# Reducing Exposure to Particle Pollution in Homes: Sources, Impacts, Solutions

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# Our Aim Today is to Build

Awareness of the **health threats** small particle pose
& the **opportunities** that addressing them presents.

April is National Healthy Home Month – Stop by HUD booth in vendor area

## Who Are You?

What you do

How long in this field

What questions do you bring to this session

# Opening Reflection

1. What do you think are the most threatening particles to you and your household?

2. What is the most important thing a contractor/crew can do on the job to control particles?

# The End Game

Overload Alert!

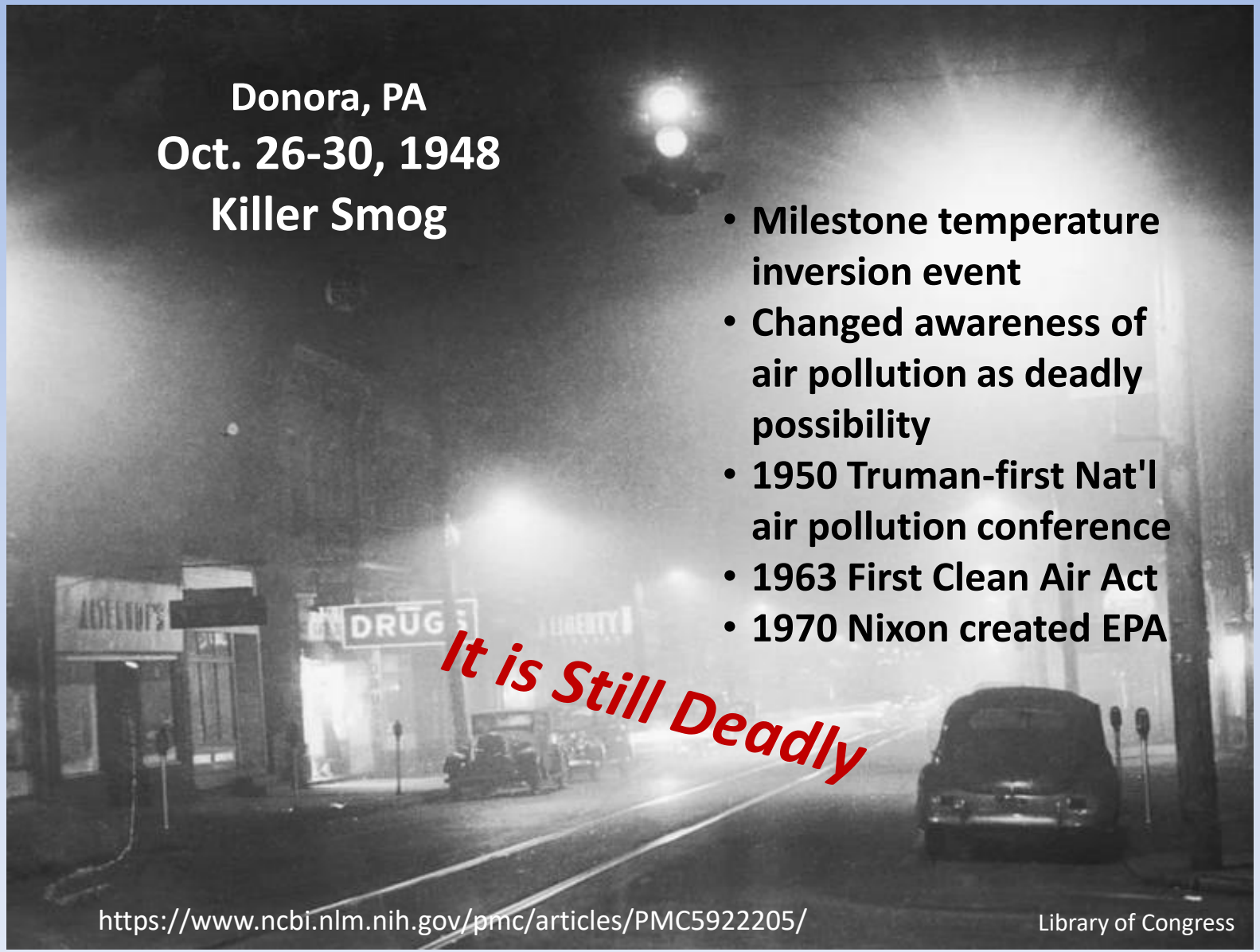


HUD Healthy Homes & BPI Healthy Housing Principles Reference Guide

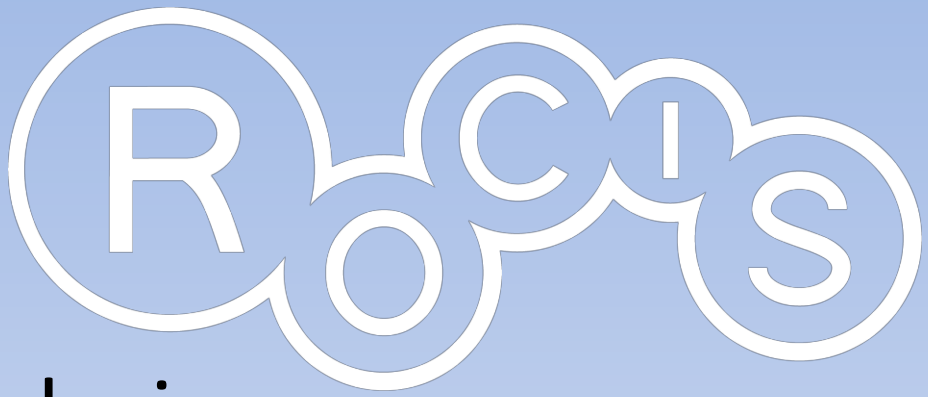
# Conclusions: Reducing Particle Exposure

1. Outdoor & indoor fine and ultrafine particles are significant health threats
2. A comprehensive, wholistic approach is needed that addresses outdoor & indoor sources
3. Many actions can reduce our exposure
4. Low cost monitoring can empower occupants to take action & to confirm impact

# Small Particle Pollution is Not New



The ROCIS **Low Cost Monitoring Project** (LCMP) began in 2015. With funding from The Heinz Endowments we have managed 58 cohorts with testing, feedback & interventions for > 480 participants -- most in the greater Pittsburgh area.




**R**educing

**O**utdoor

**C**ontaminants

in

**I**ndoor

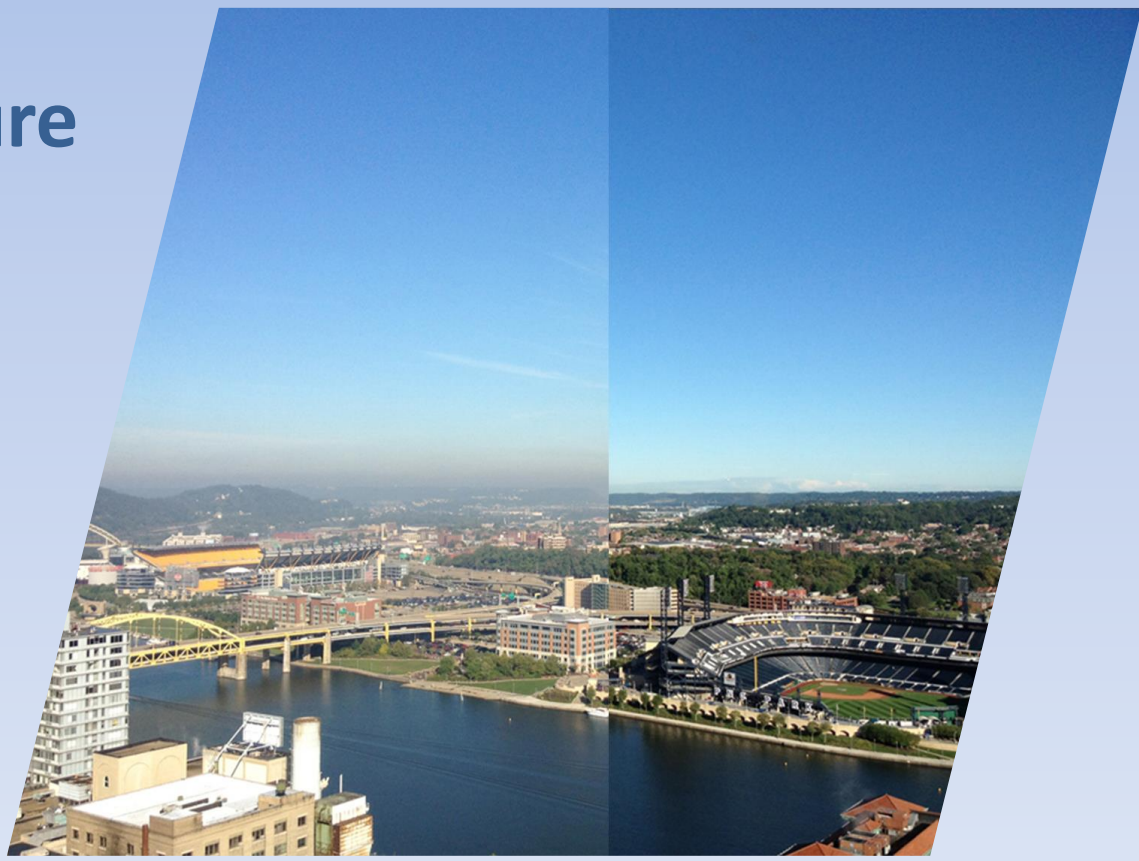
**S**paces

**"A Southwestern Pennsylvania initiative to reduce the impact of exterior pollution in indoor spaces"**

ROCIS.org

*Allegheny County (Pittsburgh, PA) ranks in the top 1% of counties in the U.S. for **cancer** risk from air **pollution**.*

**Most of our exposure to outdoor pollution happens INSIDE buildings**



https://www.iaqscience.lbl.gov

https://breatheproject.org/public-health-facts/

# Health Calculation for Risk

**Time x Exposure = Risk**

# Particulate Matter (PM)

## U.S. Environmental Protection Agency (EPA):

Particulate matter (PM), also known as particle pollution, is a complex mixture of extremely small solid & liquid particles that get into the air. Once inhaled, these particles can affect the heart & lungs & cause serious health effects.

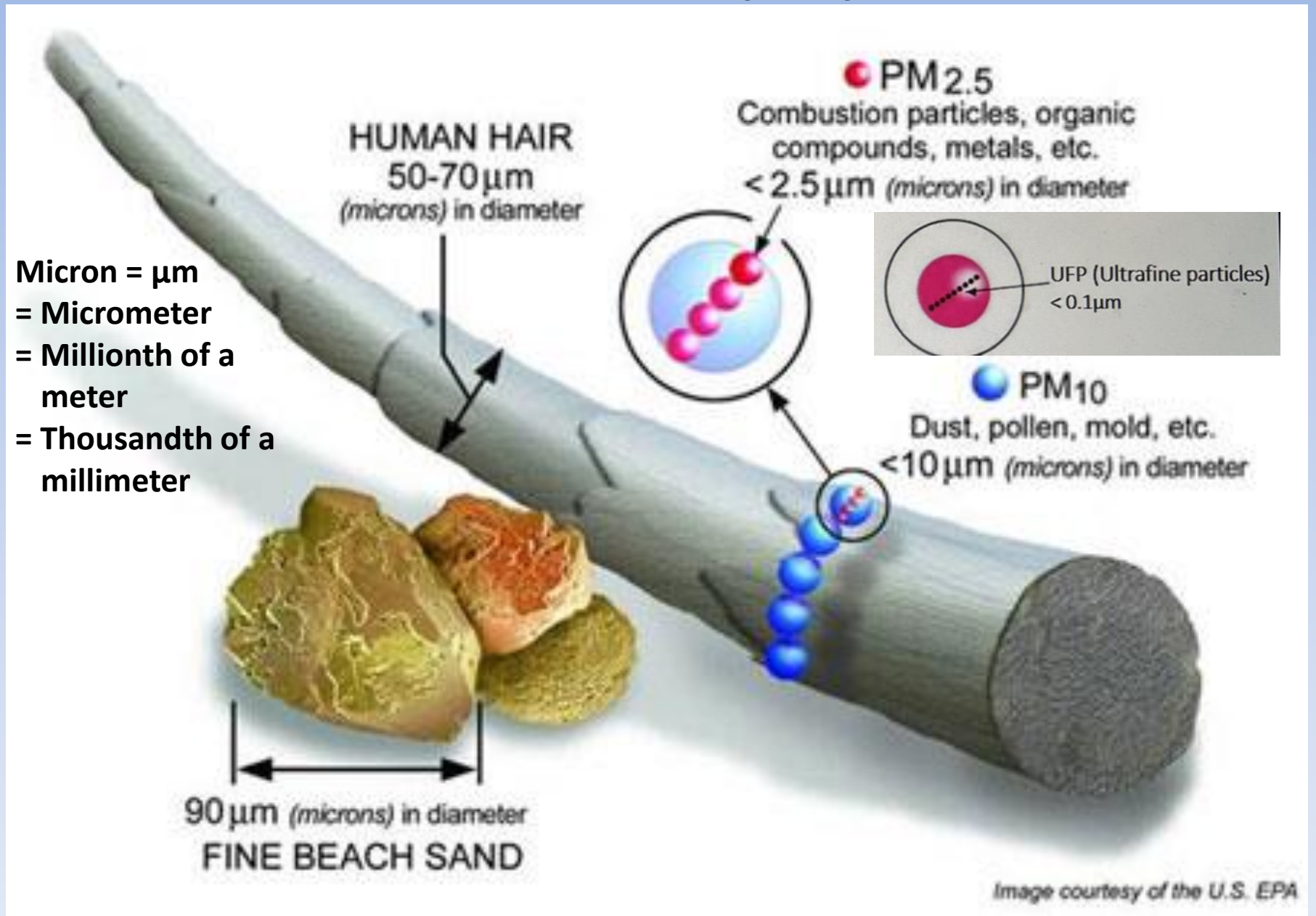
# Particles—Health Concerns

- Differ in toxicity
- Can have adverse synergy with other co-pollutants.
- Fine & ultrafine particles can be vehicles to increase exposure of toxic contaminants such as SVOCs & metals

