Welcome to the CIAQ Webinar/Meeting
Wednesday, 14th February 2018
1:00 – 4:30 PM EST

Please standby, the CIAQ Webinar will being momentarily – thank you.

Register for the Webinar
attendee.gotowebinar.com/register/2723662213966879745
Operator Assisted Conference Call
1-855-833-8661
Conference Call ID#
4286469

Opt-in here to receive email updates about healthy indoor air.
[https://public.govdelivery.com/accounts/usepaiaq/subscriber/new]

Welcome to the CIAQ Webinar/Meeting
Wednesday, 14th February 2018
1:00 – 4:30 PM EST

Webinar: attendee.gotowebinar.com/register/2723662213966879745; Audio: 1-855-883-8661 / ID#: 4286469

- Welcome, introductions and announcements, *Laureen Burton, Moderator EPA*

- Updates on IAQ & IEQ activities from Federal CIAQ Member Agencies
  1—*DOE, Department of Energy*
  2—*NIST, National Institute of Standards and Technology*
  3—*CPSC, Consumer Product Safety Commission*
  4—*EPA, Environmental Protection Agency*

  Q&A (DOE, NIST, CPSC and EPA updates)

Presentations:

Responses of Consumer Grade Monitors to Residential Sources of Fine Particulate Manner

- Brett Singer, Indoor Environment Group Lead, Lawrence Berkeley National Laboratory

Responses of Consumer Grade Monitors to Residential Sources of Fine Particulate Manner

- Linda Wigington, Team Leader, Reducing Outdoor Contaminants in Indoor Spaces (ROCIS)

Consumer IAQ Monitor Responses to Residential Sources of Fine Particulate Matter

Brett C. Singer and Wm. Woody Delp
Lawrence Berkeley National Lab
wwdelp@lbl.gov
bcsinger@lbl.gov

Presented to the
Federal Interagency Committee on IAQ
February 14, 2018

BERKELEY LAB
Lawrence Berkeley National Laboratory

Acknowledgements

Funding:

- US Dept. of Energy, Building America Program
- US Environmental Protection Agency, Indoor Environments Division
- US Dept. of Housing and Urban Development, Office of Healthy Homes and Lead Hazard Control
- US-China Clean Energy Research Center – Building Energy Efficiency Project, IEQ Study

Simon Walker helped with experiments and data downloads.

Dr. Yang-Seon Kim weighed filters for gravimetric measurements.

Consumer Grade Monitors

AB

PM, T, RH

1 sec

AVN

$PM_{2.5}$, PM_{10}, CO_2, T, RH

10 sec – 15 min

AQE

PM, T, RH

1 min

AWA

PM, CO_2, VOC, T, RH,

10 sec – 5 min

FOB

PM, CO_2, VOC, T, RH,

5 min

PA

$PM_{1.0}$, $PM_{2.5}$, PM_{10}, T, RH

80 sec

SPK

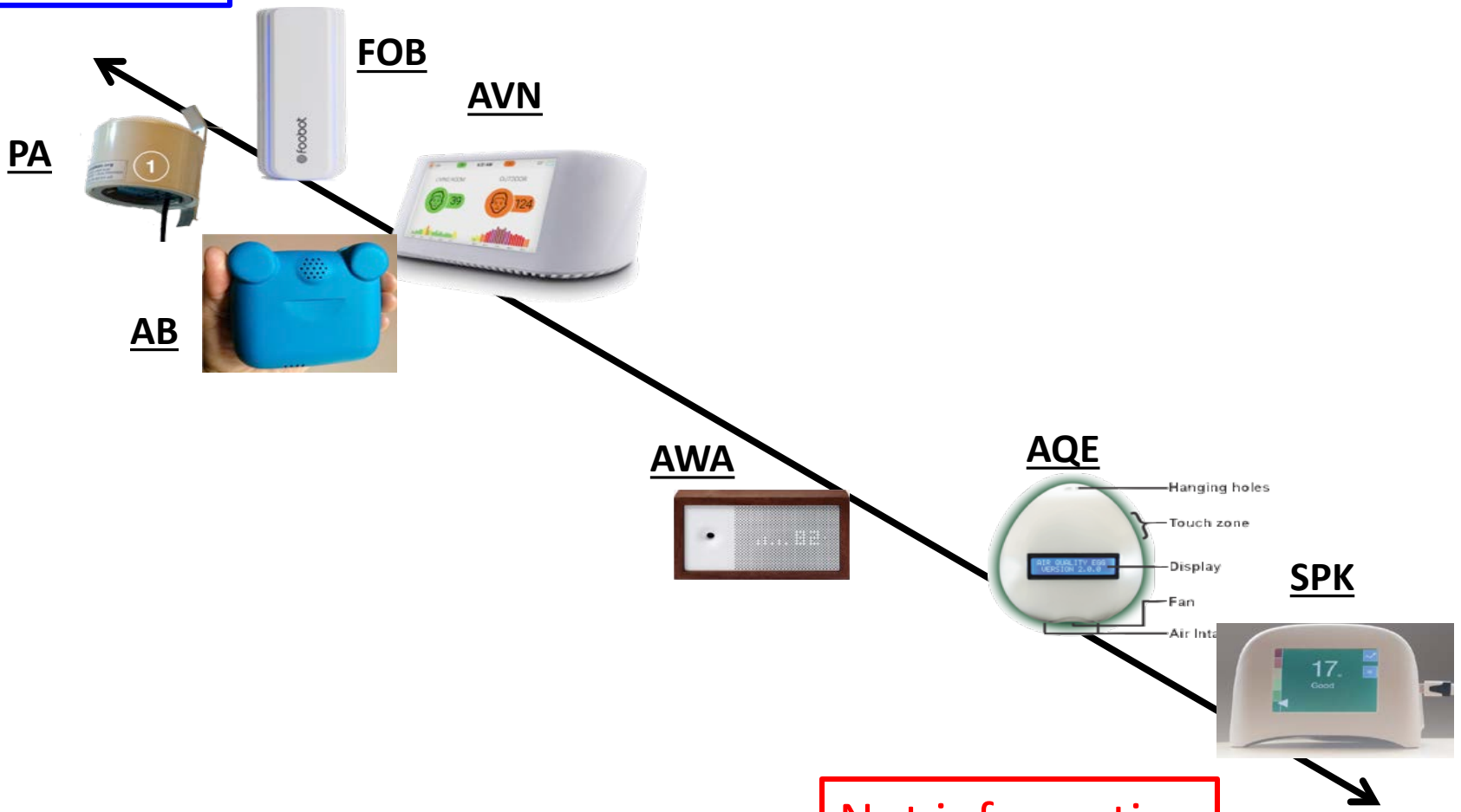
PM, # particles T, RH

1 min

These use mass-produced particle sensors that cost <$10 to $35

Results

Informative



Not informative

Focus on Fine Particulate Matter ($PM_{2.5}$)

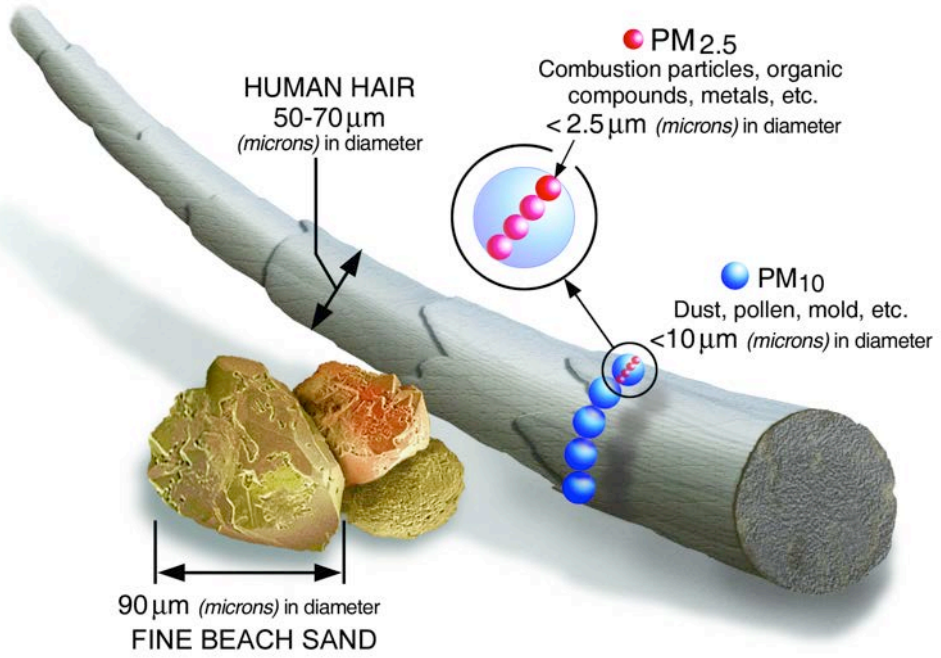
Higher ambient $PM_{2.5}$

…causes increased cardiovascular morbidity and mortality;

…is associated with and likely causes respiratory illness.[1]

In-home exposure to $PM_{2.5}$ causes more health damage than any other non-biological air pollutant.[2]

$PM_{2.5}$ detection can enable control by ventilation or filtration.



www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM

1. EPA, *Integrated Science Assessment for Particulate Matter*. Washington, DC: U.S. Environmental Protection Agency; 2009.
2. Logue, *Environ Health Perspect.* 2012;120:216-222.

$PM_{2.5}$ Benchmarks

Standard	Annual mean ⌈g /m³	24-h mean ⌈g /m³
US Ambient Standard (2012)	12	35
WHO Guideline Values (2005)	10	25
Canadian Ambient Standard 2015	10	28
Canadian Ambient Standard 2020	8.8	27

Reference $PM_{2.5}$ Measurements

- U.S. federal reference method (FRM) is gravimetric: specifies pump, inlet, filter, and weighing procedures
  - Designed for 24h int.
  - Too noisy for indoors.
- Alternative gravimetric sampling equipment designed for indoor spaces

  - Integrated
  - $1500
- Federal equivalent methods (FEM)
  - Tapered Element Oscillating Microbalance
  - Beta attenuation
  - Specialized optical methods

1h or less
$10-25K per unit

Research PM Monitors

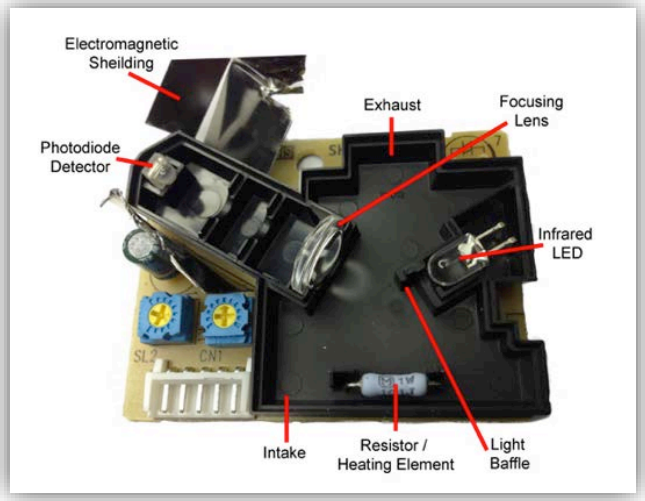
- Photometers that measure scattering of composite aerosol developed for occupational health, used for residential research.
- Cost $4-10K for analyzer; $500 for OEM sensor unit.

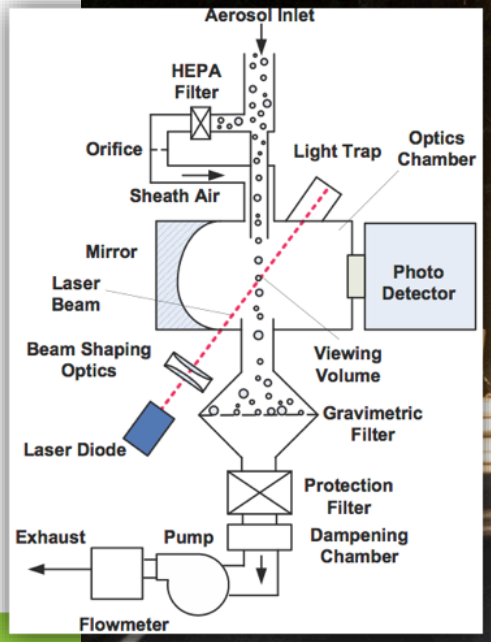
Scattering Light

The intensity of scattered light depends on:

- Light wavelength
- Detection angle
- Particle size
- Refractive index

Approximately linear with mass!

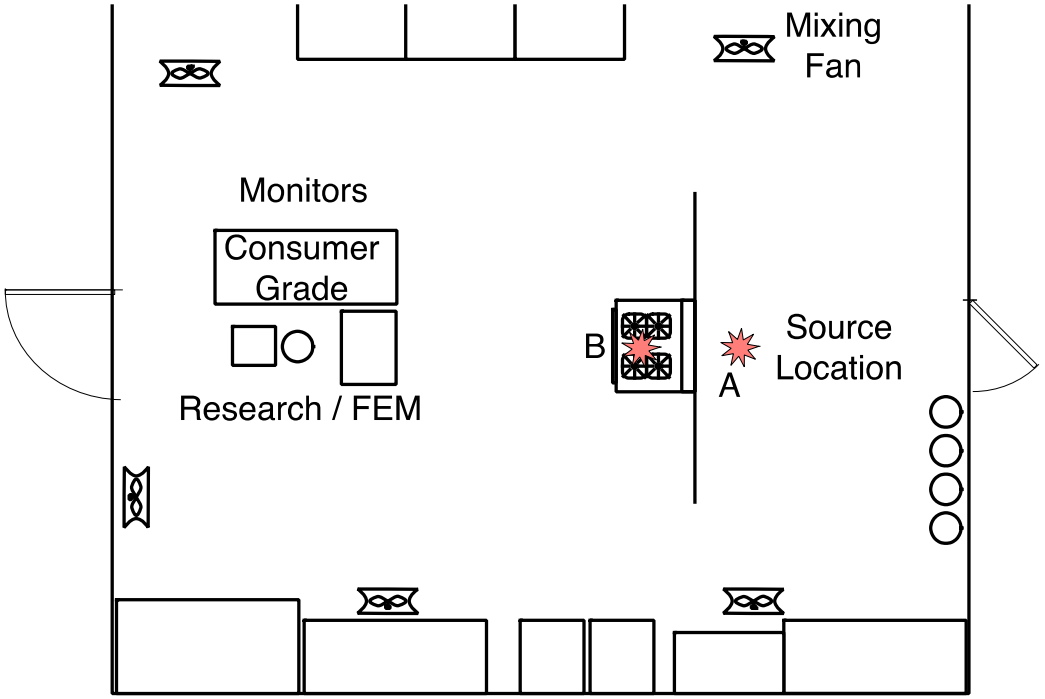


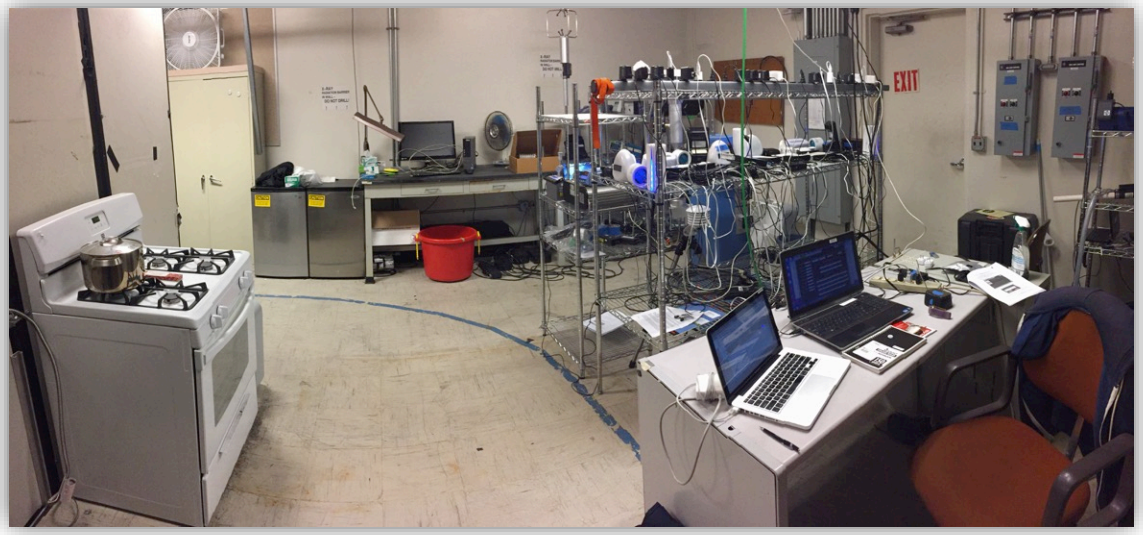


Room Setup

450 ft^2
~126 m^3

It is generally linear with mass!





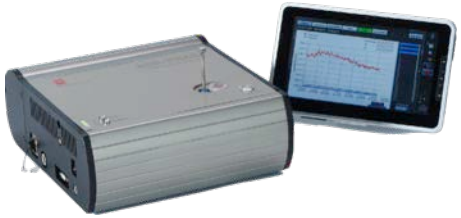
Reference & Research Instruments

FDMS-TEOM (FEM)

5 min*

PEM + Pump

~1 hr



1 min

GRM

Sophisticated optical particle spectrometer coupled with an electrical mobility analyzer provides 41 bins from 10 nm up to 35 μm

"True" $PM_{2.5}$ estimated using FDMS to get mass and GRM to get time-resolution

Mass reading scattering devices

PDR

20 sec

BT

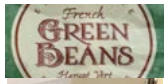
Sources



Burned incense, candles and cigarettes



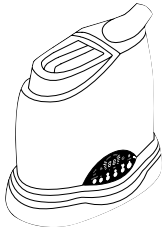

Heated pots of water, an oven, a hair dryer, and an electric burner





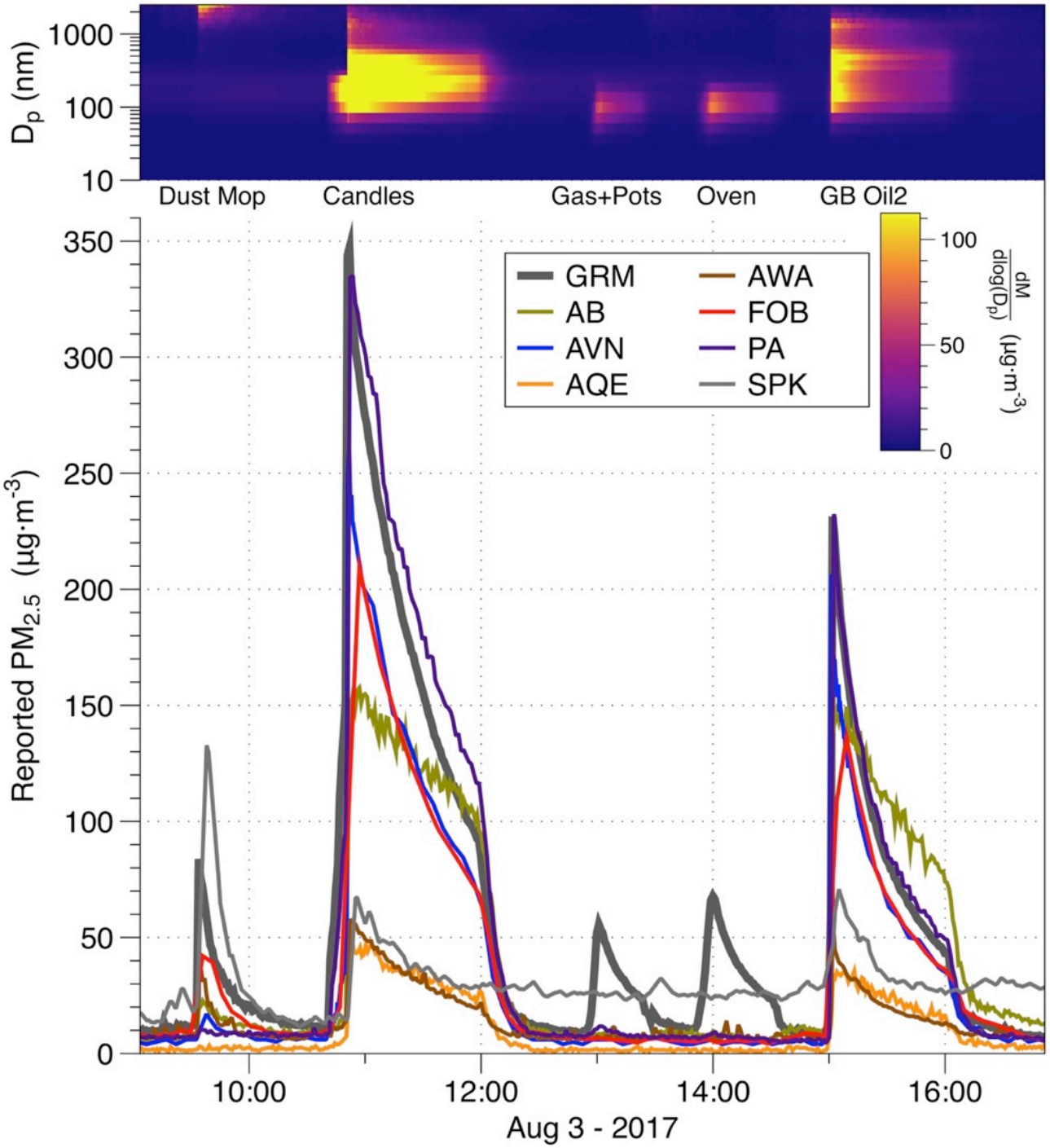


Cooked green beans, bacon, pancakes, toast, and a pizza, and heated canola oil

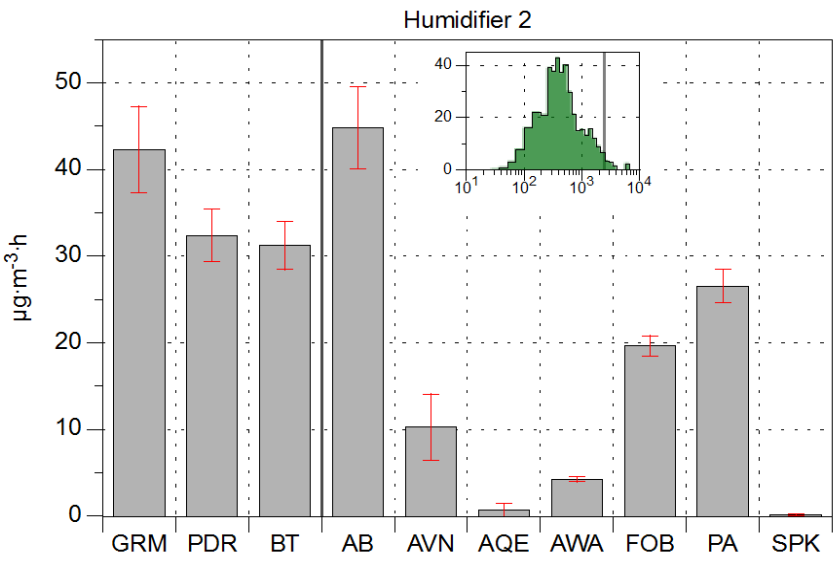



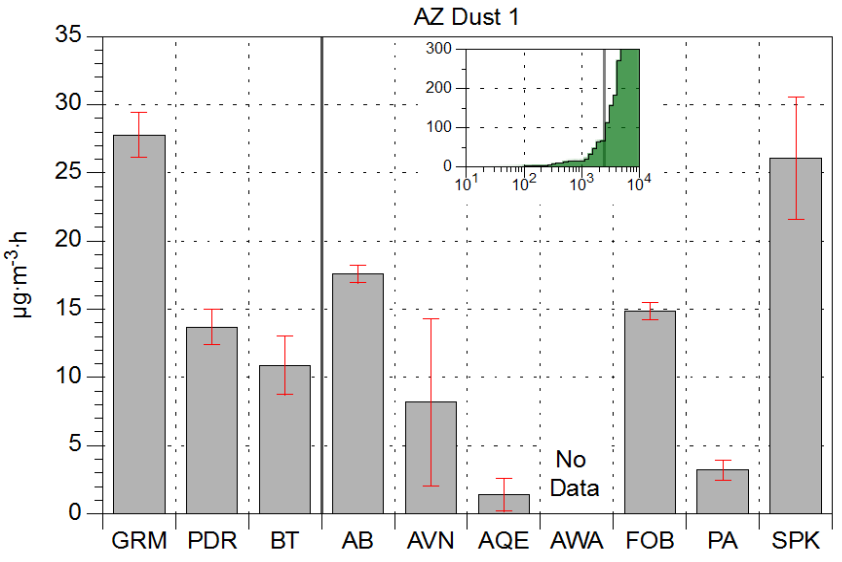
Released AZ test dust, shaked a dust mop, and operated an ultrasonic humidifier using unfiltered tap water

