CITIZEN SCIENCE: *INDOOR AIR MONITORING THE ROCIS EXPERIENCE*

Tuesday, Nov. 19, 2019

USC Citizens for Land Stewardship
Annual Meeting

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ROCIS *(Rock-us) or (Raucous)*
Reducing Outdoor Contaminants in Indoor Spaces

WWW.ROCIS.ORG

1. What is ROCIS?

2. How does ROCIS work?

3. What do ROCIS participants learn?

4. Examples of ROCIS impacts

What is ROCIS?

Citizen Science: projects in which volunteers partner with scientists to answer real-world questions

ROCIS MISSION

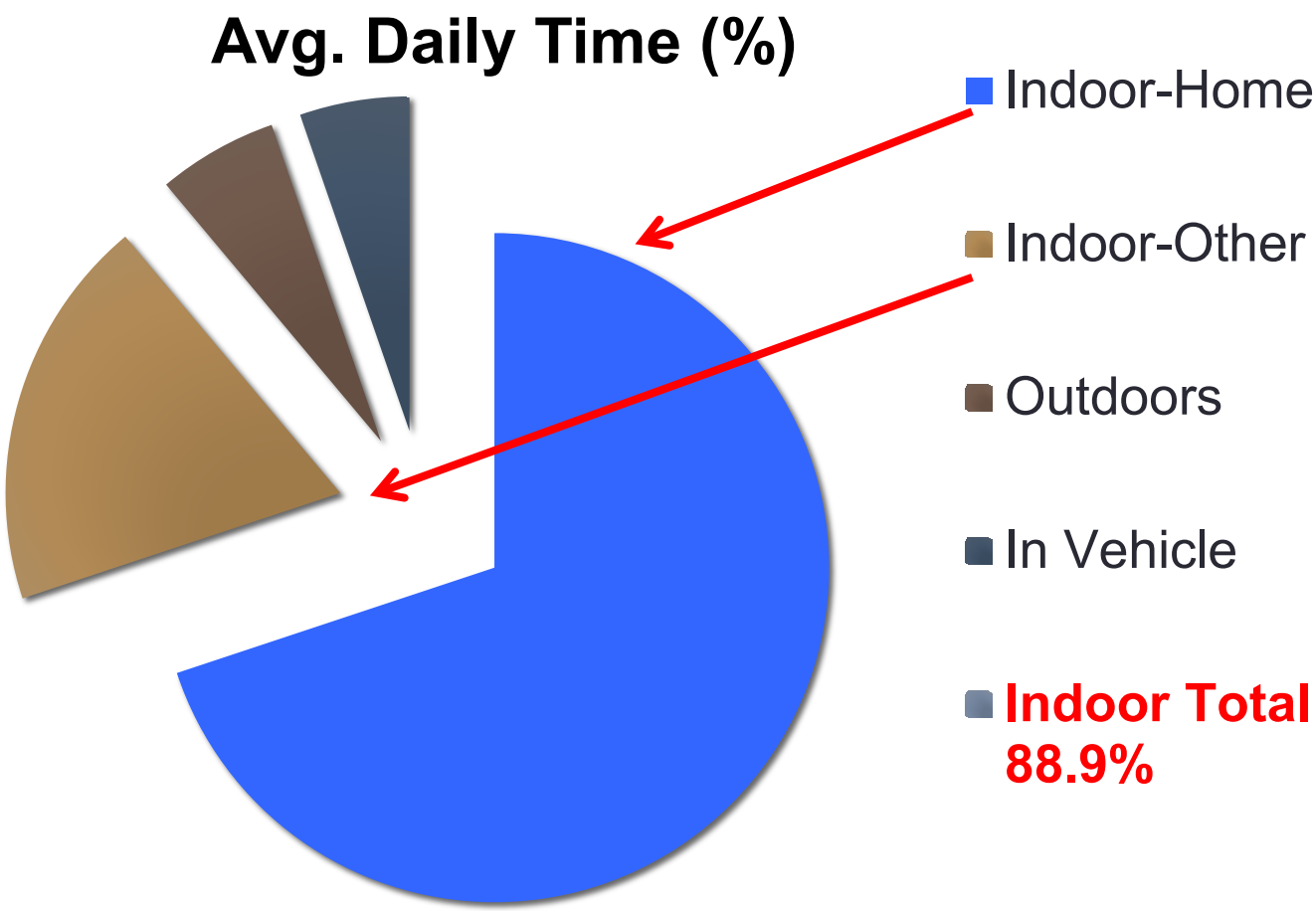
A Southwestern Pennsylvania initiative to reduce the impact of exterior pollution in indoor spaces.

Why??

Most of our exposure *to outdoor pollution* happens in buildings[1]

http://www.iaqscience.lbl.gov

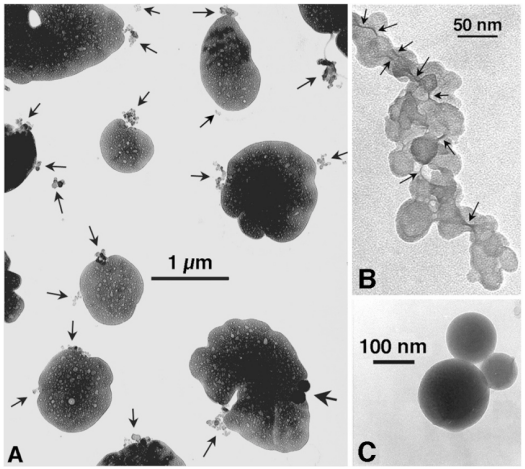
About 90% of our time is spent indoors



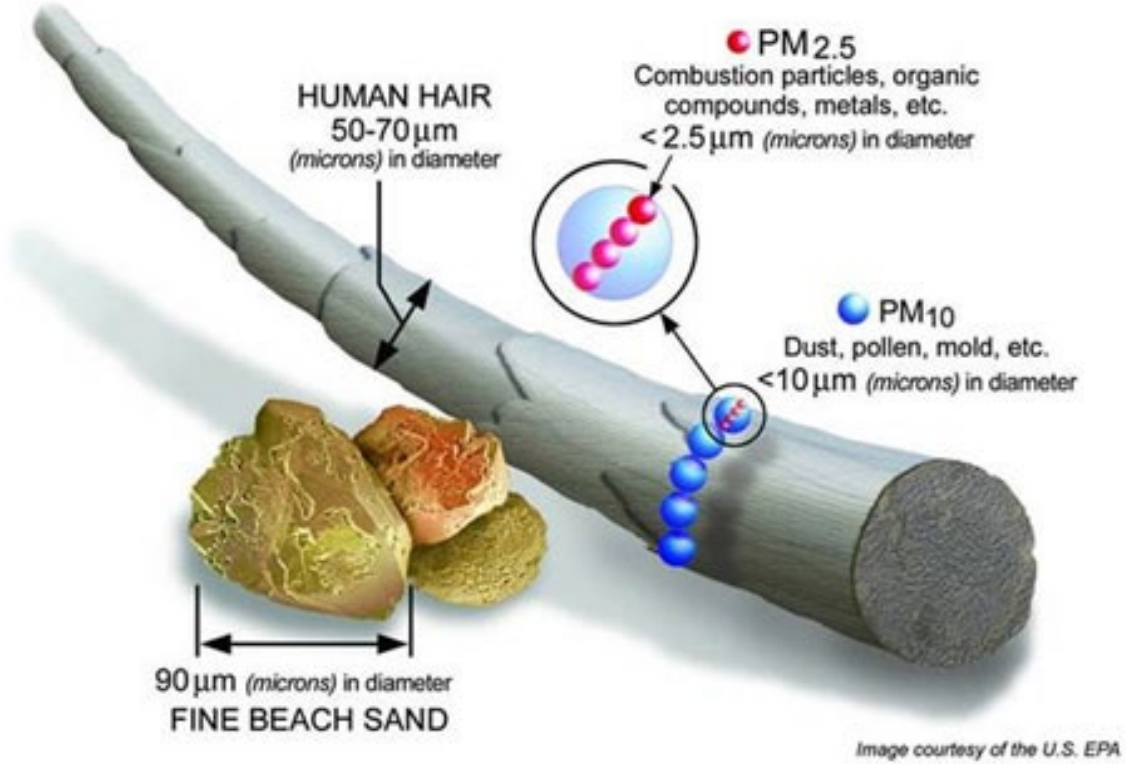
Canadian Human Activity Pattern Survey 2, 2010-11

Matz, C.J.; Stieb, D.M.; Davis, K.; Egyed, M.; Rose, A.; Chou, B.; Brion, O. Effects of Age, Season, Gender and Urban-Rural Status on Time-Activity: Canadian Human Activity Pattern Survey 2 (CHAPS 2). *Int. J. Environ. Res. Public Health* 2014, *11*, 2108-2124.

PARTICULATE MATTER (PM)



OUTDOOR BLACK CARBON
50 nm to 1 µm



PM_{10}: Particulate matter less than 10 µm in diameter
$PM_{2.5}$: Particulate matter less than 2.5 µm in diameter
ROCIS LCMP Dylos: $PM_{0.5}$+: Particles ***greater than*** 0.5 µm in diameter (1/100 of human hair!)

Particulate Matter (PM)

Complex mixture of extremely small particles and liquid droplets.

May be composed of numerous components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles.

