



In-ROOM HEPA AIR PURIFIER DEPLOYMENT for PM CONTROL IN OCCUPIED SCHOOLS CLASSROOMS

“TRUST but VERIFY”



Mark Hernandez & Friends



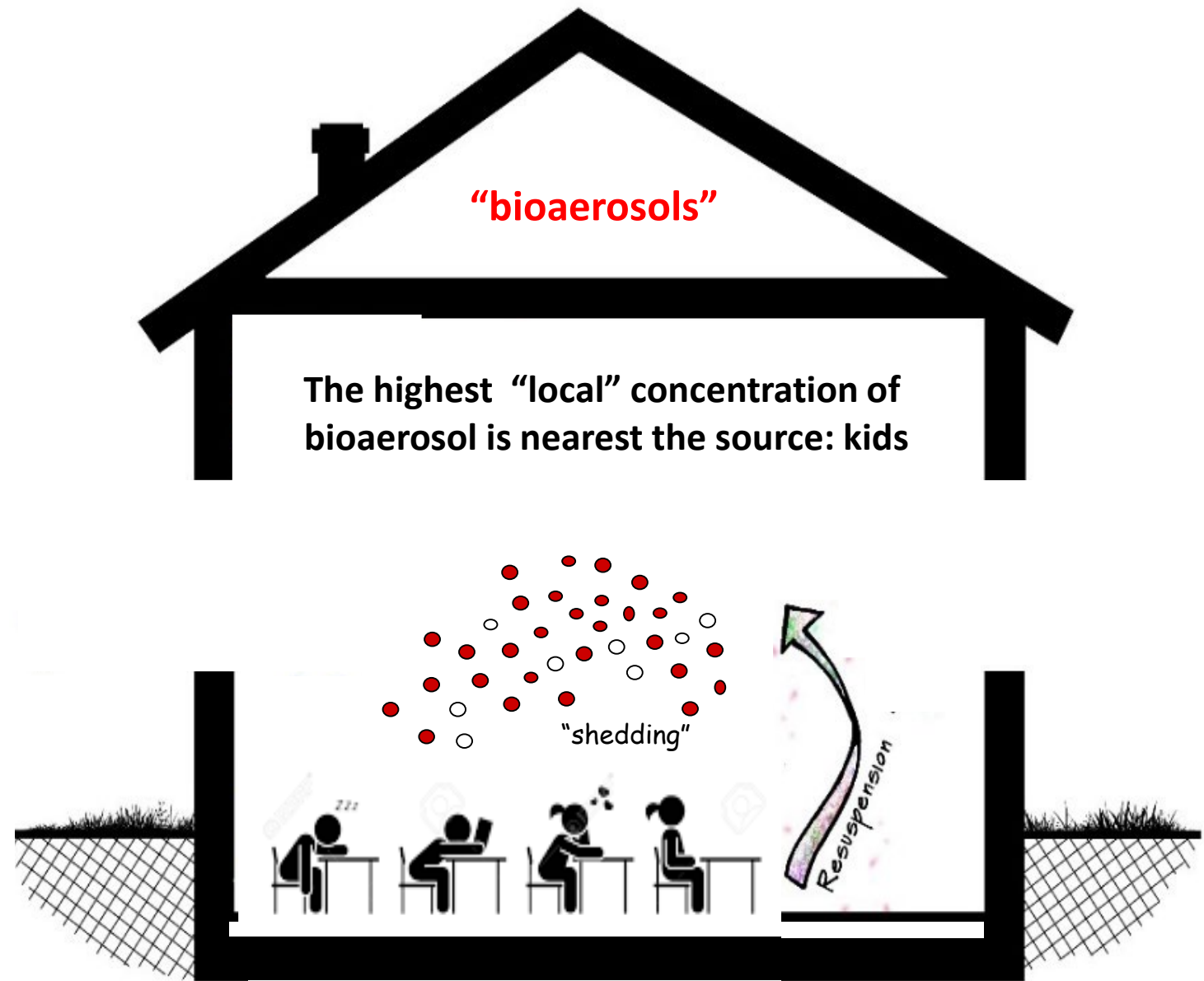
Environmental Engineering
UNIVERSITY OF COLORADO **BOULDER**

Be Boulder.
Be Boulder.

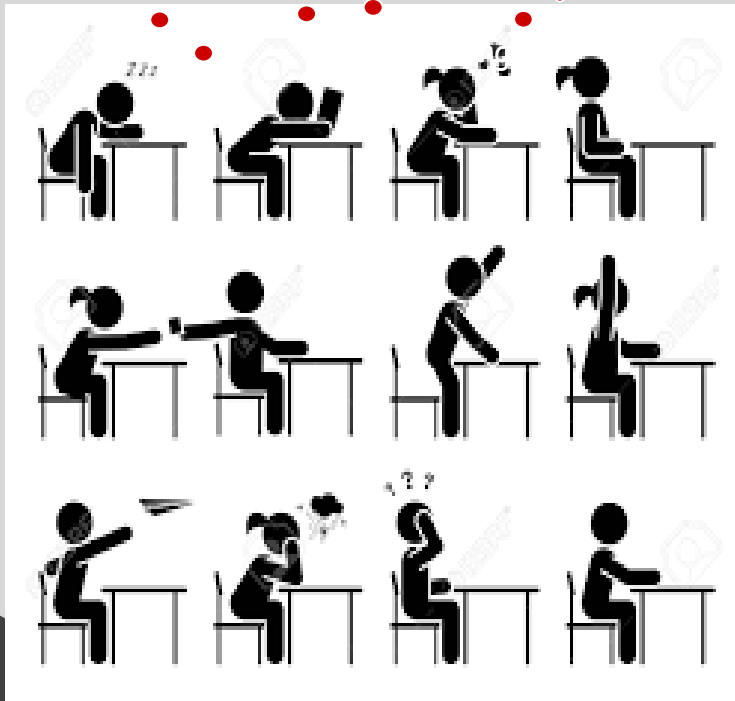
Fact : all people, *ill or not*, shed
and resuspend microbes
in their local indoor environment
(AKA: bioaerosols)



"shedding"
& resuspension



From a practical facilities perspective

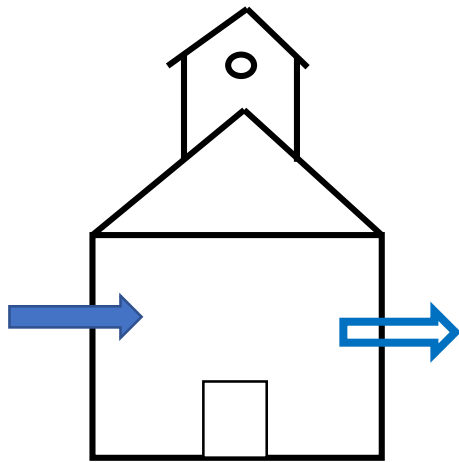


Reducing indoor aerosol load (PM)
= reducing exposure risk !

