Indoor Air Quality 101

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Name Some Indoor Pollutants

Major Points of Session

- Moisture can be a hazardous pollutant, but it is not the only one.
- Researchers are now able to quantify the hazards of pollutants with DALYs.
  - The benefits of ventilation can be demonstrated with this analysis.
- The control measures of source control, ventilation, and filtration can help.

IAQ Management

- Keep pollutants out of the house air we breathe.
  - Source control.
    - Keep pollutants out of house.
      - Moisture.
      - Others?
    - Manage those that are in the house.
      - Ventilation at source.
      - Air cleaning and filtration.
      - Vented combustion appliances.
      - No unvented combustion appliances.
  - Dilution.
    - Air leakage.
    - Ventilation.

IAQ in Perspective

- IAQ problems of one sort or another are common.
- Workers and students spend half of their waking hours at work and school.
- On average people are indoors 75% to 90% of the time.
- Pollutant levels are often higher indoors than outdoors.
- IAQ problems increase operation, overhead, and healthcare costs.

Source: Terry Brennan

Common Health Effects

- Allergy or asthma.
- Eye, nose, throat, lung or skin irritation.
- Injury to internal organ systems (e.g. cardio-vascular, central nervous, immune, gastro-intestinal, kidney, liver, endocrine, or limbic systems).
- Cancer.
- Infectious disease.

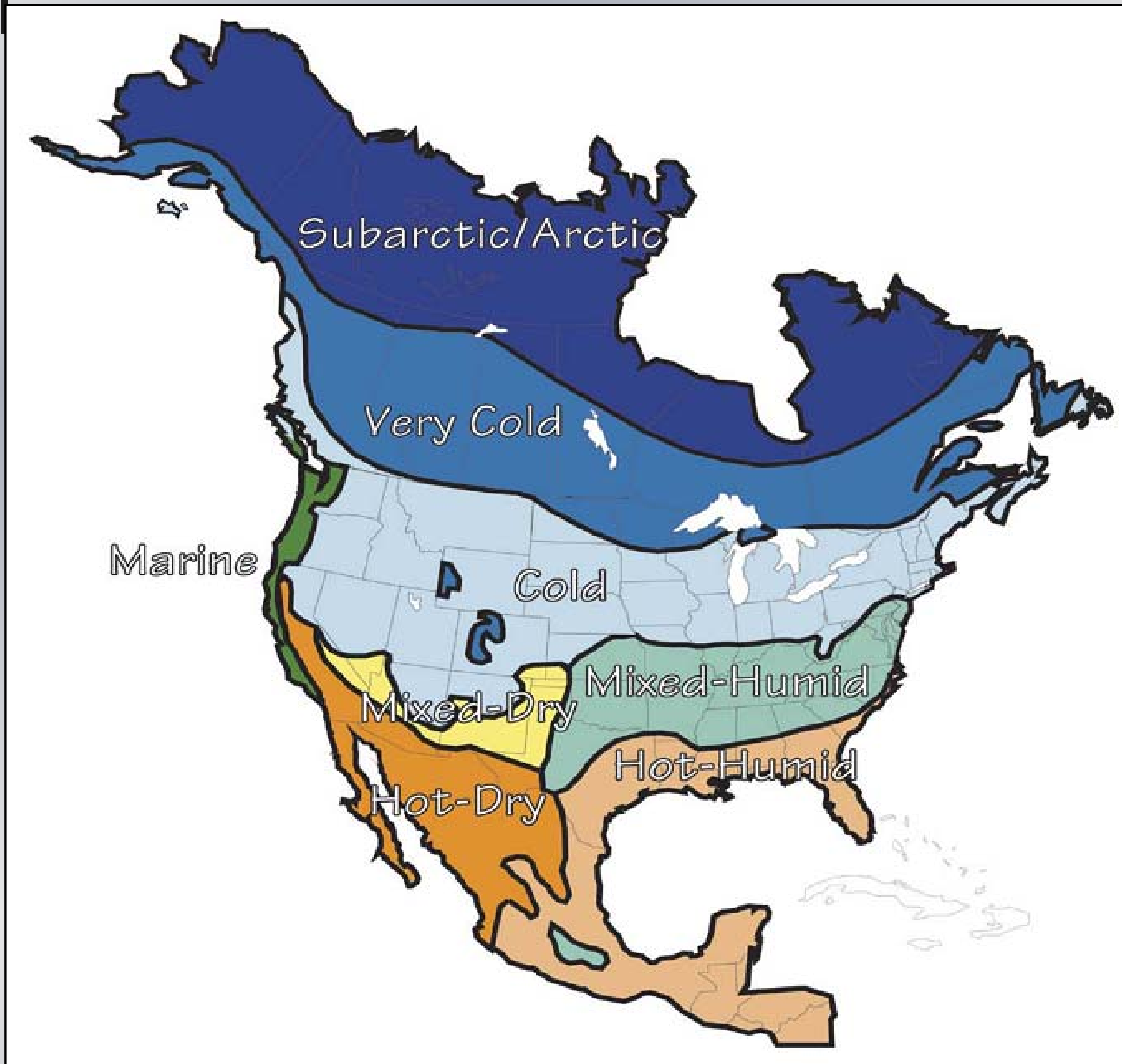
Source: Terry Brennan

Moisture as a Pollutant

Indoor Air Quality 101

Source: Terry Brennan

Indoor Air Quality 101



Source: Terry Brennan

Results of Bad Terminations

Different attics

What to Look For

- Wet stuff.
- Peeling paint.
- Water stains.
- Efflorescence.
- Condensation (windows, basements, crawlspaces).
- Mold and decay.
- Unvented baths, dryers, heaters, ranges.
- Humidifiers.

