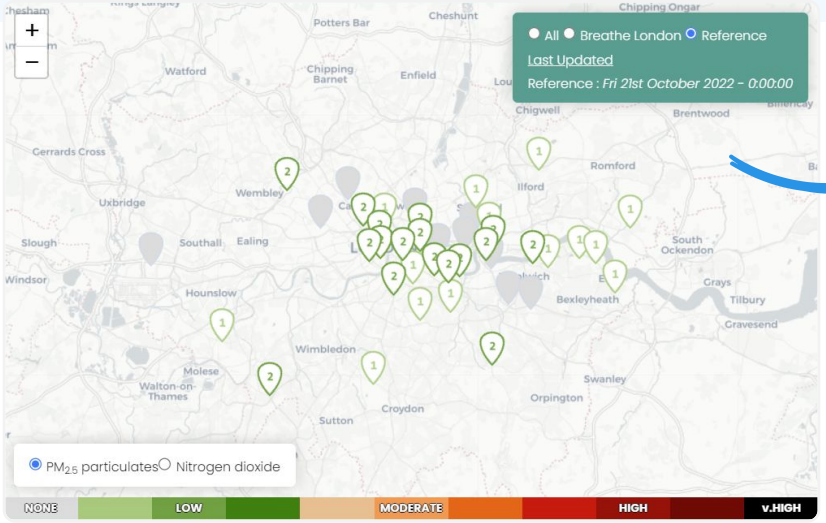
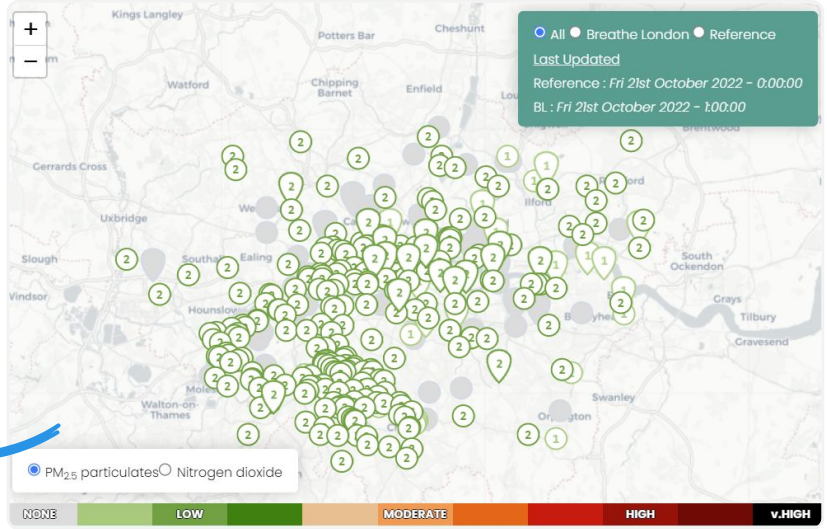
Hybrid Networks in Action: London



Regulatory monitoring network only



Regulatory + Breathe London sensors

500+ measurement points!

Integrating Additional Air Quality Parameters

Clarity Add-On Modules

Wind Module

Helps you know where air pollution is coming from for source apportionment.