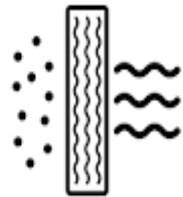


**The product of built environment practices
can significantly reduce exposure (risk)**

Conventional FACILITIES & INFRASTRUCTURE

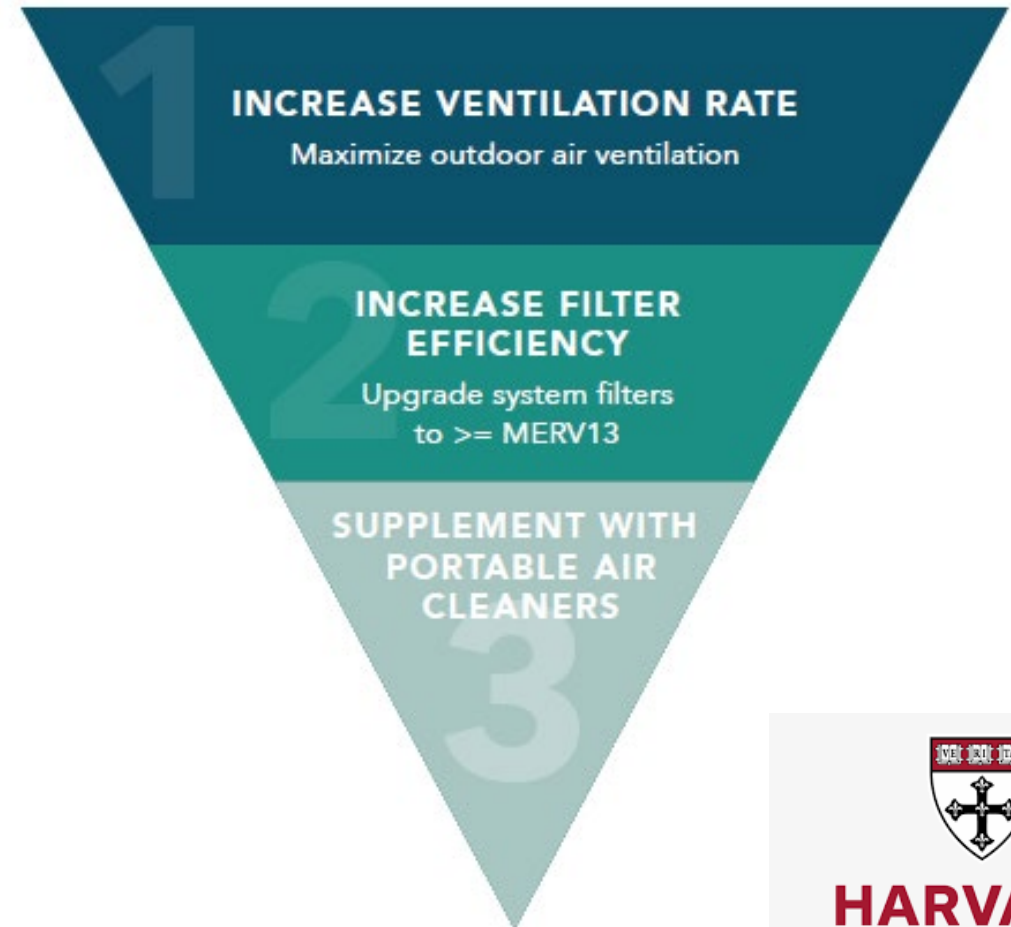


ventilation ↑



enhanced
filtration

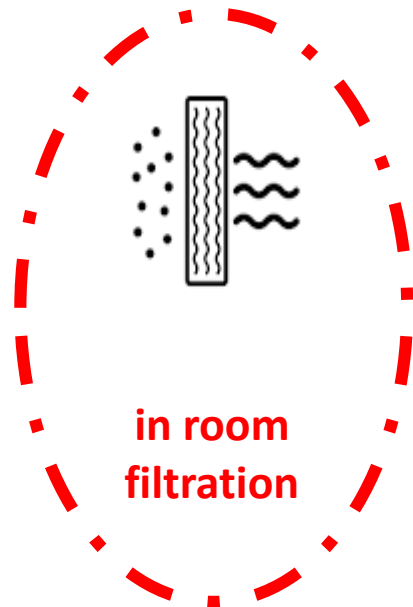
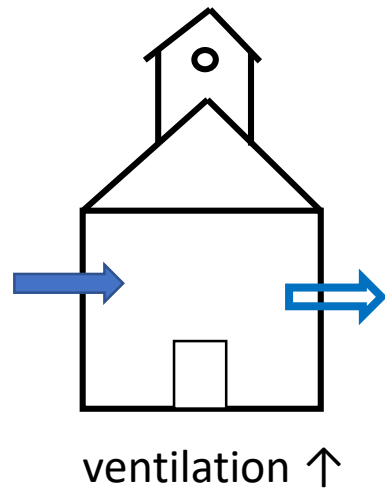
Prioritization of Engineering Controls to Reduce Long-Range Airborne Transmission



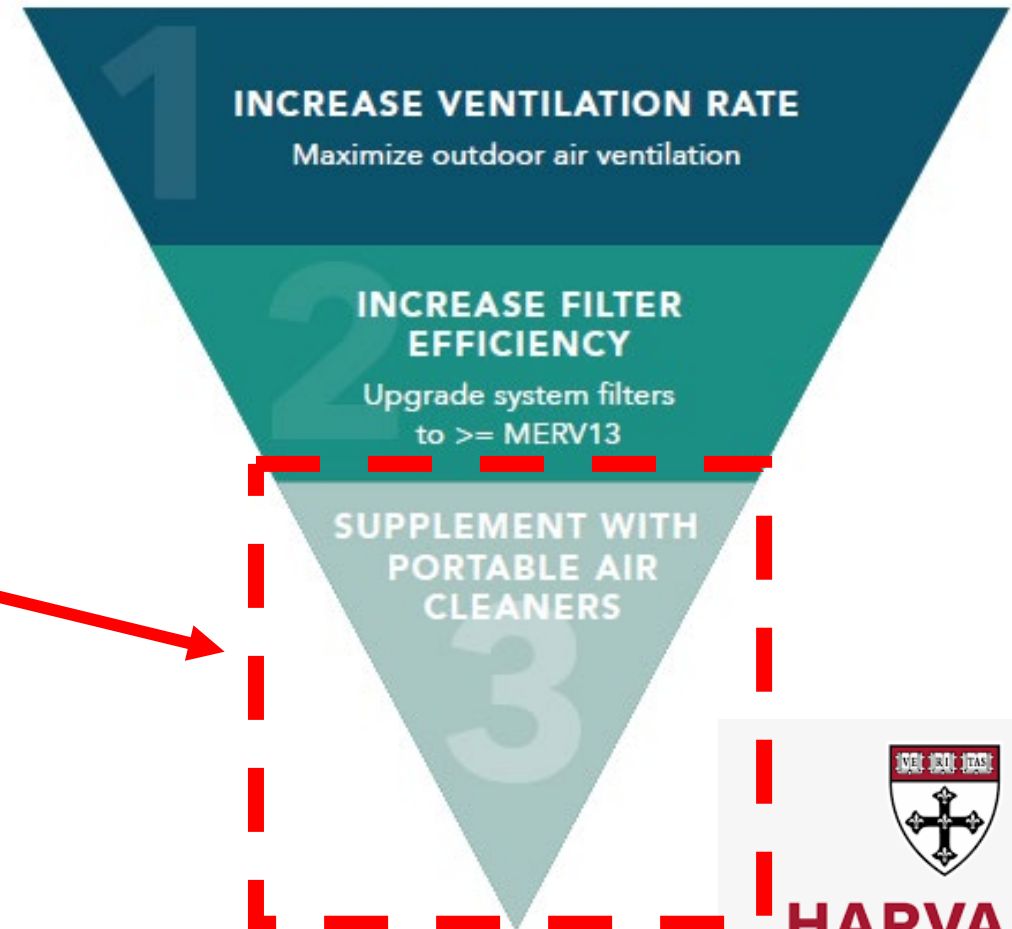
HARVARD
SCHOOL OF PUBLIC HEALTH
Powerful ideas for a healthier world

FOCUS: demonstrate effectiveness of flexible engineering controls that *supplements* ventilation with high efficiency filtration nearest the PM source

FACILITIES / INFRASTRUCTURE



Prioritization of Engineering Controls to Reduce Long-Range Airborne Transmission





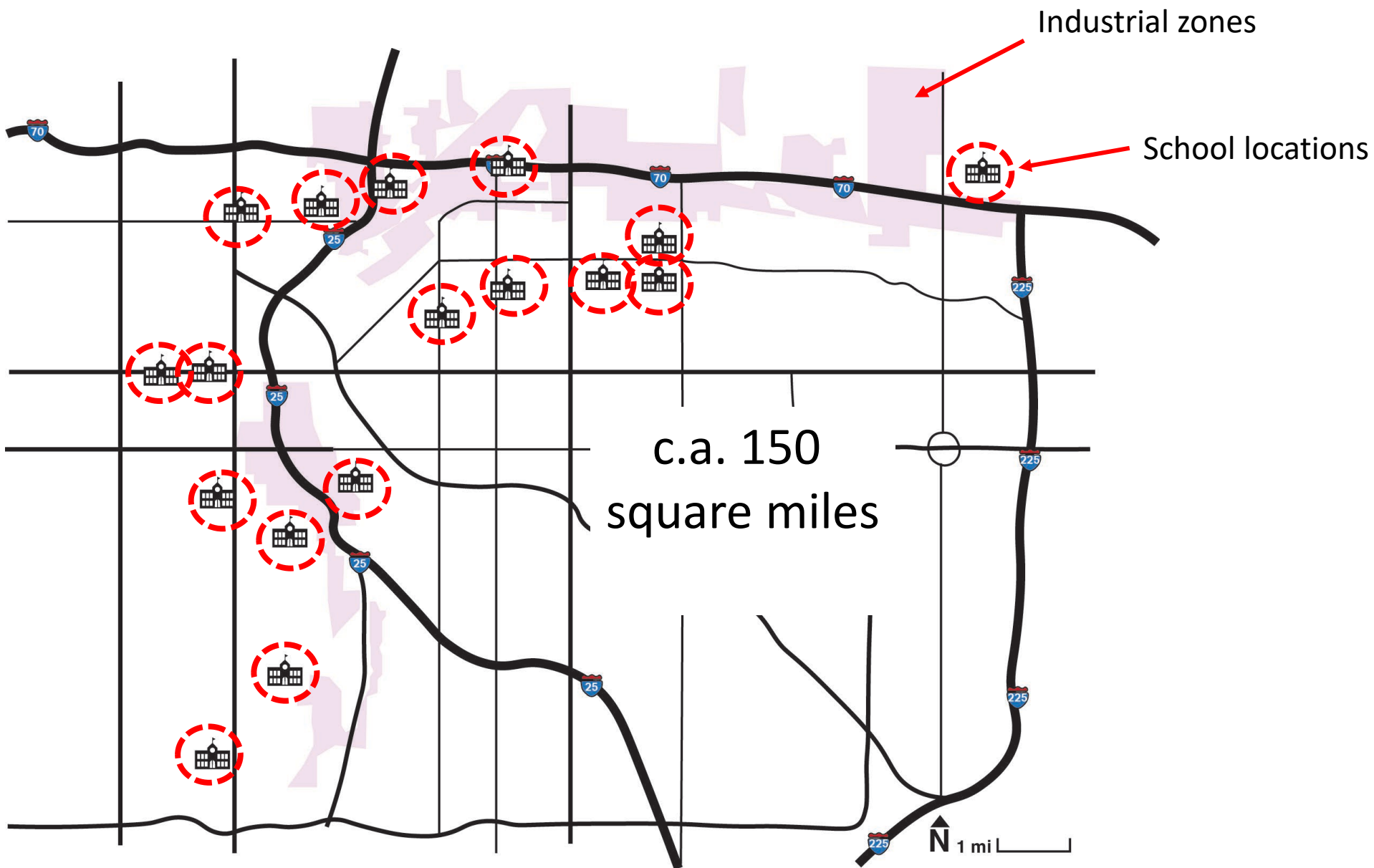
HEPA AIR PURIFIER EFFECTIVENESS DEMONSTRATION