Source: Terry Brennan

Where to Look:

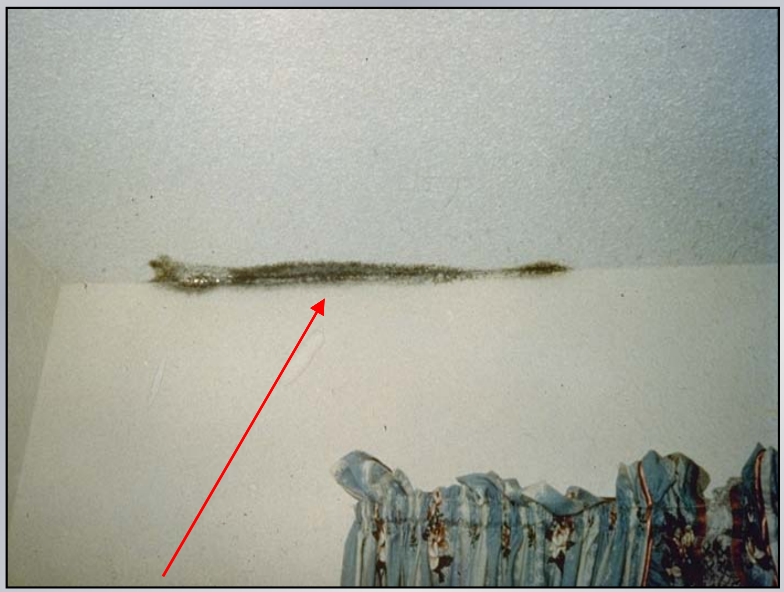
- Exterior drainage.
- Roofing, flashing, siding.
- Attic.
- Basement.
- Crawlspace.
- Windows/doors.
- Walls under windows.
- HVAC units.
- Sinks, toilets, dishwashers, clothes washers, plumbing lines.

Source: Terry Brennan

What conditions caused this mold formation?

Source: Terry Brennan

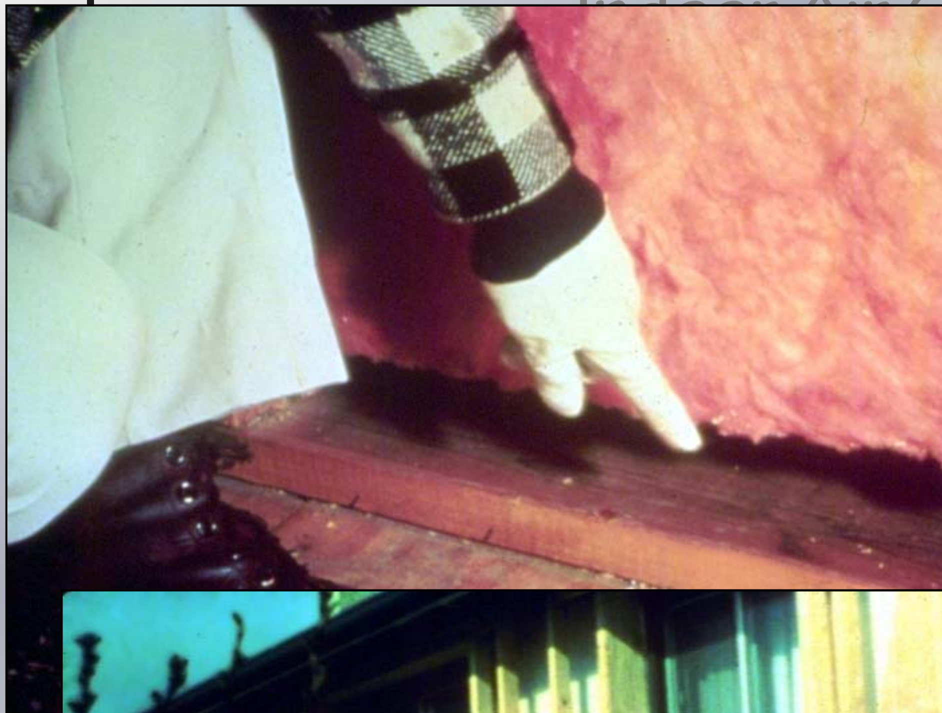
Condensation when it's Cold Outdoors



Mold due to poor insulation or wind blowing through insulation.

Mold around window where there is no insulation.

Source: Terry Brennan



Source: Terry Brennan

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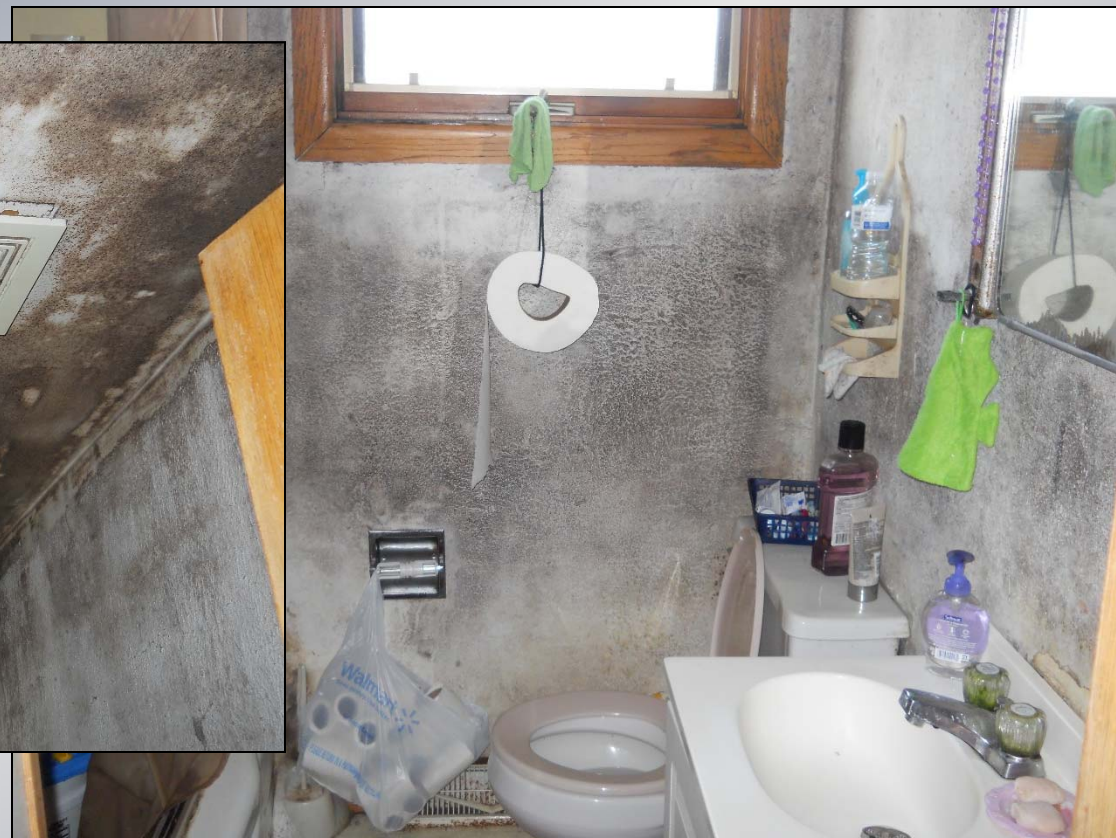