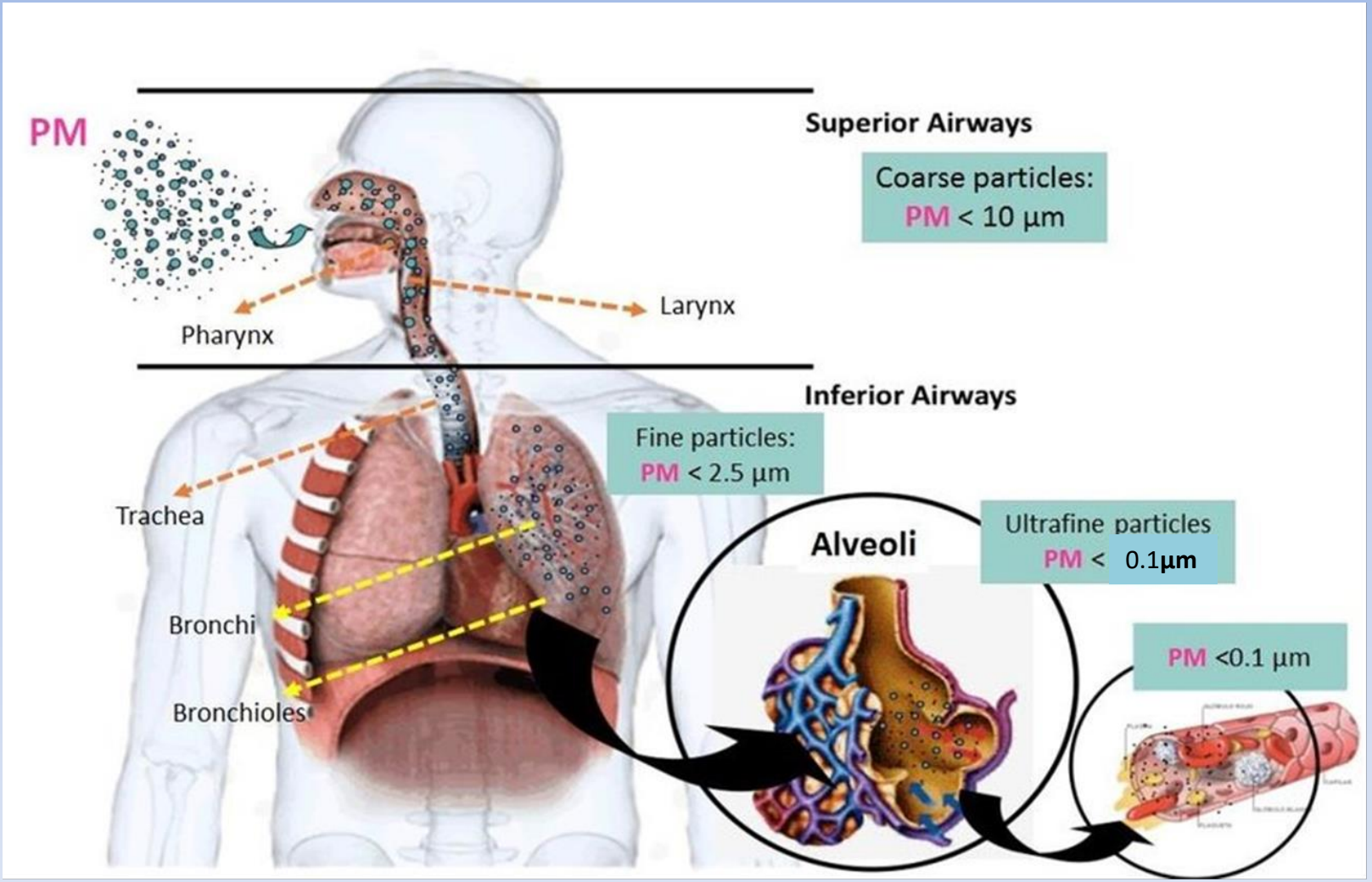
- ROCIS premise: “Precautionary principle” – avoid or minimize your exposure

# Particles – Particulate Matter (PM) – Size

**Micron = µm**
**= Micrometer**
**= Millionth of a meter**
**= Thousandth of a millimeter**

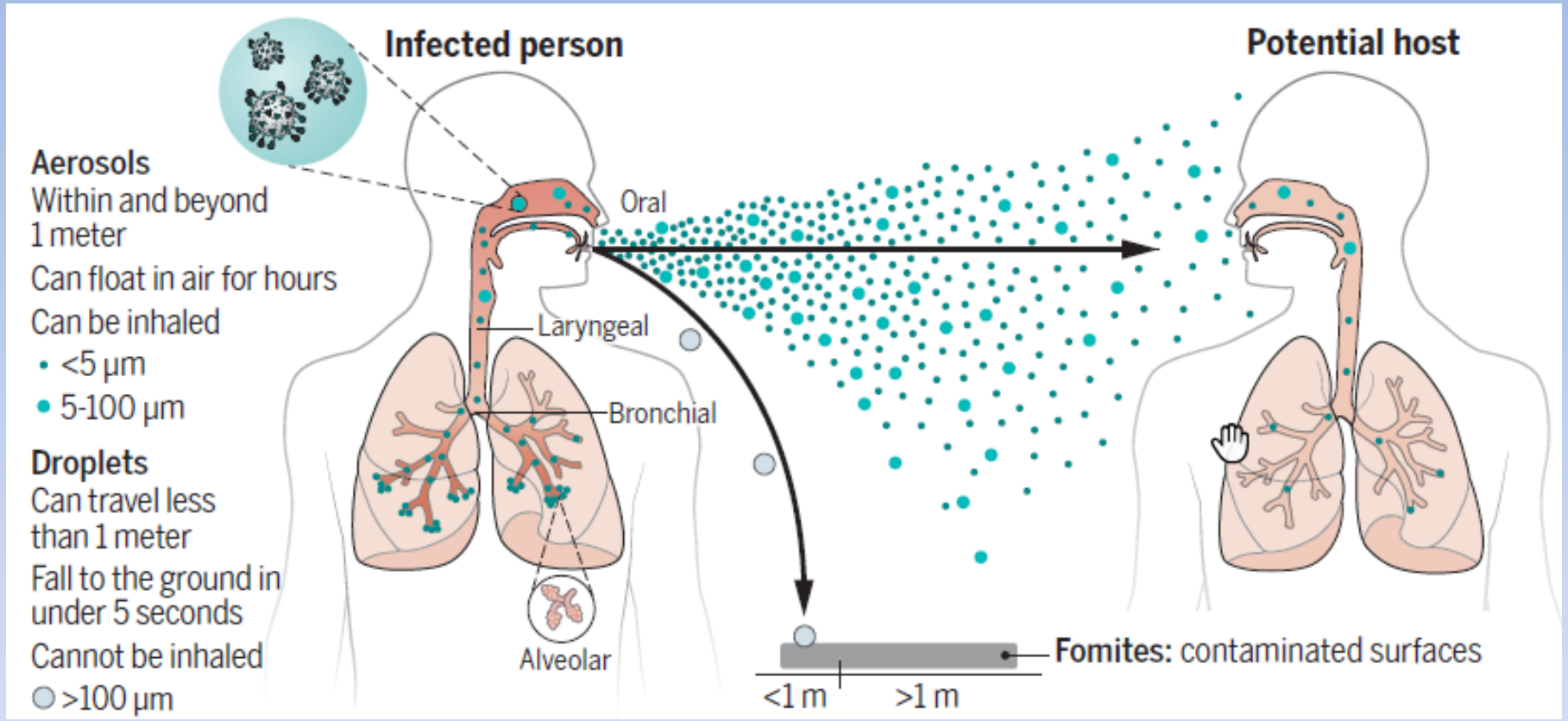


# Size Really Matters




From Castelo, Fiorella Barraza. *Human exposure assessment related to oil activities in Ecuador: from the air quality monitoring to the study of metallic contaminants transfer in the soil-plant continuum*. Diss. 2017.

# Aerosols vs Droplets




**Airborne Transmission of Respiratory Viruses**

http://science.sciencemag.org/ on August 27, 2021

See also from May, 2021
https://www.wired.com/story/the-teeny-tiny-scientific-screwup-that-helped-covid-kill/

# Health Concerns - ≤ PM2.5

## Established PM2.5-associated diseases:

cardiovascular disease, heart attack, stroke, asthma, COPD, lung cancer, silicosis, low birth weight, pre-term birth, dementia, premature death

## Recent associations with PM2.5 exposure include:

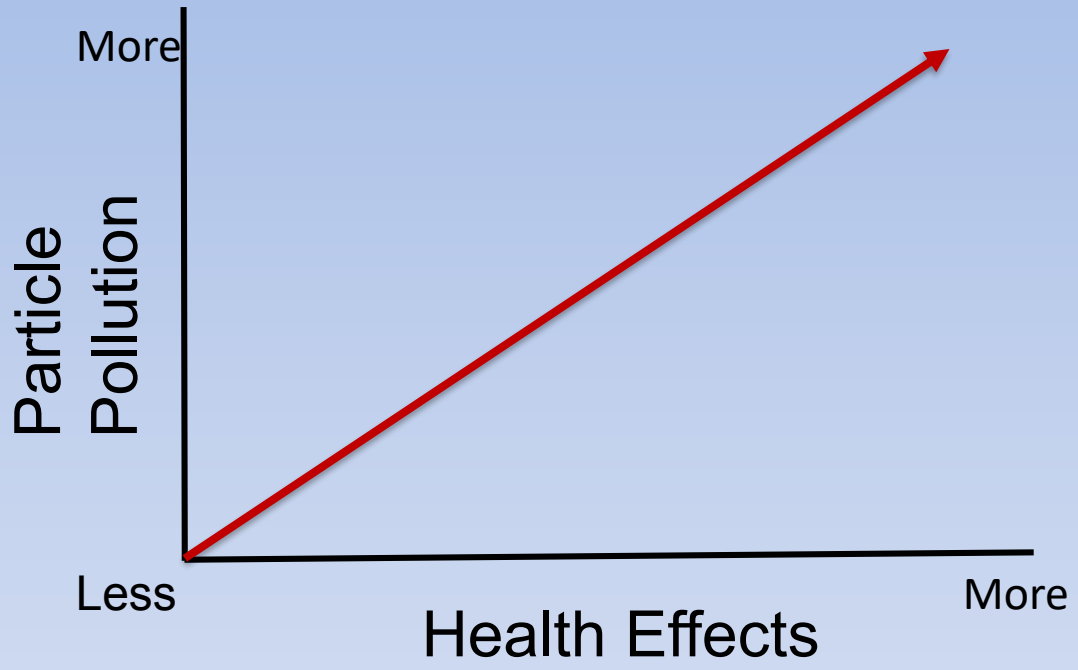
idiopathic pulmonary fibrosis, type 2 diabetes, kidney disease, hypertension, SIDS, fetal harm, autism, Alzheimer's disease, decreased cognitive function, poor sleep, allergies, learning difficulties, glaucoma

Loxham, M., & Nieuwenhuijsen, M. J. (2019). *Particle and fibre toxicology*

Survey of experts

ROCIS.org

# Concentration – Response Relationship




A clear **concentration-response relationship** between particle pollution & health effects has been established by scientific studies

Higher particle concentration is associated with increased impacts to health

https://www.epa.gov/pmcourse/particle-pollution-exposure

# What's New


ASHRAE PUBLISHES STANDARD 241, CONTROL OF INFECTIOUS AEROSOLS
A significant advancement in reducing the risk of disease transmission in buildings


NATIONAL ACADEMIES
Health Risks of Indoor Exposure to Fine Particulate Matter and Practical Mitigation Solutions
Consensus Study Report

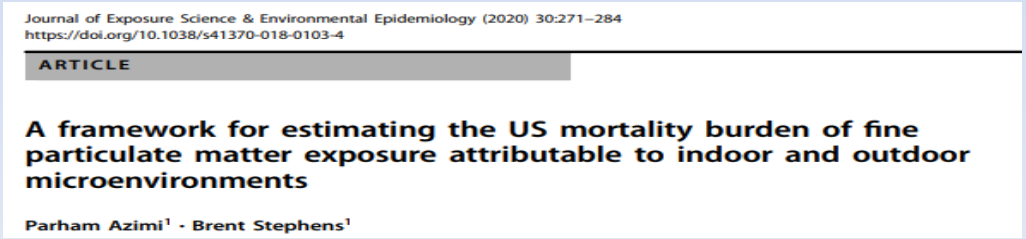

EPA
Final Rule to Strengthen the National Air Quality Health Standard for Particulate Matter
Fact Sheet
On February 7, 2024, the U.S. Environmental Protection Agency (EPA) announced a final rule to strengthen the nation's National Ambient Air Quality Standards (NAAQS) for fine particle pollution, also known as fine particulate matter ($PM_{2.5}$) or soot.
EPA is setting the level of the primary (health-based) annual $PM_{2.5}$ standard at 9.0 micrograms per cubic meter (µg/m3) to reflect new science on harms caused by particle pollution.

# Outdoor Particulate Matter & Human Health

- US mortality burden associated with total PM2.5 exposure in the year 2012 range from ~230,000 to ~300,000 deaths

- Indoor exposure to PM2.5 of outdoor origin is typically the largest total exposure, accounting for ~40–60% of total mortality

- This was followed by residential exposure to indoor PM2.5 sources


Journal of Exposure Science & Environmental Epidemiology (2020) 30:271–284
https://doi.org/10.1038/s41370-018-0103-4

ARTICLE

**A framework for estimating the US mortality burden of fine particulate matter exposure attributable to indoor and outdoor microenvironments**

Parham Azimi[1] · Brent Stephens[1]

# Low Cost Monitoring Project Design

## Not a Regulatory Focus

- **Measuring particle count, not mass**
- **1-minute resolution**
- **Real-time feedback**

# The Indoor/Outdoor Conundrum

~~**Outdoor vs. Indoor**~~

Outdoor Plus Indoor!

**A wholistic, comprehensive approach**

# Low Cost Monitoring Project Objectives

1. Learn how low-cost monitors empower occupants
2. Examine the impacts of outdoor on indoor air
3. Explore Interventions to improve indoor air quality
4. Develop champions!

# LCMP Cohort Tools

Participants borrow monitoring equipment to measure:

- Particles:
  Small/Total ≥ 0.5 µm
  Large ≥ 2.5 µm


- Carbon Dioxide (CO2)
- Temperature
- Relative Humidity


- Carbon Monoxide (CO)


- Radon

During the course of the 4-week cohort, participants:

- Learn from the ROCIS team
- Benefit from each other's experiences
- Receive weekly individualized feedback in response to their data, observations, & questions.

# Making Sense out of Millions of Data Points






CleanAirChronicles

From FaceBook *Andreas von der Heydt*, the VP of Chewy,
identified the difference between Raw Data and the Stories Data can tell.

# Caution!

## Good Readings

## ≠

## Good Indoor Air Quality

**Know the limitations of our particle monitoring.**

**What we cannot easily monitor could be important!**

# Ongoing Monitoring – Many Options

AirThings View Plus



**PA Zen**

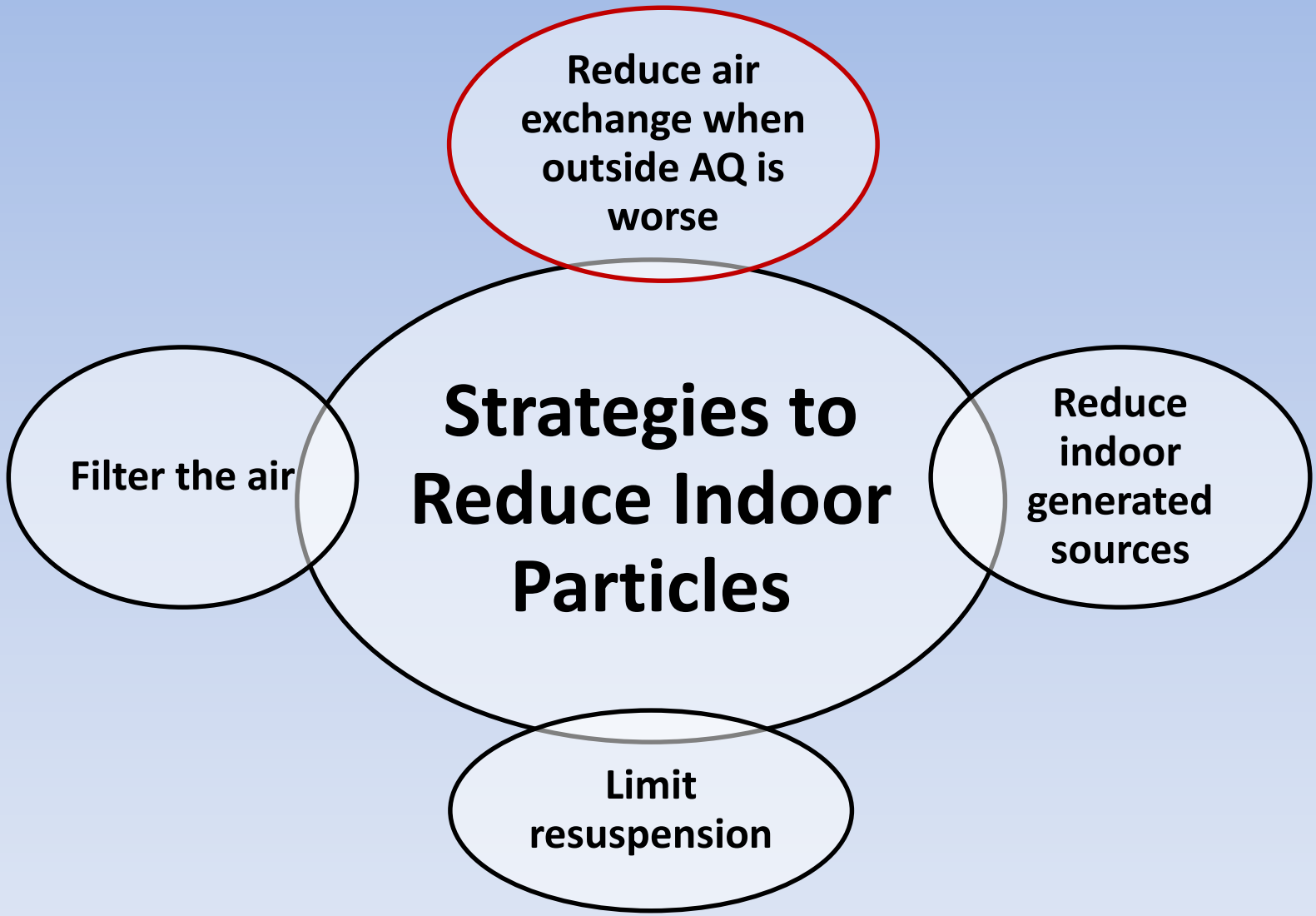
- Indoor or Outdoor
- Linked to map
- Particles
- TVOCS
- Temp & RH

