



IAQ Research at the California Air Resources Board: Air Cleaners, Building Decarbonization, and IAQ Guidelines

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BIES mission statement:

- Analyze and quantify emissions from building and indoor related sources to determine possible impacts on the health and welfare of Californians
- Identify and assess exposures to indoor air pollutants,
- Promote actions to reduce or prevent those exposures.
 - ✓ Strategies for the reduction of indoor exposures to air pollution originating from both indoor and outdoor sources, including wildfires
 - ✓ Increased ventilation and filtration
 - ✓ Decarbonization
 - ✓ Creating clean air spaces
 - ✓ Approving funding for clean air centers across the state.

Topics for Today's presentation

- **Completed Multifamily Housing Compartmentalization Study**
- **White Paper Projects**
 - Air Cleaning Technology Emissions
 - Low-Cost Sensors (Saturday's session)
- **Fieldwork Research Projects**
 - PAIR (**P**ortside **A**ir Quality and **I**mprovement **R**elief) study
 - HIFIVE (**H**ealth **I**mpacts of **F**iltration **I**mpro**V**ements in **E**lementary Schools) study
- **Buildings / Decarbonization Related Projects**
 - Commercial Buildings - Equitable Electrification Project
- **Updated Indoor Air Quality Guidelines for NO₂**
- **Updated Indoor Air Quality Report**



**Completed
Multifamily Home
Study**

Research Project: Improving Indoor Air Quality, Energy Efficiency, and Greenhouse Gas Reductions through Multifamily Unit Compartmentalization

Multifamily Housing

- >50% of new residential housing in California
- Exchange air, pollutants, smells, and noise with those units due to common walls
- More challenging to achieve healthful indoor air quality (IAQ) as well as significant energy use and greenhouse gas (GHG) reductions

Compartmentalization

- Improve the sealing of each multifamily unit from adjacent units, other interior spaces, and the exterior, such that each unit is effectively its own compartment
- Reduce air transfer between units and thus provide improved IAQ, energy savings, and GHG reduction benefits

Current California Building Code Requirements

- Title 24-2019, effective January 1, 2020, set a requirement that all new-construction multifamily units:
 - either a) meet a compartmentalization requirement of 0.3 cfm at 50 Pa per square foot ($\text{cfm}_{50}/\text{ft}^2$) of apartment (unit) enclosure area,
 - or b) provide balanced ventilation to each dwelling unit
- Is it sufficient to ensure good IAQ and to adequately promote GHG reduction?
 - New constructions can bypass compartmentalization requirements by installing balanced ventilation systems
 - $0.3 \text{ cfm}_{50}/\text{ft}^2$ was based on estimated air-sealing feasibility instead of evidence for specific IAQ improvements

Study Objective

- Investigate IAQ, energy, and GHG impacts of different levels of compartmentalization (airtightness) and ventilation strategies in new multifamily buildings in California.
- Inform the update of compartmentalization and ventilation requirements in CA Building Codes

Field Testing - Buildings Tested

	Building A	Building B	Building C
Location	Oakland, CA	El Cerrito, CA	San Jose, CA
Rate	Affordable	Market	Affordable
Construction type	In-situ construction (traditional)	Modular	In-situ construction (traditional)
Airtightness Target	0.3 cfm ₅₀ /ft ²	N/A	0.23 cfm ₅₀ /ft ² (LEED)
Ventilation System	(un)Balanced with heat recovery*	Balanced	Exhaust

* The design intent is to have a balanced system, but the field testing showed more exhaust air than supply air, so it's unbalanced.

Key Findings - Building Characterization

- Measured Unit Leakage Levels were ~50% lower than code: [A tighter standard is achievable](#)
- Unit leakage and ventilation flow rates varied with a standard deviation of ~10–15%

Key Findings - Indoor Air Quality

- Compartmentalization to **Stricter Leakage Targets Results in Lower Gaseous Pollutant Transfer**
- No observed particulate transfer between units in buildings tested
- For units with gas stoves, NO₂ exposure was higher than the outdoor regulatory level (the NAAQS for 1-hour NO₂) if the kitchen exhaust fan was not used
- Modeling the highest leakage level (0.45 cfm₅₀/ft²), units living next to a smoker have benzene exposure above the 1 x 10⁻⁶ cancer risk level