Source: Tony Francis, Wisconsin Rapids, WI

Indoor Air Quality 101

Source: Terry Brennan

Indoor Air Quality 101

Foam board keeps warm, humid summer air from cold concrete – prevents condensation.

90 – latitude = ground temp

Source: Terry Brennan

Indoor Air Quality 101

Source: Terry Brennan

Source: Terry Brennan

Dehumidifiers

Wattage.
EnergyStar rated.
Water removal rate.
Noise.
Drainage.
Icing.
Filter.

Other Pollutants that are "Priority Hazards"

Top 10 Chronic IAQ Hazards

- "Priority Hazards"
  - Acetaldehyde (combustion, etc.)
  - Acrolein***
  - Benzene (VOC, hydrocarbon)
  - Butadiene (plastic and fuels)
  - Dichlorobenzene (mothballs)
  - Formaldehyde (VOC, adhesives, etc.)
  - Naphthalene (mothballs, tobacco)
  - NO_2 (Combustion)
  - $PM_{2.5}$***
- Not Listed in Report
  - Carbon tetrachloride
  - Ozone
  - Radon
  - Tobacco smoke

*** Will look more closely at these pollutants.

Source: Logue et al., *Hazard Assessment of Chemical Air Contaminants Measured in Residences*, June 2010, LBNL-3650E

Acrolein

- What is it?
  - Colorless liquid with a piercing, disagreeable, acrid smell.
  - An aldehyde
  - VOC.

Acrolein

- Uses/Sources:
  - 500,000 tons are produced annually in North America, Europe, and Japan.
  - Used as a contact herbicide to control floating weeds and algae in irrigation canals.
  - Cooking.
  - Tobacco smoke.
  - Perfumes, food supplements, and resins.
  - Military poison gas mixtures.
  - Superfund sites.

Acrolein

- Health effects:
  - Toxic following inhalation, oral, or dermal exposures.
  - Strong irritant to the skin, eyes, and nasal passages.
  - Can cause death, but strong smell tends to protect people from fatal exposures.

Acrolein

- Lowering risk:
  - Eliminate from indoor environment.
  - Ventilate.