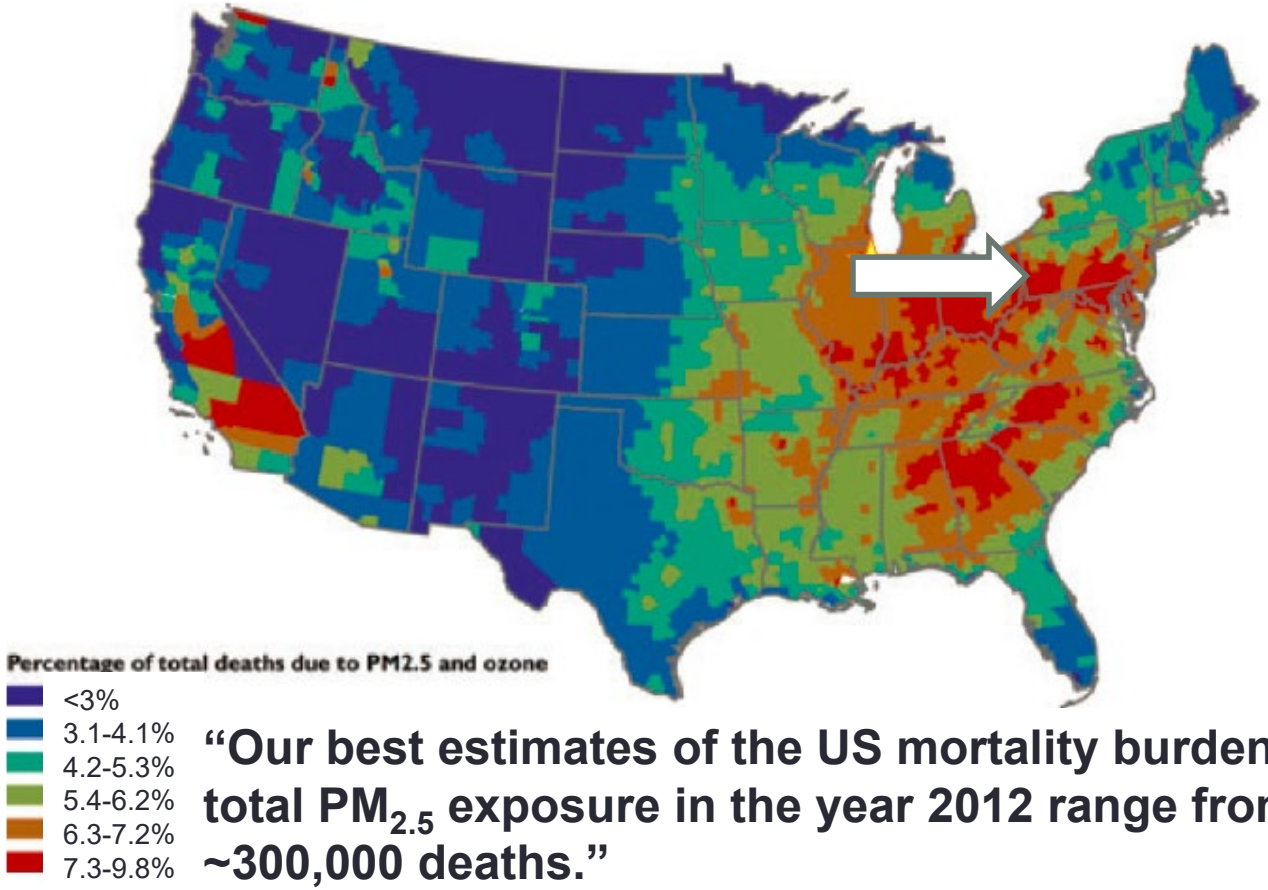
Health Concerns (<PM10)

Established PM-associated diseases: cardiovascular disease, asthma, and lung cancer

Recent associations with PM exposure include: idiopathic pulmonary fibrosis, type 2 diabetes, Alzheimer's disease, and decreased cognitive function.

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

Outdoor Particles (PM) & Human Health



"Our best estimates of the US mortality burden associated with total $PM_{2.5}$ exposure in the year 2012 range from ~230,000 to ~300,000 deaths."

Fann et al. 2012 *Risk Analysis*

- **Indoor exposure to $PM_{2.5}$ of outdoor origin: typically the largest total exposure; ~40–60% of total mortality**
- **Followed by residential exposure to indoor $PM_{2.5}$ sources, which also drives the majority of variability in each scenario.**

Azimi, P., & Stephens, B. (2018). *Journal of exposure science & environmental epidemiology.*

Pittsburgh's Air Quality is Poor

*People Most at Risk in the U.S. from **Year-Round** Particle Pollution (Annual $PM_{2.5}$)*

- 7th worst city
- Worst city east of the Rockies

…From Short-Term Particle Pollution (24-hour PM2.5)

- 10th worst city[1] & worst city east of the Rockies

1. Pittsburgh-New Castle-Weirton (PA-WV-OH)

SOURCE: American Lung Association State of the Air Report 2019
https://www.lung.org/assets/documents/healthy-air/state-of-the-air/sota-2019-full.pdf

How does ROCIS work?

ROCIS
Low Cost Monitoring Project (LCMP)

Objectives

1) Learn how low-cost air monitors empower occupants

2) Examine the impacts of outdoor pollution on indoor air

3) Explore interventions to improve indoor air quality

4) *Develop champions!!*

LCMP Cohorts

LCMP Cohorts

Participants receive the loan of monitoring equipment to measure:

- **Particles (0.5 um and 2.5+ um)**
- **Carbon dioxide (CO_2)**
- **Carbon monoxide (CO)**
- **Radon**
- **Temperature**
- **Relative humidity**

During the course of 4 meetings, participants:

- **Receive one-on-one support**
- **Learn from the ROCIS team**
- **Learn from each other**

Participants receive weekly individualized feedback in response to their monitoring data, observations, and questions.

ROCIS equipment

(3) Dylos **Particle** Counter DC1700
http://www.dylosproducts.com/dc1700.html

(2) AirThings **Radon** Monitor https://airthings.com/us/

(1) **Carbon Monoxide (CO)** Monitor

(Experts Model 2015) http://coexperts.com/2015-2/

(1) **Carbon Dioxide (CO_2)** TIM12 Datalogging Meter
www.co2meter.com

Making the Invisible Visible

Dylos 1700 Optical Particle Counter:

Particles per 1/100 ft^3, 1 min. resolution

2 size ranges of Particles:

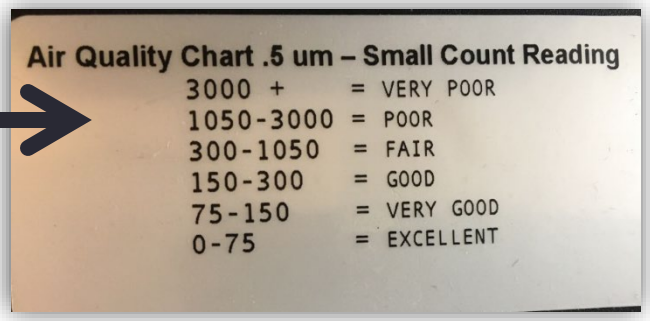
> **0.5+ µm (Dylos "Total")**

> 2.5+ µm (Dylos "Large")

3 Dylos / Site

- Outside, Inside (living area) Roamer (usually bedroom)

NOTE: Scale at right is from manufacturer; not health-based



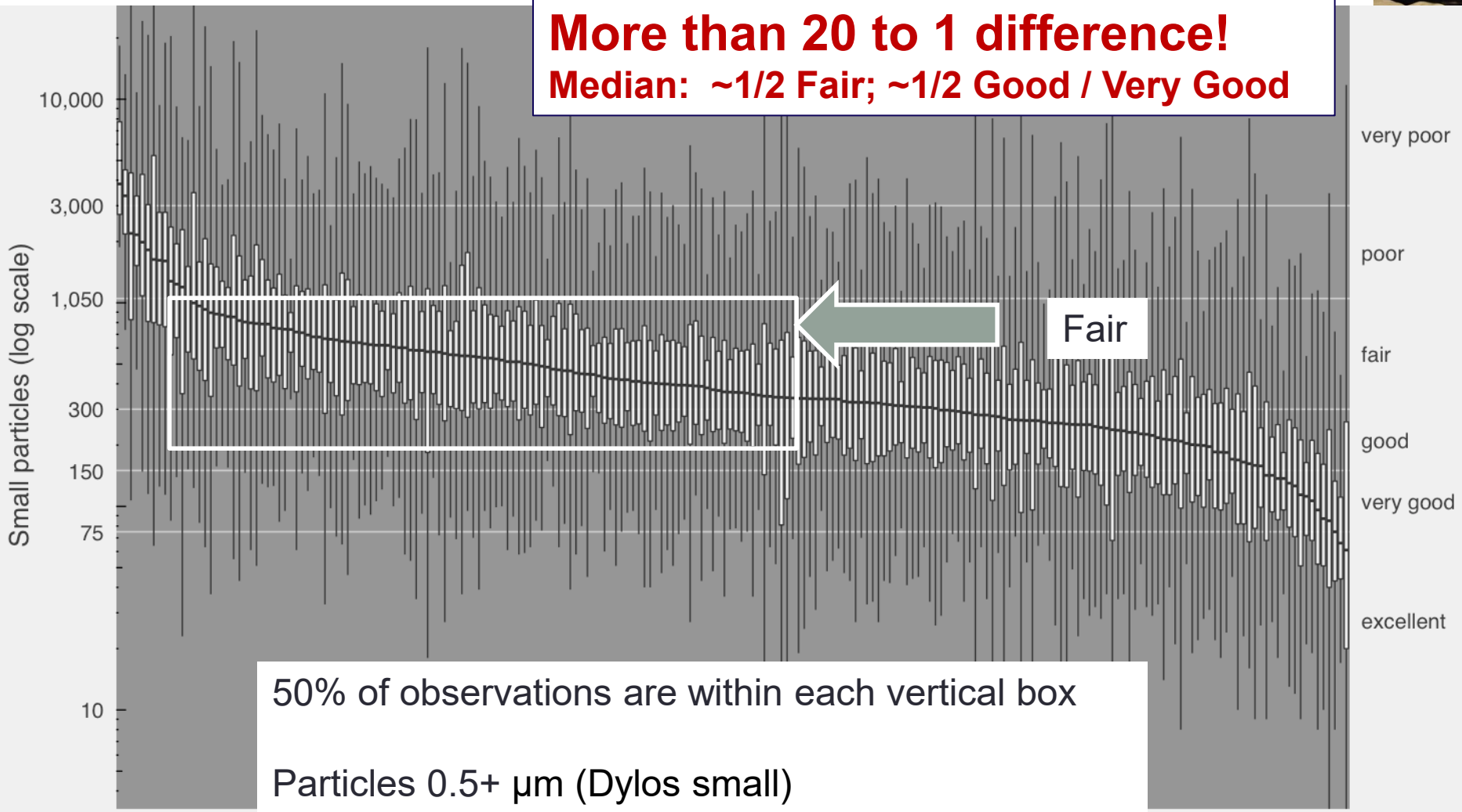
Dylos 1700 http://www.dylosproducts.com/dc1700.html

What do ROCIS participants learn?

Indoor Particle Distribution – All Sites

More than 20 to 1 difference!