Key Findings - Energy Use and GHG Emissions

- HVAC energy and GHG savings of **4-6%** by tightening from 0.45 cfm₅₀/ft² to 0.15 cfm₅₀/ft²
- Additional **5-20%** of HVAC energy and GHG savings by going from balanced to single-fan ventilation OR **16-26%** by adding heat exchangers to balanced systems (not including pressure losses)
- EnergyPlus results had to be modified to account for window openings - otherwise simulates San Francisco as a cooling-dominated climate
- EnergyPlus dramatically overestimates infiltration

Potential Code Implications

- Tighter leakage targets in the code are clearly achievable
- Modest energy and GHG savings and measurable IAQ improvements can be achieved with tighter leakage targets in the code
- More significant energy and GHG savings can be achieved by either
 - Eliminating two-fan energy use by using either supply-only or exhaust-only ventilation OR
 - Adding heat exchangers to balanced ventilation systems
 - Climate dependent
 - Pressure-drop increases not analyzed

White Paper Projects

- **Air Cleaning Technologies White Paper**
- Low-Cost Sensor White Paper (Saturday's session)

White Paper: Air Pollutant Emissions and Possible Health Effects from Electronic Air Cleaning Devices

- CARB's air cleaner regulation went into effect in 2008
- Requires certification of air cleaning devices for electrical safety and ozone emissions (8,800 certified)
- Air cleaning technologies can emit substances other than ozone into the air
- Purpose of White Paper is to:
 - Describe air cleaning technologies and emissions
 - Identify interactions of emissions with other chemicals in indoor air
 - Characterize exposure pathways and potential health effects
 - Describe data gaps and future research needs

Characterization of Electronic Air Cleaning Technologies

- Types of air cleaning technologies reviewed:
 - Ion Generator, Electrostatic Precipitator, Photocatalytic Oxidation, Ultraviolet Germicidal Irradiation, Hypochlorous Acid, Nano-confined Catalytic Oxidation
- Types of emissions include:
 - Ozone, formaldehyde, acetaldehyde, hydroxyl radicals, hydrogen peroxide, acetone, acrylonitrile, ultrafine particles, UV light

Conclusions and Recommendations

- Compounds of clear health concern: ozone, formaldehyde, ultrafine particles
- Recommend CARB further reduce ozone emissions through regulation
- Future research needed to estimate exposure to emissions and resulting health impacts, such as exposure to:
 - Hydrogen peroxide
 - HOCl
 - Ions and ionized particles
 - Direct UV radiation considering vulnerable subgroups, such as infants and children

Field Work Research Projects

- **PAIR Study**
- HIFIVE Study

Data Analysis for the Portside Air Quality Improvement and Relief (PAIR) Program



- ❑ USS Bonhomme Richard Navy Ship Fire (July 12-16, 2020)
- ❑ \$653,000 funding from County of San Diego and Port of San Diego for “residential air quality monitoring, air purifiers, and data analysis”
- ❑ ~600 air purifiers and ~600 air monitors for residents of Portside AB 617 community.
- ❑ Opportunity to investigate the effectiveness of the use of portable air cleaners in combination of low-cost air monitors.



PAIR Project's Objective: Perform data analysis on indoor and outdoor monitoring data from the PAIR program

Portside AB 617 Community



In addition,

- Observe the impact of air purifiers distributed to residents and
- Understand what factors can affect the effectiveness of air purifiers.

Project Timeline

- Started in May 2023
- To be completed in October 2024

PAIR Project's Potential Analysis

- Average levels of indoor air pollutants for each day
- 1-hour daily max-levels
- Indoor/Outdoor daily ratios of selected air pollutants
- Comparisons of metrics from households of different ages, types, and square footages, or others.
- Impact of meteorological conditions on indoor air quality.

