A Breath of (Measureable?) Fresh Air – An IAQ Scoring tool for Homes

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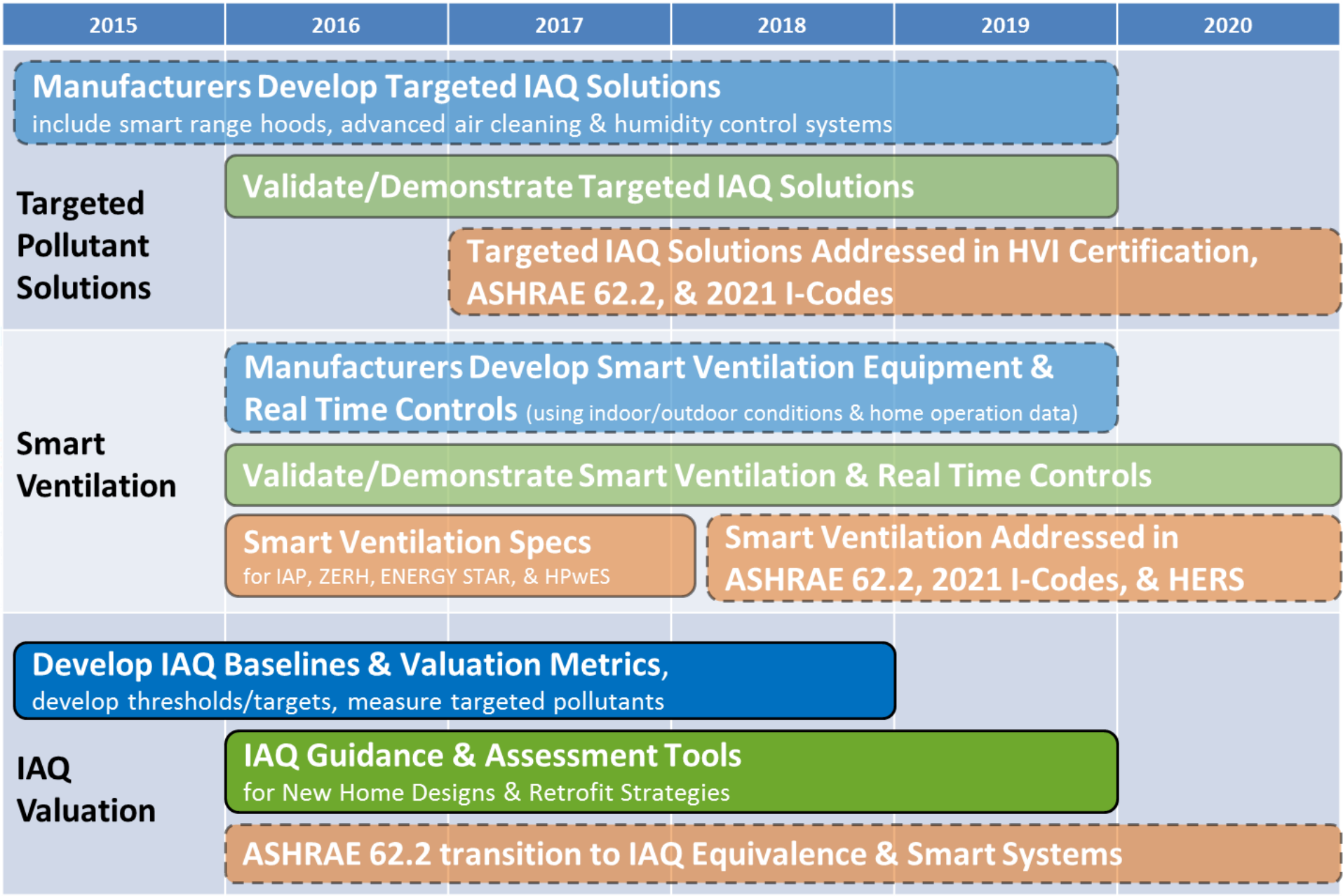
C. Optimal Ventilation & IAQ Solutions



Introduction

- Currently there is no IAQ score for homes
- Part of US DOE Building America strategic plan – maintaining good IAQ an essential part of high performance homes
- Some checklist approaches: EPA IA+, Living Product Challenge, etc.
  - Don’t include all aspects
  - Don’t develop a single referenceable number
- Score is in development
  - Getting expert and stakeholder input…..

Goal

“ …an index of IAQ must be able to communicate indoor air pollution levels to a non-scientific audience, must be correlated to the symptoms experienced by the occupants and should be used as a management tool to improve effectively air quality… “

Goal

Develop an asset rating tool that can be used by the building industry to uniformly and consistently rate homes for IAQ

- Have a single number – like HERS but IAQ not Energy
- Develop a trusted third-party rating system
- Based on observations about the home and possibly some diagnostics
- Include health, odor & moisture
- Must be doable by home energy rater or contractor (see BPI Healthy Home Evaluator Credential) NOT researchers!