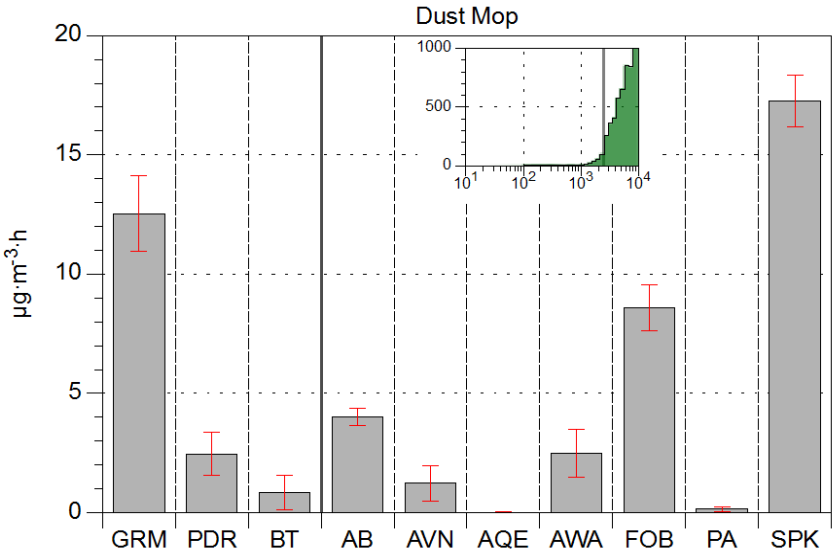
Example Data

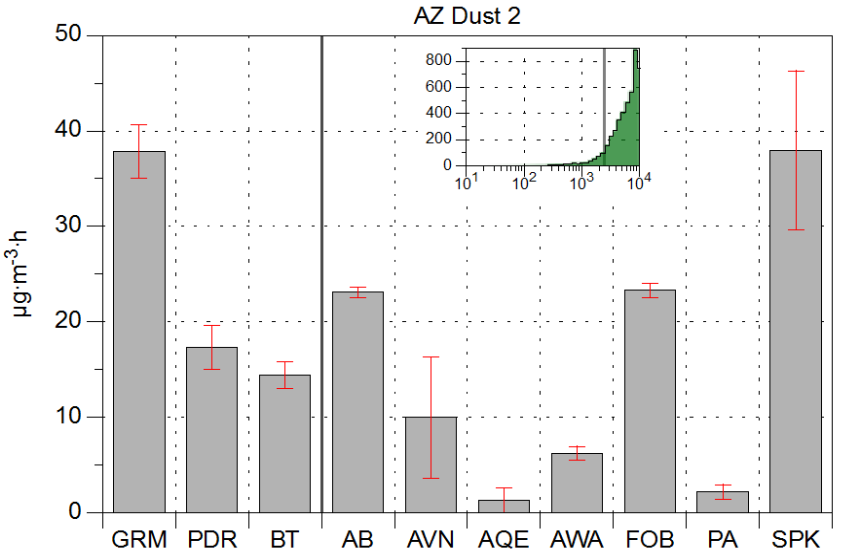


Unfiltered Humidifier and Dust

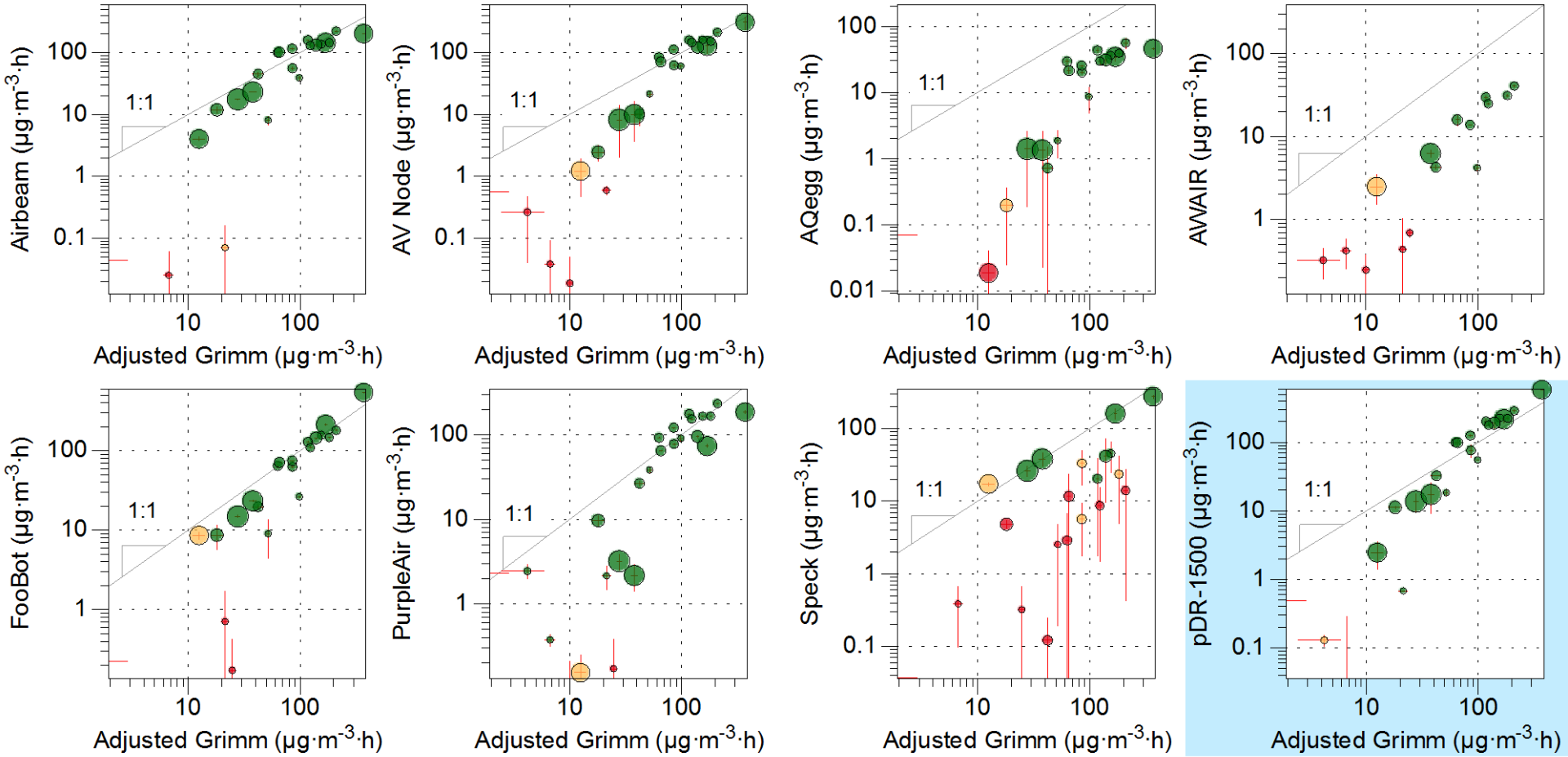




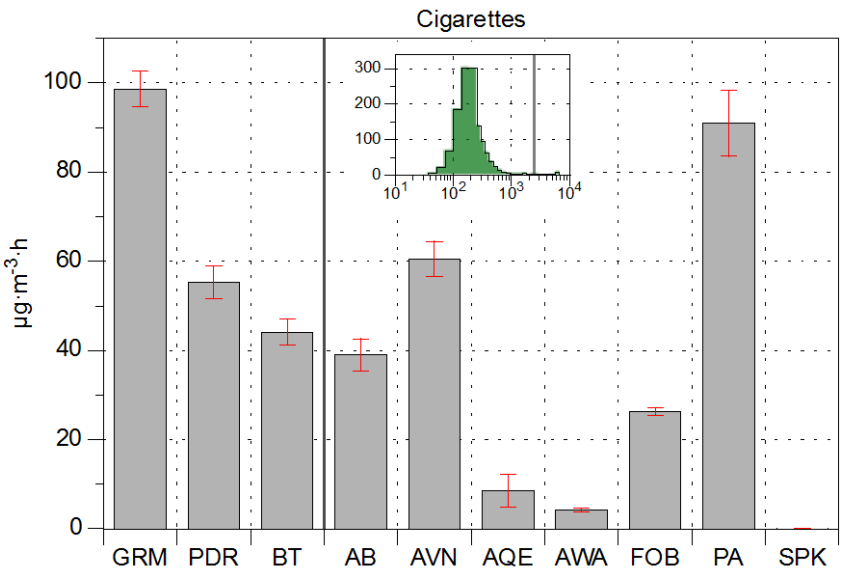


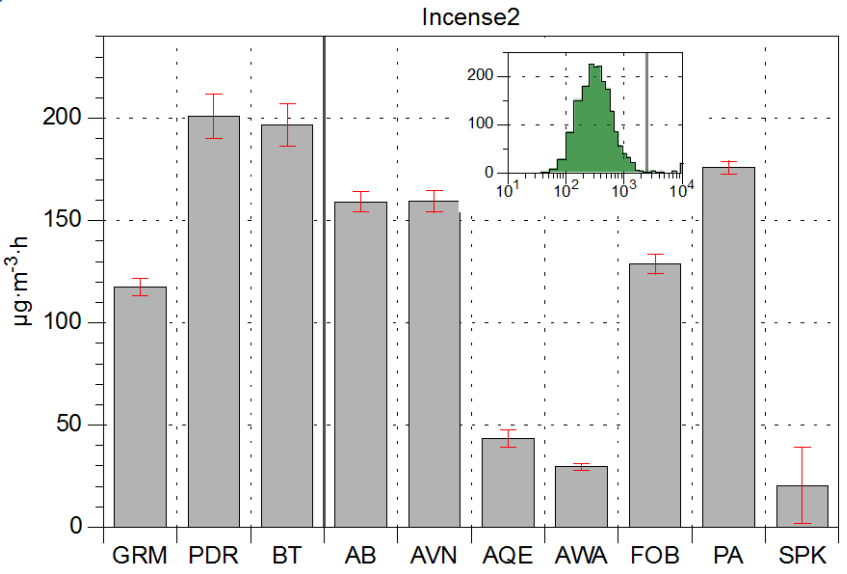


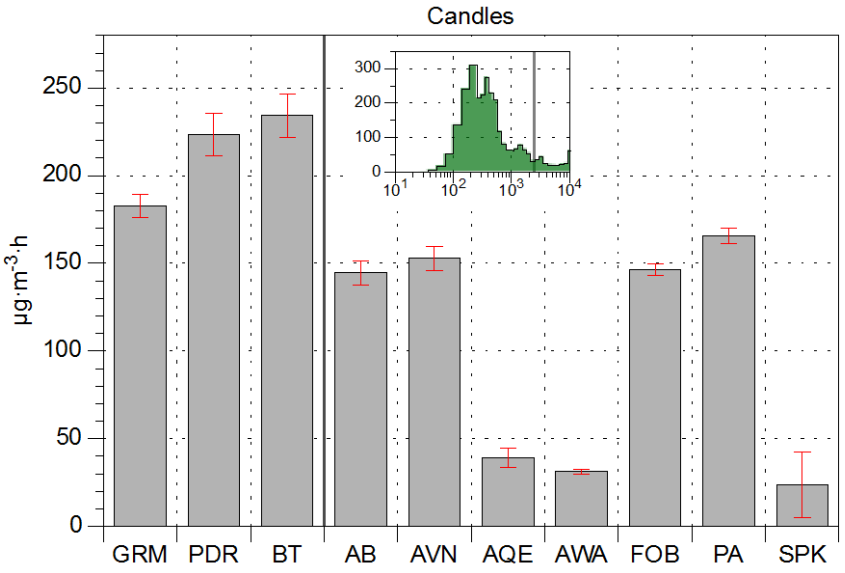
Results

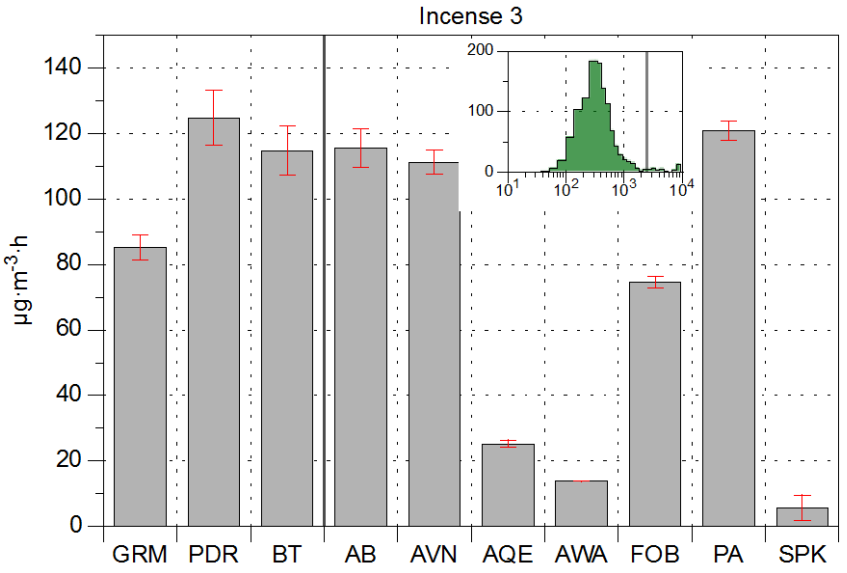

Airbeam (µg·m-3·h)
AV Node (µg·m-3·h)
AQegg (µg·m-3·h)
AWAIR (µg·m-3·h)
FooBot (µg·m-3·h)
PurpleAir (µg·m-3·h)
Speck (µg·m-3·h)
pDR-1500 (µg·m-3·h)
1:1
Adjusted Grimm (µg·m-3·h)
Spearman's Correlation
< 0.6
≥ 0.6 < 0.8
≥ 0.8
1800
900
300
150
PSD
MMD (nm)