**AirThings ViewPlus & Awair**

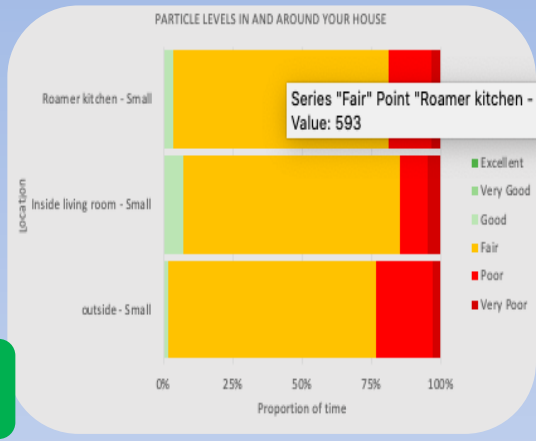
- PM2.5
- TVOCs (total volatile organic compounds)
- CO2
- Humidity
- Temperature
- Radon (AirThings VP)

PurpleAir Zen

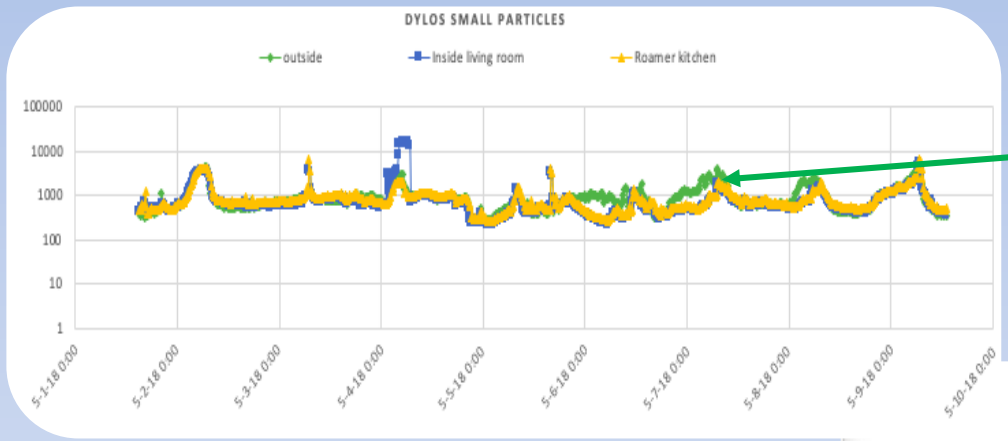
# Strategies to Reduce Indoor Particles



# Reduce Outdoor Air Exchange When Particle Count is High

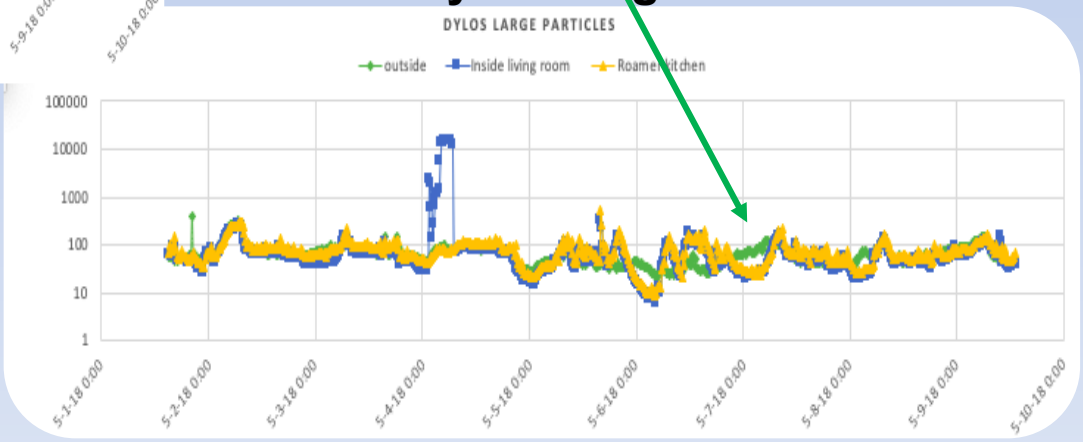



## Dylos Total




Outdoor

## Dylos Large

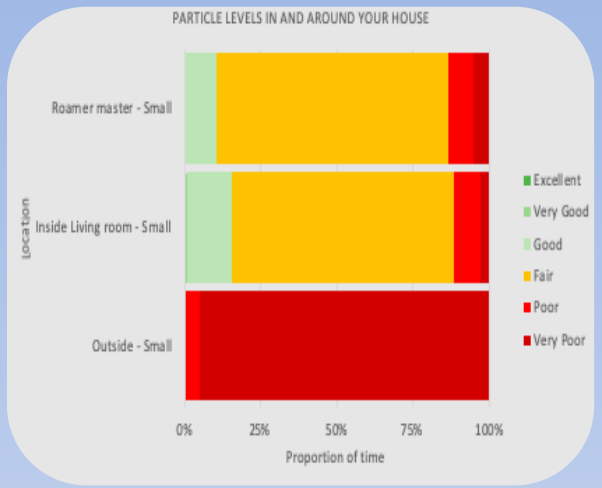


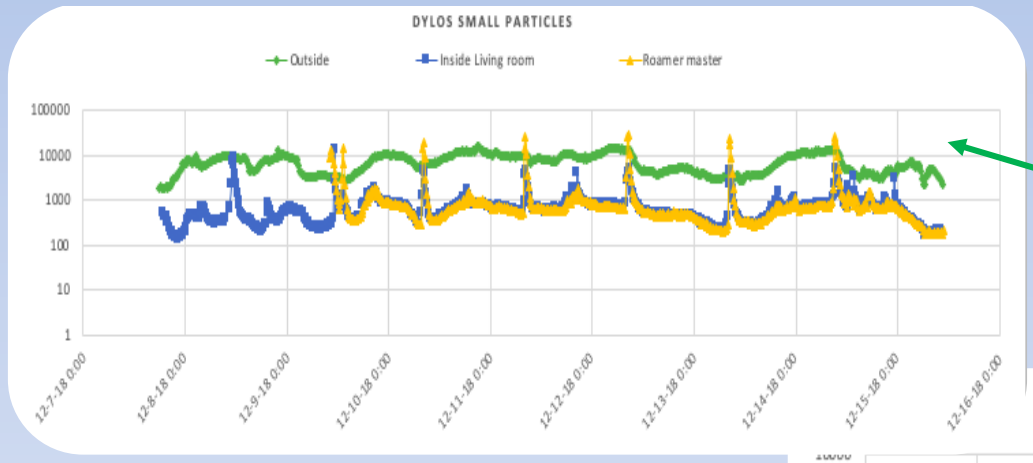

House with Wide Open Windows

Green (O), Blue (I), Yellow (R)

# Windows Closed

## 1941 House in Winter with High Outside Particle Counts

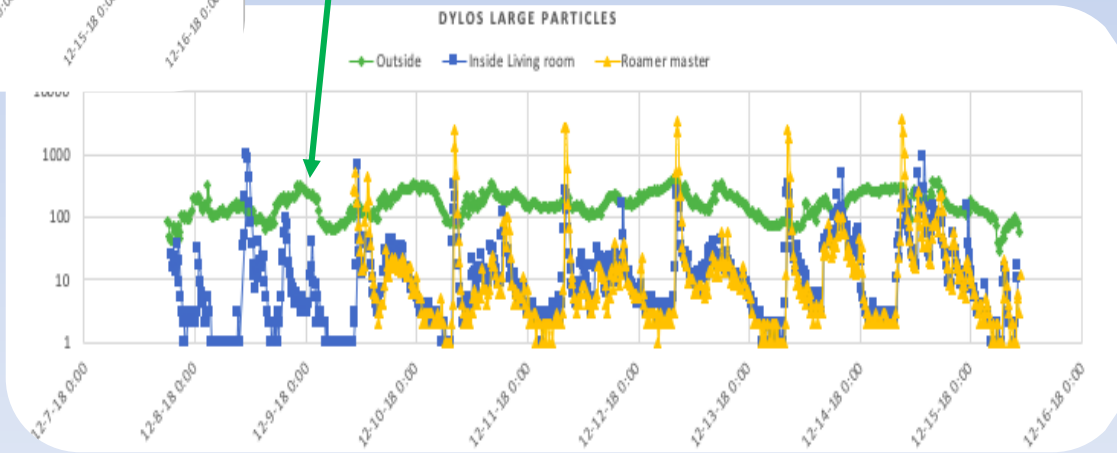



**Dylos Total**

Outdoor

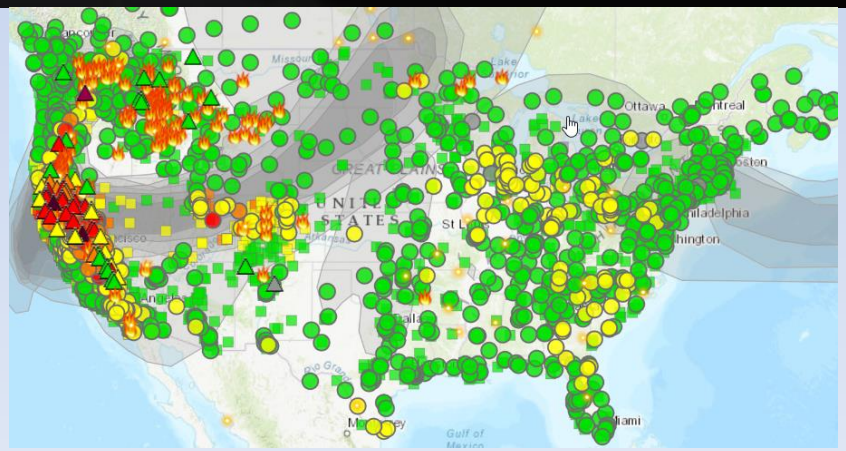
**Dylos Large**



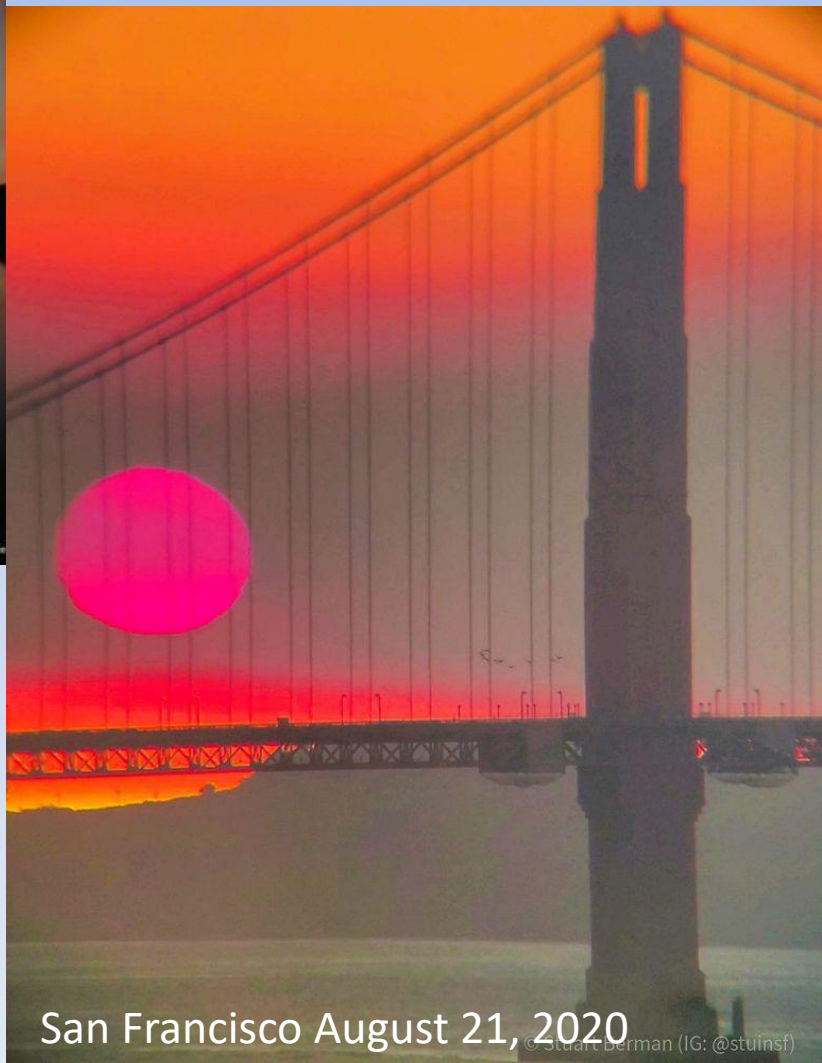

Green (O), Blue (I), Yellow (R)

