# Utilizing IAQ Monitoring in Data-Driven Decision Making for Efficient and Healthy Schools

Tracy Enger
EPA IAQ Tools for Schools

June 21, 2023

The Washington Post
Democracy Dies in Darkness



HEALTH

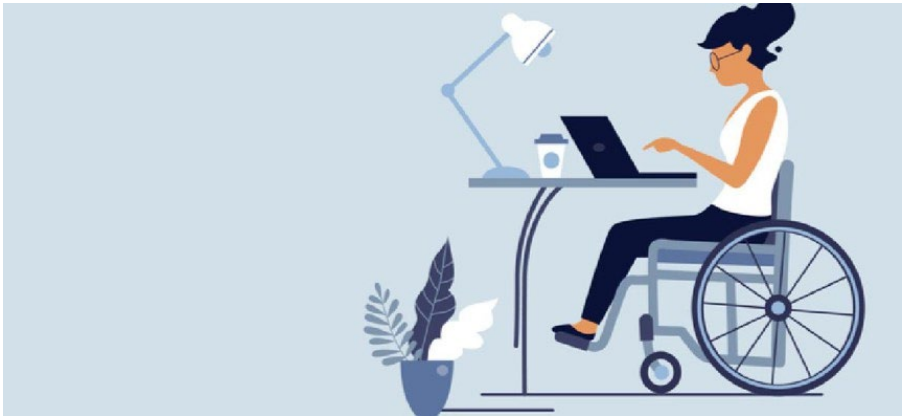
# What the end of the covid public health emergency means for you

By Lena H. Sun and Amy Goldstein


**“It didn't have to be this way, and it doesn't have to be this way again.”**

**—Maria Van Kerkhove**
**World Health Organization**

# COVID Changed Us For Good and Sometimes for the Better

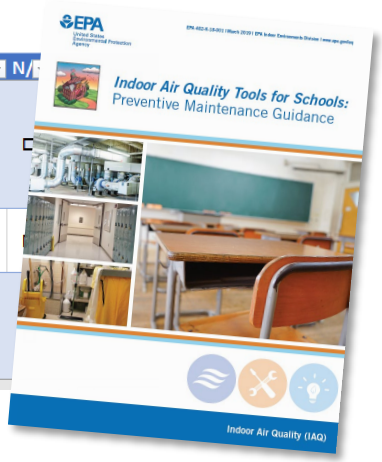


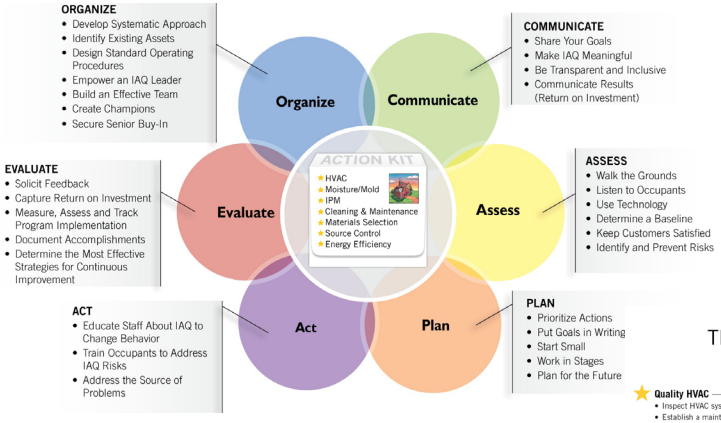

# Implementing Layered Risk Reduction Strategies

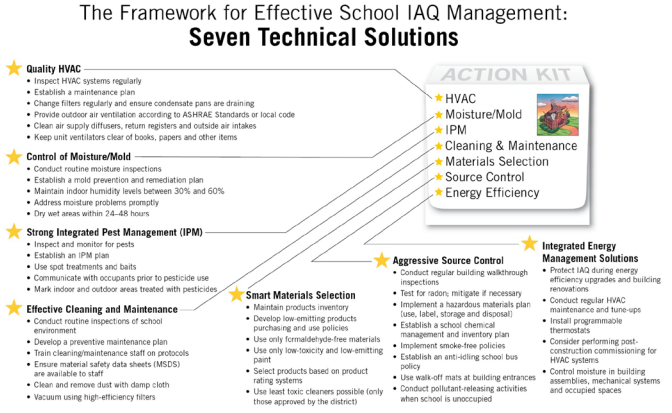
**Layered Risk Reduction (LRR) Strategy**

- Reduce source
- Require masks indoors
- Distance from source
- Reduce time indoors
- Ventilate
- Filter / Inactivate
- Clean
- Educate

| Category | Category Deta | Action | Priorit | Y | N/ |
|---|---|---|---|---|---|
| HVAC | Outdoor Air Ventilation | Implemented pre-occupancy ventilation control for ventilation systems that serve spaces that are not continuously occupied, to provide the design minimum outdoor air ventilation rate for a period of one hour prior to expected occupancy whenever the spaces have been unventilated for a period longer than 24 hours. | EA | ☐ | ☐ |
| HVAC | Outdoor Air Ventilation | Adjusted existing HVAC systems to meet all requirements of ASHRAE Standard 62.1, where possible, using the Ventilation Rate Procedure. | MA | ☐ | |
| HVAC | Outdoor Air Ventilation | Considered the impacts of building envelope air sealing on ventilation. Avoided tightening the building shell and reducing air exchange rates if increasing ventilation or installing additional ventilation is not possible. Ensured school buildings that rely on | MA | ☐ | |



# American Rescue Plan (ARP):
## *Funding for COVID-19 Response*

- American Rescue Plan Act – Title II sets aside **$122 billion** to Department of Education for the Elementary and Secondary School Emergency Relief Fund (in addition to funds available through the Education Stabilization Fund)

- Under Title II U.S.C. § 2001(e)(2), approximately $81 billion is being awarded to state education agencies (SEAs) to address 18 areas of activity in schools, including **five IAQ-related activities and infrastructure improvements**

**American Rescue Plan Act, Title II U.S.C. § 2001(e)(2) (2021)**

(H) Training and professional development for staff of the local educational agency on sanitation and minimizing the spread of infectious diseases.

(I) Purchasing supplies to sanitize and clean the facilities of a local educational agency…

