Boston Public Schools

Indoor Air Quality and Ventilation at BPS

December 1, 2022

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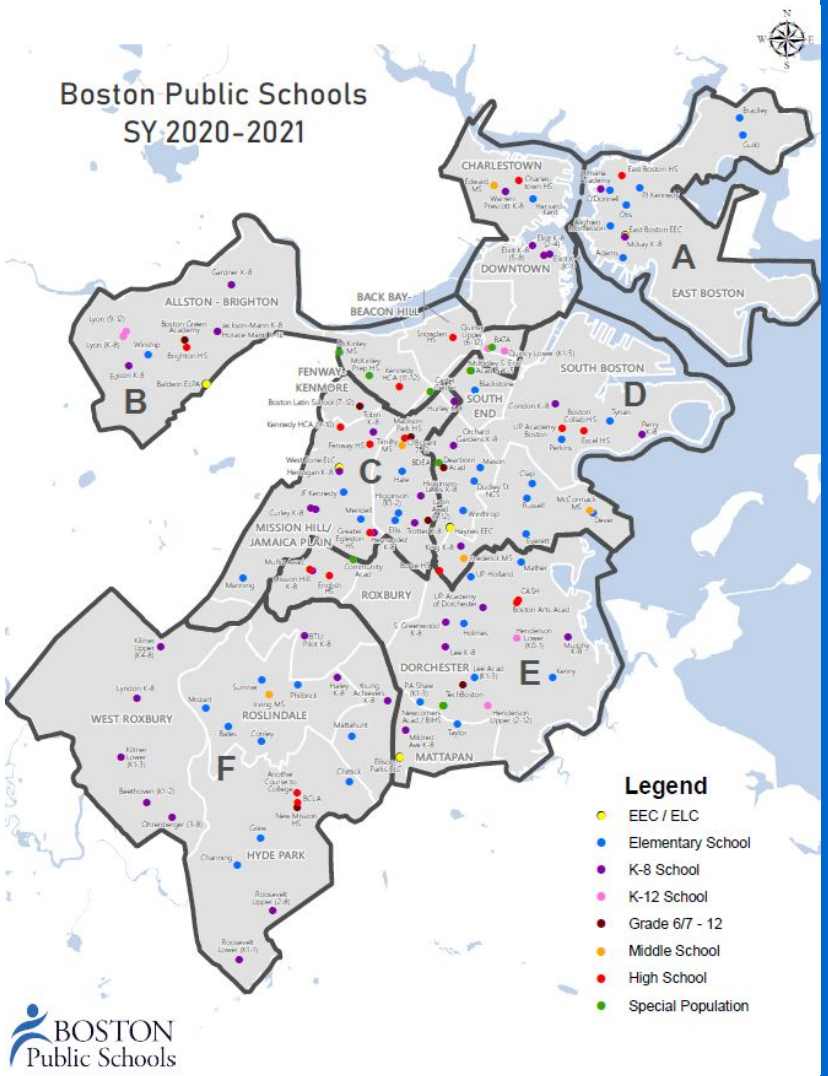


Boston Public Schools (BPS) is the oldest public school system in the United States.

School Year 2021–2022

- 121 schools
- 49,261 students
- 10,000+ staff

132 buildings

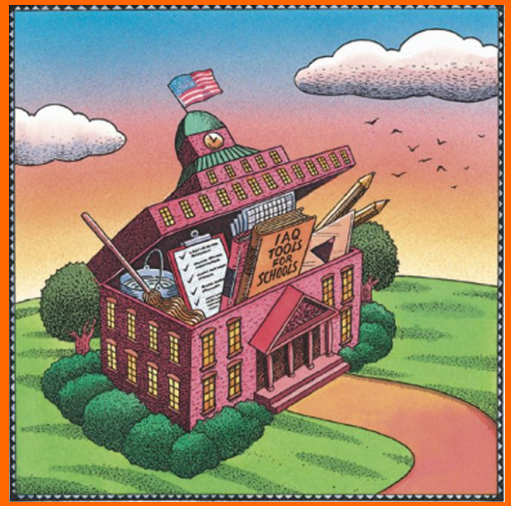
- 59% of built before 1950
- 73% built before 1970

STATUS OF BPS HVAC

- 35 school sites have **Central HVAC** as their primary source of ventilation.
  - 25 do not have operable windows
  - 10 have operable windows

- 96 school sites have **Operable Windows** as their primary source of ventilation.
  - 47 have supplementary/limited mechanical ventilation
  - 49 have no mechanical ventilation

BPS INDOOR AIR QUALITY MANAGEMENT PROGRAM



U.S. EPA's IAQ Tools for Schools

Indoor Air Quality (IAQ) is very important to Boston Public Schools.

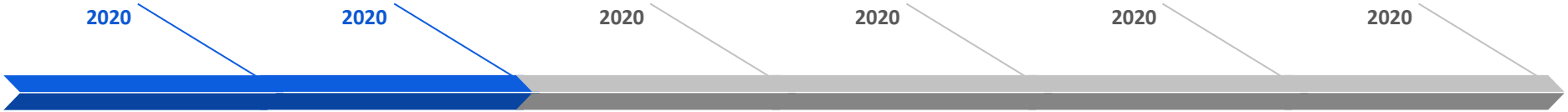
> "Good IAQ contributes to a favorable environment for students, performance of teachers and staff, and a sense of comfort, health and well-being. These elements combine to assist a school in its core mission — educating children."
> — U.S. EPA

BPS follows guidance from the **U.S. EPA's "*IAQ Tools for Schools*"** program and implements a **layered risk reduction approach** to its Indoor Air Quality Management program.

The *IAQ Tools for Schools* definition of good indoor air quality management includes:

- Control of airborne pollutants;
- Introduction and distribution of adequate outdoor air; and
- Maintenance of acceptable temperature and relative humidity.

COVID-19 INDOOR AIR QUALITY & VENTILATION TIMELINE



2020

March - August

HVAC preventative maintenance and adjustments ongoing; 12,000 filters replaced

Inspection of 27,000 windows underway

2020

July - August

Receipt of COVID-19 guidance for schools from CDC, DESE, ASHRAE, etc. BPS creates compliance documents.

2020

September

Indoor Air Quality Testing of School Buildings and release of results

Distribution of 6,437 Fans

2020

October

Indoor Air Quality Testing of Admin Buildings and release of results

Annual School Environmental Audits commence

2020

November

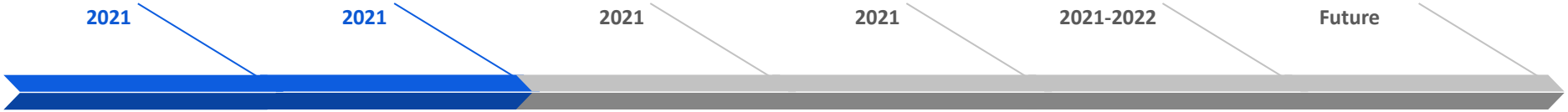
Air Exchange Testing of High In Person Priority (HIPP) Schools and release of results

2020

December

Distribution of 5,164 HEPA Air Purifiers

RFP for Indoor Air Quality Sensors



2021

February - March

Air Exchange Testing of Remaining Schools

Installations of 4,327 MERV-13 filters completed

2021

April

Release of ACH Testing results

Needed repairs on 12,500 windows completed

2021

June

Annual School Environmental Audits completed

2021

June - August

All HVAC and air purifier filters replaced

2021-2022

July - Present

Implementation of Indoor Air Quality Sensors Initiative

Ongoing analysis of data and responding to elevated levels.