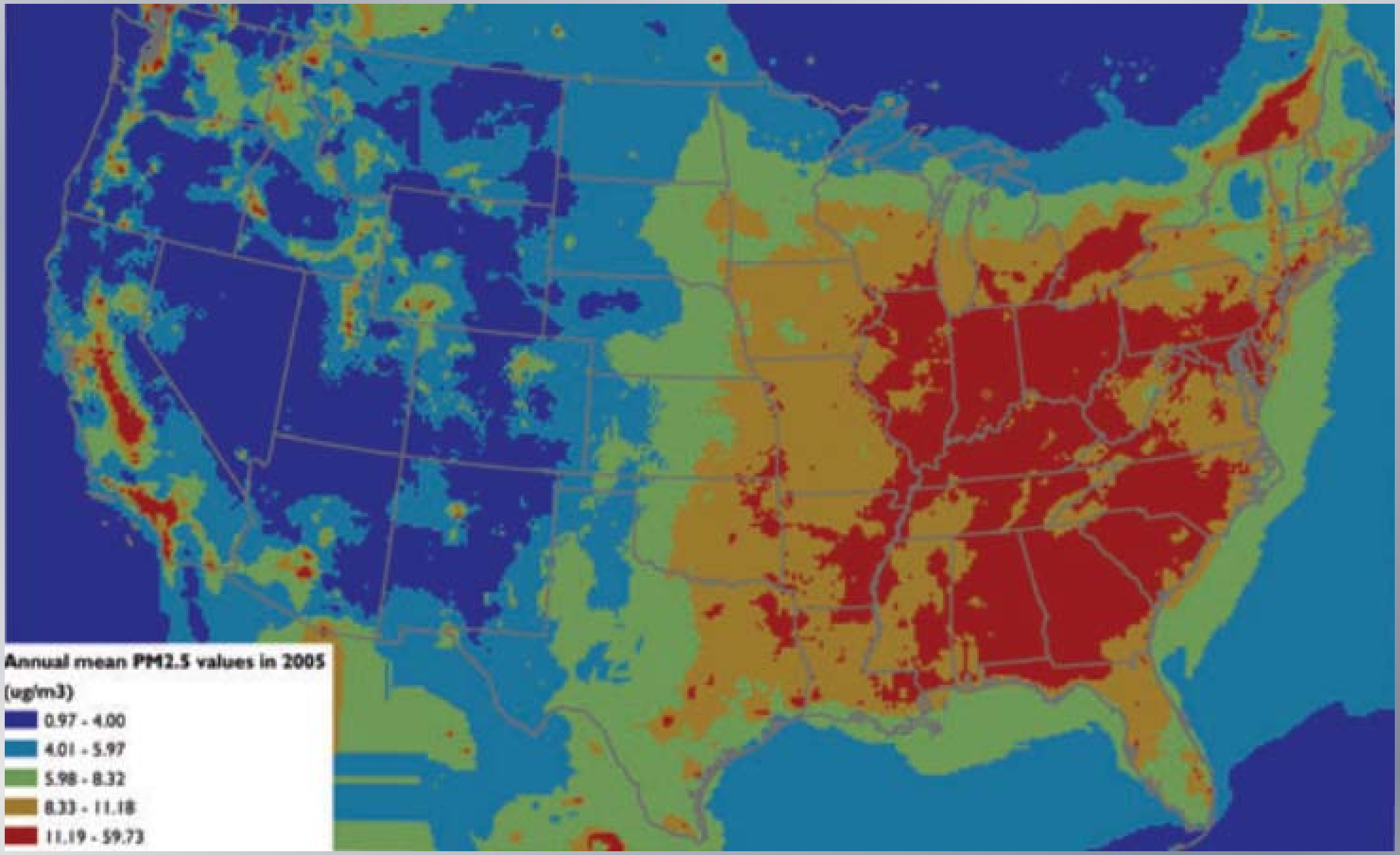
$PM_{2.5}$

- What is it?
  - Particulate Matter (PM) with a diameter of 2.5 micrometers or less.
  - Small enough to invade the smallest airways of the lungs.
  - Generally the source is from activities that burn fossil fuels, such as traffic and cooking.

$PM_{2.5}$

- Sources:
  - Cars/trucks are biggest source.
  - Burning fossil fuels.
  - Oven cleaning.
  - Cooking fish on gas range.
  - Candles emitting soot.
  - Cooking.
  - Grilling.
  - Sweeping.
  - Kerosene lamps.

$PM_{2.5}$ Annual Mean Levels



Source: Fann et al., *Estimating the National Public Health Burden Associated with Exposure to Ambient $PM_{2.5}$ and Ozone.* 2011. Risk Analysis.

$PM_{2.5}$

- Health effects:
  - Coughing, wheezing, shortness of breath.
  - Chronic and acute bronchitis.
  - Aggravated asthma.
  - Lung damage.
  - Premature death for those with existing heart disease.
  - Premature death for those existing lung disease.
  - Lost work days.

$PM_{2.5}$

- Public cost:
  - 130,000 deaths from 2005 air quality levels in USA.
    - During same period there were 120,000 deaths due to accidents, 72,000 due to Alzheimer's, and 72,000 due to influenza.
  - Among the population aged 65 - 99 nearly 1.1 million life years lost.
  - Greatest cost to health and life is in large metropolitan areas.

$PM_{2.5}$

- Lowering risk:
  - Avoid $PM_{2.5}$.
  - Clean up auto emissions.
  - Fewer vehicles on road.
  - Generate less electricity.
  - Be aware of particle pollution.
  - Filter air with HEPA filters.

$PM_{2.5}$

United States Environmental Protection Agency

AIR QUALITY INDEX

Air Quality Guide for Particle Pollution

Good	0-50	None
Moderate	51-100	Unusually sensitive people should consider reducing prolonged or heavy exertion
Unhealthy for Sensitive Groups	101-150	People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion.
Unhealthy	151 to 200	People with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion. Everyone else should reduce prolonged or heavy exertion
Very Unhealthy Alert	201 to 300	People with heart or lung disease, older adults, and children should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.

Cost of Adverse Health Effects

- Disability Adjusted Life Years (DALYs)

DALY = YLL + YLD

  - YLL = Years lost to premature death
  - YLD = Equivalent years lost to disability

Cost of Adverse Health Effects

- Disability Adjusted Life Years (DALYs)

Source: Wikipedia: http://en.wikipedia.org/wiki/Disability-adjusted_life_year

Cost of Adverse Health Effects

- **Disability Adjusted Life Years (DALYs)**

Table 1. Energy use (E) in 10^{-3} quads and DALYs (D) per 100,000 households per year

Ventilation Cases	*Energy (quads /10^{-3})*	*ΔE ($\Delta E/E_{base\text{-}case}$)*	*DALYs lost (years)*	*ΔD ($\Delta D/D_{base\text{-}case}$)*
Base Case-Infiltration only	3.5	-----	160	-----
Unbalanced Mechanical Ventilation	4.0	5 (14%)	90	70 (-41%)
Balanced Mechanical Ventilation	4.3	8 (21%)	70	90 (-54%)

Assumes DALYs lost per 100,000 California homes, (assuming an occupancy of 4 people per home)

Source: Logue et al., *Assessment of Indoor Air Quality Benefits and Energy Costs of Mechanical Ventilation*, June 2011, LBNL-4945-E

Ventilation

Natural Air Leakage Alone Doesn't Cut It!

- Air leakage-only ventilation leads to:
  - Too much outdoor air at low outdoor temperatures.
  - Too little outdoor air at warmer temperatures
  - Unpredictable outdoor air ventilation rates, thus, substandard IAQ.
  - Wasted energy.