IAQ Score – Scope and Applicability

Scope

- Asset rating not “in use” rating
  - including effectiveness of measures, usability, and robustness
  - Allows evaluation of new homes w/o occupants
  - Allows for design of homes to get a good score

Applicability

- New and existing single-family homes
  - Multifamily issues with compartmentalization and shared ventilation systems not included (debatable?)

IAQ Hazards NOT included

- **Radon**. Should credit and debit be given for presence or lack of radon control in a high radon region? Should this be left to building codes?
- **Smoking**. Not part of the asset so not included.

Fundamental Issues

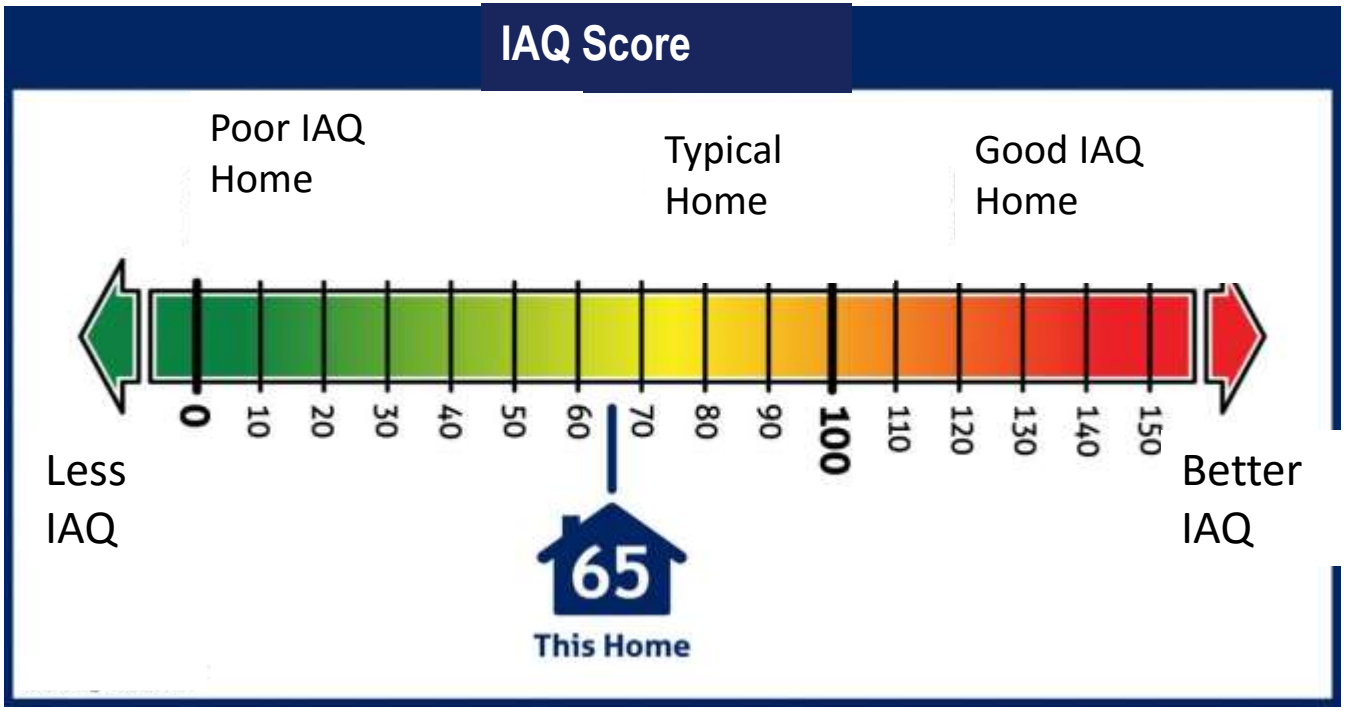
- Relative or absolute score?
  - Absolute – get points for home characteristics
    - Very difficult to define a reference for a relative score
- Checklists or tradeoffs or measurements?
  - Tradeoff – many paths to the same score
  - Checklist – visual observation
  - Measurements – feature performance not pollutants directly
    - Too expensive, needs to be over long time, snapshots not useful (e.g., cooking events)

IAQ Score - Scale

Basic 0 to 100 from poor to good – opposite of HERS……is this OK?

A very bad house could be negative

An amazing house might be a more than 100



IAQ Score - Methodology

1. Home features add (or subtract) points:
   - A good filtration system would add points
   - A lack of kitchen ventilation would subtract points
2. Magnitude of points based on health, odor or moisture impact
   - Three separate sub-scores: health, odor, moisture
   - Tricky part is the relative impact
3. Health based on DALYS - Odor and moisture less clear

There is no definitive approach – expert opinion required

Converting Home Features into a Number

- **Features/Measures are scored according to the following criteria**
- Potential effectiveness: What is the risk reduction benefit if measure is implemented as intended?
- Usability: How easy and intuitive is it to use or implement the measure?
- Durability: Is the measure likely to retain its utility over time?
- Robustness: How commonly does the system work when implemented as intended?
- Maintenance: How much effort is required to maintain the measure?
- The following will NOT be included:
- Cost : What is cost of implementing the measure?
- Energy: Does the feature consume energy at a rate that will substantially impact efforts to achieve low-energy homes?