Future

Expand mechanical ventilation across more schools

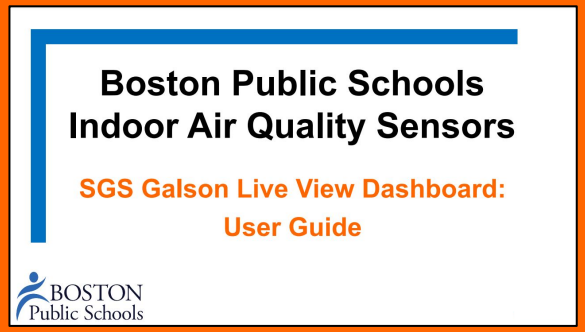
INDOOR AIR QUALITY MONITORING INITIATIVE

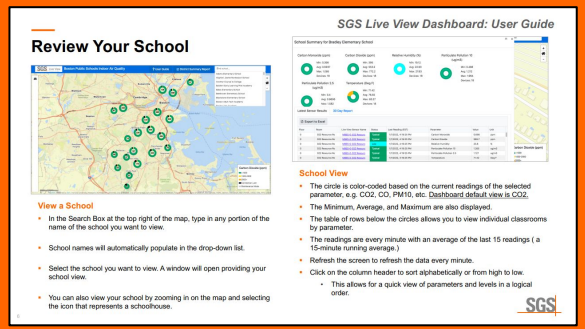
Why install Indoor Air Quality Sensors?

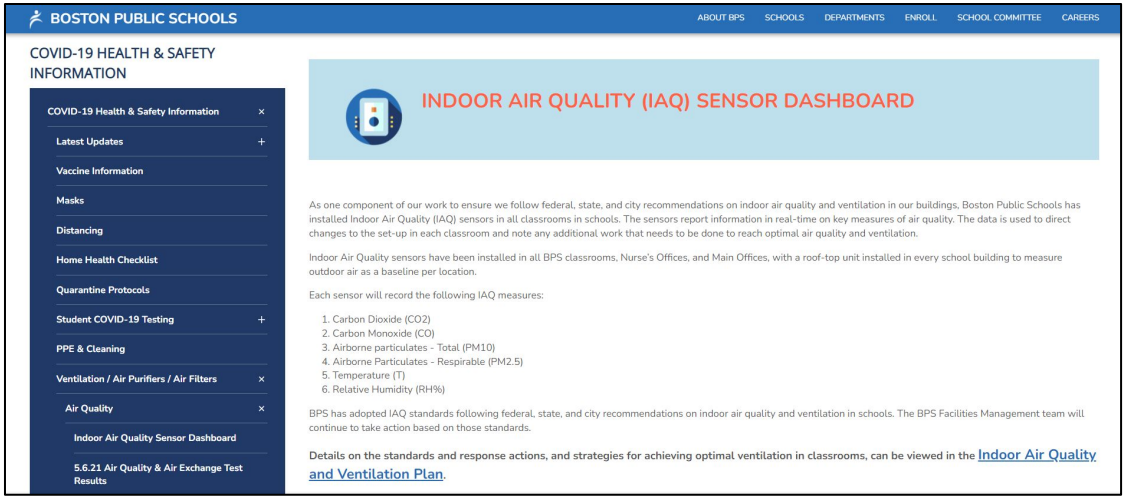
Monitoring & Reporting Risk Reduction Layer

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

INDOOR AIR QUALITY MONITORING INITIATIVE







- BPS Landing Page
  - Indoor Air Quality Sensor Dashboard
  - Indoor Air Quality Monitoring and Response Action Plan
- Communications to School Leaders, Staff, and Families
- Launch of indoorairquality@bostonpublicschools.org
- Public Dashboard - https://bostonschoolsiaq.terrabase.com/
  - User Guide

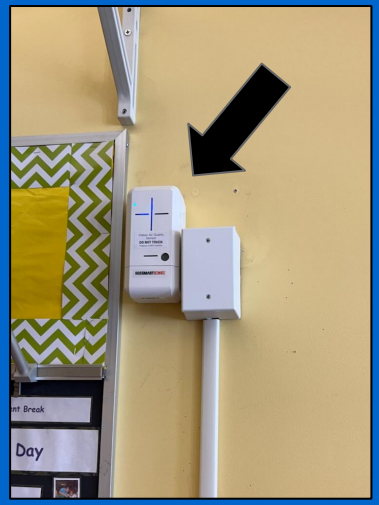
INDOOR AIR QUALITY MONITORING INITIATIVE

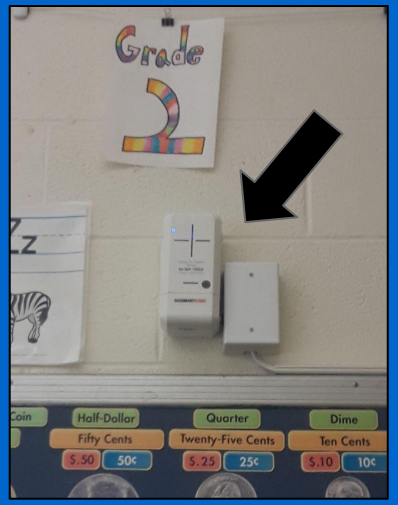
~4300 IAQ sensors installed across all classrooms, Main Offices, and Nurses' Offices.

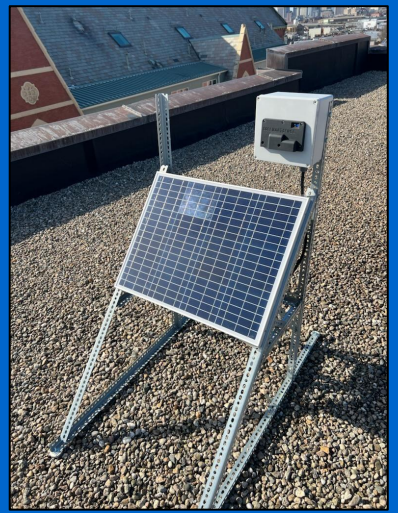
135 OAQ sensors installed across all BPS school rooftops.

