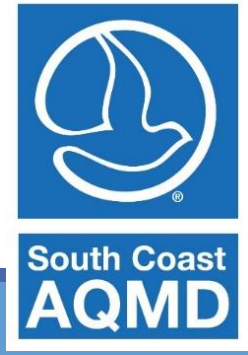
An Overview of Community in Action: A Comprehensive Educational Toolkit on Air Quality Sensors

SOUTH COAST AQMD



September 2021

The AQ-SPEC Program & the STAR Grant

- **AQ-SPEC**, the Air Quality Sensor Performance Evaluation Center, was established in 2014
- *Main Goals:*
  - Evaluate the performance of commercially available "low-cost" air quality sensors
  - Provide guidance and clarity for ever-evolving sensor technology and data interpretation
  - Catalyze the successful evolution, development, and use of sensor technology

In 2015 the South Coast AQMD was awarded funding from the US EPA under their "Science to Achieve Results" (STAR) Program, topic: "Air Pollution Monitoring for Communities"

Project title: "*Engage, Educate, and Empower California Communities on the Use and Applications of Low-Cost Air Monitoring Sensors*"

Main Objective: Provide communities across California with the knowledge necessary to appropriately select, use, and maintain "low-cost" sensors and to correctly interpret the collected data

Project Implementation:

[Project period: 5/1/2016 - 4/30/2022]

Introductory Workshop with Community

14 Recruited

Sensor Training & Distribution

PurpleAir PA-II

Sensor Installation by Community

Surveys Collected

"During-the-Deployment" Workshop with Community

Surveys & Discussions

Development of Tools & Resources by South Coast AQMD and Partners

Deployment End, Final Community Workshops & Dissemination

Educational Toolkit (incl. Guidebook, Resources, and Data Analysis Tools), Reports, Publications, Presentations, etc.

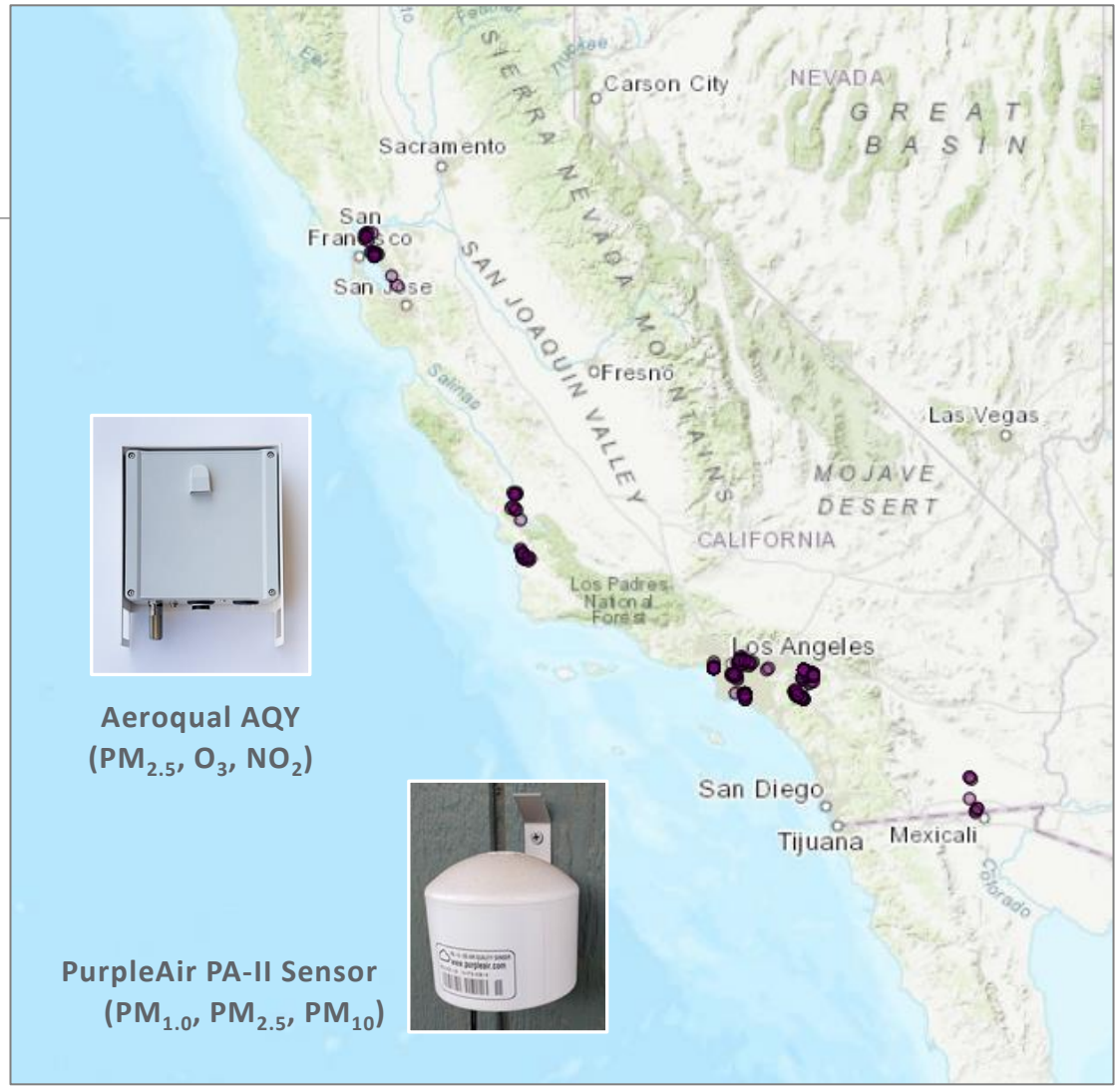
Final Products

Project Outcomes

- Partnered with 14 different communities
- ~300 PM sensors installed
- ~100 multi-pollutant sensors deployed

- Workshops and surveys to engage with and learn from communities
  - 33 community workshops held
  - 86 sensor installation surveys returned
  - 113 surveys collected during workshops

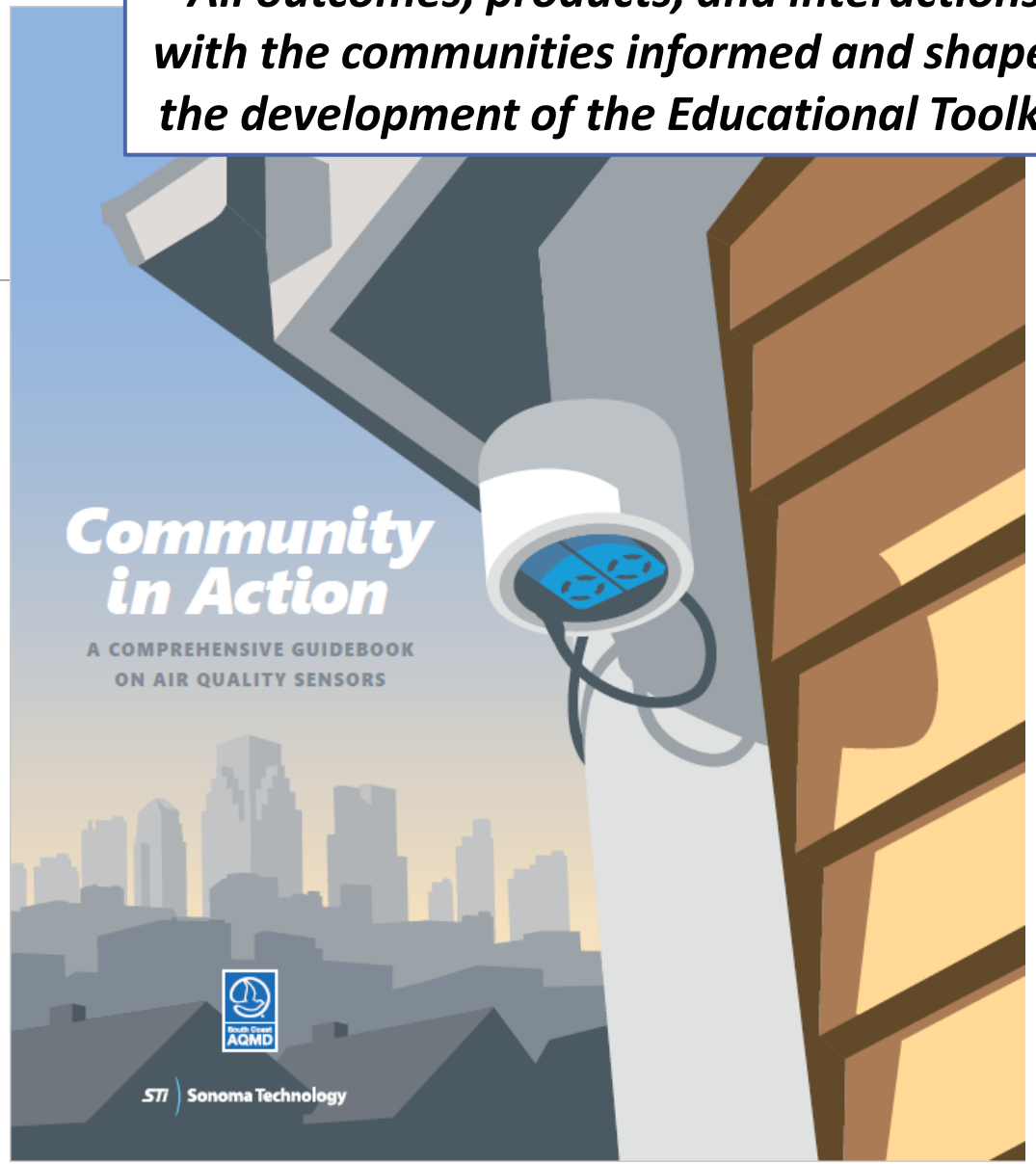
- Some communities led their own data analysis
  - 3 locally-relevant reports
  - 1 website



Final Product – Educational Toolkit

All outcomes, products, and interactions with the communities informed and shaped the development of the Educational Toolkit

