



What Does a Check Box Signify?

**A Breath of Fresh Air: Talking About IAQ in Homes,
Beyond Ventilation**

Two guys who like to talk

Dan Wildenhaus



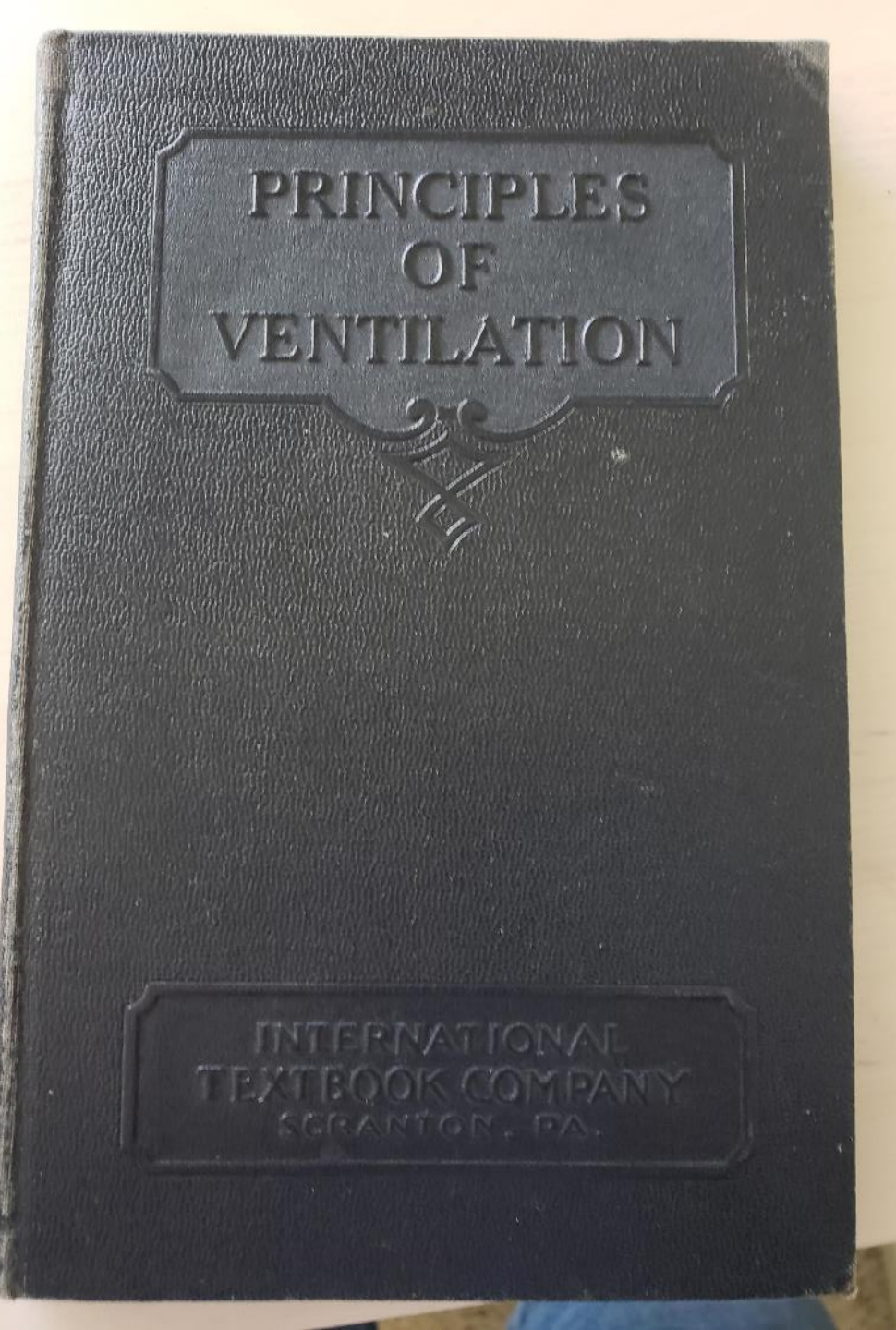
Bruce Manclark





Who's in the
room?

Raise your hand if you are a...



We Are Not The First To Worry about IAQ

- Published in the 1920's. Big Concerns:
- Diminution of oxygen
- Vitiated air
- Ground air
- Cellar air

“When a definite animal or musty odor begins to be perceptible. The air is said to be *“rather close”* and the exhaled carbon dioxide is found to amount to 4 or 5 parts per 10,000. When the portion increases 7 or 8 the air is called *“very close”* When its in excess of 12 the air pronounced *“very bad”*



**What do you think matters the most
regarding IAQ?**

Survey to start

The Components Of Good Indoor Air Quality

Dilution

Exhaust of
“bad” air
sources

Distribution

Filtration

Does it get
used

Can it be
maintained

Low VOC
materials

Good House
Keeping

Good IAQ = Low-Risk of **Bad IAQ**

Current Trends: Outdoor & Indoor AQ

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





KEEP CALM AND PREPARE FOR A TEST

Pre Test

- Is the outside air always better than indoor air? (y/n)
- When does the average person receive the most exposure from outside air pollutants? (Inside or Outside)
- Does the current ASHRAE 62.2 Standard have filtration requirement? (y/n)
- For verifiers, what's the hardest part of a house to verify

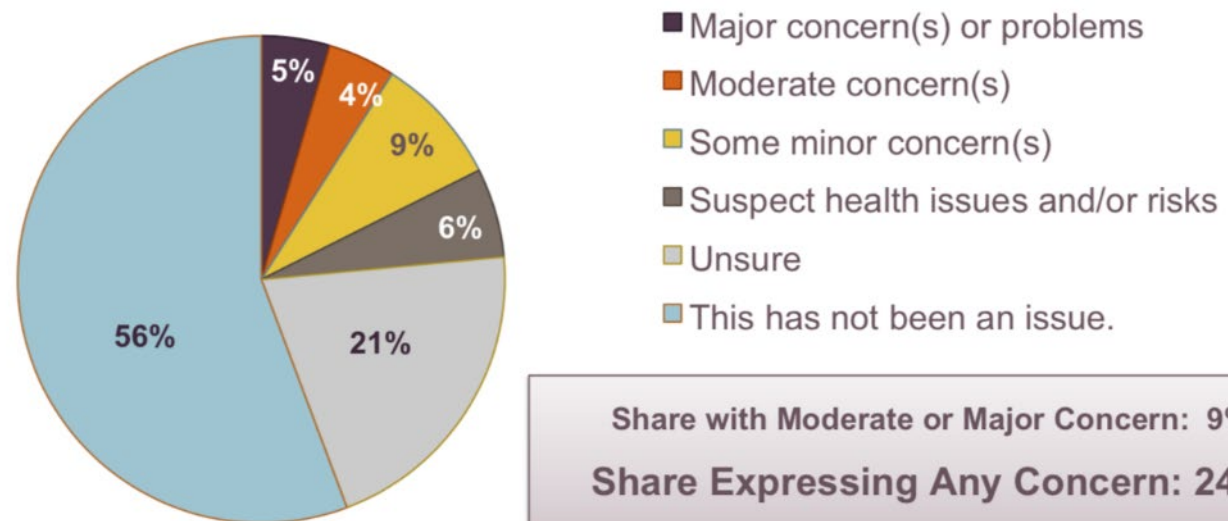
The Pro and Cons: Reality Check

Type	Cost	Ability of Humans to Install Correctly	Potential Negatives	Potential Positives	Energy Impacts
Exhaust Only	Low	High	House under negative pressure. No distribution	House acts as a MERV 6 Filter	Low
Supply (Hole in return)	Medium	Medium	Comfort complaints Introduction of particulate matter	Can be balanced. Distribution	High with wrong fan type
ERV/HRV	High	Low	Difficulty. High energy Use if Done well	Can be filtered Great distribution	Very low if done well
The Ideal continuous distribution and filtration, easy to maintain with HRV		Needs attention		Filtration, distribution, filtration	Low if done well

Are Healthy Homes Marketable?