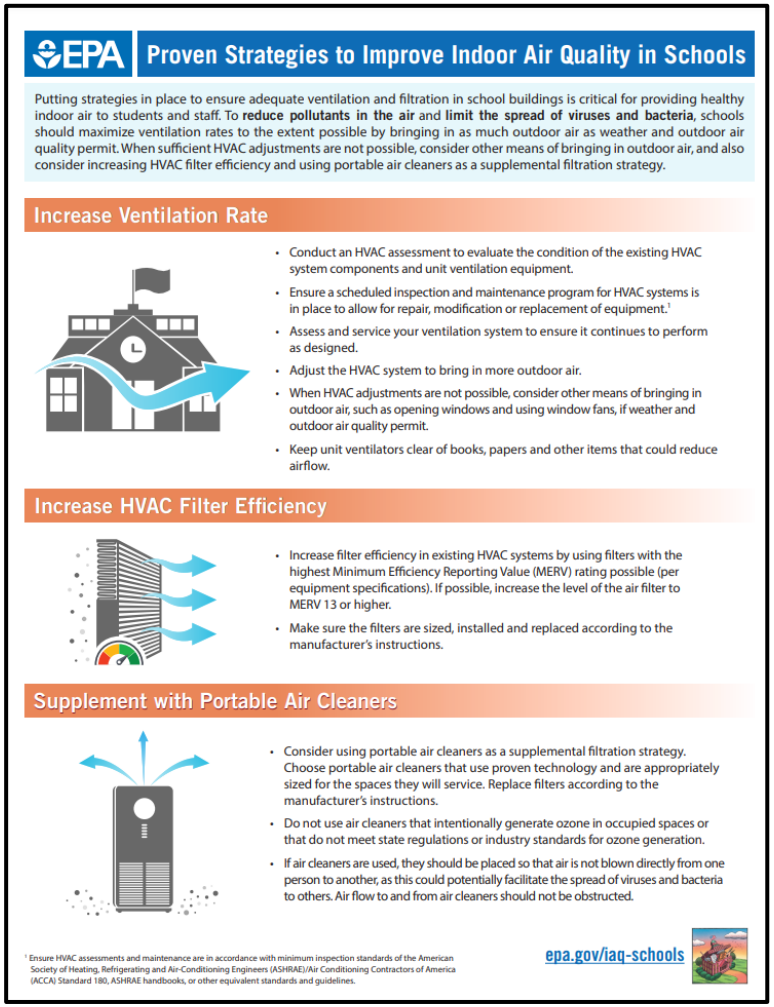
(O) School facility repairs and improvements to enable operation of schools to reduce risk of virus transmission and exposure to environmental health hazards…

(P) Inspection, testing, maintenance, repair, replacement, and upgrade projects to improve the indoor air quality in school facilities, including mechanical and non-mechanical heating, ventilation, and air conditioning systems, filtering, purification and other air cleaning, fans, control systems, and window and door repair and replacement.

(Q) Developing strategies and implementing public health protocols including . . . policies in line with guidance from the Centers for Disease Control and Prevention for the reopening and operation of school facilities to effectively maintain the health and safety of students, educators, and other staff.

# Proven Strategies to Improve IAQ in Schools Infographic

- Increase ventilation rate
- Increase HVAC filter efficiency
- Supplement with portable air cleaners



EPA Proven Strategies to Improve Indoor Air Quality in Schools

Putting strategies in place to ensure adequate ventilation and filtration in school buildings is critical for providing healthy indoor air to students and staff. To **reduce pollutants in the air** and **limit the spread of viruses and bacteria**, schools should maximize ventilation rates to the extent possible by bringing in as much outdoor air as weather and outdoor air quality permit. When sufficient HVAC adjustments are not possible, consider other means of bringing in outdoor air, and also consider increasing HVAC filter efficiency and using portable air cleaners as a supplemental filtration strategy.

Increase Ventilation Rate

- Conduct an HVAC assessment to evaluate the condition of the existing HVAC system components and unit ventilation equipment.
- Ensure a scheduled inspection and maintenance program for HVAC systems is in place to allow for repair, modification or replacement of equipment.[1]
- Assess and service your ventilation system to ensure it continues to perform as designed.
- Adjust the HVAC system to bring in more outdoor air.
- When HVAC adjustments are not possible, consider other means of bringing in outdoor air, such as opening windows and using window fans, if weather and outdoor air quality permit.
- Keep unit ventilators clear of books, papers and other items that could reduce airflow.

Increase HVAC Filter Efficiency

- Increase filter efficiency in existing HVAC systems by using filters with the highest Minimum Efficiency Reporting Value (MERV) rating possible (per equipment specifications). If possible, increase the level of the air filter to MERV 13 or higher.
- Make sure the filters are sized, installed and replaced according to the manufacturer's instructions.

Supplement with Portable Air Cleaners

- Consider using portable air cleaners as a supplemental filtration strategy. Choose portable air cleaners that use proven technology and are appropriately sized for the spaces they will service. Replace filters according to the manufacturer's instructions.
- Do not use air cleaners that intentionally generate ozone in occupied spaces or that do not meet state regulations or industry standards for ozone generation.
- If air cleaners are used, they should be placed so that air is not blown directly from one person to another, as this could potentially facilitate the spread of viruses and bacteria to others. Air flow to and from air cleaners should not be obstructed.

[1] Ensure HVAC assessments and maintenance are in accordance with minimum inspection standards of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)/Air Conditioning Contractors of America (ACCA) Standard 180, ASHRAE handbooks, or other equivalent standards and guidelines.

epa.gov/iaq-schools

Center for Green Schools

**Key findings from Fall 2022 survey to school districts:**

- **Many districts do not have written IAQ management plans.**
  - Half of respondents reported not having an IAQ plan and that establishing one is a top priority.
- **K–12 staff need resources and support to educate staff, teachers, and community members about IAQ.**
  - 90% reported that they do not have established processes in place to communicate about IAQ activities with the community or provide training to teachers and staff on identifying or reporting IAQ issues.
- **Guidance is needed on creating district-level IAQ teams.**
  - Half of respondents reported needing training on creating a district-level IAQ team and establishing IAQ contacts in each school.


# KEY DRIVER:
# Evaluate Your Results for Continuous Improvement

## EVALUATE

- Solicit Feedback
- Capture Return on Investment
- Measure, Assess and Track Program Implementation
- Document Accomplishments
- Determine the Most Effective Strategies for Continuous Improvement

Photo credits: Dave Blake and Rich Prill's images from the 2013 Virtual School Walkthrough Webinar


# KEY DRIVER:
# Evaluate Your Results for Continuous Improvement

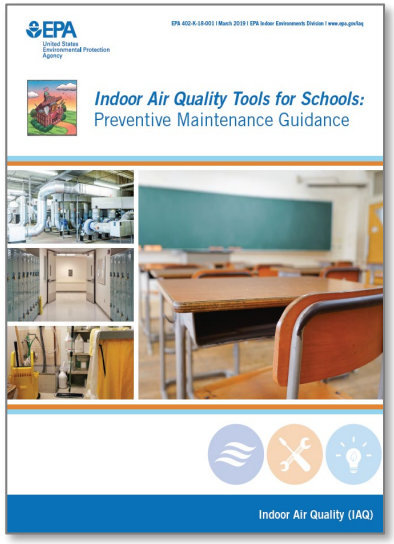
## Evaluate Your Results for Continuous Improvement

- **Measure, assess and track program implementation.** Use tracking sheets or tables to record collected data and develop metrics to allow you to evaluate your program's progress and impact.
- **Solicit feedback.** Collect information about the facility IAQ from school staff using the Collection of IAQ Checklists.
- **Determine the most effective strategies for continuous improvement.** Capturing return on investment by monitoring metrics—such as the number of IAQ complaints, the cost of IAQ-related repairs, and changes in school nurse visits, attendance rates and test scores over time—can help you assess the success of your work and better understand how you can refine your plan as needed. In addition, IAQ sensors are a newer technology that can be integrated into a building management system to help continuously monitor certain IAQ metrics. For COVID-19 risk reduction, in particular, use such tools as FaTIMA from the National Institute of Standards and Technology (NIST) and COVID-19 Risk Estimator to determine which control measures to put in place and their effectiveness in reducing risk.