Started with (*in situ*):
Ventilation Survey

**20 (19) Elementary
Schools**

stratified
socioeconomic
backgrounds
(6 bilingual schools)

bordering
commercial
suburban
industrial zones &
interstate highways



while we “trust” HEPA filters can work

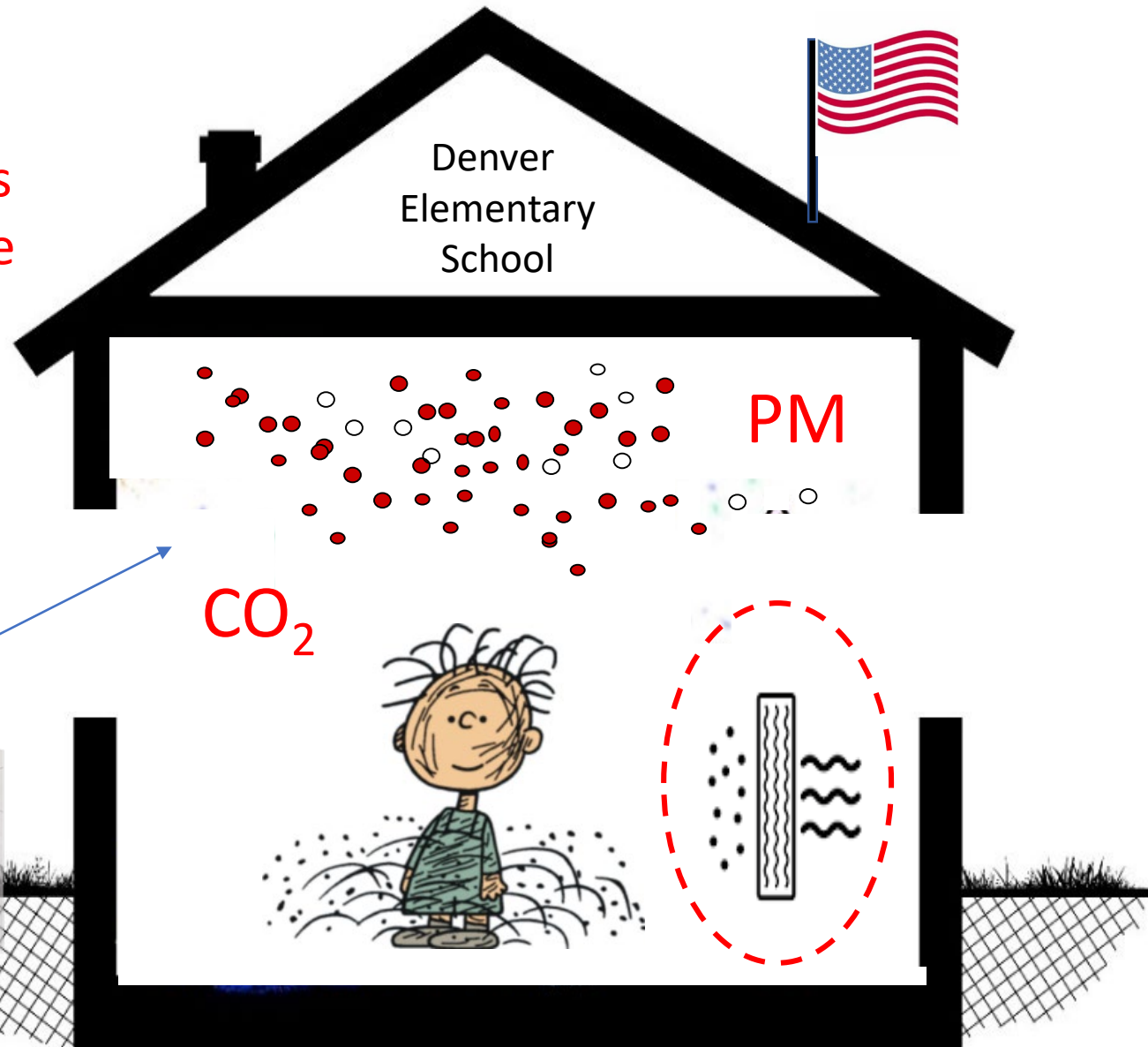
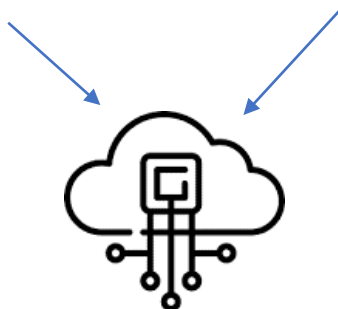
THE POINT: determine actual filtration effects
by continuous measurements that can expose
patterns of CO₂ & PM departures



wall-mounted
composite sensors
(near return)



mobile
bioaerosol sensor
(aerosol cytometer)

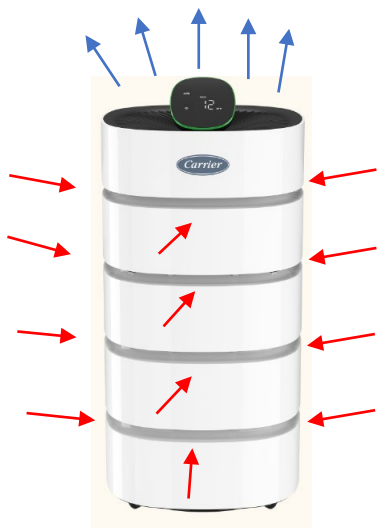


Longitudinal Observations → Spring 2021
“little kids”: first to come back; last to vaccinate