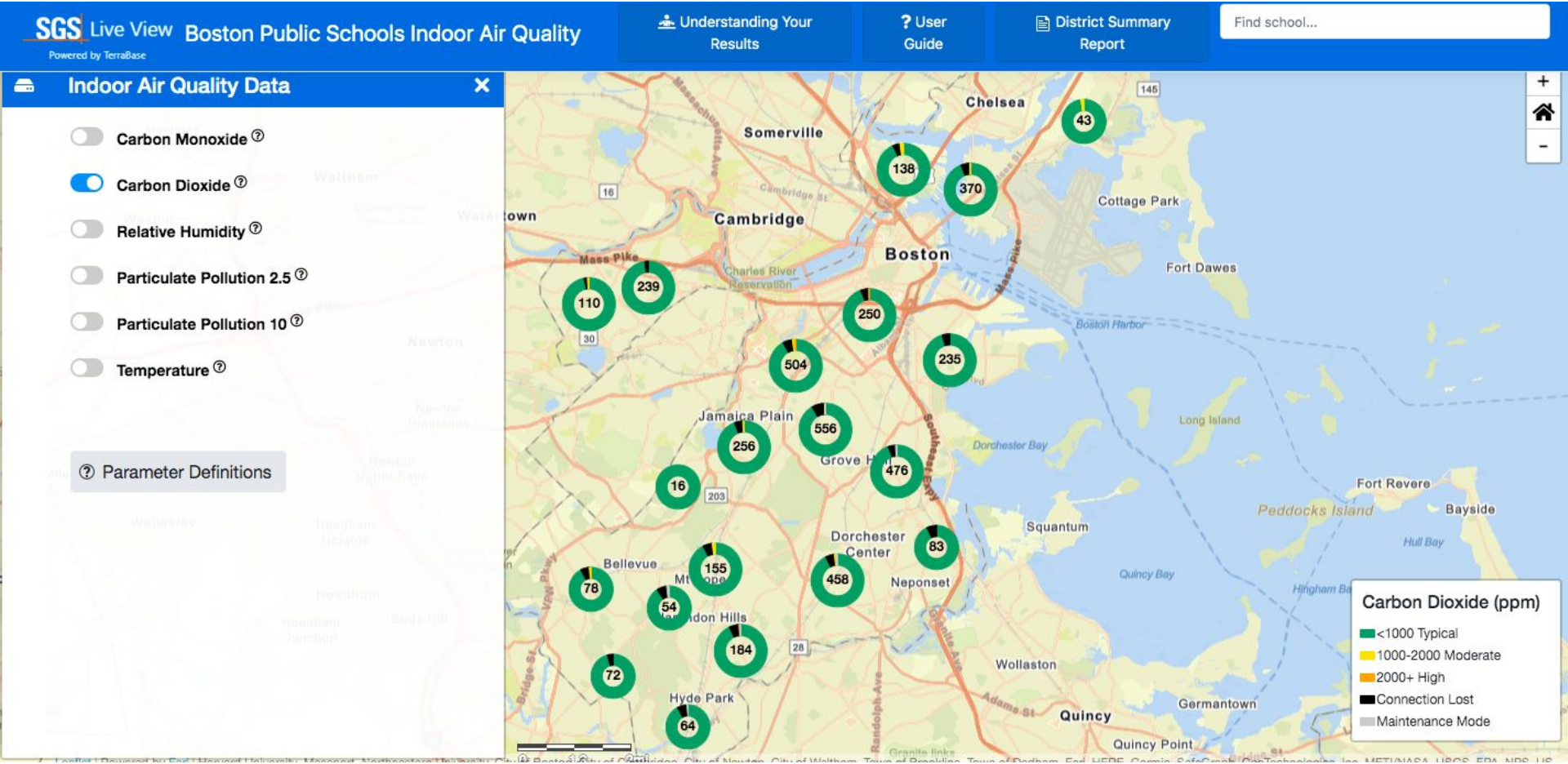
Each professional grade sensor records the following parameters:

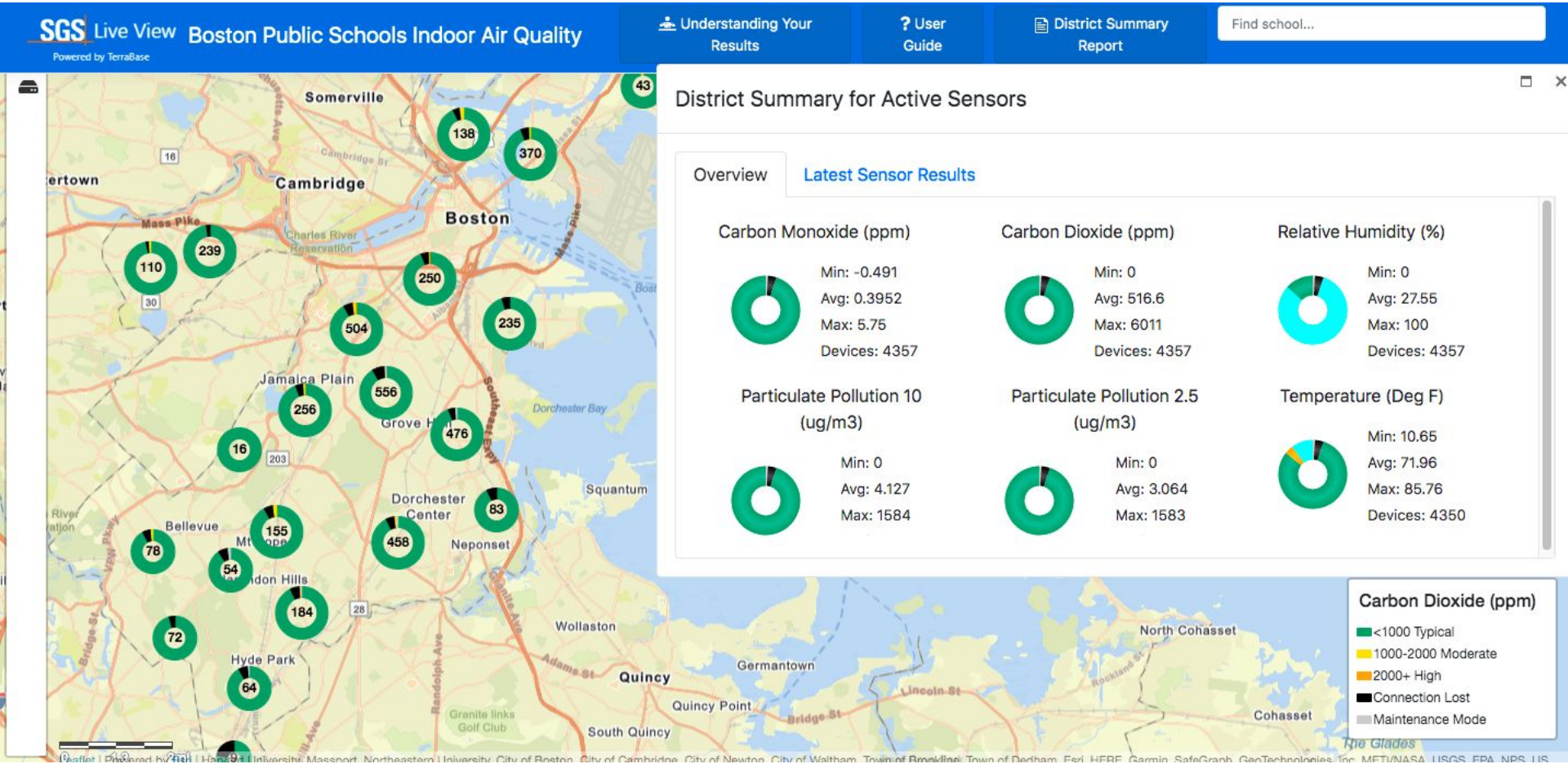
- Carbon Dioxide (CO_2)
- Carbon Monoxide (CO)
- Airborne particulates - Total (PM_{10})
- Airborne particulates - Respirable ($PM_{2.5}$)
- Temperature (T)
- Relative Humidity (RH%)