Median: ~1/2 Fair; ~1/2 Good / Very Good



50% of observations are within each vertical box

Particles 0.5+ µm (Dylos small)
Dylos Corporation scale (on right)

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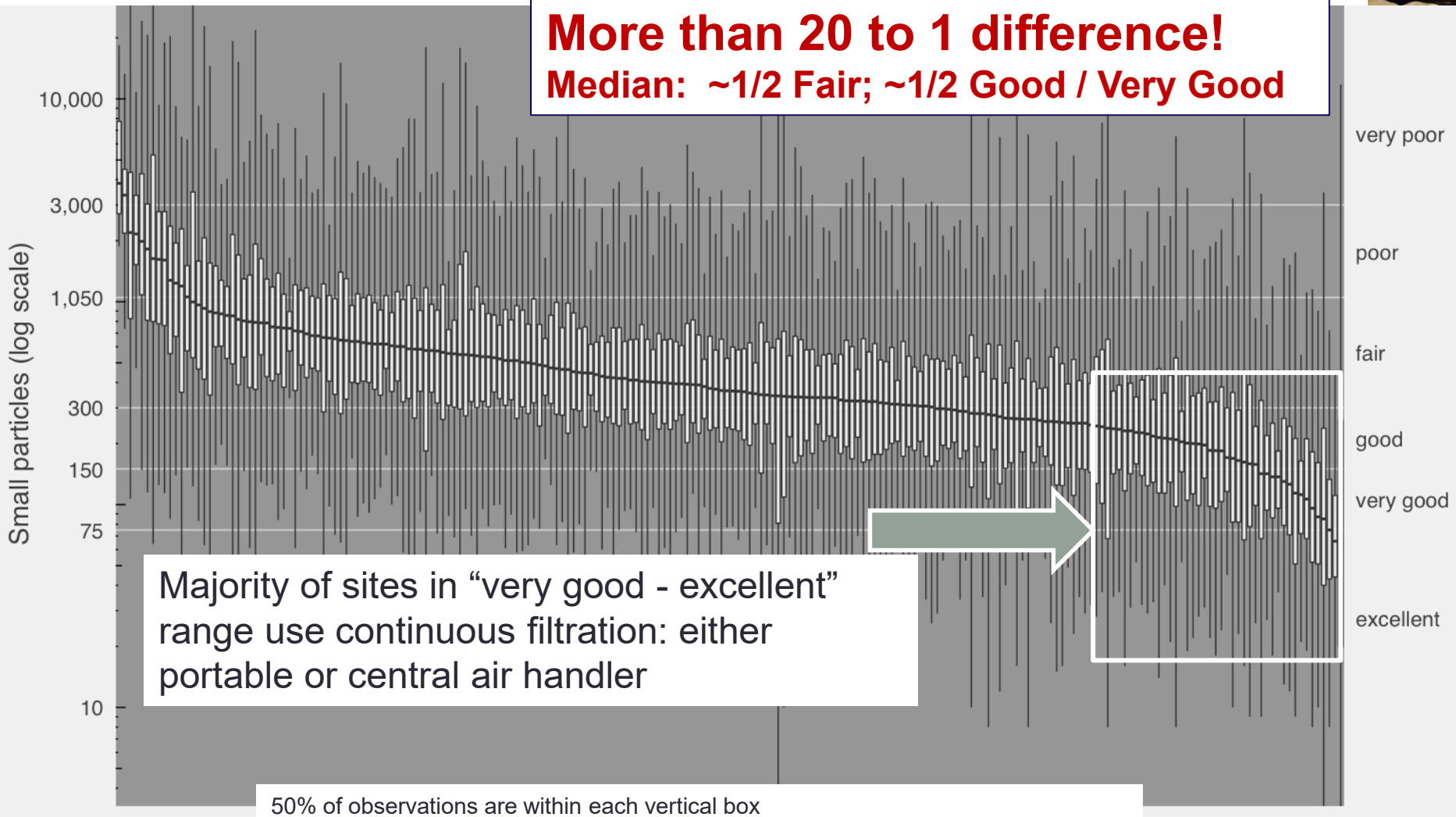
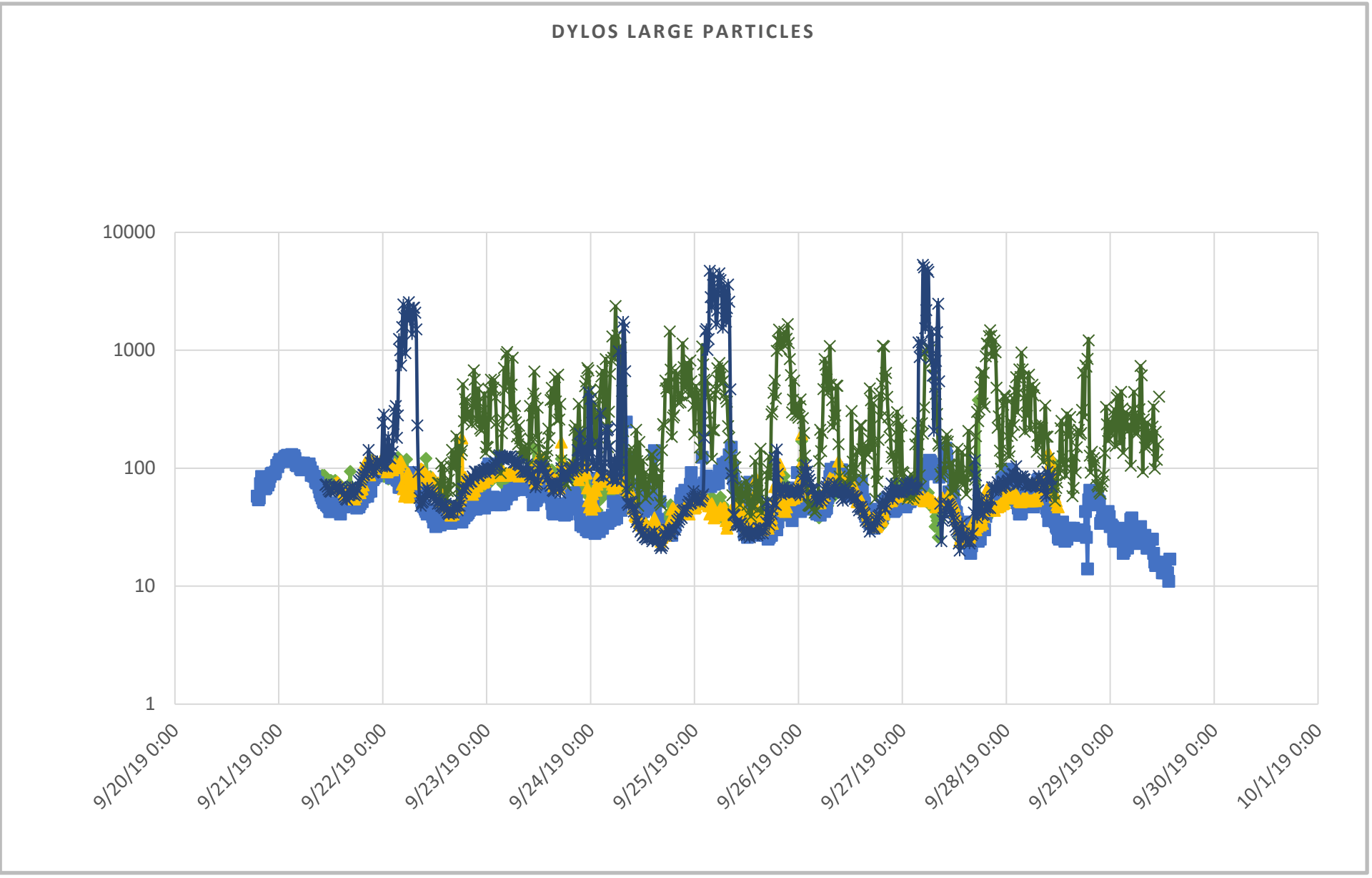
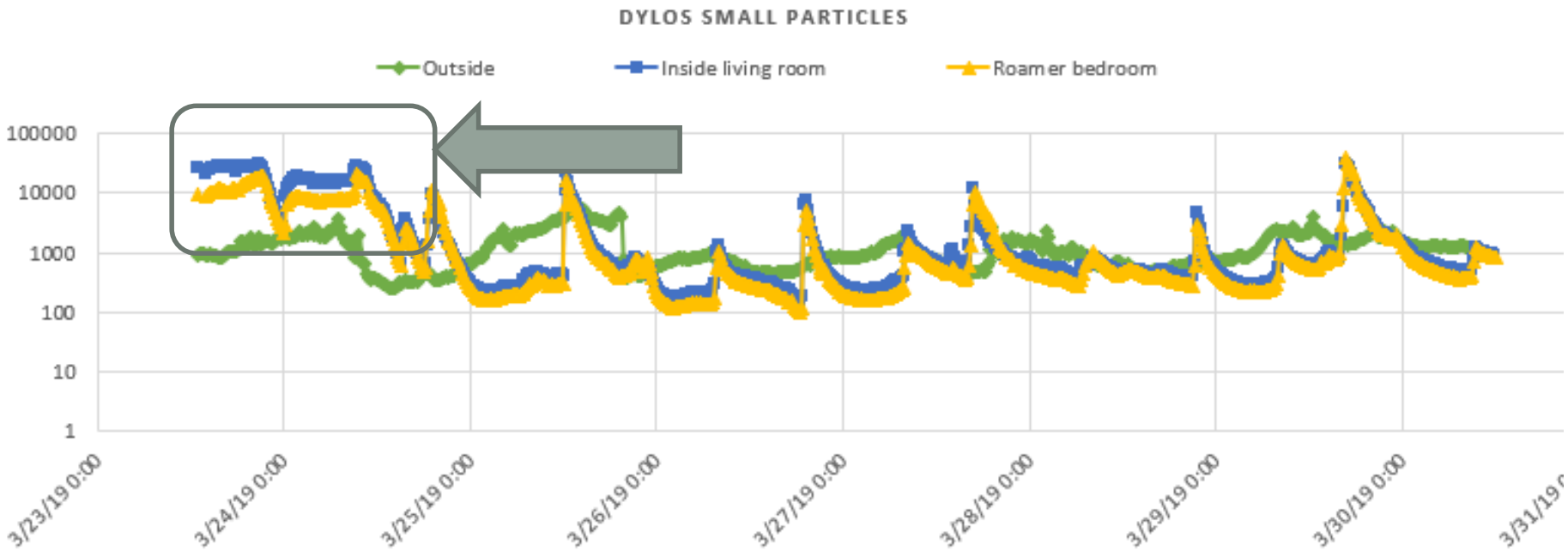


Majority of sites in "very good - excellent" range use continuous filtration: either portable or central air handler

50% of observations are within each vertical box
Particles 0.5+ µm (Dylos small)
Dylos Corporation scale (on right)


DYLOS LARGE PARTICLES
10000
1000
100
10
1
9/20/19 0:00
9/21/19 0:00
9/22/19 0:00
9/23/19 0:00
9/24/19 0:00
9/25/19 0:00
9/26/19 0:00
9/27/19 0:00
9/28/19 0:00
9/29/19 0:00
9/30/19 0:00
10/1/19 0:00