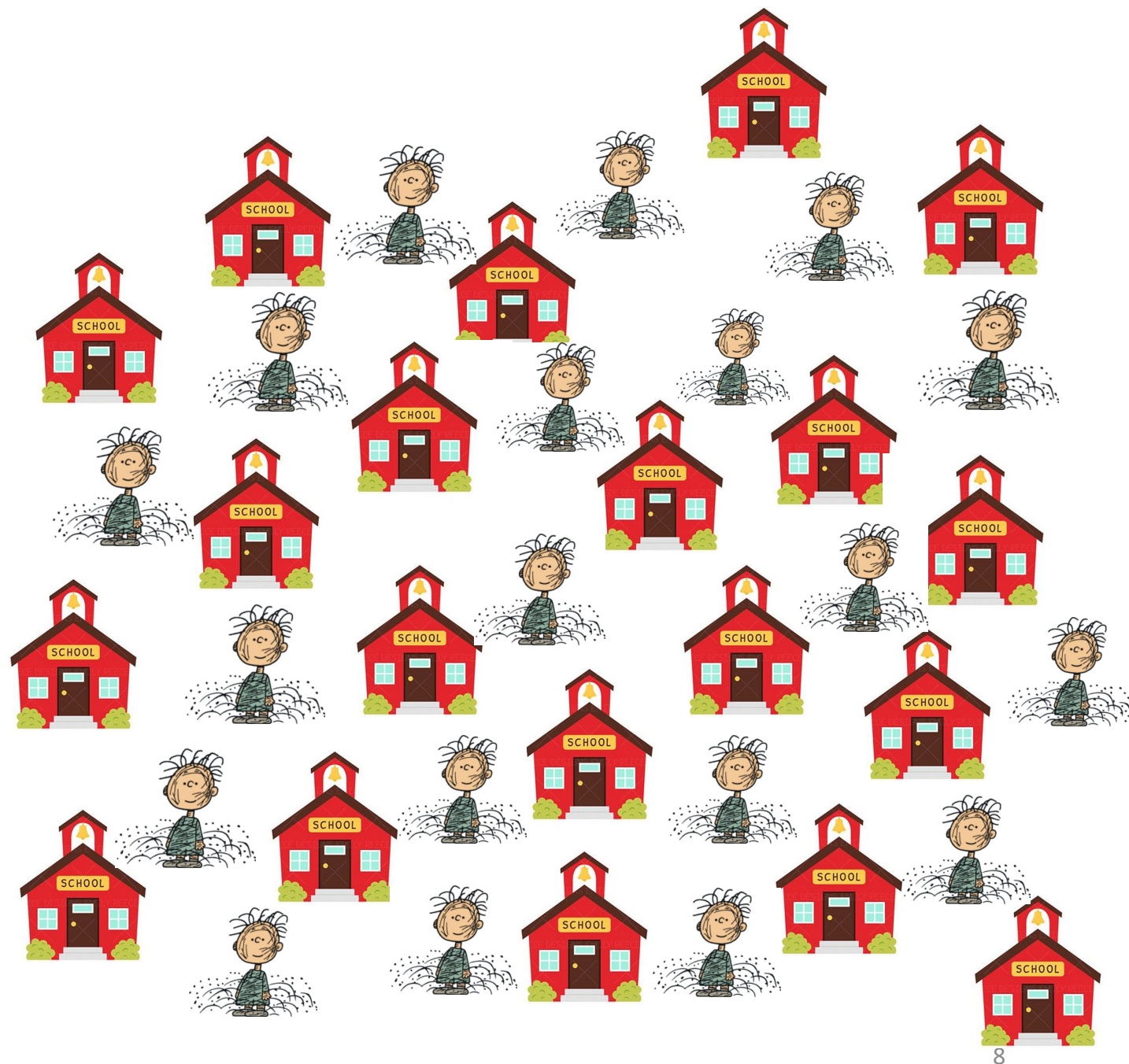
Survey design

Randomized Control Trial: (n=79 classrooms) of in-room air purifier deployments

New generation of radial intake
HEPA air (filter) purifiers

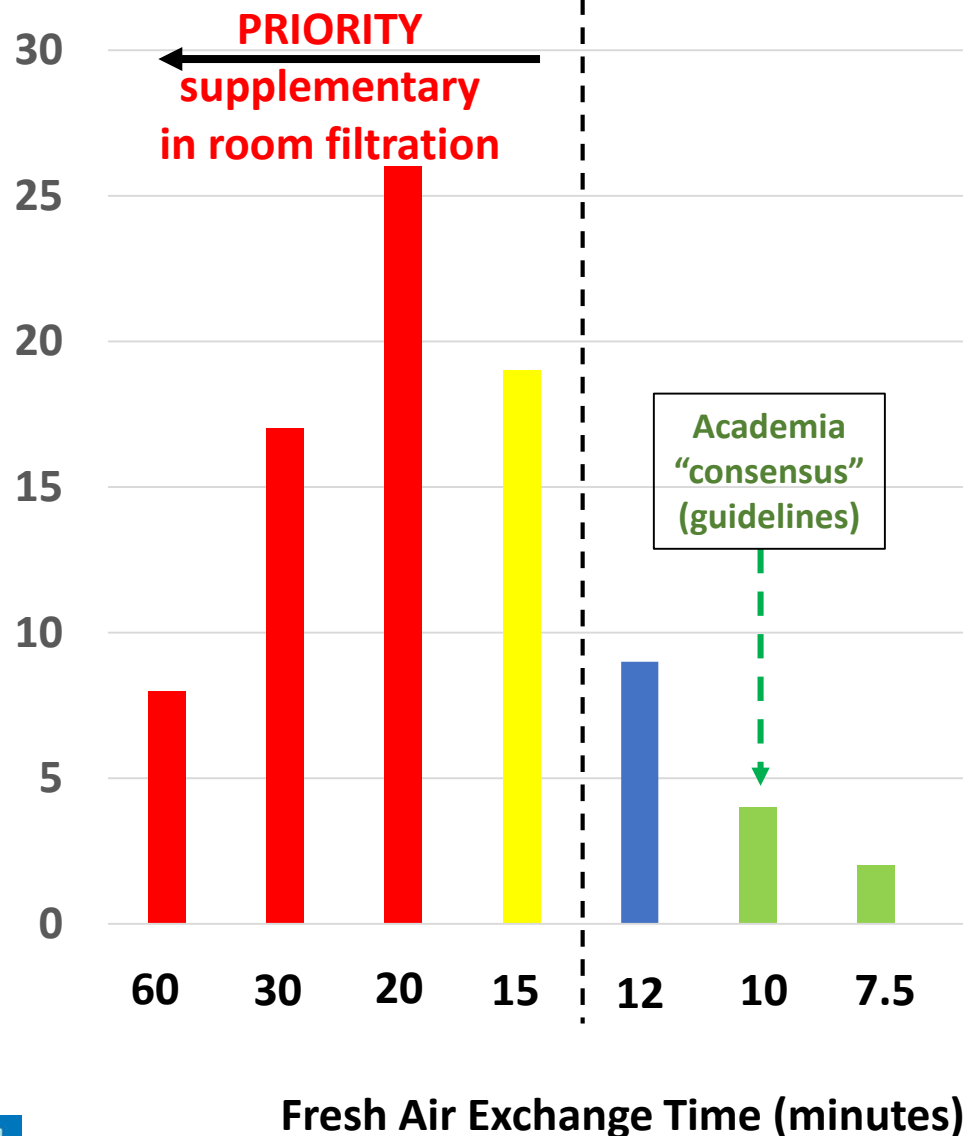


in situ flow rate (CADR)
determined by instructional
“acoustic tolerance”
(average was 2 x c.a. Σ 500 cfm)

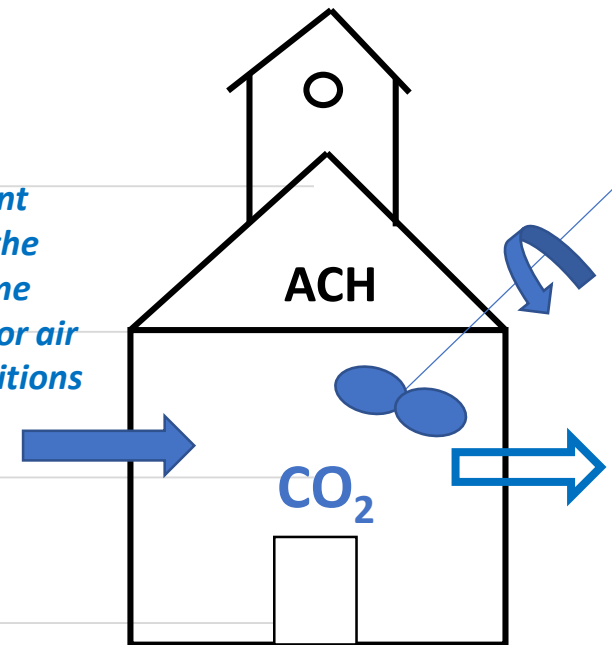


Strategy for Staged Air Purifier Installations

School Classrooms Surveyed



The average amount of time to replace the entire indoor volume with "fresh" outdoor air in well-mixed conditions



Translated to minutes

TARGET IS AT LEAST 5 TOTAL AIR CHANGES PER HOUR

10 min	Ideal (6 ACH)
12 min	Excellent (5-6 ACH)
15 min	Good (4-5 ACH)
20 min	Bare minimum (3-4)
30 min	Low (<3 ACH)

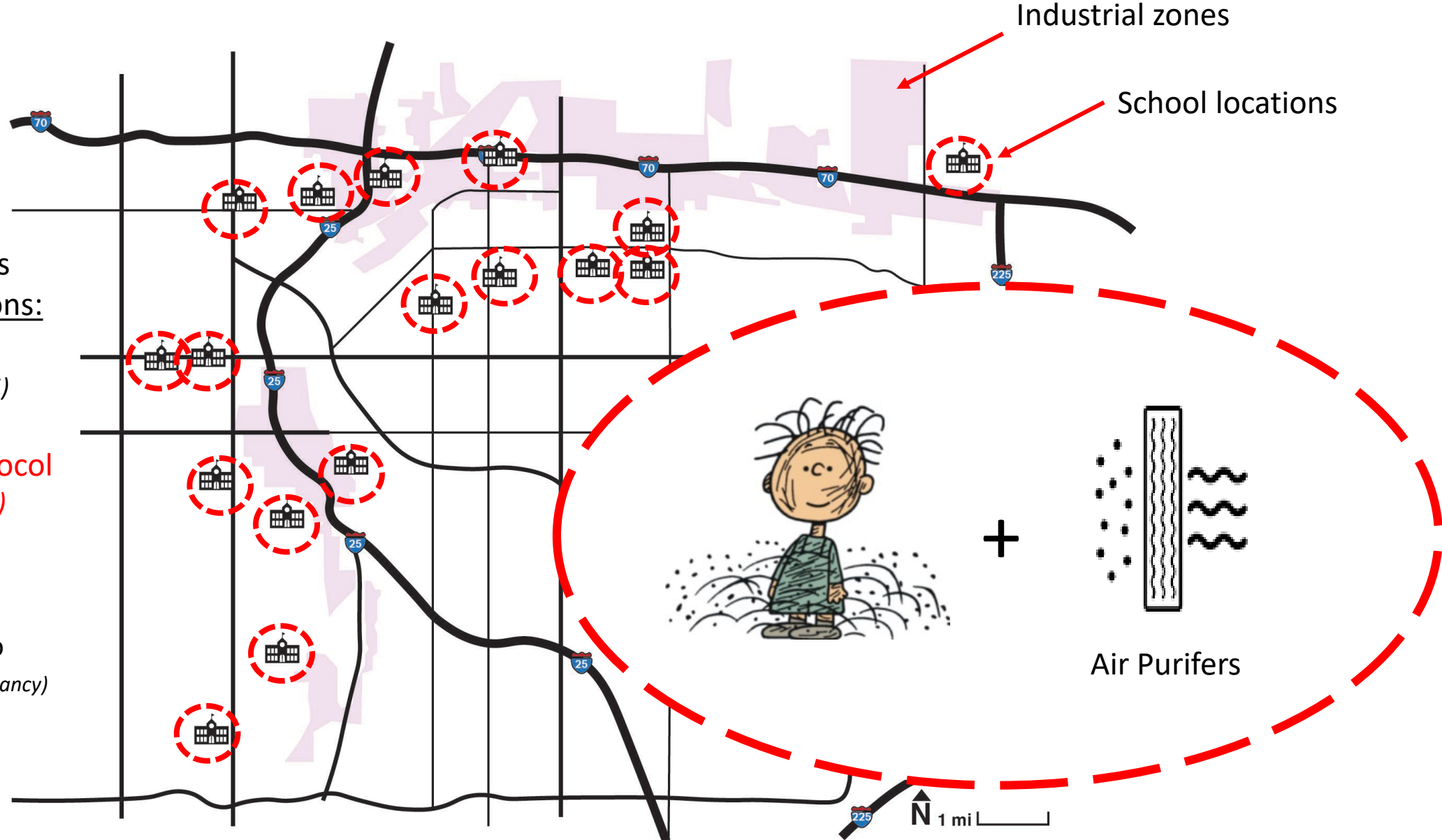
HEPA AIR PURIFIER EFFECTIVENESS DEMONSTRATION