SGS Live View
Powered by TerraBase
Boston Public Schools Indoor Air Quality
Understanding Your Results
User Guide
District Summary Report
Find school...
Indoor Air Quality Data
Carbon Monoxide
Carbon Dioxide
Relative Humidity
Particulate Pollution 2.5
Particulate Pollution 10
Temperature
Parameter Definitions
Somerville
Chelsea
Cambridge
Boston
Cottage Park
Fort Dawes
Jamaica Plain
Grove Hall
Dorchester Center
Neponset
Squantum
Fort Revere
Peddocks Island
Bayside
Hull Bay
Quincy Bay
Dorchester Bay
Long Island
Boston Harbor
Bellevue
Hyde Park
Wollaston
Quincy
Germantown
Quincy Point
Mass Pike
Charles River Reservation
Southeast Expy
Granite Ave
Adams St
Randolph Ave
Bridge St
West Pkwy
43
138
370
239
110
250
504
235
556
256
16
476
83
155
458
78
54
184
72
64
Carbon Dioxide (ppm)
<1000 Typical
1000-2000 Moderate
2000+ High
Connection Lost
Maintenance Mode


SGS Live View
Powered by TerraBase
Boston Public Schools Indoor Air Quality
Understanding Your Results
User Guide
District Summary Report
Find school...
District Summary for Active Sensors
Overview
Latest Sensor Results
Carbon Monoxide (ppm)
Min: -0.491
Avg: 0.3952
Max: 5.75
Devices: 4357
Carbon Dioxide (ppm)
Min: 0
Avg: 516.6
Max: 6011
Devices: 4357
Relative Humidity (%)
Min: 0
Avg: 27.55
Max: 100
Devices: 4357
Particulate Pollution 10 (ug/m3)
Min: 0
Avg: 4.127
Max: 1584
Particulate Pollution 2.5 (ug/m3)
Min: 0
Avg: 3.064
Max: 1583
Temperature (Deg F)
Min: 10.65
Avg: 71.96
Max: 85.76
Devices: 4350
Carbon Dioxide (ppm)
<1000 Typical
1000-2000 Moderate
2000+ High
Connection Lost
Maintenance Mode
Somerville
Cambridge
Boston
Jamaica Plain
Dorchester Center
Neponset
Wollaston
Quincy
Germantown
Quincy Point
South Quincy
North Cohasset
Cohasset
Hyde Park
Bellevue
Squantum
Dorchester Bay
Charles River Reservation
Granite links Golf Club
The Glades
138
370
43
110
239
250
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235
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556
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184
72
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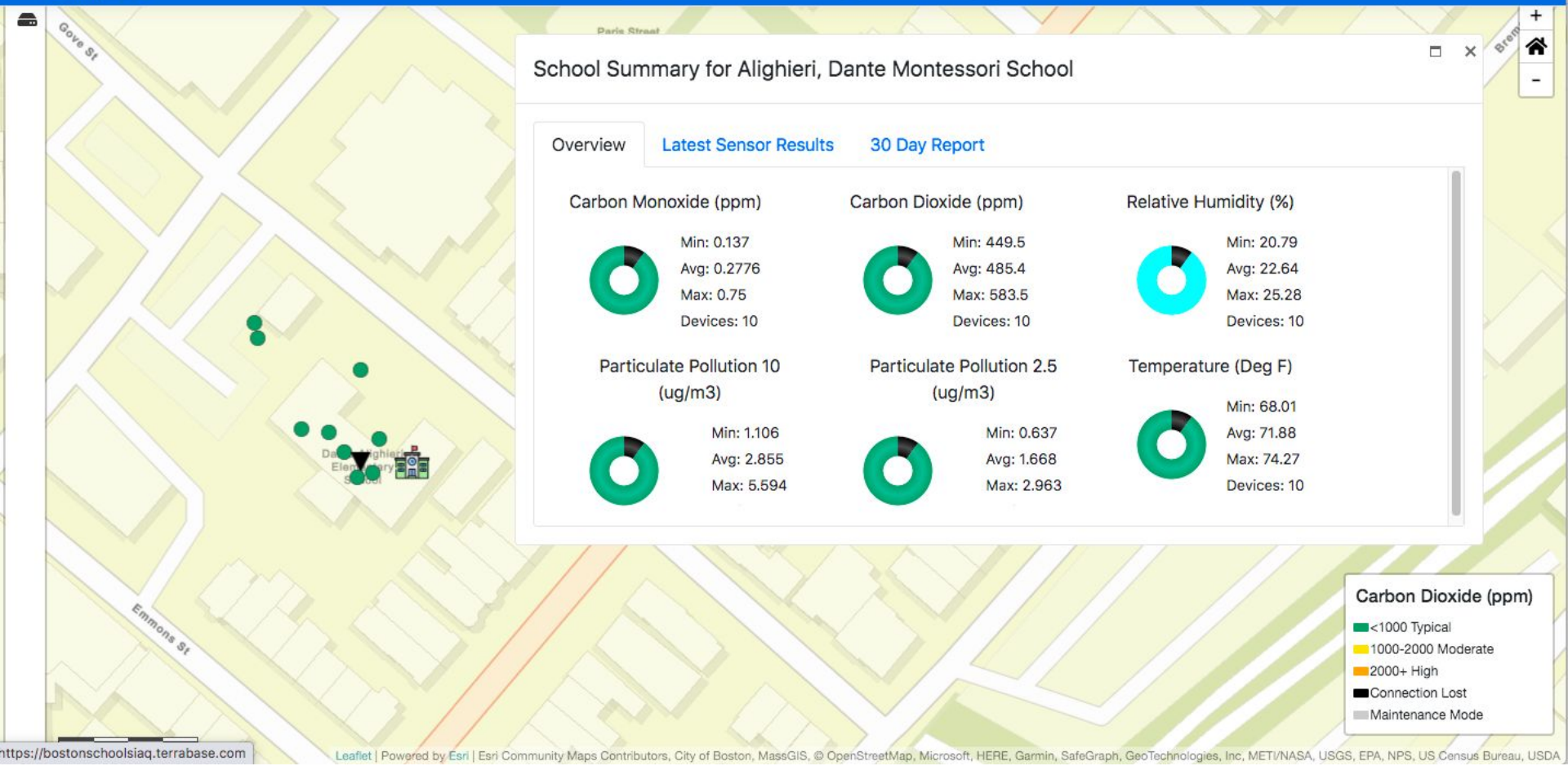


School Summary for Alighieri, Dante Montessori School

Overview | Latest Sensor Results | 30 Day Report

Carbon Monoxide (ppm)

Min: 0.137
Avg: 0.2776
Max: 0.75
Devices: 10

Carbon Dioxide (ppm)

Min: 449.5
Avg: 485.4
Max: 583.5
Devices: 10

Relative Humidity (%)

Min: 20.79
Avg: 22.64
Max: 25.28
Devices: 10

Particulate Pollution 10 (ug/m3)