Example from the participant's perspective



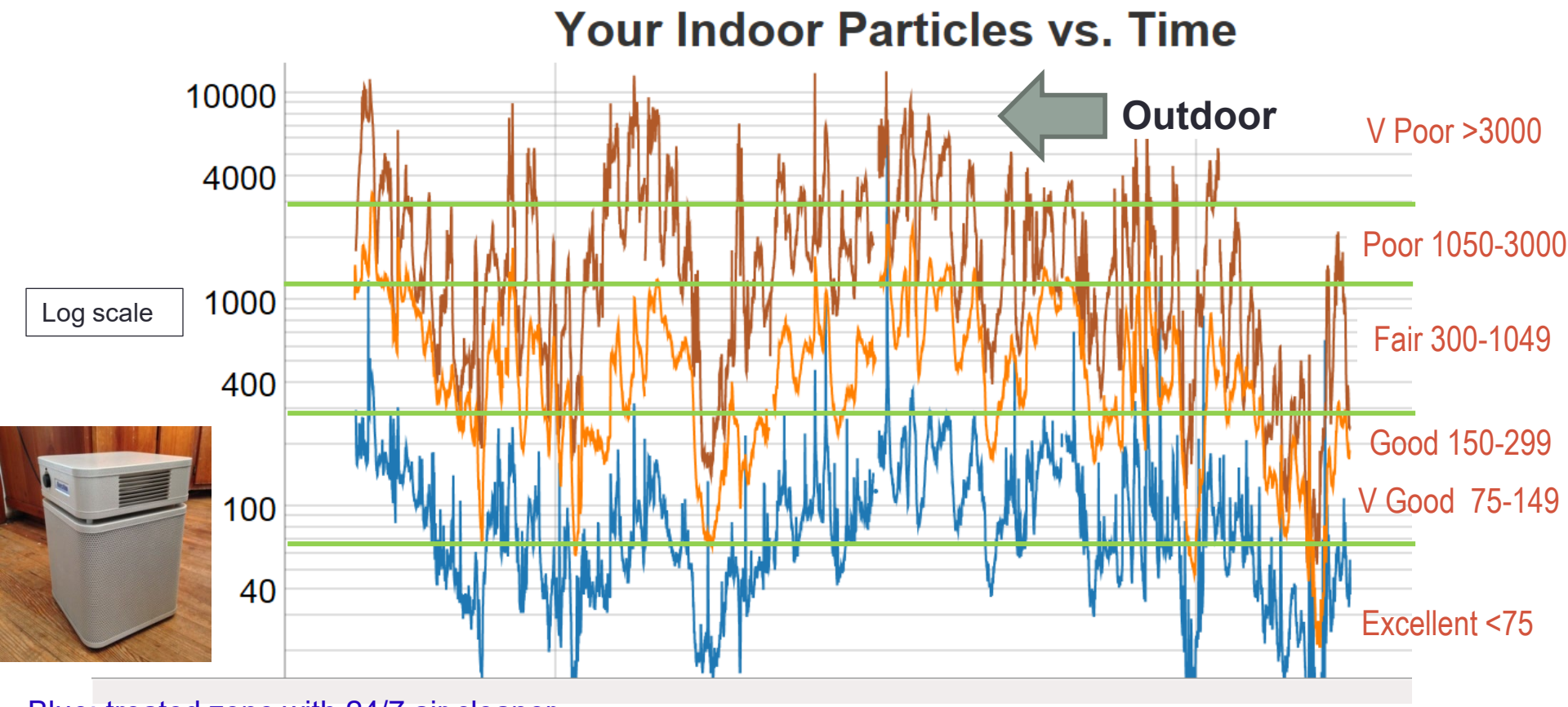
"….the indoor particle counts zoom up usually around meal times. These could be cooking emissions. The first day and a half, though, is constant which is not characteristic of cooking. Sometimes we see this pattern happening when a 'Cool-mist' humidifier is being run on tap water, instead of distilled water.

Let me know if you have any questions or clarifications.

Don"

Use of Portable Air Cleaner

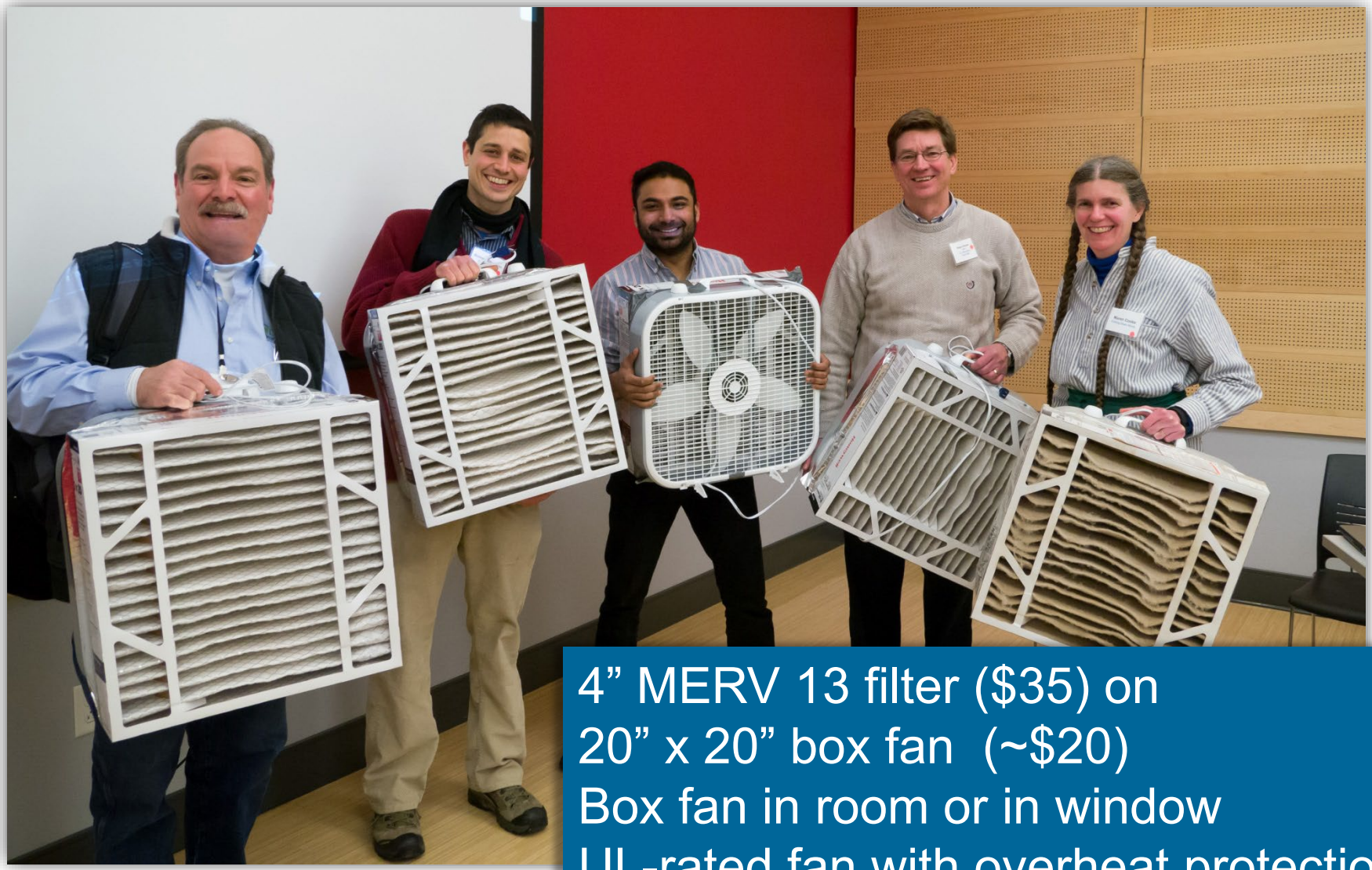
http://rocis.org/rocis-data-explorer (j1t8) 0.5+ µm Particles by Time (15-min. avg.)



Blue: treated zone with 24/7 air cleaner
Orange: untreated zone
Red: outdoors
Tight, single family home
Though order of magnitude lower; Indoor (Blue/orange) tracks Outdoor

Examples of ROCIS impacts

Fan/Filter Intervention: Low Cost, MERV 13

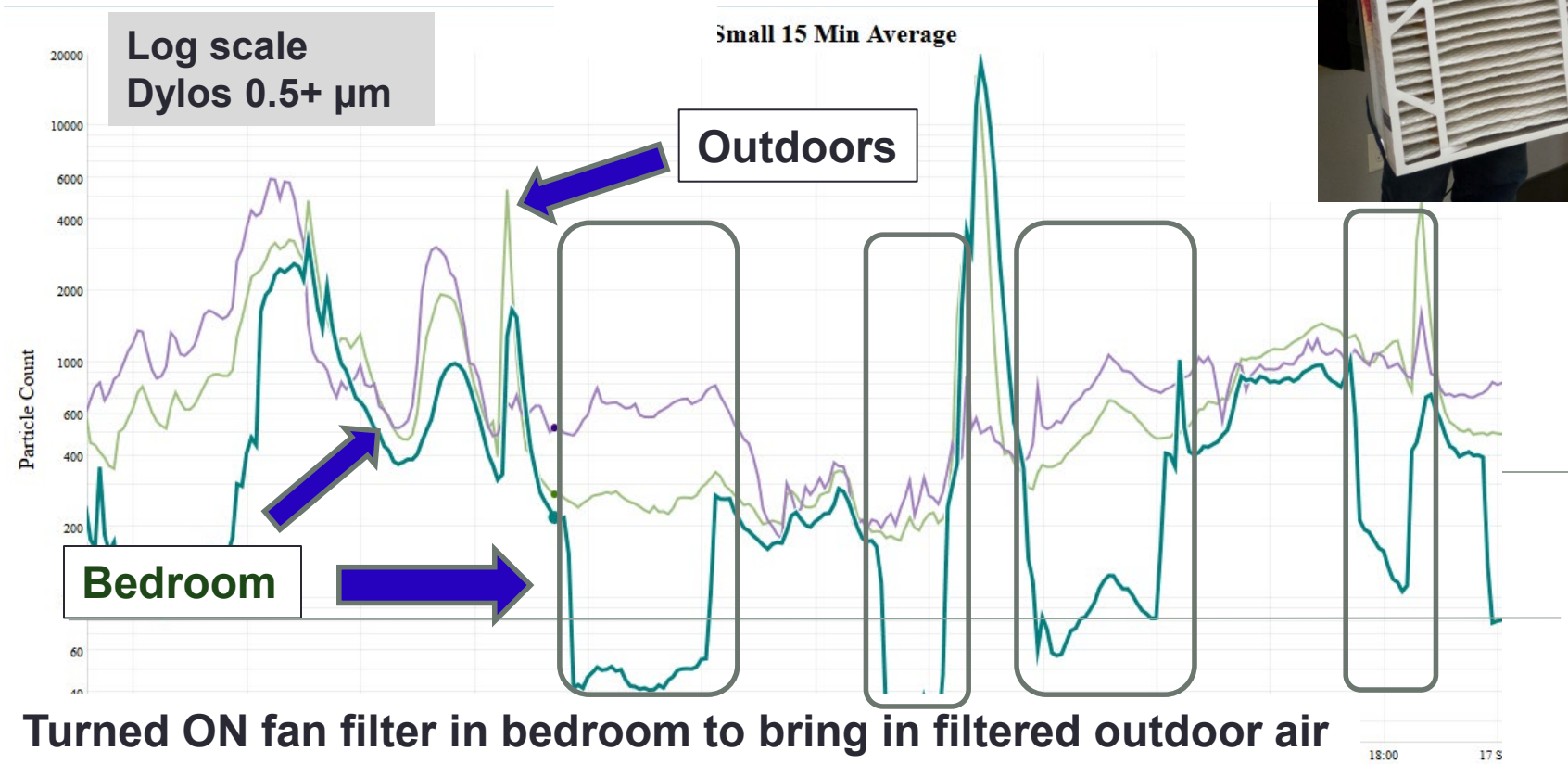


4” MERV 13 filter ($35) on
20” x 20” box fan (~$20)
Box fan in room or in window
UL-rated fan with overheat protection