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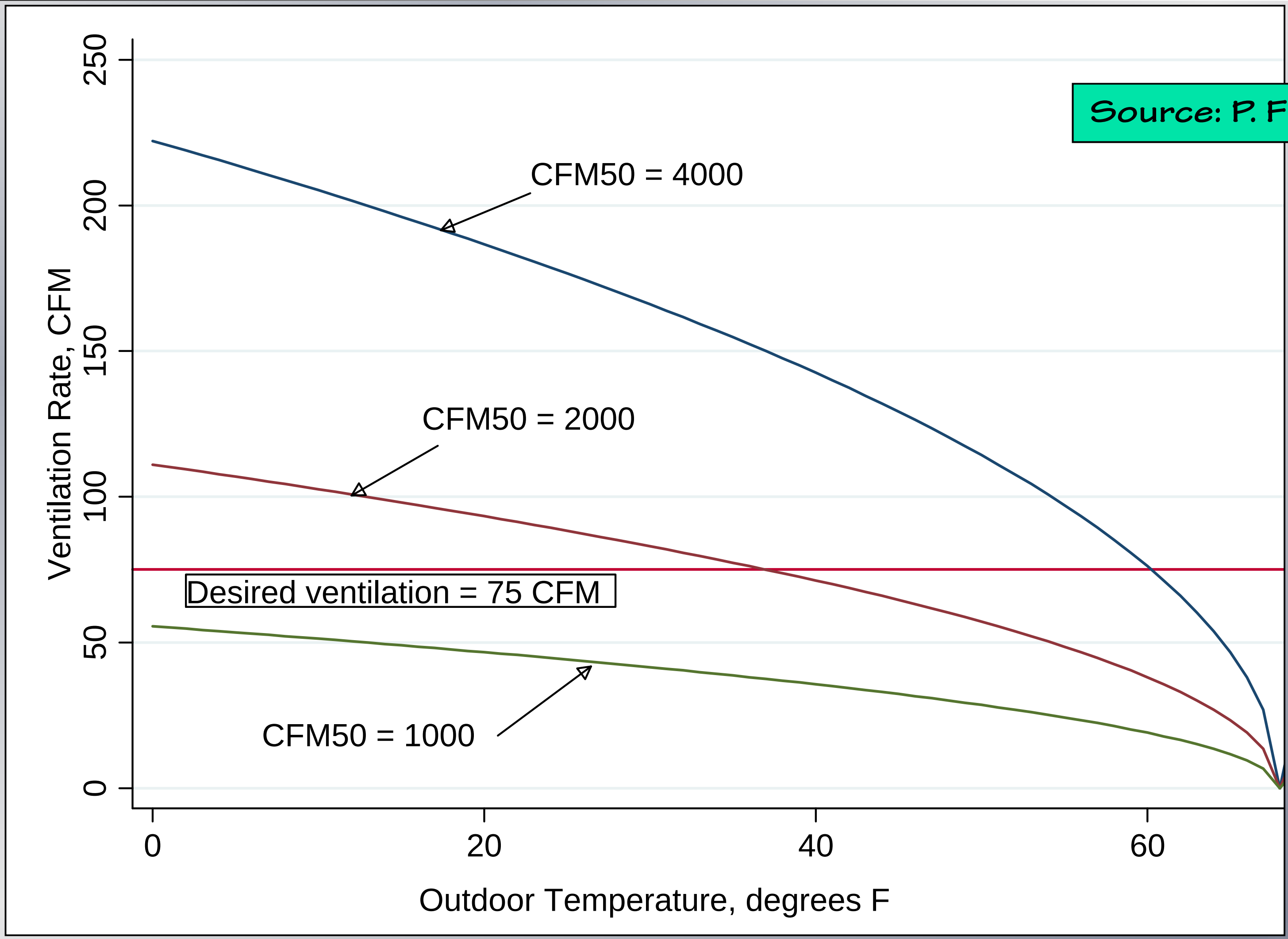


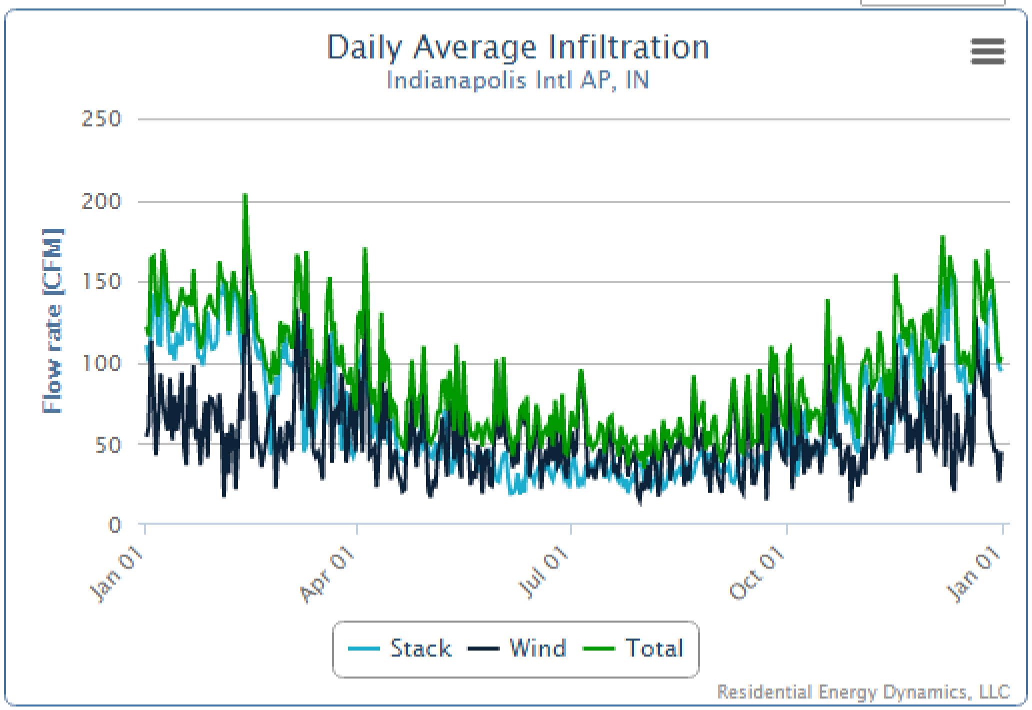
Source: P. Francisco

Based on single-story 1500ft² house

Date range for all the following results:
January ▼ 1 ▼ to December ▼ 31 ▼

Hourly Flow [CFM ▼]	Low	Average	High
Stack infiltration	0	66.8	172.1
Wind infiltration	0	55.5	232
Total infiltration	0.791	91.1	248