From Expert Workshop

- No mandatory features to generate a score
- No commissioning/measurement *requirements*
  - i.e., you **can** get a score without measurements – but it might not be as good
- Consider outdoor air quality
  - Analogous to weather for energy ratings
- Credits for contaminant control e.g., filtration, air cleaning, dehumidification
- Deductions for observable hazards e.g., mold, backdrafting, tobacco contamination

Quantitative Scoring for Health-Relevant Pollutants

- Health outcomes
  - Chronic – long term – a year or more
  - Acute – short term down to 1 hour or less
- Valuation
  - Chronic: Disability Adjusted Life Year (DALY)
  - Acute: Avoid exceeding health guideline levels

Acute and Chronic Not the Same

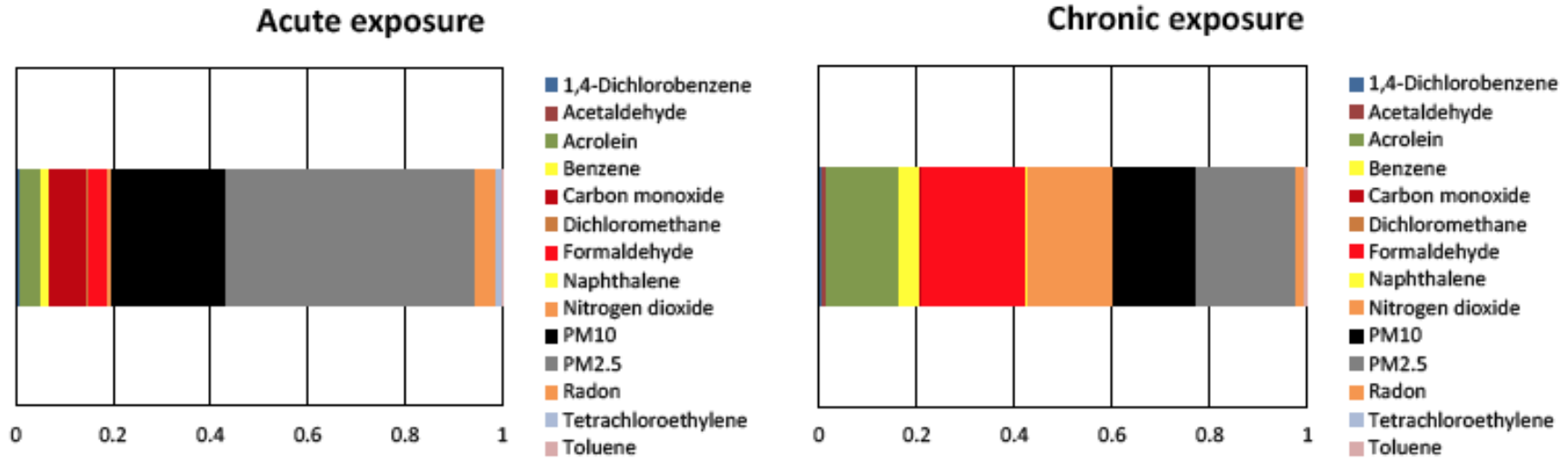


Figure 1. Relative importance of indoor pollutants for residential building sector (left: acute exposure, right: chronic exposure); the data based on study by Djouad et al. (2015).

Djouad I, Abadie M., Blondeau P, Petit P. 2015. *Validation sanitaire des systèmes de contrôle développés et d'évaluation sanitaire des produits, systèmes et solutions mises au point*, Report L3.3.1B for the VAICTEUR AIR[2] project, 51 pages.

What's a DALY?

DALY

Disability Adjusted Life Year is a measure of overall disease burden, expressed as the cumulative number of years lost due to ill-health, disability or early death