Fan/Filter Intervention– Bedroom Window at Night

Open window with/without box fan and filter on:

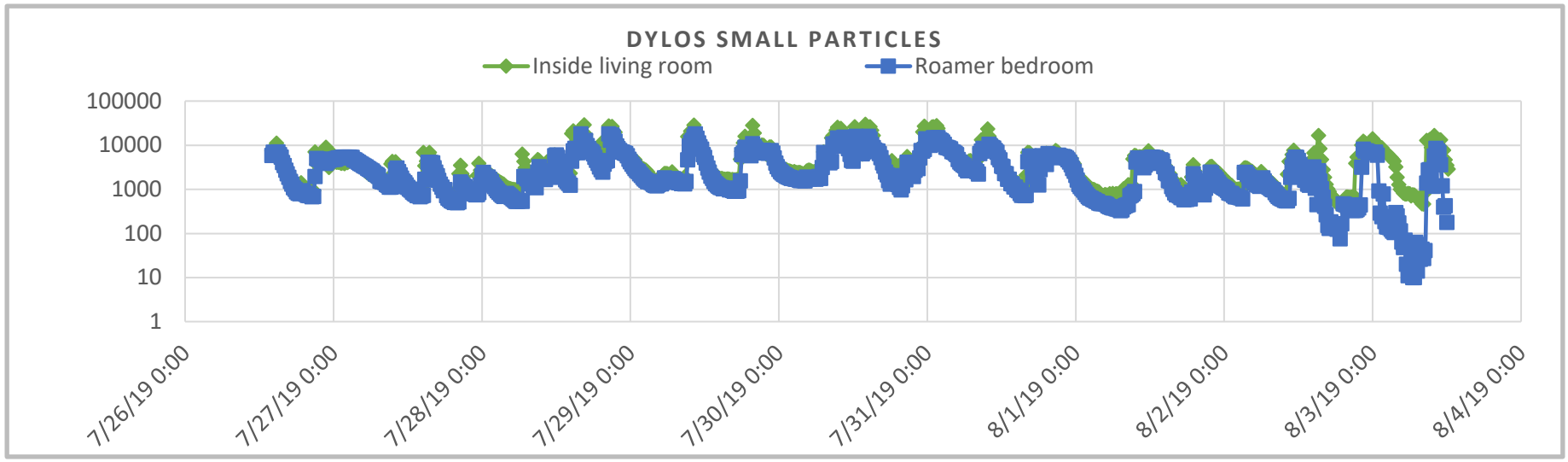
Indoor tracks outdoor closely

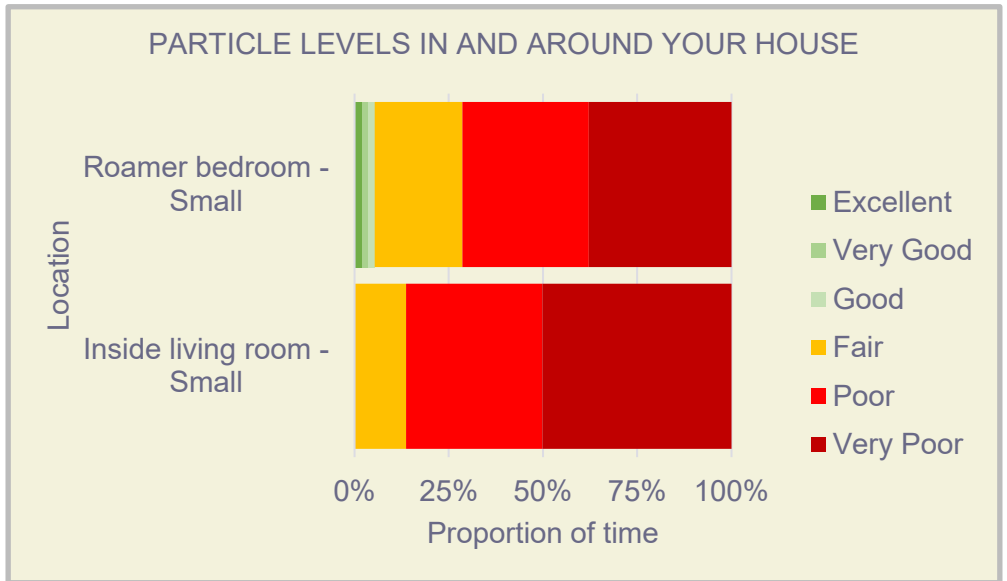


Turned ON fan filter in bedroom to bring in filtered outdoor air
Turned OFF fan filter each morning (f5q4)

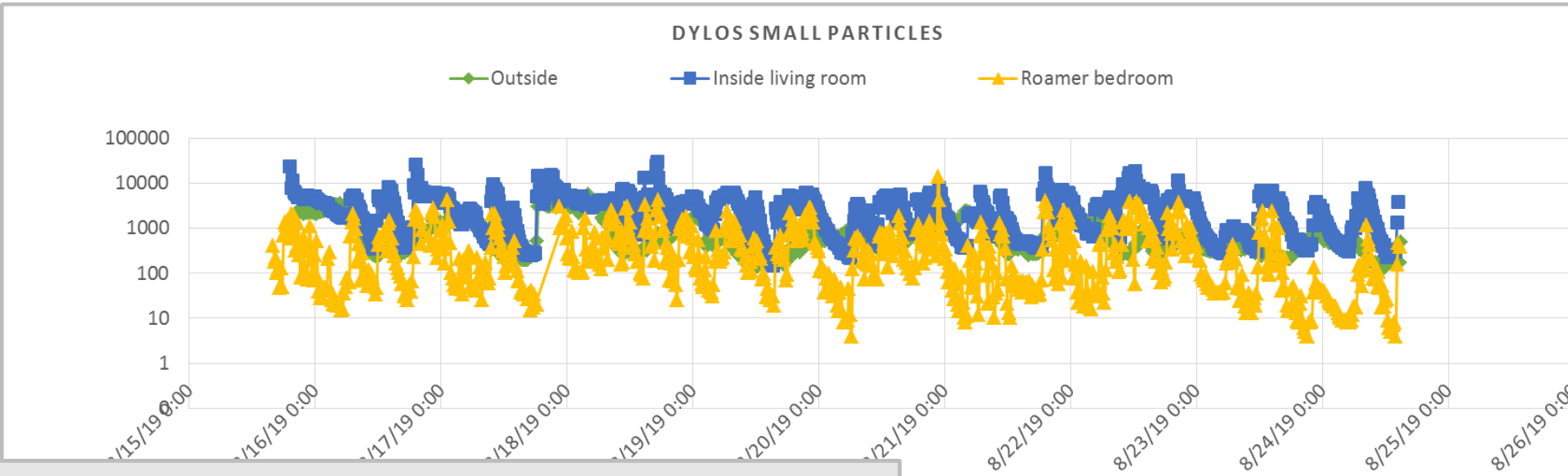
This Represents Opportunity!

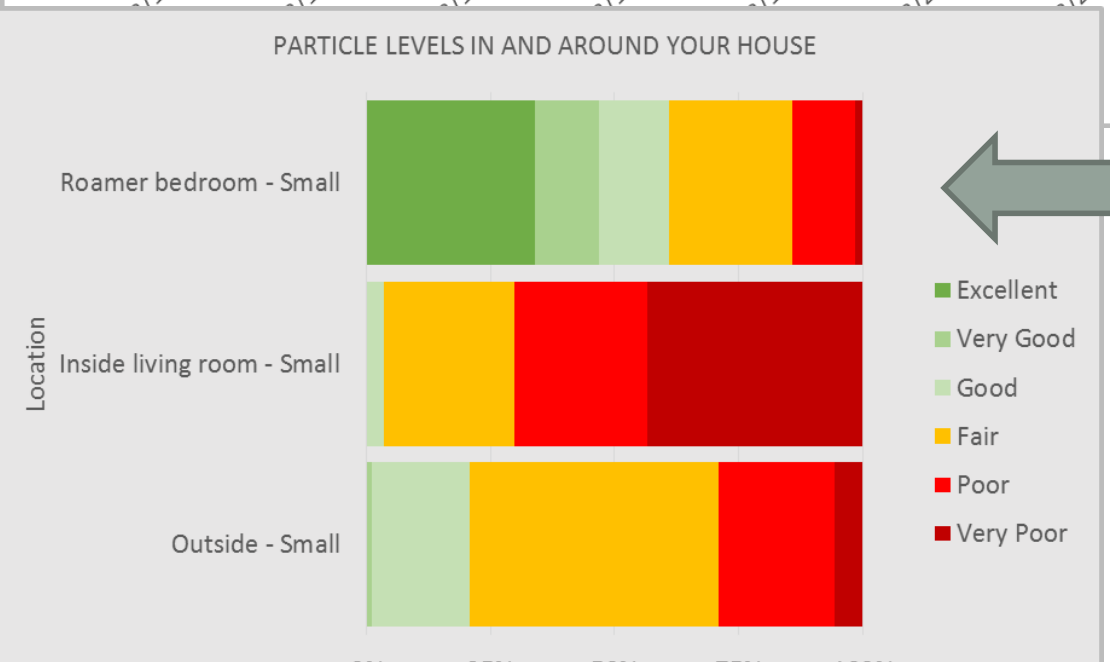
(week ending 8/03/19)