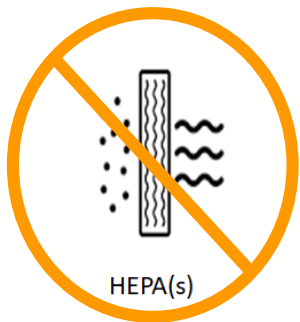
(OCCUPIED k-5 Classrooms)



PM Reduction Trials performance conditions:

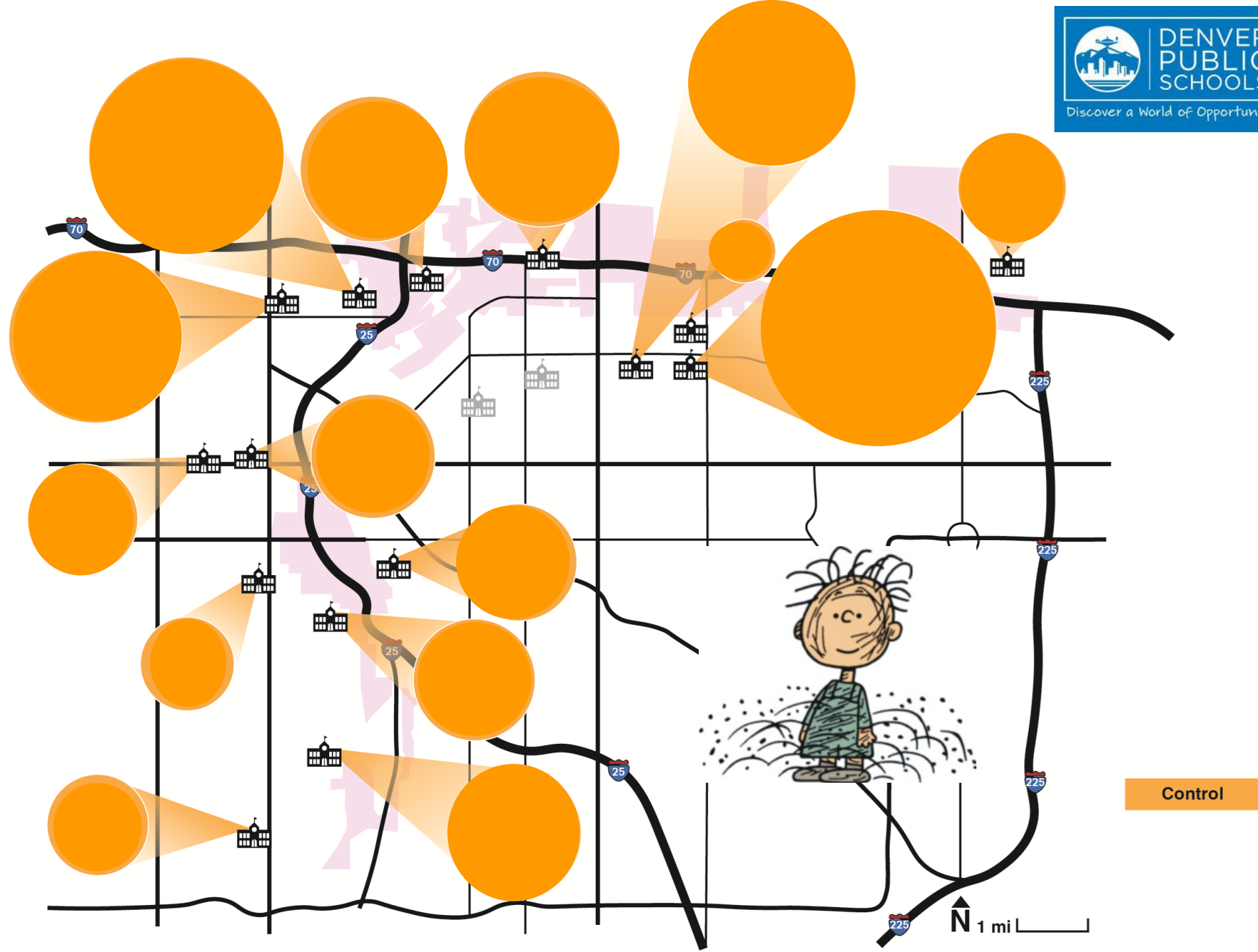
- fully occupied (*c.a. 25*)
- **COVID building protocol**
(*classroom doors open*)
- *As-is* ventilation
- 3 HEPA : 1 control ratio
(*identical grade levels & occupancy*)

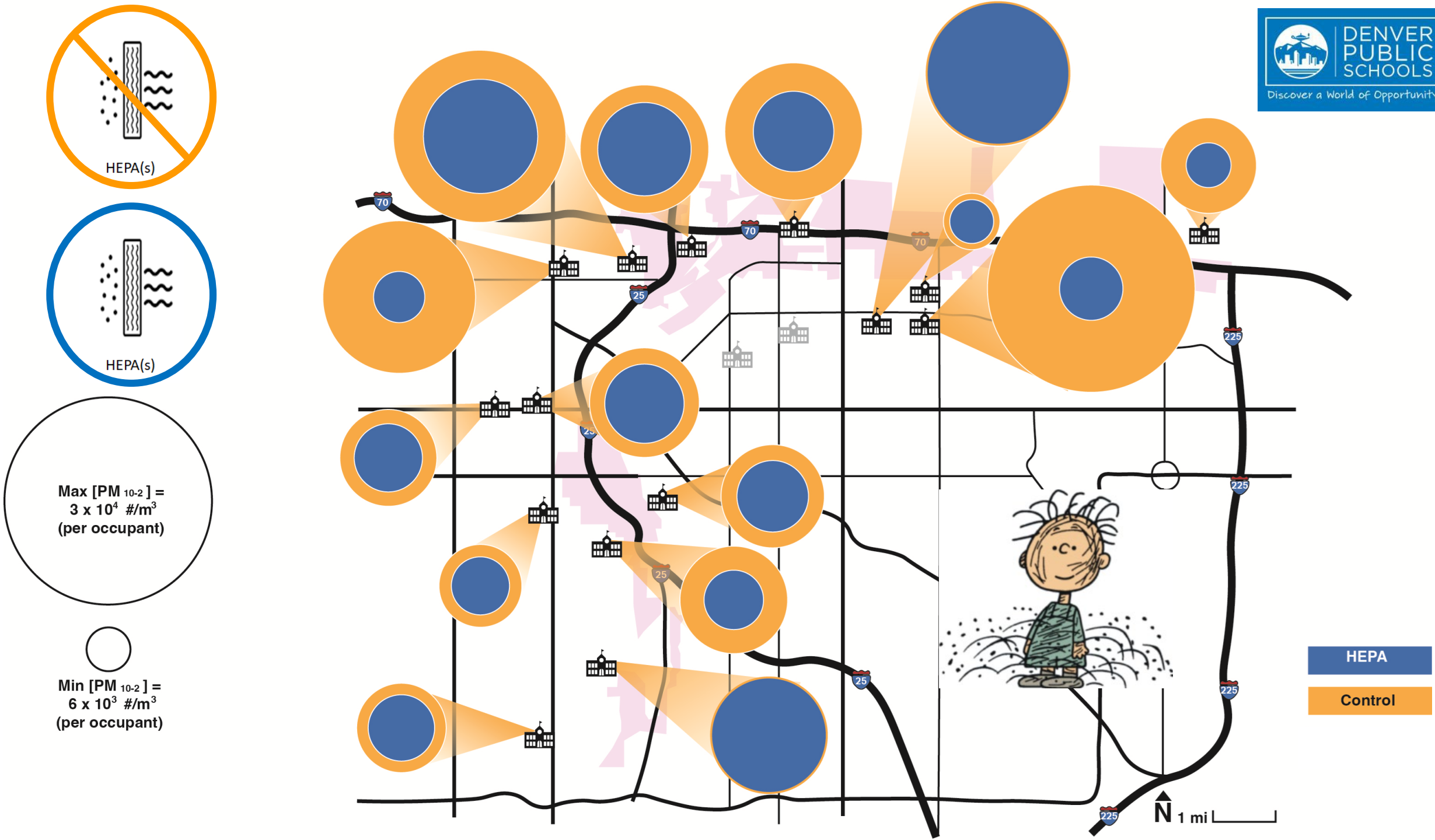


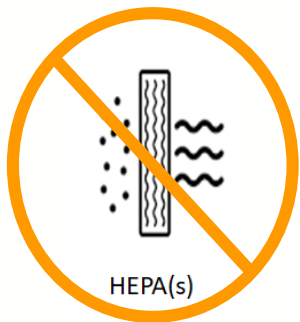


Max [PM₁₀₋₂] =
 3×10^4 #/m³
(per occupant)

Min [PM₁₀₋₂] =
 6×10^3 #/m³
(per occupant)