- Training videos (3)
- Community in Action: A Comprehensive Guidebook on Air Quality Sensors
- Data analysis & visualization tools (the AirSensor R-package and DataViewer web-based interface)
- Supplemental Resources:
  - Installation guides
  - Surveys and project forms
  - Workshop slides
  - Infographic examples
  - Examples of community reports & analysis
  - Publications



https://www.youtube.com/watch?v=dQ1qciicpbU

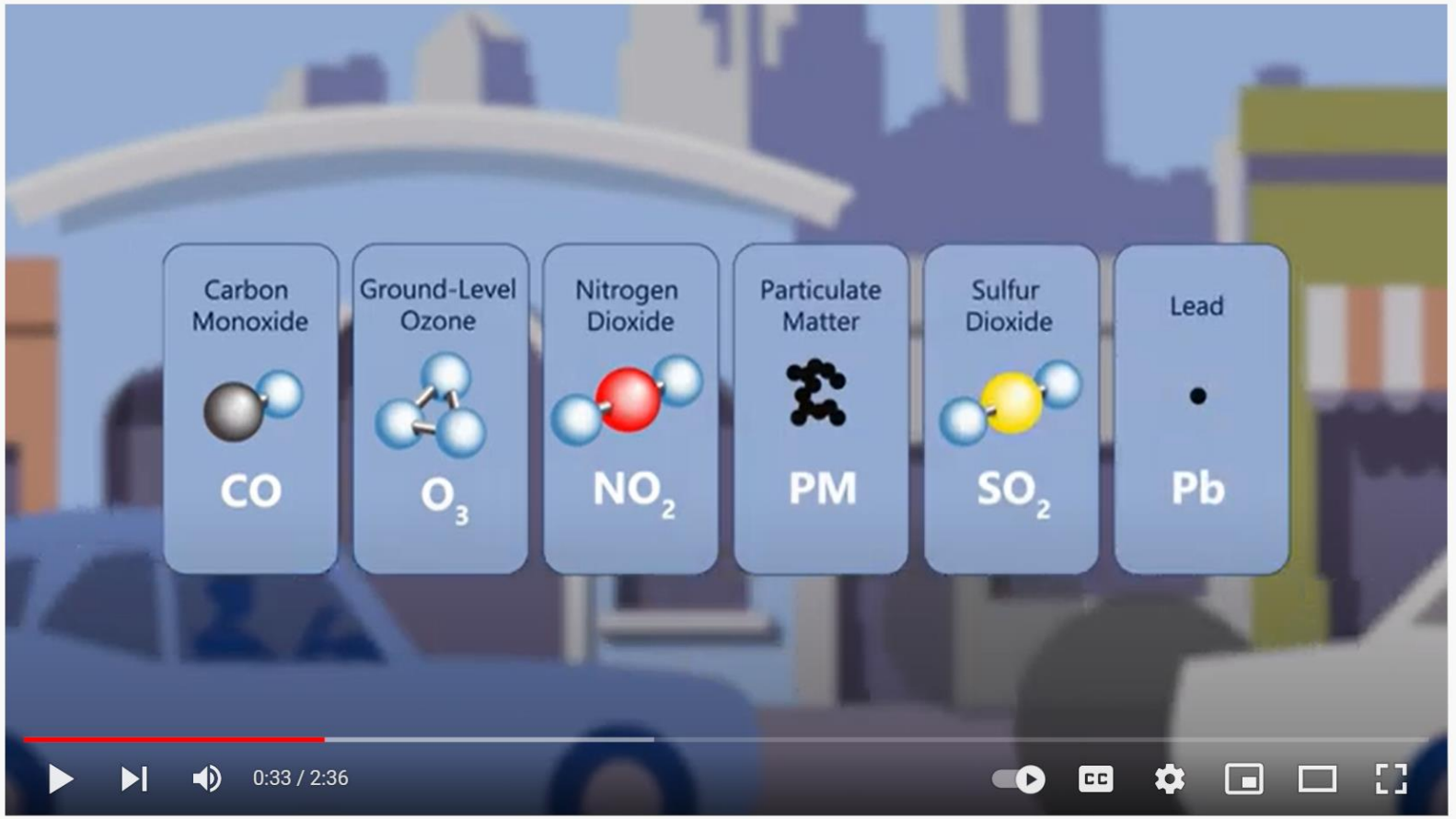
Overview of Training Videos (1)

- Air Sensor Training #1: Community in Action - A Comprehensive Guidebook on Air Quality Sensors
- Introduces the Guidebook and how to use sensors to learn about air quality in your community

https://www.youtube.com/watch?v=2r0XxQm50lE

Overview of Training Videos (2)

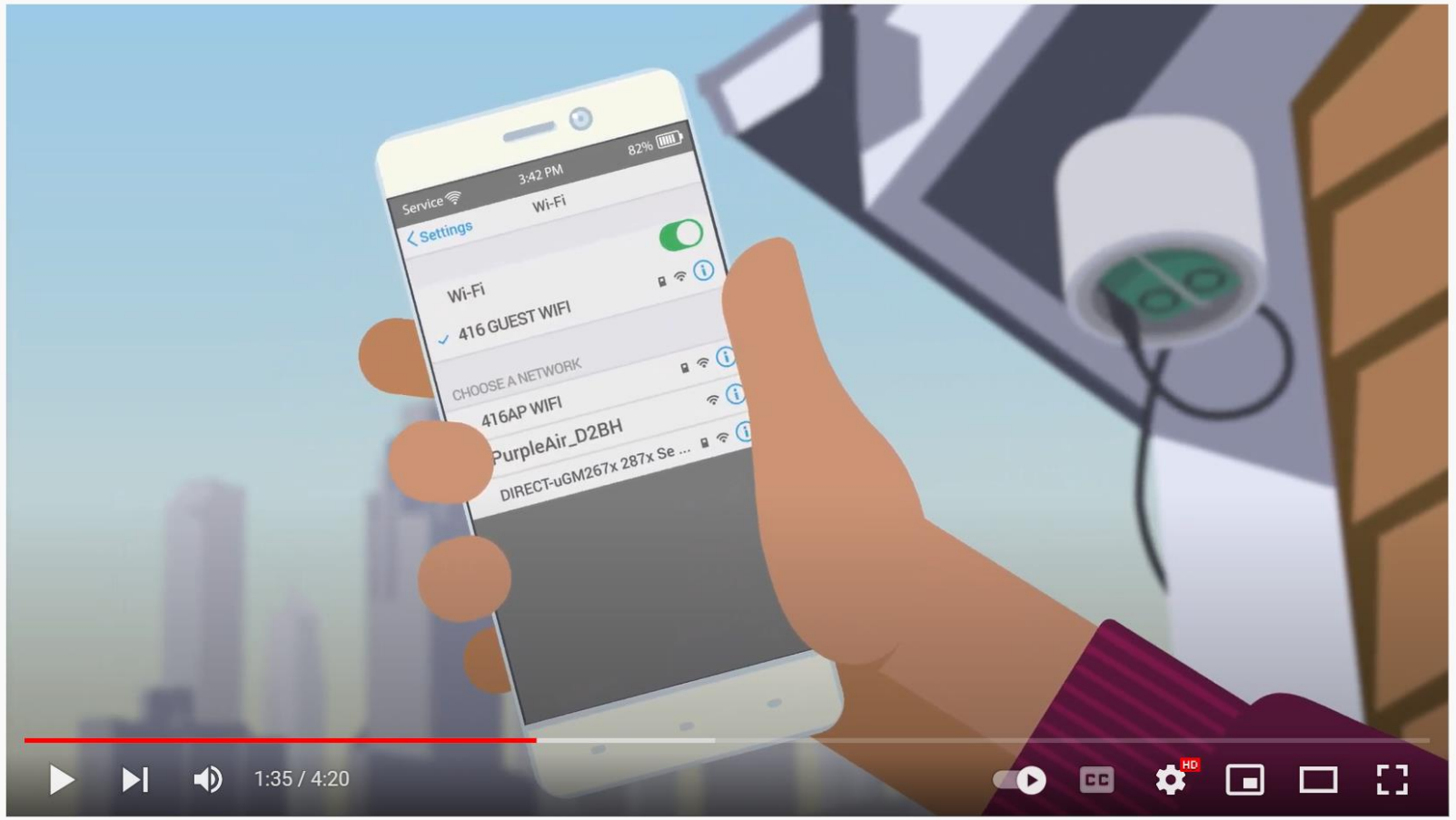
- Air Sensor Training #2: Understanding Air Quality and Monitoring
- Provides background on air quality monitoring
- Including key pollutants, sources of pollution, and different types of monitoring instruments



https://www.youtube.com/watch?v=cOZgyDRFc4U

Overview of Training Videos (3)

- Air Sensor Training #3: PurpleAir PA-II Sensor Installation
- Walks the viewer through the steps involved in installing a PurpleAir PA-II sensor



Guidebook Objectives

Major objectives for the content, structure and “look and feel” of the guidebook:

- ✓ Be accessible to the public and not overly technical
- ✓ Be informative and visually engaging, perhaps communicated as a narrative featuring real members of the community
- ✓ Be translated into one or more languages
- ✓ Establish monitoring expectations and support successful outcomes
- ✓ Increased decision-making to reduce exposure
- ✓ Good data collection practices will build compelling evidence about air quality issues
- ✓ Provide resources for additional information
- ✓ Provide direction for contacting local government

Versatile Product

- Guidebook and other resources are designed to meet the needs of a broad range of users and projects
- For example, users could include:
  - An academic researcher new to community-based work
  - A community leader new to air quality and concerned about local sources
  - Staff from a government agency experienced in working with the public, but new to sensors
  - An individual interested in using sensors to better understand their own air quality

Chapter 1, "Introduction"