Recreational Combustion

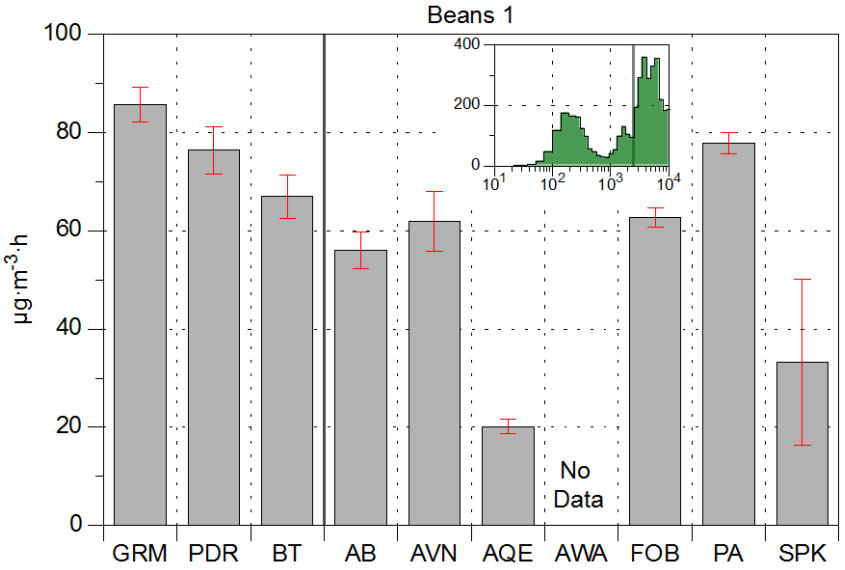


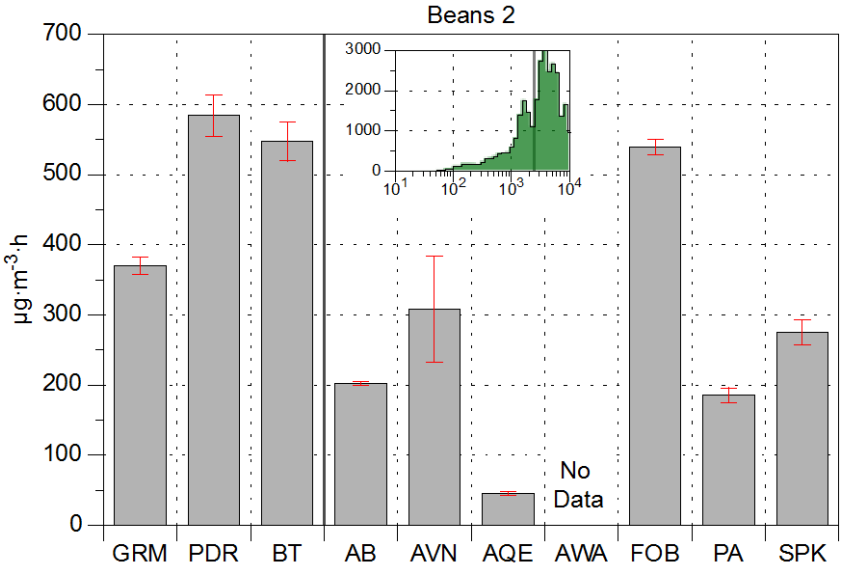


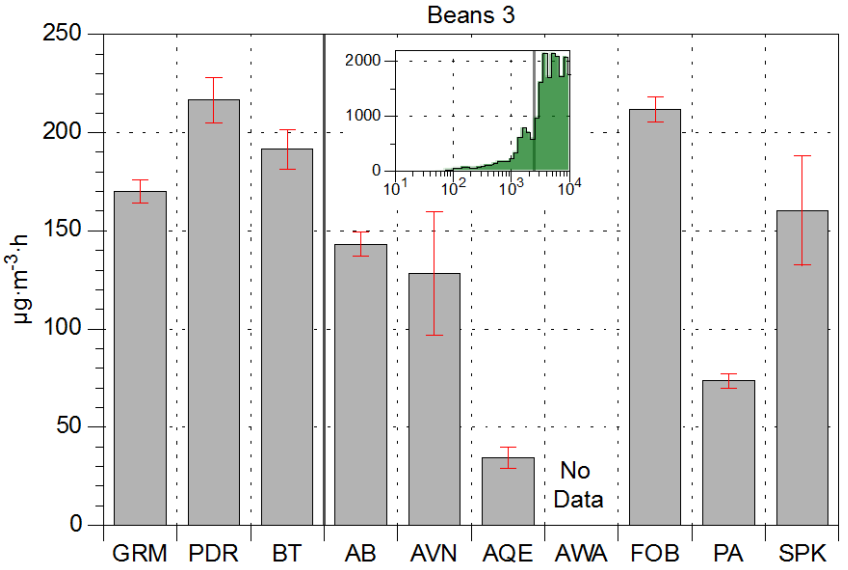


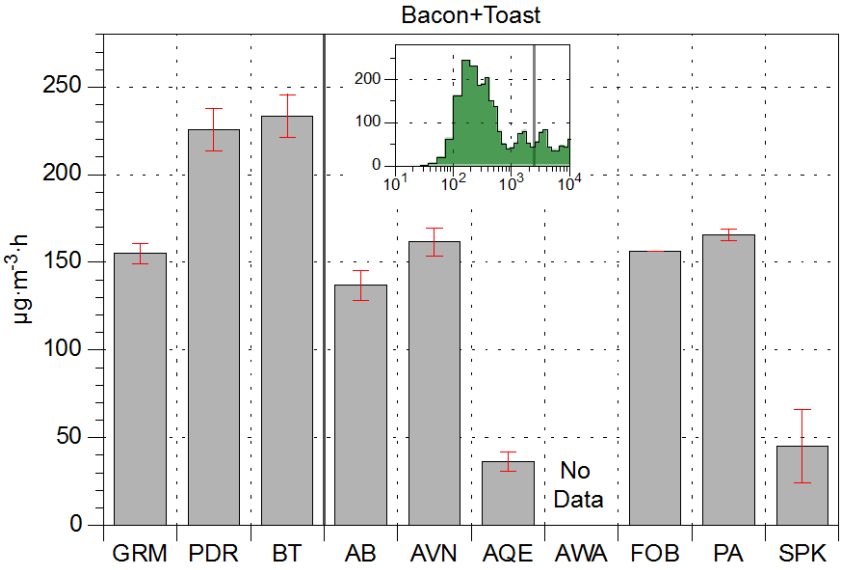


Stir-Frying and Frying + Toasting

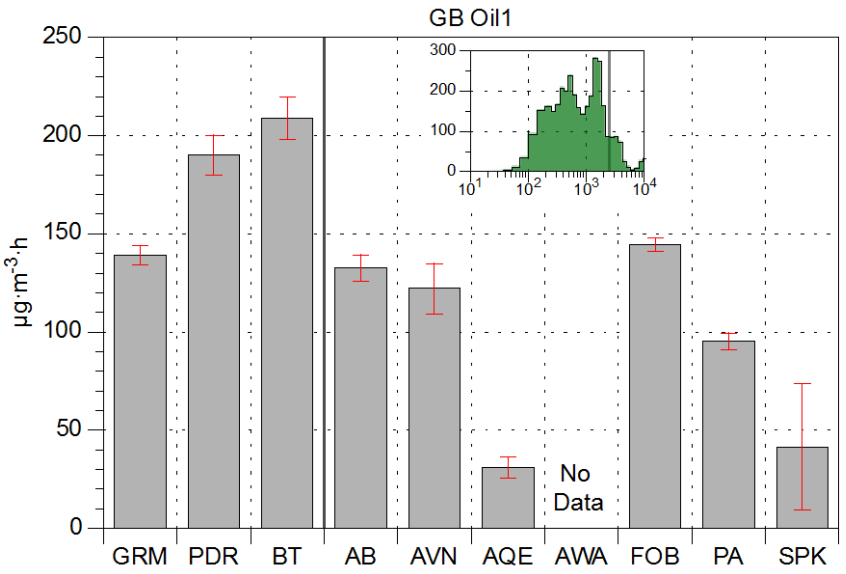


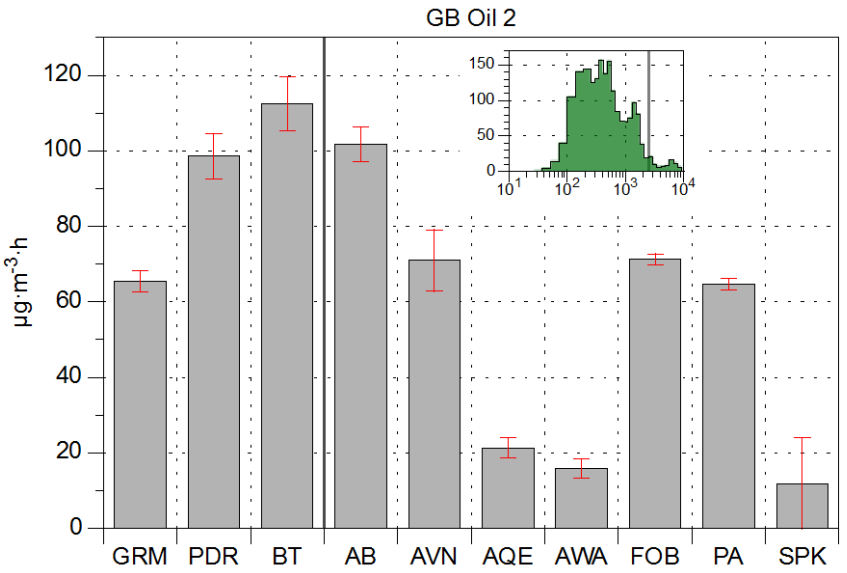


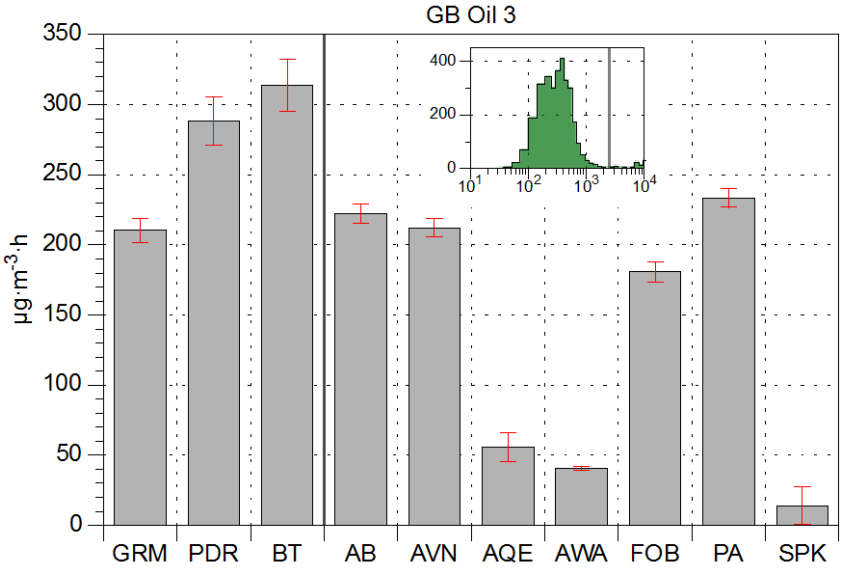


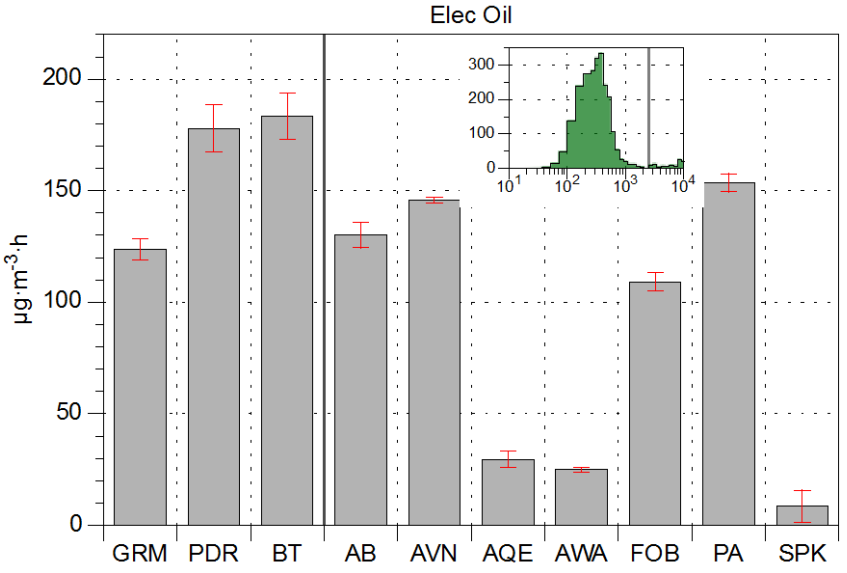


Heating Oil on Gas or Electric Burners

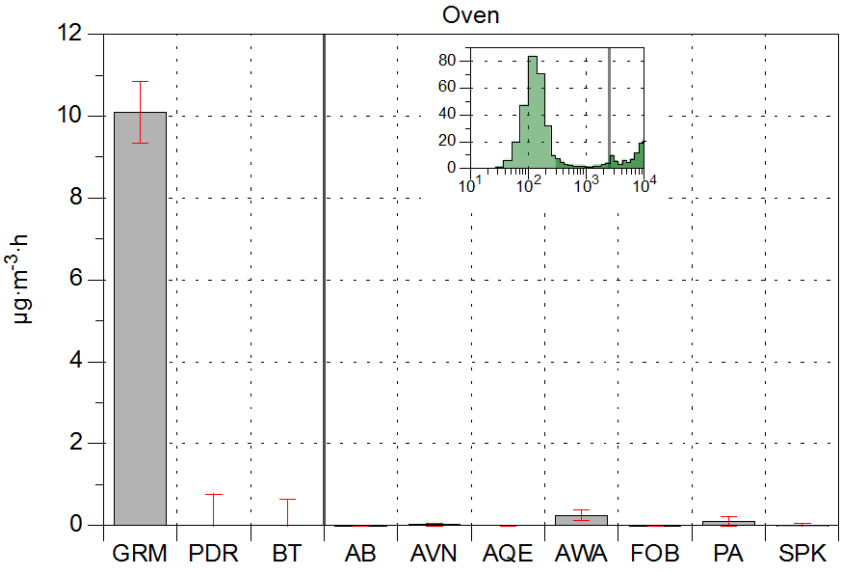


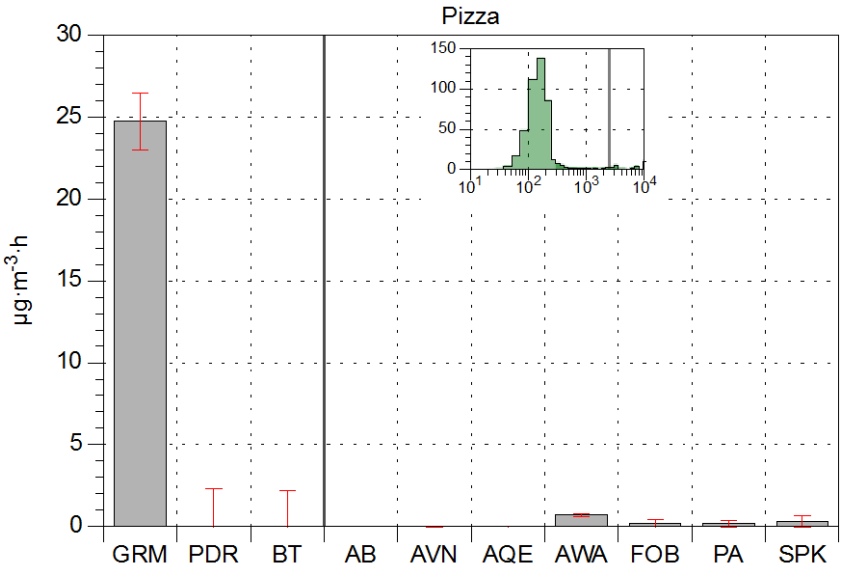


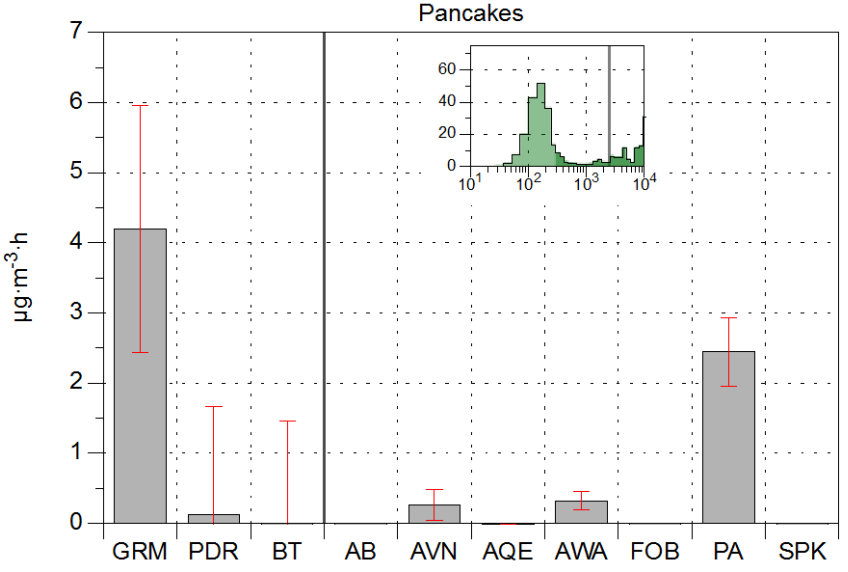


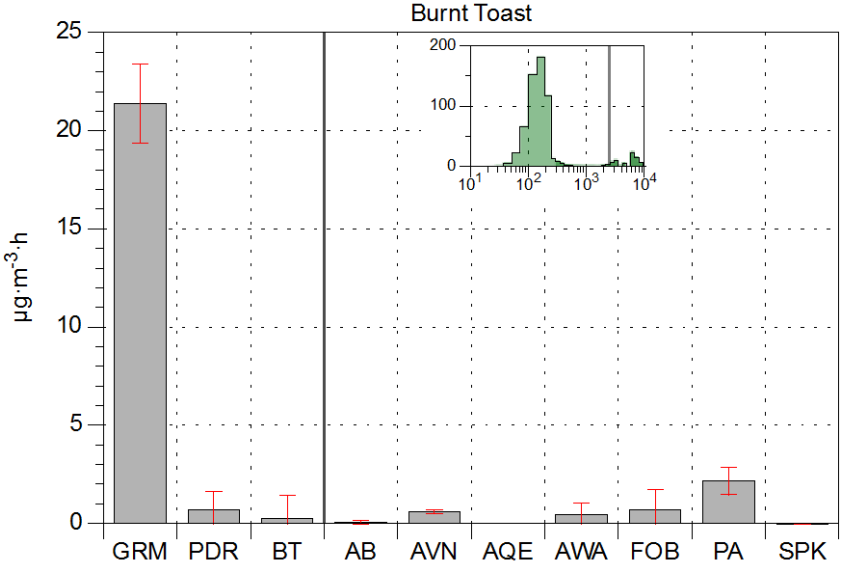


Cooking that Emits Mostly <0.3 um Particles

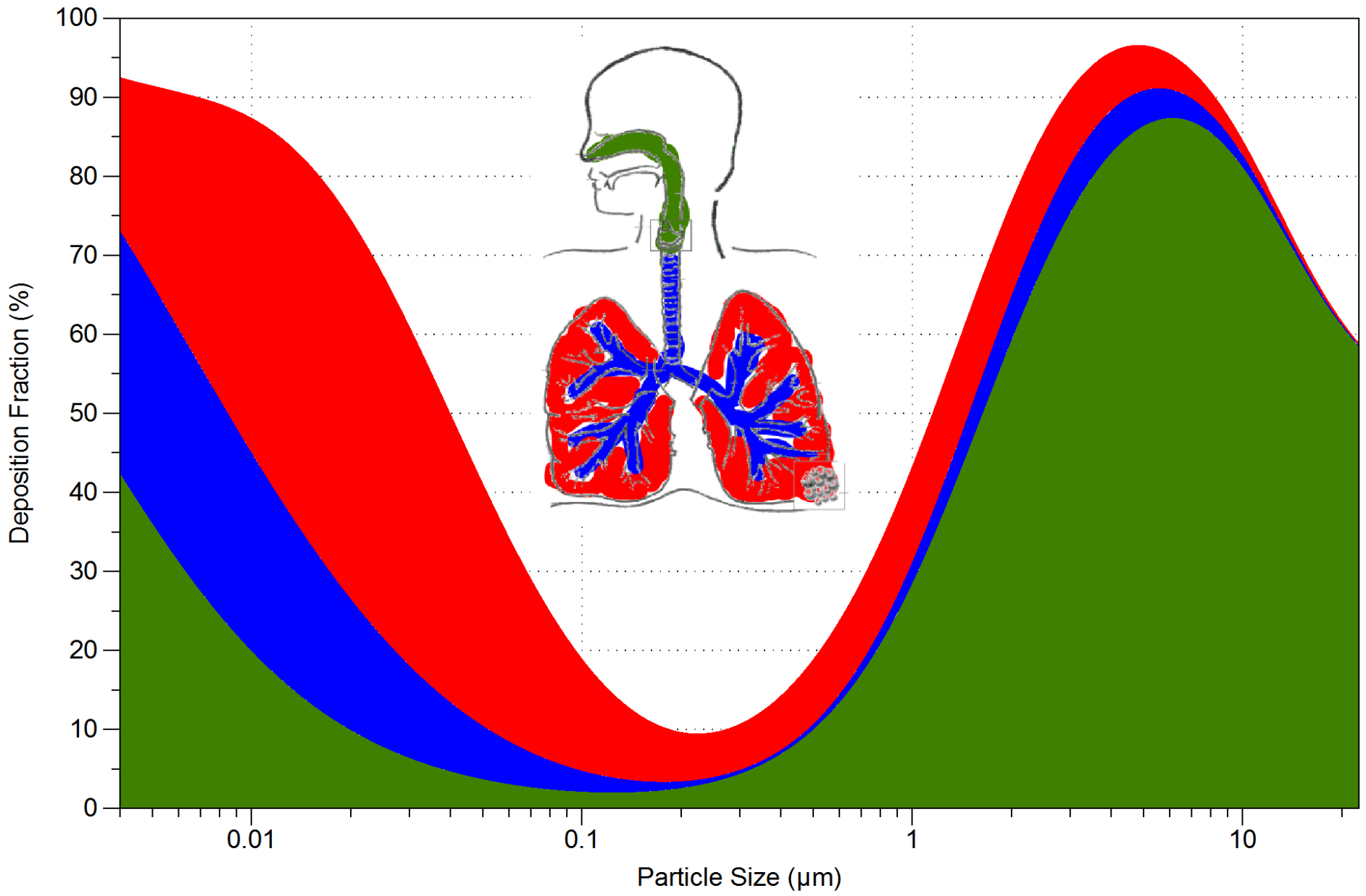






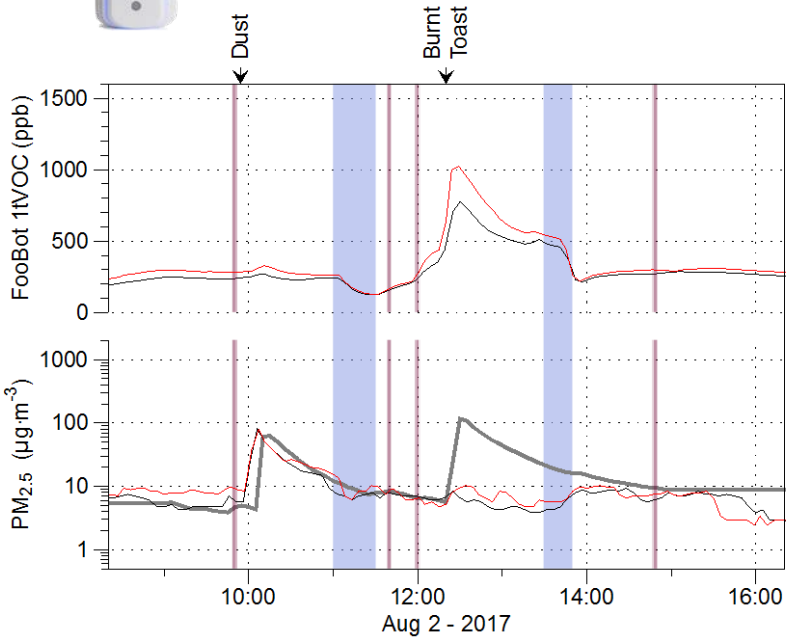


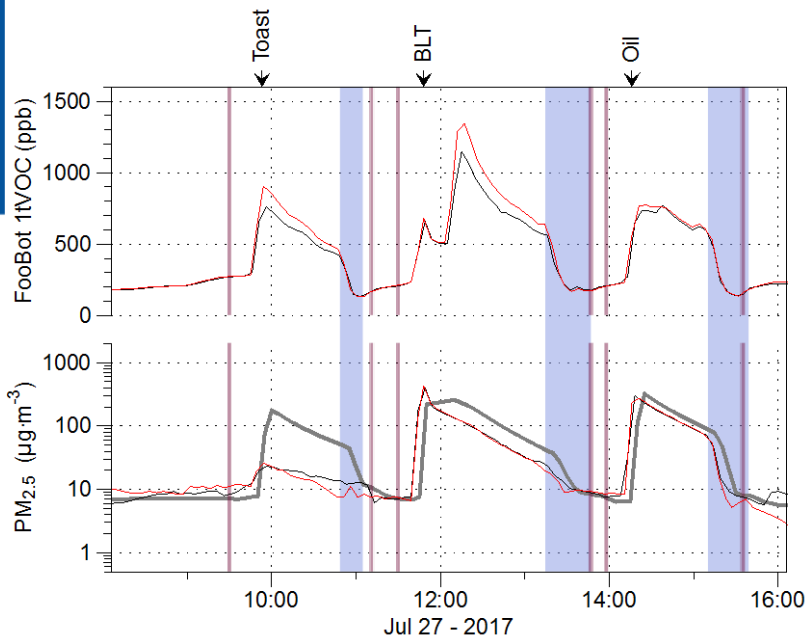
Size Matters for Particles

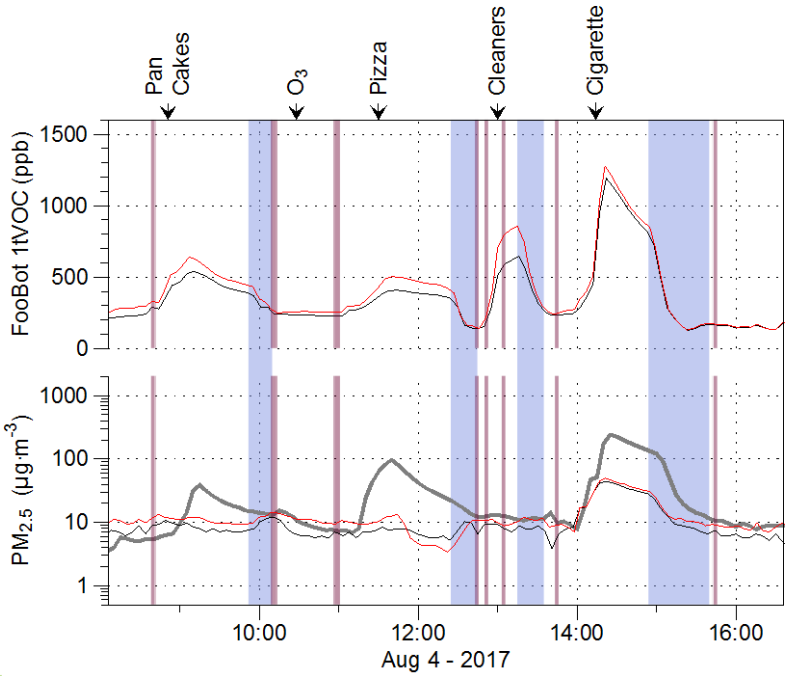


Developed from ICRP Publication 66. Human Respiratory Tract Model for Radiation Protection, 1994.

VOC sensor detected cooking events with only small particles

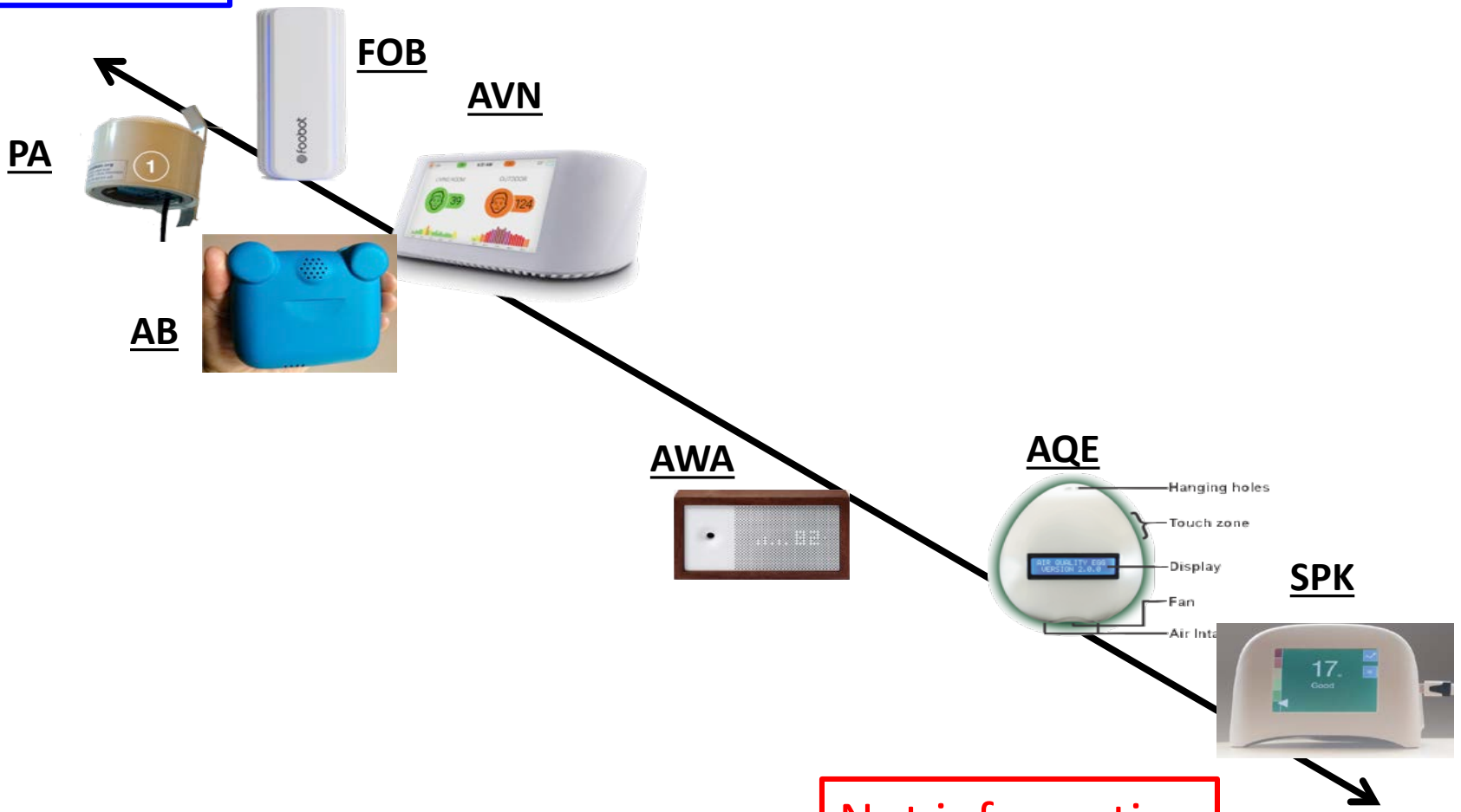






Results

Informative



Not informative

Conclusions

Four consumer monitors detected most sources and quantitatively measured all large sources of $PM_{2.5}$.

➔Appear suitable to manage IAQ.

Two consumer monitors detected many sources but not quantitatively.

One monitor was not informative.

Results should be verified in homes.

- What fraction of $PM_{2.5}$ detected?
- How durable are the devices?

Consumer monitors not suitable to detect & control ultrafine particles.

PA

FOB

AB

AVN

AWA

AQE

SPK

Questions?