# Outdoor Air Quality –
## Coal Plants & Wildfires


https://www.youtube.com/watch?v=9f-eDKEC14A



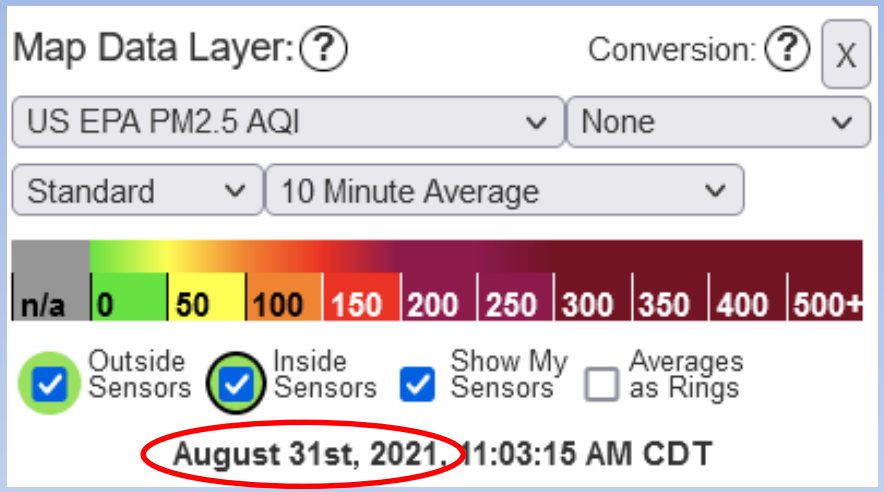
https://fire.airnow.gov/

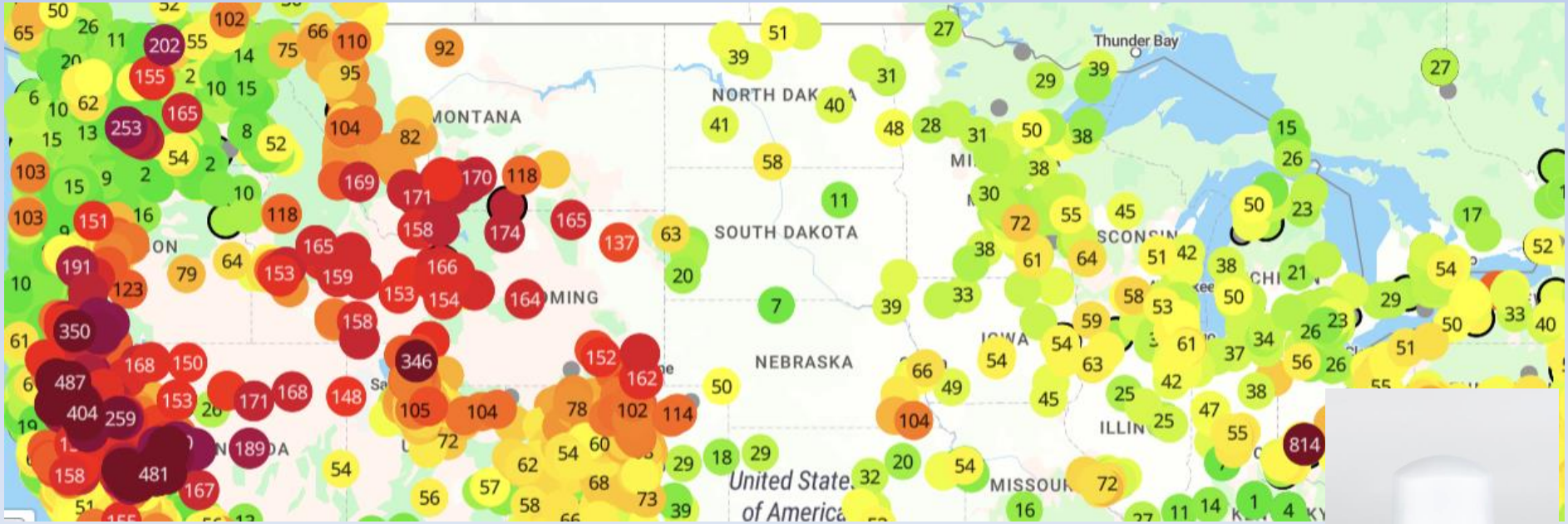


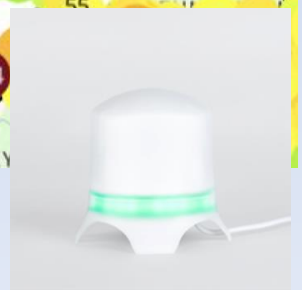
San Francisco August 21, 2020

# Current Ambient Air: Purple Air

- Global monitor network
- Real time & historic
- Reports from individually owned monitors with wi-fi connectivity
- Indoor & outdoor data
  - PM2.5, Temperature, RH
- Feeds AirNow Wildfire & Smoke website



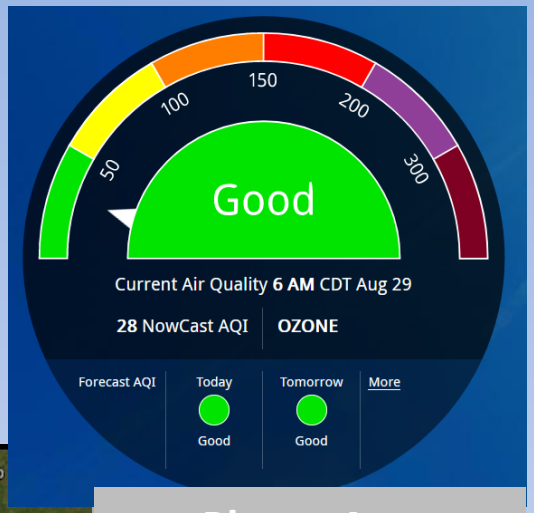



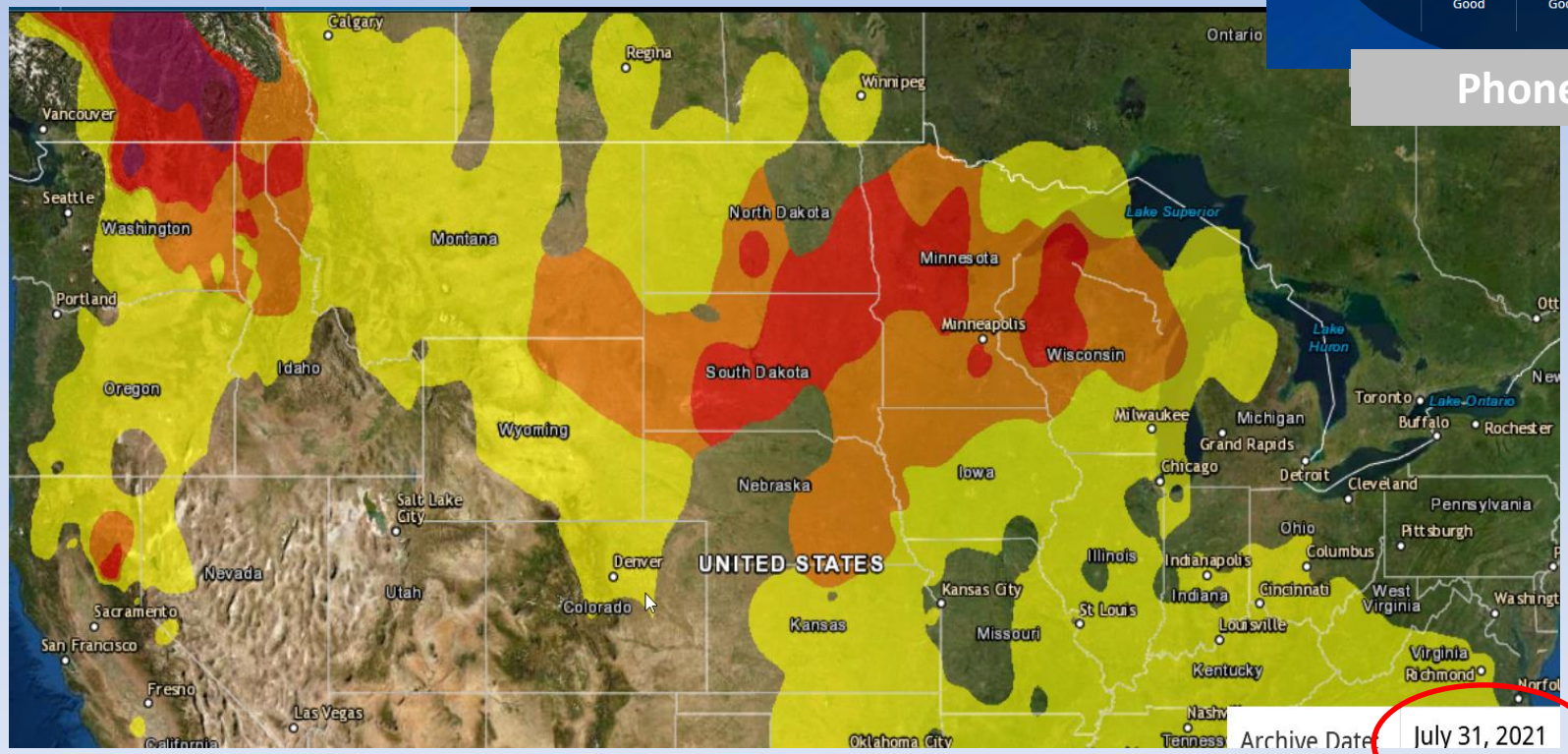
www.purpleair.com/map

# EPA AirNow

- National monitor network
- Real time & historic data
- Ozone and/or PM2.5 display




Phone App

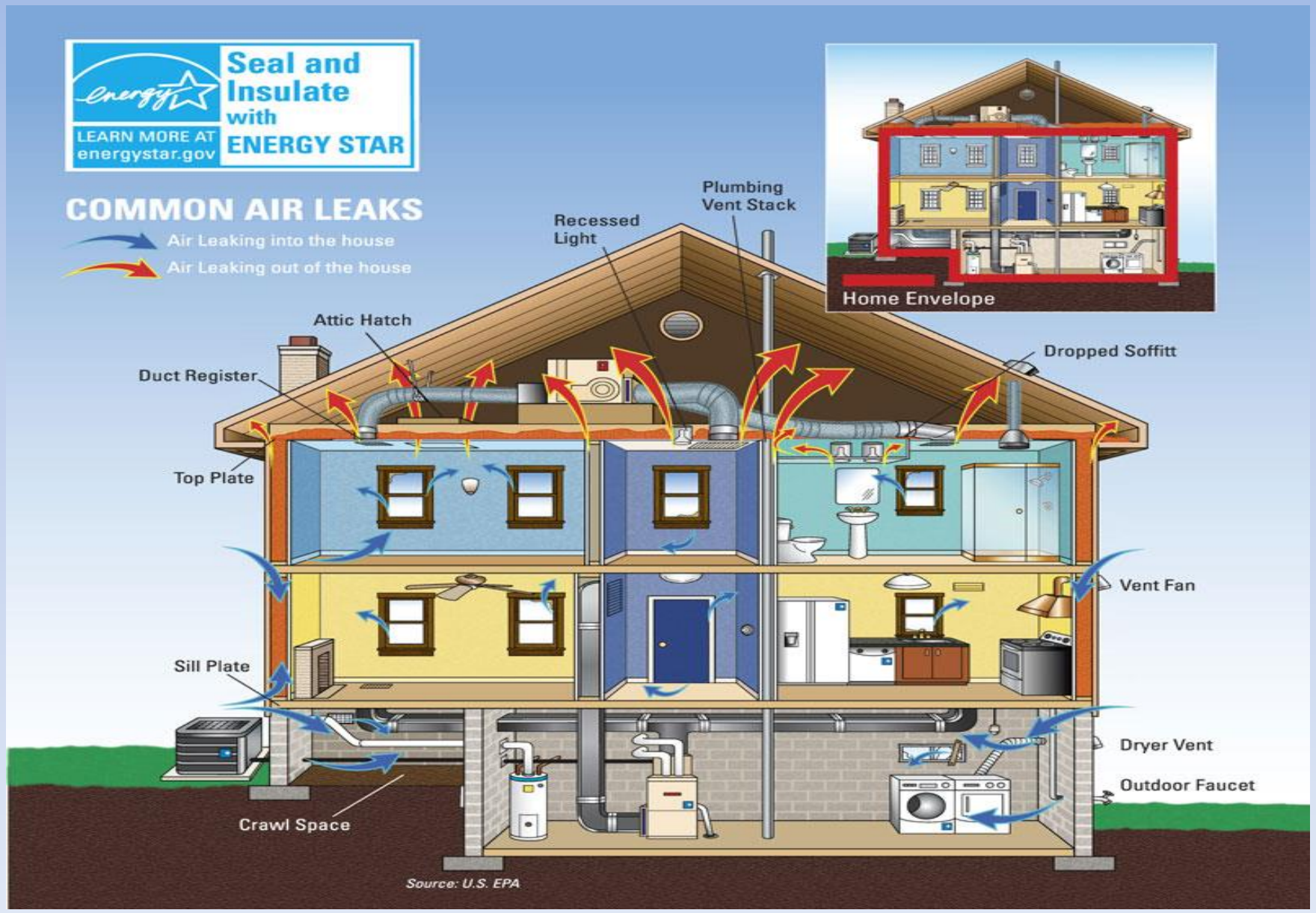



**U.S. Air Quality Index** https://gispub.epa.gov/airnow/

# Window Operation

- Single biggest factor affecting IAQ when outdoor counts are high
- Most contentious!!
- Poor air quality usually not perceptible
- Balancing passive cooling, preferences, dilution of indoor pollutants, ventilation
- Implications – social justice, heat stress (no AC)

# Control Airleakage



# Kevin & Dara's Home

Saint Paul, MN 1927 Stucco 2 Walk-in attics R-11 Balloon walls R-4
1942 sf 2960 CFM50 ~7 air changes/hour = Comfort & IAQ Concerns

- 2nd Floor warmest in winter & summer
- Drafty & snow melted fast
- High utility bills

and

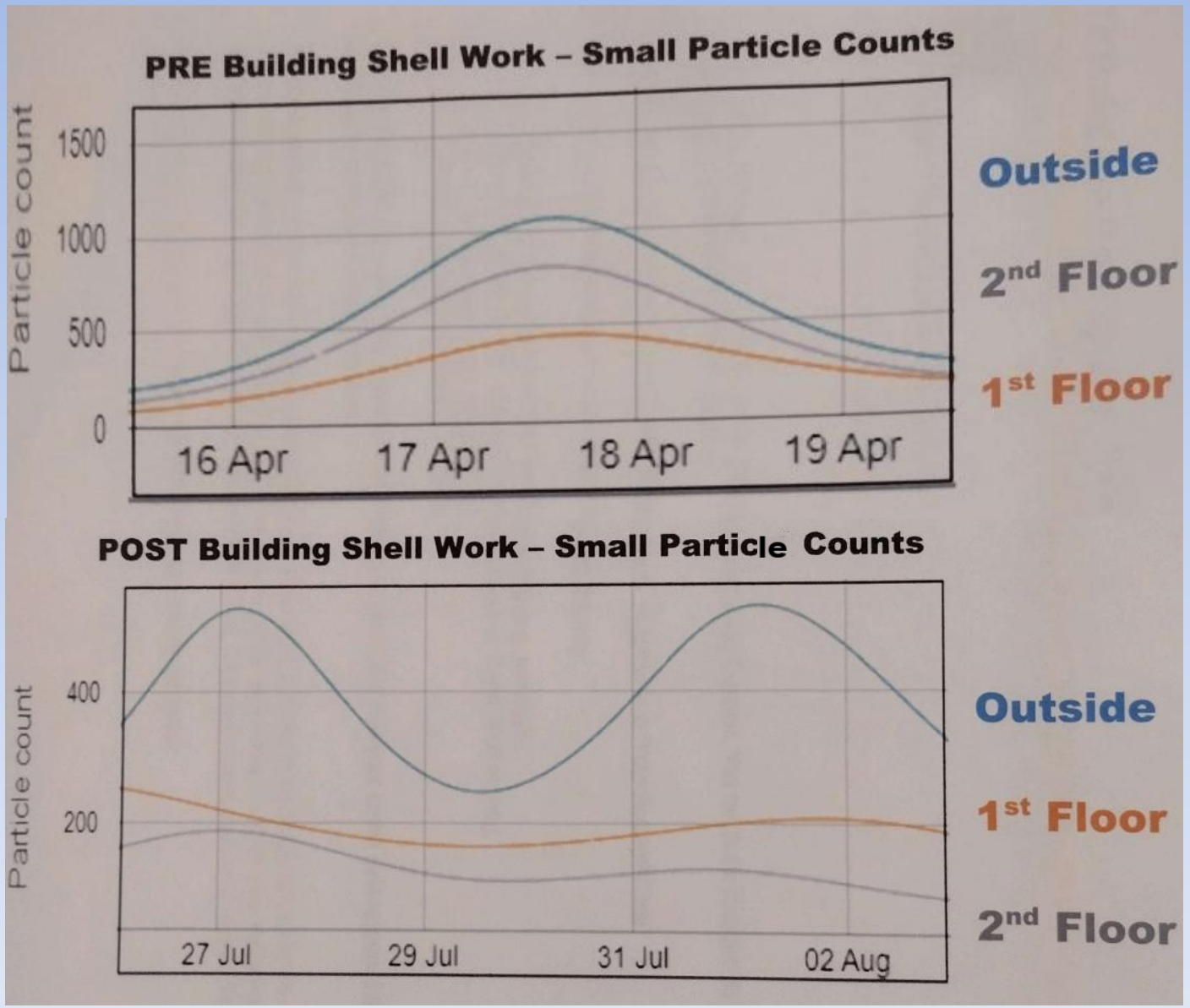
- 2nd floor PM2.5 always showed higher particle count than 1st floor
- 2nd floor PM2.5 particle count closely tracked outside PM2.5 levels

# Kevin & Dara's Home

Pre: **2960** CFM50. Post: **1650** CFM50 = **44% less**

**Pre WX**
Particle trends indicate house well connected to the outside

**Post WX**
Particle trends indicate house less connected to the outside



# Dara & Kevin's Air Seal & Insulation Work

44% reduction in CFM50 equals

- More comfort
- Lower utility bills
- Smaller HVAC load, smart Tstat shows downsize oppt'y
- Increased resilience in extreme weather

~50% reduction of outdoor small particles inside

- Reduced outside particle load = healthier home

Shell work can deliver more than is seen

# Prime Home Performance Opportunities

## Optimize Work You Already Do

- Source Issues
- Job Site Controls
- Potential Benefits
- Behavioral Change

# An Ounce of Particle Prevention…

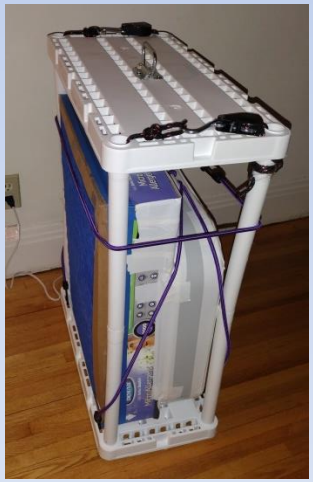
- "Our attic access is in a closet. I'd never seen 'zip poles.' The contractor left our clothes in the closet and used zip poles to hang plastic everywhere. All kept clean!"
- "The contractor taped cardboard to my steps and everything stayed clean."