Nearly One in Four Householders Expressed Concern About Healthy Home Problems or Risks

Share of Owner Households Expressing 'Healthy Home' Concerns (Percent)



Notes: Sample size is 2,249. Households were asked, "In the past few years, how concerned have you been about your current home negatively affecting your or another occupant's health? "

Source: JCHS tabulations of Healthy Home Owner Survey, The Farnsworth Group.



JOINT CENTER FOR HOUSING STUDIES OF HARVARD UNIVERSITY

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Who Knew There Was A state Of The Air Report

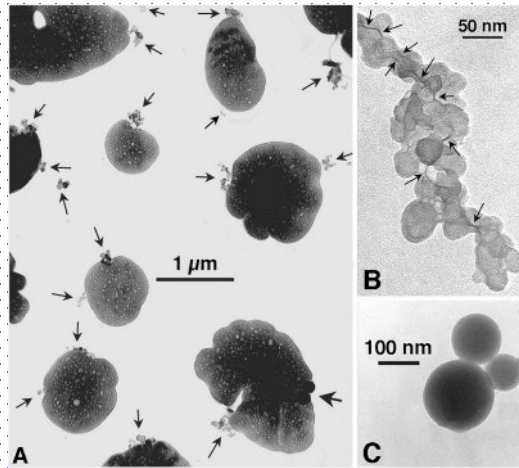


Dang, I
Thought the
Northwest
had “good”
Air

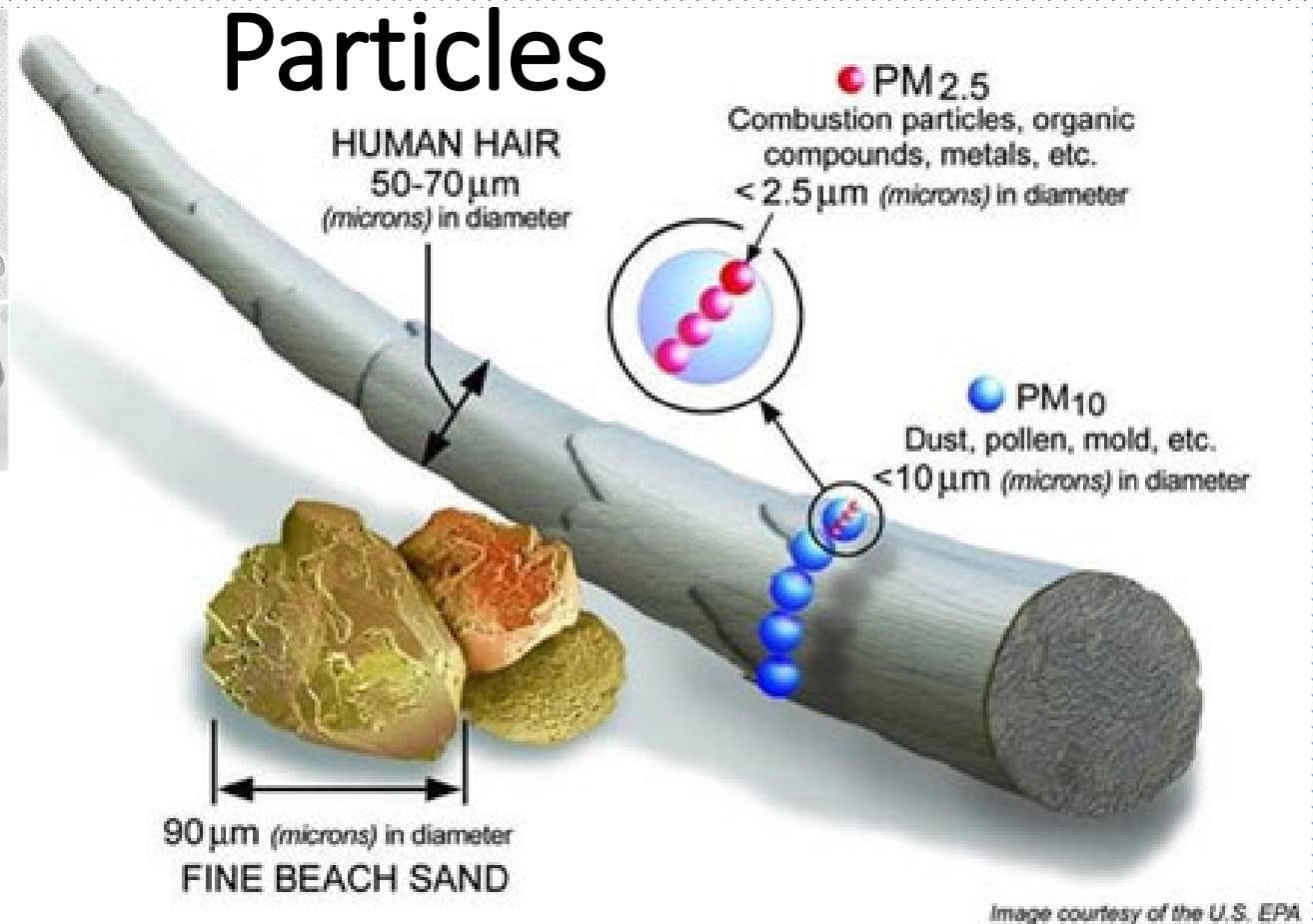
2017 Rank ¹	Metropolitan Statistical Areas	Total Population ²	Under 18 ³	65 and Over ³	Pediatric Asthma ^{4,6}	Adult Asthma ^{5,6}	COPD ⁷	Lung Cancer ⁸	CV Disease ⁹	Diabetes ¹⁰	Poverty ¹¹
1	Bakersfield, CA	882,176	257,727	88,992	18,417	47,777	23,732	384	36,297	57,322	185,990
2	Visalia-Porterville-Hanford, CA	610,828	185,471	63,293	13,253	32,579	16,291	266	24,985	39,208	154,039
2	Fresno-Madera, CA	1,129,859	322,159	132,448	23,021	62,047	31,883	490	49,778	77,435	274,927
4	Modesto-Merced, CA	806,843	226,215	95,841	16,165	44,619	23,071	350	36,214	56,432	171,672
5	Fairbanks, AK	99,631	24,116	8,349	2,045	7,139	2,756	56	3,943	4,891	7,671
6	San Jose-San Francisco-Oakland, CA	8,713,914	1,877,655	1,214,016	134,173	526,751	280,172	3,779	448,510	696,765	933,311
7	Salt Lake City-Provo-Orem, UT	2,467,709	757,422	231,853	53,789	154,727	60,714	653	90,218	115,839	255,652
8	Logan, UT-ID	133,857	41,508	12,489	3,008	8,322	3,200	38	4,693	5,854	19,910
9	Los Angeles-Long Beach, CA	18,679,763	4,383,662	2,376,130	313,246	1,099,027	571,985	8,096	902,929	1,409,515	2,928,894
10	Reno-Carson City-Fernley, NV	605,706	131,049	102,549	7,661	38,311	33,137	356	39,626	49,111	81,422
11	El Centro, CA	180,191	51,119	22,442	3,653	9,934	5,187	78	8,178	12,647	41,685
12	Lancaster, PA	536,624	128,793	89,727	14,397	41,751	28,456	353	38,439	42,053	55,725
13	Missoula, MT	114,181	22,154	16,172	1,404	8,203	4,628	66	5,905	6,350	17,461
14	Sacramento-Roseville, CA	2,544,026	593,452	374,195	42,407	150,701	81,902	1,102	132,685	204,433	379,600
14	Anchorage, AK	399,790	101,387	38,009	8,596	27,941	11,714	223	17,279	21,498	34,981
16	Yakima, WA	248,830	74,063	32,662	4,838	16,416	10,504	138	13,029	14,296	46,794
17	Pittsburgh-New Castle-Weirton, PA-OH-WV	2,648,605	509,215	497,830	56,223	218,112	158,026	1,748	213,287	232,472	327,752
17	Seattle-Tacoma, WA	4,602,591	1,000,111	626,375	65,324	339,697	216,668	2,557	263,773	293,479	482,638
19	Medford-Grants Pass, OR	297,312	60,886	65,587	5,714	26,407	14,726	167	21,709	28,402	58,695
20	Philadelphia-Reading-Camden, PA-NJ-DE-MD	7,183,479	1,592,239	1,085,893	162,777	525,438	349,693	4,605	470,916	542,896	916,171
21	South Bend-Elkhart-Mishawaka, IN-MI	725,065	178,459	113,087	13,523	56,107	43,911	511	54,707	62,712	109,079
21	Harrisburg-York-Lebanon, PA	1,247,235	272,926	209,814	30,509	99,682	68,539	820	92,638	101,485	126,887
23	Eugene, OR	362,895	68,799	64,973	6,456	33,296	16,555	204	23,240	31,518	67,777
24	Phoenix-Mesa-Scottsdale, AZ	4,574,531	1,127,596	670,488	122,981	324,484	214,829	2,233	264,628	340,926	727,788
25	Bend-Redmond-Prineville, OR	196,898	41,110	38,464	3,858	17,521	9,377	111	13,392	17,982	26,721