Woody Delp
wwdelp@lbl.gov

Brett C. Singer
bcsinger@lbl.gov

ROCIS:
LOW-COST PARTICLE MONITORING INSIGHTS & INTERVENTIONS

Federal Interagency CIAQ MEETING

February 14, 2018

Linda Wigington
Team Leader, ROCIS Initiative
lwigington1@outlook.com
724-852-3085
www.ROCIS.org

Conclusions

- Outdoor particle counts have a significant impact on indoor levels
- Visualization tools influence how one interprets the data
- Particle monitors that measure down to 0.5+µm (or lower) appear to have a significant benefit (over 2.5+ um) when viewing outdoor air impacts.
- Low-Cost monitors can contribute to awareness, behavior change, use of technical interventions, & building capacity of people, communities, & organizations

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

WWW.ROCIS.ORG

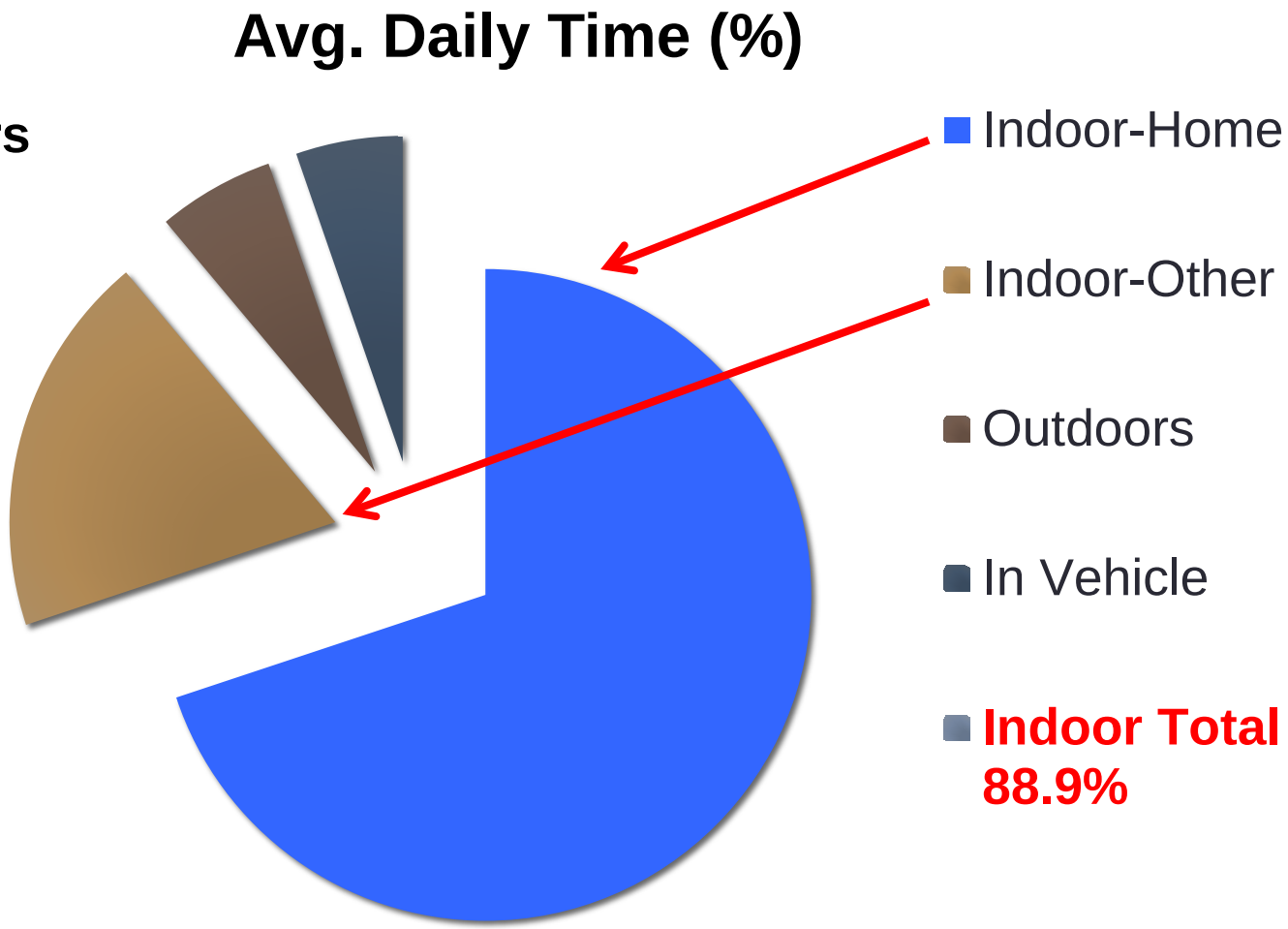
WHAT IS ROCIS ?

MISSION

Reduce the impact of exterior environmental pollution in southwestern Pennsylvania to improve healthy & energy efficient indoor environments where we live, work, & learn

Why is IEQ Important?

- About 90% of our time is spent indoors
- Vulnerable groups spend more time indoors (95%+)



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.

LOW COST MONITORING PROJECT

FOCUS ON PARTICLES

Also referred to as Particulate Matter (PM)

Low Cost Monitoring Project (LCMP)
Objectives

1. **Understand How to Use Monitors to Empower Occupants/Build Capacity**

2. **Collect Baseline Data**

3. **Explore the Impact of Behavioral & Technical Interventions**

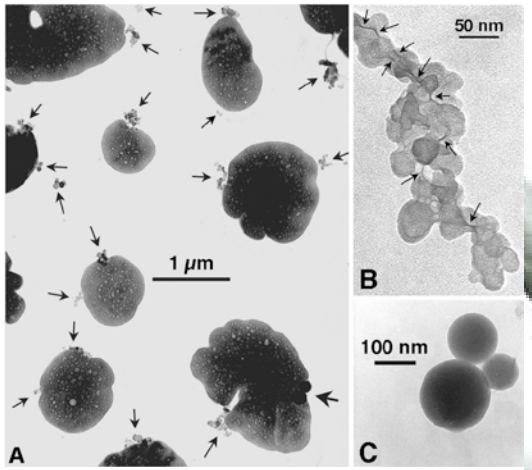
Pittsburgh's Air Quality is Poor

- **8th worst city[1], and worst city east of the Rockies**
- **People Most at Risk in the U.S.**
- **Year-round particle pollution (Annual $PM_{2.5}$)**
- **On the county level, Allegheny County (Pittsburgh) is 13th worst**

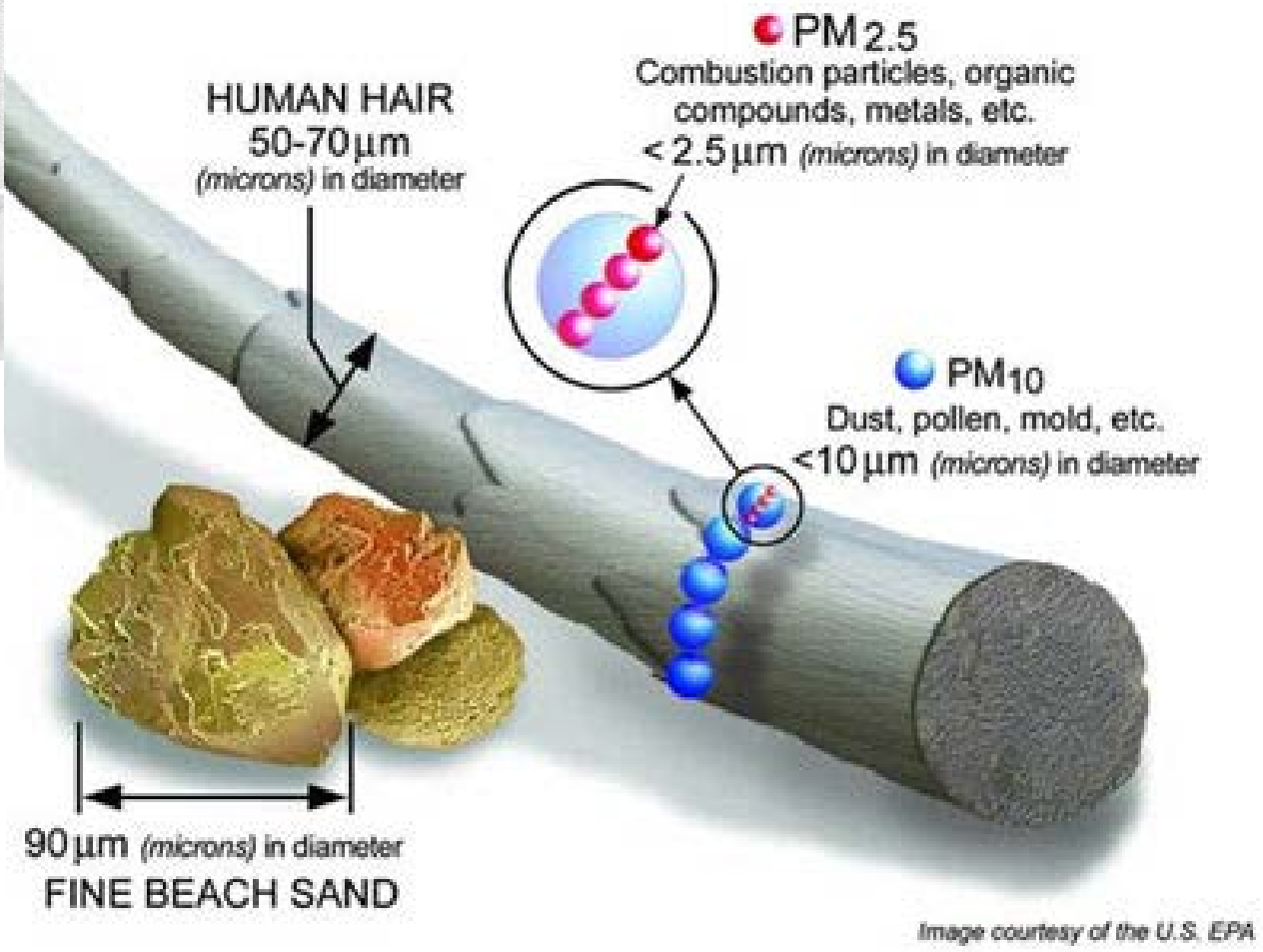
1. Pittsburgh-New Castle-Weirton (PA-WV-OH)

SOURCE: American Lung Association State of the Air Report 2017
http://www.lung.org/assets/documents/healthy-air/state-of-the-air/state-of-the-air-2017.pdf

Particles



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: $PM_{0.5}$+: Particulate matter is *greater than* 0.5 µm in diameter (1/100 of human hair!)

Making the Invisible Visible

Dylos 1700 Optical Particle Counter:
Particles per 100 ft^3, 1 min. resolution

2 size ranges:

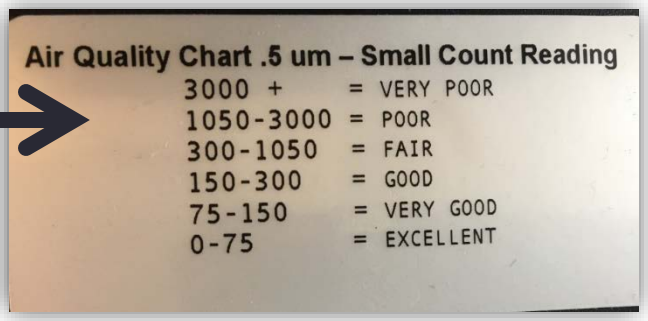
- > **0.5+ µm (Dylos "Total")**
- > 2.5+ µm (Dylos "Large")

Cost: $300 - 400; 1 week data storage

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

LCMP Design: Not a Regulatory Focus

- **Measuring particle count, not mass; 1-min. resolution**
- **Household / building level**
- **Cohort of occupants – 3-4 week monitoring period**
- **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
  - Precautionary principle should apply – avoid or minimize exposure

Occupant Insights – Real-Time Visualization of Particles

Spikes dominate awareness

Biggest Impressions (Indoor Incidents)

- Cooking
- Cleaning
- Active occupants (e.g. children)
- Remodeling

Visualization Challenges
Making Sense out of Data!

80 million data points –

…downloaded manually, 20K at a time!

- **Comparison to others**
- **Impact of outside counts on inside**
- **Comparison over time / Impact of interventions**
  - Did actions make a difference? How much?

Visualize Impact of Outdoor on Indoor, and Impact of Interactions

ROCIS LCMP tools include:

(http://rocis.org/rocis-data)

- Outdoor Dylos Data Plot by Cohort (Weebly site)
- LCMP Averager (Excel macro)
  - Feedback after each download
  - http://rocis.org/rocis-averager
- LCMP Data Explorer (R Shiny web app)
  - http://rocis.org/rocis-data-explorer

Initially, We Failed to Anticipate…

Cost and time required to -

1. Manage inventory of equipment
2. Address calibration

1. Between Cohorts: Quick Calibration Check

Compare against several reference monitors

2. Longer-term continuous monitoring

Compare against other onsite monitors & swap out every 4-6 months

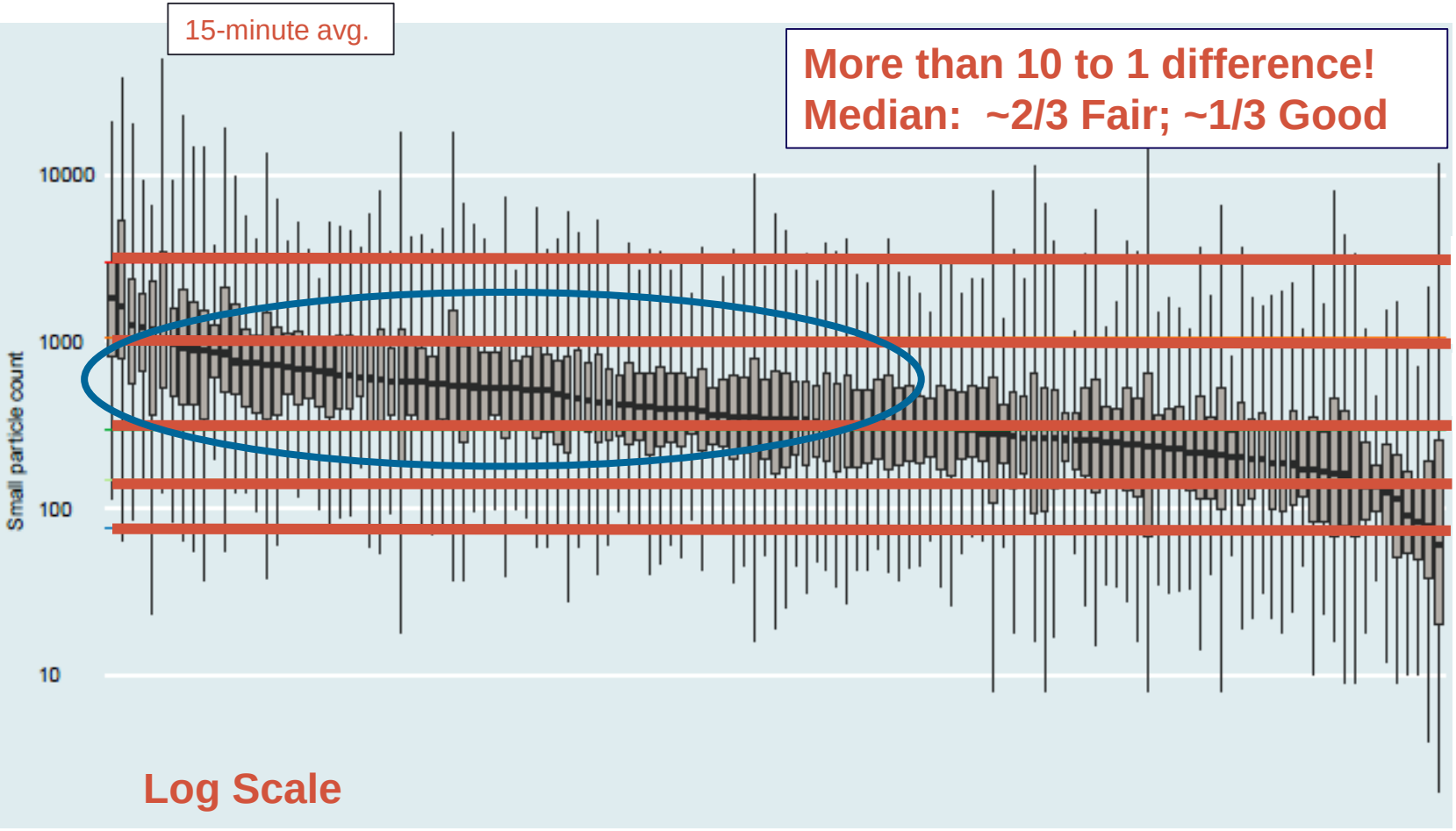
3. Return to Factory Annually

Clean and calibrate

LCMP: BASELINE DYLOS DATA

Indoor Median & Distribution

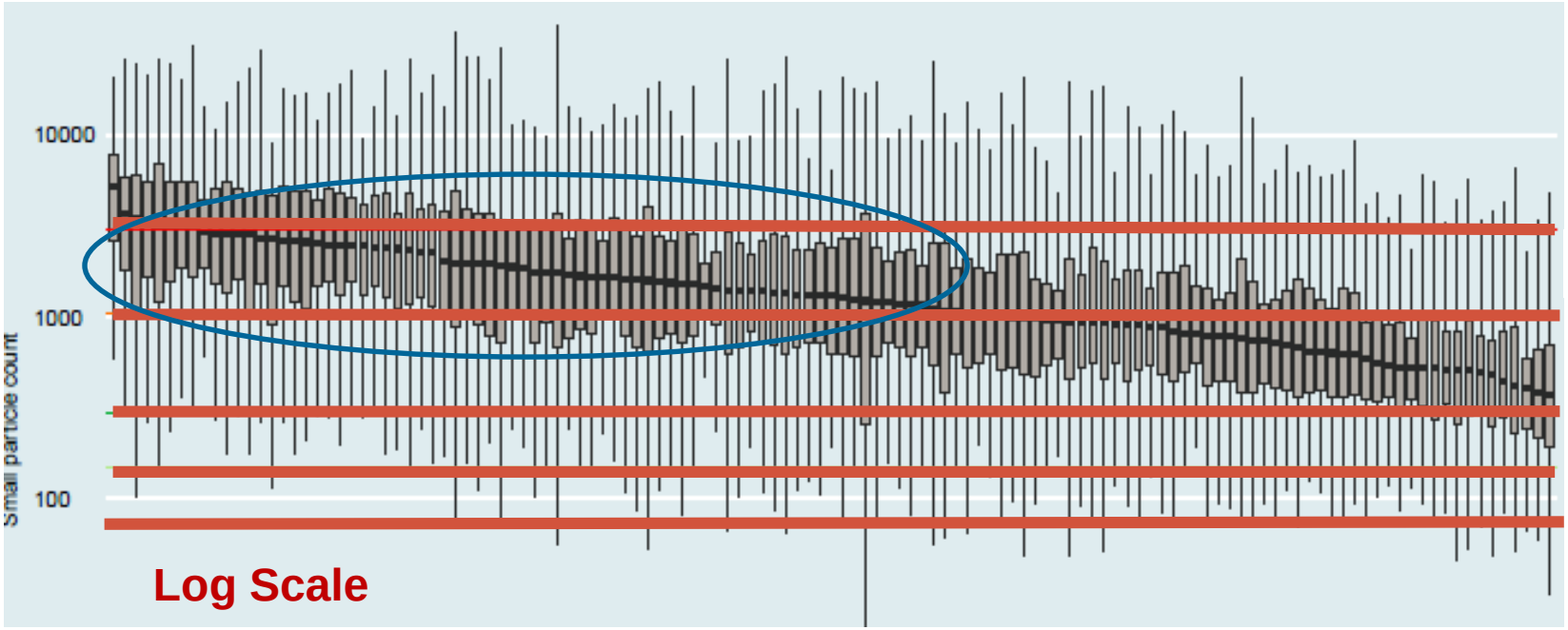
(Dylos Total 0.5+ µm)



Outdoor Median & Distribution
(Dylos Total - 0.5+ um)

15-minute avg.

~½ Poor; ½ Fair



V Poor >3000

Poor 1050-3000

Fair 300-1049

Good 150-299

V Good 75-149

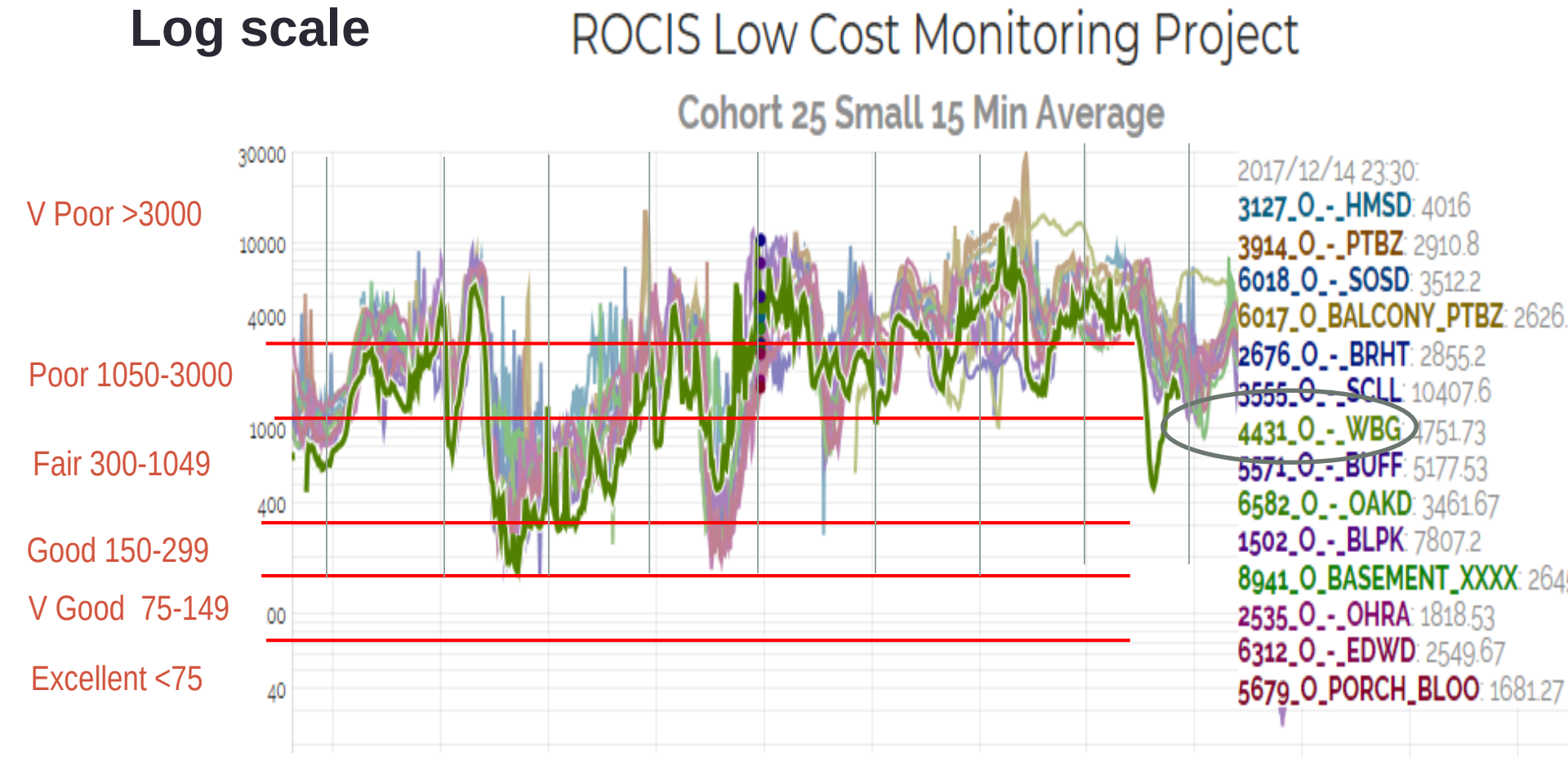
Excellent <75

50% of observations are within each vertical box

OUTDOOR PARTICLES IMPACT INDOOR PARTICLES

Outdoor Data by Cohort - (70 mile spread) - Readings track

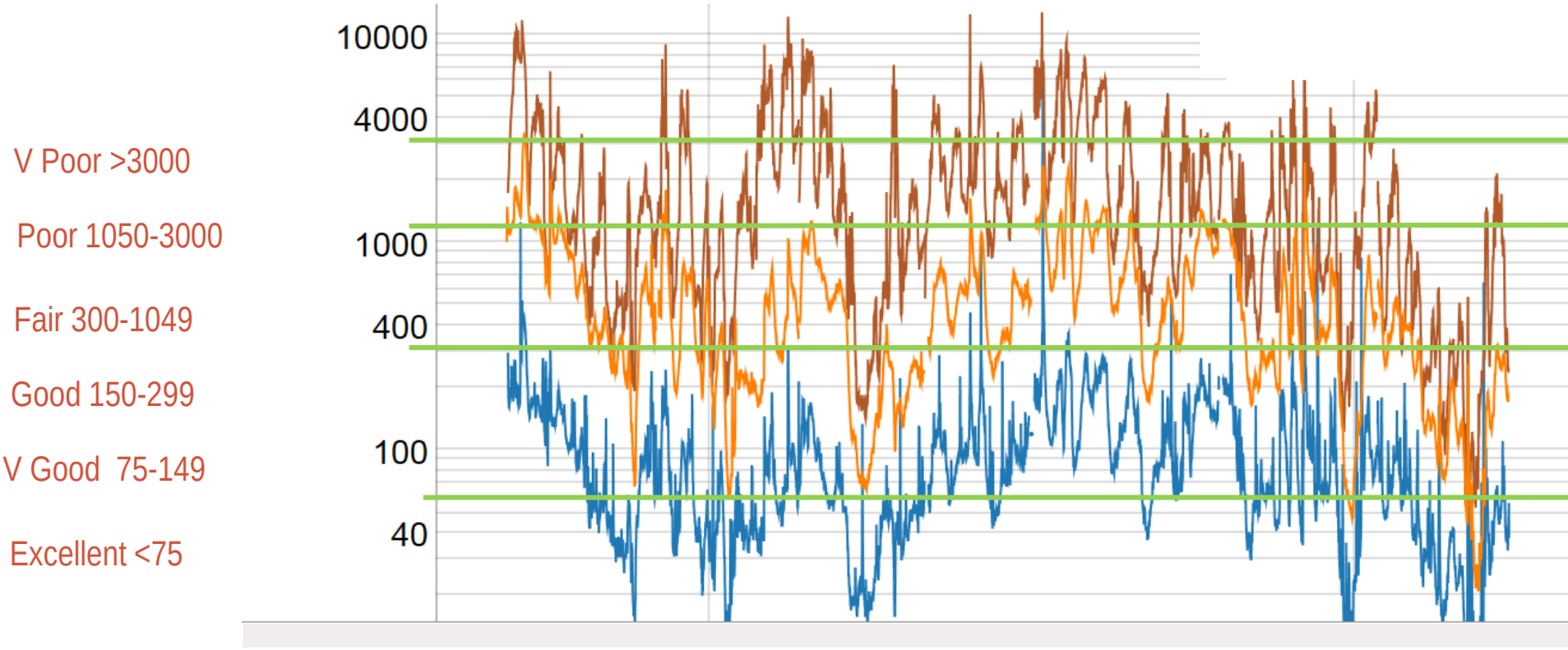
Log scale



Most sites are Pittsburgh; Green line (Wbg) is 50 miles south
Dylos particles (0.5+ µm)

