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

Iain Walker, LBNL
AIVC Workshop 2017

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 from 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, NO₂, 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.
Table 1
Inhalation reference concentrations for chronic exposure (RfC), reference exposure limits (REL) and guidelines as defined by the US EPA, the Cal OSHA, and the WHO, respectively.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Inhalation RfC(^a)</th>
<th>Inhalation REL(^b)</th>
<th>WHO guideline(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide</td>
<td>55 µg m(^{-3}) (A)</td>
<td>9 µg m(^{-3}) (B)</td>
<td>100 mg m(^{-3}) (0.25 h)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9 µg m(^{-3}) (C)</td>
<td>60 mg m(^{-3}) (0.5 h)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 mg m(^{-3}) (8 h)</td>
<td>30 mg m(^{-3}) (1 h)</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>Not assessed</td>
<td>0.6 µg m(^{-3}) (A)</td>
<td>1 µg m(^{-3}) (annual)</td>
</tr>
<tr>
<td></td>
<td>0.06 µg m(^{-3}) (B)</td>
<td>0.03 µg m(^{-3}) (C)</td>
<td></td>
</tr>
<tr>
<td>Mercury</td>
<td>3 × 10(^{-6}) mg m(^{-3})</td>
<td>9 µg m(^{-3}) (C)</td>
<td>200 µg m(^{-3}) (1 h)</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>3 × 10(^{-2}) mg m(^{-3})</td>
<td>9 µg m(^{-3}) (C)</td>
<td>40 µg m(^{-3}) (annual)</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>Value not estimated</td>
<td>470 µg m(^{-3}) (A)</td>
<td>0.25 mg m(^{-3}) (1 week)</td>
</tr>
<tr>
<td>Styrene</td>
<td>1 mg m(^{-3})</td>
<td>21 000 µg m(^{-3}) (A)</td>
<td>200 µg m(^{-3}) (1 h)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>900 µg m(^{-3}) (C)</td>
<td>40 µg m(^{-3}) (annual)</td>
</tr>
<tr>
<td>2,4-/2,6-Toluene diisocyanate</td>
<td>7 × 10(^{-5}) mg m(^{-3})</td>
<td>9.07 µg m(^{-3}) (C)</td>
<td>0.26 mg m(^{-3}) (1 week)</td>
</tr>
<tr>
<td>Toluene</td>
<td>5 mg m(^{-3})</td>
<td>37 000 µg m(^{-3}) (A)</td>
<td>25 µg m(^{-3}) (24 h)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>300 µg m(^{-3}) (C)</td>
<td>10 µg m(^{-3}) (annual)</td>
</tr>
<tr>
<td>Xylenes</td>
<td>0.1 mg m(^{-3})</td>
<td>22 000 µg m(^{-3}) (A)</td>
<td>50 µg m(^{-3}) (24 h)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>700 µg m(^{-3}) (C)</td>
<td>20 µg m(^{-3}) (annual)</td>
</tr>
<tr>
<td>PM(_{2.5})</td>
<td></td>
<td></td>
<td>100 µg m(^{-3})</td>
</tr>
<tr>
<td>PM(_{10})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radon(^d)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example Hazard: Cooking

- Moisture & CO\(_2\)
- NO\(_2\) and formaldehyde
- Ultrafine particles & CO

Fuel
- Ultrafine particles

Food
- Ultrafine particles
- VOCs including acrolein
- Moisture and odors
Example Hazard: Cooking

Hazard severity depends on heat source

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
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’
  – 19 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?
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