- IAQ Preventive Maintenance Guidance—Evaluation (EPA)
- IAQ Walkthrough and Ventilation Checklists (EPA)
- FaTIMA Model to determine the indoor air fate of microbiological aerosols (NIST)
- COVID-19 Risk Estimator (Setty)


# KEY DRIVER:
## Evaluate Your Results for Continuous Improvement

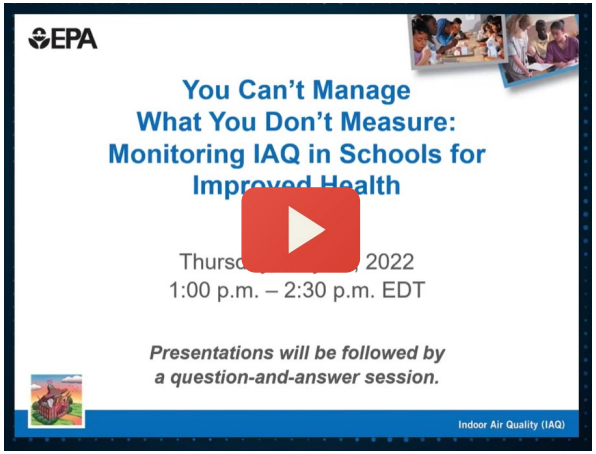
- Decide which data points to track.
- Create tracking sheets/tables.
- Create baselines.
- Find ways to compare your data.
- Reassess and fine-tune your goals.
- Continue to make the (business and health) case to decision-makers.




***Indoor Air Quality Tools for Schools:***
**Preventive Maintenance Guidance**

# IAQ Sensors and Monitoring

- Collect, monitor, measure, and evaluate IAQ data in order to take appropriate action and make improvements.
  - Carbon dioxide levels are used as an indicator of adequate ventilation and air exchange rates.
- Communicate and educate about IAQ measures.
- Develop community agency, collaboration, and trust around school environmental health.




**Learn more in this webinar:**
*"You Can't Manage What You Don't Measure: Monitoring IAQ in Schools for Improved Health"*
featuring Boston Public Schools

# IAQ Monitoring in Schools

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June 21, 2023

www.epa.gov/indoor-air-quality-iaq/clean-air-buildings-challenge

EPA

# Clean Air in Buildings Challenge

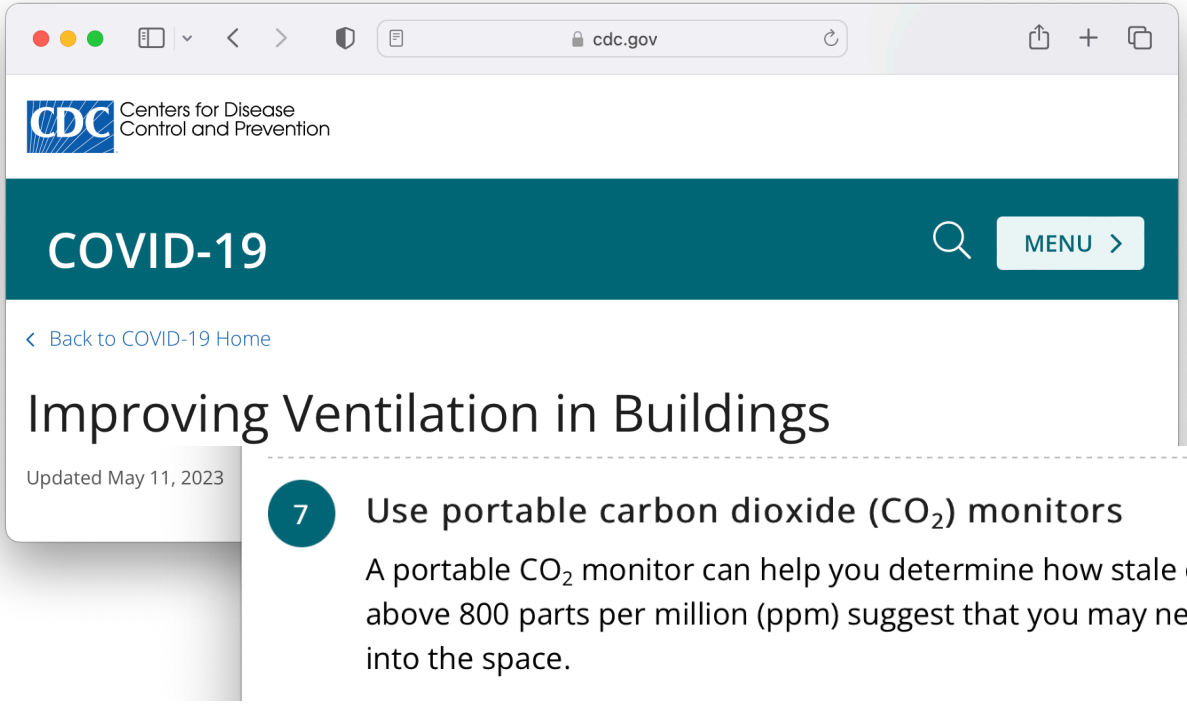
U.S. ENVIRONMENTAL PROTECTION AGENCY MARCH 2022

1. **CREATE AN ACTION PLAN FOR CLEAN INDOOR AIR IN YOUR BUILDING(S)** that assesses IAQ, plans for upgrades and improvements, and includes HVAC inspections and maintenance.

2. **OPTIMIZE FRESH AIR VENTILATION** by bringing in and circulating clean outdoor air indoors.

3. **ENHANCE AIR FILTRATION AND CLEANING** using the central HVAC system and in-room air cleaning devices.

4. **GET YOUR COMMUNITY ENGAGED IN YOUR ACTION PLAN** by communicating with building occupants to increase awareness, commitment, and participation in improving indoor air quality and health outcomes.




https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/Improving-Ventilation-in-buildings.html

# Monitor CO2 to show improvement in ventilation

Lower Grade (Ages 6-10)

- Average CO2 emission: 0.0043 L/s per person
- About **10.5 L/s-person** outside air needed to keep CO2 below 800 ppm

Upper Grade (Ages 11-16)

- Average CO2 emission: 0.0057 L/s per person
- About **14 L/s-person** outside air needed to keep CO2 below 800 ppm

Currently, code required outdoor air ventilation rate is about **7 L/s per person**.

https://www.epa.gov/indoor-air-quality-iaq/wildfires-and-indoor-air-quality-schools-and-commercial-buildings#wildfire


8. Prepare to monitor indoor $PM_{2.5}$ by purchasing one or more low-cost air sensors designed to measure the pollutant. These low-cost sensors can be used to show trends in $PM_{2.5}$ levels (i.e., whether $PM_{2.5}$ is increasing or decreasing). These low-cost sensors will not be as accurate as regulatory monitors, but can show whether your interventions are reducing indoor $PM_{2.5}$.