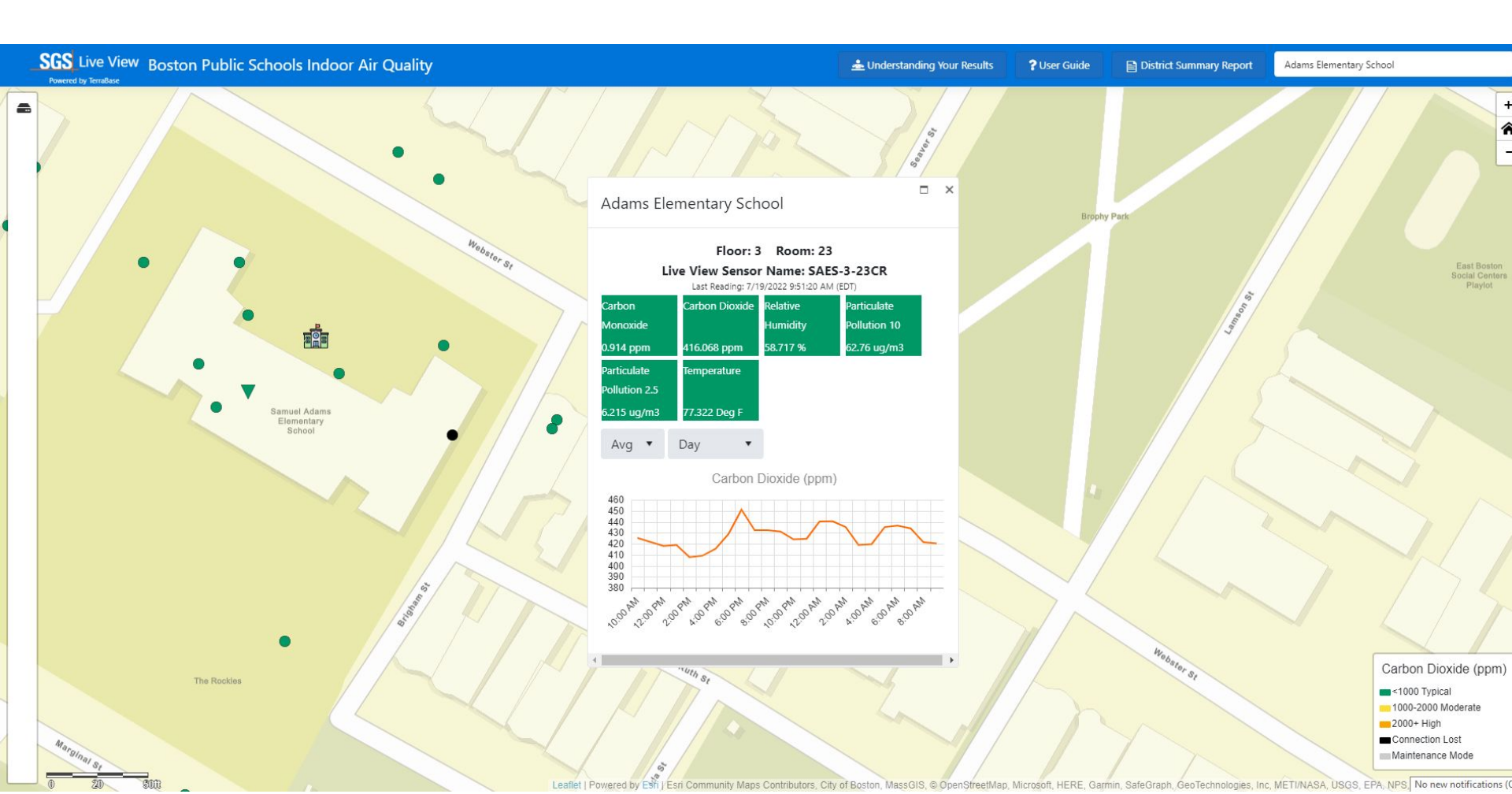
Min: 1.106
Avg: 2.855
Max: 5.594

Particulate Pollution 2.5 (ug/m3)

Min: 0.637
Avg: 1.668
Max: 2.963

Temperature (Deg F)

Min: 68.01
Avg: 71.88
Max: 74.27
Devices: 10


SGS Live View
Powered by TerraBase
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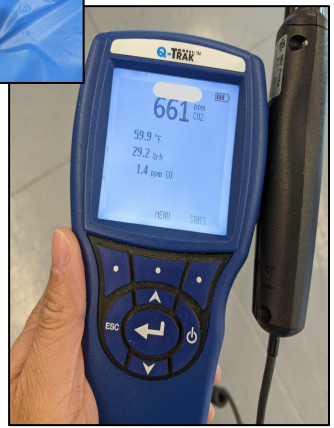
User Guide
District Summary Report
Adams Elementary School
Adams Elementary School
Floor: 3 Room: 23
Live View Sensor Name: SAES-3-23CR
Last Reading: 7/19/2022 9:51:20 AM (EDT)
Carbon Monoxide 0.914 ppm
Carbon Dioxide 416.068 ppm
Relative Humidity 58.717 %
Particulate Pollution 10 62.76 ug/m3
Particulate Pollution 2.5 6.215 ug/m3
Temperature 77.322 Deg F
Avg
Day
Carbon Dioxide (ppm)
460
450
440
430
420
410
400
390
380
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
Webster St
Brigham St
Samuel Adams Elementary School
The Rockies
Seaver St
Brophy Park
Lamson St
East Boston Social Centers Playlot
Marginal St
0
20
300
Carbon Dioxide (ppm)
<1000 Typical
1000-2000 Moderate
2000+ High
Connection Lost
Maintenance Mode
Leaflet | Powered by Esri | Esri Community Maps Contributors, City of Boston, MassGIS, © OpenStreetMap, Microsoft, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS
No new notifications

IAQ MONITORING & OPERATIONAL RESPONSE ACTIONS

Investigating Elevated Levels and Response Action Examples

- Re-entrainment*
- Summer school heat index*
- Fire*
- Barge
- Construction dust
- School Thanksgiving potluck sternos
- Unapproved cleaning products
- Closed windows and doors



2022 Q1 IAQ Adams Elementary School Data					
	CO Avg	CO2 Avg	PM 2.5 Avg	PM 10 Avg	Temp Avg
Mean	0.423344655	617.2637931	1.280619239	1.895642328	71.14505747
Median	0.3204	546.1	1.035	1.5895	71.3
Minimum	0.05462	398.8	0.5	0.75	58.38
Maximum	2.381	3733	10.73	12.38	88.87

CHALLENGES & LESSONS LEARNED

- Unrealistic installation timeline and deadline for “going public”.
- Technical issues with the sensors:
  - Calibration
  - Connectivity
  - Power Loss
- Research and media requests, and unknown public uses of data.
- Data management: analyzing and responding to the amount of data and understanding the trends.
- Communications of the monitoring initiative and public understanding of IAQ data.