# … Is Worth a Pound of Cash Cure

- "We complained when the contractor insulating our attic filled our basement clothes closet with cellulose. They payed for all our dry cleaning."
- "When the cellulose got into our high-end electronic components, they all had to be replaced and the contractor paid for it."

# An Ounce of Particle Prevention…

**Small foot print job site fans:**

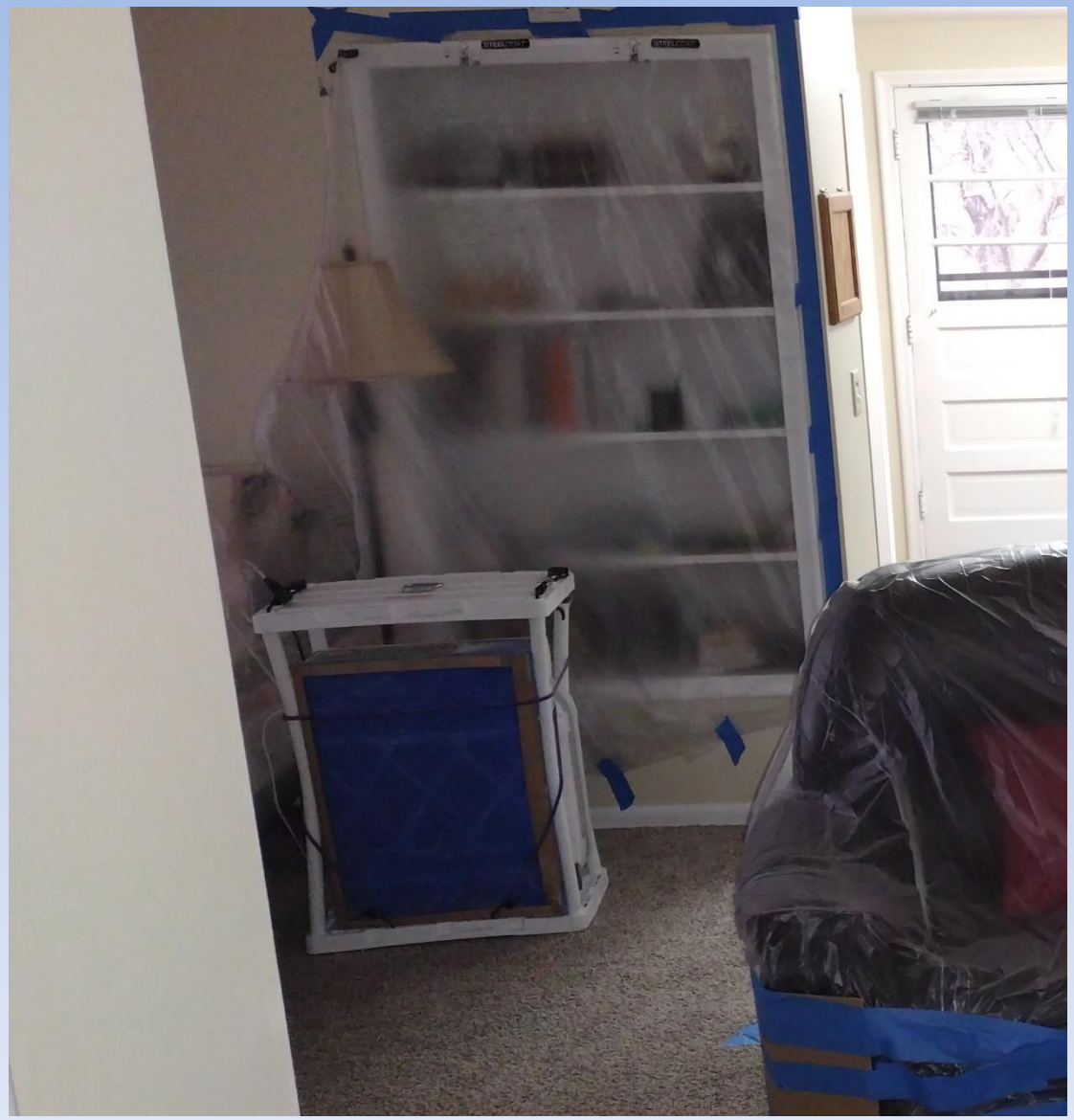



**~300 CFM**

Stable 20”x20” box fan, 4” 25x20 MERV13 +
1” MERV2 bungeed in a lightweight frame

10” desk fan, 1” x14”x25”
MERV13 (3M Filtrete)

# An Ounce of Particle Prevention…

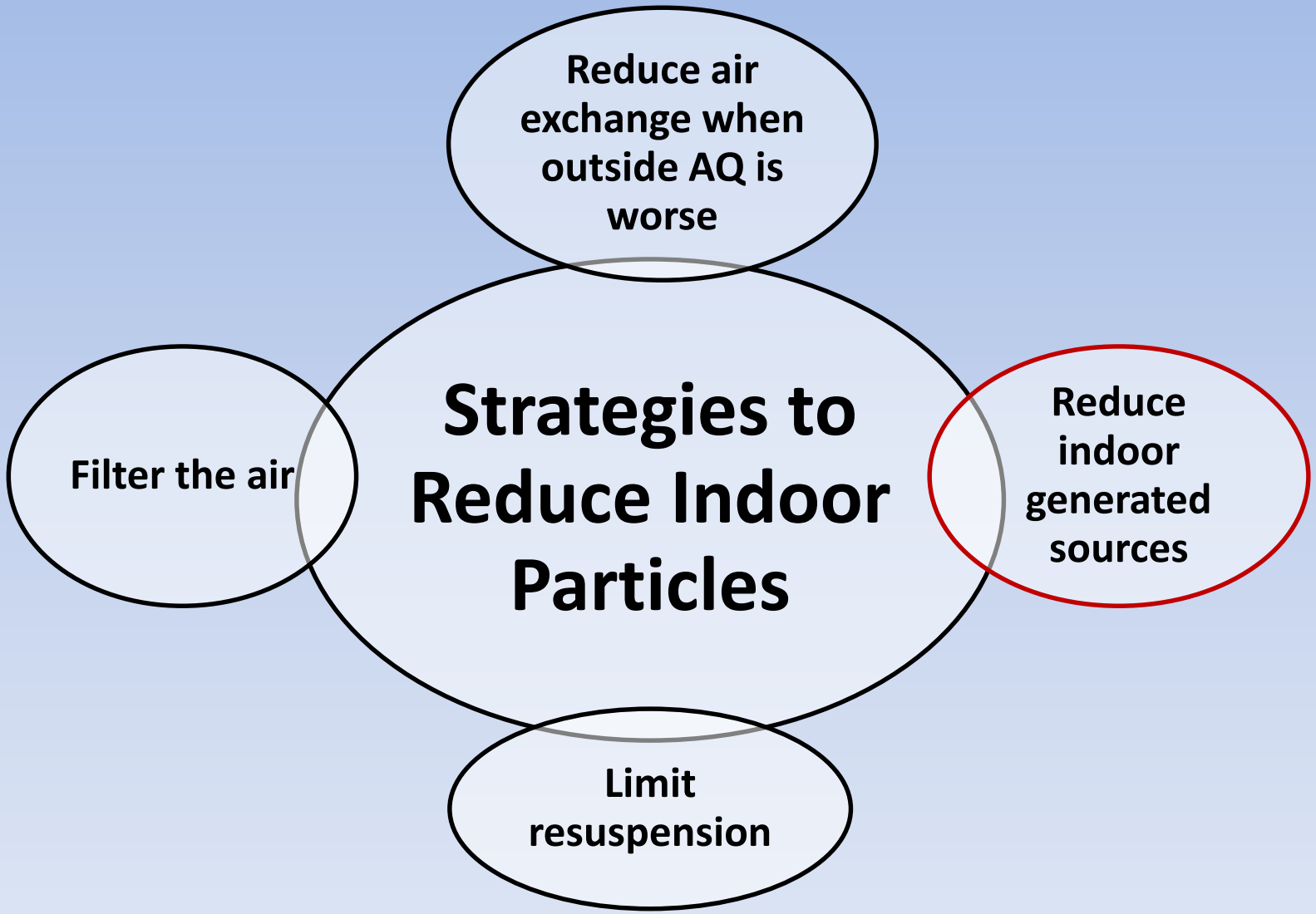


# What Might You Add To Your Toolbox?

More Listening Than Talking

- Expand initial interview
  - What comfort concerns do you have?
  - What, if any, moisture problems do you have?
  - What kinds of issues does anyone have relating to asthma or health?
  - Where and when do comfort or health issues show up?
- Be proactive with presentation & prep
- Protect with drop cloths, zip poles, poly, cardboard, tape…
- Leave site as clean as found or better--free of dust
- Provide resources & follow-up that fits the family
- Run Filter Fans during work
- Consider offering assessments to upgrade HVAC filtration

# Strategies to Reduce Indoor Particles



# Manage Cooking Emissions

**Use *EFFECTIVE* ducted kitchen range hood**

## Key Issues for Range Hoods

- Ducted to outdoors
- Noise
- Complete coverage over cooking surface
- Height above cooking surface ~32”
- No backdraftng of other appliances
- Operations – 15 minutes pre & post cooking

Kevin Brauer

## Check out ROCIS ISSUE BRIEF

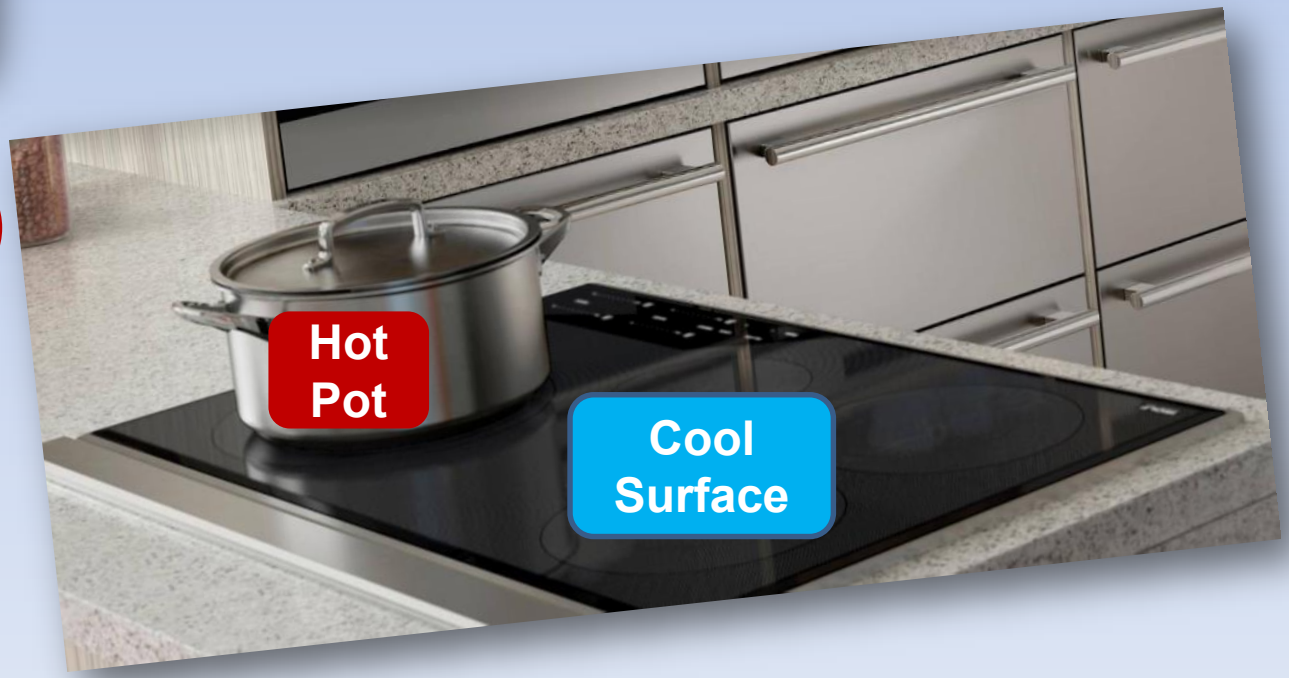
- *Ducted Range Hoods: Recommendations for New and Existing Homes*

http://rocis.org/kitchen-range-hoods

# Take Combustion Out of the Kitchen


**Dangerous Byproducts of Combustion** include Water vapor, CO, NOx, SO2, soot, benzene, polycyclic aromatic hydrocabons (PAH) & PM2.5

**Induction Cooktops & Burners**



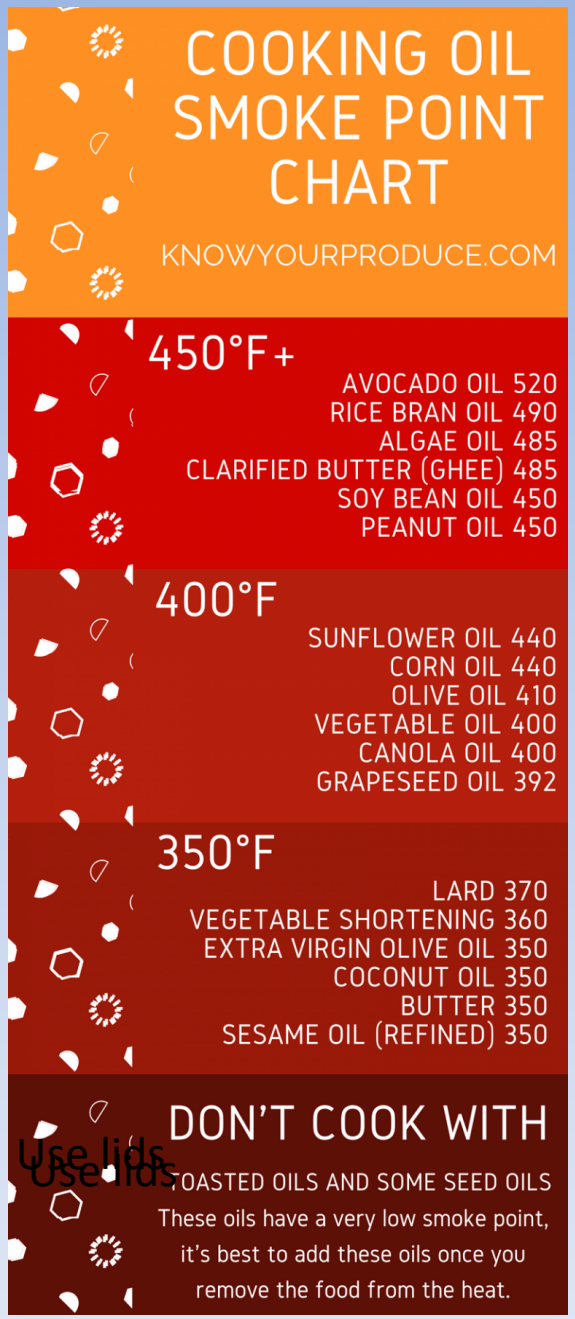

**Issues**

- Cookware
- Cost
- Change

# Other Cooking Considerations

**To manage PM2.5 during cooking:**

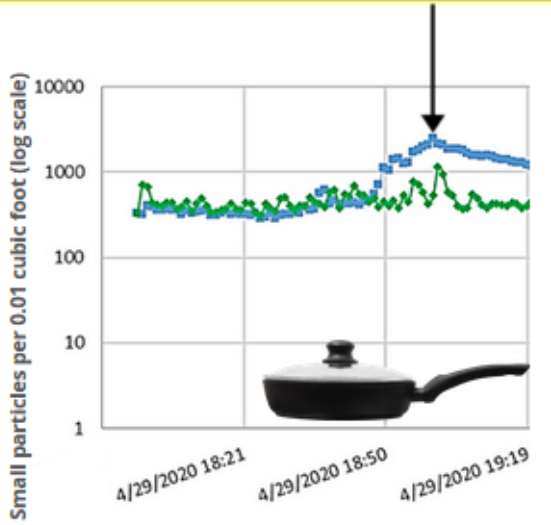
- Use the (effective) range hood
- Adjust cooking style
  - Heat: high & fast vs low & slow
  - Add salt & pepper before heating oil
  - Smoke point of various oils vs. butter
  - Use lids