# Classroom HVAC Retrofit Evaluation Study

WCEC WESTERN COOLING EFFICIENCY CENTER

CALIFORNIA ENERGY COMMISSION

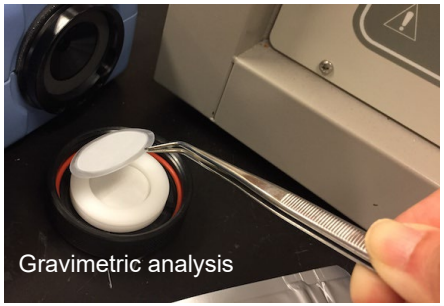
vironmental-quality-california-schools

# IAQ monitoring (2017/2018)

- Two schools, 13 classrooms, all with retrofitted HVAC
- Measurements:
  - $CO_2$ (Vaisala)
  - $PM_{2.5}$ (DustTrak, gravimetric)
  - Black carbon (ABCD)
  - Ozone (2BTech)
  - Formaldehyde (Time-resolved and passive)

| | Bakersfield Region Elementary School | Sacramento Region High School |
|---|---|---|
| Visit 1 | Dec 5–19, 2017 | Feb 1–9, 2018 |
| Visit 2 | May 7–14, 2018 | May 29–June 5, 2018 |
| Visit 3 | Oct 10–18, 2018 | Oct 30–Nov 8, 2018 |


TSI DustTrak II 8530


Gravimetric analysis


Aerosol Black Carbon Detector

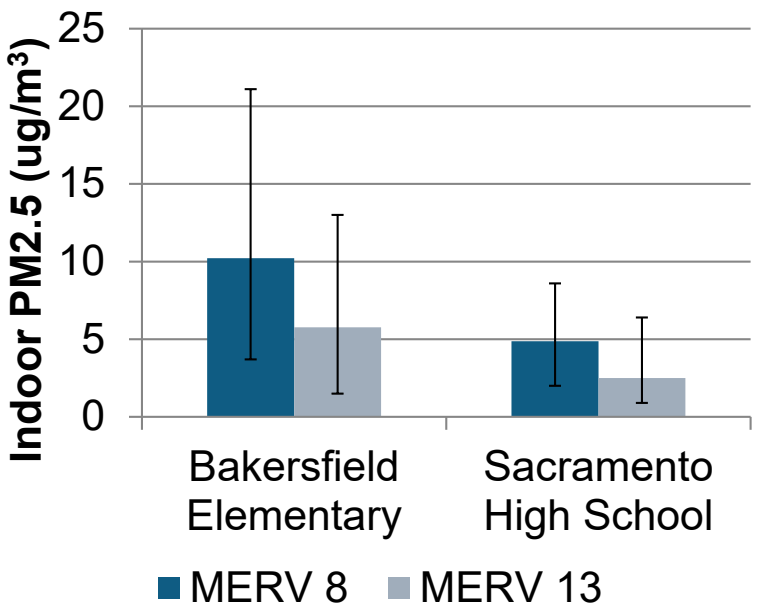
2BTech 202/205

Vaisala GMW94


SKC UMEx

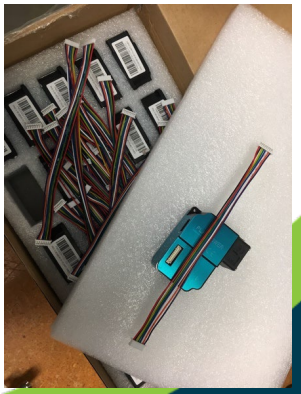
Graywolf FMM

# Monitor indoor $PM_{2.5}$ to show the effect of filtration




- 44% (Bakersfield) and 49% (Sacramento) reduction in mean $PM_{2.5}$ from the three visits
- Long-term Plantower sensor data show 41% (Bakersfield) and 45% (Sacramento) reduction in mean $PM_{2.5}$

Plantower PM Sensor



vironmental-quality-california-schools

# Baseline and document ventilation / filtration improvements

| What indoor air pollutants to measure? | |
|---|---|
| CO2 (carbon dioxide)<br>PM (particulate matter) | Yes |
| Temperature<br>Relative humidity | Yes |
| Other gaseous air pollutants:<br>O3 (ozone)<br>SO2 (sulfur dioxide)<br>NO2 (nitrogen dioxide)<br>CO (carbon monoxide) | Maybe; for addressing specific concerns about exposure to polluted outdoor air (O3, SO2), or emissions from combustion (NO2, CO) |
| TVOCs (total volatile organic compounds) | Not informative to guide actions |

Air Quality Sensors

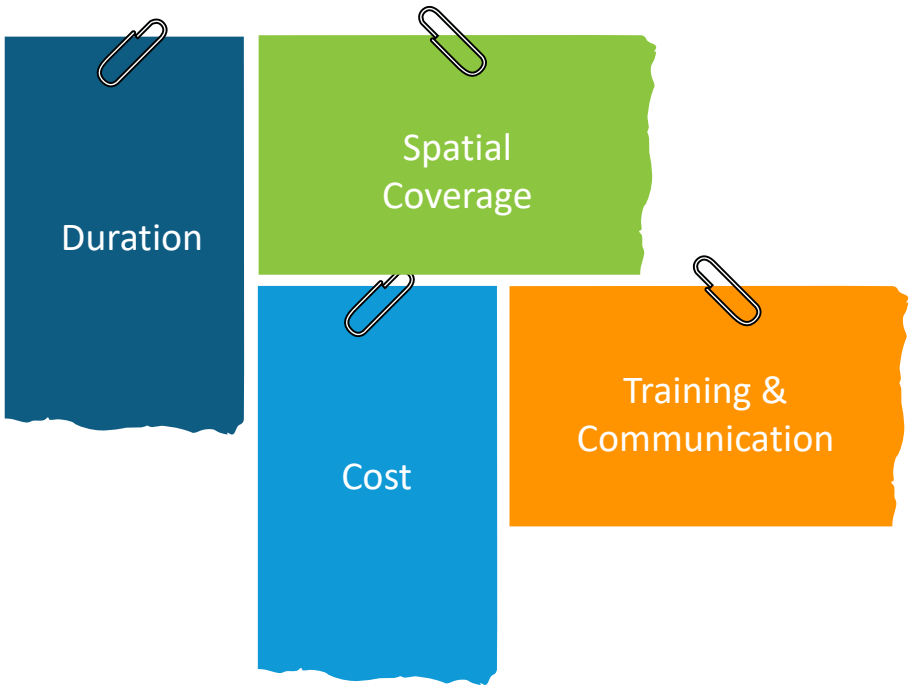
# Set Goals of IAQ monitoring

1. **Communication Tool**
   Visualization; Need consensus from stakeholders on threshold levels and next steps

2. **Guide Building Operation**
   Data analytics; Compute stats helpful for facilities to identify problems and evaluate outcomes

3. **Integrated Building Control**
   System integration; e.g. HVAC operation modes

# Key Decisions



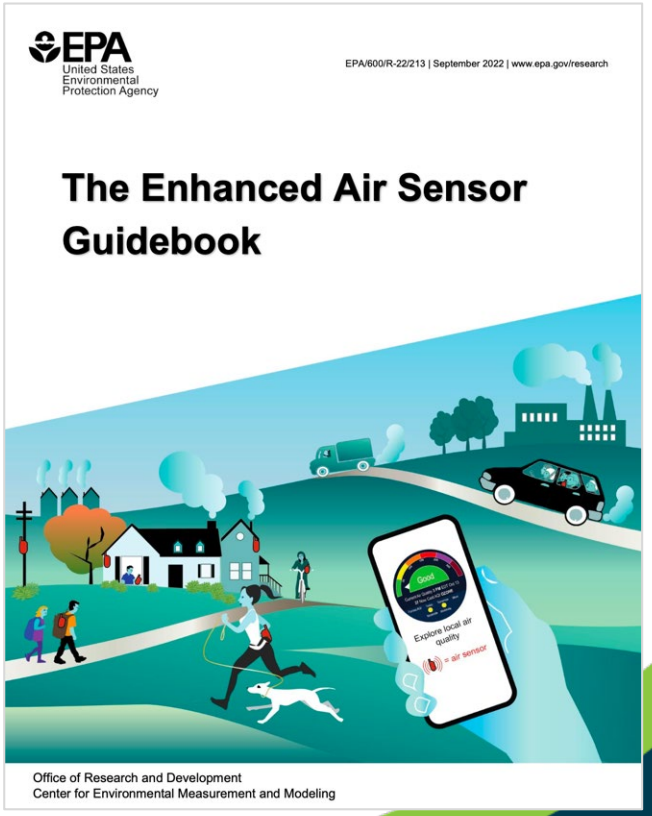

- Long-term continuous monitoring versus short-term (days or weeks) audit.
- Entire school or prioritize classrooms; monitor in each room or use a sampling approach
- Consider installation and ongoing maintenance costs: access to data platform, monitoring equipment replacement
- Staff training and communication with stakeholders about key findings