Transforming IEQ sensor data into research data for decision making

Boston University School of Public Health
Department of Environmental Health

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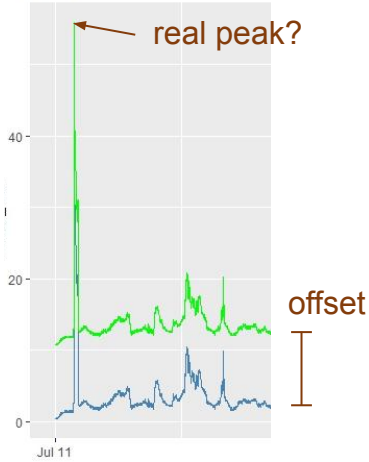
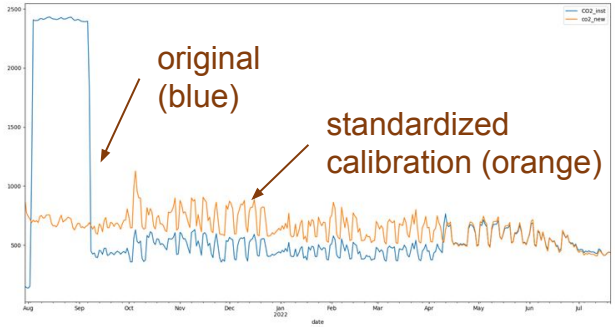
Data

IEQ

CO, CO_2, $PM_{2.5}$, PM_{10}, RH, Temp

- Public dashboard
  - 15 minute rolling averages
  - Real-time posting
  - Current calibration
- Raw data
  - 1 minute capture
  - Not calibrated
  - Year 1 (08/2021-08/2022)
    - ~2.4 billion data points, ~1 million csv files





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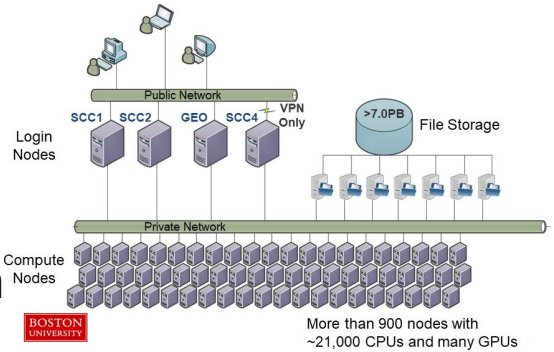
Database management

- Storage & processing
  - Amazon S3
  - BU's Shared Computing Cluster
- Cleaning algorithms
  - Outliers
  - Offline values
  - Power outages
  - Standardize calibration
- Documentation
- Analytical datasets
  - School, classroom/roof, level
  - Time stamps: weekday, school hours
  - Occupancy status
  - Aggregation

IEQ

CO, CO_2, $PM_{2.5}$, PM_{10}, RH, Temp



https://www.bu.edu/tech/files/2021/07/scclayout.png

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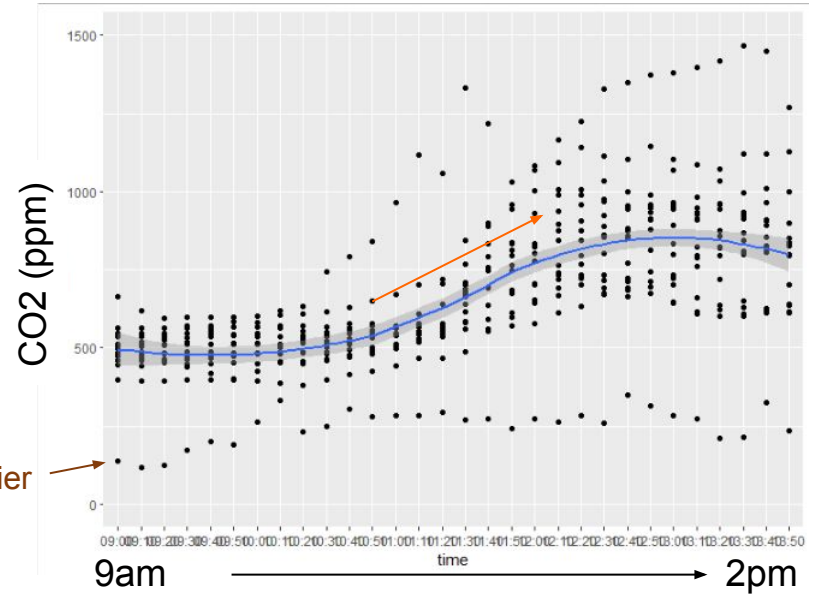
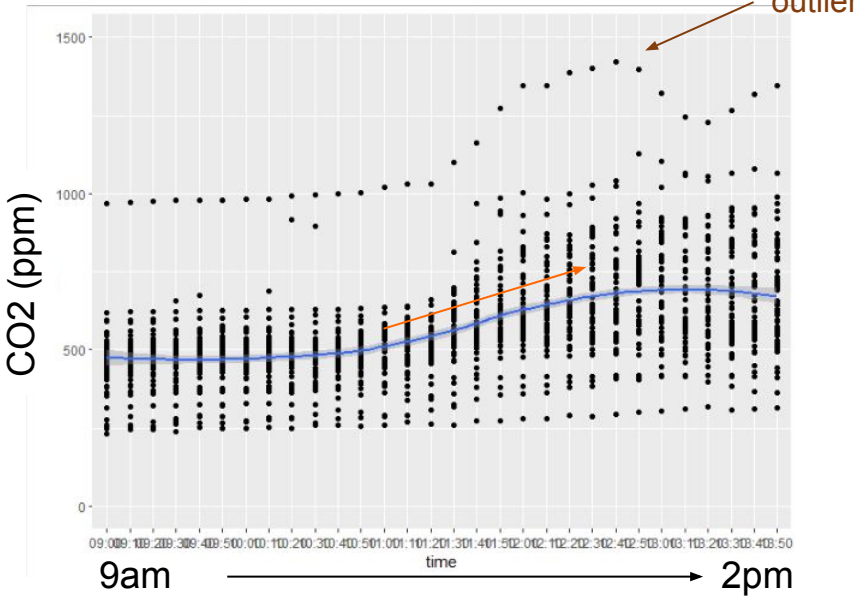
Smooth of 10-min average CO_2, all classrooms, School A



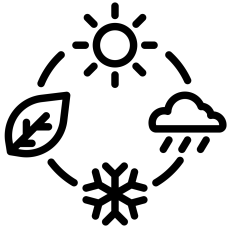
Smooth of 10-min average CO_2, all classrooms, School B



Comprehensive Database

Built environment

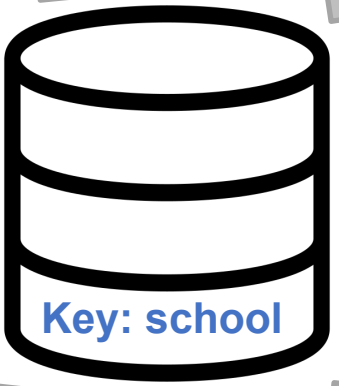
Meteorology



- Data science
- GIS
- Statistics

IEQ

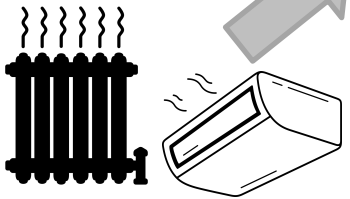
CO, CO_2, $PM_{2.5}$, PM_{10}, RH, Temp



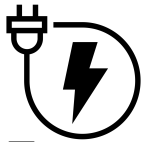
Neighborhood

- Air pollution
- Greenspace
- Demographics
- Segregation
- ...

