

BUILDING AMERICA ROADMAP: INDOOR AIR QUALITY



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Optimal Ventilation and IAQ Solutions

Many cross-cutting activities

Use the following code:

TPS – Targeted Pollutant Solutions

SV – Smart Ventilation

IAQV – IAQ Valuation

Why are we ventilating?

□ Remove or dilute pollutants

- Moisture – generated by people and their activities: washing, cleaning, showering, cooking, etc. + groundwater, leaks, wet basements and crawlspaces
- Odor – generated by people and their activities: bio-effluent, cooking, cleaning, etc.
- **NEW EMPHASIS: Health-related pollutants of concern (a path to IAQ Valuation):**
 - Particles - combustion
 - Formaldehyde – building materials and contents
 - NO₂ – combustion
 - Be careful about outdoor sources: particles and ozone (tend to be periodic)



How do we deal with these pollutants?

- Local exhaust
 - Kitchen for moisture, odors and combustion products
 - Bathroom for moisture and odors
- Whole house ventilation
 - Everything else
- How much ventilation?
 - ASHRAE 62.2 gives **minimums** for both
 - 100 cfm kitchen, 50 cfm bathroom intermittent exhaust
 - Whole house based on floor area and number of occupants + **credit** based on measured envelope leakage (but not in multi-family)
 - Whole house typically 1/3 ACH
 - Has special allowances for existing homes
 - Other standards (e.g., EPA IndoorAir Plus) have above minimum specifications
- Source control – e.g., formaldehyde limits
- **How do we do this better?**
- **How do we do this without a big energy penalty?**



Targeted Pollutant Solutions

- Dealing with pollutants at source
 - ▣ Lower emitting materials
 - ▣ Smart Range Hoods – high capture efficiency but they only work if turned on!
 - ▣ Air cleaning – filtration
- We need
 - ▣ Product development – e.g., high Capture efficiency automatic range hoods
 - ▣ Demonstrations in homes
 - ▣ Technical support for code and standard changes and/or credits

IAQ Valuation

- A “score” like HERS for IAQ
 - ▣ Asset rating
 - ▣ Need metrics to combine health, odor, moisture
- Include system design
 - ▣ Filtration, automatic range hoods, smart ventilation control
- Include diagnostics
 - ▣ Measure air flows, test alarm systems
- Include construction materials
- Move away from simplistic air flow spec.
 - ▣ Allow builders more flexibility for meeting standards and way to value better performance
- How to include energy issues??

Ventilation in high performance homes

- They are tighter
 - ▣ Housing stock 15 ACH50
 - ▣ 90s: 7–10 ACH50 – this gave about 1/3 of an ACH
 - ▣ New code homes: 3-5 ACH50
 - ▣ High performance home: ~2 ACH50
 - ▣ Passive House: 0.6 ACH50
- Tighter homes under ventilated if they rely on natural infiltration
- Tighter homes are more dependent on mechanical ventilation
 - ▣ Essential that mech. vent. commissioned and robust
- Tighter envelopes filter particles (M9-13 equivalent) and allow better control of outdoor sources – needs more study

Ventilation in high performance homes

- They have less natural draft combustion
 - ▣ Furnace and water heater backdrafting a safety issue - Sealed combustion furnace/water heater or use of heat pumps/electric heat removes this hazard
 - ▣ Move combustion outside tight envelope reduces this hazard: attics and garages for furnaces and water heaters
 - ▣ Note that gas cooking is still open combustion – but we require a range hood for venting



Notes on Combustion Safety

- You can't have commercial kitchen exhaust (>400 cfm) and:
 - ▣ natural draft combustion appliances (best not to have this inside with you)
 - ▣ open fireplaces (best not to have this)
 - ▣ You **MUST** have tempered supply air – required by code and too often ignored (a good idea even without natural draft combustion)
- Developing improved (simpler & better indicator of problems) combustion safety test procedures with focus on:
 - ▣ CO
 - ▣ Draft test
 - ▣ Correct flue installation (and combustion air supply)