# EPA Resources on Air Sensors

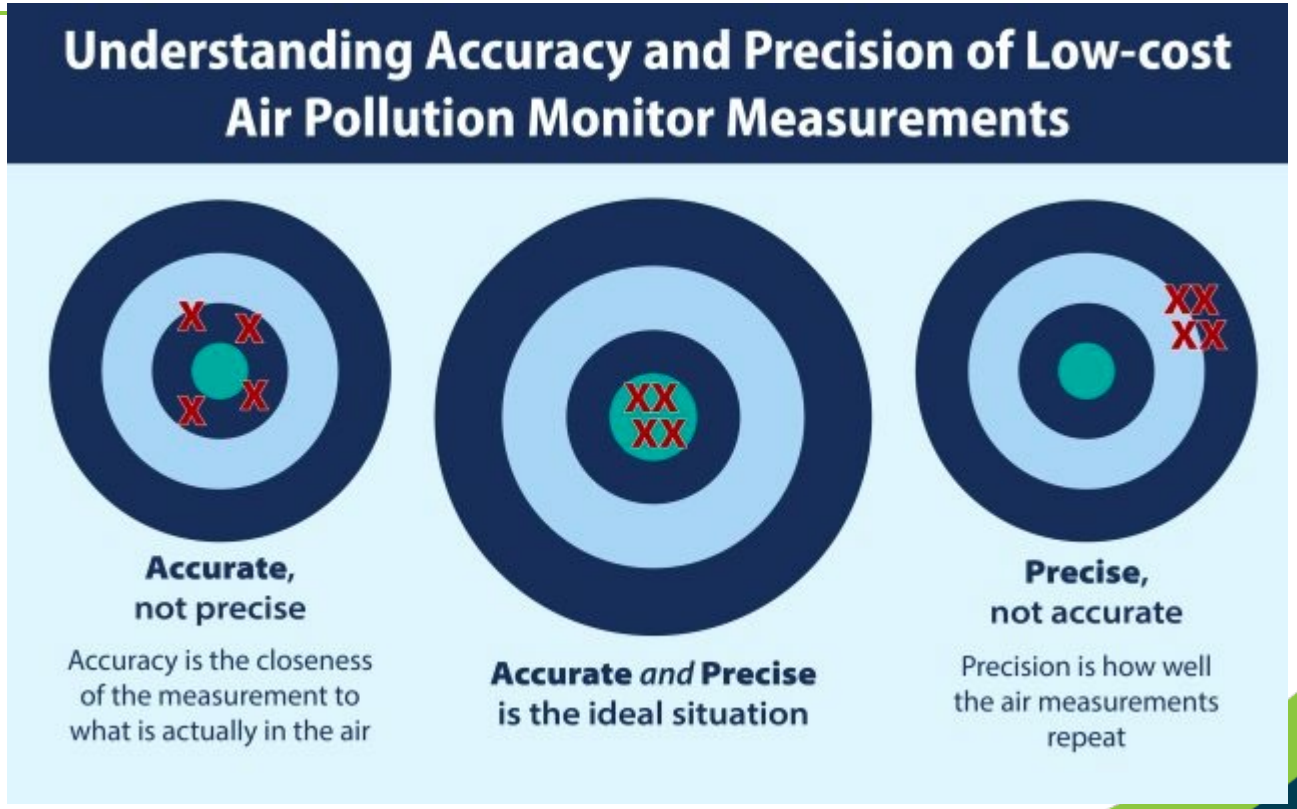
www.epa.gov/air-sensor-toolbox

www.epa.gov/indoor-air-quality-iaq/air-sensor-technology-and-indoor-air-quality

**Air Sensor Technology and Indoor Air Quality**



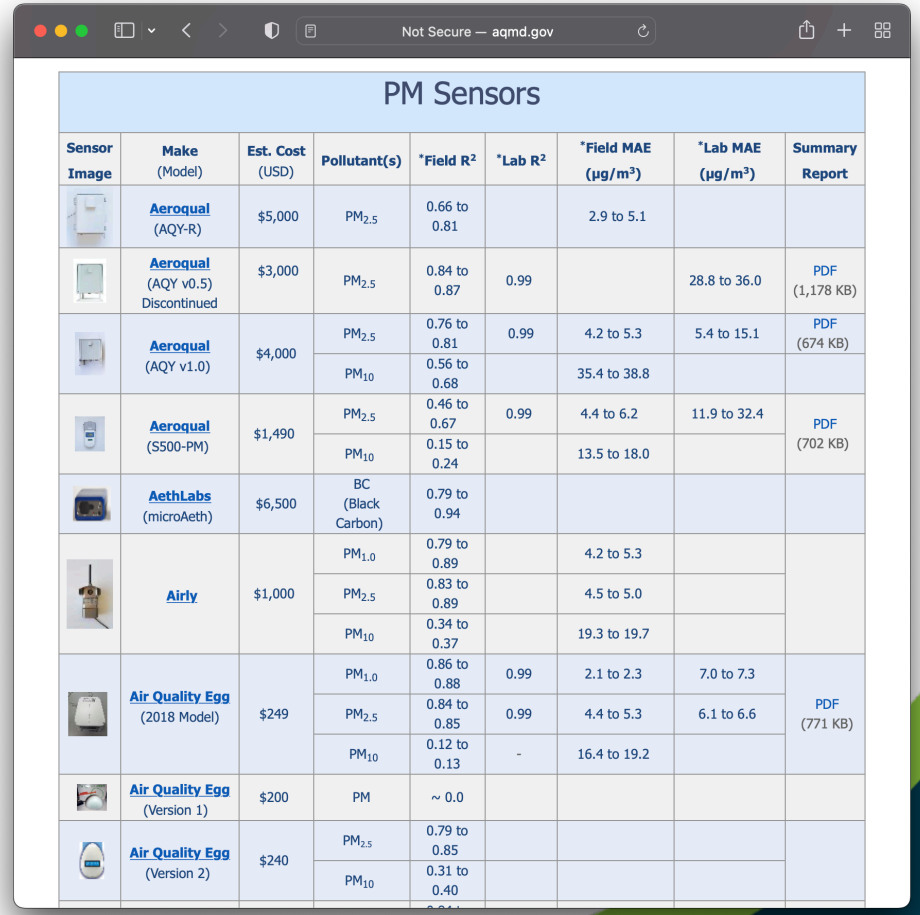
https://www.epa.gov/indoor-air-quality-iaq/low-cost-air-pollution-monitors-and-indoor-air-quality



# Additional Resources

- South Coast Air Quality Management District - Air Quality Sensor Performance Evaluation Center (AQ-SPEC)