Week Ending 8/24/19

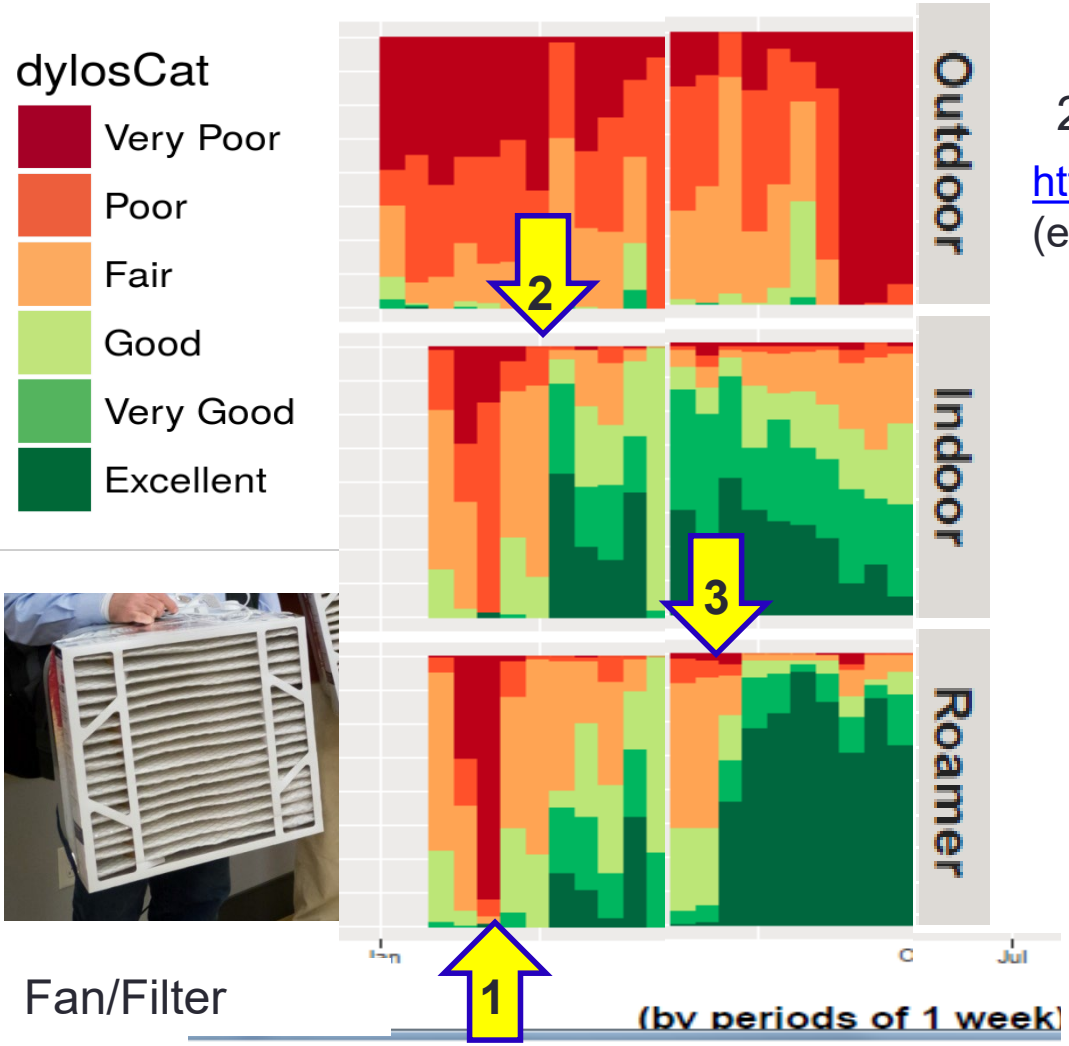




Box fan w MERV 13 4” deep filter on in bedroom this week.

Behavior *Plus* Technical Intervention

Motivated Occupant



Fan/Filter

2-burner Induction Stovetop

http://rocis.org/rocis-data-explorer (h9j2) (example 2)

INTERVENTIONS

1) **Change use of humidifier**
2) **Add induction stovetop & use fan/filter (living room)**
3) **Add fan/filter (bedroom)**

Air Handler Intervention

CASE 1 Pre

16x25x1 MERV 12

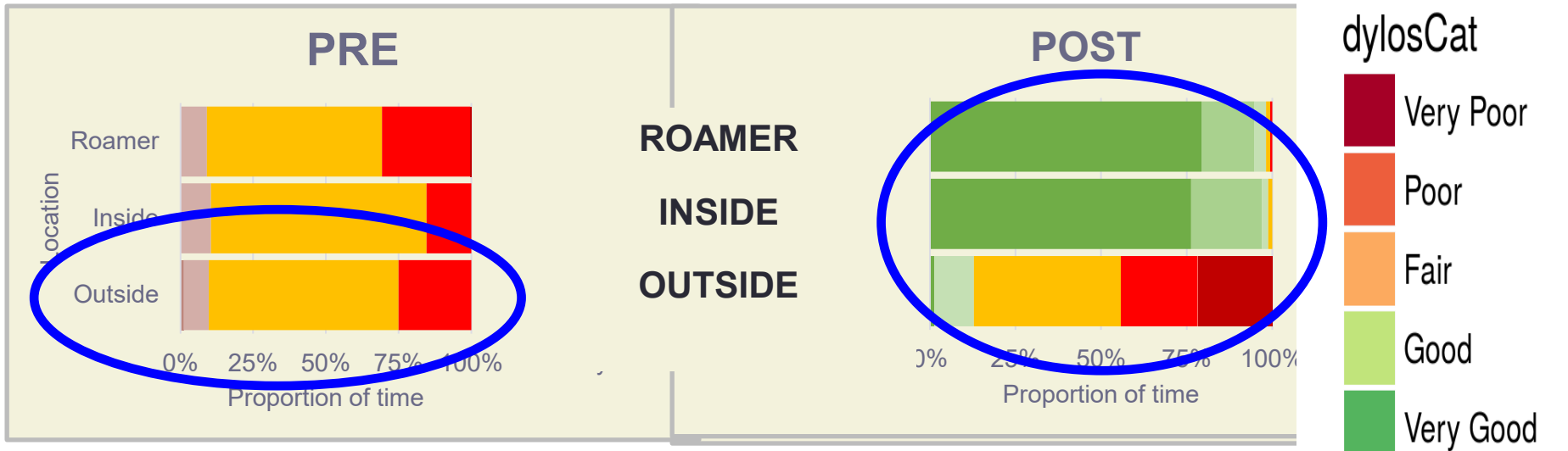
Post

20x25x4 MERV 13

CASE STUDY: Indoor Air Quality Interventions
Chris Guignon, evolveEA

Case 2 Pre & Post Particles

Air Handler Intervention



Week ending 5-24-2017 **(windows open)** vs. 7-31-2017, poorer outdoor counts

INTERVENTION:

ECM blower (lower air flow & energy cost on continuous setting)

New return (larger 20" x 25" MERV 13 filter & pre-filter)

Cost – labor & materials: $1,000

RESULTS: Lower CO_2 in bedroom **24/7 annual operating cost: $131.40**

Conclusions

Insight to Date re Interventions

- Air filtration can significantly reduce particle counts *if the application is appropriate*
- Low cost monitors reinforce use of filtration as well as source control
- Tighter the house, the greater the impact of filtration
- But, tighter the building, the more critical it is to control indoor sources
- In some cases, shift focus from building exposure to human exposure (bedrooms?)

Thanks to Phil Johnson &

The Heinz Endowments for support

of the ROCIS initiative

(Reducing Outdoor Contaminants

in Indoor Spaces)

And 270+ LCMP participants

Upcoming opportunities to participate in a ROCIS cohort!

January: Cohort in Upper St. Clair
February: Open cohort

CITIZEN SCIENCE: INDOOR AIR MONITORING THE ROCIS EXPERIENCE

Tuesday 4:30-5:00 PM, Nov. 19, 2019

Shale & Public Health Conference –
Pitt University Club

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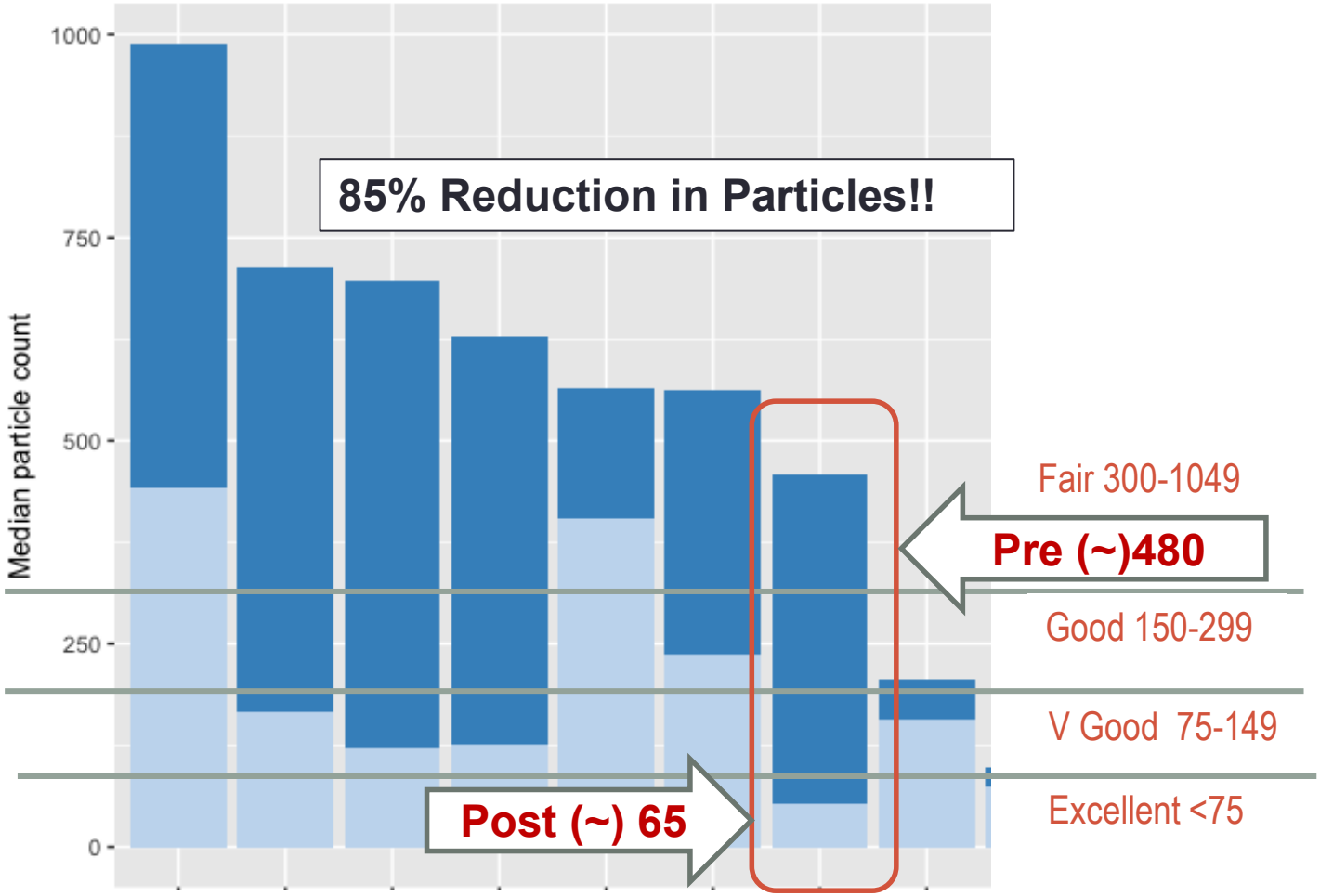
EXTRAS