PM=Particulate
Matter, The
number is their
size in microns

PM ₁₀	<ul style="list-style-type: none">• Inhalable particles• Deposit in the extra thoracic /upper tracheo-branchial region
PM _{2.5}	<ul style="list-style-type: none">• Fine particles• Deposit in deeper lung
PM _{0.1}	<ul style="list-style-type: none">• Ultra-fine particles• Pass into the circulatory system



OUTDOOR BLACK CARBON
50 nm to 1 μm



PM₁₀: 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!)



Results & Implications

Linda Wigington

ROCIS Air Handler Inquiry

Making the Invisible Visible

Dylos 1700 Optical Particle Counter:

Particles per 1/100 ft³, 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>



Air Quality Chart .5 μm – Small Count Reading		
3000 +	=	VERY POOR
1050-3000	=	POOR
300-1050	=	FAIR
150-300	=	GOOD
75-150	=	VERY GOOD
0-75	=	EXCELLENT

**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/year¹)

**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

Duct leaks (energy waste & pressure-related problems)

Example 2
Pre-retrofit



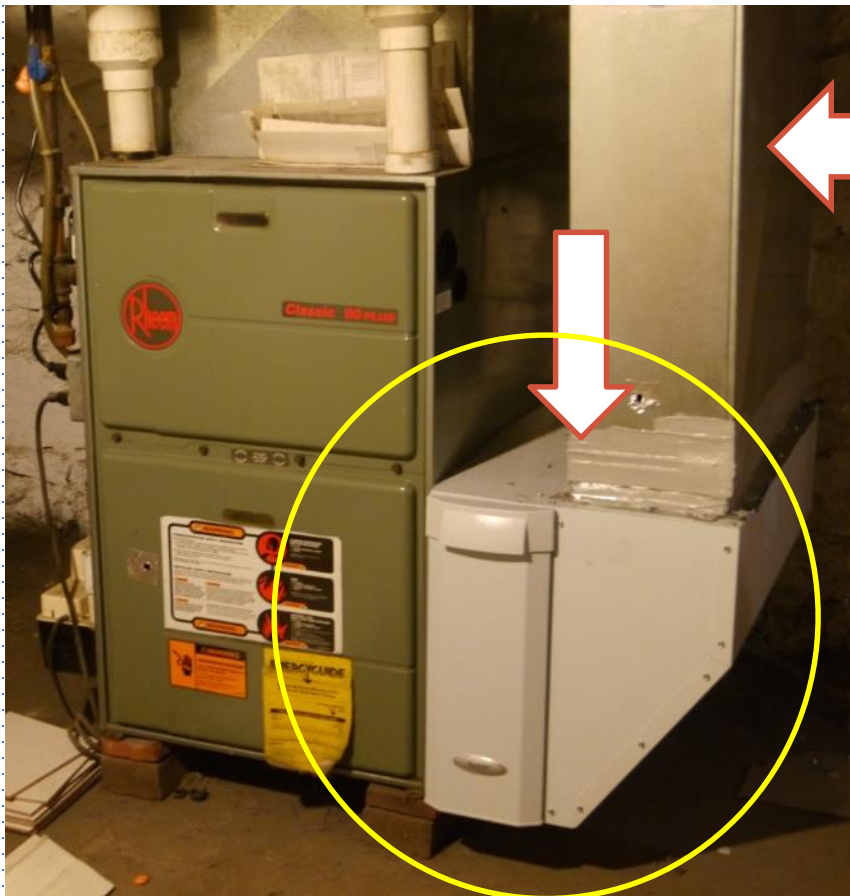


Example 2 Post-retrofit

New ductwork & filters
About \$500.00
(parts and labor)