South Coast AQMD

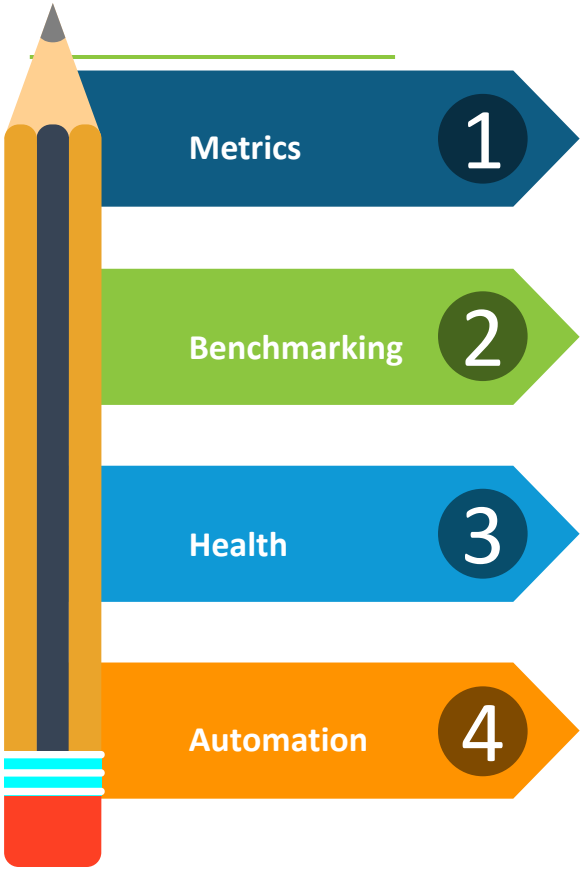



PM Sensors

| Sensor Image | Make (Model) | Est. Cost (USD) | Pollutant(s) | *Field $R^2$ | *Lab $R^2$ | *Field MAE ($\mu g/m^3$) | *Lab MAE ($\mu g/m^3$) | Summary Report |
|---|---|---|---|---|---|---|---|---|
| | Aeroqual (AQY-R) | $5,000 | $PM_{2.5}$ | 0.66 to 0.81 | | 2.9 to 5.1 | | |
| | Aeroqual (AQY v0.5) Discontinued | $3,000 | $PM_{2.5}$ | 0.84 to 0.87 | 0.99 | | 28.8 to 36.0 | PDF (1,178 KB) |
| | Aeroqual (AQY v1.0) | $4,000 | $PM_{2.5}$ | 0.76 to 0.81 | 0.99 | 4.2 to 5.3 | 5.4 to 15.1 | PDF (674 KB) |
| | | | $PM_{10}$ | 0.56 to 0.68 | | 35.4 to 38.8 | | |
| | Aeroqual (S500-PM) | $1,490 | $PM_{2.5}$ | 0.46 to 0.67 | 0.99 | 4.4 to 6.2 | 11.9 to 32.4 | PDF (702 KB) |
| | | | $PM_{10}$ | 0.15 to 0.24 | | 13.5 to 18.0 | | |
| | AethLabs (microAeth) | $6,500 | BC (Black Carbon) | 0.79 to 0.94 | | | | |
| | Airly | $1,000 | $PM_{1.0}$ | 0.79 to 0.89 | | 4.2 to 5.3 | | |
| | | | $PM_{2.5}$ | 0.83 to 0.89 | | 4.5 to 5.0 | | |
| | | | $PM_{10}$ | 0.34 to 0.37 | | 19.3 to 19.7 | | |
| | Air Quality Egg (2018 Model) | $249 | $PM_{1.0}$ | 0.86 to 0.88 | 0.99 | 2.1 to 2.3 | 7.0 to 7.3 | |
| | | | $PM_{2.5}$ | 0.84 to 0.85 | 0.99 | 4.4 to 5.3 | 6.1 to 6.6 | PDF (771 KB) |
| | | | $PM_{10}$ | 0.12 to 0.13 | - | 16.4 to 19.2 | | |
| | Air Quality Egg (Version 1) | $200 | PM | ~ 0.0 | | | | |
| | Air Quality Egg (Version 2) | $240 | $PM_{2.5}$ | 0.79 to 0.85 | | | | |
| | | | $PM_{10}$ | 0.31 to 0.40 | | | | |

# Questions to think through about IAQ monitoring

- How to check for agreement among the many IAQ monitors in schools?
- How to identify monitors that are not performing?
- How to compare measurements from inside a school and outdoor air quality data?
- How to compare IAQ measurements with data being collected using different monitors?




Clear metrics for setting goals to achieve better indoor air quality in schools

Benchmarking of indoor air quality data in a large, representative cohort of schools

Further our understanding on how indoor air quality parameters can inform health and learning

Advance data analytics for automated diagnostics to improve building operation

# IAQ Monitoring in Schools

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June 21, 2023

JUNE | 21 | 2023

# Classroom IAQ Monitoring Through Central Controls

Sacramento City
UNIFIED SCHOOL DISTRICT

Sacramento City Unified School District

# Project Team

- Chris Ralston – Director, Facilities Management
- Chamberlain Segrest – Sustainability Manager
- Mike Taxara – Project Manager
- Alex Constance – Supervisor, HVAC

# Project Goals

- Replace very old central controls system
- Grant funding (free money) – ESSER II/III Funding
- Efficient project execution – Complete by September 2024
- Be able to adjust to new environmental expectations quickly
  - COVID
  - Wildfires
  - Energy Efficiency
- No Classroom visual displays

# Project Details

- Install new Metasys platform control center
- Install new t-stats, CO2 in every classroom and gathering space
- Install new combo t-stat/CO2/PM sensor in select classrooms to get site average for particulate matter
- Install or repair dampers to allow for automatic demand ventilation changes
- Install outside senor at each school project (23 schools in current project)
  - CO2
  - PM
  - VOC
- Long term data gathering