= YLD
Years Lived with Disability

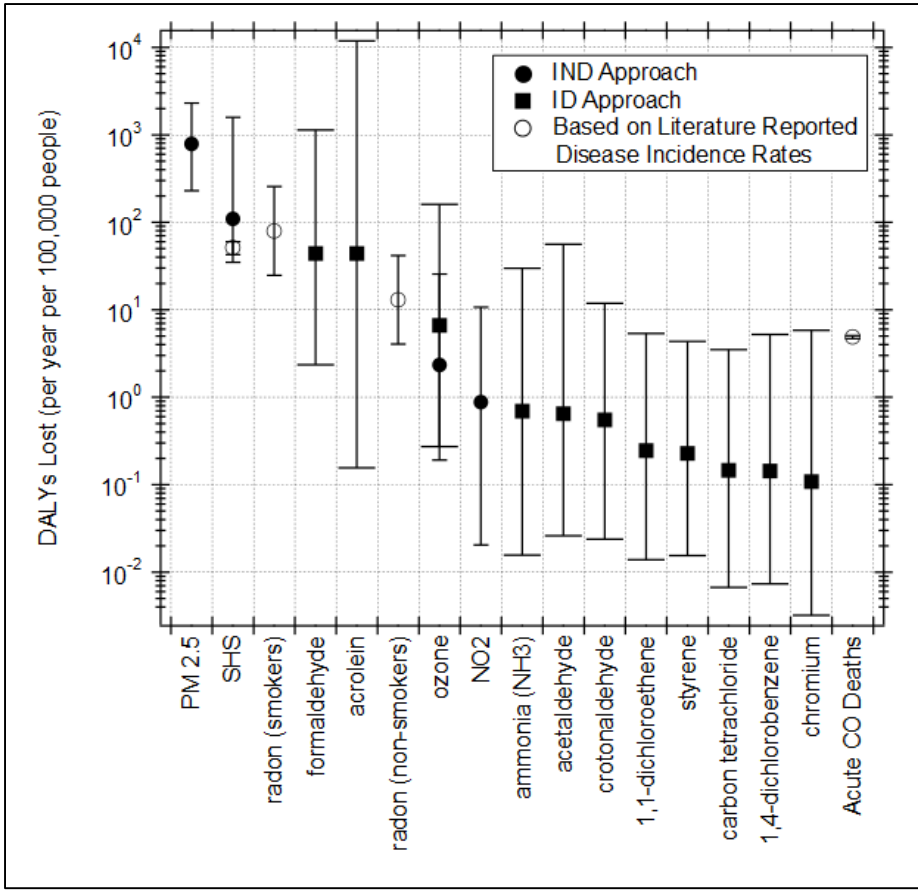
\+ YLL
Years of Life Lost

Graphic source: wikipedia

Health Score - Chronic

- Focus on pollutants of concern: PM2.5, NO_2, Formaldehyde, acrolein

- Score based on features of the home change these pollutant concentrations:
  - Kitchen ventilation, cooking equipment, building products, filtration, whole house ventilation, etc.



Health Guidelines: Exposure Limits

Table 1
Inhalation reference concentrations for chronic exposure (RfC), reference exposure limits (REL) and guidelines as defined by the US EPA, the Cal OEHHA and the WHO, respectively.

Compound	Inhalation RfC[a]	Inhalation REL[b]	WHO guideline[c]
Carbon monoxide			100 mg m^{-3} (0.25 h) 60 mg m^{-3} (0.5 h) 30 mg m^{-3} (1 h) 10 mg m^{-3} (8 h)
Formaldehyde	Not assessed	55 μg m^{-3} (A) 9 μg m^{-3} (8) 9 μg m^{-3} (C)	100 μg m^{-3} (0.5 h)[d]
Mercury	3×10^{-4} mg m^{-3}	0.6 μg m^{-3} (A) 0.06 μg m^{-3} (8) 0.03 μg m^{-3} (C)	1 μg m^{-3} (annual)
Naphthalene	3×10^{-3} mg m^{-3}	9 μg m^{-3} (C)	
Nitrogen dioxide	Value not estimated	470 μg m^{-3} (A)	200 μg m^{-3} (1 h) 40 μg m^{-3} (annual)
Styrene	1 mg m^{-3}	21 000 μg m^{-3} (A) 900 μg m^{-3} (C)	0.26 mg m^{-3} (1 week)
2,4-/2,6-Toluene diisocyanate	7×10^{-5} mg m^{-3}	0.07 μg m^{-3} (C)	
Toluene	5 mg m^{-3}	37 000 μg m^{-3} (A) 300 μg m^{-3} (C)	0.26 mg m^{-3} (1 week)
Xylenes	0.1 mg m^{-3}	22 000 μg m^{-3} (A) 700 μg m^{-3} (C)	
$PM_{2.5}$			25 μg m^{-3} (24 h) 10 μg m^{-3} (annual)
PM_{10}			50 μg m^{-3} (24 h) 20 μg m^{-3} (annual)
Radon[e]			100 Bq m^{-3}

A = acute; 8 = eight hours; C = chronic.
[a] From USEPA as on March 4, 2010 (http://www.epa.gov/iris).
[b] From Cal OEHHA as on December 18, 2008 (http://www.oehha.ca.gov/air/allrels.html).
[c] World Health Organization (2000, 2006a).
[d] Reevaluated by WHO in 2009.
[e] Not a guideline – recommended level for remedial action in buildings.