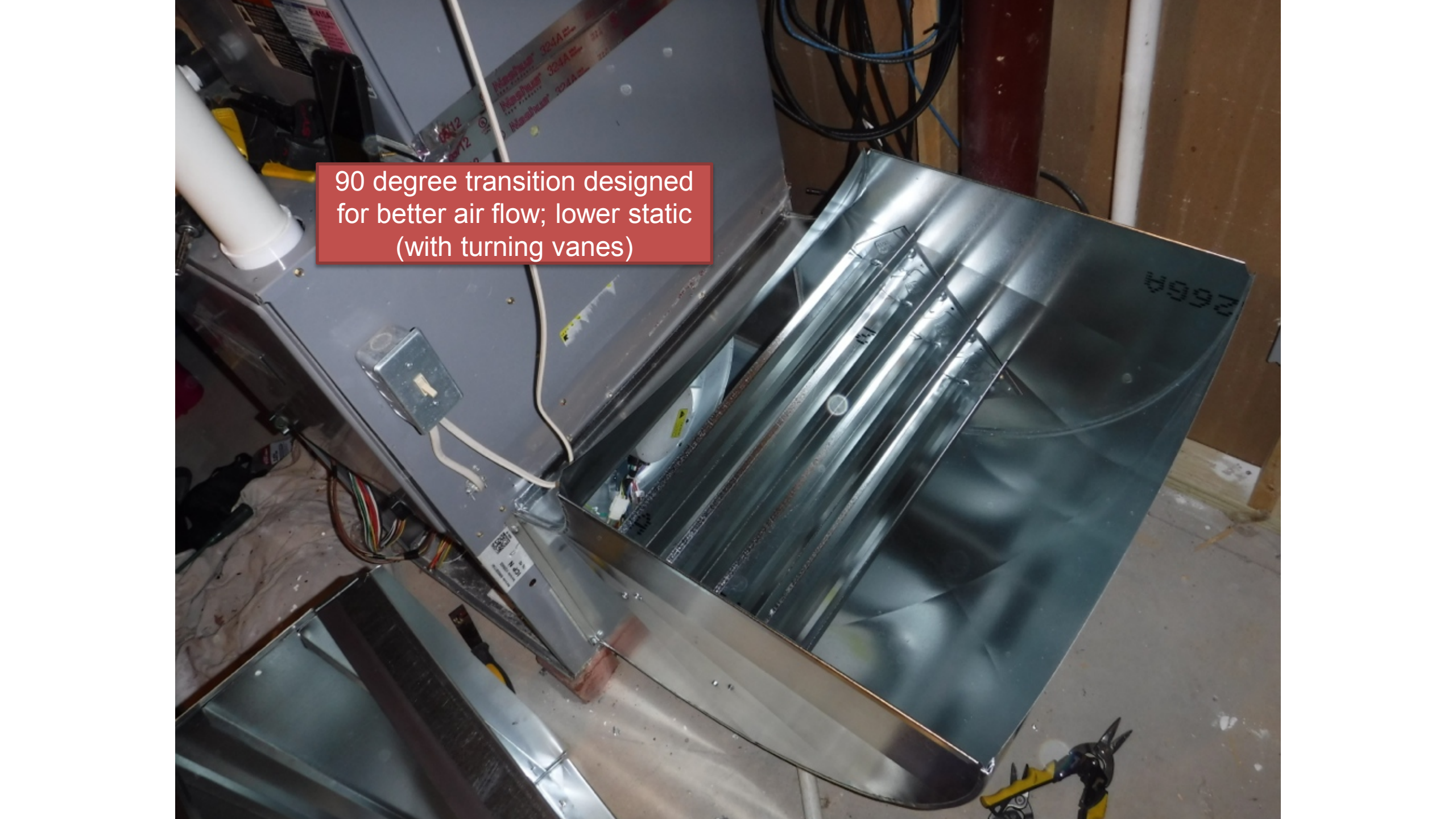
Lessons Learned: An Early Change-out

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



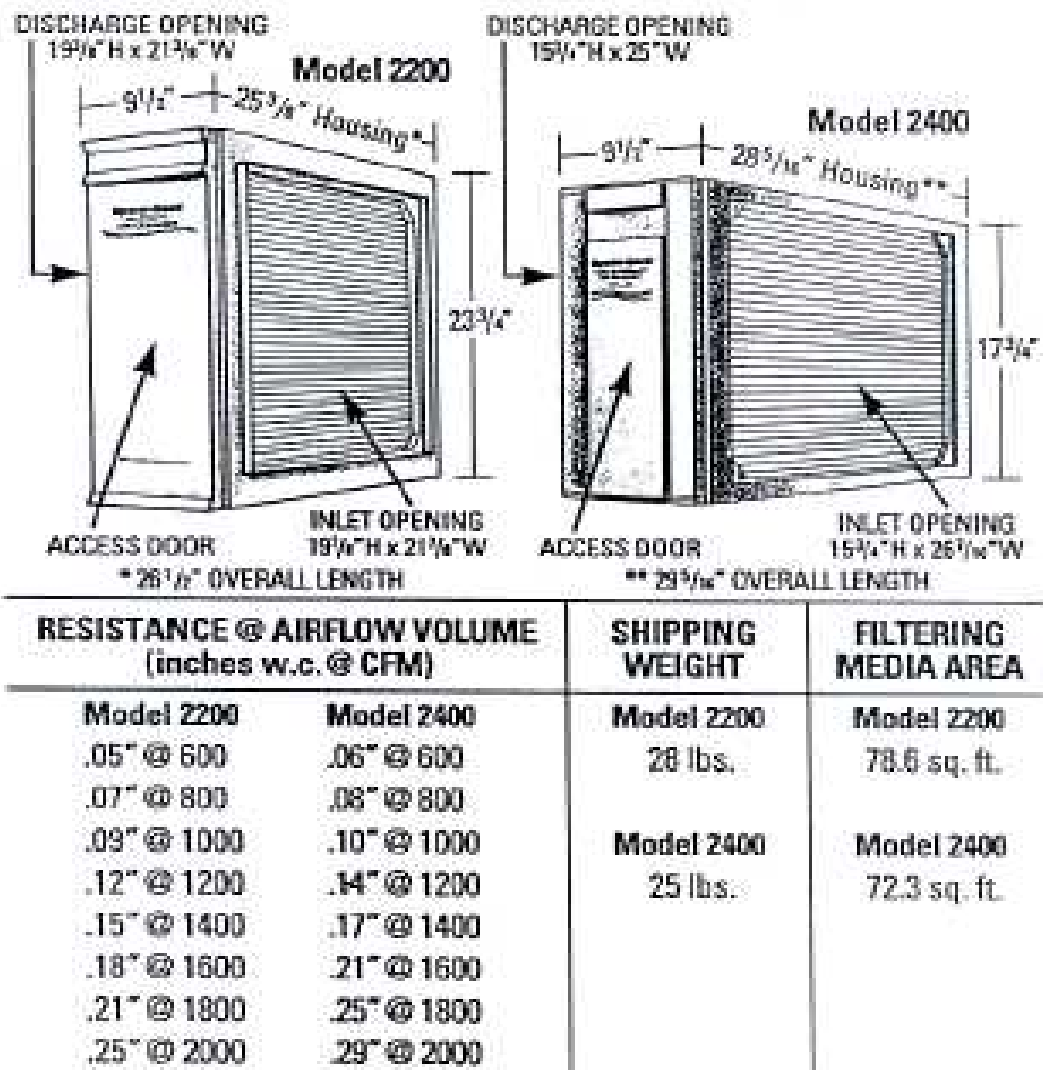
Not Effective!

- 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"



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

Pressure Drops Matter



We want cleaner air, but can our systems take the extra restrictions presented by the filter?



1" high MERV filters tend to be very restrictive.

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

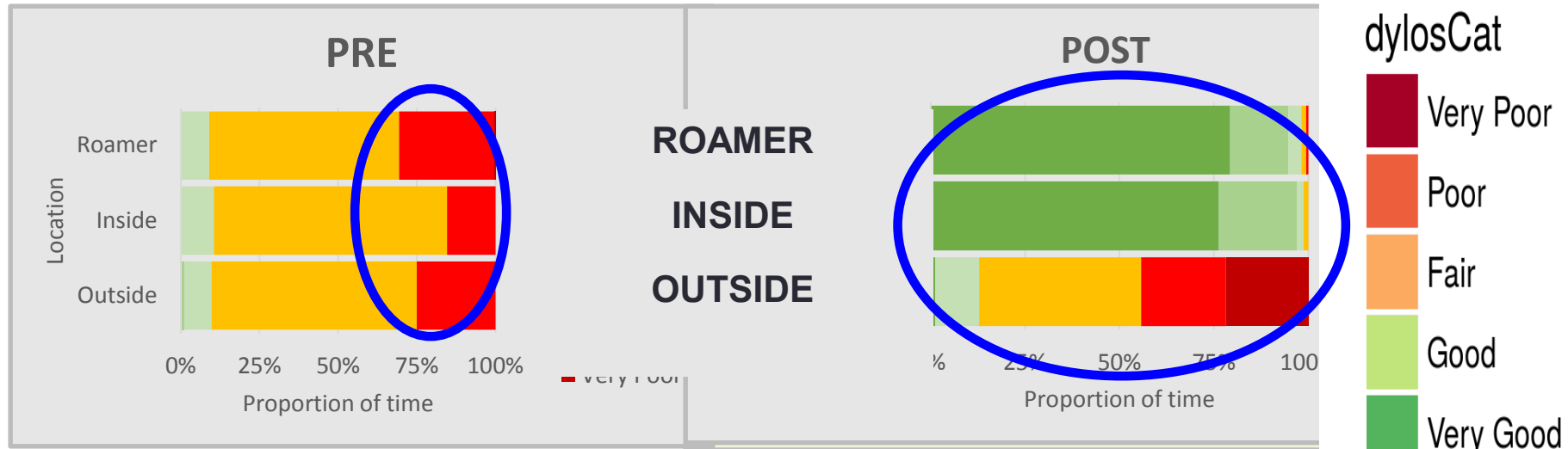
Due to air resistance, filters over MERV 13 not recommended in home HVAC systems

Source: Adapted from EPA, 2009 in Wikipedia, 2018

Filter Table

Tests for Pressure Drop and Efficiency on Air Filters							
Filter	Depth	300 fpm	400 fpm	500 fpm	Ambient Particles	Particles After Filter	% Particle Drop
Precisionaire Easy Flow	1"	.10"	.12"	.14"			
True Blue Fiberglass	1"	.10"	.11"	.13"			
Filtrete 300	1"	.19"	.21"	.24"	1567000	1468000	6.32%
Filtrete 600	1"	.21"	.24"	.26"	1168000	943000	19.26%
Filtrete 1000	1"	.22"	.24"	.27"	740000	549000	25.81%
Filtrete 1250	1"	.22"	.24"	.27"	831000	716000	13.84%
Filtrete 1700	1"	.25"	.27"	.31"	767000	493000	35.72%
MERV 7	1"	.17"	.19"	.22"	940000	890000	5.32%
MERV 7	2"	.14"	.16"	.18"			
MERV 7	4"	.10"	.13"	.14"			
Carbon	2"	.14"	.16"	.18"	992000	948000	4.44%
MERV 11	1"	.26"	.28"	.31"	972000	865000	11.01%
MERV 11	2"	.20"	.23"	.25"	945000	821000	13.12%
MERV 12	2"	.23"	.24"	.26"	701000	452000	35.52%
Polyester	1"	.14"	.15"	.16"	1333000	1303000	2.25%
Polyester	2"	.30"	.33"	.37"	1322000	1303000	1.44%
Ring Panel	2"	.27"	.30"	.34"	1304000	1240000	4.91%
					1304000	135400	-3.83%
MERV 13	2"	.35"	.38"	.42"	168000	647000	39.42%
MERV 14	2"	.39"	.44"	.48"	1021000	508000	50.24%
MERV 14	4"	.29"	.36"	.40"	935000	455000	51.34%

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 **24/7 annual operating cost: \$131.40**

Are ECMs the Solution?