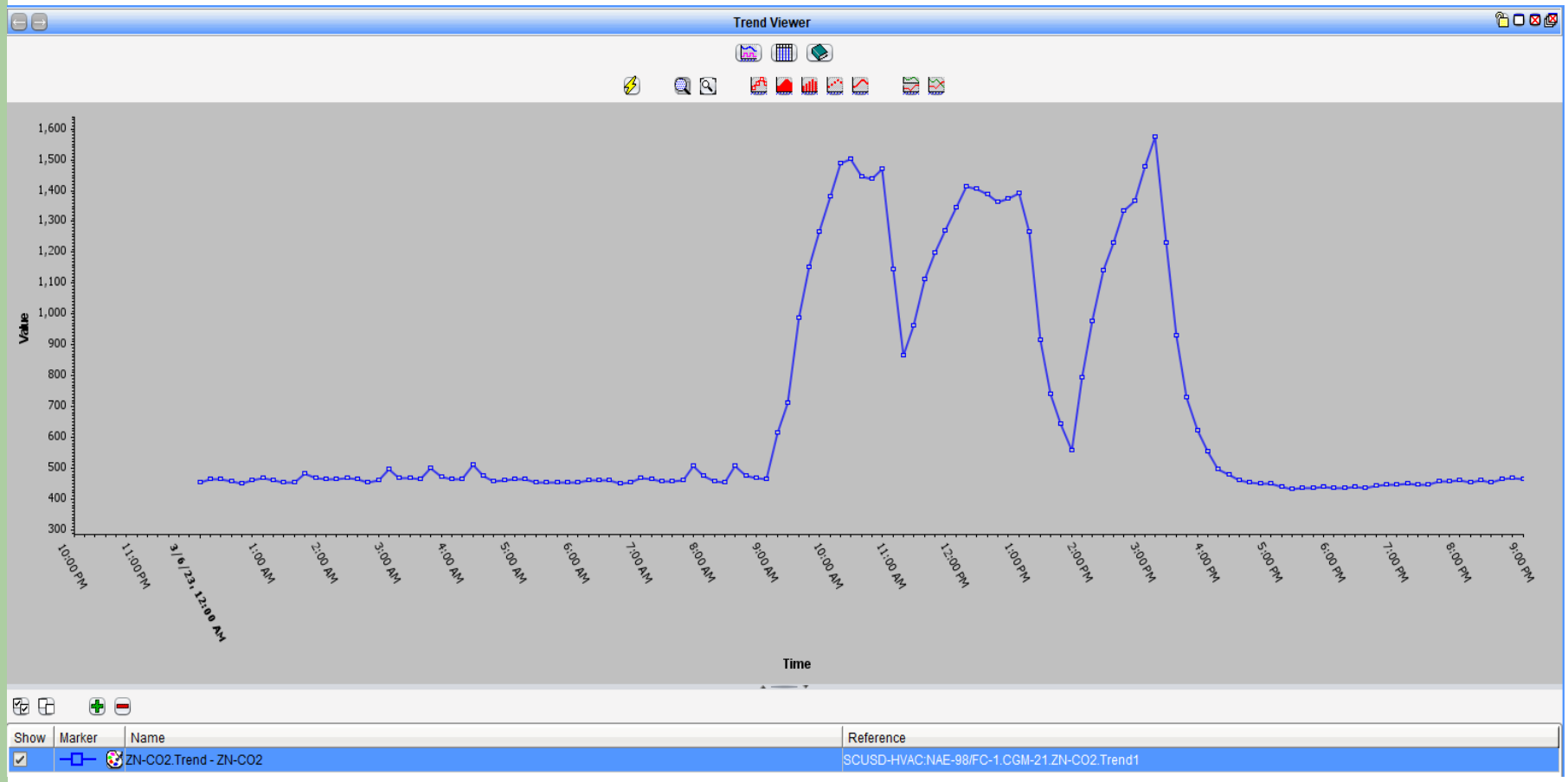
# Field Application

Hollywood Park Room 14

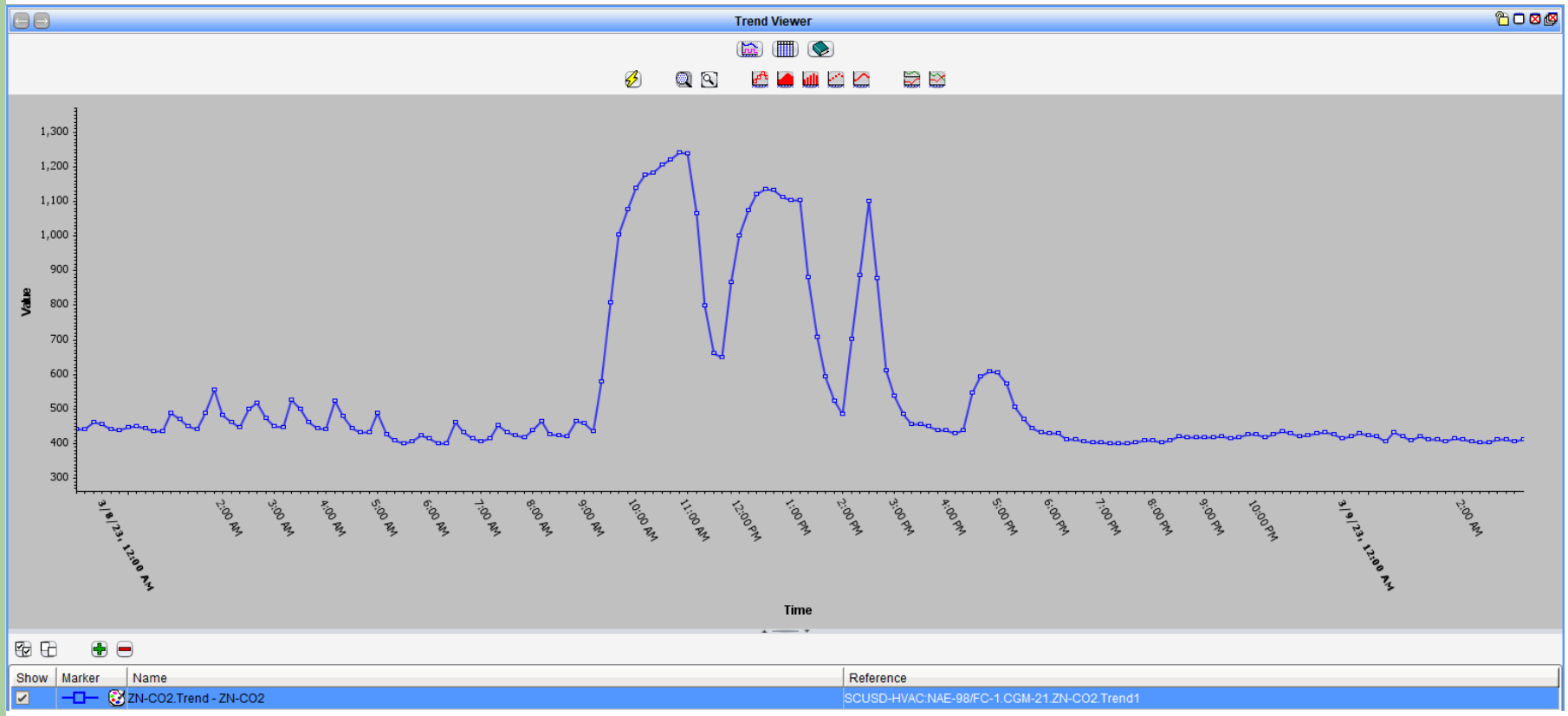
# Classroom Details – Hollywood Park Room 14

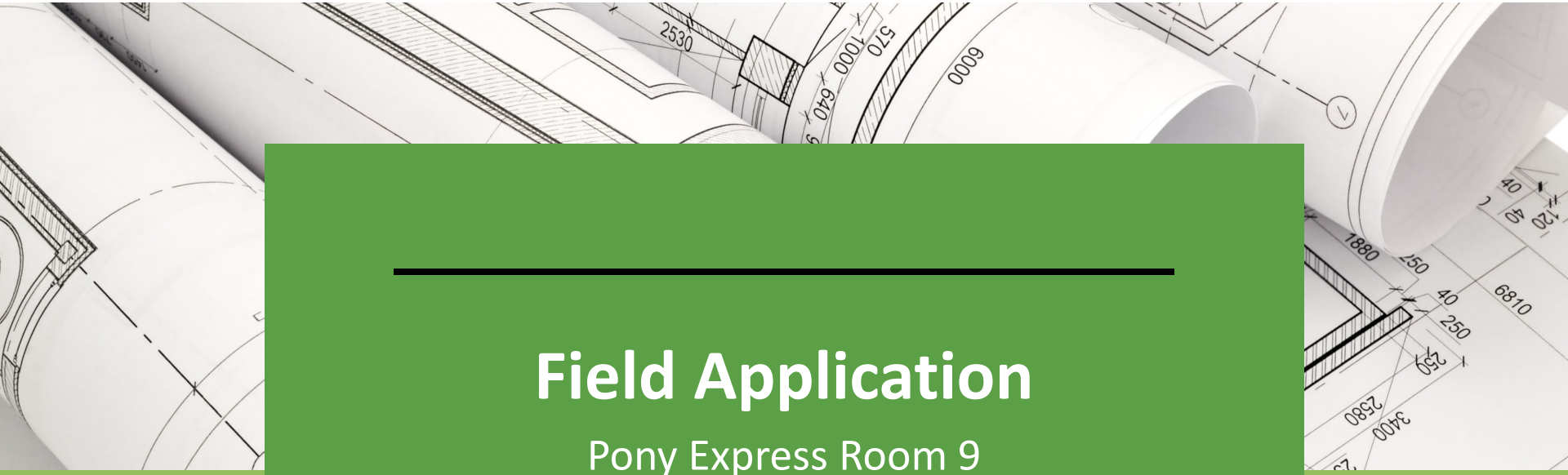
- 960 square foot classroom – portable
- Student load rate 33:1
- Actual load rate 39 students
- Bard unit
- ½ to HWY 99, ¼ Mile to Executive Airport, 1 mile to I-5