Salthammer, T. (2011). Critical Evaluation of Approaches in Setting Indoor air Quality Guidelines. Chemosphere 82 (2011) 1507–1517

Example: Kitchen Ventilation

- NOTE: all this complexity hidden from user
  - User just inputs observable/measureable characteristics

- Moisture & CO_2
- NO_2 and formaldehyde
- Ultrafine particles & CO

- Ultrafine particles

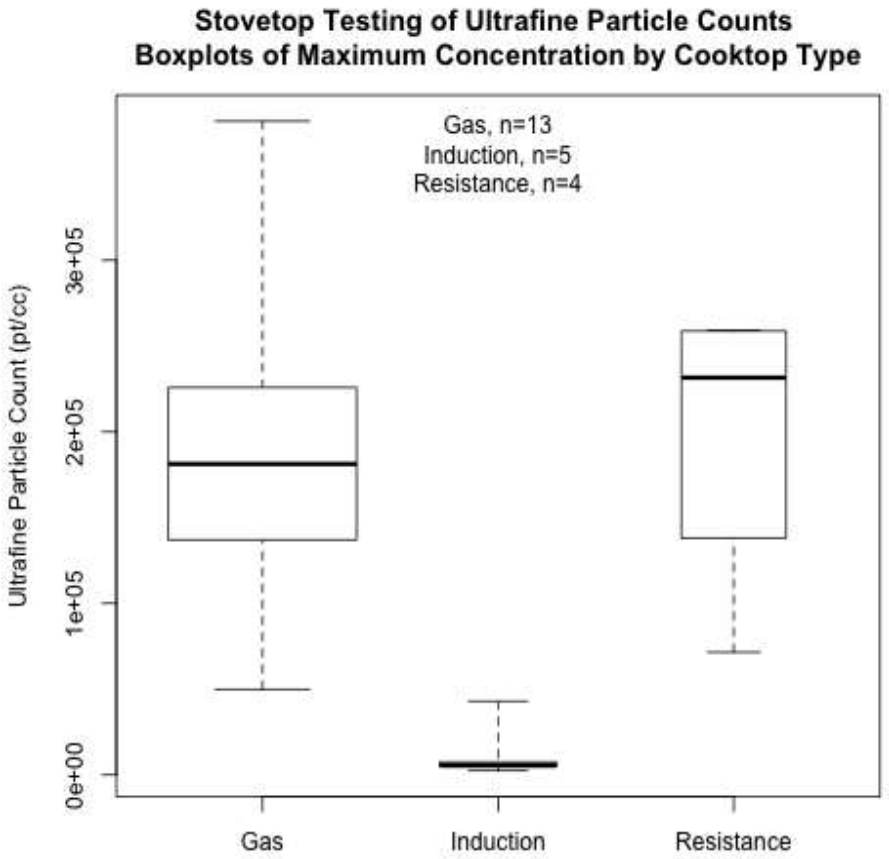
- Ultrafine particles
- VOCs including acrolein
- Moisture and odors

Example: Kitchen Ventilation

Source strength

old cooking appliances have poor burners and pilots so more water vapour, NO2, CO,CO2, partially-burned hyrocarbons…