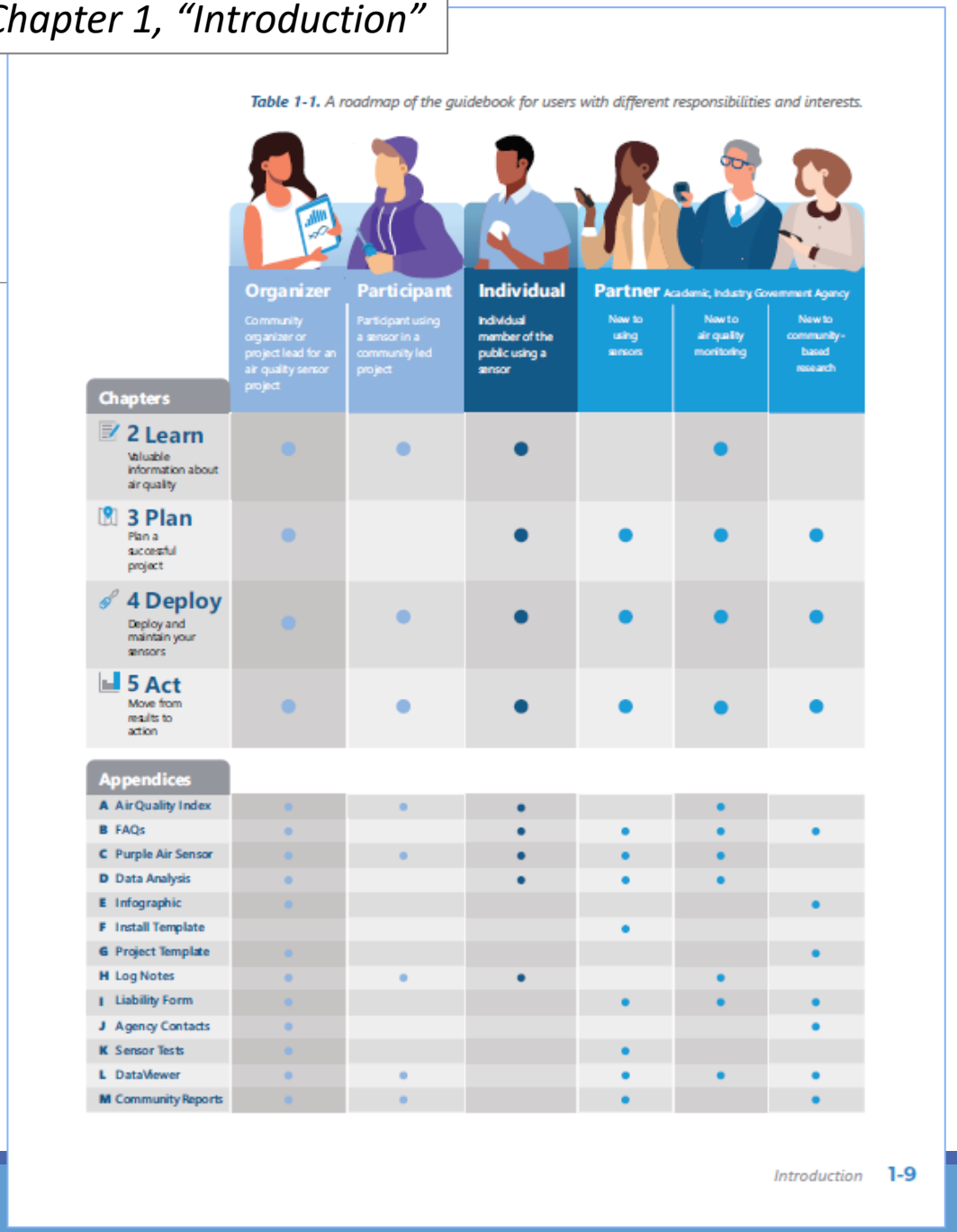
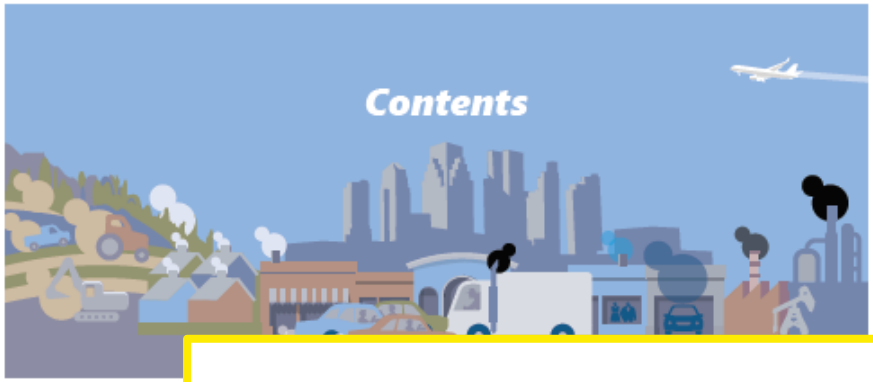


Table 1-1. A roadmap of the guidebook for users with different responsibilities and interests.

	Organizer Community organizer or project lead for an air quality sensor project	Participant Participant using a sensor in a community led project	Individual Individual member of the public using a sensor	Partner Academic, Industry Government Agency New to using sensors	 New to air quality monitoring	 New to community-based research
Chapters						
2 Learn Valuable information about air quality	●	●	●		●	
3 Plan Plan a successful project	●		●	●	●	●
4 Deploy Deploy and maintain your sensors	●	●	●	●	●	●
5 Act Move from results to action	●	●	●	●	●	●
Appendices						
A Air Quality Index	●	●	●		●	
B FAQs	●		●	●	●	●
C Purple Air Sensor	●	●	●	●	●	
D Data Analysis	●		●	●	●	
E Infographic	●					●
F Install Template				●		
G Project Template	●					●
H Log Notes	●	●	●		●	
I Liability Form	●			●	●	●
J Agency Contacts	●					●
K Sensor Tests	●			●		
L DataViewer	●	●		●	●	●
M Community Reports	●	●		●		●



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Chapter 2, “Understanding Air Quality and Monitoring”

Particle Pollution

Particle pollution is a general term for a mixture of solid particles and liquid droplets

Some particles are large enough to be seen as dust or dirt; others are so small that they can only be detected with an electron microscope. Particles are both directly emitted into the air and can be formed in the air from other pollutants.

Particle Size

Particles in the air are referred to as particulate matter, or PM. Another term used in atmospheric science is aerosols which are small solid particles or liquid droplets suspended in air. Particles range in size and composition. Most commonly, measurements focus on two size ranges – particles less than 10 microns in diameter (coarse particles, PM_{10}) [or micrometers (µm) in aerodynamic diameter] and particles less than 2.5 microns in diameter (fine particles, $PM_{2.5}$) [or, micrometers (µm)

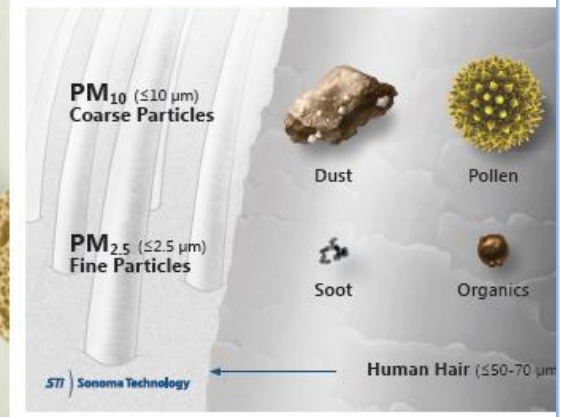

Figure 2-1. *$PM_{2.5}$ and PM_{10} particle sizes compared to a human hair.*

decreased lung function, and increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing. Particle size is directly linked to the potential for causing respiratory problems. Larger particles impact the upper respiratory tract, while smaller particles can enter the lower respiratory tract and even enter the bloodstream (**Figure 2-2**).

The U.S. Environmental Protection Agency (EPA) sets National Ambient Air Quality Standards (NAAQS) to protect human health (see Appendix A). The 24-hr standards for $PM_{2.5}$ and PM_{10} are shown in **Table 2-1**. These standards stipulate that the average PM mass concentration in the outdoor air over a 24-hour time-period should not exceed a certain threshold, based on the findings of health and risk assessments. More details about the NAAQS are available on the EPA website.[2]

Table 2-1. *NAAQS (2012) for $PM_{2.5}$ and PM_{10}.*

Pollutant	Averaging time	Level
$PM_{2.5}$	24 hours	12 µg/m³
PM_{10}	24 hours	150 µg/m³

There are currently no EPA standards for $PM_{2.5}$ and PM_{10} at shorter time periods such as 1-minute or 1-hour. EPA reports the air quality index (AQI), based on several criteria pollutants, to inform the public about how clean or polluted the air is and what associated health effects might be a concern (see Appendix A).

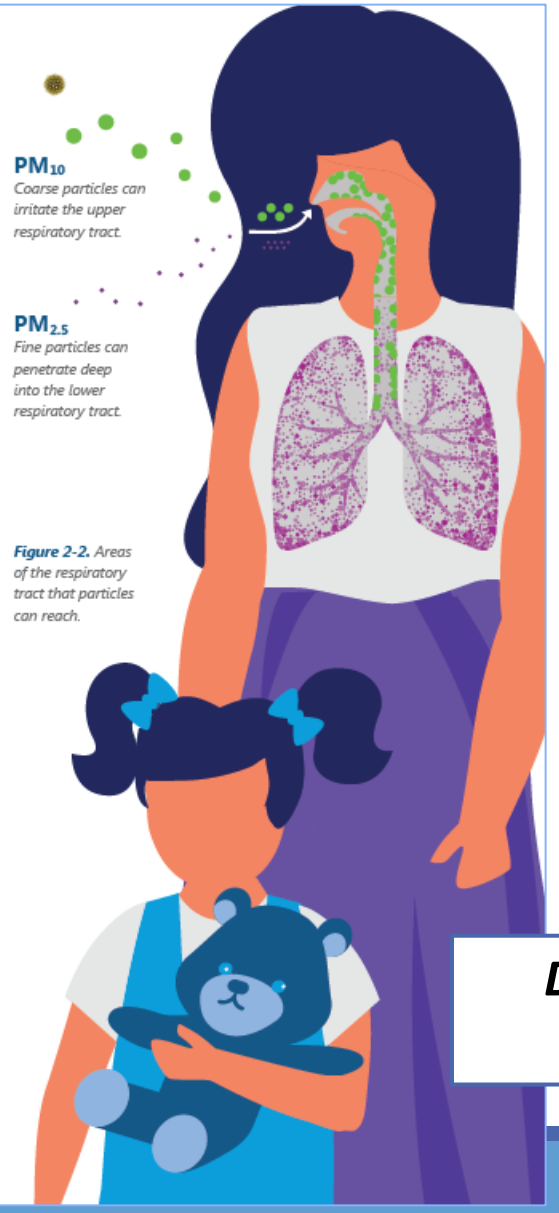

Figure 2-2. *Areas of the respiratory tract that particles can reach.*

WORLD HEALTH ORGANIZATION ESTIMATED WORLDWIDE DEATHS FROM AMBIENT AIR POLLUTION IN 2016

16%	25%	17%	26%
of lung cancer deaths	of COPD deaths	of ischemic heart disease and strokes	of respiratory infection deaths

People with compromised health and vulnerable populations (i.e., children, pregnant women, and the elderly) are more susceptible to the effects of air pollution.