Field Work Research Projects

- PAIR Study
- **HIFIVE Study**

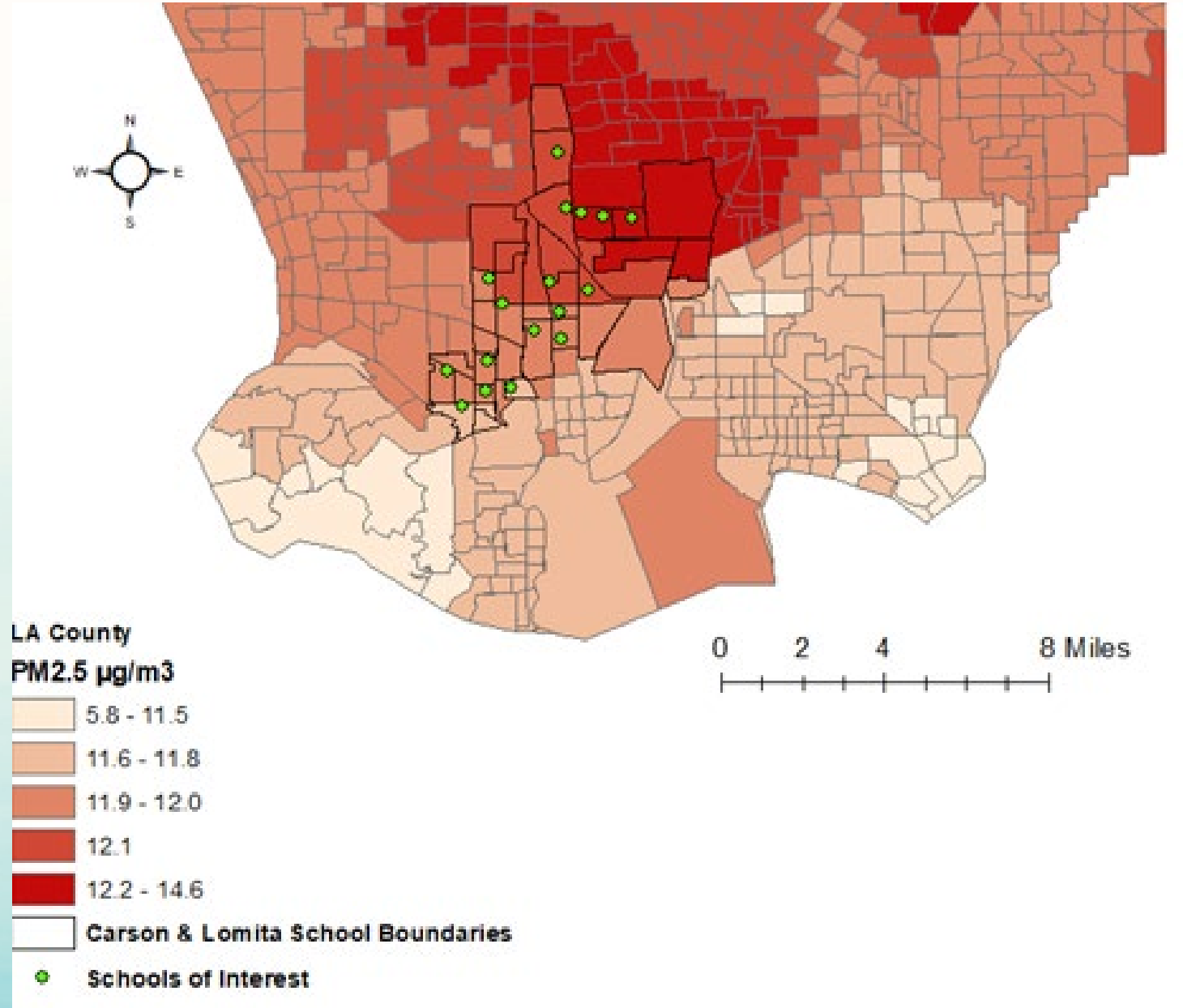
Health Impacts of Filtration Improvements in Elementary Schools (HIFIVE)

- Overall goal - investigate possible health benefits directly associated with PM2.5 exposure reduction through improved filtration in elementary schools
- Classroom filtration improvements assessed in some California schools, but very few randomized trials appear to be available for directly estimating the health benefits of air filtration improvements in schools.
- Novel aspects of study
 - First to examine the health impacts of air filtration interventions implemented in schools, where young students spend a substantial amount of the day in one room
 - Uses a rigorous crossover randomized controlled trial to ensure validity
- The results from the crossover randomized controlled trial can be generalized to other communities with similar characteristics and exposure levels.
- Contract complete April 30, 2025



HIFIVE Schools of Interest

- 17 Schools within the LAUSD
- Total of 435 classrooms
- Communities of Carson, Lomita, Torrance, Harbor City near the port of Long Beach
- Highly impacted by poor air quality



Key Equipment

IQAir AirVisual Pro

- Advanced laser technology provides highly accurate readings of PM1, PM2.5, and PM10 and CO2.
- Monitors the temperature and humidity.