Not by themselves...

Even with ECMs, 24/7 operation of central AHU can have a huge adverse impact on energy use

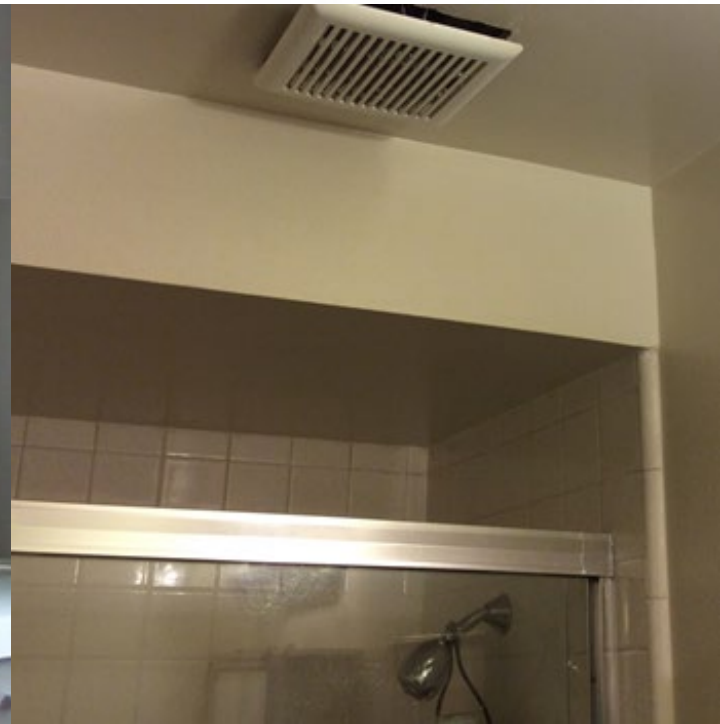
Not X13 motors but version 2 or higher

Correct blower speed, TESP, & good ducts are essential

Must avoid clogged filters & inappropriate filters

The other “V”

Spot Ventilation!





Maintenance: Who Does What

Is this a good place for a “Fresh Air Inlet”
Or an exhaust vent?

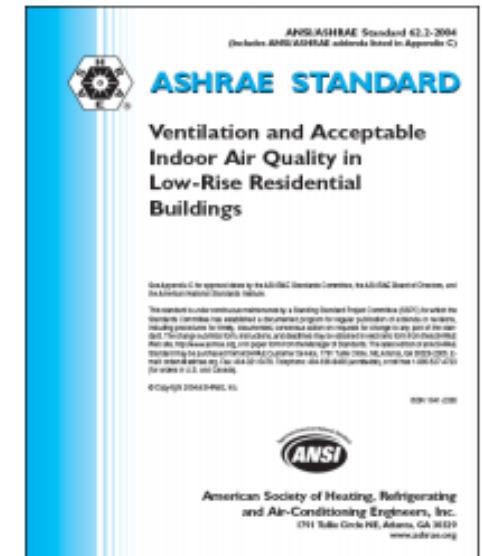
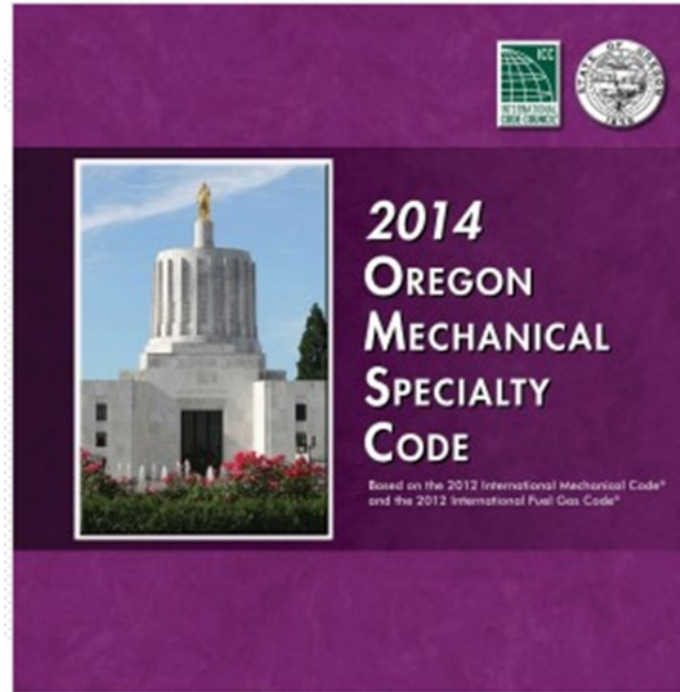
The standards

Kitchen:

100 cfm
intermittent or 25
cfm continuous (or
operable window)
or 5 ACH

Bath:

50 cfm
intermittent or 20
cfm continuous (or
operable window)



Why Do Many Ventilation Systems Get turned off

- Comfort problems
- Lack of understanding as to the purpose
- Energy concerns
- Maintenance



Is it getting
used?

Whole-House Ventilation Control	Controller Labelled?	% On As-Found
On/Off Switch	No (N=42)	5%
	Yes (N=12)	58%
Programmable Controller	No (N=10)	50%
Thermostat	No (N=2)	0%
Breaker Panel	No (N=1)	100%
No Controller	No (N=3)	100%

Kitchen range hoods

The New York Times

The Kitchen as a Pollution Hazard

BY PETER ANDREY SMITH JULY 22, 2013 3:19 PM [Comment](#)

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By midmorning, the smell of hot peanut oil dissipated and inside the tightly sealed laboratory known as Building 51F, a pink hamburger sizzled in a pan over a raging gas flame. Overhead, fans whirled, whisking caustic smoke up through a metallic esophagus of ductwork.



Lisa Haney

Woody Delp, 49, a longhaired engineer in glasses — the Willie Nelson of HVAC — supervised the green bean and hamburger experiments. He sat at a computer inside a kitchen simulator, rows upon rows of numeric data appearing on



*Brett
Singer*



*Iain
Walker*

Pollutants from burners and cooking

Gas burners

- Moisture & CO₂
- NO₂ and formaldehyde
- Ultrafine particles & CO

Electric elements

- Ultrafine particles

Cooking

- Ultrafine and fine particles
- VOCs including acrolein
- Moisture and odors



ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Experimental Evaluation of Pollutant
Emissions From Residential Appliances
Singer et al., LBNL-2897E