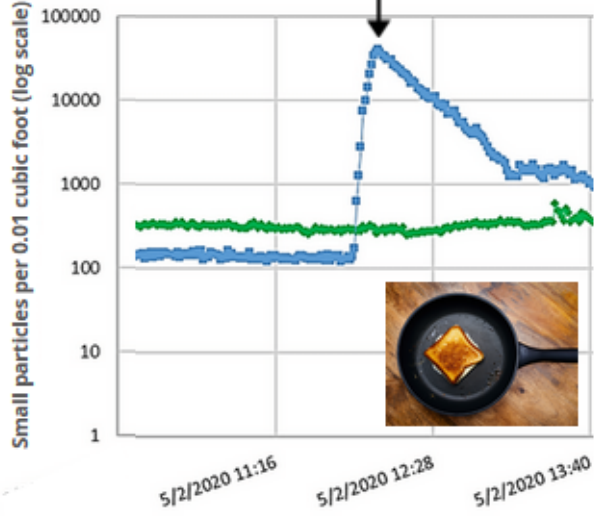

Use lids

# Data re: Using Lids When Cooking

**Indoor particles peaked at 2,500 with a grilled cheese sandwhich in a covered pan**




**Indoor particles peaked at 40,750 with a grilled cheese sandwhich in an uncovered pan**



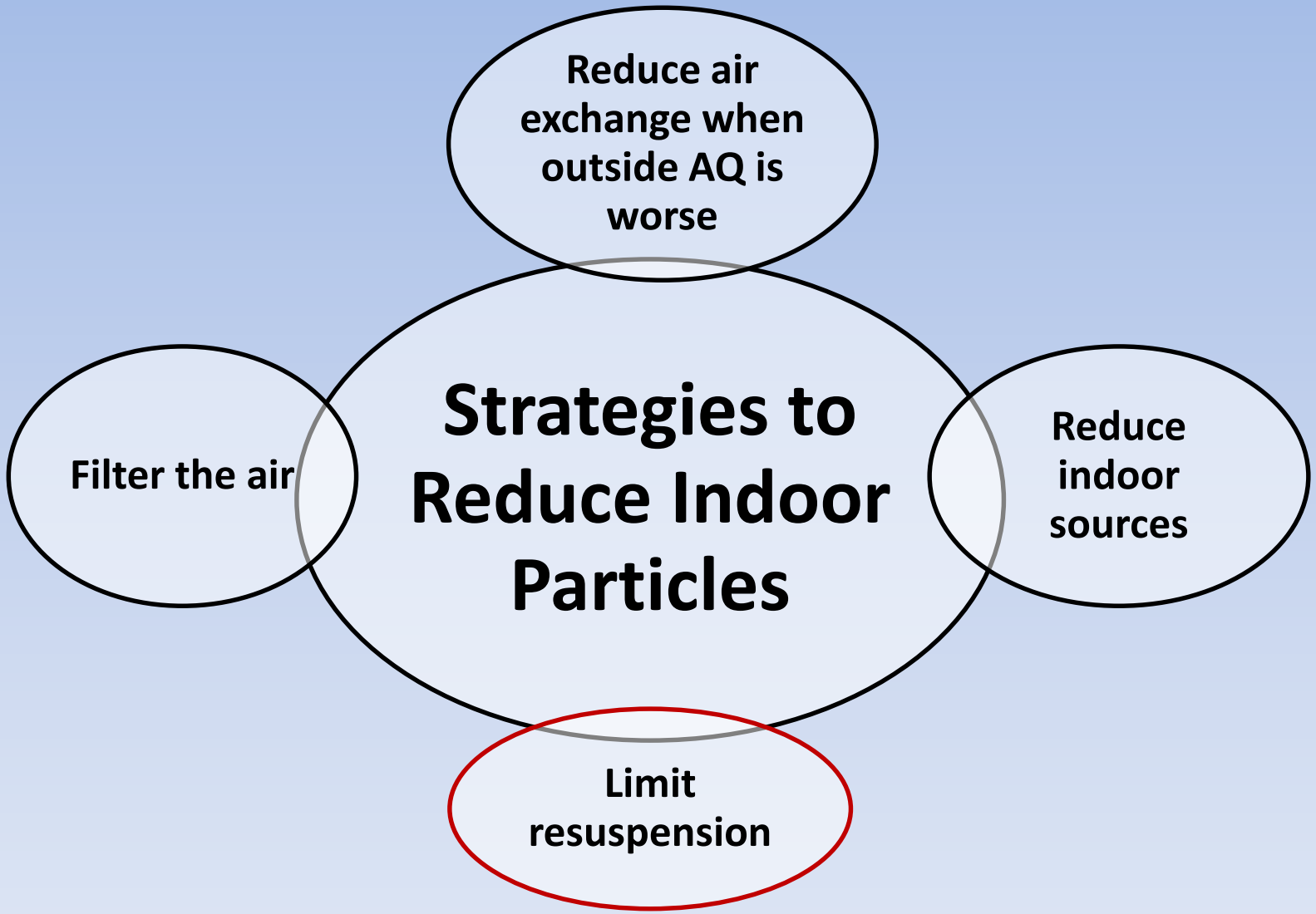

*"After reflecting on both of these cooking experiences and looking at the data for particle counts, it seems that covering the cooking surface may make a bigger difference in keeping particles from escaping into the indoor environment than some of the other actions. I recognize the importance of these behavior changes more than before and will consciously try to use them moving forward."* - ROCIS participant Sara

# Other Indoor Sources

- Wood stoves
- Humidifier using tap, not *distilled* water
- Showers – high humidity
- Cleaning products
- Recreational combustion
  - Candles, incense, diffusers
  - Cigarettes, vaping…

https://bluehouseenergy.com/blogs/bhe-blog/adventures-with-monitors-humidifiers-and-filters

# Strategies to Reduce Indoor Particles



# Clean it Safely or Don't Disturb it

Many particle spikes from activity are re-suspended – not generated

- Bedding, pillows, fabrics
- Laundry - dryer no heat
- Carpet
- Hard surface floor
- Couch - Upholstery
- Remodeling (attics, building cavities)

**What is the Original Source?**

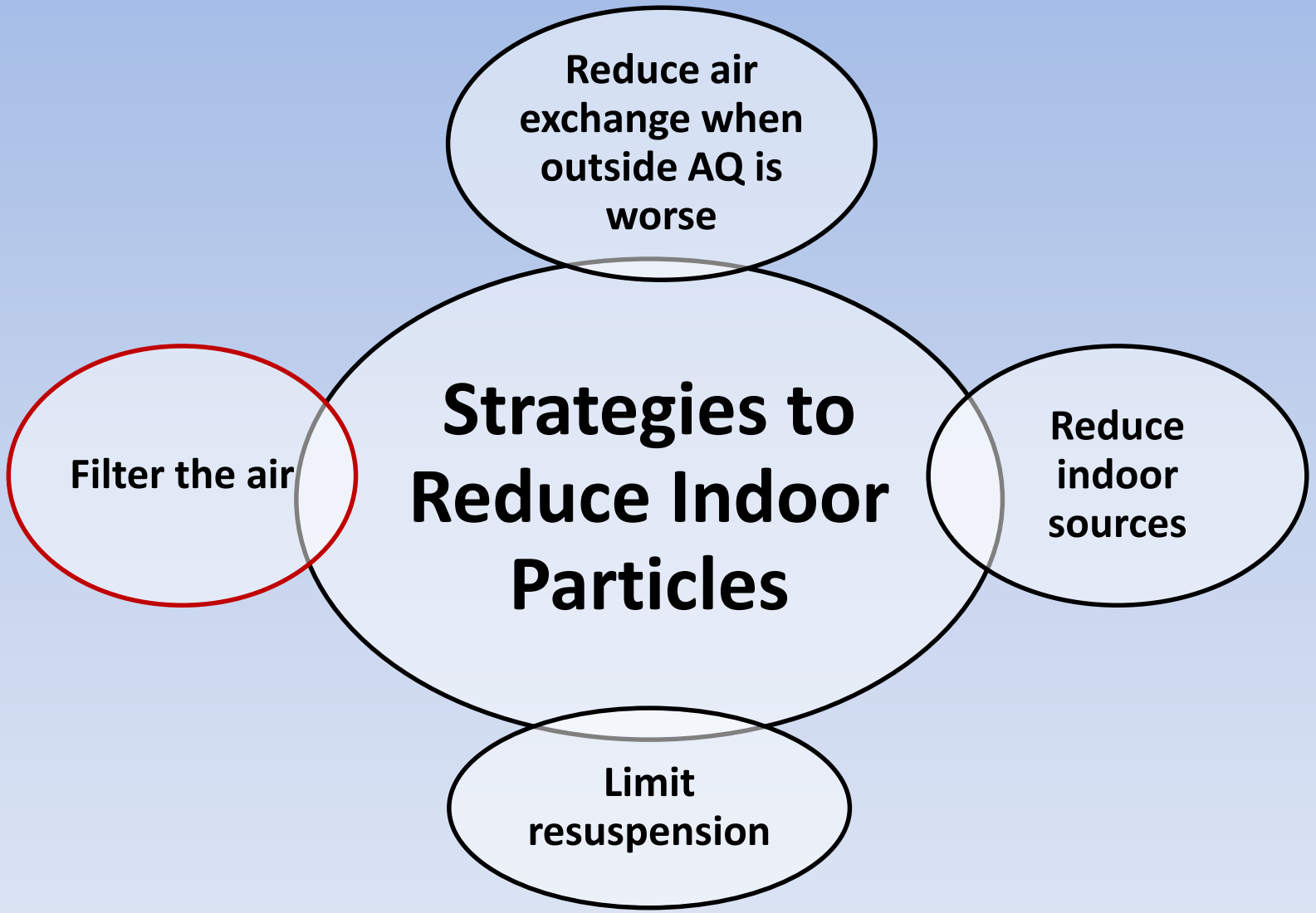
- **Emissions from 50 years ago**
- **Residue from remodeling**
- **Particles from open windows**
- **Tracked in lead dust**

# Limit Contamination & Resuspension

- Walk-off mats
- Take off shoes
- HEPA vacuum
- Thoroughly clean hard surfaces
- Get rid of carpets, old upholstered furniture

Rana Belshe

# Strategies to Reduce Indoor Particles



# Filter the Air

- Portable air cleaners
- DIY Fan Filters
- Central air handler (furnace, AC, or ventilation)

**Filtration only works when the unit is ON!**

# Portable Air Cleaners (PAC)

also referred to as Air Purifiers

- Designed to treat one room or zone
- Primarily reduce particles
- Some models offer added reduction of pollutants / odors – carbon filter
- HEPA (not HEPA-like)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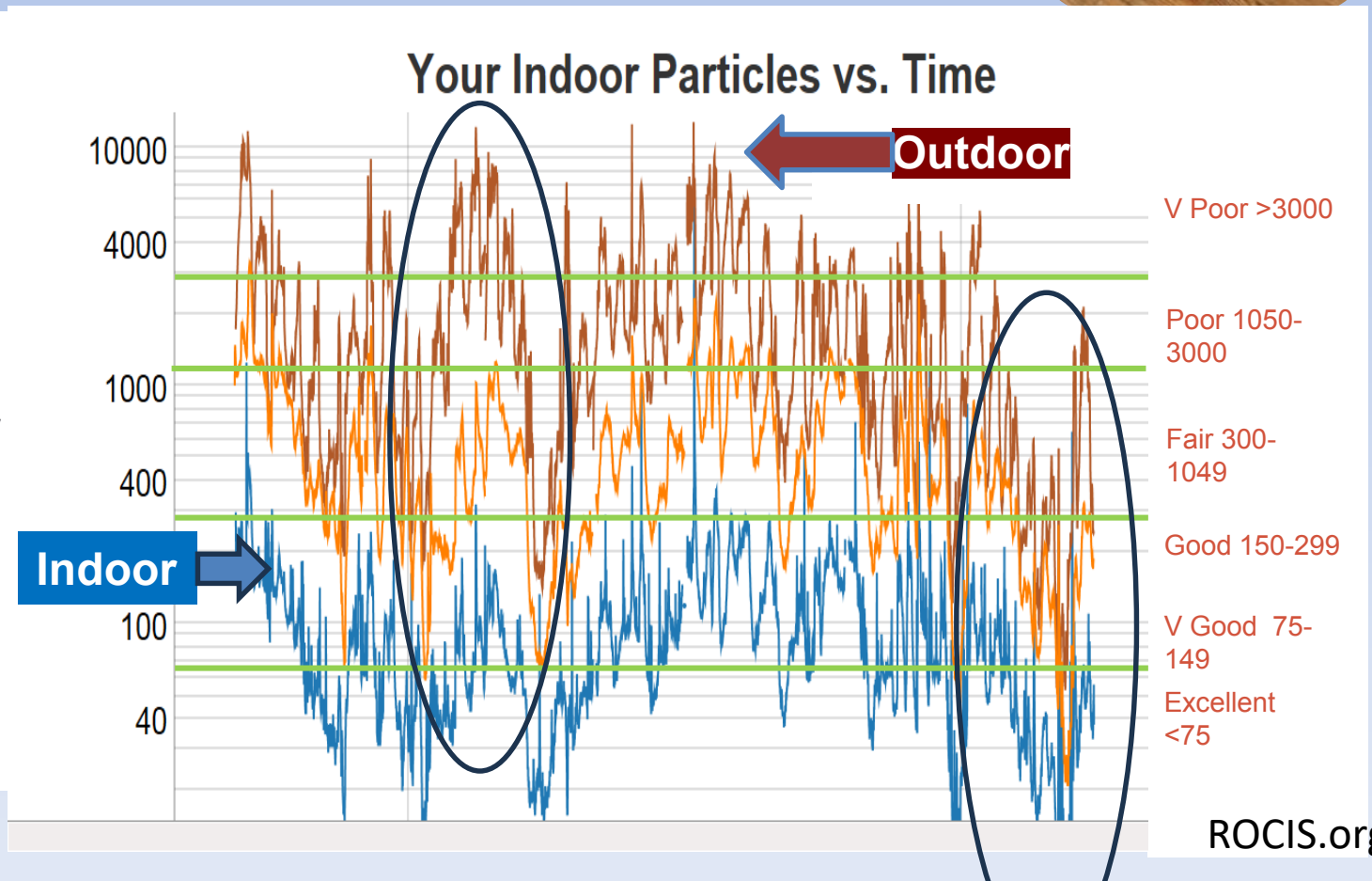
# Impact of Portable Air Cleaner

