Status and perspectives for the development of IAQ metrics in the US

Iain Walker, LBNL
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Introduction

- Currently there is no IAQ rating methodology, metric or set of metrics for homes
- Part of US DOE Building America strategic plan
- Some prescriptive checklist approaches exist
  - EPA IndoorAir PLUS,
  - Living Product Challenge, etc.

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 an energy rating (in the US this would be RESNET HERS Index)
- Develop a trusted third-party rating system
- Based on observations about the home and optional diagnostics
- Must be doable by home energy rater or contractor NOT researchers!

IAQ Index – Scope and Applicability

Scope

- Asset rating not "in use" rating
  - including effectiveness of measures, usability, and robustness
  - Allows evaluation of new homes without occupants
  - Allows for design of good score into homes

Applicability

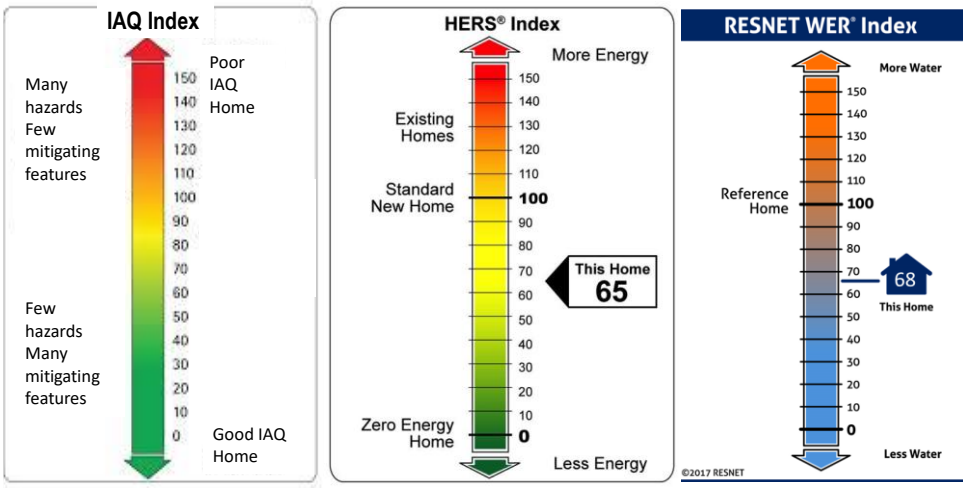
- New and existing single-family homes
  - Multifamily issues with compartmentalization and shared ventilation systems not included (debatable?)

IAQ Hazards NOT included

- **Smoking**. Not part of the asset so not included.
- **Rare High Polluting Events**. Such as emissions form hobbies.

IAQ Index - Scale

100 to zero from poor to good
A very bad house could be more than 100
An amazing house might be negative
Parallel to indexes for energy and water use



IAQ Index - Methodology

Identify potential hazards that add points to the index score

Identify Home features that mitigate hazards subtract points, e.g.,

- A good filtration system would subtract points
- A lack of kitchen ventilation would add points

Magnitude of points based on:

- the hazard level
- how much the feature mitigates the hazard, and
- the effectiveness of the mitigation strategy

Combine three separate sub-scores: health, odor, moisture

- Health based on DALYS - Odor and moisture less clear

There is no definitive approach – expert opinion required

Fundamental Issues

- Absolute scoring – get points for home characteristics
  - Very difficult to define a reference for a *relative* score
- Allow Tradeoffs – many paths to the same score
- Include checklists: visual observation
- Include some measurements: how a mitigation strategy is performing
- No requirement for direct pollutant measurement
  - Too expensive, needs to be over long time, snapshots not useful (e.g., cooking events)

Converting Home Features/Mitigation Strategies into a Number

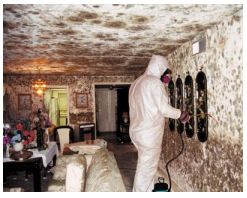
- Potential effectiveness: What is the risk reduction benefit if measure is implemented as intended?
- Usability: How easy and intuitive is it to use or implement the measure?
- Durability: Is the measure likely to retain its utility over time?
- Robustness: How commonly does the system work when implemented 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



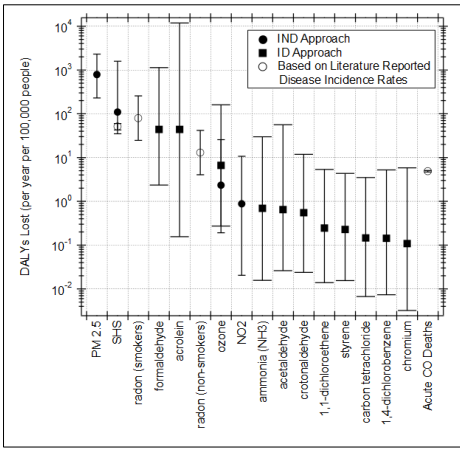
Quantitative Scoring for Health-Relevant Pollutants

- 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

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

Chronic Health Issues

- Focus on pollutants with greatest health impact: PM2.5, NO_2, Formaldehyde, acrolein & ozone
- Use DALYs to quantify health effects
- Score based on features of the home change these pollutant concentrations:
  - Kitchen ventilation, cooking equipment, building products, filtration, whole house ventilation, etc.