Dennekamp, Occup Environ Med
2001; 58:511–516



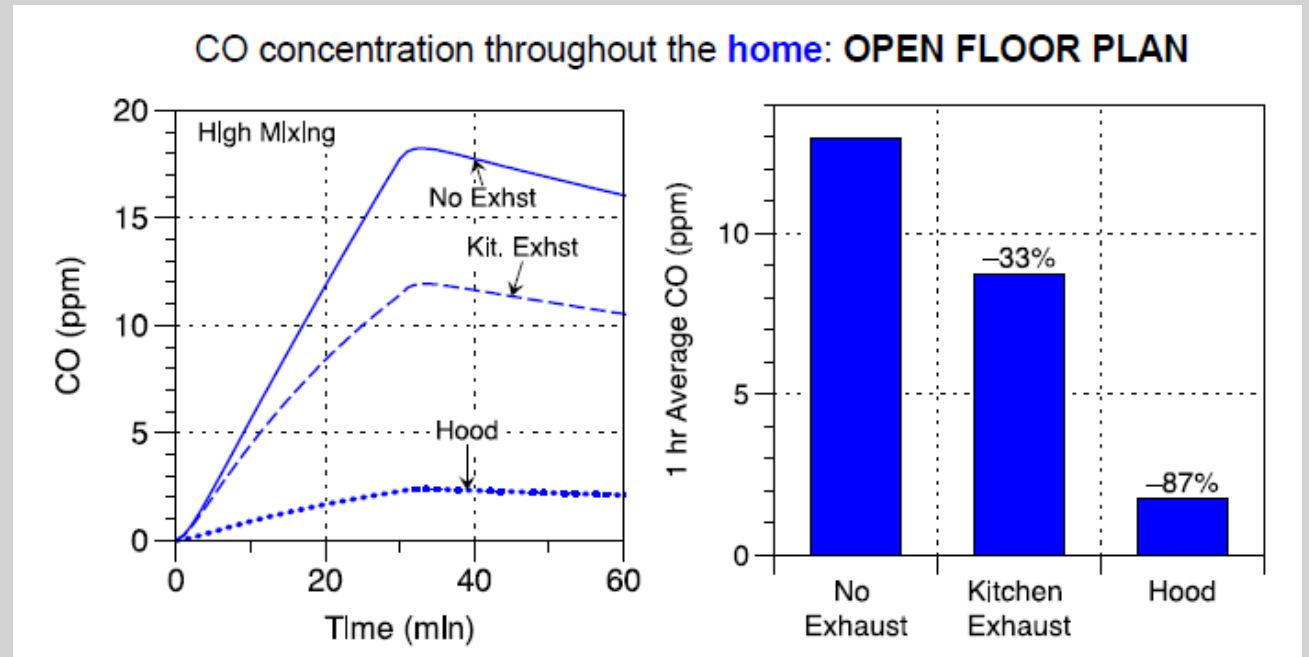
ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Compilation of PM_{2.5} Emission Rates for
Cooking and Candles...
Hu et al., LBNL-5890E

Range hoods better than general kitchen exhaust

200 cfm range hood or kitchen exhaust fan (lab simulations)

- 15,000 btu/h
- 800 ng/J CO



Capture Efficiency

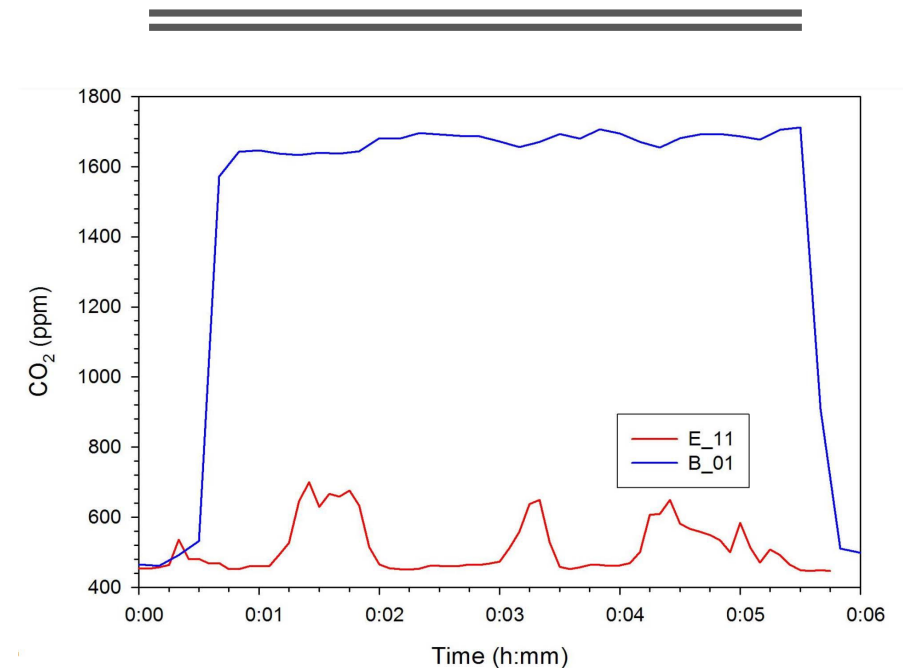
Measuring capture efficiency using CO₂

Emission rate based on fuel CH₄ → CO₂

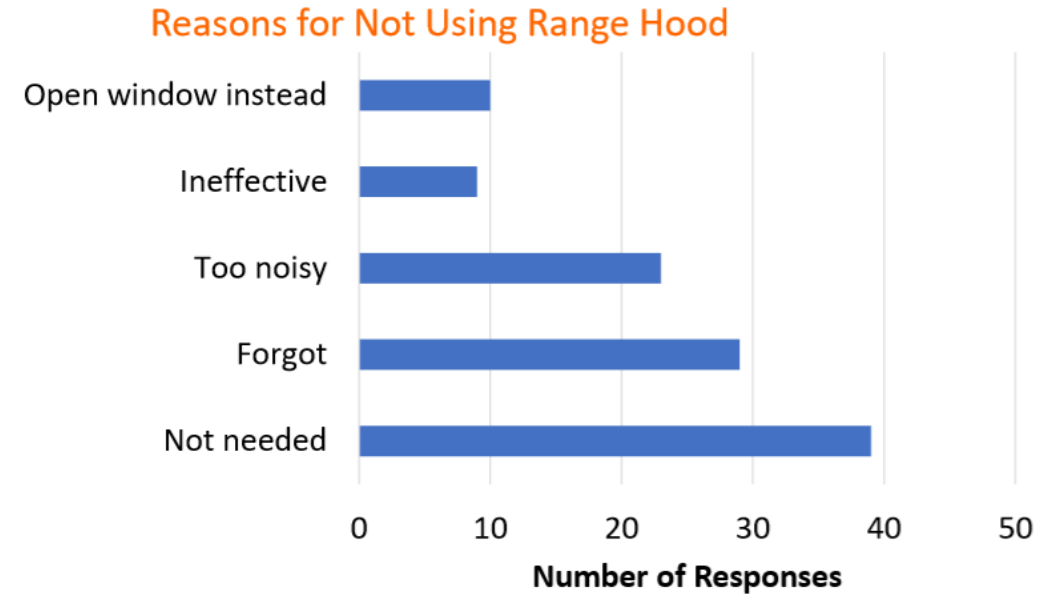
Measure concentration in hood exhaust and room

Separately measure flow in hood exhaust

$$CE = \frac{\text{removal}}{\text{production}} = \frac{Q_{air} (CO_{2-hood} - CO_{2-room})}{Q_{fuel} (C \text{ in fuel})}$$



Self-reported usage	Number	Percent
Most times (>75%) when cooktop or oven used	44	13%
Most times when cooktop used, but not oven	39	11%
About half the time	45	13%
Infrequently, only when needed	113	32%
Never	35	10%
No exhaust fan	73	21%



Is it getting used?

What determines health outcomes?

- >5% - Genetics/biology
- ~20% - Lifestyle/behavior
- ~20% - Medical care
- ~55% Physical & social environment

It's not your genetic code... it's your zip code!

Scary Statistics

- 90% - Time we spend indoors
- 75% - Deaths caused by chronic disease, up from 13% in 1800
- 85% - Of the 82,000 chemicals in use, this % lacks available health data!

Today's kids are the first generation expected to have shorter life expectancy than their parents 😞

We are just
really
learning
about toxic
materials
impacts

Asbestos

Cadmium

Chlorinated Polyethylene & Chlorosulfonated Polyethylene

Chlorofluorocarbons (CFCs)

Chloroprene (Neoprene)

Formaldehyde (added)

Halogenated Flame Retardants

Hydrochlorofluorocarbons (HCFCs)

Lead (added)

Mercury

Petrochemical Fertilizers and Pesticides

Phthalates

Polyvinyl Chloride (PVC)