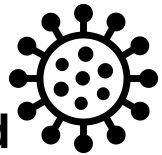
CRESSH



HVAC



Energy



Covid interventions

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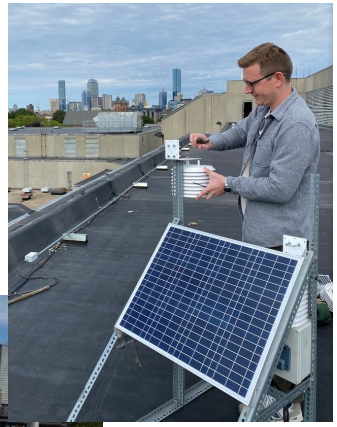
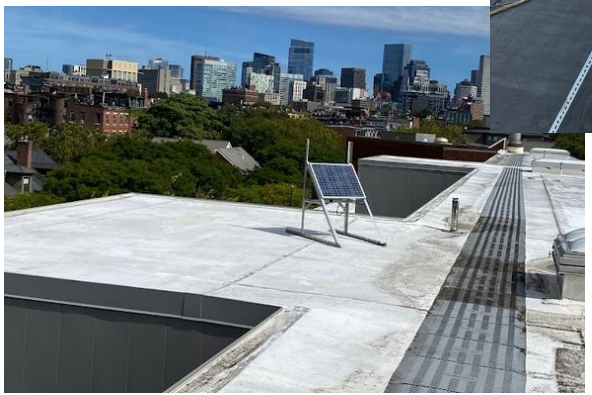
Analyses

- Support school decisions and policies
  - Prioritize investments in school infrastructure with equity lens
  - Impact & co-benefits of Covid interventions (e.g., filters, HVAC) & human behavior (e.g., windows)
- IEQ in classrooms
  - About the data (e.g., missing, trends)
  - Profiles within and across schools
  - Indoor/outdoor relationships
- Sustainability & climate
  - Weather related school closings
  - Energy-IEQ tradeoffs
  - Cooling interventions (e.g. white roofs, AC, greenspace)





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WHAT'S NEXT

- **Ongoing analysis of data** and **responding to elevated IAQ levels** - stay focused on the daily operations of BPS buildings and continuous improvement of BPS indoor air quality.
- Finishing **annual calibration** of all sensors (Fall 2022).
- **Research study** with Boston University, "Understanding indoor air quality, thermal comfort, and energy use in classrooms, and the impact of SARS-CoV-2 engineering controls", which will include **data analysis and reporting**, **addressing inaccuracies** in historical data due to calibration, connectivity, and power issues, and the **development of IAQ communications materials** (e.g. newsletters) for BPS community.
- Where possible, connect the sensors to the existing BPS Building Management System to **automate mechanical adjustments** in correlation with indoor air quality levels.
- Use the data to advocate and pursue funding opportunities for **HVAC investments** in BPS school buildings.
- Long-term, the data may be used for other research ideas and partnerships related to **public health, student outcomes**, and City of Boston **air pollution and climate change studies**.

CONTACTS

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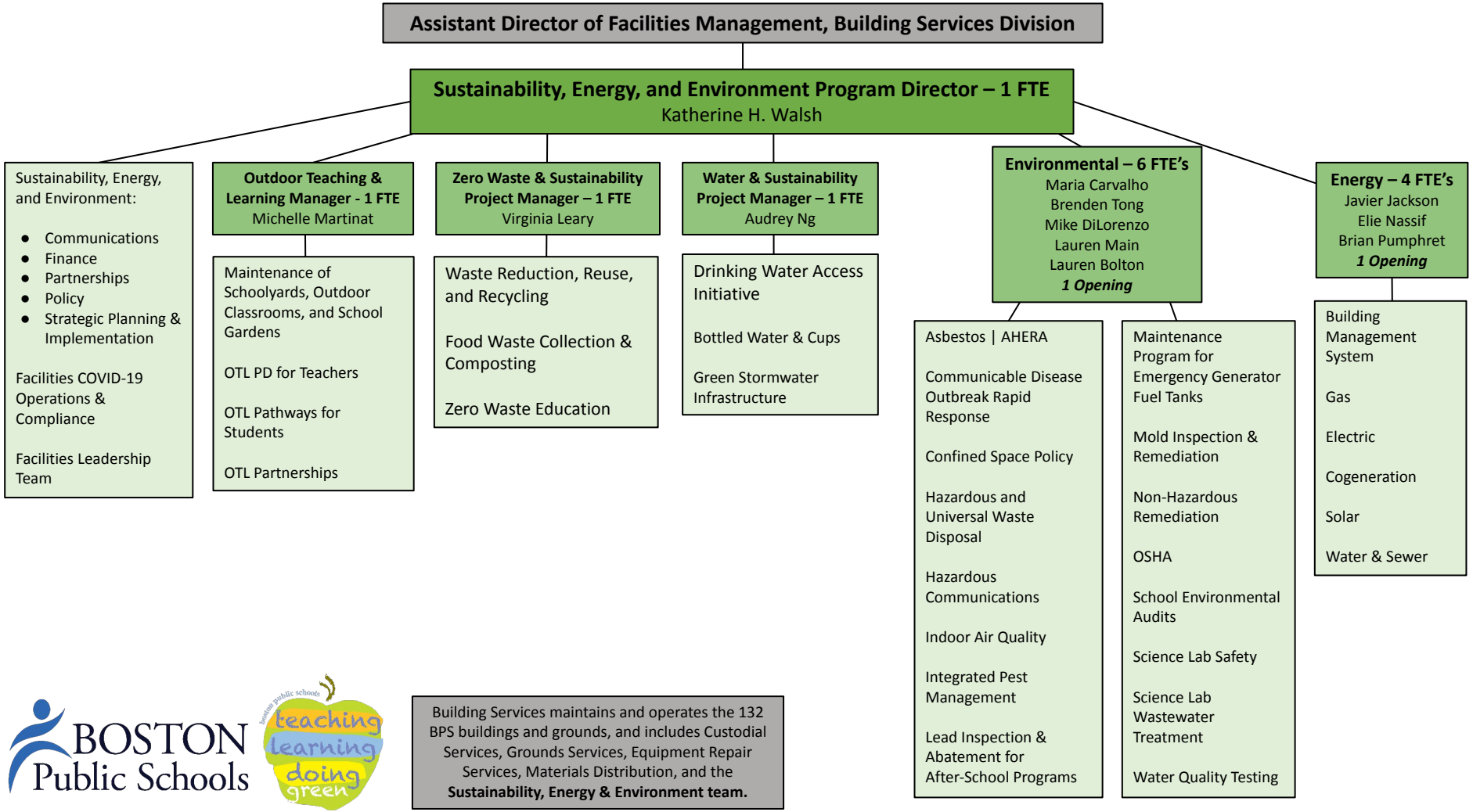
APPENDIX