Show infiltration chart   Chart units CFM ▼



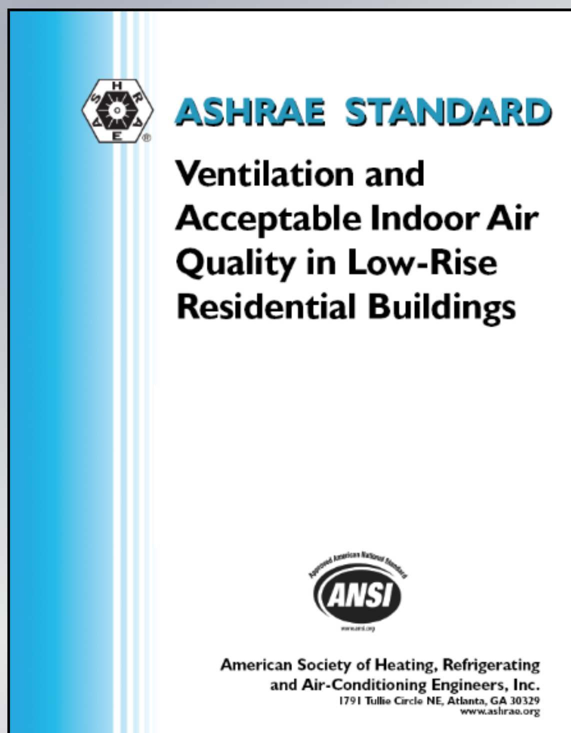
Infiltration is variable!

Indianapolis, IL
Two story
2000 CFM50
Heating and cooling

ResidentialEnergyDynamics.com

So, What To Do?

- Follow ASHRAE 62.2 for acceptable IAQ.


ASHRAE STANDARD

Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

ANSI

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle NE, Atlanta, GA 30329
www.ashrae.org

This IAQ standard applies to single-family and multifamily residential buildings of three stories or fewer above grade, including manufactured and modular houses.

www.ashrae.org

ASHRAE 62.2 Requirements

- Local exhaust ventilation
  - Kitchen – 100 CFM.
  - Bathroom – 50 CFM.
    - Defined as any room containing a bathtub, shower, spa, or similar source of moisture.

Source: ASHRAE 62.2-2013

ASHRAE 62.2 Requirements

- Whole-building ventilation:
  - General dilution ventilation in addition to “local ventilation”.
  - Ventilation based on the table on next slide.
    - These CFM requirements are for whole building ventilation operated either continuously or intermittently.

Local exhaust ventilation may serve double duty as whole-building ventilation

Source: ASHRAE 62.2-2013

ASHRAE 62.2-2013

Floor Area (ft^2)	Bedrooms				
	1	2	3	4	5
<500	30	38	45	53	60
501 - 1000	45	53	60	68	75
1001 - 1500	60	68	75	83	90
1501 - 2000	75	83	90	98	105
2001 - 2500	90	98	105	113	120
2501 - 3000	105	113	120	128	135
3001 - 3500	120	128	135	143	150
3501 - 4000	135	143	150	158	165
4001 - 4500	150	158	165	173	180
4501 - 5000	165	173	180	188	195

$$Q_{tot} = 0.03A_{floor} + 7.5(N_{bedrooms} + 1)$$

Ventilation System Types

Ventilation System Types

- System types:
  - Supply-only (warm climates)
    - Separate supply fan(s)
    - Ducted in-line fan
  - Exhaust-only (moderate and cold climates)
    - Separate exhaust fan(s)
    - Ducted in-line fan
  - Balanced system
    - HRV (sensible heat recovery)
    - ERV (sensible and latent heat recovery)

Supply-Only Ventilation

- Supply units only, no exhaust ventilation.
  - Supply fan serving one supply point.
  - In-line fan unit serving one or more supply points.
  - Creates positive pressure in building.
  - Not appropriate for cold climates.

Exhaust-Only Ventilation

- Exhausting unit(s) only, no supply ventilation.
  - Exhaust fan serving one exhaust point.
  - In-line fan unit serving one or more exhaust points.
  - Creates negative pressure in building.
    - Pulls pollutants from garage, etc.
    - Backdrafting potential.
  - Source of supply air?

Bathroom or Hall Exhaust Fans

Photos courtesy of Wisconsin Weatherization Program

Kitchen Exhaust Fan

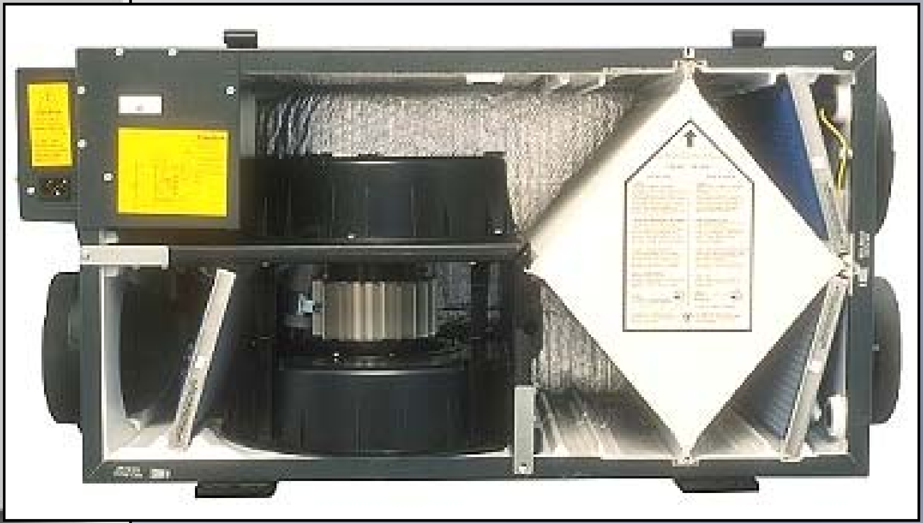
In-line Exhaust Fans

Photos courtesy of Wisconsin Weatherization Program

Balanced Ventilation

- Exhaust and supply ventilation are approximately equal CFM.
  - Heat Recovery Ventilator (HRV)
    - Unit transfers sensible heat only with no humidity transfer.
  - Energy Recovery Ventilator (ERV)
    - Unit transfers sensible and humidity.