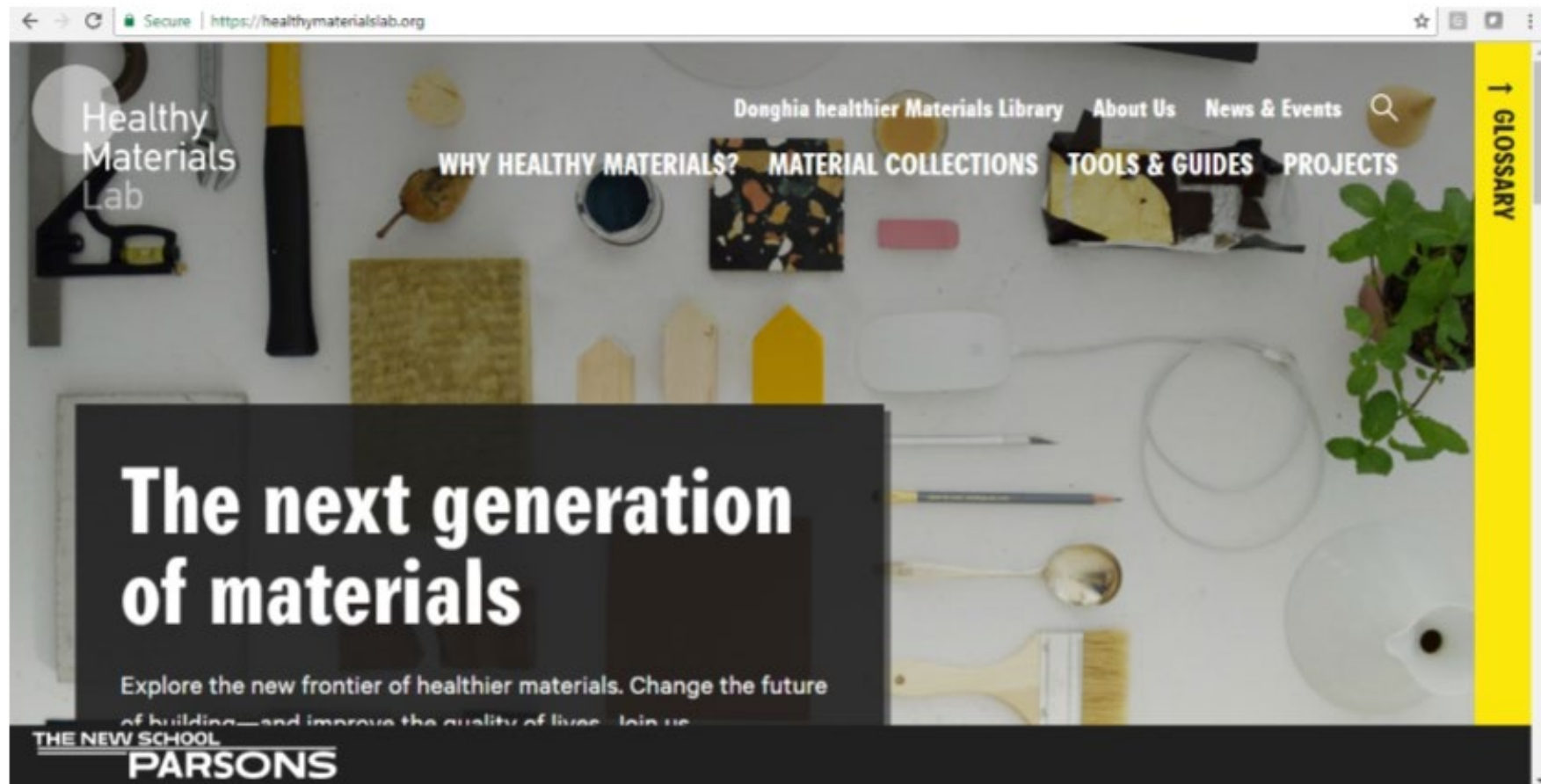
Wood treatments containing Creosote, Arsenic or
Pentachlorophenol

The 'Red' List



LIVING
BUILDING
CHALLENGESM

Resources



Google Healthy Materials Program & Cradle to Cradle Certified™

Dynamic criteria simplify acceptance.

Project teams will only specify products with scores of 4 or better.



The screenshot shows the PORTICO login page. At the top, there is a header with the PORTICO logo and a 'login' link. Below the header, there is a large text input field with the placeholder text 'Do you represent a manufacturer who received a request for information email?'. Below this field, there is a red button with the Google logo and the text 'Sign in with Google'. To the right of this button, there are two links: 'Received an invite? Complete registration here!' and 'Not yet invited? Request access here!'. Below these links, there is a section titled 'or sign in with Portico credentials'. This section contains two input fields for 'Email' and 'Password', both with asterisks indicating they are required. Below the password field, there is a checkbox labeled 'Please remember me'. At the bottom of this section, there are two buttons: 'Login' and 'Cancel'. Below the login section, there are two links: 'Forgot, change my password...' and 'Check our help center for additional sign questions...'. At the very bottom of the page, there is a footer with the text '© 2008 - 2013 by Healthy Building Network of Google. All rights reserved. | Terms & Conditions'.

Resources: On the way!

Programs

ENERGY STAR Homes

Indoor airPLUS

Green Communities 2015

LEED v4

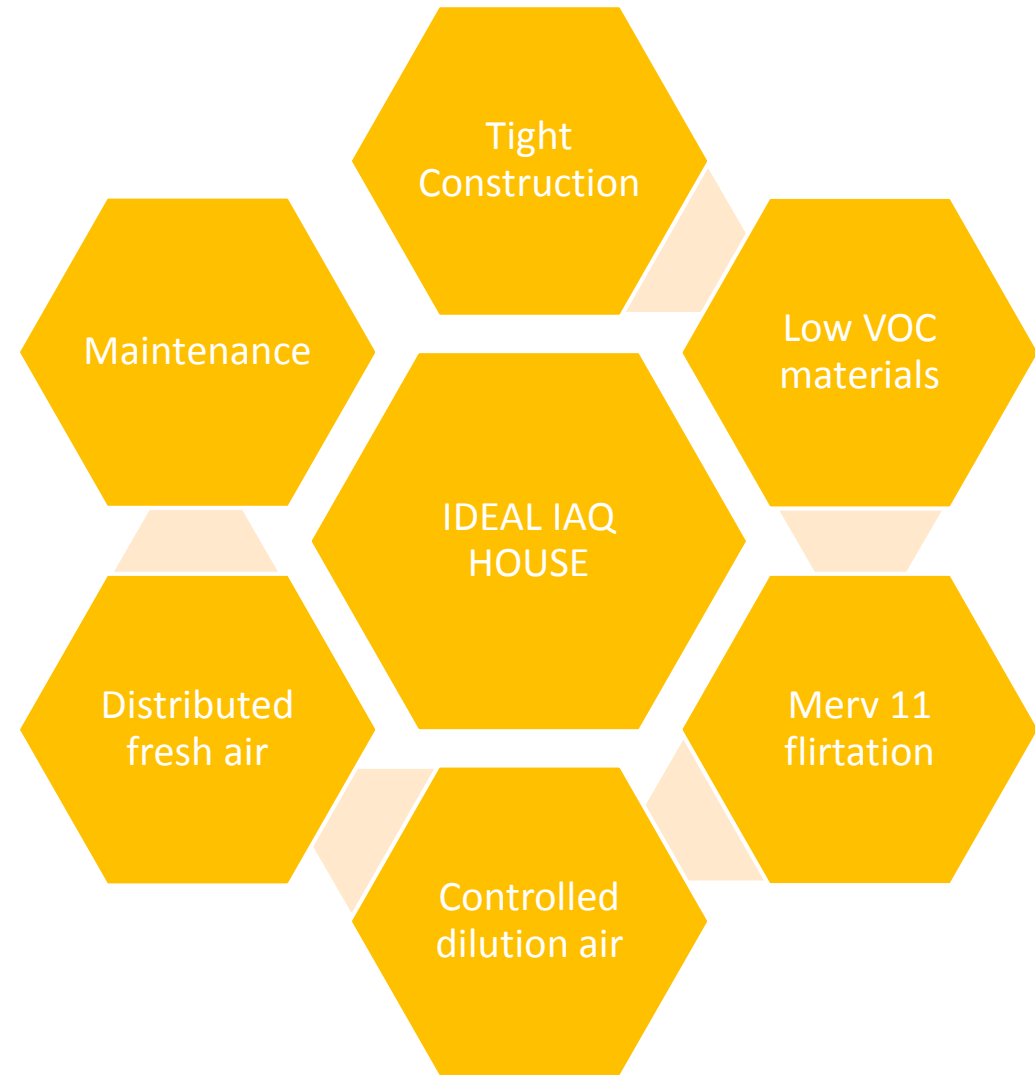
WELL Building Standard (MF)

Active Design Guidelines

Fitwel (MF)

	ES	IAP	EGC 2015	LEED v4	WELL	Fitwel
Environmental Tobacco Smoke			✓	✓	✓	✓
Biological contaminants	✓	✓	✓	✓	✓	✓
Combustion byproducts	✓	✓	✓	✓	✓	
Household products/practices			✓	✓	✓	✓
Toxic materials		✓	✓	✓	✓	✓
Radon		✓	✓	✓	✓	
Safety and security						✓
Diet & Exercise			✓	✓	✓	✓

The Ideal IAQ House(Its integrated)





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!