Worldwide, the World Health Organization[4] estimated that in 2016, ambient air pollution caused about 16% of lung cancer deaths, 25% of chronic obstructive pulmonary disease (COPD) deaths, about 17% of ischemic heart disease and stroke, and about 26% of respiratory infection deaths. A 2019 paper published in the European Heart Journal[5] estimated that air pollution could be causing double the number of excess deaths a year in Europe than had been estimated previously. The researchers found that air pollution caused an estimated 8.8 million extra deaths globally. Similarly, a 2018 study[5] estimated that 8.9 million deaths were associated with long-term exposure to outdoor $PM_{2.5}$.

8.8 million extra deaths globally *European Heart Journal, 2019[1]*

For Further Reading

If you would like more information on the overall burden of PM on human health nationally and globally, check out the following:

HealthData.org Global Burden of Disease Study 2017.[6]

World Health Organization Ambient Air Pollution.[4]

If you would like more information on the different ways in which PM exposure impacts human health, check out the following:

An association between air pollution and mortality in six U.S. cities.[7]

Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution.[8]

The effect of air pollution on lung development from 10 to 18 years of age.[9]

Designed to support users with varied technical backgrounds and expertise

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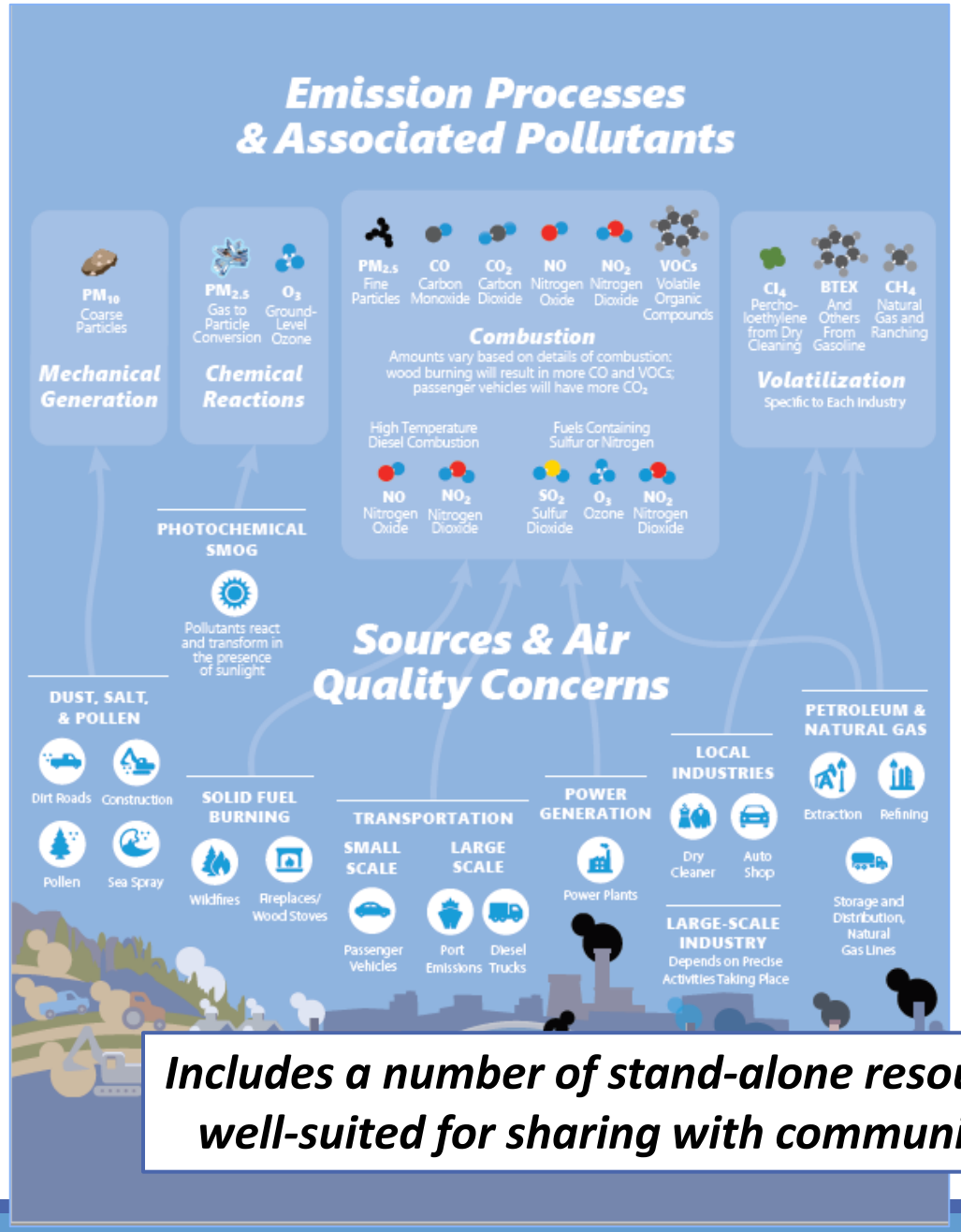
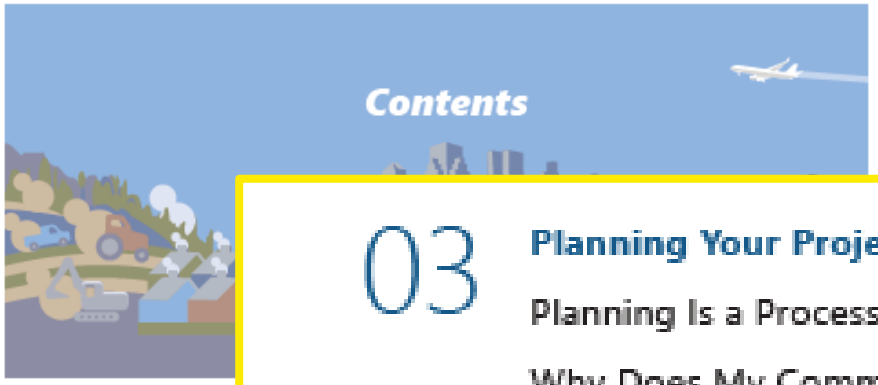
Chapter 2, “Understanding Air Quality and Monitoring”

Table 2-2. Summary of characteristics of fine and coarse particulate matter (adapted from Seinfeld and Pandis, 1998).[11]

$PM_{2.5}$ Fine Particles	PM_{10} Coarse Particles
Chemical Process *How the particles are formed*	
Reaction, nucleation, condensation, coagulation, cloud/fog processing	Suspension of dust or sea salt, mechanical process
Sources *Where the particles come from*	
Coal Combustion, Gasoline Combustion, Diesel Combustion, Wood Combustion, Motor Vehicles, Industry, Fires, Gas to Particle Conversion	Industrial Dust, Farming Dust, Mining Dust, Unpaved Roads, Biological Sources, Construction/ Demolition, Ocean Spray, Road Salt
Composition *What the particles are made of*	
Sulfates and Nitrates, Elemental Carbon, Other Organics, Water, Metals	Crustal Elements, Salt, Pollen, Mold, Plant and Animal Debris
Formation *When the particles are formed*	
Primary (directly emitted) and Secondary (formed in the atmosphere)	Primary (directly emitted)
Atmospheric Lifetime *How long the particles stay in the air*	
Days to Weeks	Minutes to Days
Travel Distance *How far the particles travel*	
100 to 1000+ km (about 60 to over 600 miles)	Generally < 100 km (< about 60 miles)



Includes a number of stand-alone resources, well-suited for sharing with communities