Heat Recovery Ventilators (HRV)



Venmar HRV, inside view

Cost of Adverse Health Effects

- Disability Adjusted Life Years (DALYs)

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Ventilation

- More ventilation is better than less, but when cost is considered, there is a point of diminishing returns.
- However, keep in mind that the International Agency for Research on Cancer (part of WHO) declared outdoor air as a "carcinogenic to humans" on October 17, 2013!*

*www.iarc.fr/en/media-centre/iarcnews/pdf/pr221_E.pdf

Air Cleaning and Filtration

Particle Control Technology

- Anything that intentionally removes pollutants.
- Most common: Filters.
- Moderately common: electrostatic precipitators/electronic air cleaners, portable air cleaners (ion generators, HEPA filters, etc.).
- Rare: UV lights, activated carbon.

Source: Jeffrey Siegel

How are Filters Rated?

- MERV = Minimum Efficiency Reporting Value from ASHRAE Standard 52.2.
- Method of testing for filters.
  - Put filters in a test rig.
  - Challenge them with particles.
  - Also, load them with standard test dust.
  - MERV is way of summarizing lowest efficiency from test.

Source: Jeffrey Siegel

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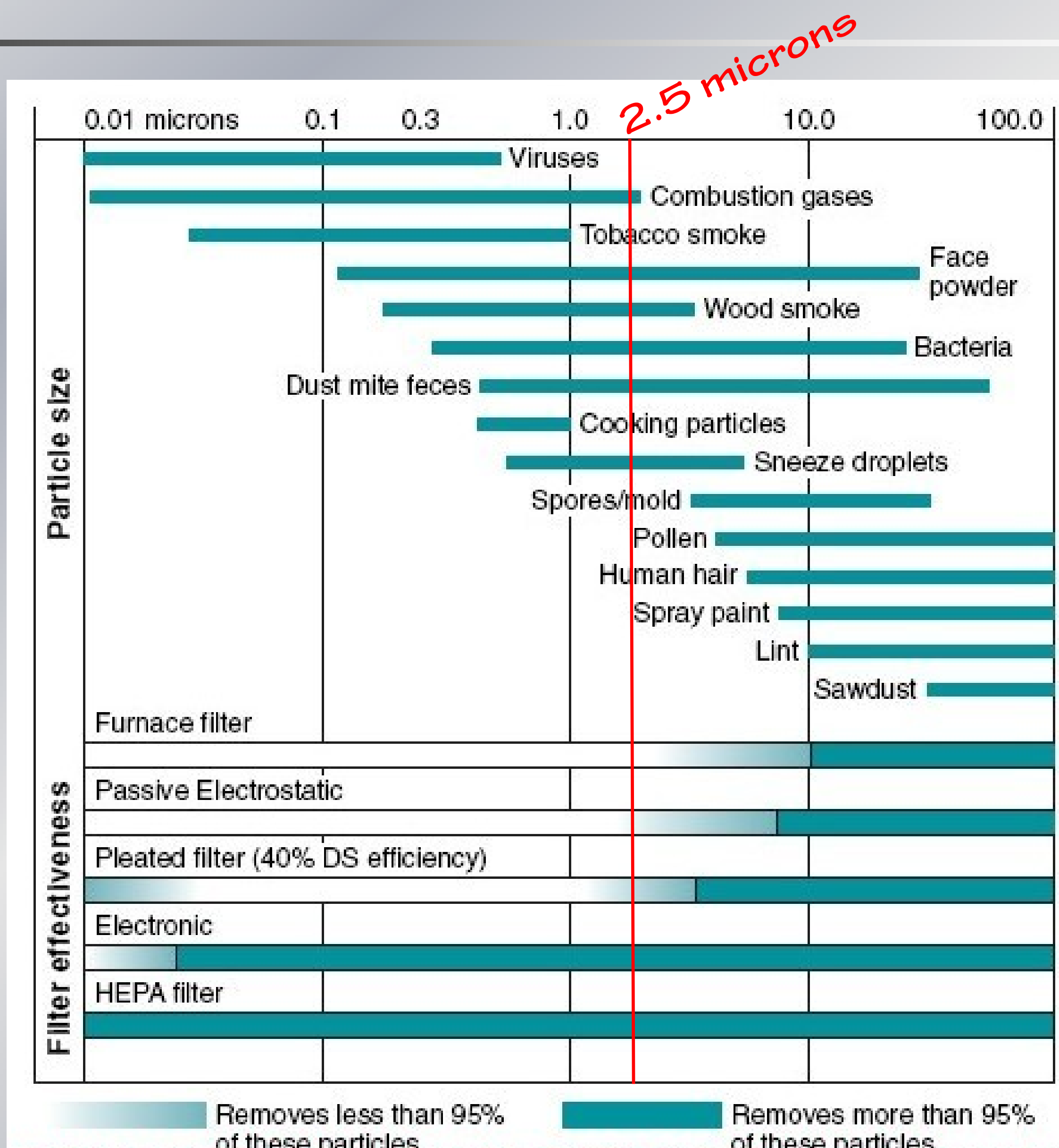
Micrometer (μm) = one-millionth of a meter



MERV Table

Standard 52.2 Minimum Efficiency Reporting Value (MERV)	Composite Average Particle Size Efficiency, % in Size Range, µm		
	Range 1 0.30 - 1.0	Range 2 1.0 - 3.0	Range 3 3.0 - 10.0
1	n/a	n/a	$E_3 < 20$
2	n/a	n/a	$E_3 < 20$
3	n/a	n/a	$E_3 < 20$
4	n/a	n/a	$E_3 < 20$
5	n/a	n/a	$20 \le E_3 < 35$
6	n/a	n/a	$35 \le E_3 < 50$
7	n/a	n/a	$50 \le E_3 < 70$
8	n/a	n/a	$70 \le E_3$
9	n/a	$E_2 < 50$	$85 \le E_3$
10	n/a	$50 \le E_2 < 65$	$85 \le E_3$
11	n/a	$65 \le E_2 < 80$	$85 \le E_3$
12	n/a	$80 \le E_2$	$90 \le E_3$
13	$E_1 < 75$	$90 \le E_2$	$90 \le E_3$
14	$75 \le E_1 < 85$	$90 \le E_2$	$90 \le E_3$
15	$85 \le E_1 < 95$	$90 \le E_2$	$90 \le E_3$
16	$95 \le E_1$	$95 \le E_2$	$95 \le E_3$