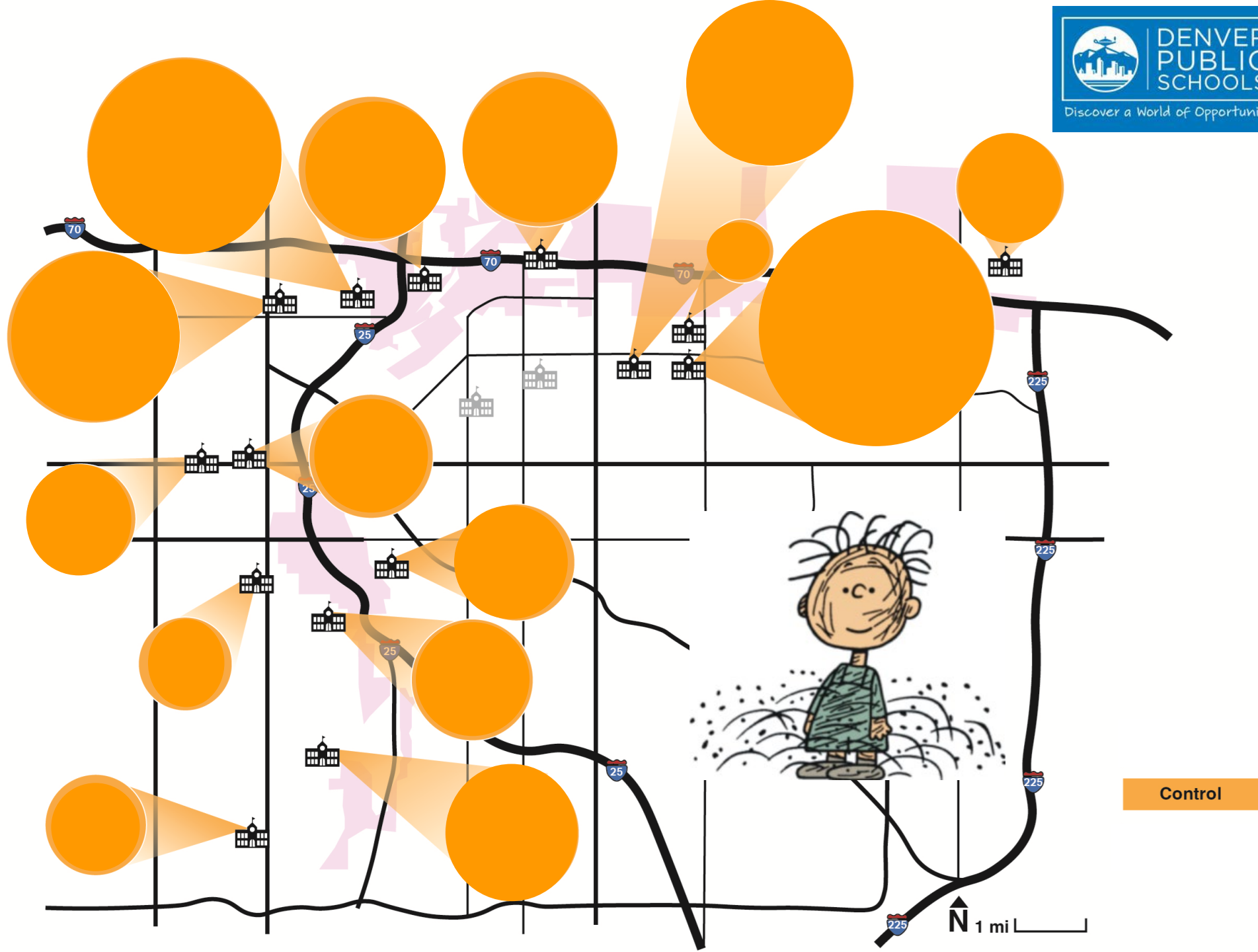


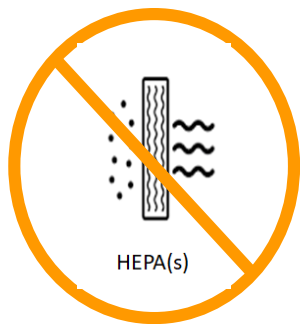
HEPA(s)

Max $[PM_{10-2}] = 3 \times 10^4 \text{ \#/m}^3$
(per occupant)



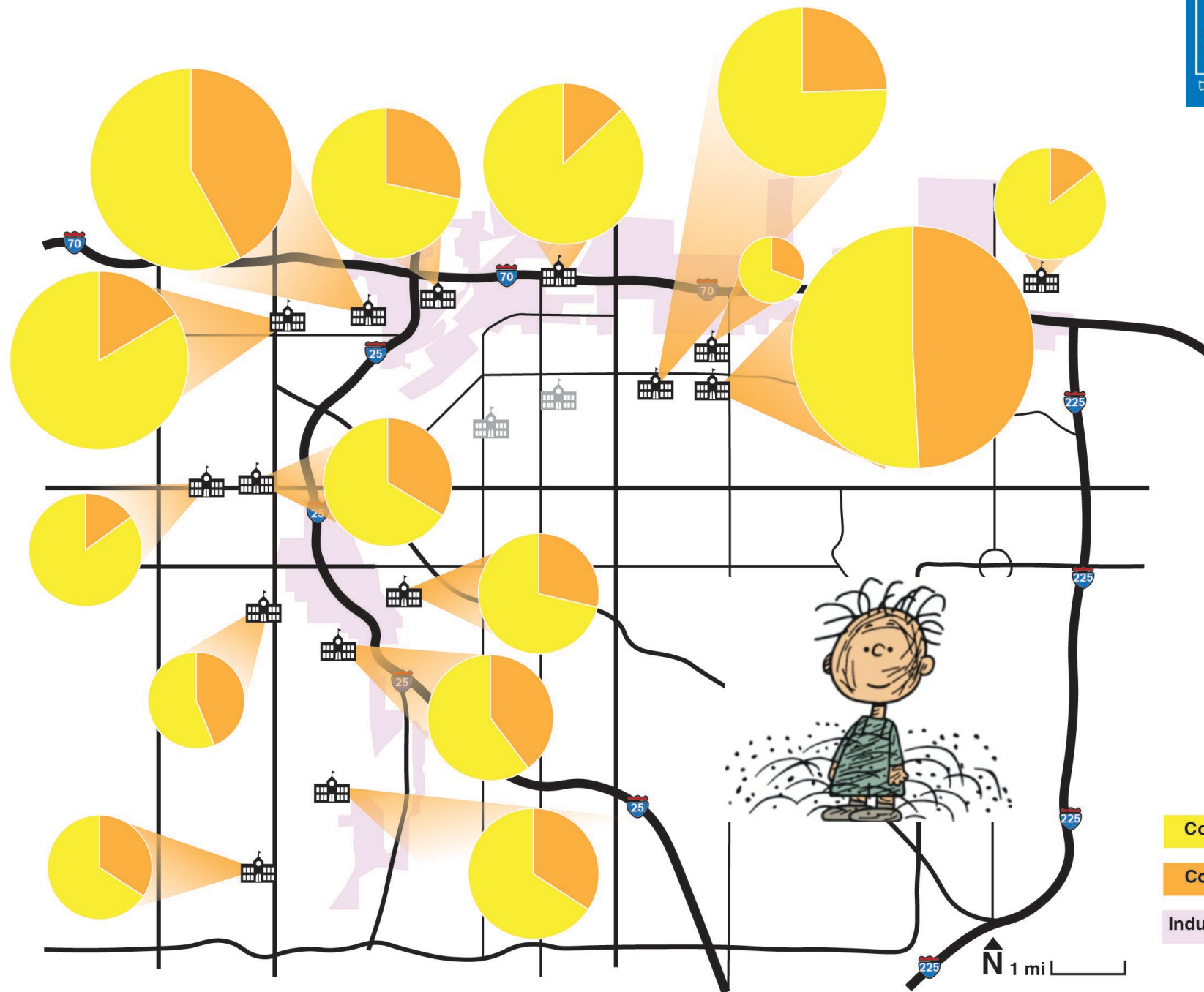
Min $[PM_{10-2}] = 6 \times 10^3 \text{ \#/m}^3$
(per occupant)



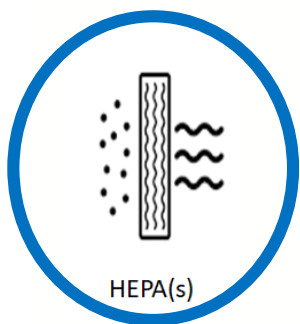
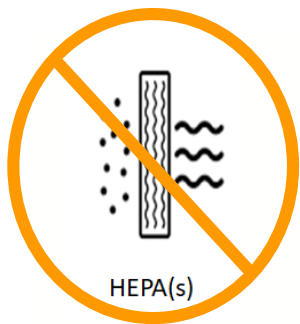


Max [PM₁₀₋₂] =
3 x 10⁴ #/m³
(per occupant)

Min [PM₁₀₋₂] =
6 x 10³ #/m³
(per occupant)