Blueair Classic 605 air monitor air cleaner

- Filters the air in a 775 ft² space in about 12.5 min (4.8x an hour)
- No louder than the 62 dB white noise of a floor fan on its highest speed



Technical Features of Study

- AirVisual Pro monitoring indoor PM2.5 levels at school locations inside half the classrooms of the 17 elementary schools
- One ambient air sensor has been placed outside each school
- In school year 2022-23, half the classrooms in each school were randomized to have Blueair Classic air cleaners with true filters and the other half with control filters
- In the current school year (started Aug 14, 2023-24), classrooms switched intervention groups over the summer
- PM2.5 data in classrooms with and without the intervention compared to determine the effect of the intervention on air quality

Expected Study Analyses

- Air Quality Data
 - Investigators will compute summary statistics for baseline PM 2.5 (pre-intervention) as well as monthly PM 2.5 for control versus intervention classrooms
 - Collect ambient air quality data at select sites
- Health Outcome Analysis
 - Individual level - longitudinal assessment of 300 asthmatic student's symptom history
 - Epidemiological Analysis - Classroom level analysis of person-days absenteeism
- Final deliverables - comprehensive final report and seminar

Buildings / Decarbonization Related Projects

CARB Building Decarbonization Efforts

- 2022 Scoping Plan Update - Building decarbonization is one of the key climate actions for achieving carbon neutrality.
- 2022 State SIP Strategy - Zero NOx and carbon limit for all new space and water heaters beginning in 2030
- Recommend zero-emission building requirements in CA Building Codes
- Continue partnerships with key state agencies and local air districts
- Fund research projects on building electrification

Research Project: Equitable Electrification of Existing Buildings: A Pathway to Decarbonization

- Building electrification - a comparatively cost-effective approach for reducing emissions from existing buildings.
- Codes and standards regulating new construction alone are insufficient for meeting State climate and air quality goals. Dramatic action in existing buildings is needed.
- The equity implications and actual costs of electrification for priority populations living and working in existing buildings require a more detailed analysis.

Study Objectives

- 1) Examine building electrification trends to date
- 2) Prioritize and assess the feasibility of equitable commercial building electrification
- 3) Describe the gap between existing policy-supported electrification and the State's long-term goals
- 4) Collect new data on electrification costs, benefits, processes, and outcomes
- 5) Inform State efforts to align standards, incentives, and regulations across policy sectors and scales to support rapid and equitable building decarbonization

Residential Buildings - Major tasks

- Compile and analyze statewide spatial data layers and literature related to electrification and equity considerations
- Examine the scale of the challenges associated with electrical service panel upgrades in older buildings
- Conduct opinion research focused on the priority population's values, knowledge, and beliefs around building electrification decisions
- Provide recommendations on the most effective strategies, programs, and/or incentive designs for scaling up electrification in existing buildings.
- A Steering Committee to ensure research decisions both consider and adequately respond to the needs of marginalized populations

Residential Building Project Timeline

1. Start: June 2022
2. Data compilation and analysis: by June 2023
3. Electric service panel upgrade analysis: by June 2023
4. Opinion research: by December 2023
5. Policy recommendations: by December 2024
6. Interim report: December 2024

Commercial Buildings - Major tasks

- Estimate CO₂ and NOx emissions for 12 commercial buildings subsector
- Assemble a prioritization index framework to generate a ranked list of subsector priorities at a statewide scale
- Select a priority subsector to assess electrification feasibility.
- Summarize the current policy gaps in commercial building electrification and provide recommendations to advance building electrification efforts equitably.

Commercial Building Project Timeline

1. Start: June 2023
2. Sub-sector analysis for prioritization: by December 2024
 - Emissions estimate: by April 2024
 - Prioritization framework: by June 2024
 - Interactive website for prioritization: by December 2024
3. Feasibility Assessment: by May 2025
4. Reports and Policy Brief: December 2025

Updated Indoor Air Quality Guidelines for NO₂

The Need to Update NO₂ Guidelines

- Incorporate advanced state of science
 - CARB IAQ guidelines are almost 20 years old
 - Other health agencies and experts have developed more recent guidelines
 - Updated science-based guidelines can better reflect needs of vulnerable groups
- Address the concerns of our communities
 - CARB responding to calls for action
 - Higher exposures and health effects of NO₂ more often experienced in low-income homes
- Inform Research and Public Outreach
 - Motivate research and technology to achieve healthy IAQ and meet guidelines
 - Provide the most current information about what levels of NO₂ are healthy
- Inform state building decarbonization efforts

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Workshop Panels and Topics



International Agencies (EPA/WHO, Health Canada)
Guideline Development and Scientific Foundations



State Agency Perspectives (OEHHA, CDPH, CEC)
Recent Research on Indoor Air Quality and State Programs Affecting
IAQ



Nonprofits, Community Groups (CCAC, WE ACT, PSR)
Community Perspectives on Indoor Air Quality and Guideline Development



Academic Experts (LBNL, PEHSU)
Recent Research Findings on NO₂ and IAQ, Children's Health and NO₂