Selected ROCIS Intervention Homes Pre-Post Median Particle Count

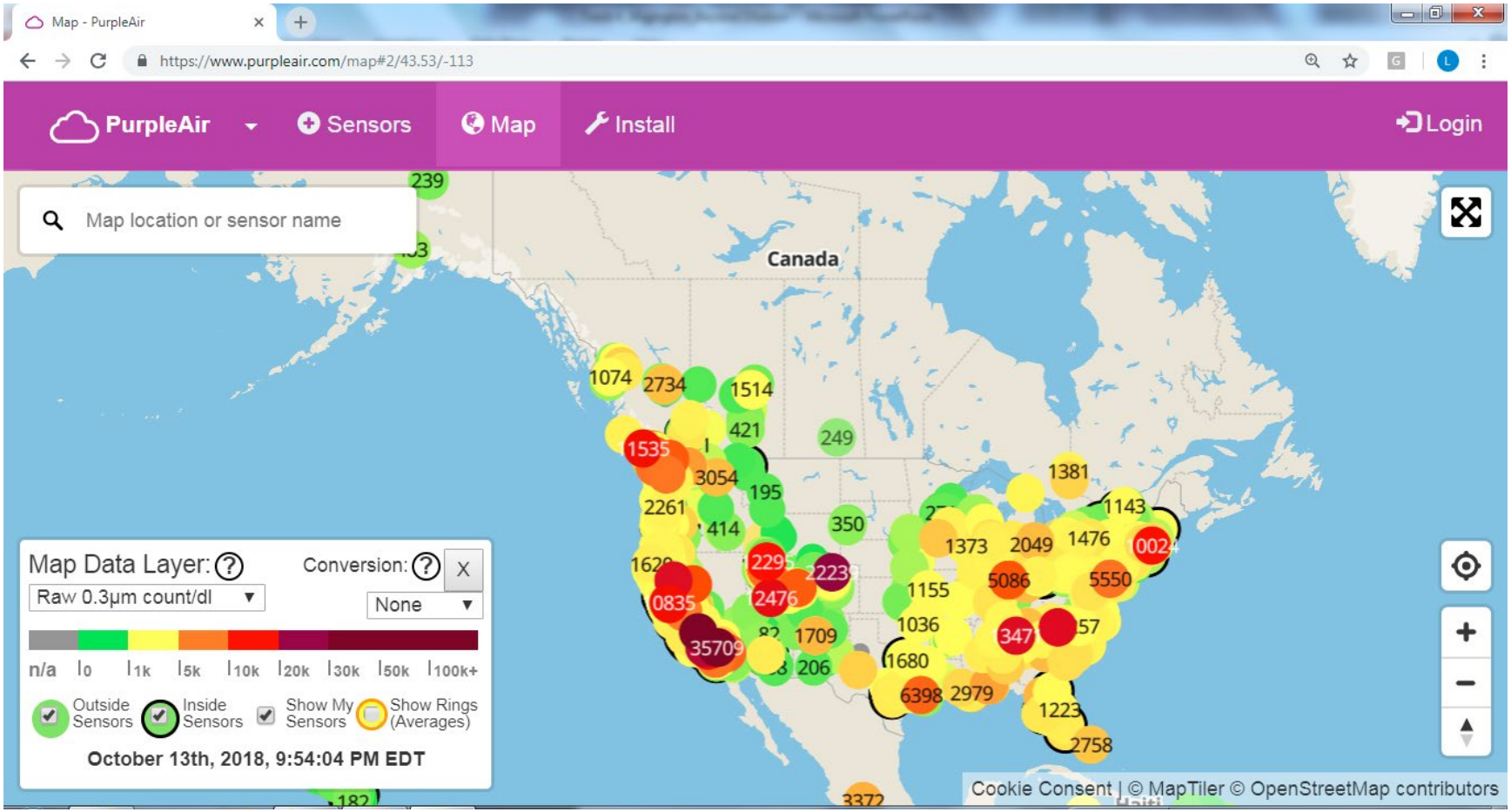


Use above code **(w2i9)** to view data on ROCIS LMCP Data Explorer
http://rocis.org/rocis-data-explorer

RESOURCES

- Health Risks of Indoor Exposure to Particulate Matter - http://www.nationalacademies.org/hmd/Activities/PublicHealth/Health-Risks-Indoor-Exposure-ParticulateMatter.aspx
- IL Institute of Technology (Built Environment Research Group) (papers & presentations) http://built-envi.com/
- IAQ Scientific Findings Resource Data bank - https://iaqscience.lbl.gov/indoor-air-quality-iaq-scientific-findings
- IAQ Radio - https://www.iaqradio.com/
- Smell Pittsburgh - https://smellpgh.org
- ROCIS website - http://ROCIS.org
- Purple Air Map - https://www.purpleair.com/gmap
- EPA Guidelines - Air Cleaners & Air Filters in the Home https://www.epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home

PurpleAir Monitor Map
World Wide or Local



https://www.purpleair.com/gmap

Interventions: What Can We Learn with Low-cost Monitors ??

Impact of interventions in different buildings

- Better vs. worse outdoor air quality
- Indoor vs. outdoor sources
- Leakier vs. tighter homes
- Air conditioners vs. no AC

Portable Air Cleaner

Applications, Impact, & Practicality of Interventions

- Mechanical ventilation systems & strategies
- Sanctuary room/zone
- Operation of portable air cleaners / DIY Fan/Filter
- Forced air distribution filtration

24/7 Air Handler – High MERV filter intervention

INSIGHTS / RESULTS FROM ROCIS INTERVENTIONS

Conclusions

Insight to Date re Interventions

- Air filtration can significantly reduce particle counts *if the application is appropriate*
- Low cost monitors reinforce use of filtration as well as source control
- Tighter the house, the greater the impact of filtration
- But, tighter the building, the more critical it is to control indoor sources
- In some cases, shift focus from building exposure to human exposure (bedrooms?)

Options to Reduce Indoor Particles

- **Reduce air exchange from outside**
  - Close windows
  - Tighten home or building
- **Reduce indoor sources**
  - Use an effective ducted kitchen hood!
  - Use induction cook top & other good practices w/ cooking
- **Reduce resuspension**
  - HEPA vacuum
  - Walk-off mats
  - Get rid of carpets, old upholstered furniture
- **Filter air**
  - Portable air cleaners
  - Central air handler (furnace, AC, or ventilation)

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Portable Air Cleaners Fan/filters

Match the load of contaminants –

Volume (air exchange and pollutant)

Issues

- Inadequate **run time**
  - Role of **feedback** (low cost monitor)
  - **Noise** and wintertime discomfort
- **Filter** replacement
- **Cost** of air cleaner(s) ($, kWh, GHG emissions)

Filtering Air with Home Heating & Air Conditioning Systems

Simultaneously…

- ***Significant missed opportunity*** to reduce particles

- ***Major liabilities*** (energy use, emissions, energy cost, equipment life, & performance)

Our solutions reduce fine particles by 50-80% while minimizing risk

High MERV Filter - Air Handler (Filter/AHU) 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 ($, equipment durability, performance, or GHG emissions)?

High MERV Filter - Air Handler (Filter/AHU) 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 ($, equipment durability, performance, or GHG emissions)?

NO !!

Diagnostic Screen is Required

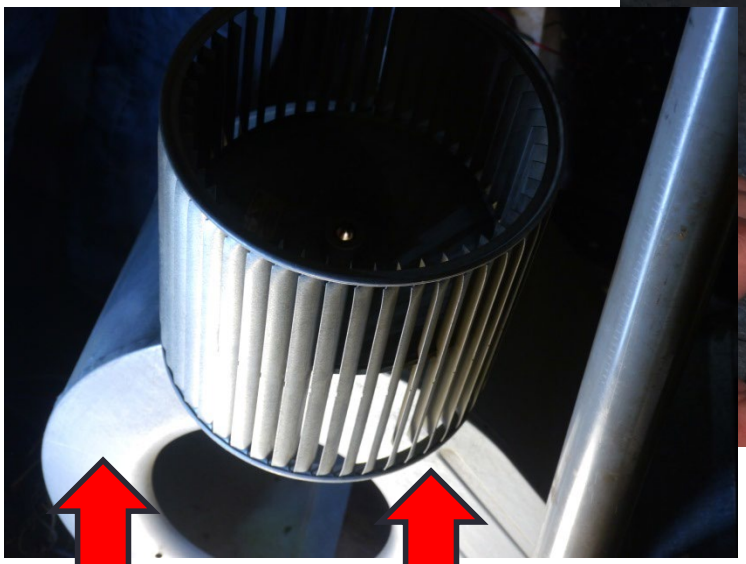
Air Handler, or Air Handling Unit

(often abbreviated to **AHU**), is a device used to regulate and circulate air as part of a heating, ventilating, & air-conditioning (HVAC) system[1]

Includes: ductwork, blower/motor, filter, coil, & controls

- [1] Wikipedia

Blower / Motor



ECM (electronically commutated motor)

This multi-speed model also allows us to set up a very low continuous movement of air for filtration, ~400 - 700 CFM, @120 - 180 Watts of power.

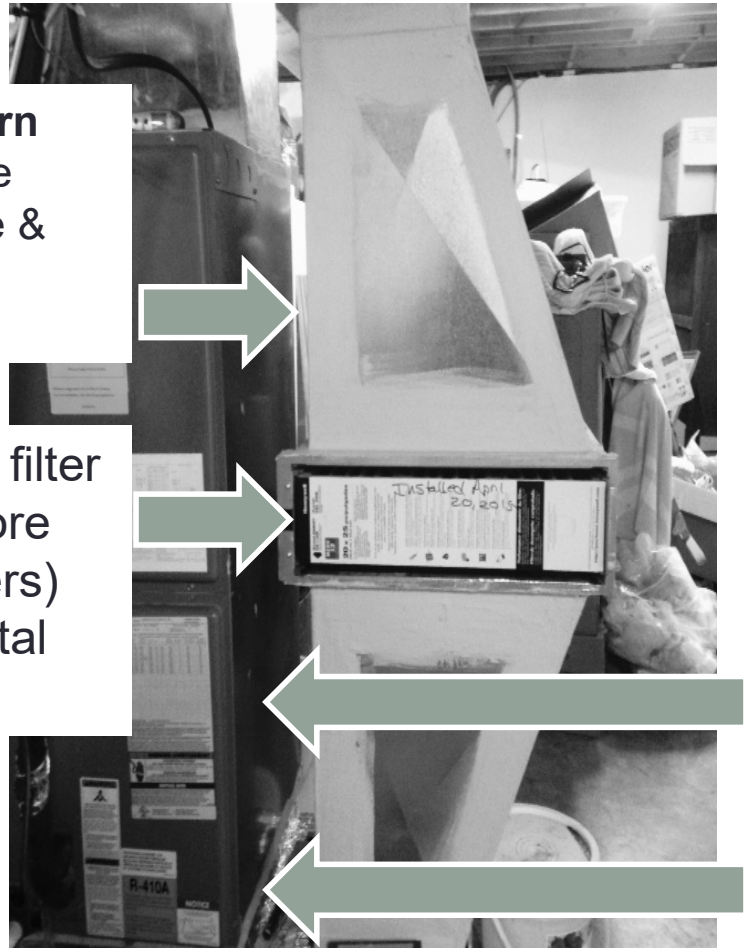
Not as efficient (or expensive) as the variable speed ECMs in many new heating & air conditioning systems.