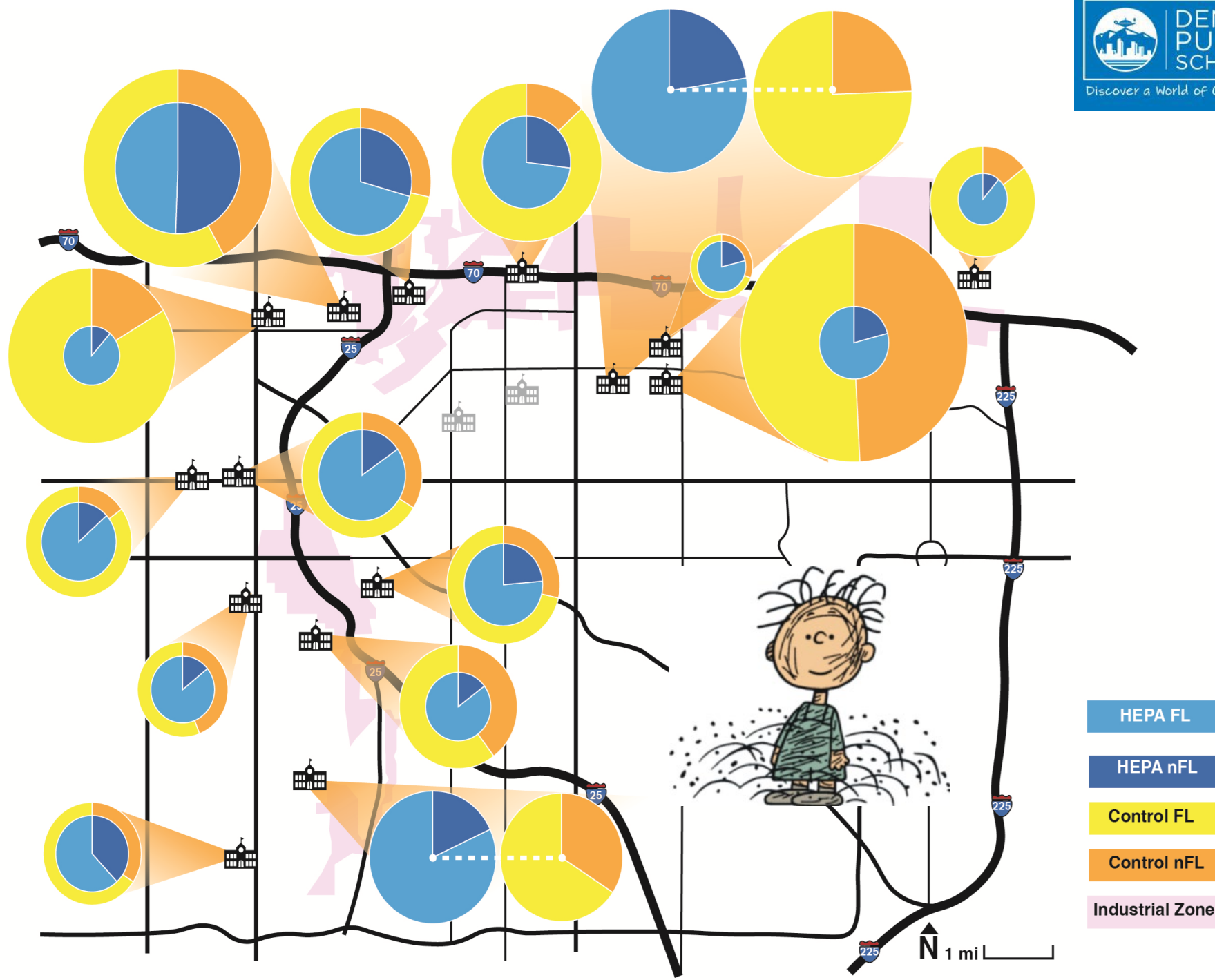


Control FL
Control nFL
Industrial Zone



Max [PM₁₀₋₂] =
3 x 10⁴ #/m³
(per occupant)

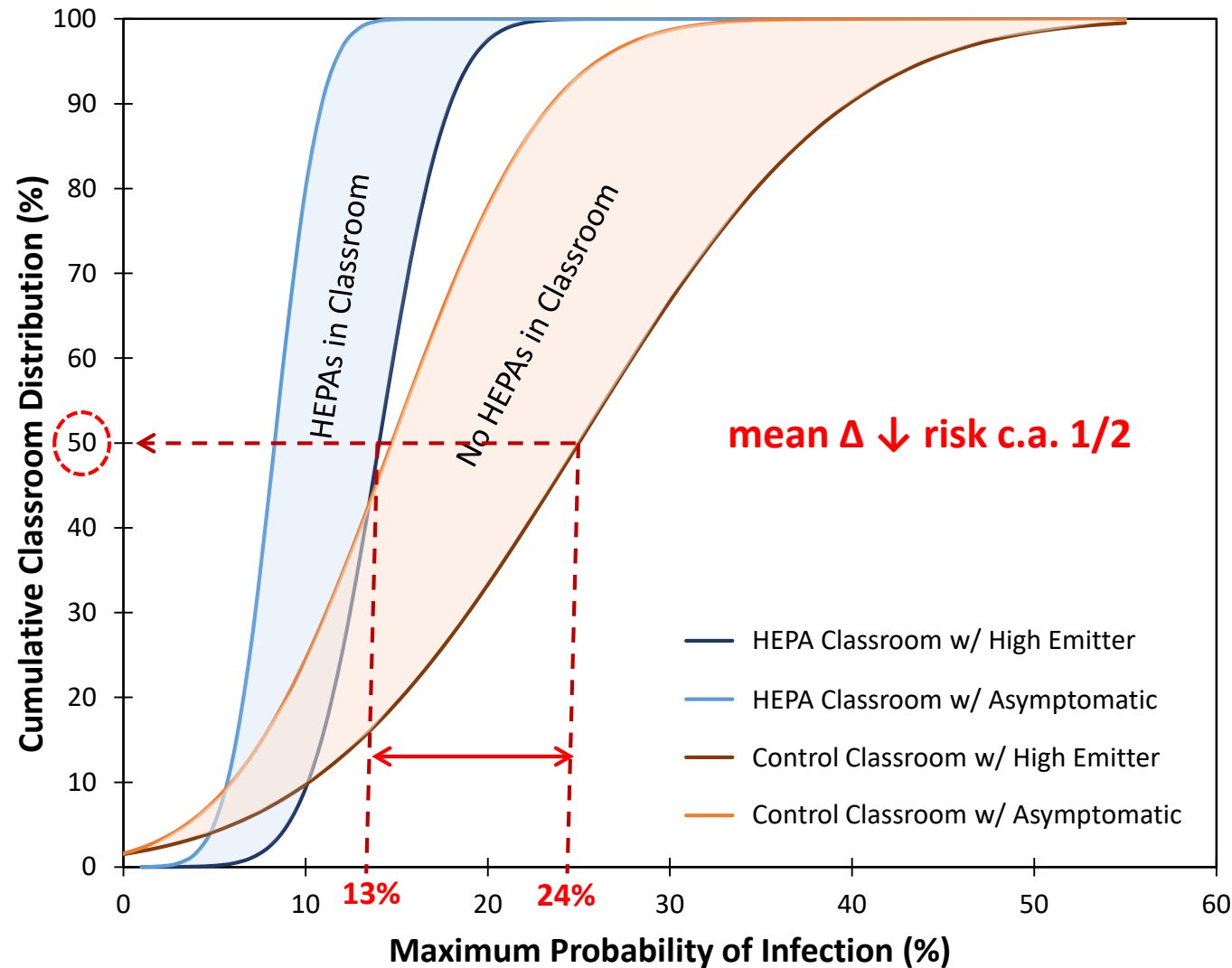
Min [PM₁₀₋₂] =
6 x 10³ #/m³
(per occupant)



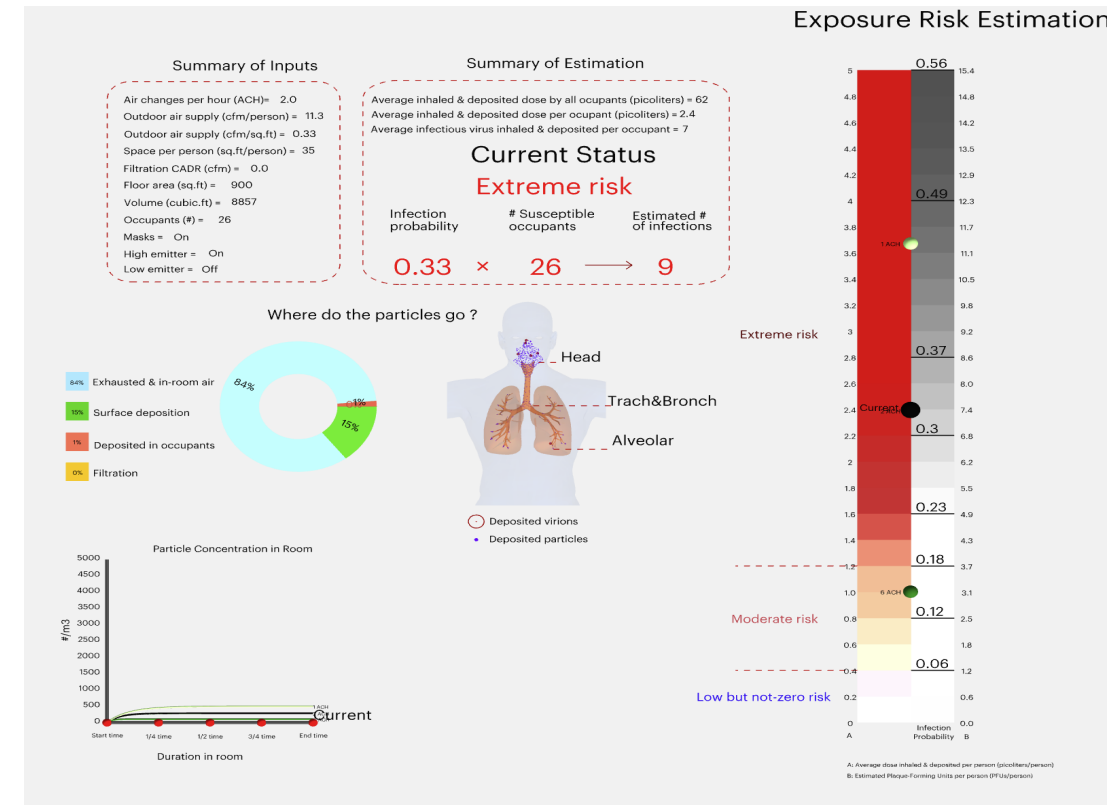
How can this translate toward estimating risk reduction *in-situ*?:

SAFEAIRSPACES COVID-19 *Relative* Risk Estimator with measured inputs

(maximum probability of infection adapting Wells-Riley, mixing regime and other common assumptions)



<https://safeairspaces.com/safeairspaces-estimator>



Measured inputs: volume, occupancy, CADR, ACH

In the Post-CoVID era of school infrastructure investments (ESSER, ARP, etc.)