Induction cooktops generate less particles



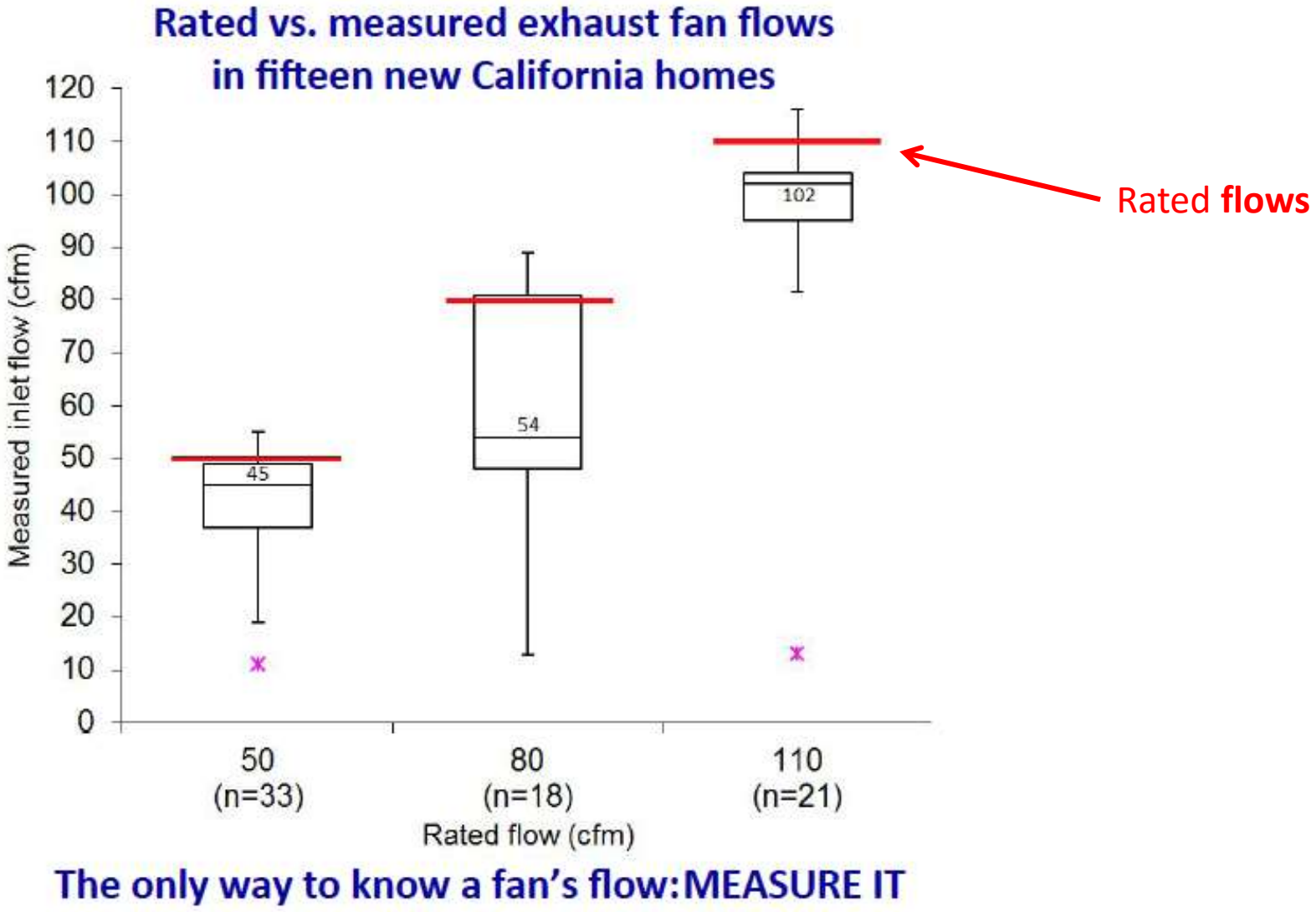
Example: Kitchen Ventilation

- Measures:
  (i) Cooktop selection
  (ii) Range hood (hood, microwave, downdraft)
  (iii) Kitchen exhaust fan
  (iv) Window
- Performance attributes: airflow (advertised/rated vs. diagnostic), noise, capture efficiency (coming soon)
- Other potential issues: depressurization at high air flow in tight homes with gas water heater inside pressure boudary

Diagnostic Air Flow Testing

Default to low performance – measure to get rated performance

Why Diagnostics?
Ventilation Measurements in 15 New CA Homes



Stratton, C., Walker, I., & Wray, C. P. (2012). *Measuring Residential Ventilation System Airflows: Part 2 - Field Evaluation of Airflow Meter Devices and System Flow Verification* LBNL-5982E

Recent FSEC Survey

Inspected 21 mechanical ventilation systems in Florida homes

- Only 3 of 21 homes had airflows close to design targets
- 2 of these 3 were disabled by occupants
- 12 of 21 ‘capable of operating’
- I9 of 21 were not operational

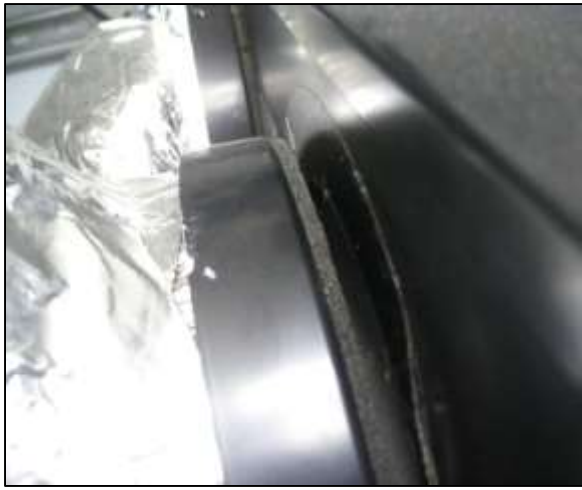
- Faults
  - Failed controllers and dampers
  - Partially disconnected or crushed ducts
  - Dirty filters
  - Outdoor air intake installed directly above outdoor unit exhaust

Dirty outdoor air intake.

Dirty ERV filters.