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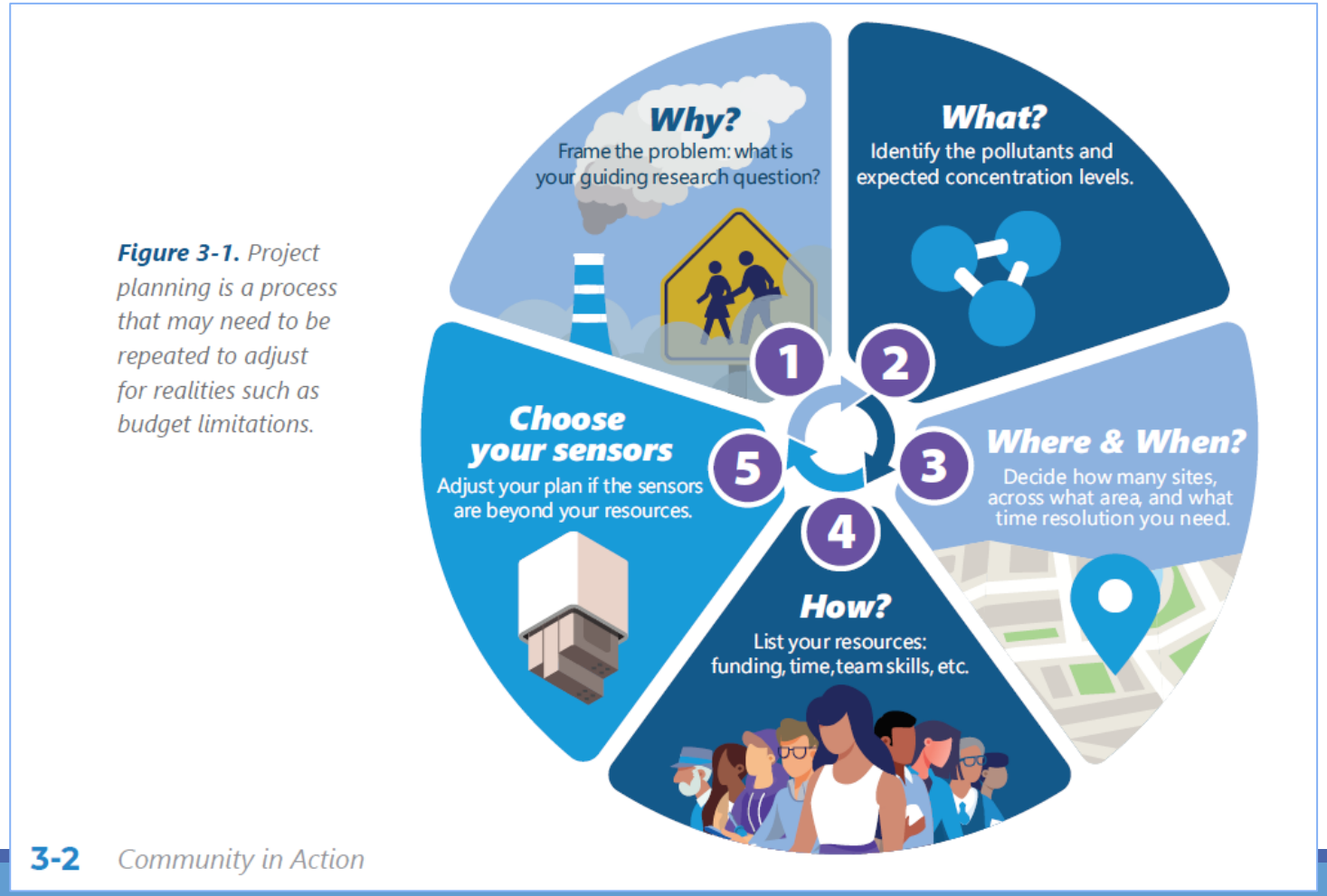
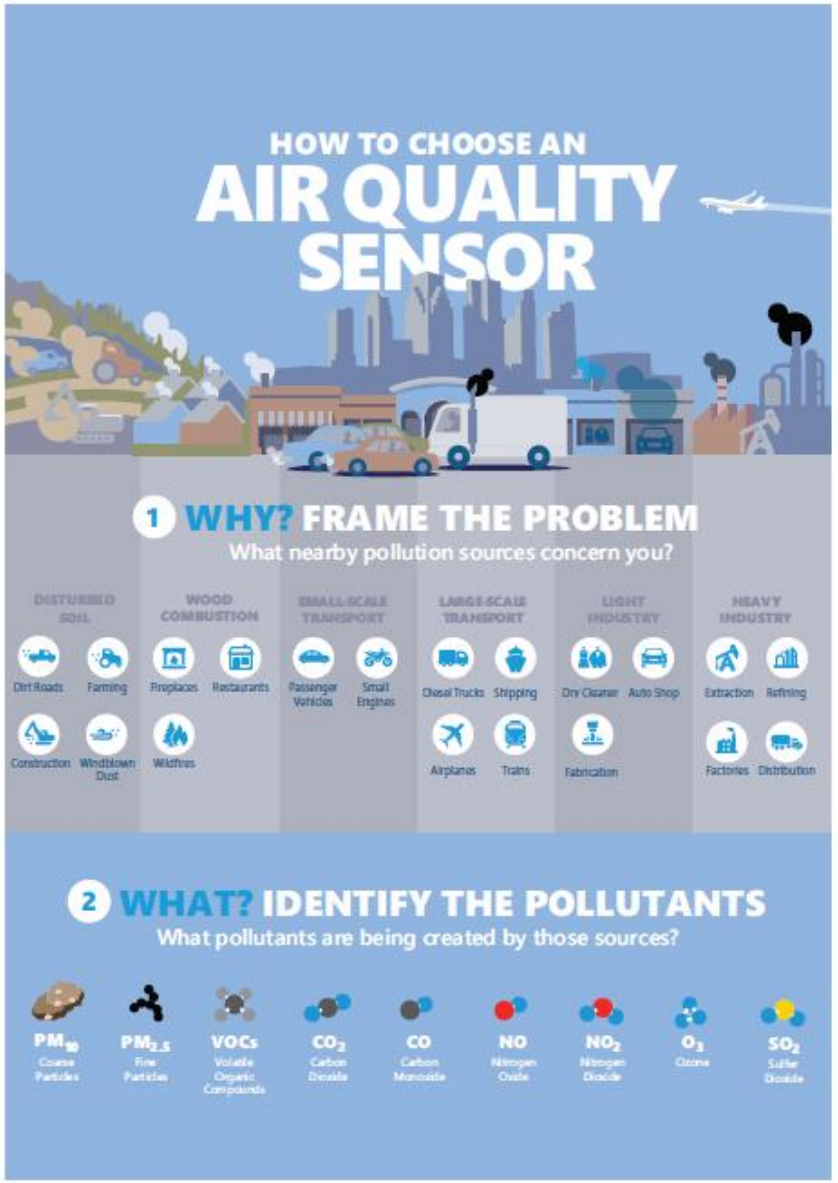
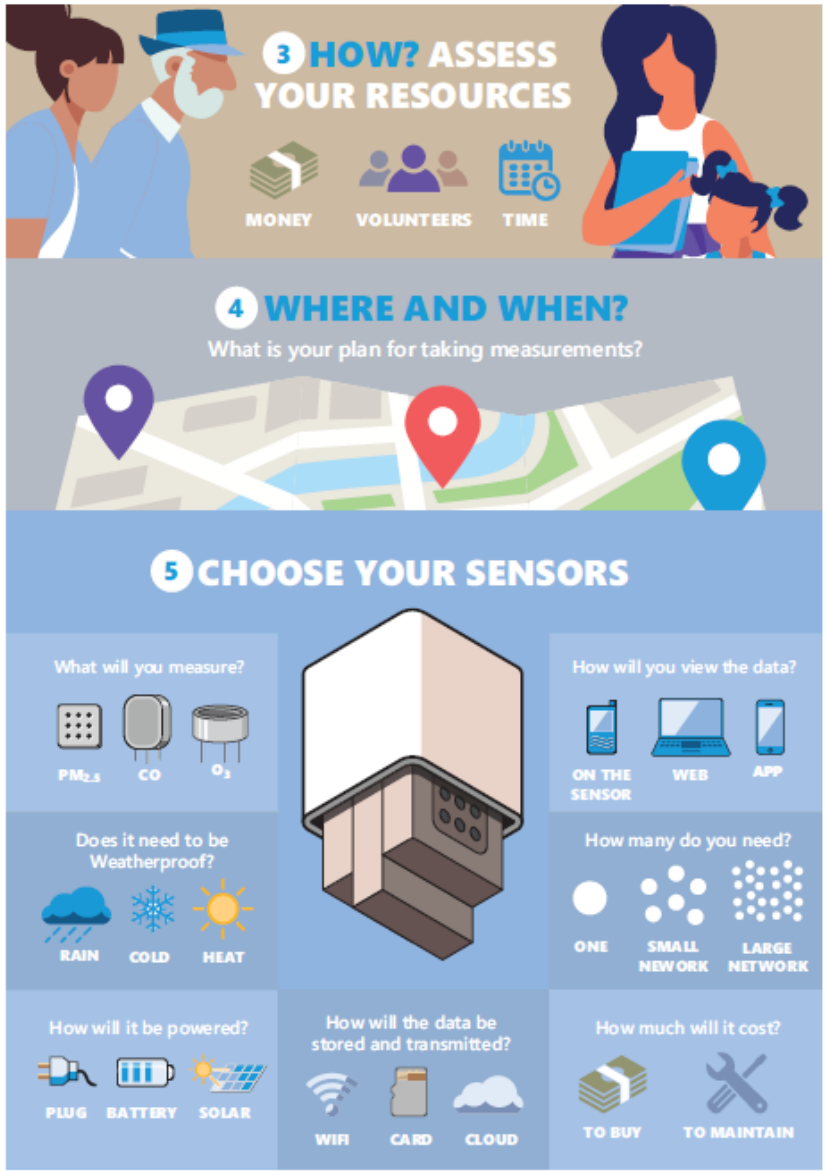
Thorough Planning Guidance

- The planning section focuses on the following considerations:
  - Project organization and structure
  - Resources and constraints
  - Air quality concerns (including where and how to learn more about sources and concentrations of interest)
  - Sensor selection



Chapter 3, “How to Select a Sensor System”





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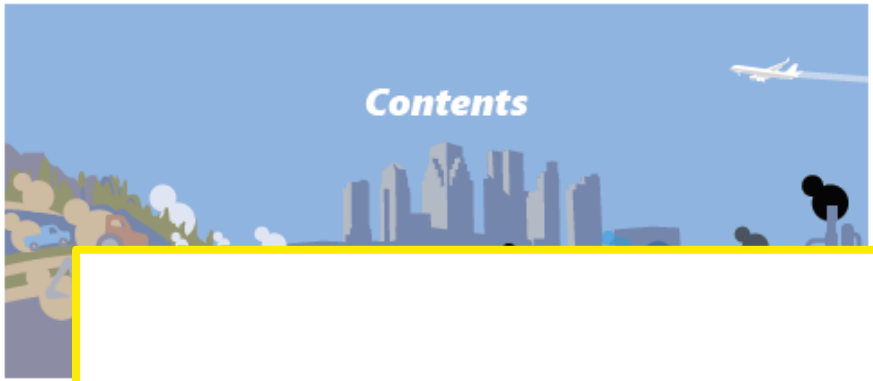