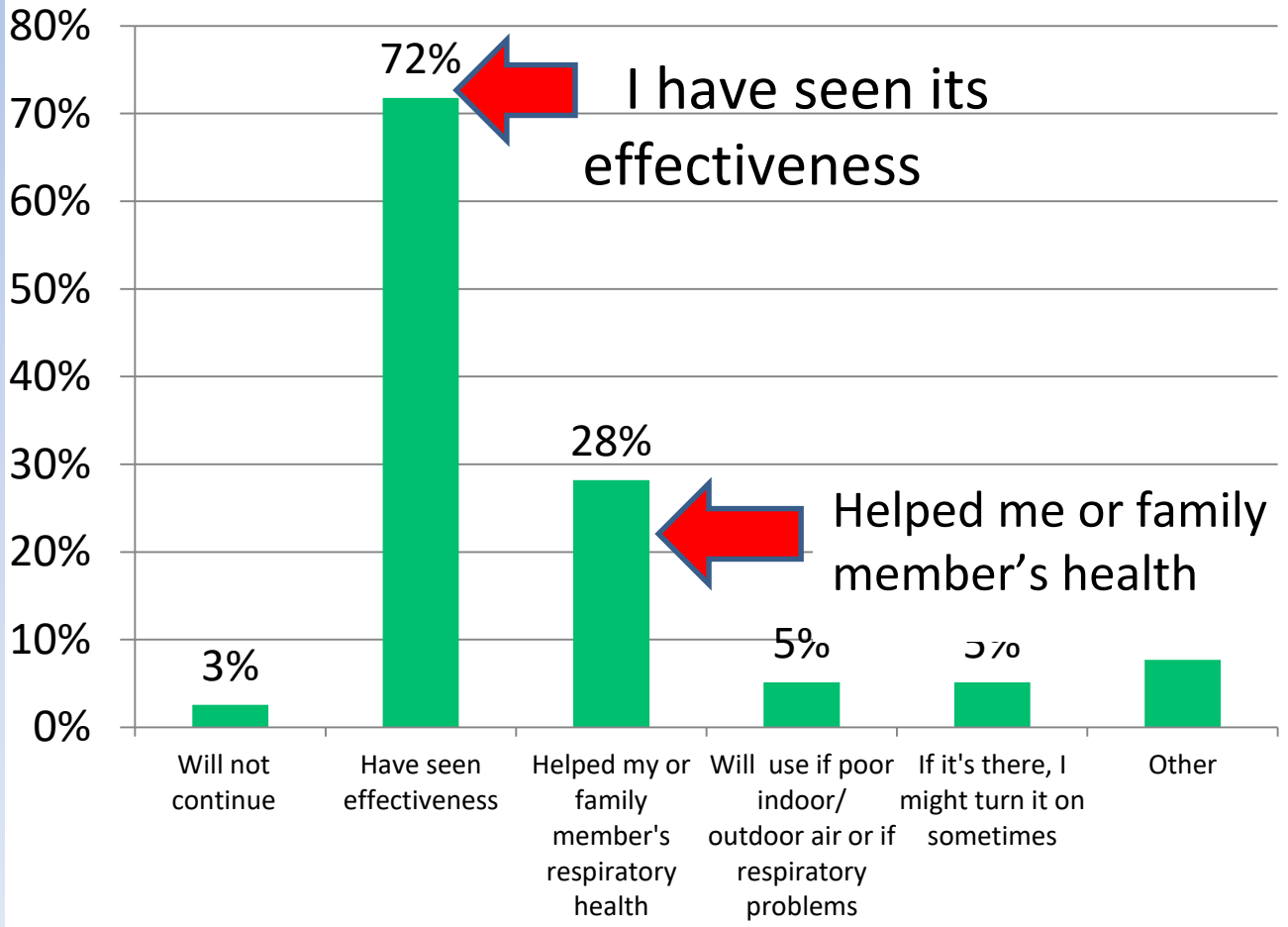
http://rocis.org/rocis-data-explorer (j1t8)
0.5+ µm Particles by Time (15-min. avg.)

Blue: treated zone with 24/7 air cleaner
Orange: untreated zone
Brown: outdoors

Tight, single family home
Though order of magnitude lower; Indoor (Blue/orange) tracks Outdoor



# Why Continue to Use an Air Cleaner or Fan/Filter?



# Guidelines for Selection

## Big Enough: Clean Air Delivery Rate (CADR)

*(Industry standard for capacity of PACs)*

Factors Affecting Ability to Effectively Treat Area

- Volume
- Distribution of filtered air
- Leakiness (Openness to other areas or outside)
- Pollutant Load
- Air Cleaner (actual air flow (CFM ) at the setting)

## Cautions: Do not “kill”, rather “capture”

"Avoid ion generators & plasma air cleaners, which can emit ozone, a respiratory hazard that can cause serious health problems.

And, avoid air cleaners with photocatalytic oxidation (PCO).

PCO air cleaners have been shown to generate formaldehyde, acetaldehyde, nitrogen dioxide, & carbon monoxide.”

*J* *Jeff Siegel, U of Toronto*

# Importance of Feedback & Behavior

1) Strategies: How to Keep Air Cleaners on
   (Many are personal preference, not necessarily good or bad: consider sound, energy use, filter change-out frequency, comfort)

2) New Equipment Features Offered (not necessarily recommended)
   - Air quality sensor (sometimes with color indicator)
   - Auto boost when spike is sensed
   - Timer

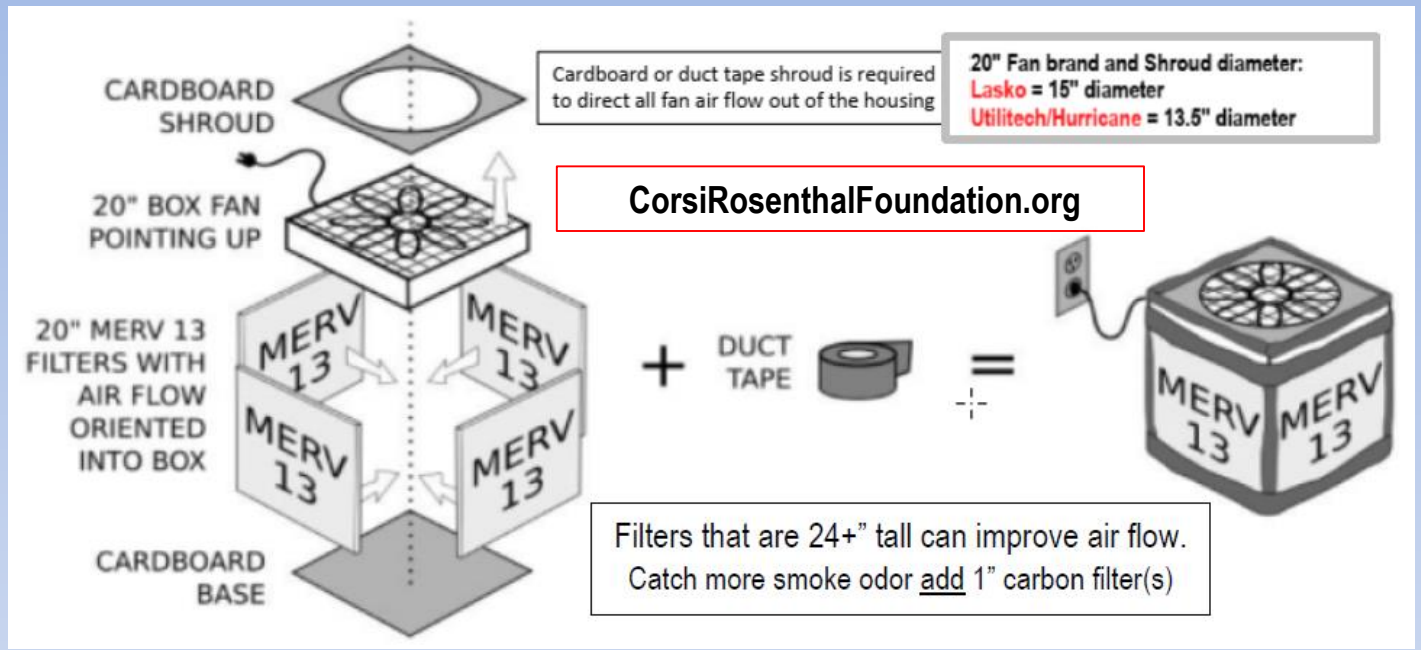
# DIY Fan/Filter Intervention: Low Cost, MERV 13

- 4” MERV 13 filter ($50) on 20” x 20” box fan (~$20)
  - UL-rated with overheat protection – newer than 2012
- Works as stand-alone air cleaner or in window

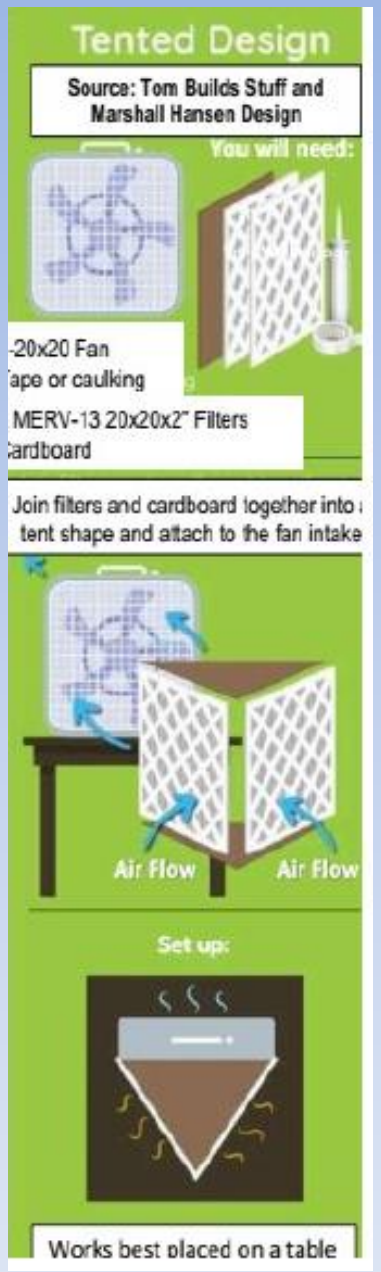
MERV Filter Primer by Robert Bean: http://www.healthyheating.com/IAQ/Indoor-Air-Quality-Air-Filters1.htm#.Y1rXxuTMKMo