# Classroom Data March 6, 2023 (Before)



# Classroom Data March 8, 2023 (After)





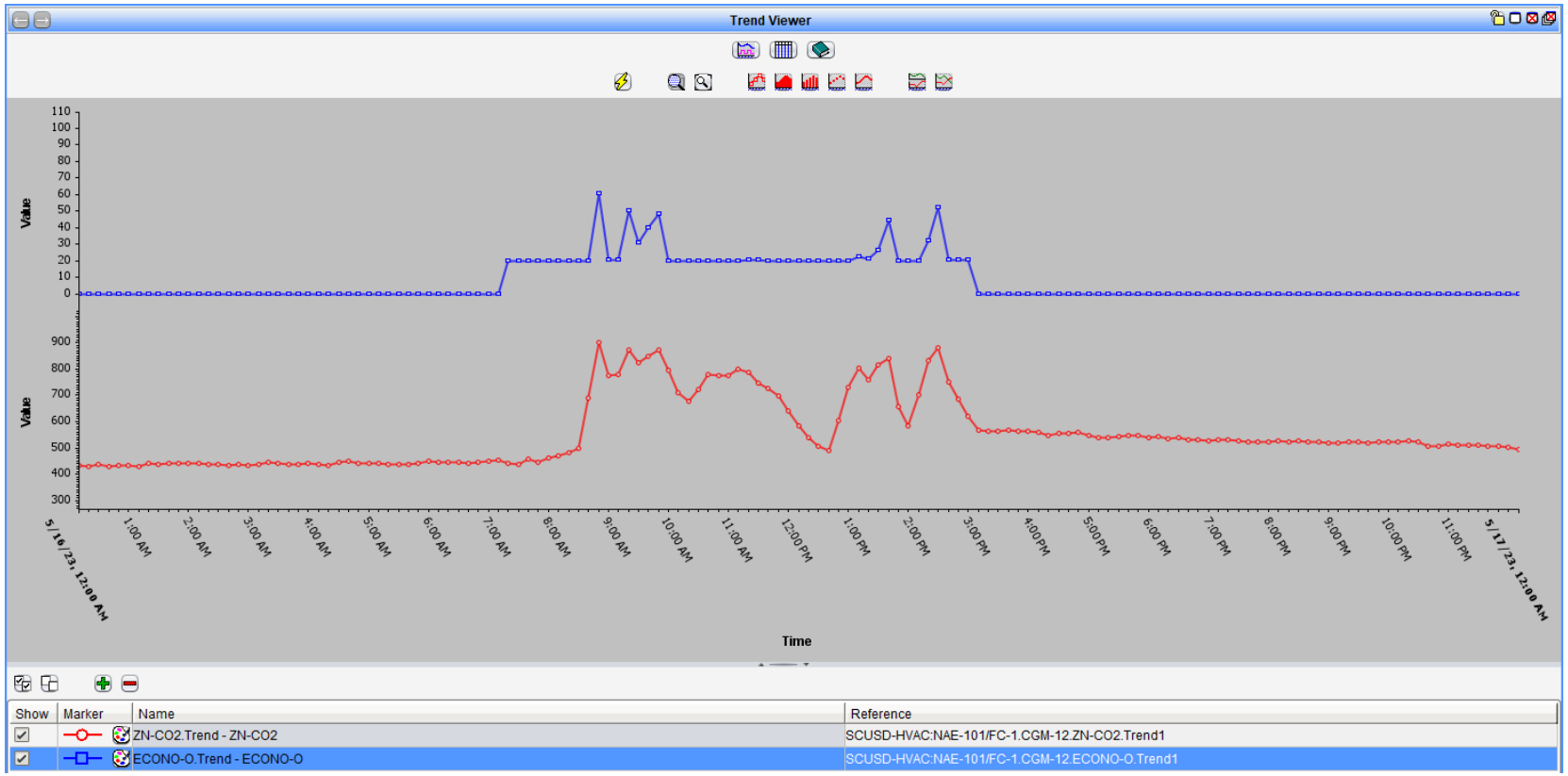
# Field Application

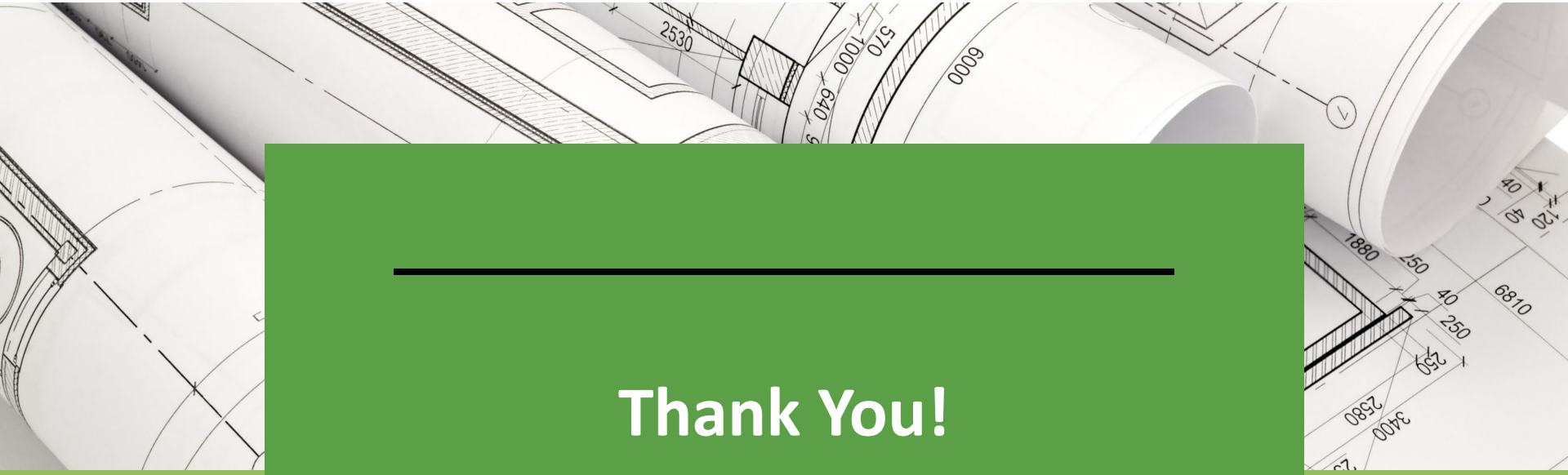
Pony Express Room 9

# Classroom Details – Pony Express Room 9

- 900 square foot classroom – Standard Construction
- Student load rate 24:1
- Actual load rate 24 students
- 4 Ton Split system – Gas furnace
- 1500 feet to I-5, 2000 feet to Executive Airport

# Classroom Data March 10, 2023 – Pony Express





# Thank You!