ASHRAE Standard 52.2-2007

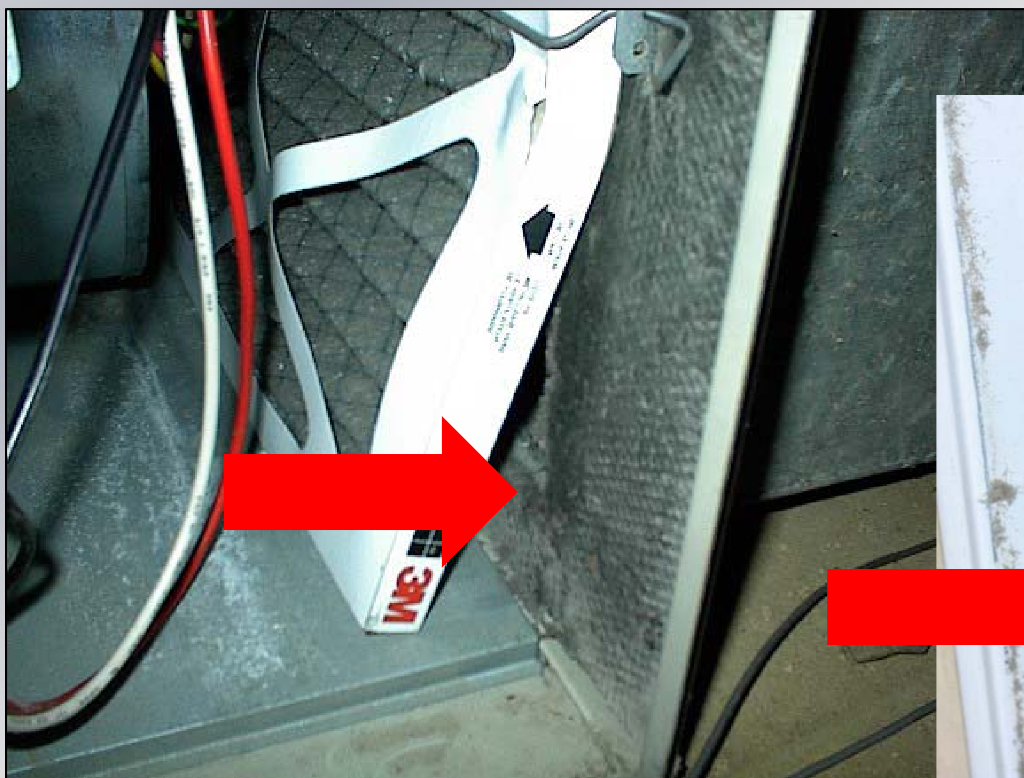
RED

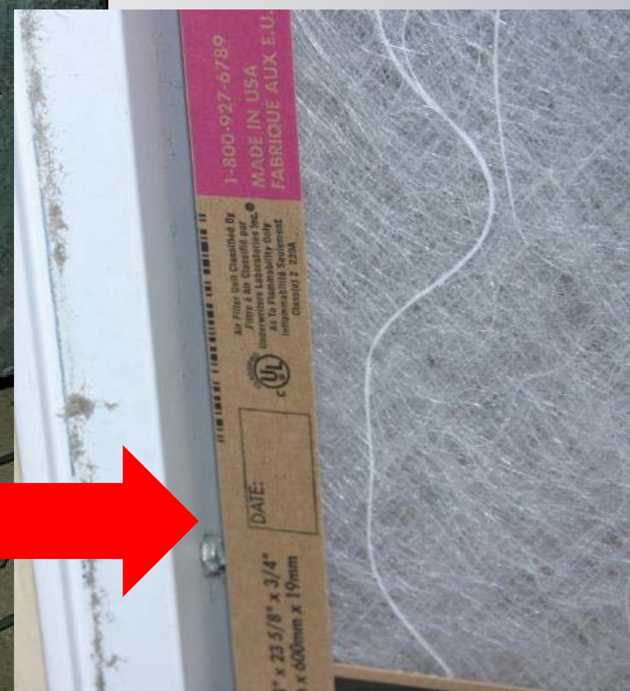
Filter/MERV Items

- Filters may perform better or worse over time.
- Often not all the air goes through the filter.
  - Bypasses degrade filtration efficiency.
- Air handler that filter is part of might not run very much and filters only work when fan is operating.
  - Swing seasons.
  - After energy retrofits.

Source: Jeffrey Siegel

Filter Gaps





Source: Jeffrey Siegel

Combustion Appliances, Vented and Unvented

Combustion Appliance Types

- Vented combustion appliances:
  - Furnaces, boilers, water heaters, vented space heaters, solid-fuel, and gas dryers.
    - Make sure combustion by-products are completely vented to outdoors.
    - Ensure they are as clean burning as possible.
    - Reduce hazard with CO alarms.
- Unvented combustion appliances:
  - Unvented space heaters and gas ranges.
    - Eliminate use whenever possible.
    - Ensure they are as clean burning as possible.
    - Ventilate/dilute by-products of combustion.
    - Reduce hazard with CO alarms.

Unvented Appliance

Best to keep this out of house.

Avoid using any unvented combustion appliances in dwelling.

Oven Bake Burner Testing

A gas range is difficult to keep out of house, so make sure it is clean burning!

Use ventilation when operating.

Combustion Safety Testing

- Combustion safety testing is VERY important.
  - Test pre-weatherization.
  - Test at the end of a work day?
  - Test post-weatherization.
  - Test
    - Combustion Appliance Zone (CAZ) depressurization against appliance limits (vented only).
    - Spillage (vented only).
    - Draft (vented only).
    - CO (vented and unvented).
    - Combustible gas leaks (vented and unvented).

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