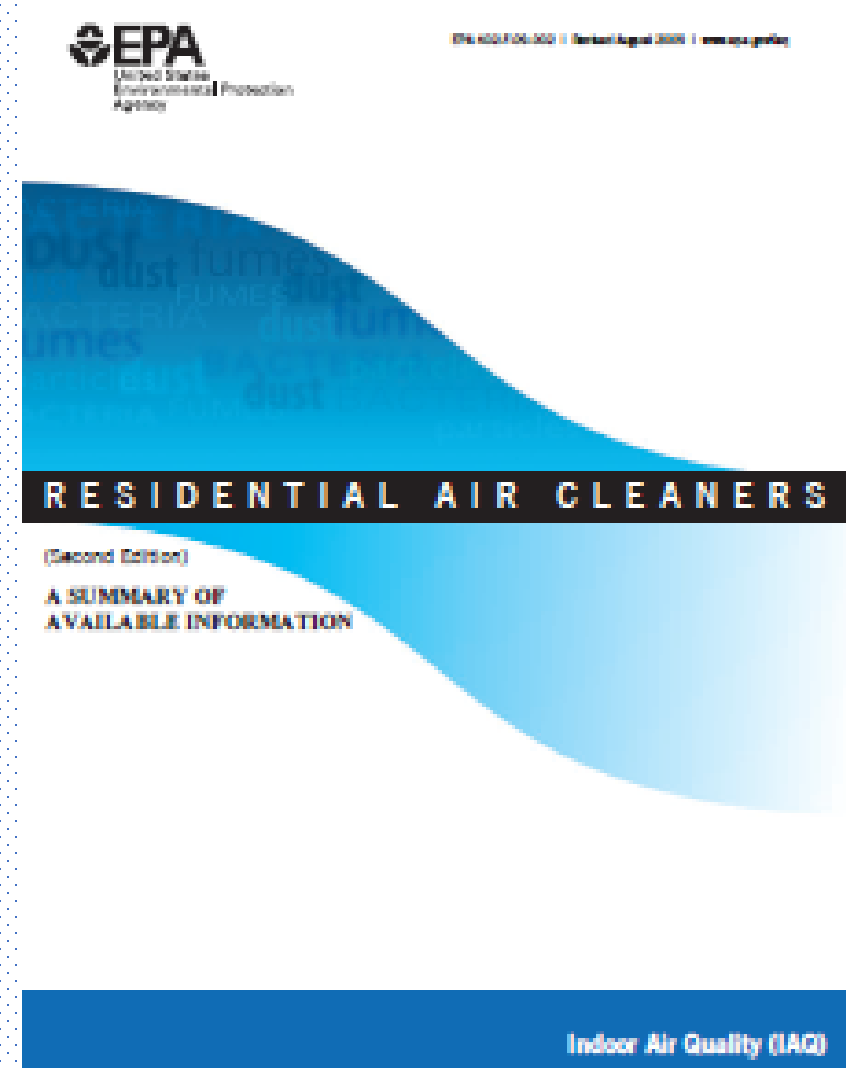
Resources: Filtration & Air Cleaners

Available from:

[U.S. EPA's web site](http://www.epa.gov/iaq/pubs/residair.html)

<http://www.epa.gov/iaq/pubs/residair.html>

[Residential Air Cleaners](#)



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

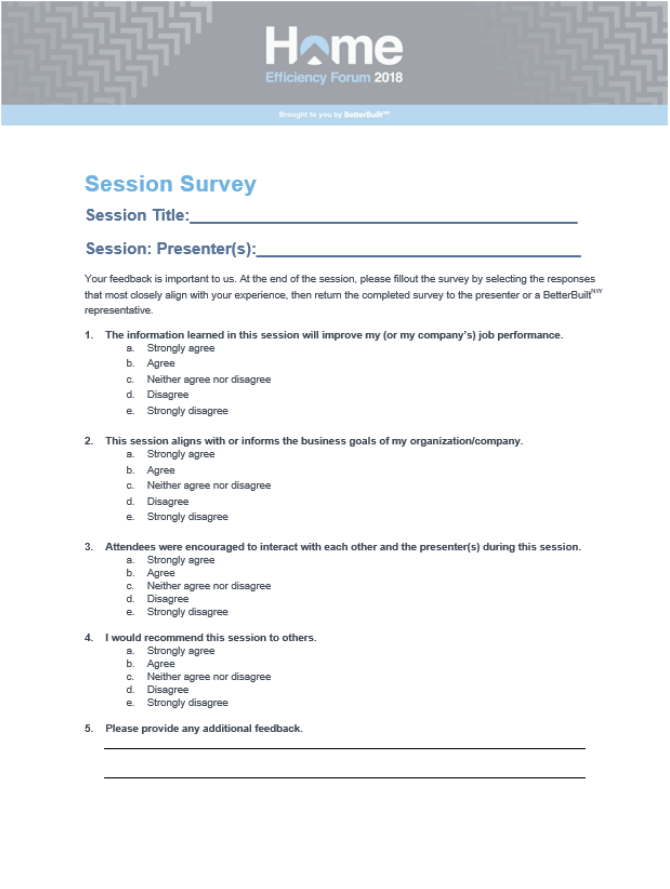
<https://iaqscience.lbl.gov/>

Indoor Air Quality Science Resource Bank

Session Survey Instructions

At the end of each session, you will be given 5 minutes to complete the session survey.

- Surveys will be distributed before the end of the session
- Complete the survey and provide it to the room moderator or drop them by the registration desk
- We greatly appreciate your feedback as it assists in improving the conference
- Assistance available at the BetterBuiltNW table



The image shows a survey form titled "Session Survey" for the "Home Efficiency Forum 2018". The form is brought to you by BetterBuiltNW. It includes fields for "Session Title:" and "Session: Presenter(s):". Below these fields, there is a paragraph explaining that feedback is important and that respondents should select responses that most closely align with their experience. The survey consists of five numbered questions, each with five response options (a. Strongly agree, b. Agree, c. Neither agree nor disagree, d. Disagree, e. Strongly disagree). The questions are: 1. The information learned in this session will improve my (or my company's) job performance. 2. This session aligns with or informs the business goals of my organization/company. 3. Attendees were encouraged to interact with each other and the presenter(s) during this session. 4. I would recommend this session to others. 5. Please provide any additional feedback. There are two lines for additional feedback.

Home
Efficiency Forum 2018
Brought to you by BetterBuiltNW

Session Survey

Session Title: _____

Session: Presenter(s): _____

Your feedback is important to us. At the end of the session, please fillout the survey by selecting the responses that most closely align with your experience, then return the completed survey to the presenter or a BetterBuilt^{NW} representative.

1. The information learned in this session will improve my (or my company's) job performance.
 - a. Strongly agree
 - b. Agree
 - c. Neither agree nor disagree
 - d. Disagree
 - e. Strongly disagree
2. This session aligns with or informs the business goals of my organization/company.
 - a. Strongly agree
 - b. Agree
 - c. Neither agree nor disagree
 - d. Disagree
 - e. Strongly disagree
3. Attendees were encouraged to interact with each other and the presenter(s) during this session.
 - a. Strongly agree
 - b. Agree
 - c. Neither agree nor disagree
 - d. Disagree
 - e. Strongly disagree
4. I would recommend this session to others.
 - a. Strongly agree
 - b. Agree
 - c. Neither agree nor disagree
 - d. Disagree
 - e. Strongly disagree
5. Please provide any additional feedback.

