Analysis of Zoned Residential Ventilation Controls

Iain Walker, PhD
Lawrence Berkeley National Laboratory
iswalker@lbl.gov
Learning Objectives

• Knowledge of optimized residential ventilation system design for zoning
• Understanding of the impact of ventilation zoning on energy use
• Understanding of the impact of ventilation zoning on indoor air quality
• Understanding of the limitations of ventilation zoning
Acknowledgements

• Co-Authors: Brennan Less, David Lorenzetti and Mike Sohn – LBNL
• Funding:
  • US Department of Energy, Building Technologies Office
  • California Energy Commission
  • Aereco
Simulation Background

• New California code compliant homes:
  • single family with envelope leakage of 0.6, 2 and 3 ACH50
  • Apartment, 3 ACH50
• Central forced air for non-zoned and distributed zonal heat pumps for zoned systems

<table>
<thead>
<tr>
<th>California Climate Zone</th>
<th>HDD</th>
<th>CDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2400</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>1700</td>
<td>70</td>
</tr>
<tr>
<td>10</td>
<td>950</td>
<td>950</td>
</tr>
<tr>
<td>16</td>
<td>2800</td>
<td>250</td>
</tr>
</tbody>
</table>
Contaminant Emissions

From HENGH field study of 70 California homes

• Continuous emission:
  • “Generic” contaminant
  • Formaldehyde (depends on Temperature, Humidity and Ventilation Rate)

• Periodic Emission:
  • PM2.5 from cooking
  • CO₂ and H₂O from occupants
  • Occupant schedules

• Use reference exposure limits for chronic exposure:
  • Formaldehyde: OEHHA REL is 9 μg/m³ for 8-hour and chronic exposures
  • Particles (PM2.5): WHO Chronic level is 10 μg/m³
  • CO₂ : 1100 ppm
  • Moisture: 60% RH
Smart Ventilation Strategies

• Track occupants (assumes we know occupancy)
• Combine with outdoor temperature (shift to milder conditions)
• Zonal Air flow options:
  1. Air flow
     1. Keep total air flow constant. Direct air to zones that need venting.
     2. Reduce total air flow. Vent each zone that calls for venting at rate proportional to fraction of total floor area.
  2. Number of zones
     1. Four + zones: kitchen, bathrooms, bedrooms and “other” living spaces
     2. Two zones: 1. sleeping & 2. All other spaces
Exposure-based Controls

• Keep relative exposure below 1 when occupied, 5 when vacant
• Match relative exposure to continuously operating system
• Track occupant individual exposure
• Ventilate at low rate unoccupied, higher when occupied. No exposure calculations
• Contaminant-based:
  • Vent dwelling if any contaminant in any zone above threshold
  • Vent zone if that zone above threshold
  • Vent zone if occupied and above threshold
  • Control RH between 30% and 60%
Many controls saved energy but increased exposure OR decreased exposure but used more energy.

Occupancy-based systems without exposure control lead to high exposures.

Contaminant controls operate a lot – driven by need to control formaldehyde.

Zoning not a clear advantage.
Best performance was for exhaust systems.

Zoning using occupancy controls looks OK.
Exposures and Ventilation Rates – no contaminant controls

Zoning can:

- **increase** exposure
  - For particles
  - For generic and formaldehyde exposure

- **decrease** exposure
  - For most CO₂ cases
Zoning Exposure Results for VarQ controller (best energy performance) with contaminant controls

Zonal controls can either **increase** or **decrease** exposure:

**Biggest **decrease: **consistently better for CO₂**
- because occupants are source

**Biggest **increase: **consistently poor for PM₂.₅ supply & balanced systems**
- Exhaust more effective at concentrated contaminant removal
Are more zones better for contaminants?

Controlling more zones is sometimes good, some times not for CONTAMINANTS

As occupants move from zone to zone they are exposed to higher contaminant levels upon entry to a zone that was previously under-ventilated.
Are more zones better for energy savings?

Sometimes good: SF homes

Sometimes not: apartment
Other observations

• Direct contaminant control
  • Can’t vent enough to control formaldehyde – even at double the ASHRAE 62.2 minimum required rate
  • Future work will need to allow for much higher formaldehyde – is this OK?

• Exhaust systems:
  • Least zonal (but still good for bedroom CO₂ control)
  • Most consistent contaminant control

• Supply systems
  • More effective zoning – lowest total ventilation
  • Higher power fans mean bigger energy use… but also bigger savings when controlled
  • Not so good for particles: more from outside + not as good at removing particles from cooking

• Balanced systems
  • Effective zoning – highest total ventilation but also highest fan power. Had the biggest energy savings from smart controls
Conclusions

• Few control strategies saved energy without increasing exposure
• Hard for zonal ventilation to control all contaminants
• Exhaust systems most consistently saved energy
• Effective zoning limited by:
  • Open doors
  • Occupant movement (continually entering less ventilated space)
  • Zoning effect depends on contaminant
    • Particles increased, CO₂ decreased, HCHO/generic source up or down
• Direct contaminant controls were ineffective due to the inability to control formaldehyde below chronic levels
• Adding extra zones beyond sleeping/other ineffective

Additional details in:

Questions?

Iain Walker
iswalker@lbl.gov
Thank you!