Minneapolis supplier of affordable filters: https://twincityfilterservice.com/

# DIY Filter Fan Designs








bluehouseenergy.com

# Other DIY MERV13 Filter Fan Designs

**20” Box Fan**



**1 – 4” x 20” x 20” ~300 CFM**

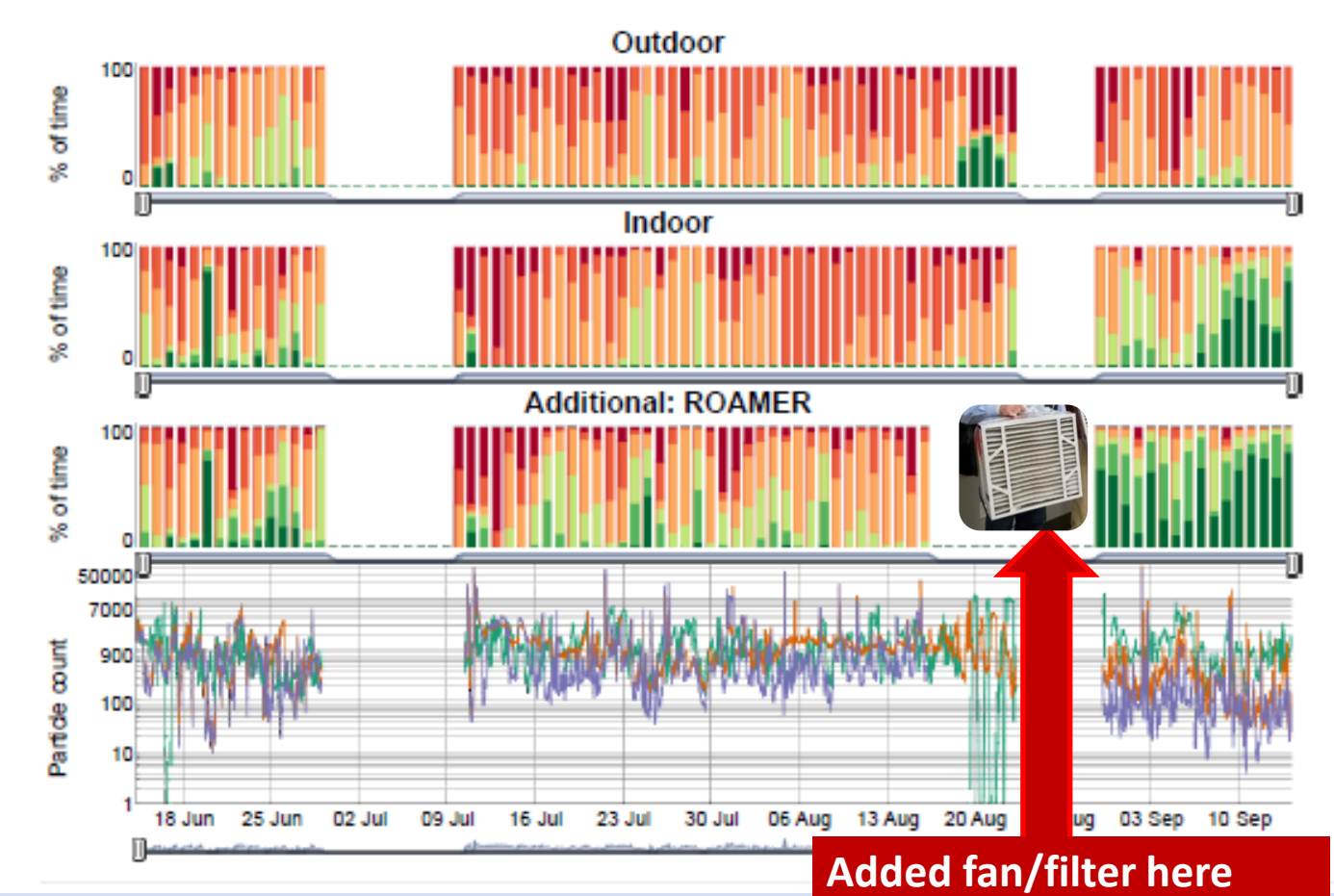
**9” Table Fan**


**4 – 1” x 14”x25”**
**MPR1900 ~100CFM**

**cleanairkits.com**
**6 – PC fans**


**4 – 1” x 16” x 25”**
**MPR1900 ~340 CFM**

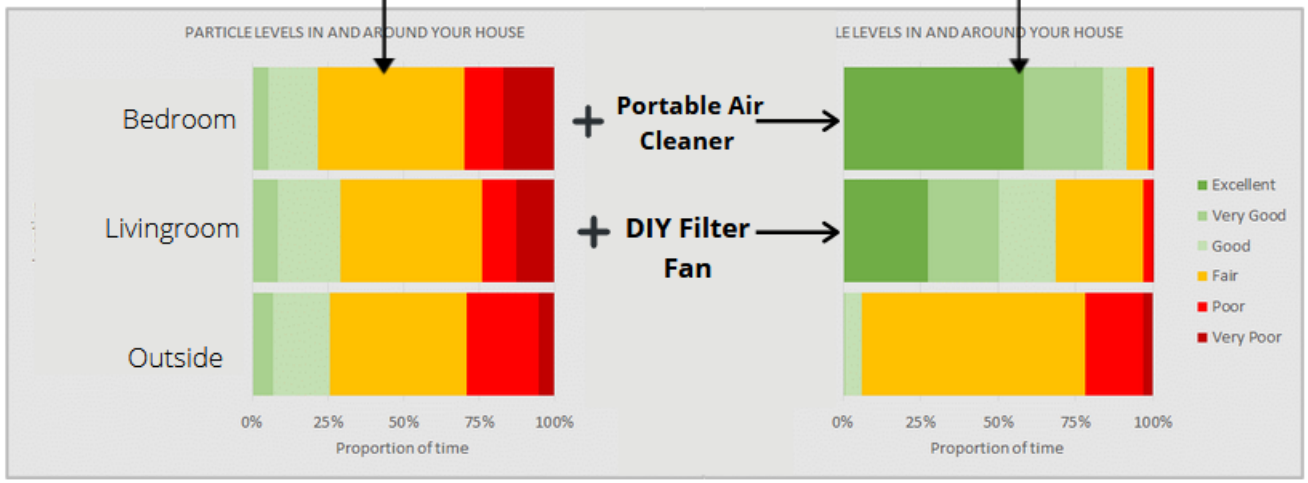
# Indoor Fan/Filter 24/7 Impact



# Results with Portable Air Cleaner & Fan/Filter

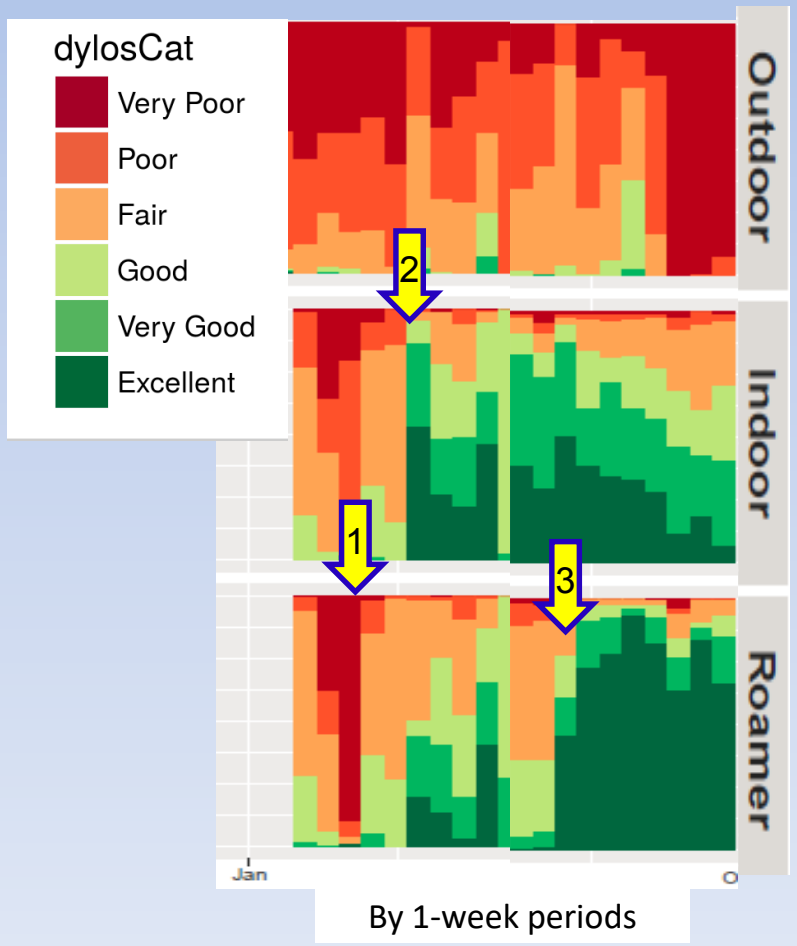
**Week 1:**
- Windows opened occasionally
- No portable air cleaner
- No filter fan
- Air quality indoors similar to outdoors

**Week 2:**
- Windows opened occasionally
- Portable air cleaner
- Filter fan
- Air quality indoors better than outdoors




*"We noticed a marked difference with the use of both the fan filter and portable air cleaner. We observed our baseline particle counts were lower overall…We also observed that our particle counts lowered more quickly with both interventions after cooking, which was our biggest source of high indoor particle counts."*
- Val, ROCIS Participant

# Motivated Occupant = Technical Interventions *Plus* Behavior Change




By 1-week periods

**2-burner Induction Stove Top**



**Interventions:**

1. Change use of humidifier
2. Add induction stove top & use fan/filter (living room)
3. Add fan/filter (bedroom)

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# Filtering Air with Forced Air Systems

Simultaneously…

- *Significant missed opportunity* to reduce particles
- *Major liabilities* (energy use, energy cost, equipment life, & performance)

***ROCIS solutions reduced fine particles by 50-80% while minimizing risk***

# High MERV Filter - Air Handler Unit Inquiry

***Initial Question…***

Is there an easy way to determine if I can use a high MERV filter with a longer air handler run-time without causing problems?

**NO !!**
**Diagnostic Screening is Required**

See Air Handler Inquiry tab at www.ROCIS.org/solutions

# Big Issues with 24/7 High MERV Filter

**Air handler (AHU) energy use** can be high due to 500 to 1,500 watt-draw

- High cost of running air handler continuously
  (360 kWh to 1080 kWh/month = ~$500 to $1500/year @ $.12/kWh

**Wrong blower speed**

- Seldom set in field
- Often defaults to high speed, not low, in continuous mode
- Higher energy cost, less effective filtration

**Ductwork issues** introduce additional problems

- Static pressure too high (can lead to equipment failure)
- Duct leaks (energy waste & pressure-related problems)

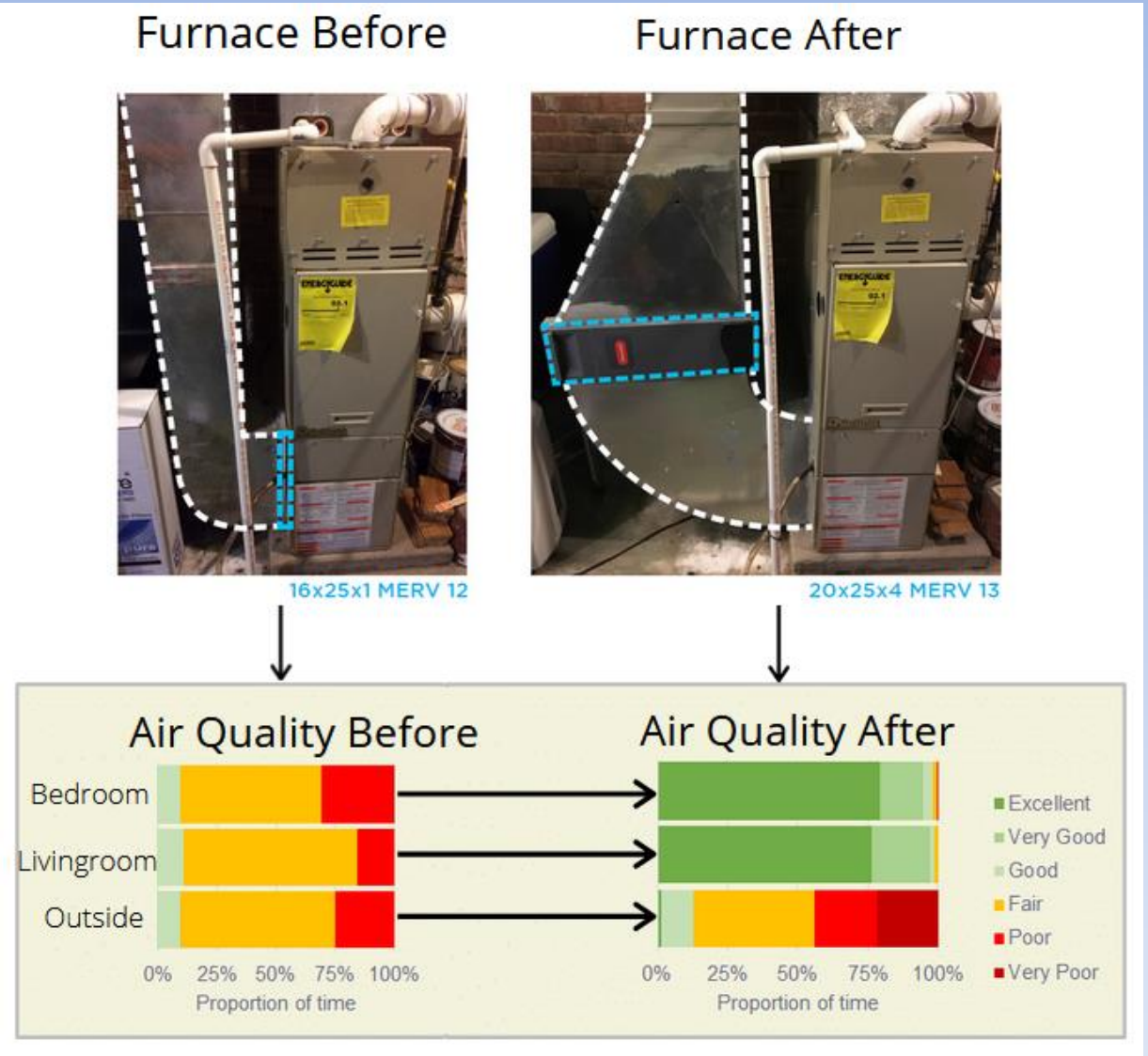
# Elements for 24/7 Operation of Air Handler Unit

- **ECM (electronically commutated motor) Blower**
  - Increase control to optimize (& lower) air flow
  - Drops electricity use, ***but only if static pressure*** is low/correct
- **4" Pleated MERV 13 filter – ideally also larger area**
  - Lower air flow thru filter increases reduction of smaller particles
  - 4" deep filter longer life without clogging
  - Option for 2nd filter (pre or post)
- **Good Duct System**
  - Minimal leaks to outside
  - Air flow & total external static pressure (TESP) within name plate specifications

***NOT RECOMMENDED:***

1" pleated MERV 11 or 13 filter (equivalent) without performance testing for TESP, air flow, & watt-draw

# Modifications to Air Handler



# Big Opportunity at HVAC Replacement

- Incorporate return drop modification & option for larger, deeper filter
- Set blower speeds for optimal performance
- Address duct system shortcomings
- *Right-Size HVAC to reduce static pressure!!*

To ponder…

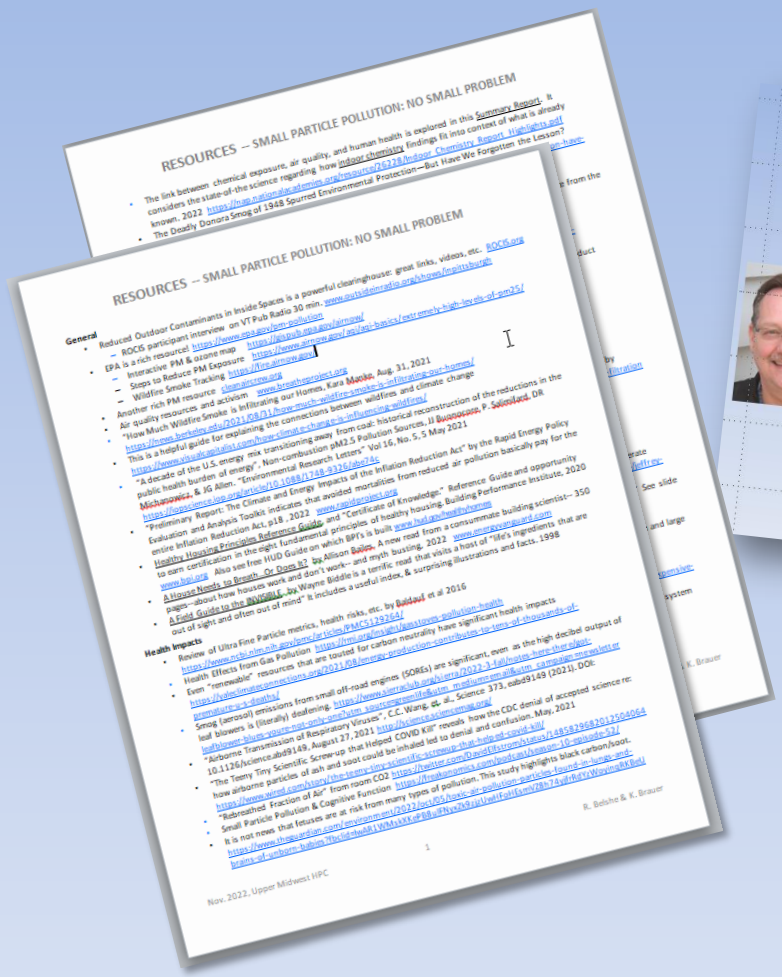
- How do we sell the value of whole house filtration with its health and comfort benefits?
- How do we help buyers choose better designed & installed HVAC systems?

See HVAC 2.0 link in Resources

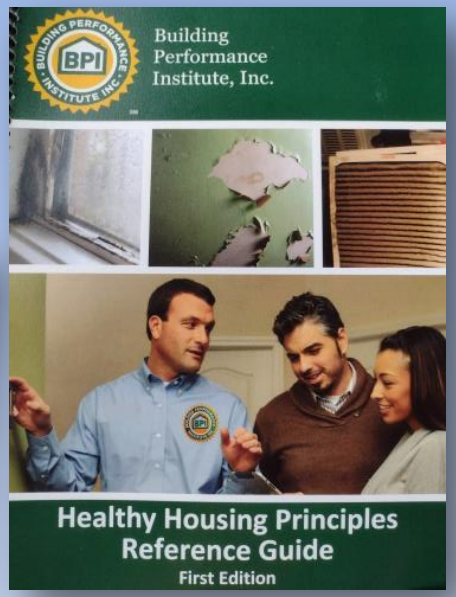
# Check out these Sessions!

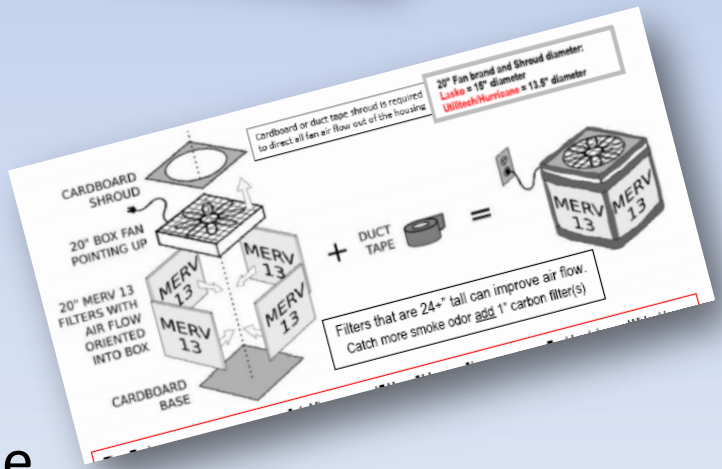
- Tue. 1 PM **Healthy Homes for All: Weatherization and Home Repair with Public Health in Mind** *(Fraser, Jimcosky)*
- Tue. 2:30 PM **Developing an Environmental Hazards Assessment Module for Home and Community Based Services** *(Hughes, Engelmeier)*\
- Tue. 2:30 PM **Continuously Venting Range Hoods to Improve IAQ: Lessons from the Field** *(Wilson, Gilleade)*
- Tue. 4 PM **Particle Filtration with Central Air Handlers: Folly or Opportunity?** *(Major, Wigington)*
- Tue. 4 PM **Novel Methods for Detection of Allergens in the Home Environment: Point-of-care Systems Utilizing Smartphone Technology** *(Panescu)*
- Tue. 4 PM **IAQ Management in Dwellings** *(Karg)*
- Wed. 1 PM **Effective and Comprehensive Healthy Homes Assessments and Reports** *(Kennedy)*
- Wed. 2:30 PM **Revolutionizing Home Performance: Unlocking Exponential Efficiency with Next-Gen Digital Tools** *(Reed, Breger)*
- Thur. 11 AM **Indoor Environments and Our Health: What the Latest Research Now Tells Us** *(Kennedy)*
- Thur. 11 AM **Elders Alert System About Imminent Environmental Risks** (Tohn, et.al.)

# Resources & References








See Conference Website for these

# Fast Feedback

***Will YOU do anything differently?***

1. What do you think are the most threatening particles to you and your household?

2. What is the most important thing a contractor/crew can do on the job to control particles?

# We Welcome All Feedback!

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724-986-0793

Interested in participating in our next Low Cost Monitoring cohort?
Contact Linda ASAP 724-986-0793 (text)
Add name to clip board!

www.facebook.com/groups/rocislcmp