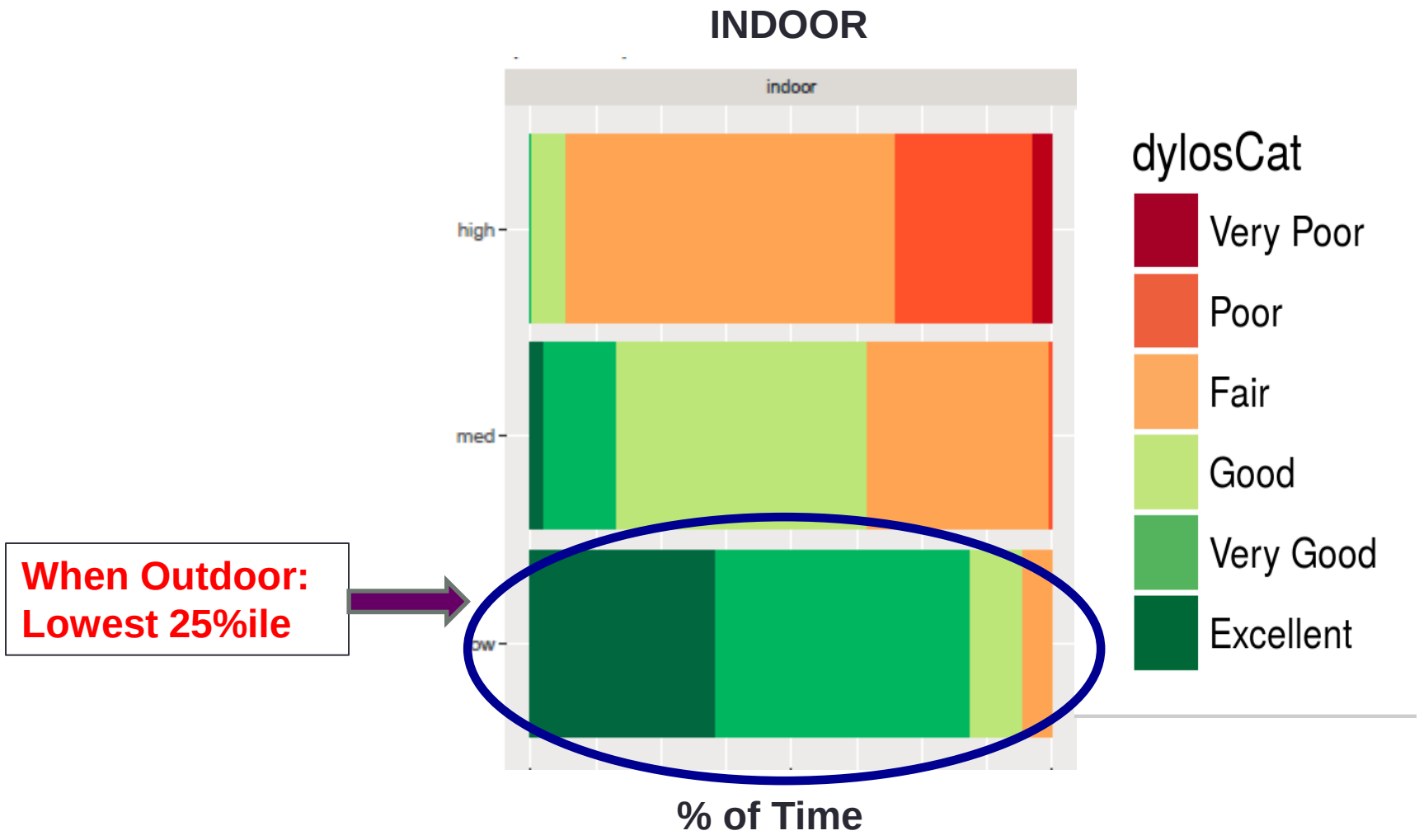
Online Data Explorer
Indoor Counts Track Outdoors

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



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

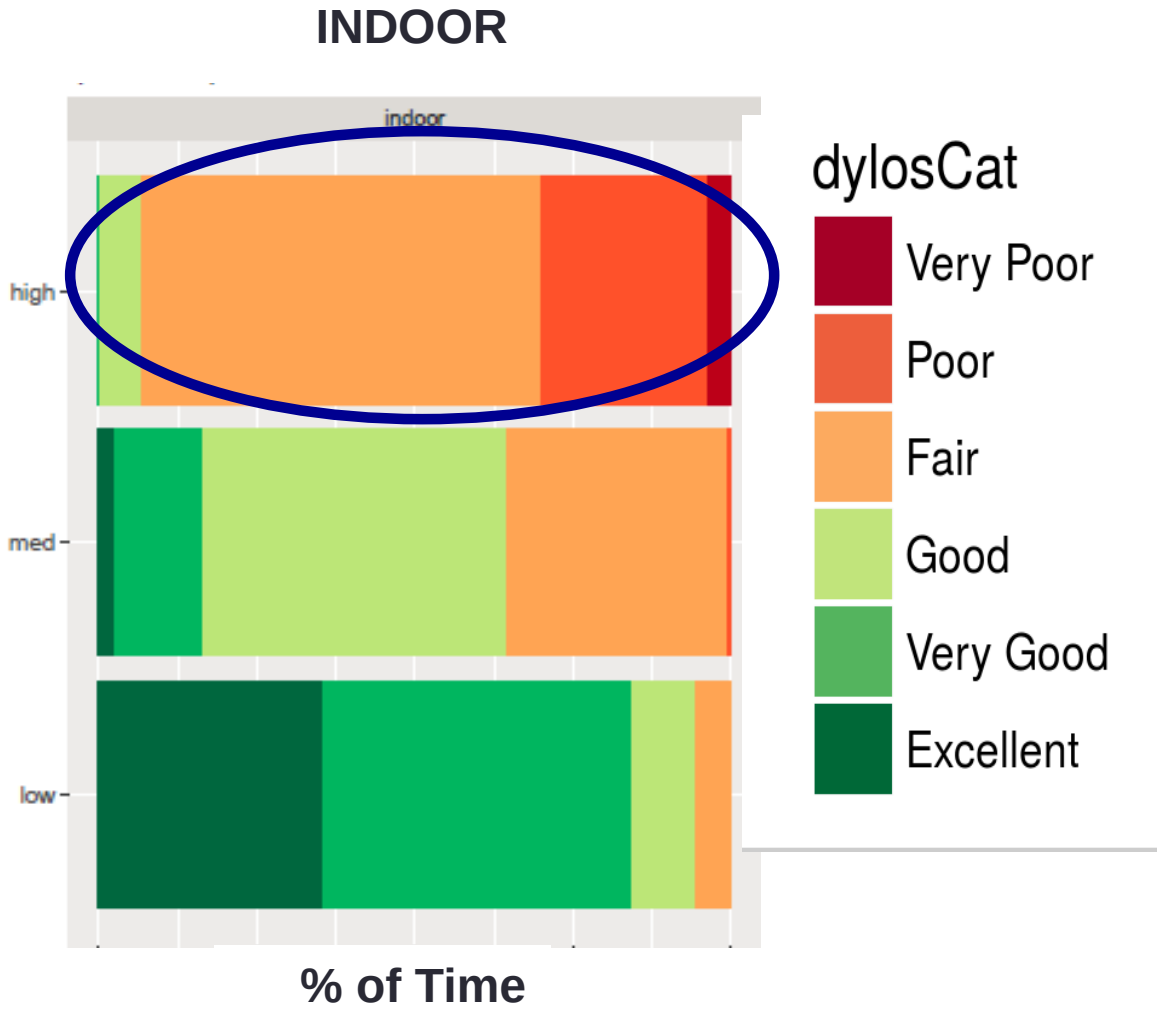
What if outdoor AQ was “good” all the time?



Using online ROCIS Data Explorer
http://rocis.org/rocis-data-explorer

What if outdoor AQ was “bad” all the time?

When Outdoor: Highest 25%ile



Using online ROCIS Data Explorer
http://rocis.org/rocis-data-explorer

INTERVENTION INSIGHTS

And the Role of Low Cost Monitors

Options to Reduce Indoor Particles

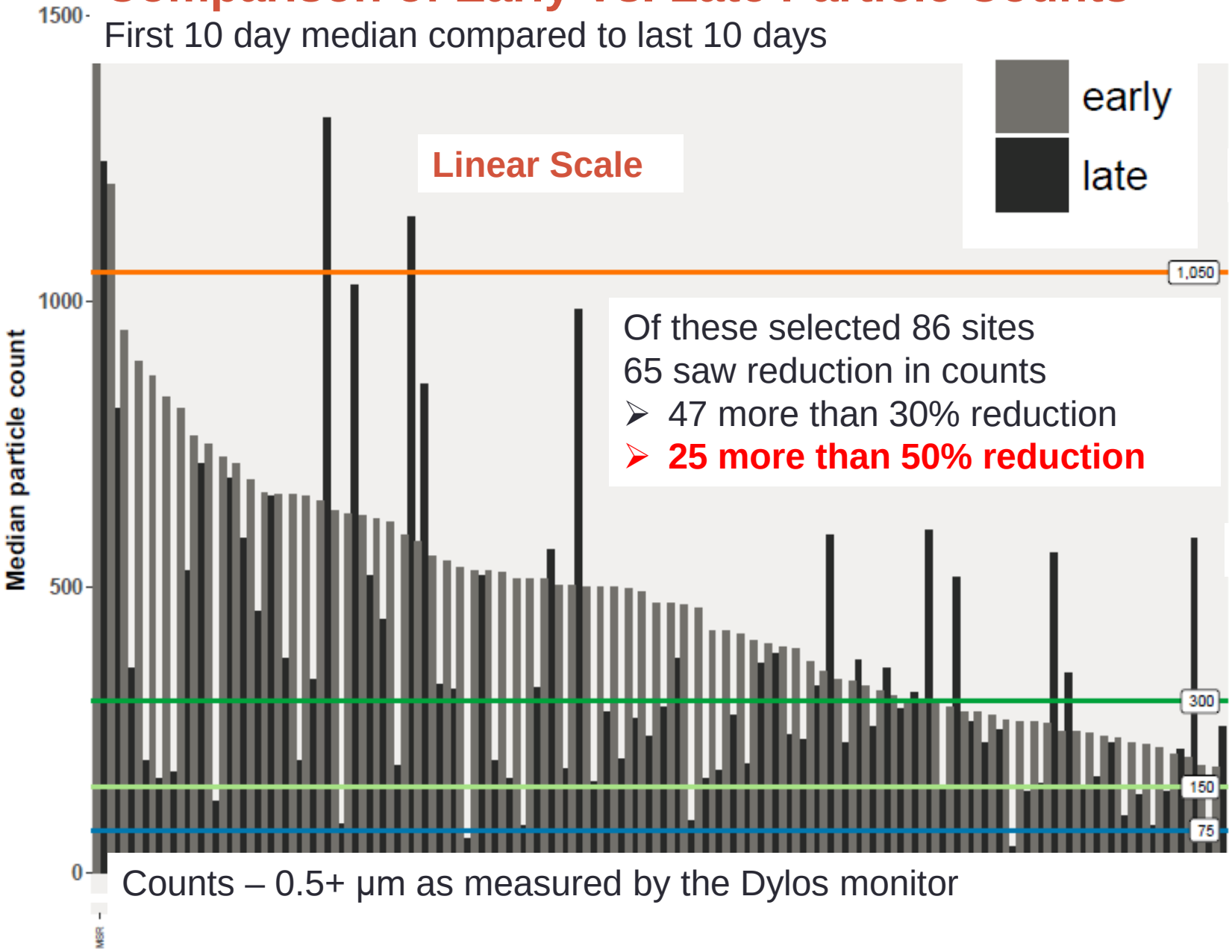
- **Reduce air exchange from outside**
  - Close windows
  - Tighten home or building
- **Reduce indoor sources**
  - Use an effective ducted kitchen hood!
  - Use induction cook top & other good practices w/ cooking
- **Reduce resuspension**
  - HEPA vacuum
  - Walk-off mats
  - Get rid of carpets,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

LCMP Focus - Proof of Concept

- Explore interventions: **effectiveness and feasibility**
- What is **possible?** What are the **constraints?**
- Gain **experience and insight** to help bring interventions to pilot & / or scale
- Most critical issues;
  - **Cost** and energy/GHG impacts
  - Range of **particle reductions**
  - Appropriate **fit** for the house & household
  - **Operation and persistence**
  - Lack of implementation direction and **technical guidance**

Comparison of Early Vs. Late Particle Counts

First 10 day median compared to last 10 days



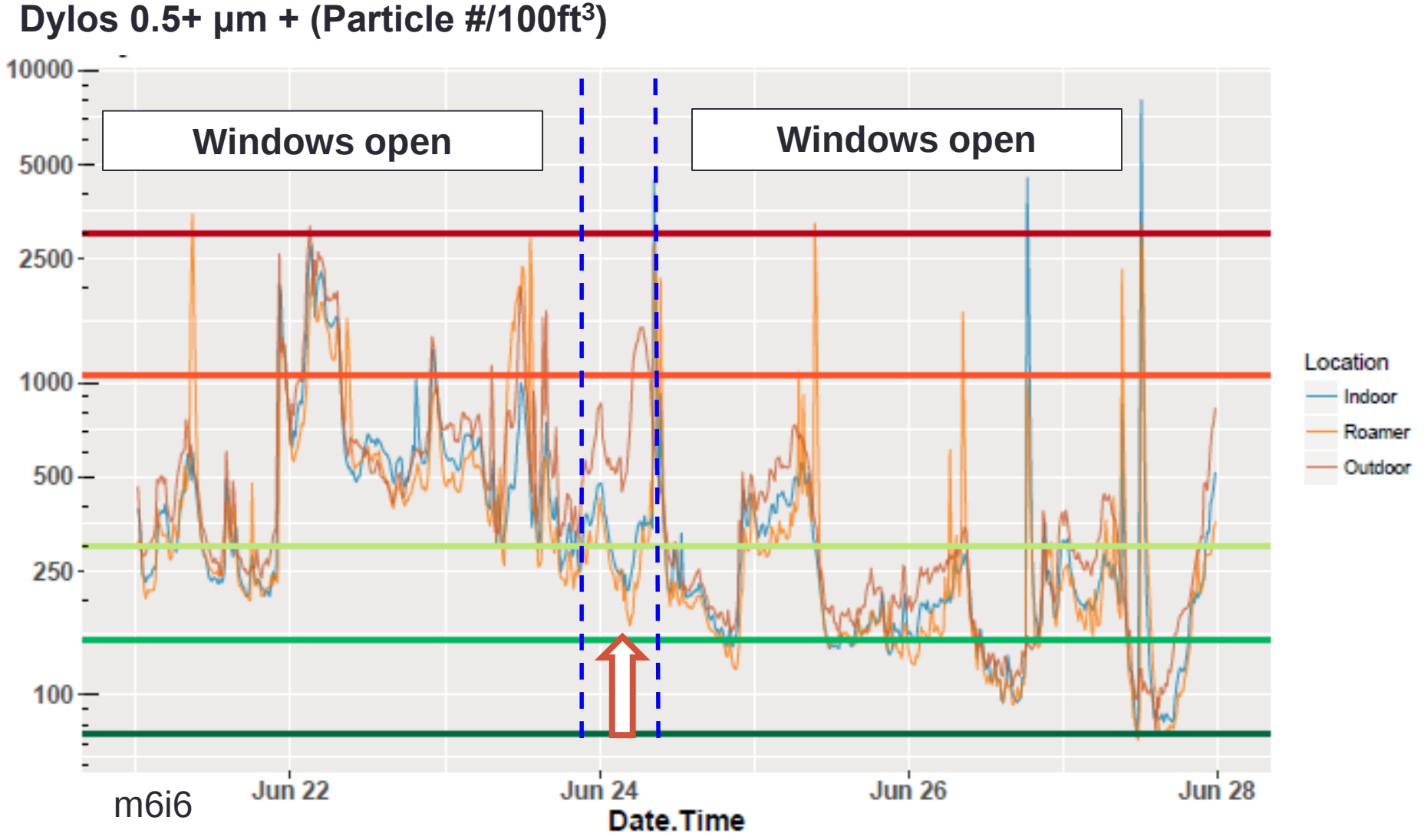
Options to Reduce Indoor Particles

- **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)

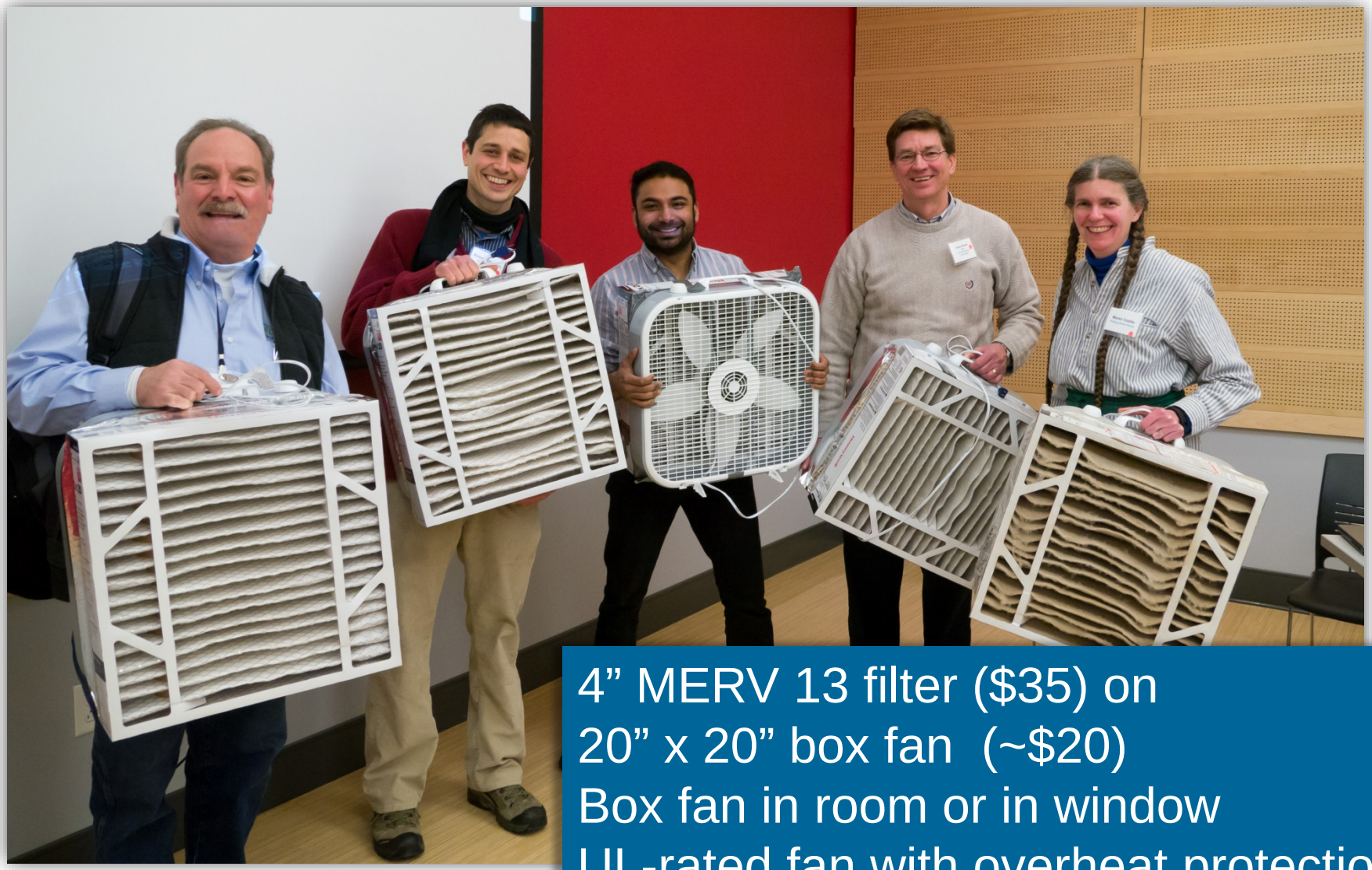
Window Operation

- Single **biggest factor** affecting IAQ when outdoor counts are high
- In Pittsburgh, particle counts tend to be **higher at night** and early morning when windows are often open
- **Poor air quality usually not perceptible (terrible AQ is)**
- Most **contentious**!
- Balancing passive cooling, preferences, dilution of indoor pollutants, and ventilation
- Implications – social justice, heat stress (no AC)

Occupant Behavior: Windows Open vs. Closed



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

Green arrow – turned ON fan filter in bedroom to bring in filtered outdoor air

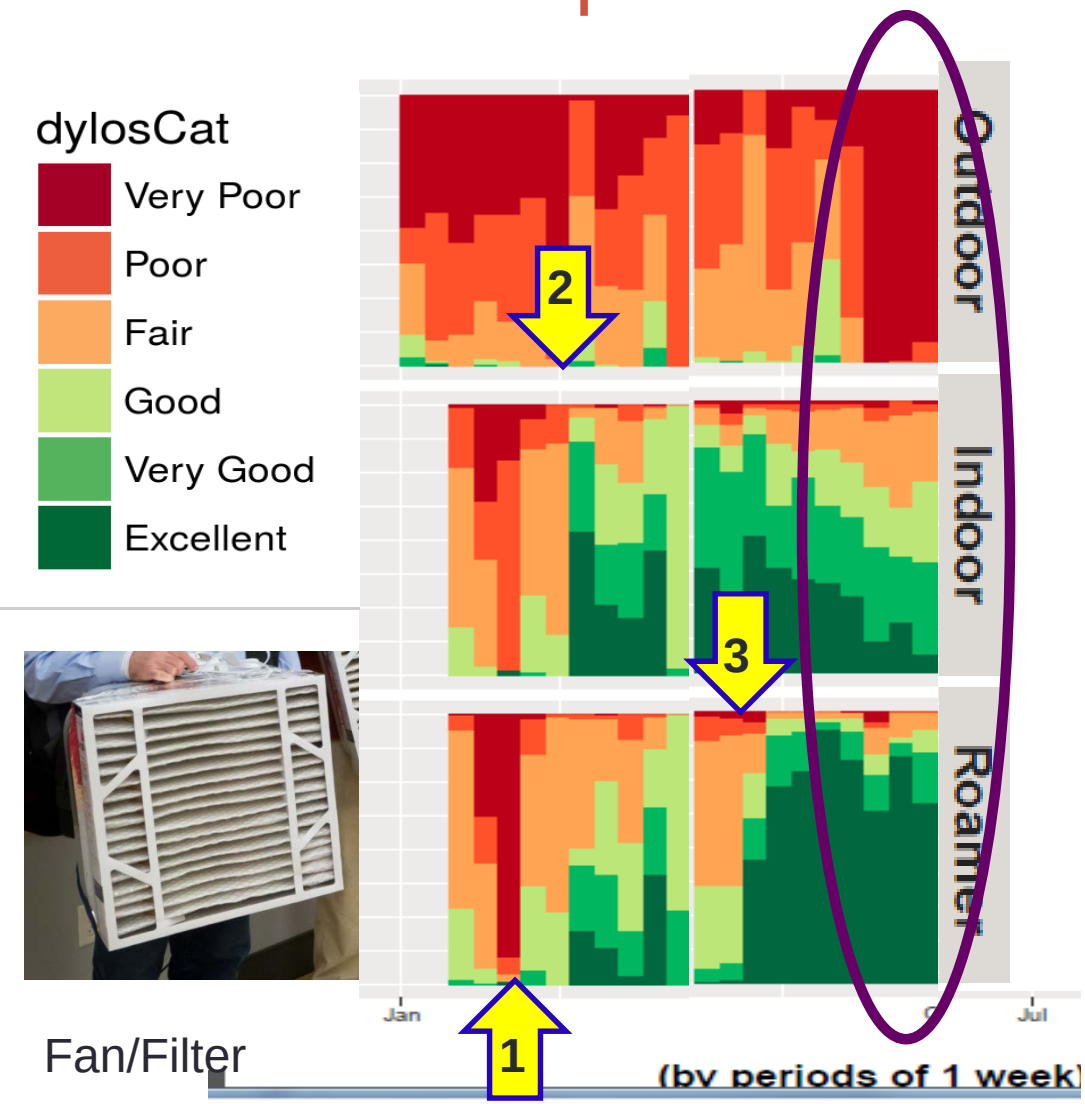
Red arrow – turned OFF fan filter each morning (f5q4)