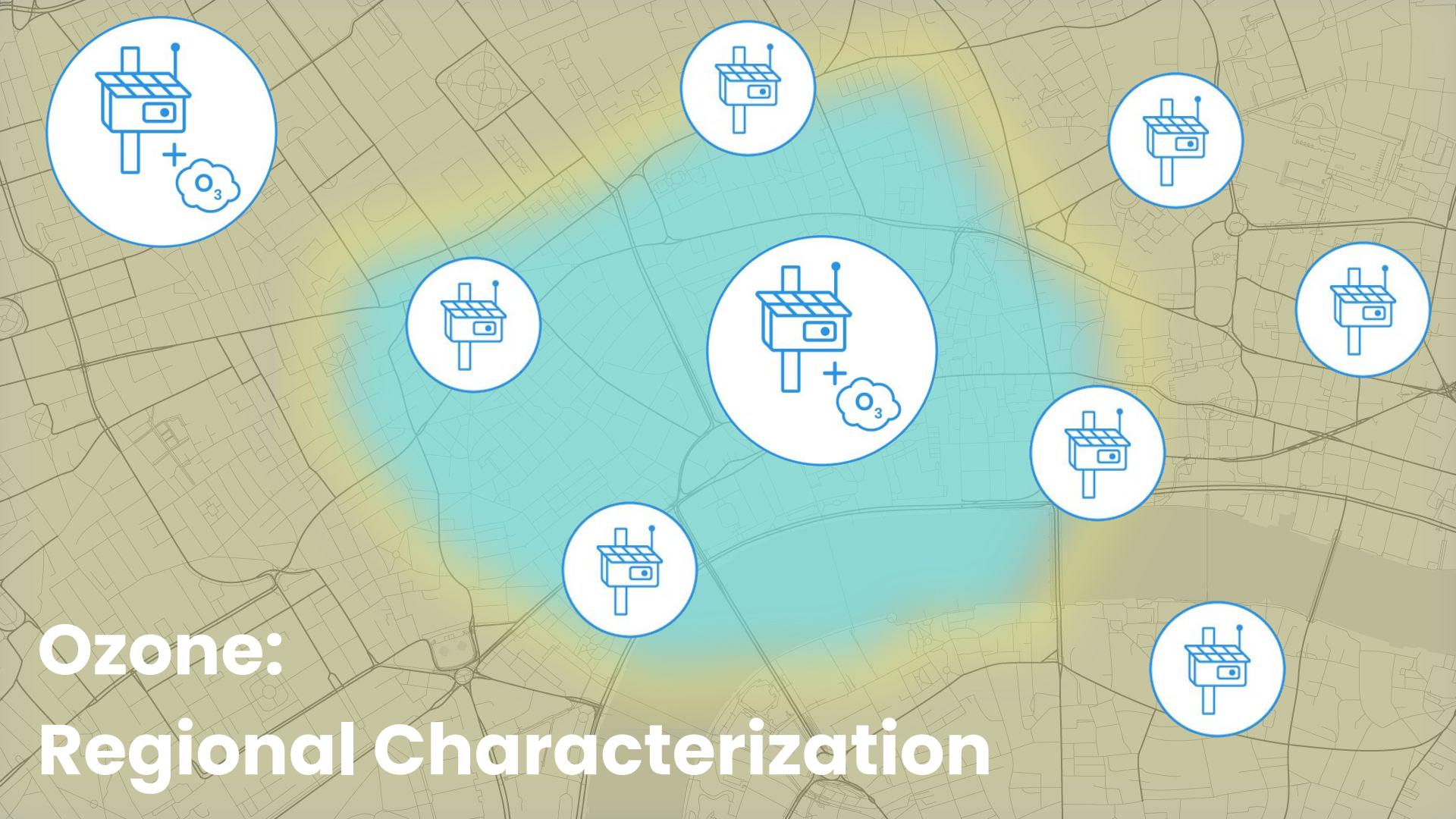
Ozone Module

FEM-capable, helps you confirm ozone attainment.

Black Carbon Module

Helps you understand the composition of particulates.

Source Attribution: Wind Speed & Direction


Ozone:
Regional Characterization

Black Carbon: Understanding PM Composition

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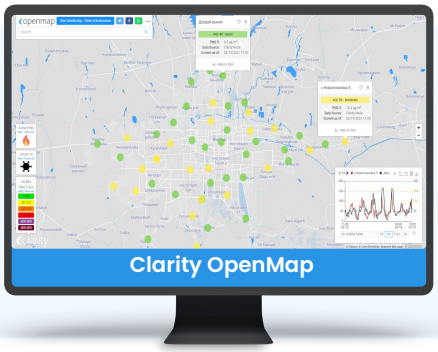
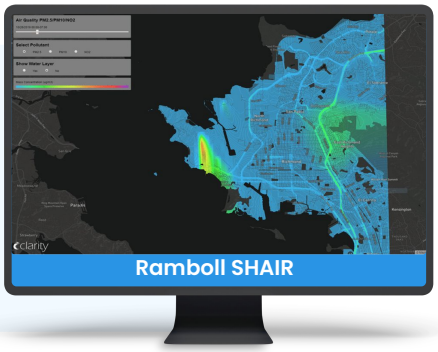
Visualizing and Leveraging your Air Quality Data



Clarity cloud-based tools

Third-party apps via API



Conclusions

- Increasing spatial coverage of air quality monitoring and understanding is important for public health and the environment
- Low-cost sensor network design is an emerging topic, but can begin with this decision framework
- Hybrid government and low-cost sensor networks can be used to enhance local understanding of air quality and provide appropriate resources

Air Quality Sensor Bootcamp — Next Steps

1. Complete the homework for all sessions by 6/28 to receive a certificate of completion!
2. Continue to connect via Slack channel with fellow bootcampers — it will remain active after Bootcamp ends!
3. Get in touch with our team if you are interested in collaborating on an air monitoring program!



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Thank you!

Questions?