Key take aways from Workshop #1

1. International agencies such as WHO and Health Canada robust methodologies for the prioritization of studies and evaluations for their health risks calculations. It would be advantageous to take advantage of this work for updating CARB indoor standards
2. There are many avenues for coordination with other California state agencies such as the Energy Commission, CDPH, and OEHHA for both the assessment and possible implementation of updated indoor air guidelines
3. There is great interest among community-based organizations both within California and other parts of the country to improve indoor air quality and updated indoor guidelines would be helpful for that effort

Progress to date on Indoor Air Quality Guidelines



Program webpage

- Current information about the indoor air quality guideline updates
- Presentations from the first workshop

<https://ww2.arb.ca.gov/our-work/programs/indoor-air-quality/indoor-no2-guidelines-update>

Updated Indoor Air Quality Report

Research Project: Indoor Air Quality in California: New Evidence and Environmental Justice Implications

- Funding appropriated by the California Legislature
- Goal: to include updated scientific and public health findings including, but not limited to, potential health effects from ozone-emitting consumer products, natural gas sources, and indoor sources of per and polyfluoroalkyl substances (PFAS).

Background

- [CARB's 2005 report, Indoor Air Quality in California - A Report to the Legislature](#), reviewed the many health concerns posed by indoor pollutants and ranked indoor health threats in California.
- Since 2005, new challenges such as climate change that impact indoor air quality, new tools for indoor air quality assessment, new scientific facts for indoor air pollutants, along with new concerns on Environmental Justice (EJ) have emerged.
- Two major questions:
 - What are the priority indoor air pollutants in California?
 - How can exposures to these pollutants be mitigated to enhance human health protection?

Literature Review Framework

1. Emerging indoor air pollutants and sources – natural gas, PFAS, vaping, cannabis, wildfire, etc.
2. Concentration levels of typical indoor air pollutants in different indoor environments
3. Parameters related to IAQ and exposures – outdoor, indoor and building characteristics
4. Health impacts of indoor air pollutants – Epi studies, modeling
5. Current standards and guidelines
6. Local, state, and national policies and programs
7. Strategies to reduce indoor air pollution including education and behavior change

TAG and EJ Partners

- **TAG (Technical Advisory Group)**

- 5-8 experts from universities, research institutes, national laboratories, or government agencies
- Attend meetings to explore important issues for indoor air quality in California, discuss the progress, and provide feedback on the interim update
- Review the final draft report and provide scientific comments in writing.

- **Environmental Justice Partners**

- Assist the Contractor with interviews by recruiting interviewees from impacted communities, designing interview questions, providing Spanish interpreters, etc.,
- Present in the virtual public workshop and help recruit participants from impacted communities
- Provide comments on the draft final report
- Distribute materials from this project for community outreach and collect feedback if any.

Public engagement

- **A series of structured qualitative interviews**

- Academic researchers
- Government agencies and environmental health specialists
- Residents, property owners and managers, and occupants of non-residential and non-industrial buildings
- Non-profit organizations, standard entities, and manufacturers

- **A public Workshop**

- To seek and gather input from potential stakeholders including policymakers, building experts, EJ advocates, academic researchers, and the public.

Timeline

1. Project start: June 2023
2. TAG and EJ Partners: formed by October 2023
3. Literature review: by May 2024
4. Interviews: by May 2024
5. Public workshop: by August 2024
6. Draft report: by November 2024
7. Final report and presentation: May 2025

Future Directions, Key Contacts and Questions

Future projects and directions

- Additional amendments to CARB's air cleaner regulation
- More projects on factors which can impact IAQ levels especially in vulnerable communities with a focus on community engagement and partnerships
- Projects focusing on updating current information regarding Time-Activity data
- Increased outreach to inform the public about clean air centers in their community especially during wildfire smoke episodes
- Studies focused on health and reduced indoor air pollution exposure benefits of decarbonization

Key Contacts

- **Qunfang (Zoe) Zhang** (QunfangZoe.Zhang@arb.ca.gov)
 - Multifamily Housing project
 - Decarbonization / Commercial Buildings
 - Low-Cost Sensor White Paper
 - Indoor Air Quality Report
- **Jeffery Williams** (jeffery.williams@arb.ca.gov)
 - HIFIVE Study
 - Indoor Air Quality NO₂ Guidelines Update
- **Julia (Ky) Gress** (julia.gress@arb.ca.gov)
 - Air Cleaning Technologies White Paper
- **Jinhyok Heo** (Jinhyok.Heo@arb.ca.gov)
 - PAIR Study

Thanks! And Questions?

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