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)

Behavior *Plus* Technical Intervention

Motivated Occupant



2-burner Induction Stovetop

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

Fan/Filter

INTERVENTIONS

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

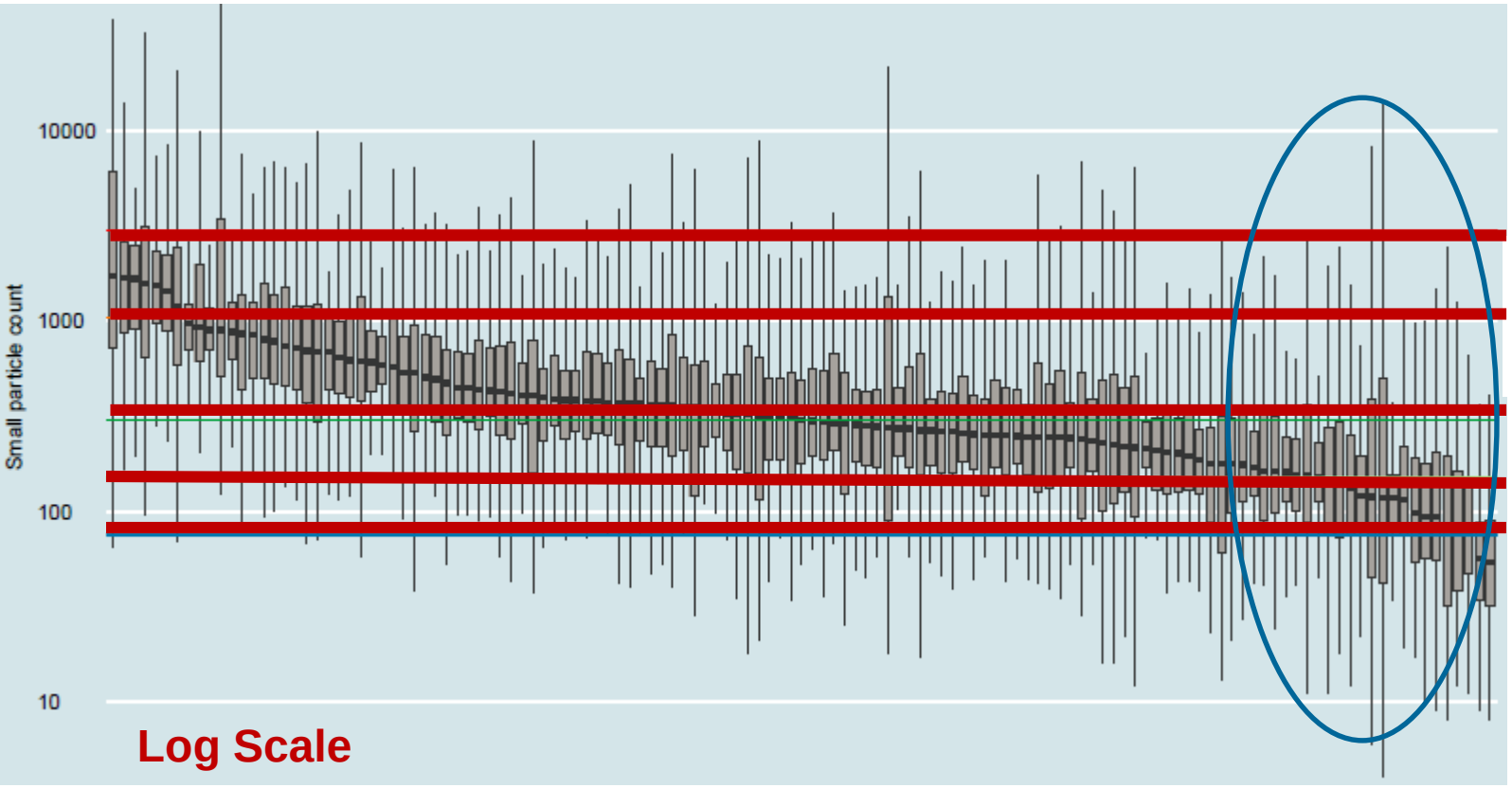
Options to Reduce Indoor Particles

- **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)

LCMP Sites (most recent 21 days)

Indoor Median (Dylos Total 0.5+ µm)

15-minute avg.



V Poor >3000

Poor 1050-3000

Fair 300-1049

Good 150-300

V Good 75-149

Excellent <75

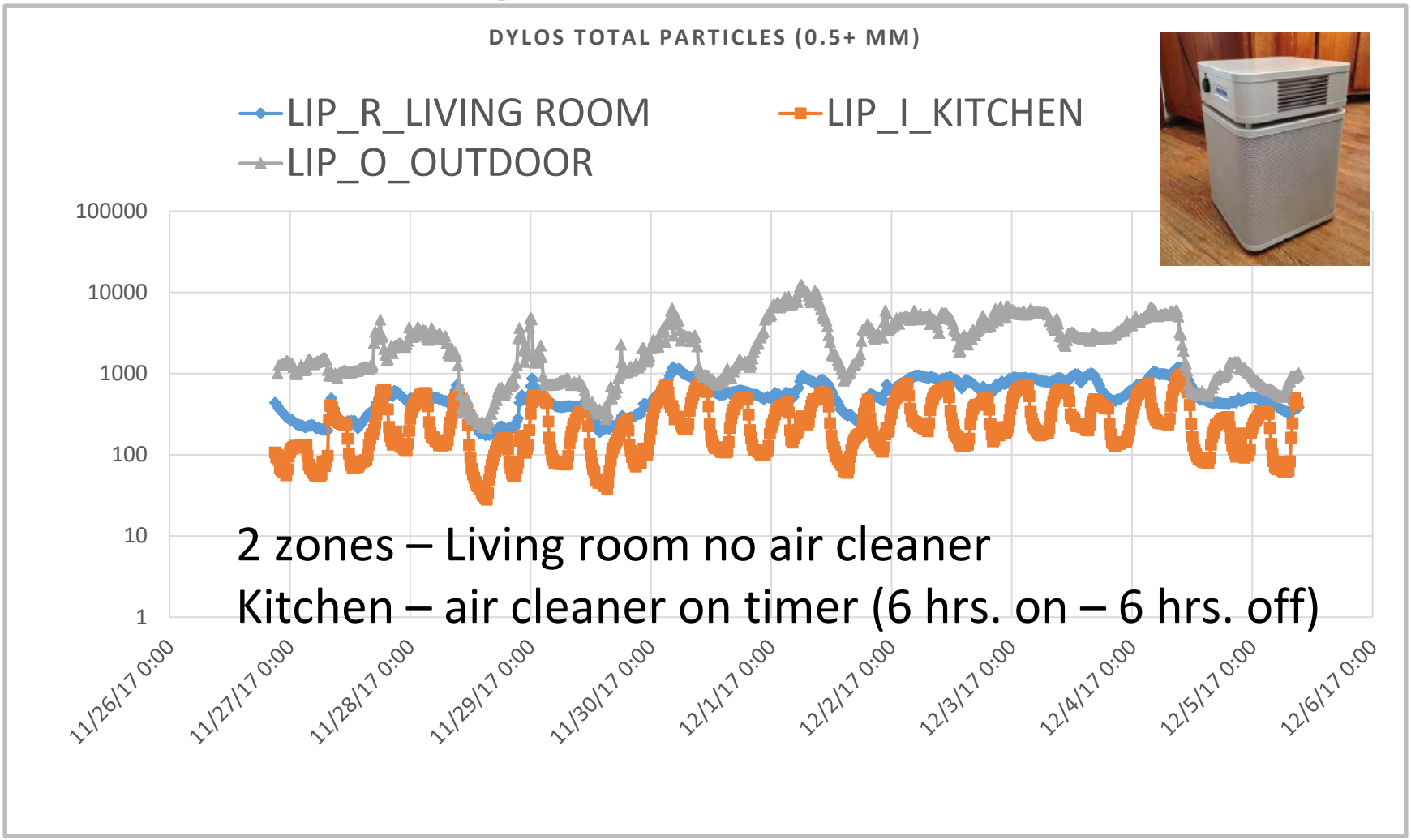
Impact of Portable Air Cleaner

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

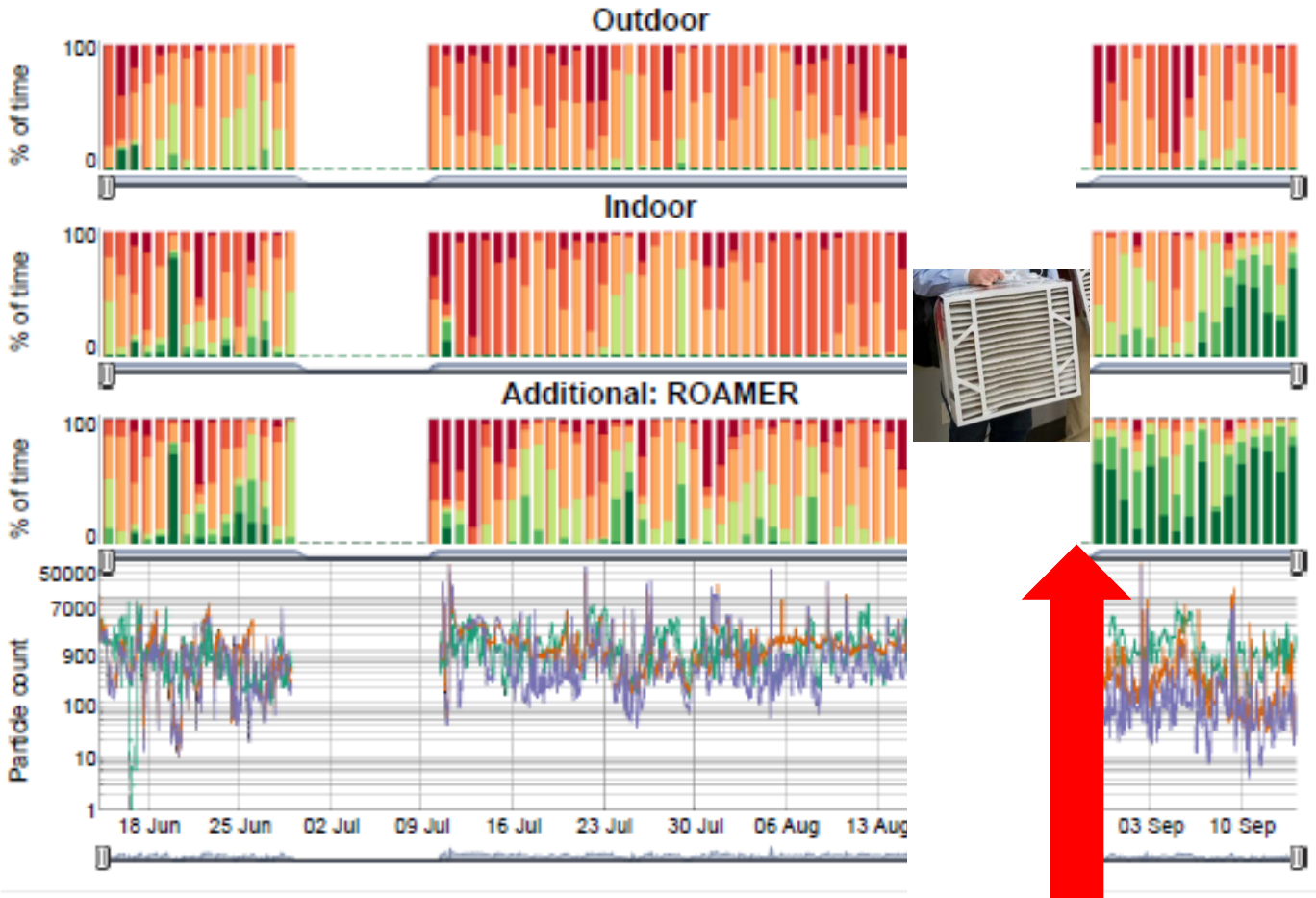
Blue: treated zone
Orange: untreated zone
Red: outdoors
Tight, single family home
Though order of magnitude lower; Indoor (Blue/orange) tracks Outdoor

Air Cleaner Cycled On & Off (6 hrs.)

House unoccupied



Indoor Fan Filter 24/7 Impact



http://rocis.org/rocis-data-explorer (k4x3)

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)

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)

MERV Filter Rating – Particle Size

…your mileage will vary at any given MERV rating

MERV	Particle Size Range	Typical controlled contaminant
1–4	> 10 µm	Pollen, dust mites, cockroach debris, sanding dust, spray paint dust, textile fibers, carpet fibers
5–8	3 – 10 µm	Mold, spores, dust mite debris, cat and dog dander, hair spray, fabric protector, dusting aids, pudding mix
9–12	1 – 3 µm	Legionella, humidifier dust, lead dust, milled flour, **vehicle emission particles**, nebulizer droplets
13–16	**0.3 – 1 µm**	Bacteria, droplet nuclei (sneeze), cooking oil, **most smoke and insecticide dust**, most face powder, most paint pigments

Source: Adapted from EPA, 2009 in Wikipedia, 2018

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

Filter/AHU Inquiry: *Context*

SW Pennsylvania typical housing stock

- Basements
- Mostly gas heat; central AC (oversized)
- Sheet metal ducts in basement
- Supplies and returns to each room

Implications are different w/ attic or crawlspace ducts & homes with central returns

Filter/AHU Inquiry: *Approach*

- Developed **diagnostic protocol**
- Over **40** air handler **systems tested** to date
- Initial visit: adjust **blower speed** as needed
- **Evaluate opportunity for MERV 13 plus 24/7 operation**
  - **Minimal impact on particle counts** if air handler operated in "Auto" mode
  - **Very good reductions in particles when operated 24/7**

BUT…

Big Issues with 24/7 High MERV Filter

- **Air handler (AHU) energy use** can be high (500 to 1,500 watts)
  - High cost of running air handler continuously (@ 500 to 1,500 watts: $54 - $130/month[1])
- **Ductwork issues** introduce additional problems
  - Leaks lead to pressurization or depressurization
  - Static pressure too high
- **Wrong blower speed**
  - Seldom set in field
  - Often defaults to high speed, not low, in continuous mode
  - Higher energy cost, less effective filtration

Elements for 24/7 Operation of AHU

ECM (electronically commutated motor) Blower

- Increase control to optimize air flow
- Drops electricity use, **but only if static pressure** is low

4” Pleated, also Larger, MERV 13 Filter

- Larger surface area & lower air flow thru filter increases removal of smaller particles
- 4” deep filter has longer life without clogging
- **NOT RECOMMENDED:** 1” pleated MERV 11 or 13 filter (equivalent) without testing TESP, air flow, & watt-draw

Good Duct System

- Minimal leaks to outside
- Minimal conductive heat loss to unconditioned spaces
- Air flow and TESP within name plate specifications

Lessons Learned: An Early Change-out

In search of an easy fix…. Don't do this!!!

Not Effective!

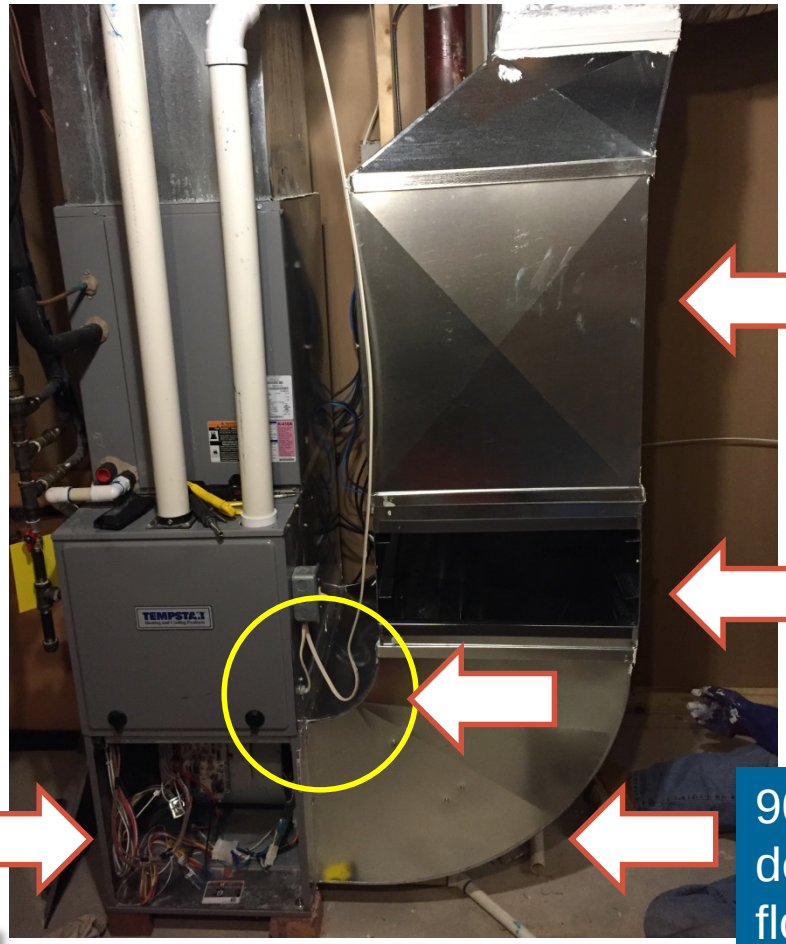
1) Return drop restricted due to size (8" x 25")
2) Poor design at throat w hard 90 degree angle

2) Filter still only 16" x 25"

Much Better Performance!

RESULTS:
5 yr. old home
Significant comfort improvement!

In continuous mode:
- 3.38 CFM/watt
- TESP Pre: 138, Post: 52
- 360 Watts (reduction)



Larger return drop

2-part filter rack (20” x 25”) Horizontal (4” MERV 13 + 2” pre or post filter)

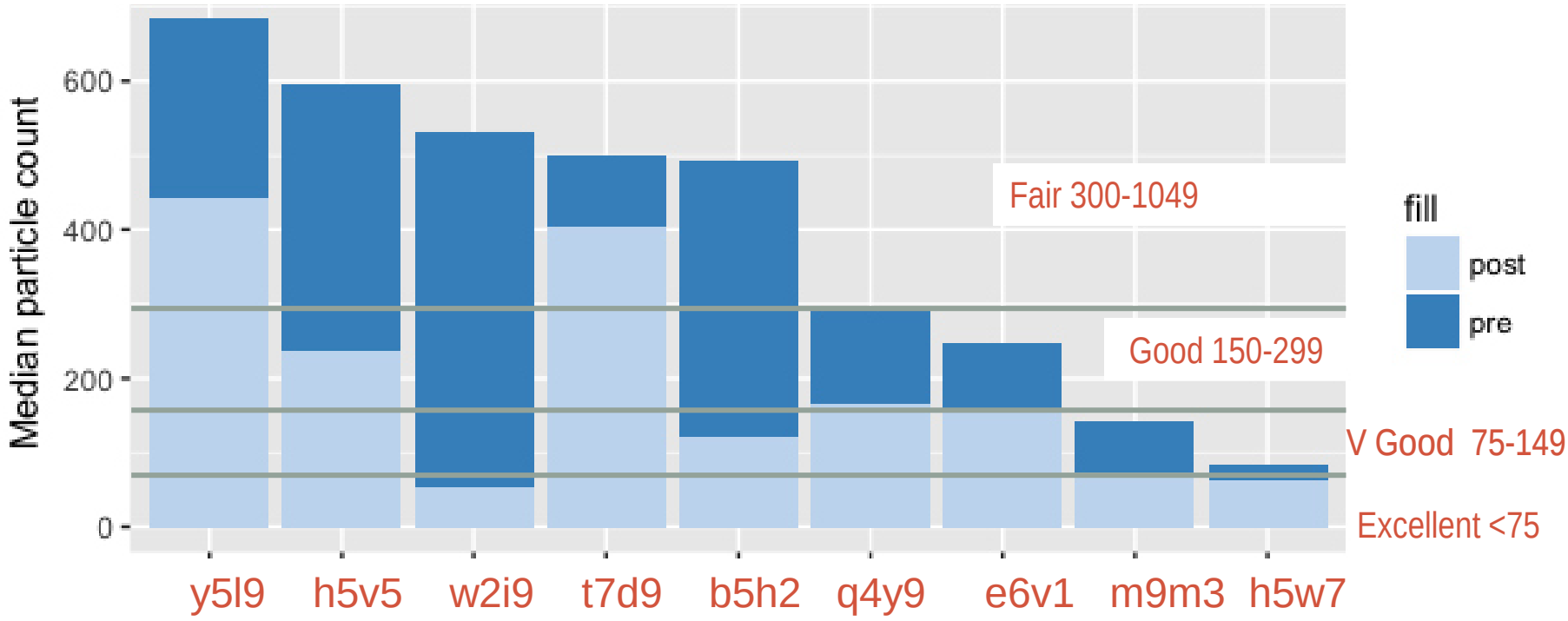
ECM replacement

90 degree transition designed for better air flow; lower static (with turning vanes)

Fan speed adjusted to optimize heating, cooling, & continuous performance.