Assistant Director of Facilities Management, Building Services Division
Sustainability, Energy, and Environment Program Director – 1 FTE
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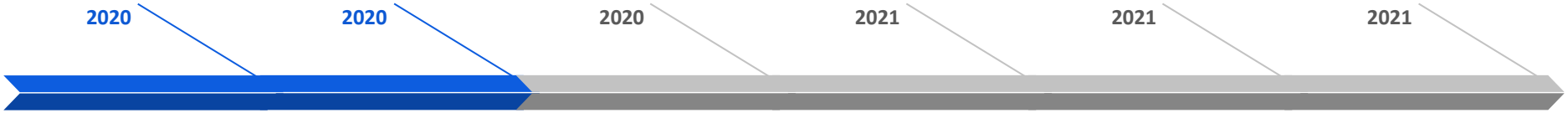
Sustainability, Energy, and Environment:
Communications
Finance
Partnerships
Policy
Strategic Planning & Implementation
Facilities COVID-19 Operations & Compliance
Facilities Leadership Team
Outdoor Teaching & Learning Manager - 1 FTE
Michelle Martinat
Maintenance of Schoolyards, Outdoor Classrooms, and School Gardens
OTL PD for Teachers
OTL Pathways for Students
OTL Partnerships
Zero Waste & Sustainability Project Manager – 1 FTE
Virginia Leary
Waste Reduction, Reuse, and Recycling
Food Waste Collection & Composting
Zero Waste Education
Water & Sustainability Project Manager – 1 FTE
Audrey Ng
Drinking Water Access Initiative
Bottled Water & Cups
Green Stormwater Infrastructure
Environmental – 6 FTE's
Maria Carvalho
Brenden Tong
Mike DiLorenzo
Lauren Main
Lauren Bolton
1 Opening
Asbestos | AHERA
Communicable Disease Outbreak Rapid Response
Confined Space Policy
Hazardous and Universal Waste Disposal
Hazardous Communications
Indoor Air Quality
Integrated Pest Management
Lead Inspection & Abatement for After-School Programs
Maintenance Program for Emergency Generator Fuel Tanks
Mold Inspection & Remediation
Non-Hazardous Remediation
OSHA
School Environmental Audits
Science Lab Safety
Science Lab Wastewater Treatment
Water Quality Testing
Energy – 4 FTE's
Javier Jackson
Elie Nassif
Brian Pumphret
1 Opening
Building Management System
Gas
Electric
Cogeneration
Solar
Water & Sewer
BOSTON Public Schools
teaching learning doing green
Building Services maintains and operates the 132 BPS buildings and grounds, and includes Custodial Services, Grounds Services, Equipment Repair Services, Materials Distribution, and the Sustainability, Energy & Environment team.

BPS INDOOR AIR QUALITY MANAGEMENT PROGRAM - A LAYERED RISK REDUCTION APPROACH

- Annual School Environmental Audits
  - One conducted by the BPS Environmental Division
  - One conducted by the Boston Public Health Commission
- Preventative Maintenance and Repairs of Buildings
- Operations, Maintenance, Repairs of HVAC Equipment and Systems
- Indoor Air Quality Monitoring and Reporting
  - Indoor Air Quality Sensors and Online Dashboard
- Asbestos Hazard Emergency Response Act (AHERA) Management
- Temperature Monitoring and Control
- Mold and Moisture Control
- Integrated Pest Management (IPM)
- Cleaning
- Chemical Management
- Waste Management
- Anti-Idling
- Tobacco and Nicotine-Free Environment Policy

INDOOR AIR QUALITY MONITORING INITIATIVE TIMELINE



2020

August

Conducted market research.

2020

September

IAQ Sensor and Monitoring Proposal made to Supt. Dr. Brenda Cassellius and Mayor Martin J. Walsh.

2020

December

Request for Proposals published.

2021

March

RFP contract awarded.

2021

April - June

Installation planning, preparation, and training with vendor.

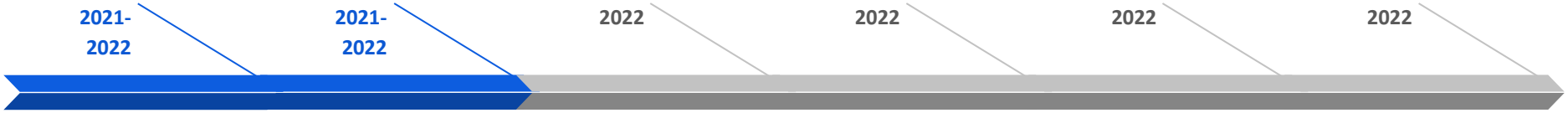
Sourcing of materials.

2021

July - November

Installation of classroom sensors.

Ongoing analysis of data and responding to elevated levels begins.



2021-2022

October - January

Design of public dashboard and user guide.

Development of accompanying IAQ and Ventilation Plan.

2021-2022

October - February

Installation of sensors in Main Offices and Nurses' Office, and any missed classrooms.

Installation of rooftop sensors for outdoor air quality baseline.

2022

March - May

Investigation and fixing of calibration, connectivity, and power issues.

2022

June - August

Annual calibration of all sensors.

Ongoing analysis of data and responding to elevated levels.

2022

August - Beyond

Use data to advocate for investments in mechanical ventilation across all BPS schools.

2022

FEDERAL, STATE, LOCAL, and PROFESSIONAL GUIDANCE

- **U.S. Centers for Disease Control and Prevention (CDC)**
- **U.S. Environmental Protection Agency (EPA)**
  - Indoor Air Quality Tools for Schools Program
  - U.S. Air Quality Index
- U.S. Department of Labor Occupational Safety and Health Administration (OSHA)
- Massachusetts Department of Elementary and Secondary Education (DESE)
- **Massachusetts Department of Environmental Protection (MassDEP)**
- **Boston Public Health Commission (BPHC)**
- **American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)**
- American Conference of Governmental Industrial Hygienists (ACGIH)
- Harvard T.H. Chan School of Public Health Healthy Schools program
- **Center for Green Schools**
- American Lung Association

FUNDING SOURCES

- BPS operational budget
- -City of Boston capital budget
- ESSER I and II

HOW CAN LEGISLATORS HELP?

- **Inspections of School Facilities Conditions**
  - Recommend or require? Prerequisite for funding, or compliance-based?
  - Establish the frequency of inspections/testing.
  - Establish criteria for measures being evaluated, how they are evaluated (internal and/or third party), and action levels for any measures.
  - Establish if, how, and with whom data is shared.
- **Enforcement**
  - Establish expectations for mitigation and remediation, related back to action levels.
- **Funding and Resource Allocation**
  - Establish accessible and equitable funding sources for new school construction and renovations, especially if facilities inspections and mitigation of issues are required.
  - Establish Points of Contact at the districts to support with Technical Assistance.
- **Leadership and Decision-Making**
  - Involve Operations staff in decision-making and feedback opportunities.
- **Engagement and Education**
  - Establish cross-agency partnership focused on engagement and education.

BUSPH team

Koen Tieskens

Pilar Botana

Johnny Rezendes

BOSTON PUBLIC SCHOOLS

SGS GALSON

BU School of Public Health
Biostatistics & Epidemiology Data Analytics Center

BU Shared Computing Cluster

Funding:
Early Stage Urban Research Award, BU Initiative on Cities
Established Investigator Innovation Award, BUSPH

BOSTON UNIVERSITY