System design, Installation & Durability Issues

- Difficulties verifying air flows
  - Tricky for kitchen range hoods
  - Tricky for supply systems
  - Tricky for HRVs (low air flow per outlet/inlet)
  - HRV connections
- Clogged inlets & filters – critical for supply and balanced systems
- Typical survey results: half of supply/HRV systems not working properly
- How best to add filtration for outdoor and indoor particles



Example #2: Filtration

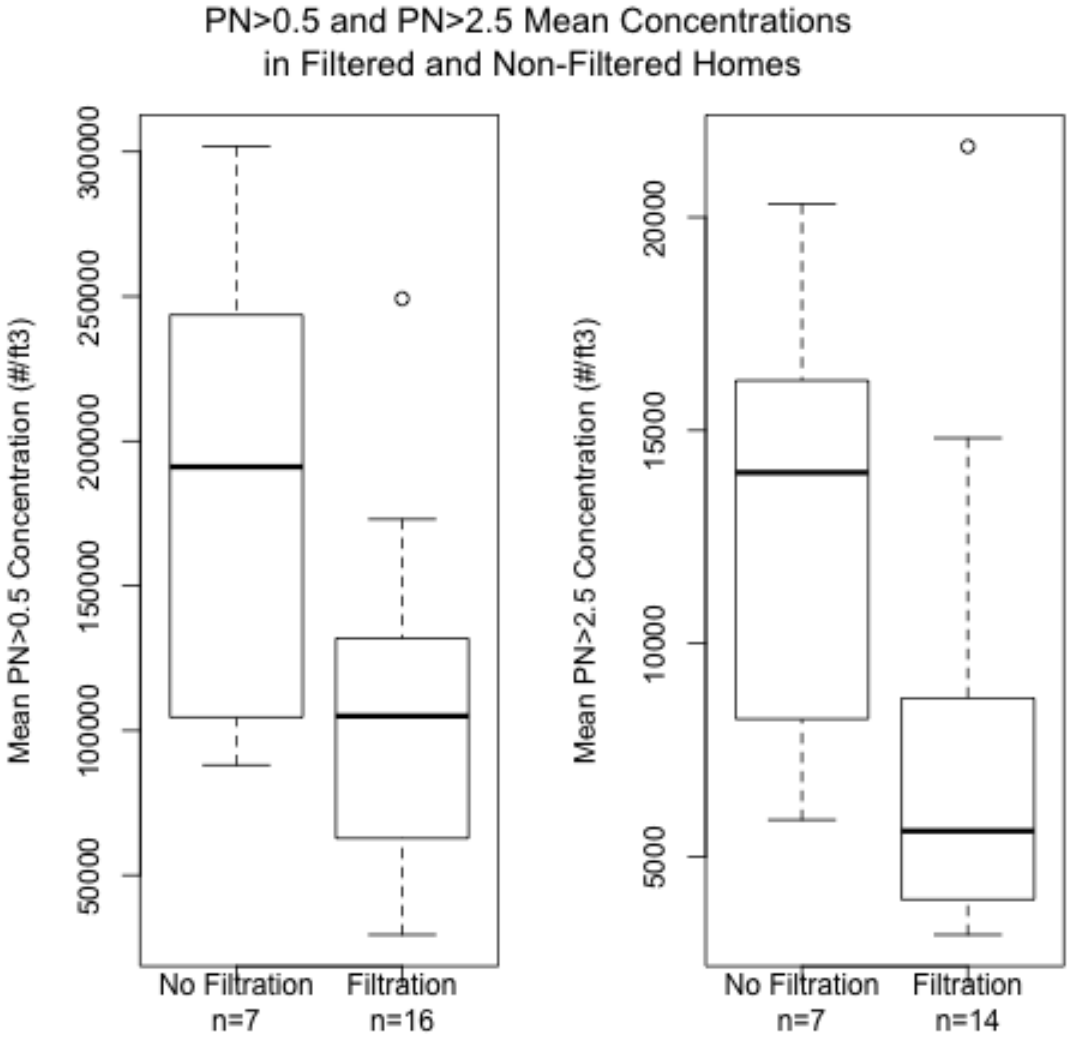
What type of filters are in the ventilation/HVAC system?

Better filter = better score
Minimum runtime = better score

Filtration in High Performance Homes

Filters in Central Forced Air System
and ventilation systems

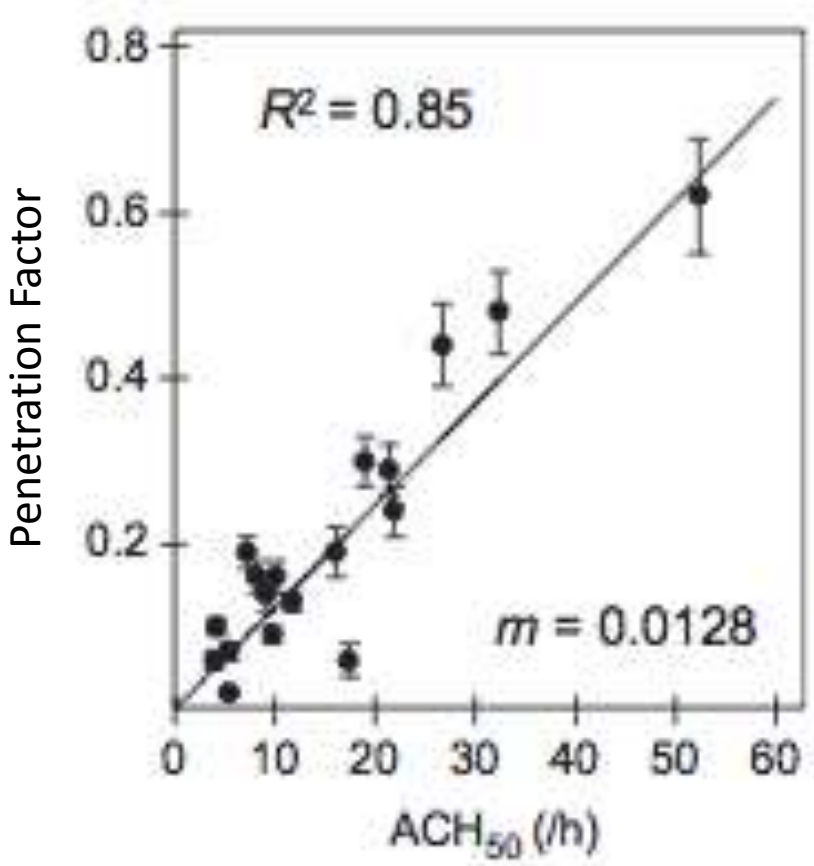
Six-day averages of particle measurements



