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%+)

Avg. Daily Time (%)

- Indoor-Home
- Indoor-Other
- Outdoors
- In Vehicle
- Indoor Total 88.9%

Canadian Human Activity Pattern Survey 2, 2010-11

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, 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)

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

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

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)

15-minute avg.

More than 10 to 1 difference!
Median: ~2/3 Fair; ~1/3 Good

Log Scale

V Poor >3000
Poor 1050-3000
Fair 300-1049
Good 150-300
V Good 75-149
Excellent <75
Outdoor Median & Distribution (Dylos Total - 0.5+ um)

15-minute avg.

~½ Poor; ½ Fair

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

V Poor >3000
Poor 1050-3000
Fair 300-1049
Good 150-299
V Good 75-149
Excellent <75
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?

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

Of these selected 86 sites
65 saw reduction in counts
  ➢ 47 more than 30% reduction
  ➢ 25 more than 50% reduction

Counts – 0.5+ μm as measured by the Dylos monitor
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

Dylos 0.5+ μm + (Particle #/100ft^3)

Windows open

Windows open
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

Log scale
Dylos 0.5+ µm

Outdoors

Bedroom

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

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

2-burner Induction Stovetop

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

Those flagged are using 24/7 operation of air handlers & portable air cleaners

Log Scale
Impact of Portable Air Cleaner

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

Your Indoor Particles vs. Time

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

2 zones – Living room no air cleaner
Kitchen – air cleaner on timer (6 hrs. on – 6 hrs. off)
Indoor Fan Filter 24/7 Impact

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

Added fan/filter here
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

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

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!!!

- Return drop restricted due to size (8” x 25”)
- Poor design at throat w hard 90 degree angle
- Filter still only 16” x 25”

Not Effective!
RESULTS:
5 yr. old home
Significant comfort improvement!

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

- ECM replacement
- Larger return drop
- 2-part filter rack (20” x 25”)
  Horizontal (4” MERV 13 + 2” pre or post filter)
- 90 degree transition designed for better air flow; lower static (with turning vanes)

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

RESULTS:
5 yr. old home
Significant comfort improvement!

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

- ECM replacement
- Larger return drop
- 2-part filter rack (20” x 25”)
  Horizontal (4” MERV 13 + 2” pre or post filter)
- 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 CO₂ 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
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

Bill Turner, P.E.
Consultant
Harrison, ME

Rhett Major
Air Handler Inquiry
North Huntingdon, PA

Greg Fanslow
LCMP Data Analysis
Burlington, VT

Yujie Xu
Data Management
Pittsburgh, PA

Rob Busher
Air Quality Fellow
Pittsburgh, PA

Norm Anderson
Advisor
Winthrop, ME

Linda Wigington
Team Leader
Waynesburg, PA

Tom Phillips
Range Hood Brief
Davis, CA

Rhett Major
Air Handler Inquiry
North Huntingdon, 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
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”.

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
(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

![Image of portable air cleaner]

- dylosCat
  - Very Poor
  - Poor
  - Fair
  - Good
  - Very Good
  - Excellent

Legend:
- Outdoor
- Indoor
- Roamer

Date (by periods of 2 days):
- May 01
- May 15
- Jun 01

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

*(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?