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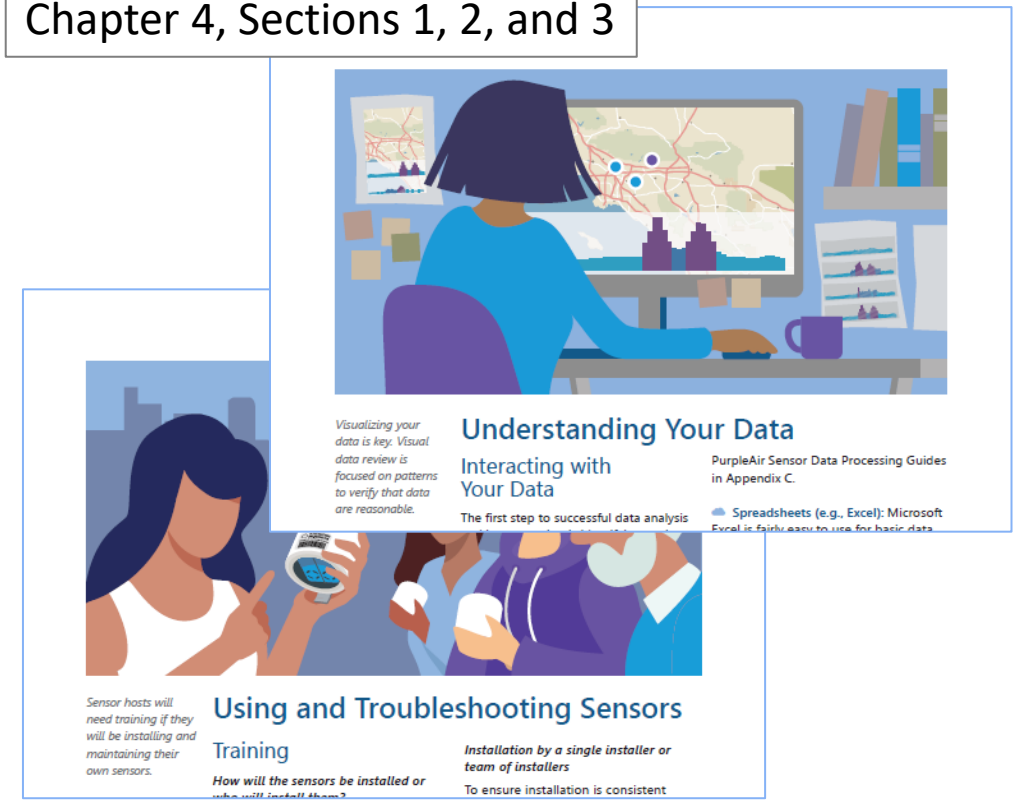
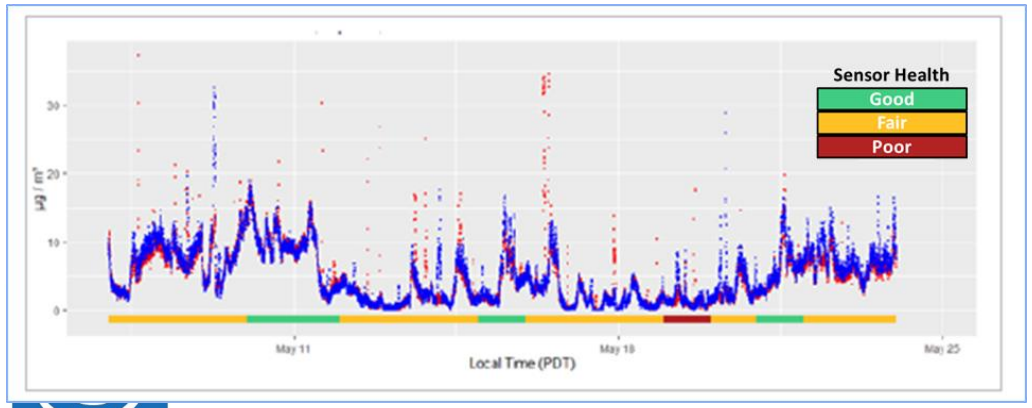
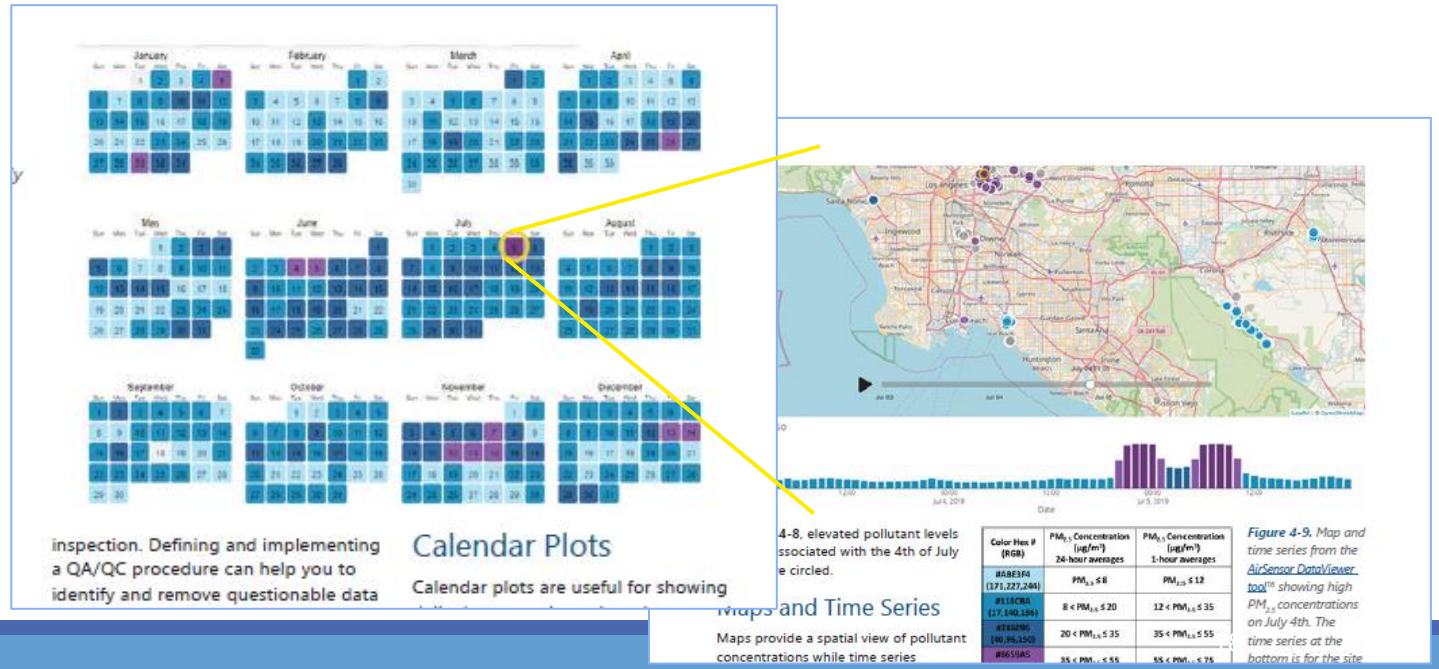
Chapter 4, Sections 1, 2, and 3



- Practical advice for siting, installing, and maintaining sensors
- Sensor co-location, correction, and calibration
- Introduction to different plot types, assessing accuracy, and useful quality control (QC) metrics/algorithms
- Ways to monitor the “State-of-Health” of deployed sensors
- Description of tools and resources available for data analysis
- Step-by-step example analysis of an air quality event (using the AirSensor DataViewer, web-based interface for exploring current and historical data)



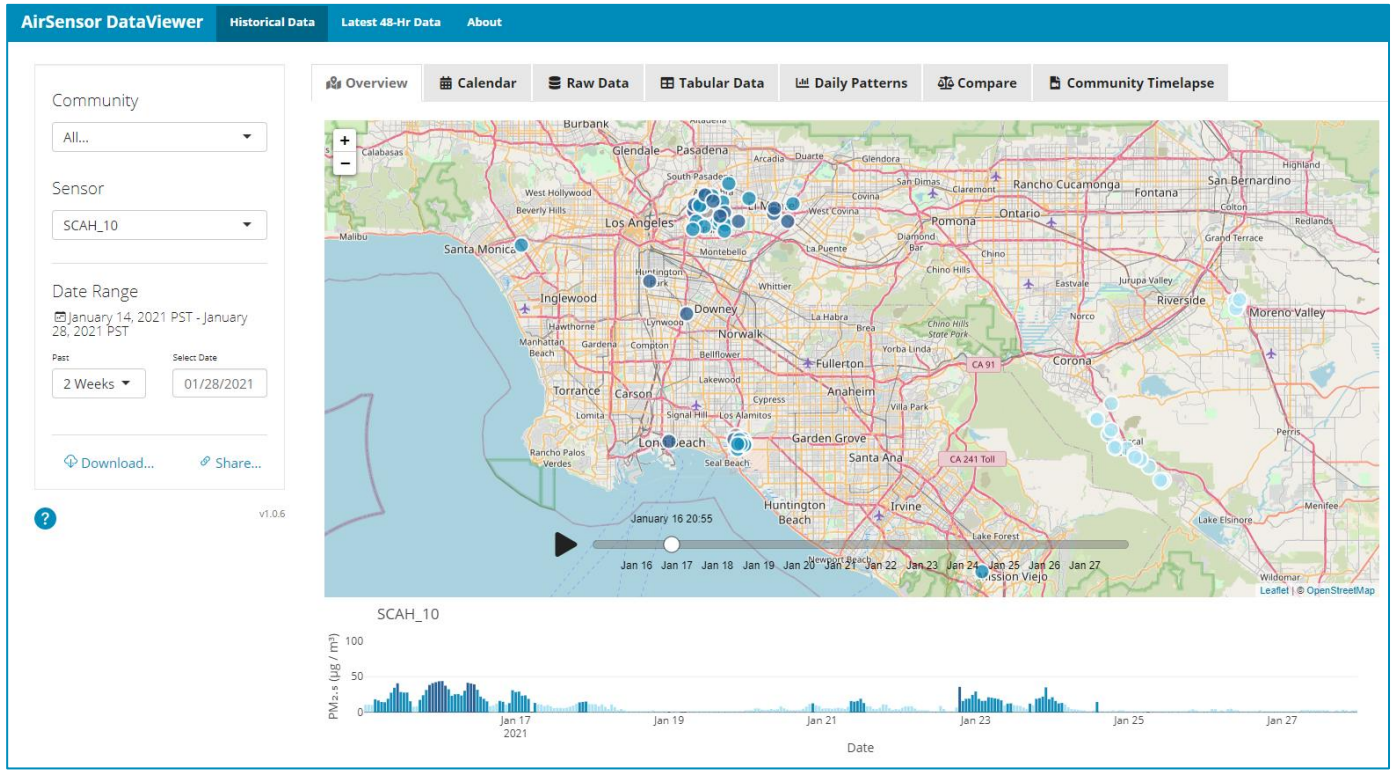


https://www.aqmd.gov/aq-spec/special-projects/airsensor

Data Analysis Tools in the Toolkit

- Guidance and example analysis
- **Data Analysis Guide**, sensor-agnostic (*in Guidebook Appendices*)
- **AirSensor package** – free and open-source R-package facilitating data access, analysis, and visualization
- **DataViewer tool** – web-based user interface for exploring current and historical data from STAR Grant sensors (no programming-experience needed)

Screenshot of DataViewer Tool



"The AirSensor open-source R-package and DataViewer web application for interpreting community data collected by low-cost sensor networks" (Feenstra et al., 2020)

Chapter 4, “Maintaining Momentum on a Project”

Maintain project momentum by sharing reports and holding occasional meetings.