Less, B. (2012). *Indoor Air Quality in 24 California Residences Designed as High Performance Green Homes*

Filtration: An Airtight Envelope Filters **Outdoor** Particles

- Field testing of envelope penetration of **submicron** particles
- Tight homes are good protection against outdoor particles:
  - 1.5 ACH_{50} = 2% penetration
- Need data for larger particles: PM2.5



Stephens & Siegel. 2012. Penetration of ambient submicron particles into single-family residences and associations with building characteristics. Indoor Air 2012.

Odor and moisture scoring

Mendell & Kamagi (California Department of Public Health):
Survey of 20 other studies:

- Observation-based metrics work best – mold-related health issues happen when problems are visible

Odor and moisture scoring

- Identify home features that improve (or make worse) odor and moisture issues:
  - Kitchen, bathroom and toilet exhaust are good – lack of these features is bad
  - Air and moisture sealed crawlspace floor is good – bare earth is bad
  - Meeting minimum per person ventilation rates is good – going higher is better, lower is worse
  - Observable mold is bad

Building Material Source Control

Credit for building materials tested/certified/assessed by 3rd parties:

- Scientific Certification Systems
- Green Guard
- Green Seal
- Carpet and Rug Institute
- Collaborative for High Performance Schools products database
- Pharos database
- Cradle-to-Cradle
- GreenScreen assessed

Prioritize materials with:

- Most surface area
- Direct paths of exposure (e.g., floor finish vs. crawlspace vapor barrier)
- Documented histories of contributing to IAQ issues

MATERIALS

RED LIST

IMPERATIVE

07

IMPERATIVE DOESN'T APPLY TO PACKAGING

The product cannot contain any of the following Red List materials or chemicals:[20]

- Alkylphenols
- Asbestos
- Bisphenol A (BPA)
- Cadmium
- Chlorinated polyethylene and chlorosulfonated polyethylene
- Chlorobenzenes
- Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs)
- Chloroprene (Neoprene)
- Chromium IV
- Chromium VI
- Chlorinated Polyvinyl Chloride (CPVC)
- Formaldehyde (added)
- Halogenated flame retardants (HFRs)
- Lead (added)
- Mercury
- Polychlorinated biphenyls (PCBs)
- Polyvinylidene Chloride (PVDC)
- Perfluorinated compounds (PFCs)
- Phthalates
- Polyvinyl chloride (PVC)
- Volatile Organic Compounds (VOCs) in wet applied products[21]
- Wood treatments containing creosote, arsenic or pentachlorophenol

20 A list of Chemical Abstracts Service (CAS) Registry Numbers that correspond with each Red List item is available on living-future.org/lcc CAS is a division of the American Chemical Society: www.cas.org.

21 Wet applied products (coatings, adhesives and sealants) must have VOC levels below the South Coast Air Quality Management District (SCAQMD) Rule 1168 for Adhesives or California Air Resource Board 2007 Suggested Control Measure (SCM) for Architectural Coating as applicable. Containers of sealants and adhesives with capacity of 16 ounces or less must comply with applicable category limits in the CARB Regulations for Reducing Emissions from Consumer Products.

Including Robustness

Some IAQ features require more maintenance than others

- Filter changes?

Some IAQ features are more likely to be used

- Automatic vs. manual kitchen or bathroom ventilation systems

The score would favor more robust features

Implementation

Who will be the “owner” of the scoring tool?

- NOT DOE/BA/LBNL
- Tool should be maintained & administered by a consensus body – ideally one that promulgates standards
- Could be RESNET – maybe others…

Thinking Ahead

Pilot Implementation

- Create a first version of the Scoring Tool
- Limited group of practitioners to score homes in target climate zones
- Beta testing by a larger group of practitioners and users
  - Looking for volunteers

Questions?

If you want to participate/volunteer in BETA testing contact:

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