Selected ROCIS Intervention Homes Pre-Post Median Particle Count

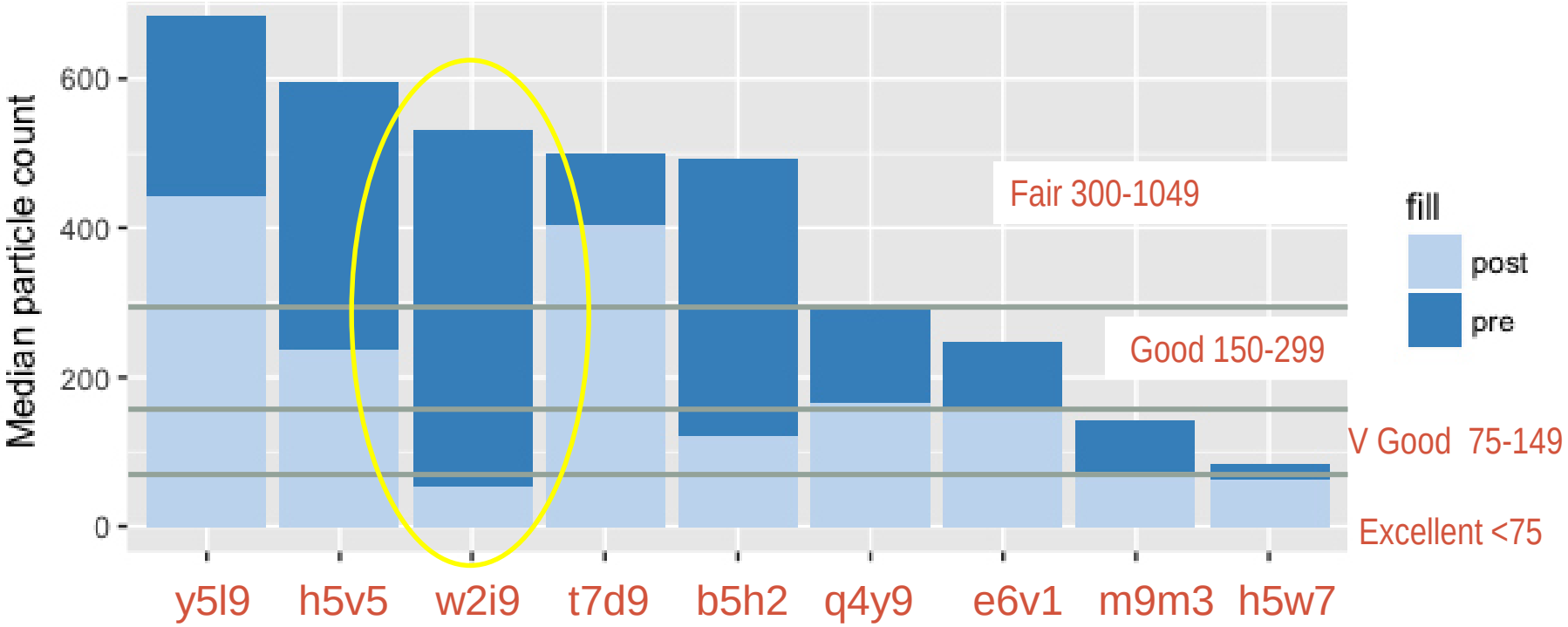
Pre & post period not always clearly defined. Also some homes had behavioral impacts & portable air cleaners, as well as 24/7 AHU w MERV 13 filters



Use above codes **(y5l9)** to view data on ROCIS LMCP Data Explorer
http://rocis.org/rocis-data-explorer

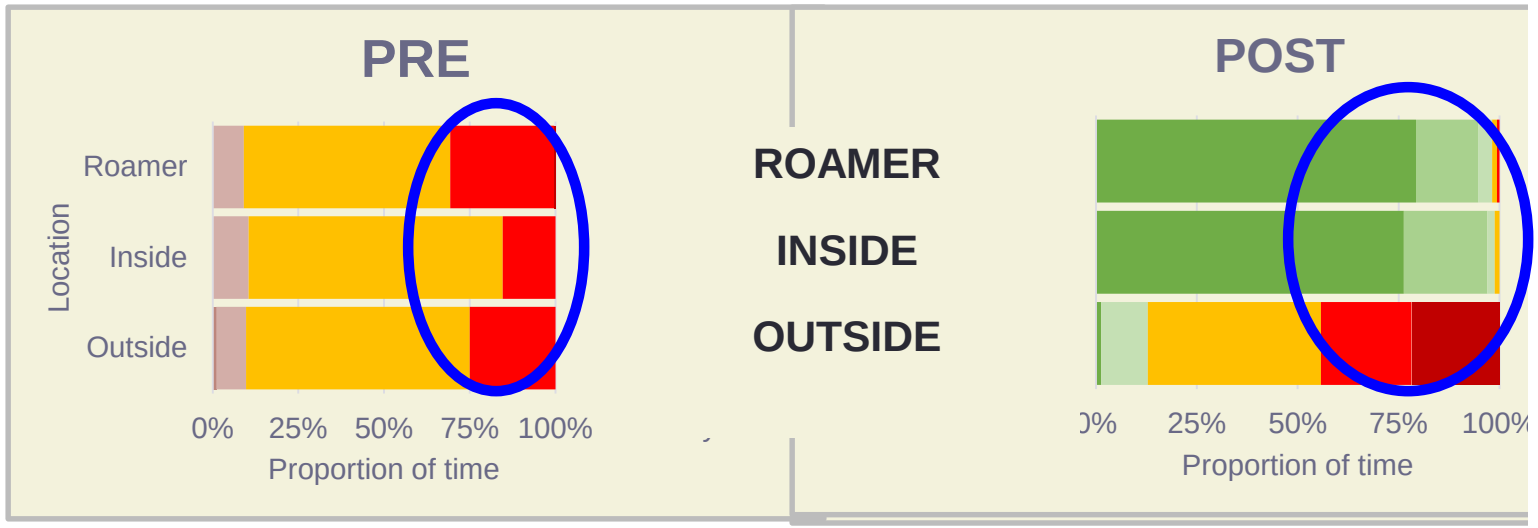
Selected ROCIS Intervention Homes

Pre & post period not always clearly defined. Also some homes had behavioral impacts & portable air cleaners, as well as 24/7 AHU w MERV 13 filters



Use these codes to view data on ROCIS LMCP Data Explorer
http://rocis.org/rocis-data-explorer

Pre & Post – Air Handler Retrofit



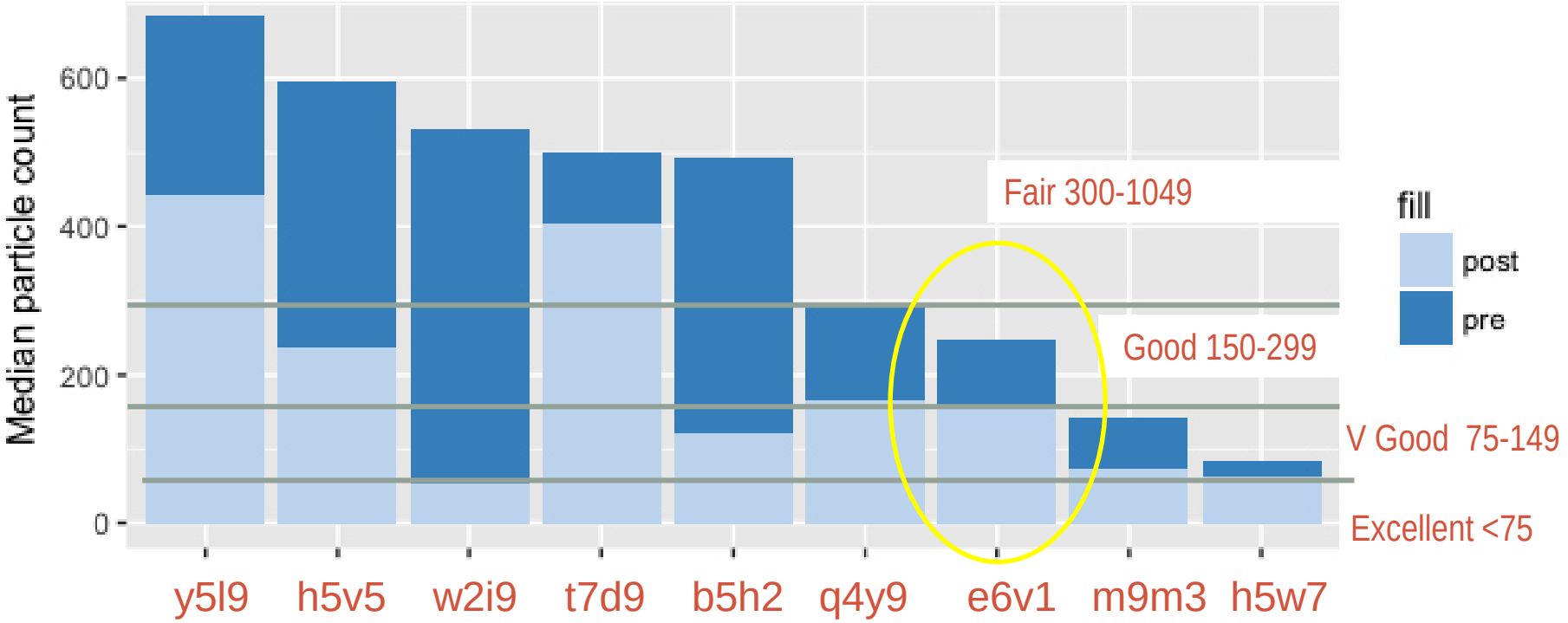
Week ending 5-24-2017 **(windows open)** vs. 7-31-2017, poorer outdoor counts

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; Watt Draw: pre 513 post 120 Watts, 24/7 annual operating cost: $131.40

Selected ROCIS Intervention Homes

Intervention date not always single point in time; some homes had combination of behavioral, portable air cleaners, as well as 24/7 AHU w MERV 13 filters

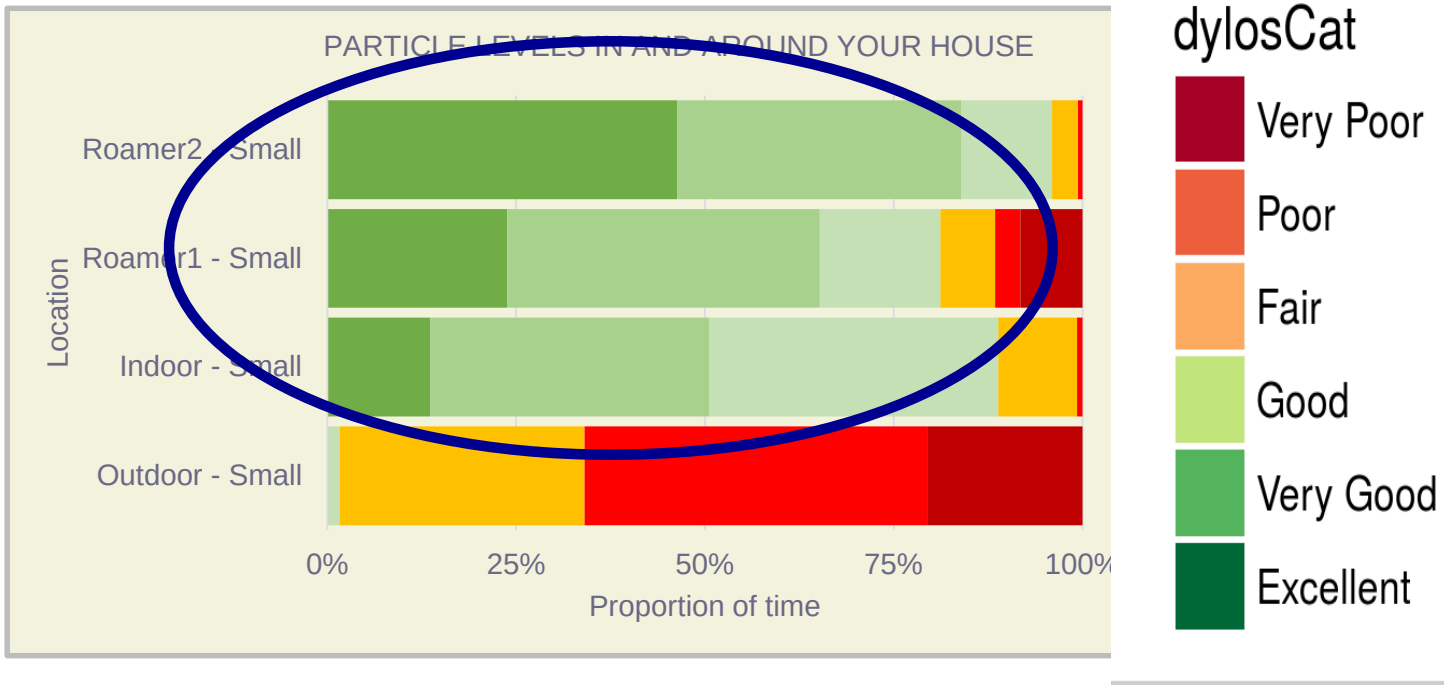


Use these codes **(y5l9)** to view data on ROCIS LMCP Data Explorer
http://rocis.org/rocis-data-explorer

24/7 Filtration/AHU + Portable Air Cleaner

Pre & post:
Used portable air cleaners

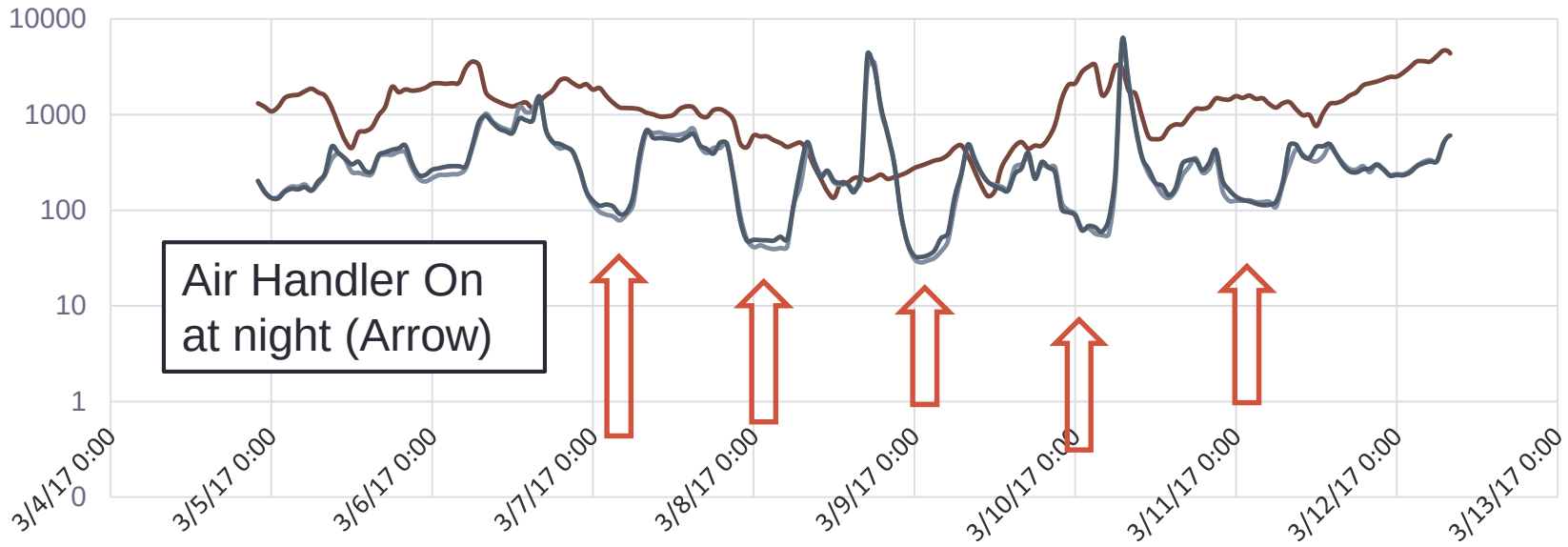
2,240 CFM_{50}



Intervention 07-12-17: ECM, new return drop w horizontal 20”x25” MERV 13 filter w/pre-filter
Results: Continuous Watt Draw: pre: 495, post:150; 2.71 CFM/Watt
Pressure drop over filter: 52 PA to 17.5 PA
24/7 annual operating cost: **$164.25**
Recommendations: increase supply-side ductwork; downsize AC when replaced

DYLOS TOTAL PARTICLES

Night-time Air Handler Use



 # 0.5+ µm particles/100 ft^3; 15-minute avg.

Lower particle exposure during periods of greatest occupancy

Intervention (Dec. 16-Mar. 17): ECM, return drop w/ horizontal MERV 12 filter & pre-filter

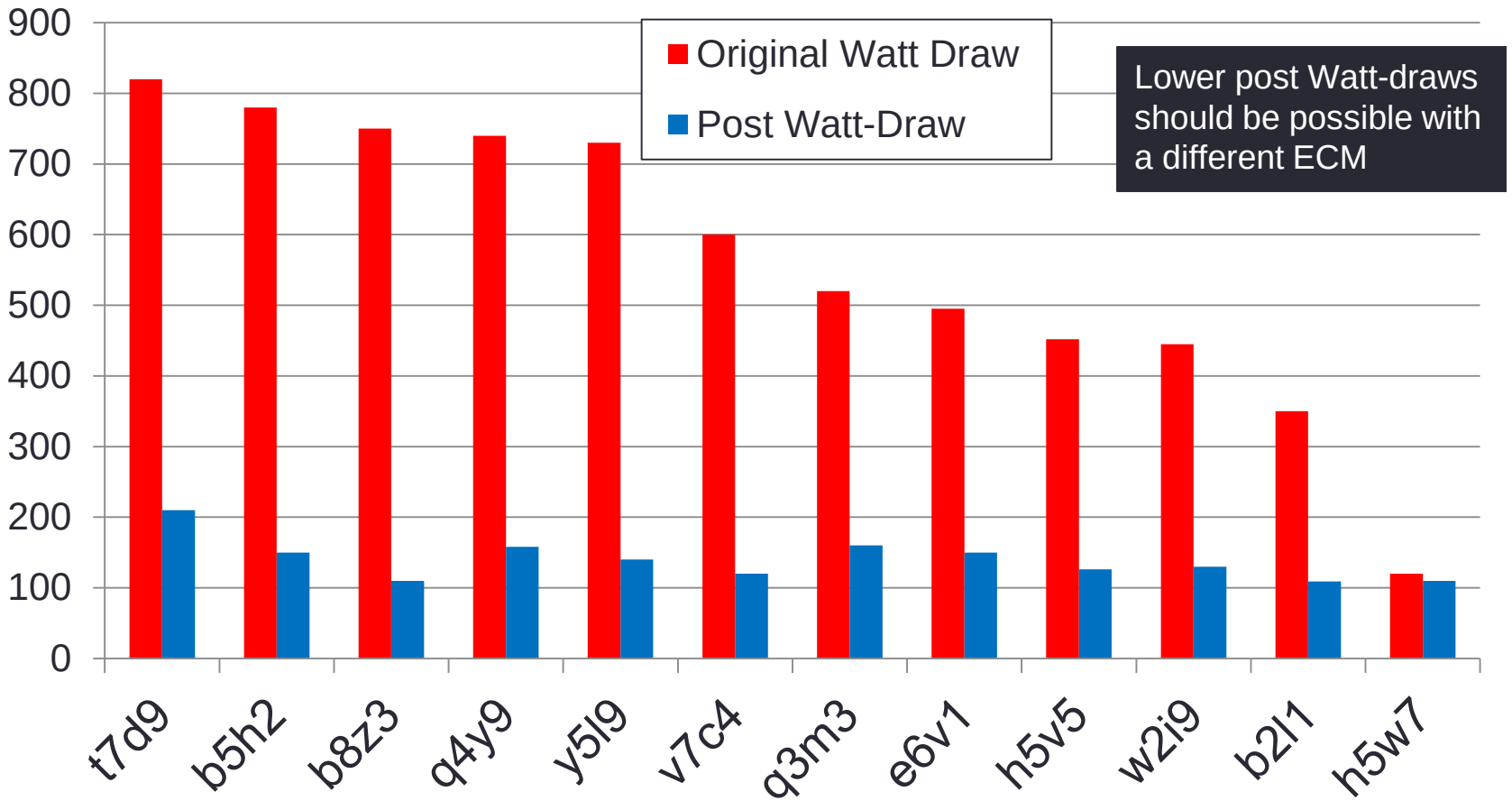
Results: Continuous Watt-draw: pre 750; post:126; 3.57 CFM/Watt

System much quieter

Annual operating cost (8 hr./day): $44

Family (b8z3) uses natural ventilation (no AHU/filter) 5+ months/year

Air Handler Interventions
Pre-Post Continuous Watt-Draw



Use these codes **(t7d9)** to view particle data on ROCIS LMCP Data Explorer
http://rocis.org/rocis-data-explorer

Air Handler – Hi MERV Filters Implications

- Correct HVAC system **design and installation** is critical to use of air handlers for filtration
- **Smart controls** coupled w/ low cost monitors increase both the **potential and risk**
  - Optimize air handler run-time
  - What is optimal? How good is good enough (data accuracy)?
  - Potential for adverse energy & HVAC system impact
- **Opportunity to differentiate** high quality HVAC installations??

Intervention Summary

- These interventions can be effective; but household & HVAC **screening is essential**
- The **tighter** the house, the **greater** the **impact** of filtration…
- But, the tighter the building, the more critical it is to **control indoor sources**
- One option - shift focus from building exposure to human **exposure,** e.g., air quality in bedrooms **while people are sleeping**

Low Cost Monitors

- Huge Potential
  - Making the **invisible visible**
  - Changing **perception**
  - **Reinforcing** behavior & interventions
    - Adoption & continued use
- Ideally within a framework of technical support and peers
- **Not known:** How much of LCMP impact is due to **engagement,** not just presence of **low cost monitors**

Low Cost Monitors - Cons

- False assurance –
  - No problem – Monitor says AQ is pretty good!
- Monitor not sensitive to particles from out-of-doors, or submicron particles
- Interventions could operate sub-optimally
- Automatic controls (HVAC)
  - In some HVAC systems - contribute to excessive energy use or shorten equipment life

Conclusions

- **Outdoor** particle counts have a significant **impact on indoor levels**
- **Visualization** tools influence how one interprets the data
- Particle monitors that measure down to **0.5+µm** (or lower) appear to have a **significant benefit (over 2.5+ um)** when viewing **outdoor air impacts.**
- Low-cost monitors can **contribute to awareness, behavior change, use of technical interventions, and building capacity** of people, communities, and organizations

Bottom Line!

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

Ideally, improve outdoor air quality!

Thanks to Phil Johnson &

The Heinz Endowments for supporting the

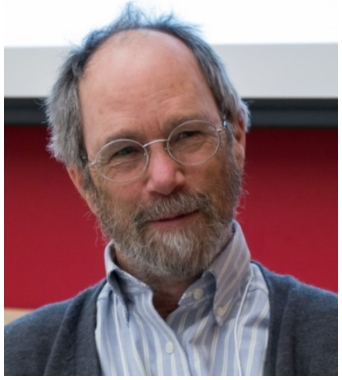
ROCIS initiative

(Reducing Outdoor Contaminants in Indoor Spaces)

and

Our 180+ Project Participants!

The ROCIS Team



Don Fugler
LCMP Research
Ottawa, Canada

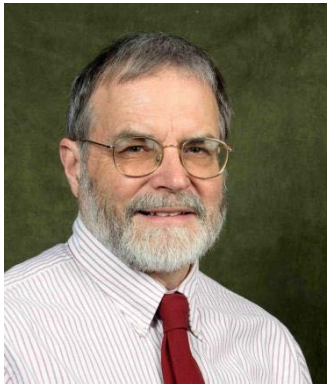
Kacy McGill
LCMP Coordinator
Pittsburgh, PA

Rhett Major
Air Handler Inquiry
North Huntingdon, PA

Greg Fanslow
LCMP Data Analysis
Burlington, VT

Tom Phillips
Range Hood Brief
Davis, CA

Norm Anderson
Advisor
Winthrop, ME



Bill Turner, P.E.
Consultant
Harrison, ME

Yujie Xu
Data Management
Pittsburgh, PA

–

Rob Busher
Air Quality Fellow
Pittsburgh, PA

Linda Wigington
Team Leader
Waynesburg. PA

Questions?

http://ROCIS.org/

- White papers & presentations
- Access to resources & research results
  - LCMP http://rocis.org/rocis-low-cost-monitoring-project
  - ROCIS Brief - Ducted Range Hood (Tom Phillips)
    - http://rocis.org/kitchen-range-hoods
  - Air Handler Inquiry http://rocis.org/air-handler-inquiry
  - ROCIS Data http://rocis.org/rocis-data
- Stay Tuned
  - ROCIS Brief - Portable Air Cleaners
  - Video Shorts - Telling the Story

Linda Wigington

Project Lead, ROCIS Initiative
724-852-3085

lwigington1@outlook.com

EXTRAS

ROCIS Low Cost Particle Monitoring & Interventions: Insights & Implications

For 2 years, ROCIS (http://rocis.org/) has engaged over 180 professionals & homeowners in monitoring their homes (& a few workplaces) in southwestern PA. Emphasis has been on monitoring particles (0.5+ microns) inside & outside to better understand the impact of outdoor air pollution on IAQ. While typical participation is for a 3-week period, 40+ sites have tested interventions & monitored for longer periods. Explore what we have learned in an effort to understand the 10 to 1 difference in median particle counts from one site to another.