Maintaining Momentum on a Project

There is typically excitement in the community at the beginning of a project, but that excitement can

Outreach over social media

Figure *Promo* *and o* *workshop using social media (Facebook).*

participants interested and engaged:

- **Providing updates to the community.** Project leads can use data visualization tools to develop regular air
- **Sending reminders to project participants.** Project leads can also send regular reminders via email or text, asking participants to take a look at their data or share anything they may have learned from their sensor or the sensor network.
- **Getting youth involved.** Students can develop science projects based on the community measurements. Students can even leverage the data from these sensors for science fair projects (see **Figure 4-18**). Also, consider reaching out to local teachers to let them know about the sensor network - they may be interested in using the data to teach in their classrooms.

Community-led data analysis

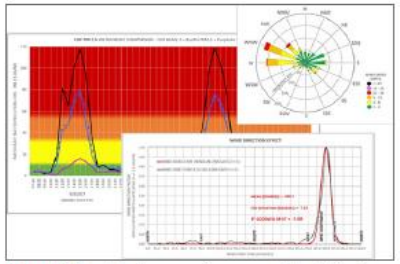


Figure 4-20. *Analysis of sensor performance and the relationship between air quality levels and wind direction, completed by a community member.*

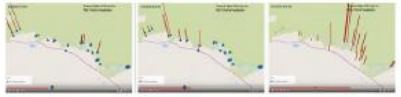


Figure 4-21. *Still images from an animated data visualization created by a community member to illustrate the dynamic $PM_{2.5}$ concentrations during a wildfire event (posted to YouTube and shared/discussed on the* *the red bar indicates the* *concentrations), while th* *speed (larger = higher w*

Interactive activities

Figure 4-22. *An activity during a community workshop, participants used different colored pins to identify various features (e.g., parks, high traffic areas, etc.) – these types of activities can be used to facilitate discussions about local air quality.*

sensors themselves and their interest can be encouraged and supported where possible (see **Figure 4-20**). For example, a community member may wish to learn more about sensor performance by collocating at a specific reference monitoring station. Having a few extra sensors and helping to facilitate relationships, such as with the local regulatory agency, can help make this work possible.

- **Having community members create custom and engaging data visualizations.** There may be individuals in your community who have the programming skills to create unique and engaging data visualizations (see **Figure 4-21**). Project leads may be able to support this work by providing access to data.
- **Connecting the sensor deployment to other projects happening in the community.** Challenge the community to think about how different issues interrelate, such as the built environment, local industry, traffic

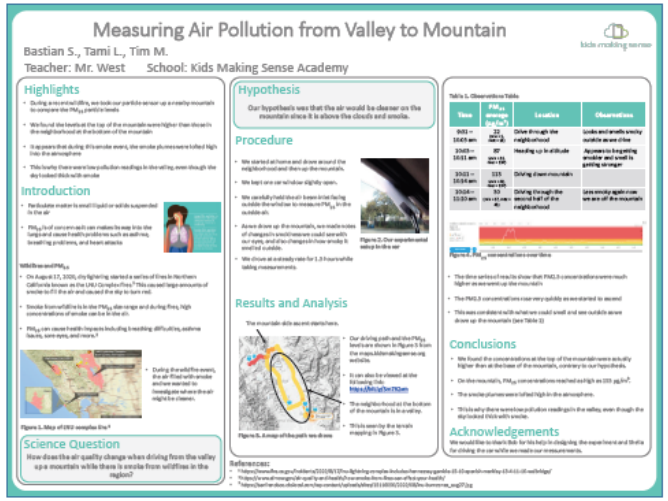


Figure 4-18. *Science fair project using low-cost sensor data.*

- **Using social media to keep conversations going about observations found by the participants about their data.** Community members can share observations related to air quality, and these platforms allow others to comment – providing a variety of input about the observations (see **Figure 4-19**). Additionally, using social media for these conversations can provide a time-stamped record that may serve as a useful reference during the data analysis phase of the project. This outreach approach requires active participation to keep the social media account active and engaging.
- **Supporting data analysis work by community members.** Community members may have their own

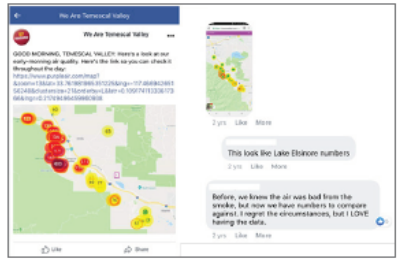
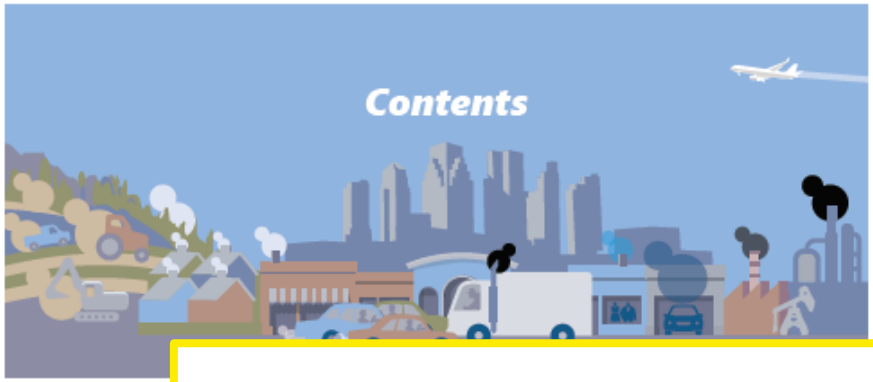


Figure 4-19. *Community sharing and discussion of data from low-cost sensors during a wildfire event through social media (Facebook).*

Outreach over social media

- Contains lessons from the STAR Grant communities on ways to maintain momentum in a project, as well as ways to enhance participation in a project



05 **Taking Action** 5-1
Local Action 5-2
Collecting More Data 5-8
Sharing Your Results and Discussing Your Project 5-10
References 5-14

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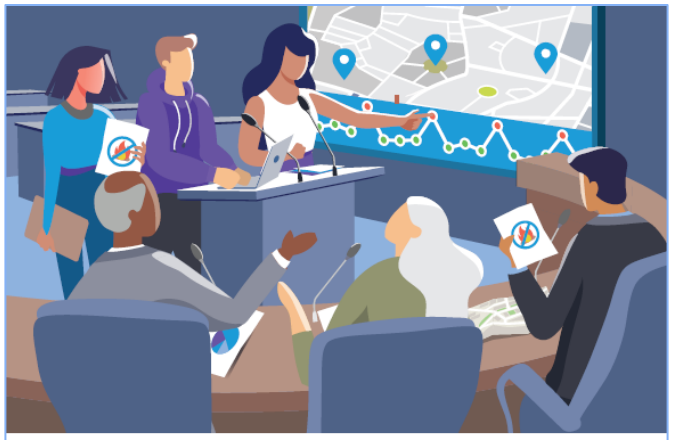
Chapter 5, Sections 1, 2, and 3

- Ideas for and examples of “local action”
- Advice to help determine whether additional data should be collected
- Strategies for communicating with local government agencies and/or the broader community



05 Taking Action

Now that you have data, what do you do with the results? Options include taking action locally

(Above) Create an anti-idling program to protect students from harmful vehicle emissions near schools.

(Left) Work with your local air quality agency to develop a no-burning policy for days with poor air quality.

Create a community awareness program that will help reduce emissions.

a flag that corresponds to the AQI: green, yellow, orange, red, and purple. EPA offers guidance on school flag programs.[15]

Other Mitigation Strategies

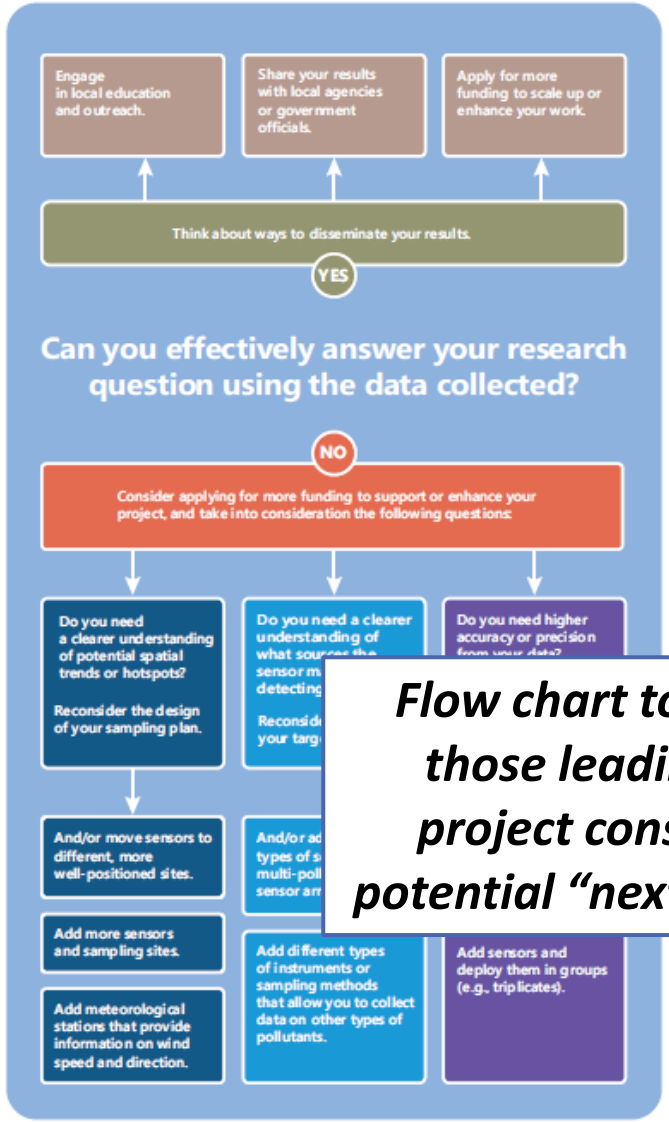


Figure 5-1. Use this decision tree to determine whether more measurements are needed to meet project objectives.