Acute Health Issues : Exposure Limits

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

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}

Example Hazard: Cooking

Fuel

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

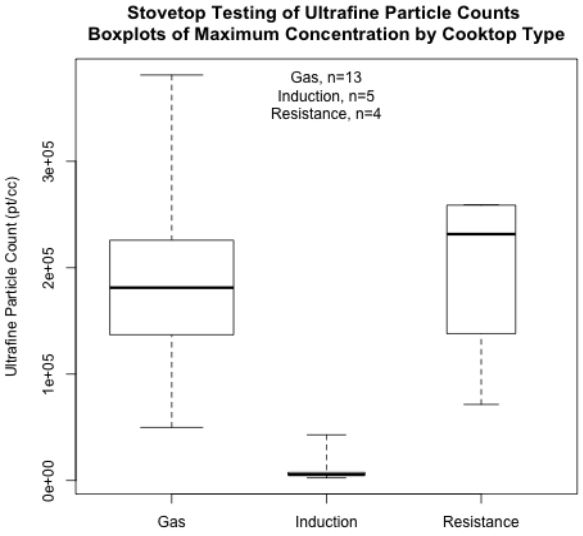
- Ultrafine particles

Food

- Ultrafine particles
- VOCs including acrolein
- Moisture and odors

Example Hazard: Cooking

Hazard severity depends on heat source



Induction cooktops generate less particles

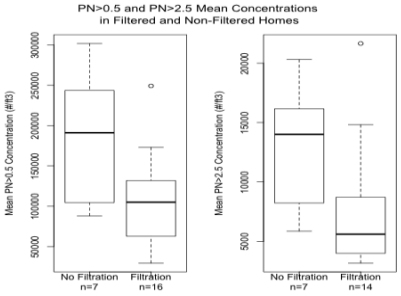
Home Features to Mitigate Cooking Hazard

- Mitigation Strategies:
  - (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 boundary

Hazard Mitigation for Particles: Filtration

Scoring will give more credit for:

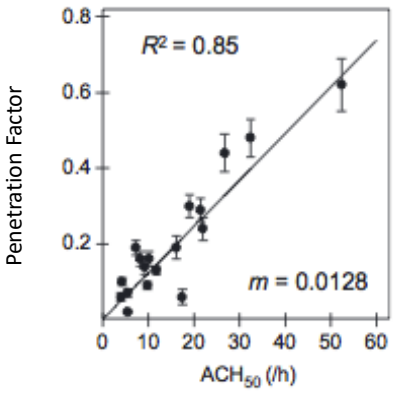
- a better filter
- minimum runtime
- cleaning both indoor and outdoor air



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

Scoring should apply a credit for tight envelopes in locations with high outdoor particle levels

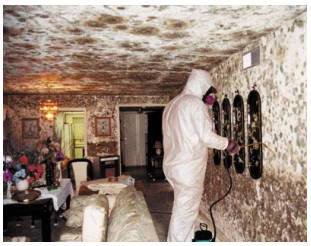


Stephens & Siegel. 2012. Penetration of ambient submicron particles into single-family residences and associations with building characteristics. Indoor Air 2012.

Odor and moisture scoring

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

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



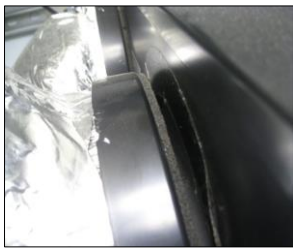
Score will identify visible mould hazards
Score will credit mitigation strategies/systems/house attributes

Diagnostic Testing of Ventilation Equipment

Index will default to low performance – measure to get rated performance

System design, Installation & Durability Issues

- Difficulties verifying air flows
  - kitchen range hoods - inlet location
  - supply systems – inlet location
  - HRVs (low air flow per outlet/inlet)
- Clogged inlets & filters – critical for supply and balanced systems
- Typical survey results: half of supply/HRV systems not working properly



Dealing with robustness: recent Florida Solar Energy Center 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

Scoring should apply a discount to supply air system performance
- Could be mitigated by on board diagnostics/alarm?

Dirty outdoor air intake.

Dirty ERV filters.

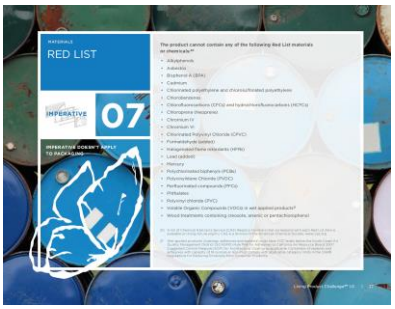
Odor and moisture scoring

- 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

Score will debit or credit for these features

Building Material Source Control

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



Prioritize materials with:

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

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 credit more robust features

Implementation

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

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

Questions

- Iain Walker – iswalker@lbl.gov
- Homes.lbl.gov