Resources: Filtration & Air Cleaners

Available from:
U.S. EPA's web site
http://www.epa.gov/iaq/pubs/residair.html

Residential Air Cleaners

Resources: Low Cost Monitoring

EPA's Air Sensor Toolbox for Citizen Scientists

https://www.epa.gov/air-sensor-toolbox

- ✓ Data interpretation guidelines
- ✓ Education & outreach
- ✓ Low cost sensor performance information

INDOOR AIR QUALITY
SCIENTIFIC FINDINGS RESOURCE BANK

TOPICS

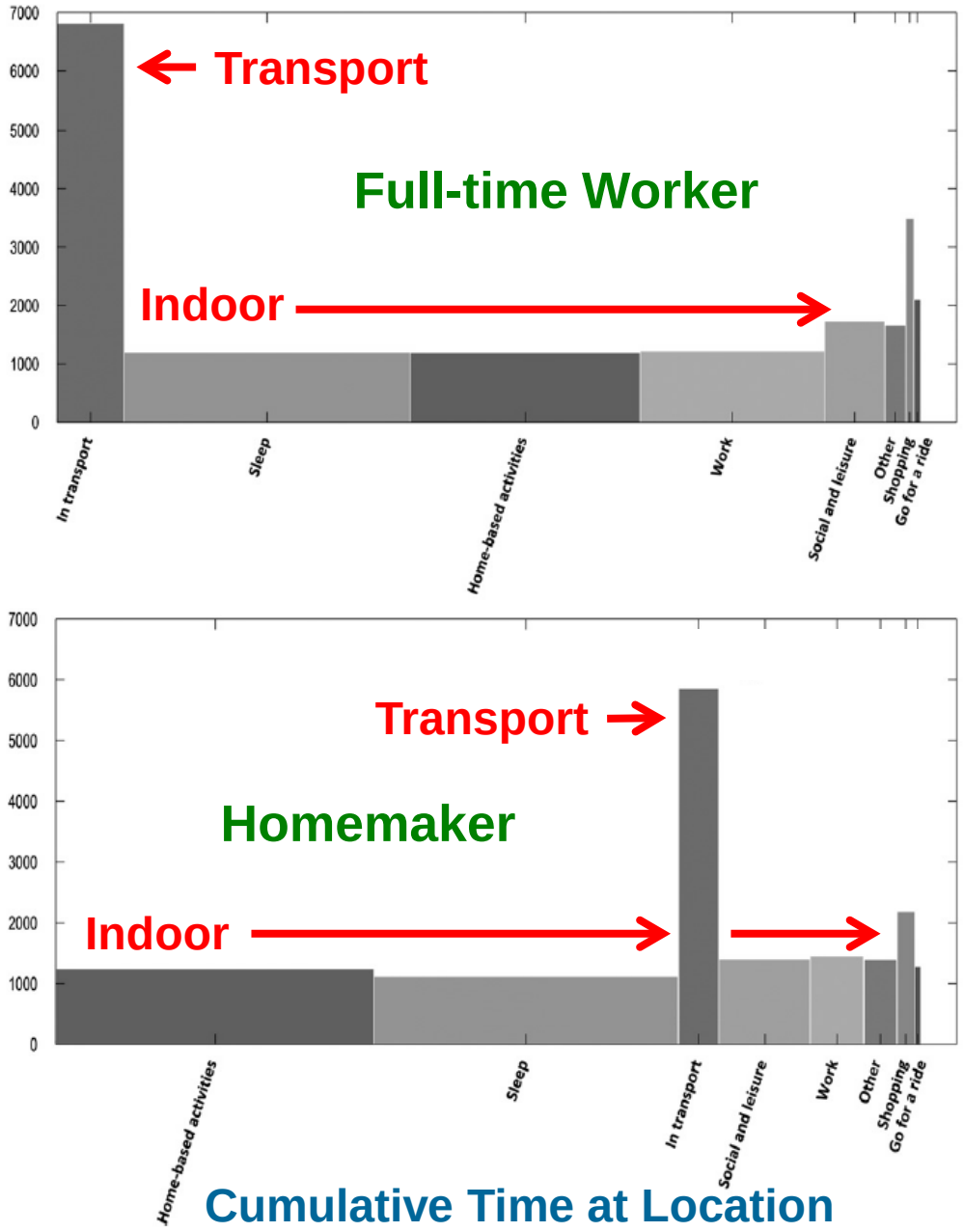
- ✓ Building Ventilation
- ✓ Indoor Dampness
- ✓ Indoor Volatile Organic Compounds
- ✓ Human Performance and Productivity
- ✓ Benefits of Improving Indoor Environmental Quality
- ✓ Air Cleaning Effects on Health and Perceived Air Quality
- ✓ Climate Change, Indoor Environmental Quality, & Health

https://iaqscience.lbl.gov/

Personal Black Carbon (BC) Exposure: BC is indicator of exposure to diesel exhaust

- 16 working adults over 7 summer days; Belgium, 2010.
- The highest BC concentrations were measured in the transport activity.
- But, when exposure duration was factored in, indoor exposures were the greatest as a whole, especially for the "home-makers".

BC exposure (ng/m^3); boxes by order of exposure surface area



Cumulative Time at Location

Dons et al., 2011. Atmospheric Environment 45: 3594-3602. doi:10.1016/j.atmosenv.2011.03.064.

Current Trends: Outdoor & Indoor AQ

- Worse **outdoor air quality**
- More frequent and larger **wildfires**
- More and a longer season**pollen**
- Hotter, longer, and more frequent **heat waves**
- More **exposure time indoors**
- **Increasing population density and proximity** to traffic and industrial emissions

Low Cost Monitoring Kit

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

(2) Corentium Radon https://airthings.com/us/

(1-2) Carbon Monoxide (CO) MONITOR

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

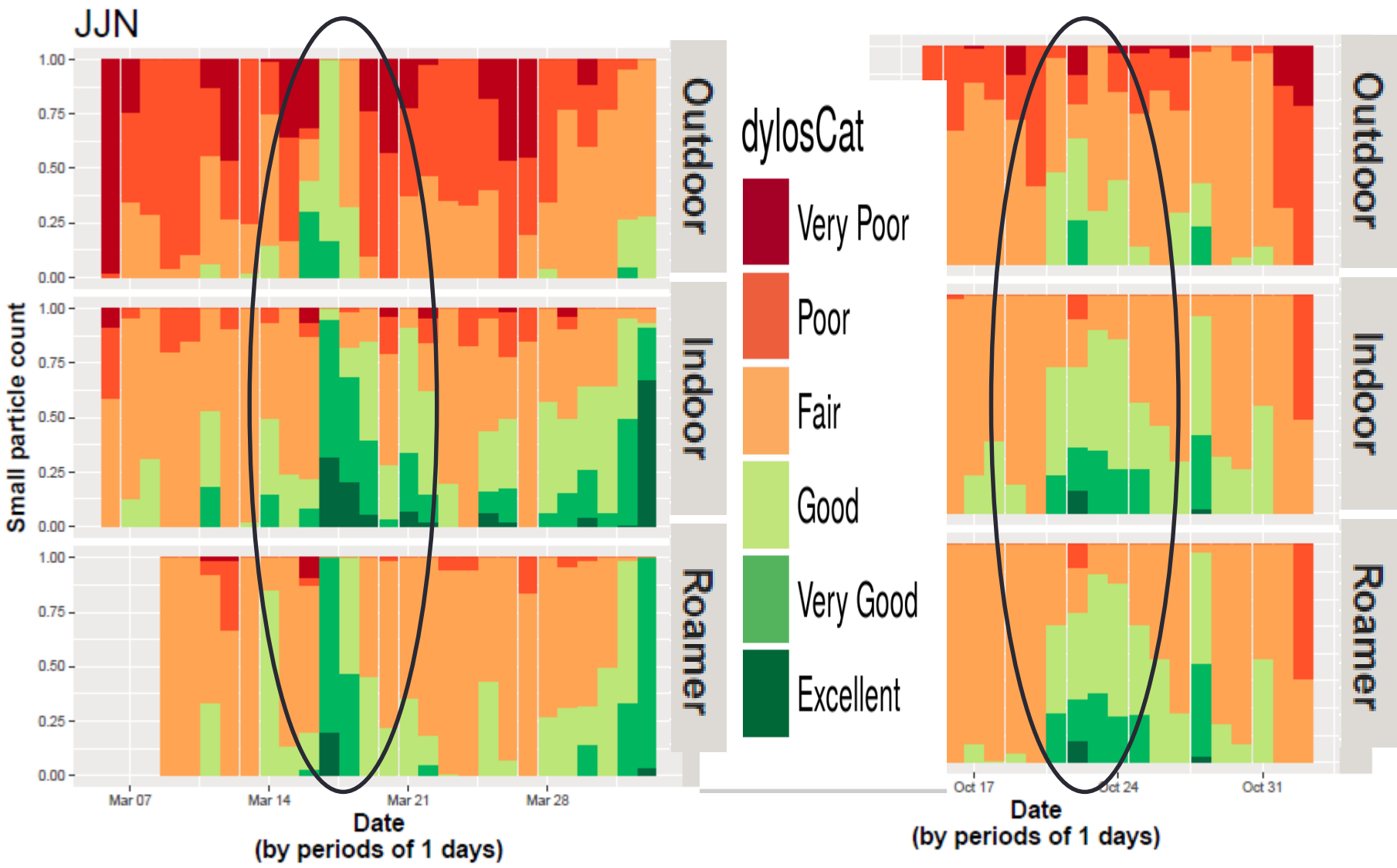
(2) CO_2 TIM12 Datalogging Meter www.co2meter.com

Our cost - ~ $1,600-$1,800/kit

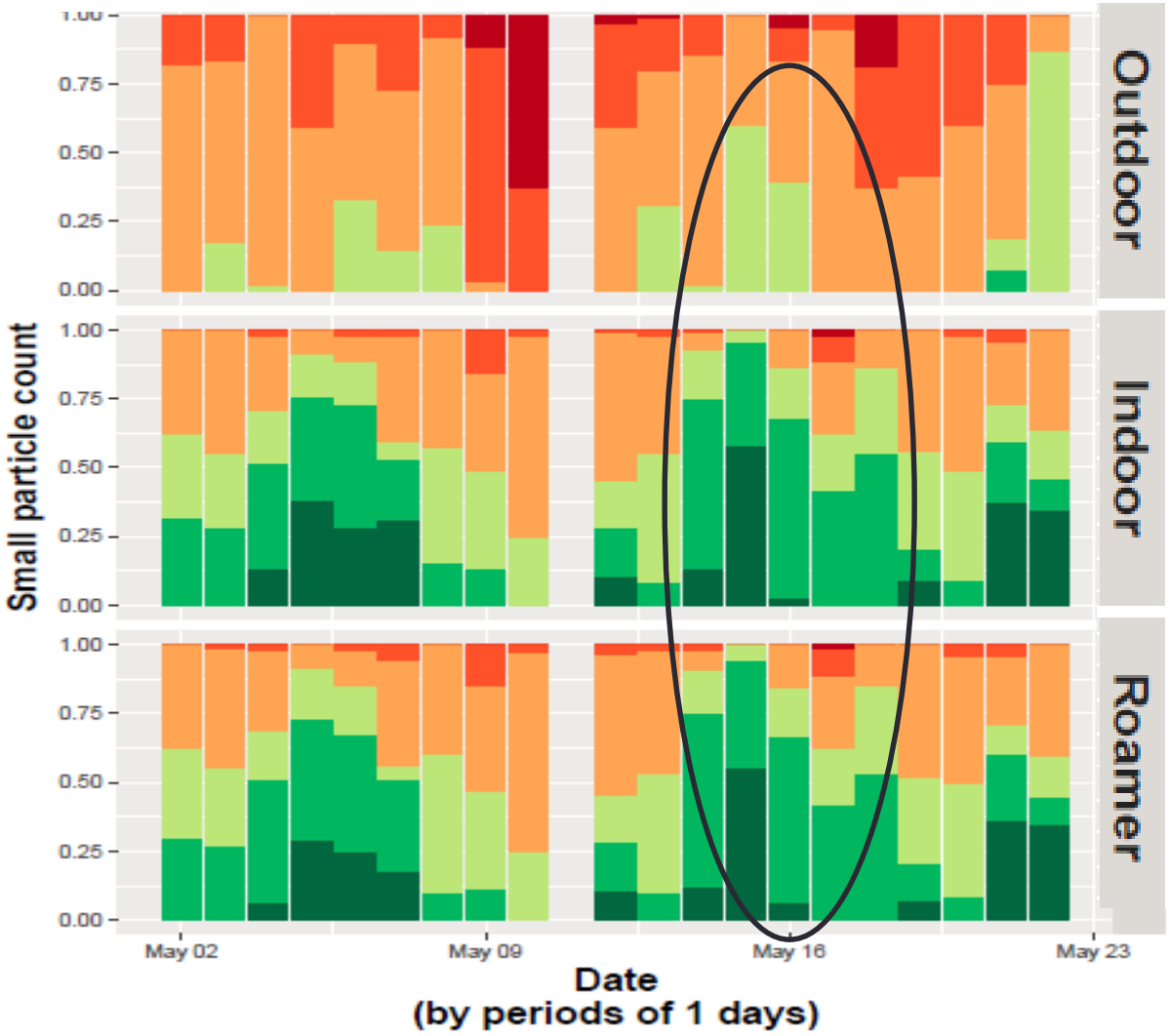
Quantity discounts, some donated equipment

No cost to participants for monitoring

When Outside Better - Inside Better

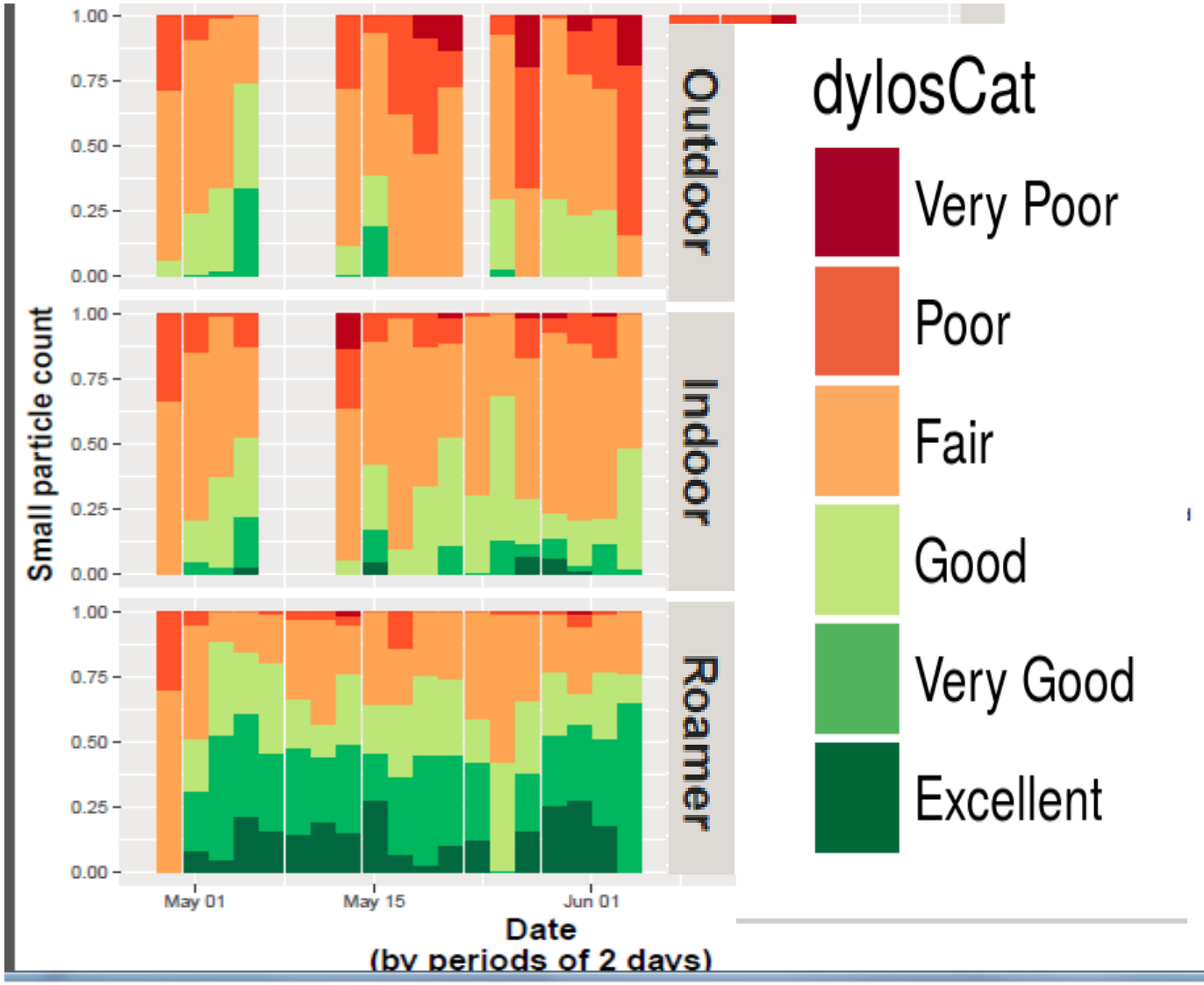


Stacked Bar - Outdoor Impacts Indoor



Online ROCIS LCMP Stacked Bar

Portable Air Cleaners – Fan/Filters



g7n5

Purchased Air Cleaner or DIY Fan/Filter

- **DIY Fan/filter** (with $30, 4” filter) often drops particles faster, but only addresses particles
  - Initial cost
- **Portable Air Cleaners** (Hepa, not Heap-like)
  - $200 - $800
- **Fan/Filter** – $25-$50
  - Operational cost (for both)
  - Electricity (~35-80 watts)
  - Cost of replacement filters

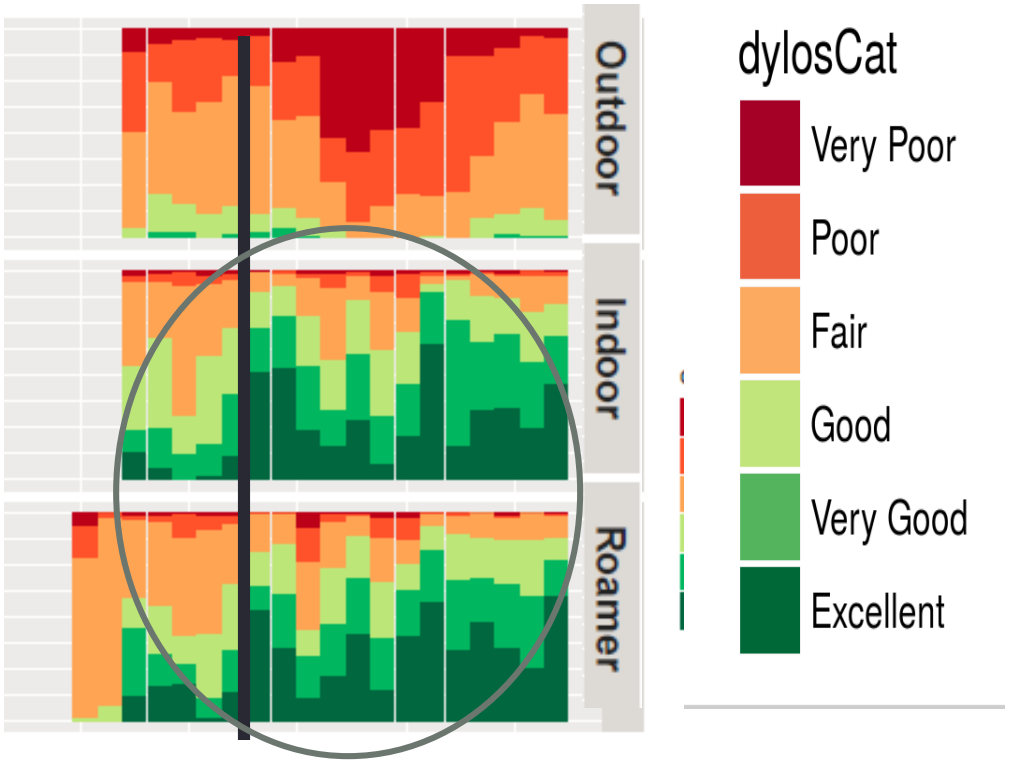
24/7 Air Handler w High MERV Filter

Our 1st air ECM handler retrofit!

ECM change-out

In June 2016 using existing 1" pleated filter

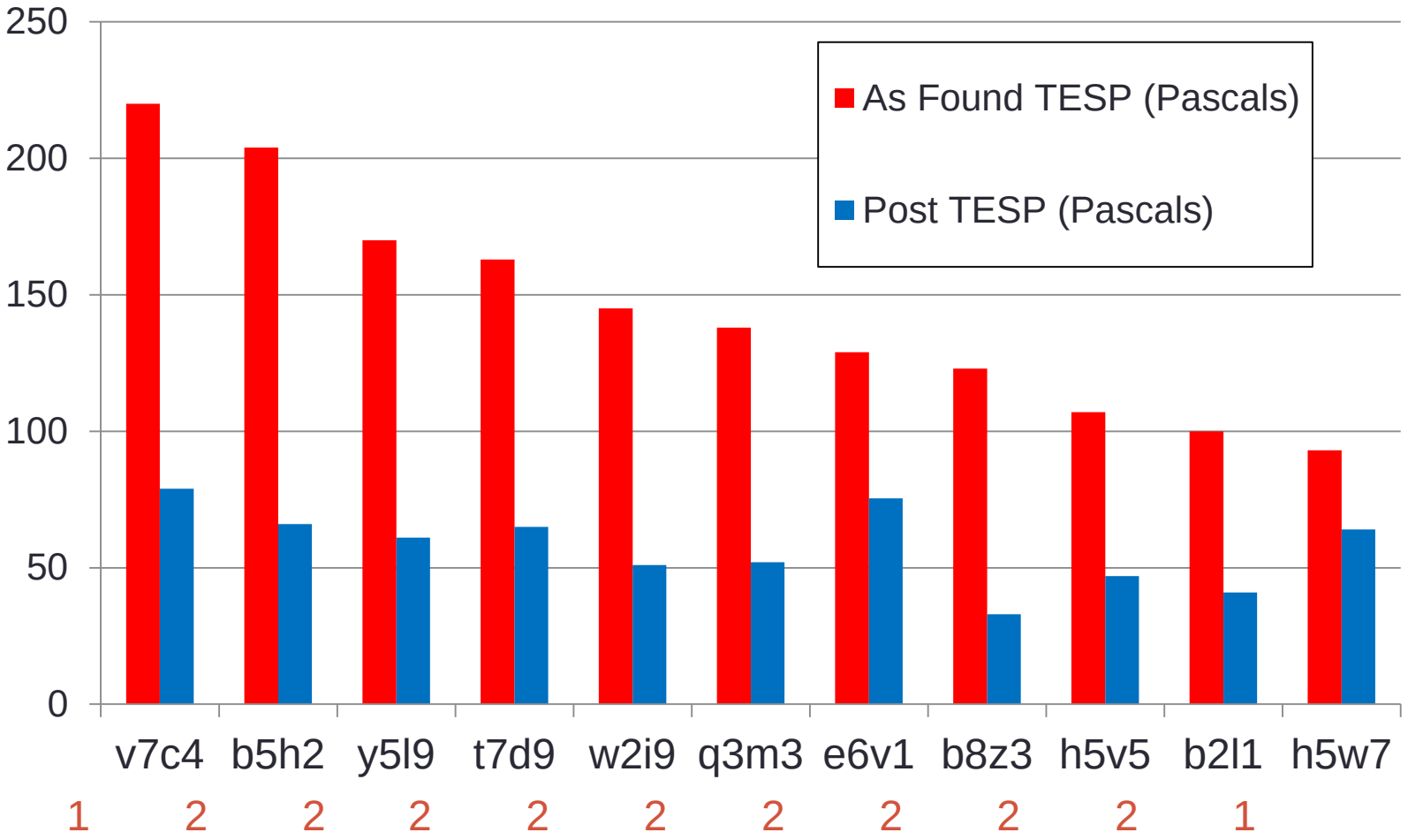
Early Sept. 2016 return drop modification w turning vanes & 4", 20"x 25", MERV 13 filter



(b5h2)

(by periods of 3 weeks)

Air Handler Interventions Pre-Post TESP (Continuous Mode)



Reduction due to 1) adjusting speed of existing ECM (2 cases); 2) ECM change-out (9 cases). **PSC motors & ECMs are ½ HP w/ nameplate limit of 125 Pascal's.**

What are Implications for Affordable Housing / Healthy Homes WAP / Home Performance

- Integrate diagnostic w/ inspection?
- Integrate as part of healthy home intervention?
- Integrate intervention w/ HVAC upgrade?

What are Implications for Affordable Housing / Healthy Homes WAP / Home Performance

- Integrate diagnostic w/ inspection?
- Integrate as part of healthy home intervention?
- Integrate intervention w/ HVAC upgrade?