Flow chart to help those leading a project consider potential “next steps”

Taking Action 5-9

Guidebook Appendices

- Installation Guides
- Surveys and Project forms
- Infographic examples
- Example reports and analysis from communities
- Workshop slides
- List of agency contacts
- Sensor-specific and sensor-agnostic resources

Appendices

Appendix C, "Installation Guide"

Measuring
AIR QUALITY
in Your Community

The South Coast AQMD Sensor Library Program seeks to enable communities to investigate their questions related to air quality and learn more about their local environment. To learn more visit our website at www.aqmd.gov/aq-spec.

Technology for Measuring Particulate Matter (PM)
PurpleAir PA-II Dual Laser Air Quality Sensor

① PurpleAir PA-II Dual Laser Sensor
② Outdoor-rated Nest Power Supply
③ USB Cable

PurpleAir PA-II Features:

- Dual PM sensors
- Measures $PM_{1.0}$, $PM_{2.5}$, and PM_{10} along with Temperature, Relative Humidity, and Pressure
- Requirements:
  1. Available power outlet
  2. Available Wi-Fi to log data to PurpleAir map
- Easy to install with a single screw or zip ties
- Wi-Fi data logging with open data access at www.purpleair.com/map

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Midiendo la
Calidad de Aire
en su Comunidad

El Programa de Biblioteca de Sensores de South Coast AQMD busca ayudar a las comunidades investigar sus preguntas relacionadas con la calidad de aire y aprender más sobre su ambiente local. Para obtener más información, visite nuestro sitio web en www.aqmd.gov/aq-spec.

Tecnología para medir Partículas (PM)
Sensor de Calidad de Aire Laser PurpleAir PA-II Dual

① Sensor de Calidad de Aire Laser PurpleAir PA-II
② Fuente
③ Cable

Características

- Sensores d
- Medidas d temperatu
- Requisitos
  1. Toma d
  2. Wi-Fi d mapa de PurpleAir
- Fácil de instalar con un solo tornillo o abrazador

Page 1 of 6

PA-II Installation Guide, revised based on community feedback. **9 iterations** to create the final version (available in English and Spanish)

South Coast AQMD

Appendix E, "Example Infographic"

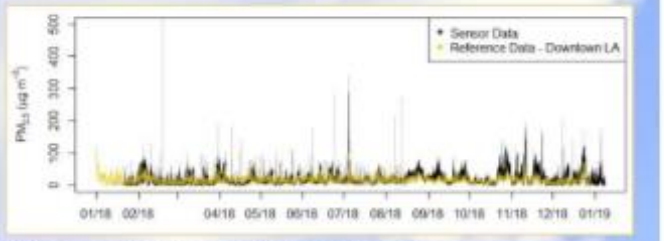
What can we learn from these PurpleAir sensors about outdoor air

A QUICK LOOK AT THE APIFM PURPLEAIR SENSORS

This analysis uses all available data from January 2018 - January 2019.
Note, the results presented here are preliminary.

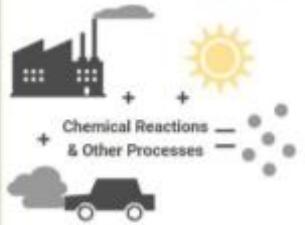
A YEAR OF DATA

- *Similar $PM_{2.5}$ trends across all 31 sensors & reference data*
- *Darker = overlapping*
- *Lighter = single sensor*

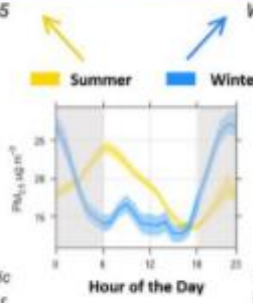


WHEN IS $PM_{2.5}$ HIGHER? ...DEPENDS ON THE SEASON

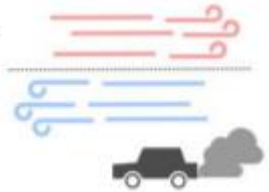
Summer - increased daytime PM2.5



*Likely due to increased "secondary organic aerosol" formation (Or, gases and smaller particles making larger particles in sunlight)**



Winter - increased night-time PM2.5

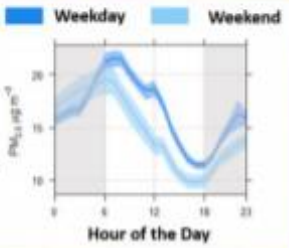


Likely due to stronger nightly "inversions" (Or, stable conditions caused by a layer of warm air over a cold one trapping emissions)

**Applies to late morning and afternoon, but the early morning peak is likely driven by other factors*

...ALSO ON THE DAY OF THE WEEK

Elevated levels on weekdays are likely due to morning rush hour and increased traffic
(data used: spring and summer)



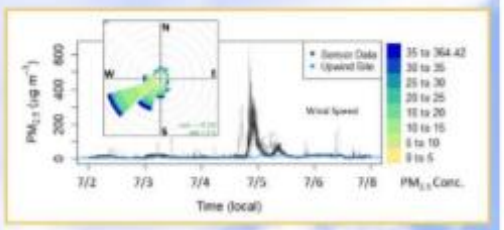
The sensor data reflects expected trends, and if sensors can show us when air quality is behaving as we might expect, can they also highlight anomalies and provide new information at sites?

What can we learn from these PurpleAir sensors about outdoor air

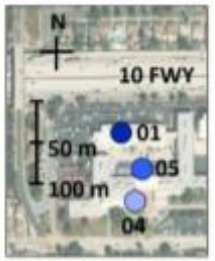
A QUICK LOOK AT THE APIFM PURPLEAIR SENSORS

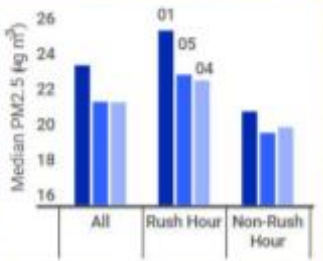
UNIQUE EMISSION EVENTS

- *High $PM_{2.5}$ on July 4th*
- *Southwest winds seem to be transporting emissions from fireworks shows in and around DTLA*
- *Sites upwind -> lower $PM_{2.5}$*



WHAT ABOUT THE 10 FWY?



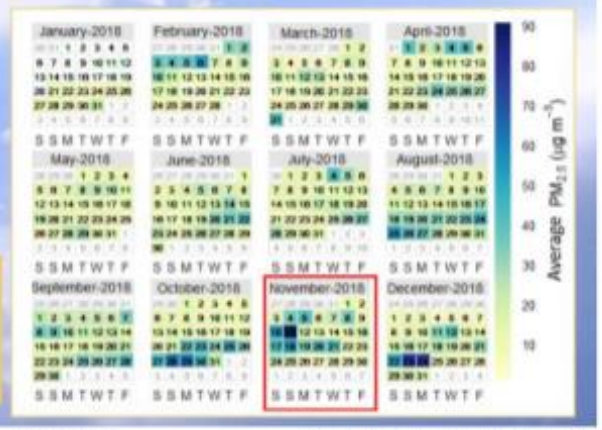


- *Data selected: summer, weekday, with northerly winds*
- *High $PM_{2.5}$ next to FWY is elevated during rush hour*
- *Lower levels during non-rush hour time*
- *Patterns such as this can help highlight when and where exposure may be the highest*

Other Events...

- *Average $PM_{2.5}$ for each day*
- *In winter months inversions may result in increased $PM_{2.5}$ for several days at a time*
- *In November, an additional contributing factor was the Woolsey Fire (11/8-11/21)*

These sensors seem to be able to provide indicative information about local air quality and air quality trends.



Conducted as part of the US EPA STAR Grant: "Engage, Educate and Empower California Communities on the Use and Applications of Low-cost Air Monitoring Sensors"

Feel free to contact us with questions:
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What Makes this Educational Toolkit Unique…

- Based on interactions and engagement with 14 diverse communities
- Based on long-term, multi-year deployments and partnerships
- Includes in-depth information on:
  - Sensor selection
  - Sensor operation and maintenance
  - Tools to support data analysis
  - And practical recommendations for ‘next steps’
- Engaging design and several useful stand-alone resources
- Finally, includes first-hand accounts and examples from real community members (such as those in the screenshot here)

How STAR Grant Participants Used Their Data

STAR Grant participants from different communities said they used sensor data to decide whether to exercise indoors or outdoors, or when to walk their dog. Residents also described checking the sensor data in the evening to decide whether or not to use their whole house fan (to pull outdoor air in).

STAR Grant

One STAR Grant community described using the sensors to monitor and guide controlled burns, including notifying nearby schools of the potential for emissions from these controlled burns.

In another STAR Grant community, using paired indoor and outdoor sensors, residents used the data to adjust their behavior in relation to cooking (e.g., adjusting ventilation based on what type of food was being prepared). Residents of this community also described using sensor data to optimize the use of indoor filtration units (i.e., improving indoor air quality, while minimizing energy usage).

One community discussed how local industry was monitoring the data made available by their STAR Grant sensors, potentially using it to inform their operations.

Conclusions & Future Work

- Educational Toolkit is available at the AQ-SPEC website: http://www.aqmd.gov/aq-spec/special-projects/star-grant

- Future Work
  - Sharing the Toolkit with STAR Grant communities will help sustain and strengthen these partnerships
  - This Toolkit can also be used for outreach to new communities and to support sensor projects locally and beyond

  ➢ ***Dissemination will bring more feedback and the opportunity to enhance and improve the STAR Grant Educational Toolkit***

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- Asian Pacific Islander Forward Movement, Los Angeles
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- Comite Civico del Valle, Imperial County
- Leisure World Club, Seal Beach
- Pioneer Valley High School, Santa Maria
- Riverside Unified School District
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- Temescal Valley Community, Riverside
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