Blower

Air Handler Inquiry – Intervention

Modified return drop to reduce static pressure & accommodate **bigger filter**

4" MERV 13 filter (plus 1 or more specialty filters) all in horizontal location



Adjust blower speed for continuous/longer operation

Consider **ECM replacement**

Elements for 24/7 Operation of AHU

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 2 filter (pre or post)

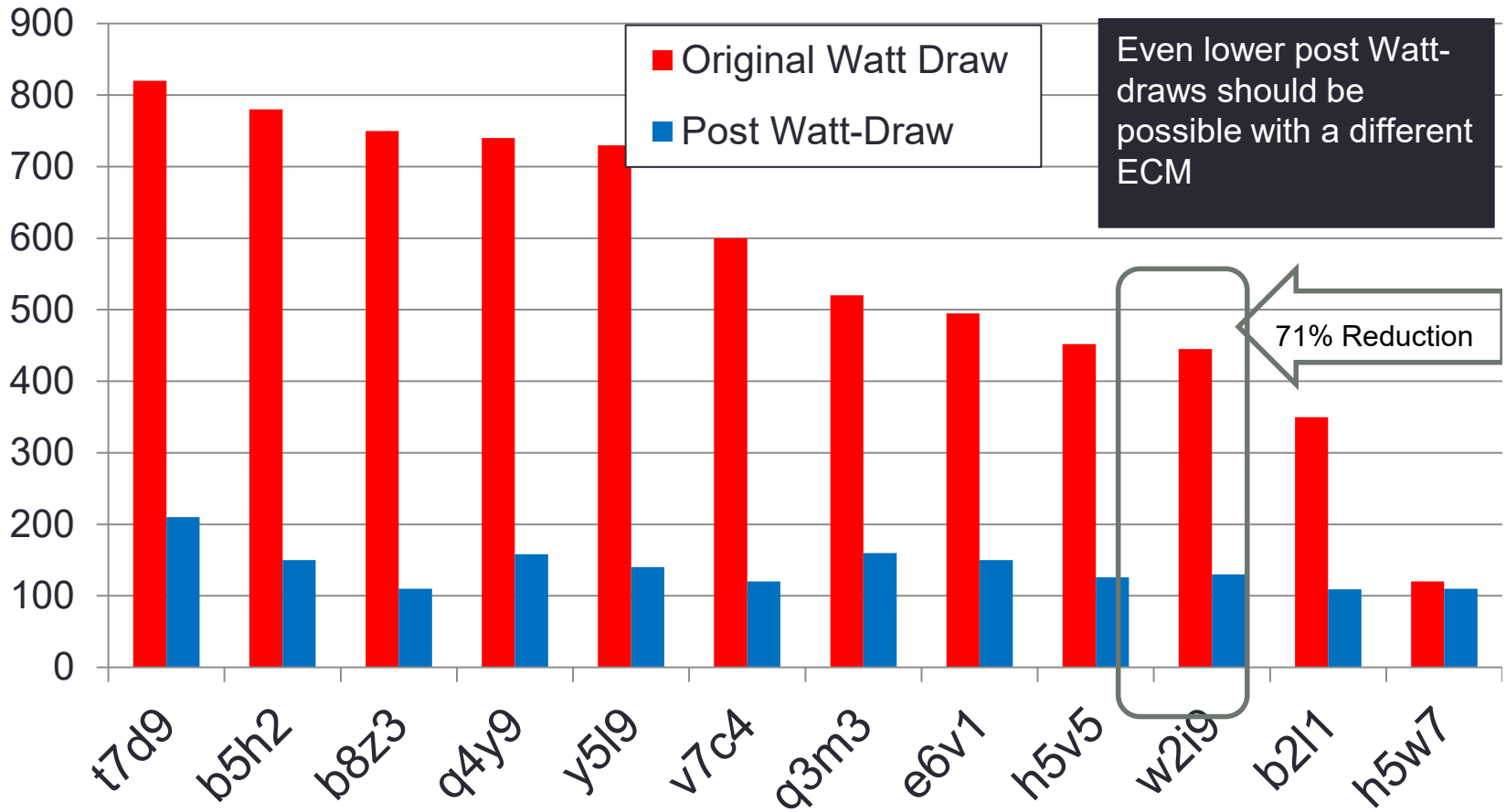
Good Duct System

- Minimal leaks to outside
- Air flow & TESP within name plate specifications

NOT RECOMMENDED:

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

Air Handler Interventions Pre-Post Continuous Watt-Draw



Use these codes **(w2i9)** to view particle data on ROCIS LMCP Data Explorer
http://rocis.org/rocis-data-explorer

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[1])

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)

[1] **$0.12/kWh**

Big Opportunity at HVAC Replacement

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

- To ponder…
  - Could potential filtration health & comfort benefits add impetus to getting HVAC systems designed & installed correctly?

Bottom Line – Air Handlers 24/7 w High MERV Filtration

- Can be very effective!
- Do not operate air handler 24/7 without confirming
  - Fan cost (electricity)
  - Minimal duct leakage to outside (big issue w/attic ducts)
  - Static pressure within operating range
  - NOTE: One-inch pleated filters can be very restrictive

Bottom Line!

Integrated solutions are needed to enhance health, resilience, energy efficiency, comfort, & durability (engagement, building tightness, source control, operation & maintenance)

Ideally, improve outdoor air quality!

Conclusions

1. Outdoor air quality affects indoor air quality
2. Low cost monitors can provide useful info on particle pollution - both on individual site basis & broader level
3. There are actions we can take to reduce our exposure - but we need an approach which is wholistic & considers both indoor & outdoor sources
4. Low cost monitoring can help empower occupants to take action & to confirm impact.

Low Cost Monitoring Project (LCMP)

- Provide indoor AQ monitoring kit – short-term loan for baseline, longer term for testing interventions
- Tap participant's homes & workplaces
- Invest in participants' experience & knowledge
- Provide protocols for reporting & interventions
- Build baseline & develop/refine best practices
- *Develop champions!!*
- 270+ participants in 41 cohorts
- Primary focus on particles (0.5+ um) indoors & outdoors

LCMP Design: Not a Regulatory Focus

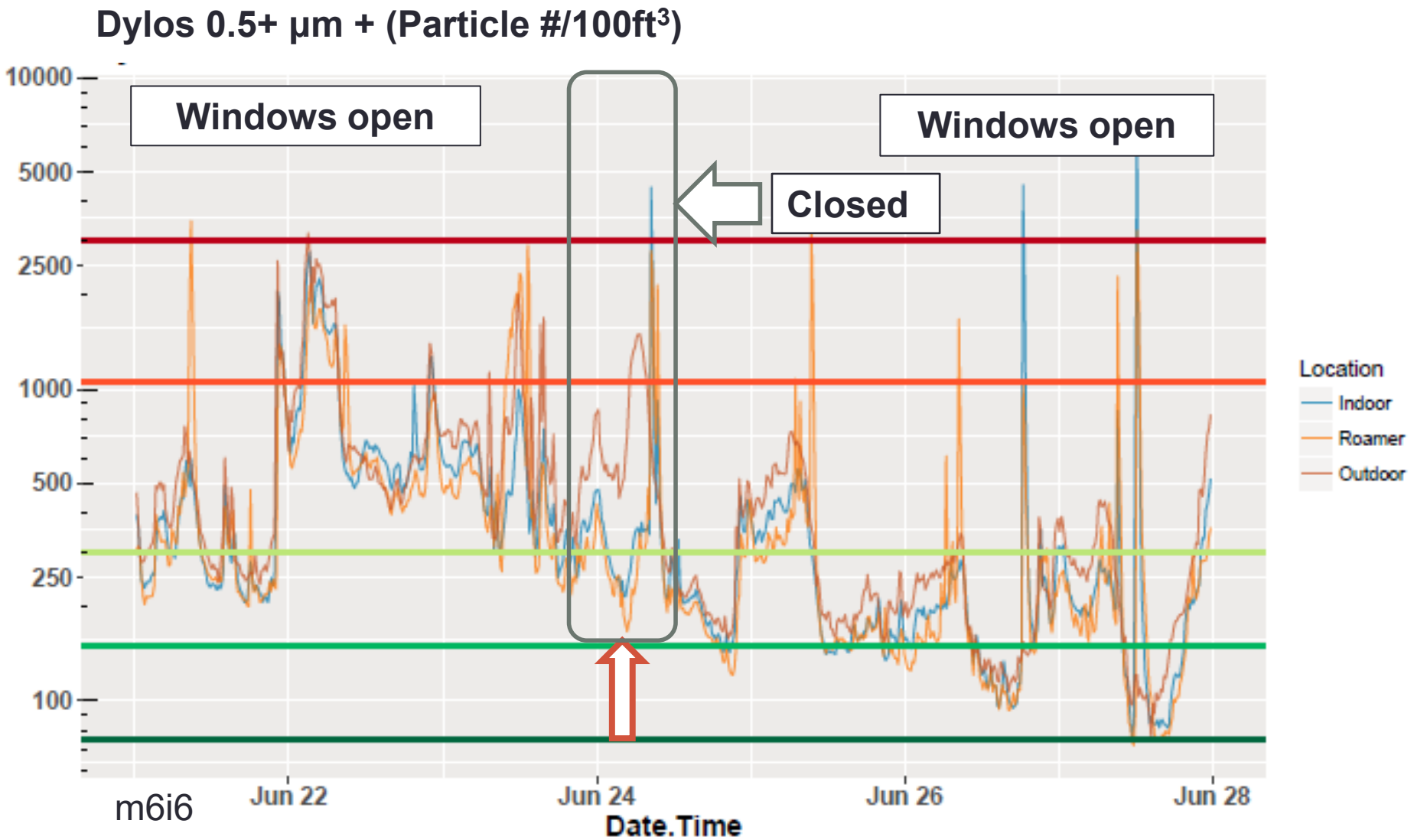
- Measuring particle count, not mass; 1-min. resolution
- Focus on indoor / outdoor comparison
- Proof of concept – exploration of interventions
- Health Concerns
  - Fine (<$PM_{2.5}$) & Ultra-Fine Particles (<$PM_{0.1}$) can be vehicles to increase exposure of toxic contaminants such as SVOCs & metals
  - Our premise: "***Precautionary principle"*** – avoid or minimize exposure

~~Outdoor vs. Indoor~~

OUTDOOR PLUS INDOOR!

CHECK OUT: HTTP://ROCIS.ORG/KITCHEN-RANGE-HOODS

Windows Open vs. Closed



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