While we know engineering controls “can” work, it does not mean they do !

“Trust by Verify !”

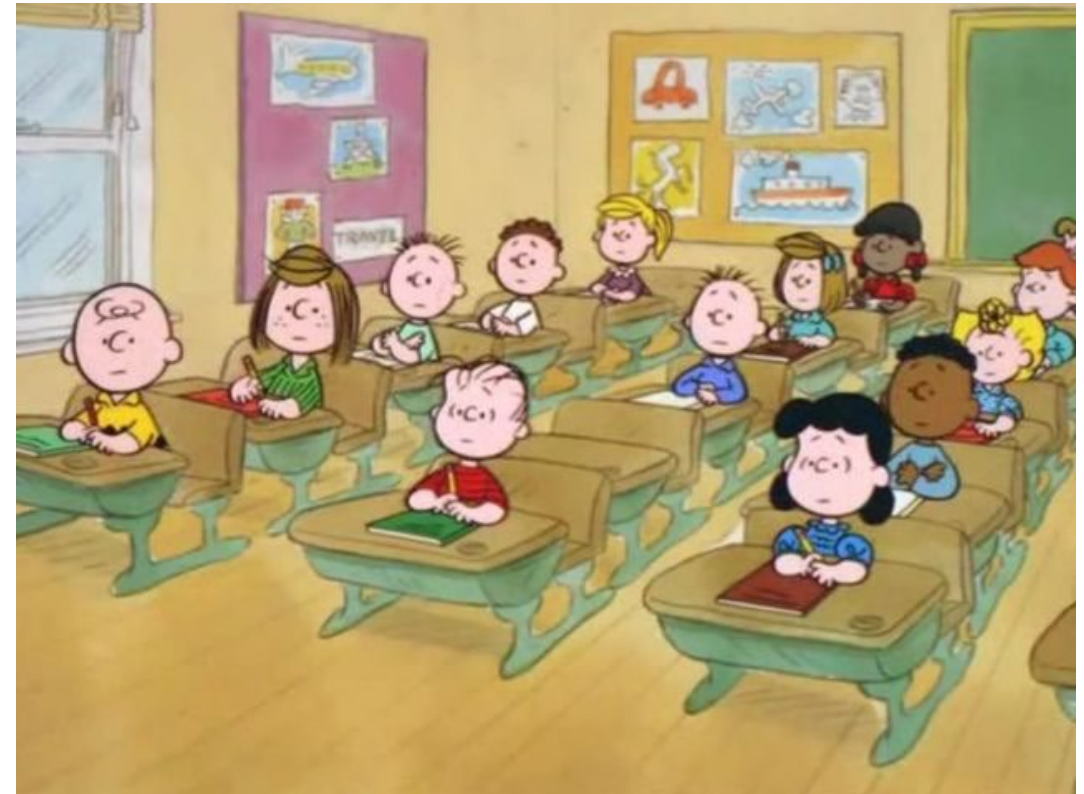
*Monitoring is a fraction of capital improvement costs;
performance verification is important now and in the future !*



Monitoring benefits reach well beyond the CoVID era !
(including co-morbidity control)

smoke, allergens, hypersensitivity triggers, urban pollution

Environmental Quality → Performance & Absenteeism





**TEAM
CU + DPS**

**Dr. Odessa
Gomez**



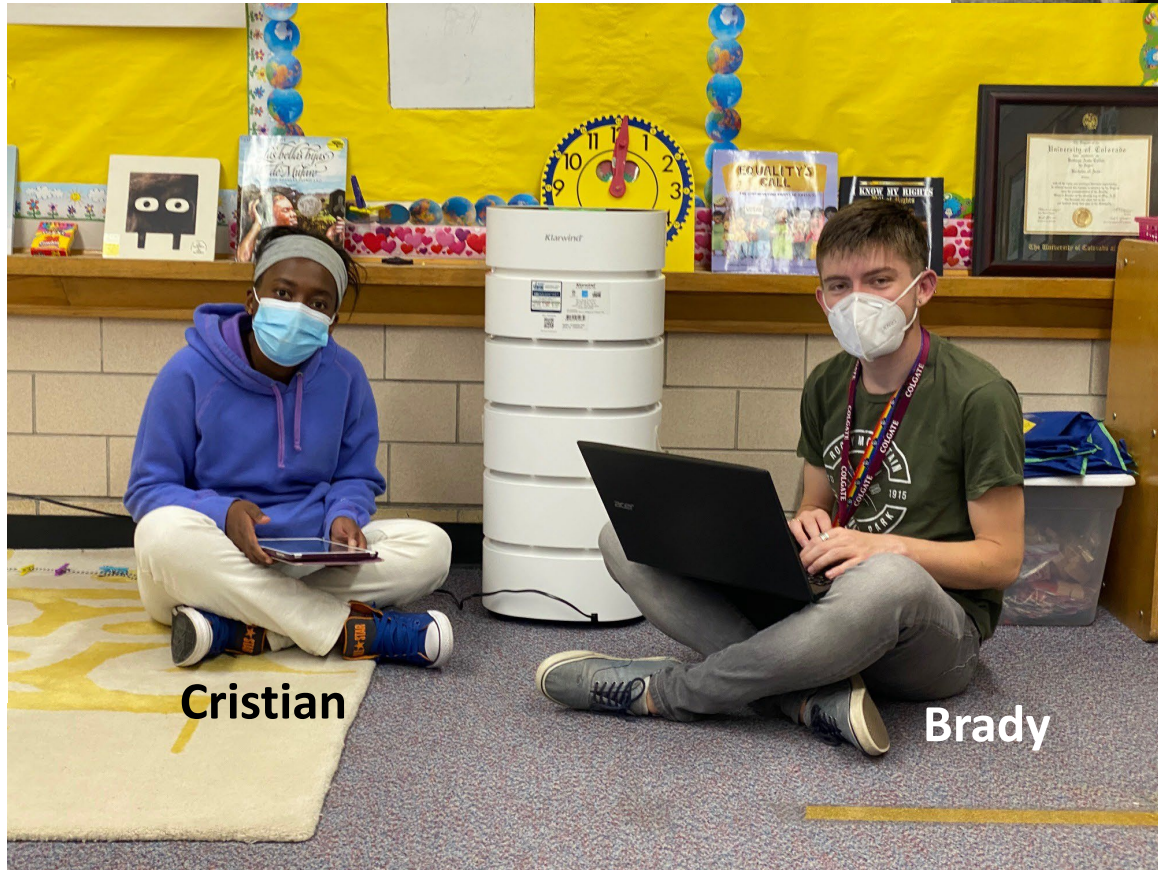
**Joni
Rix**



Sylvia

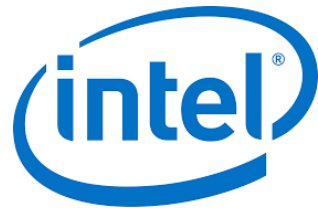
Halle

Ryan



Cristian

Brady



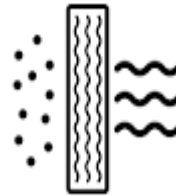
Sra. Anna Segur

In theory, practice and theory are the same; in practice, they are not.....Yogi Berra

Sales



Reality



1997 Eagle Talon
2.5 L, 4 cyl, Manual 5-spd, Premium Gasoline, Turbocharger

MPG 24
COMBINED

21 CITY **29** HIGHWAY

www.fueleconomy.gov

Your mileage may vary. Actual mileage will vary with driving conditions, driving habits, vehicle load, and other factors. For more information, see your owner's manual.

AHAM CERTIFIED
Clean Air Delivery Rate
Certified Rating

For an air cleaner to air cleaner, compare the CADR numbers. First, look at suggested room size. Then refer to the dust, tobacco smoke, and pollen Clean Air Delivery Rate (CADR) numbers. The higher the numbers, the faster the unit cleans the air.

This air cleaner is suggested for use in a single closed room up to **120** square feet.

Room size ratings center to the AHAM Certified Program criteria of 80% smoke reduction, higher Clean Air Delivery Rates provide improved performance in all room sizes. Portable air cleaners will be much more effective in rooms where all doors and windows are closed.

Dust: **80** Tobacco Smoke: **80** Pollen: **80**

These values represent performance that can be expected within the first 72 hours of operation. Subsequent performance may vary with use.

Association of Home Appliance Manufacturers **AHAM**

Classroom X					Now
71.9°F Temperature Comfortable?	28.0% Humidity Dry?	563 ppm CO₂ Good?	1.12 µg/m³ PM_{2.5} Good?	1.12 µg/m³ PM₁₀ Good?	