Pollutants in high performance homes

- They have less emitters of some pollutants (more of a new home issue than just high performance)
 - ▣ Less formaldehyde in building materials and home contents – about 50% reduction, not exceeding CA acute levels
 - ▣ Some harmful chemicals now rare or non-existent (e.g., benzene, paradichlorobenzine (mothballs))
 - ▣ Lower VOCs, in general, in building materials and home contents
 - ▣ Federal formaldehyde regulations (CFR S.1660, not yet implemented) will drastically reduce formaldehyde levels emitted from manufactured wood products
- “High Performance” includes selecting low-emitting materials
 - ▣ Some concerns remain regarding materials brought into home by occupants
 - ▣ Living Building Challenge “Red List”

System design, Installation & Durability ^{TPS/IAQV}

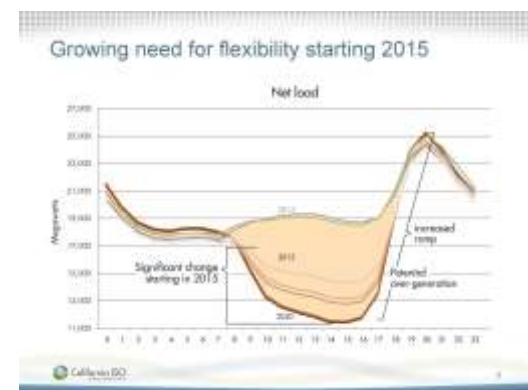
Issues

- 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



Smart Ventilation – less energy/same or better IAQ

- Change ventilation rate to times of less energy penalty but **get same exposure as a continuous system**
- Real Time Control or pre-calculated controls
- Reduce ventilation when unoccupied
- Respond to outdoor pollutants: high particle or ozone levels
- Respond to other systems: kitchen and bath exhaust, dryers
- Respond to peak demand



Smart Ventilation

- Field studies underway and planned for next couple of years
 - ▣ Look at energy savings while measuring key pollutants
- Working with ventilation equipment manufacturers to develop market-ready equipment
- Need to develop smart ventilation characteristics to allow credits in codes and standards
 - ▣ First implementation is “equivalence” calculations in ASHRAE 62.2

Filtration

- Particles most important for health
- Not required in ASHRAE 62.2²
 - ▣ Kitchen range hood requirement an excellent method of reducing cooking-related indoor particles – cooking is by far the most important indoor source
 - ▣ New ASHRAE 62.2 addendum will 20% credit for recirculation filtering
 - Example: MERV 13 requires 150-200 cfm recirc filtered air
- Tight envelope is good at removing particles (more data would be better)
- Need to solve the maintenance problem when filtering outdoor particles with HRV or Supply systems
- Use forced air heating and cooling or dedicated recirculation system to get indoor and outdoor particles
 - ▣ ~MERV 13
 - ▣ Use a high-performance blower at low air flow continuously uses the least energy

Multifamily Issues

- ▣ Need good compartmentalization
 - 62.2: 0.3 (was 0.2) cfm@50Pa/ft² envelope area
 - Is that even good enough?
 - Can we achieve this in new and retrofit?
- ▣ Kitchen and bathroom exhaust: ducting + architectural issues
- ▣ Some possible code changes to deal with inlet/outlet separation limits (already happening in ASHRAE 62.2)

Technology development

- High capture efficiency automatic range hoods
 - ▣ Lower noise and air flow requirements
- Automatic flow verification at installation and continuously + alarm for filter replacement or cleaning of air inlets
- Smart Ventilation controllers
- More filtration
 - ▣ Particles #1 health issue
- Home IAQ Score
 - ▣ Will credit for smart systems, flow verification, filtration
- All these good things given recognition in codes and standards

Codes and Standards

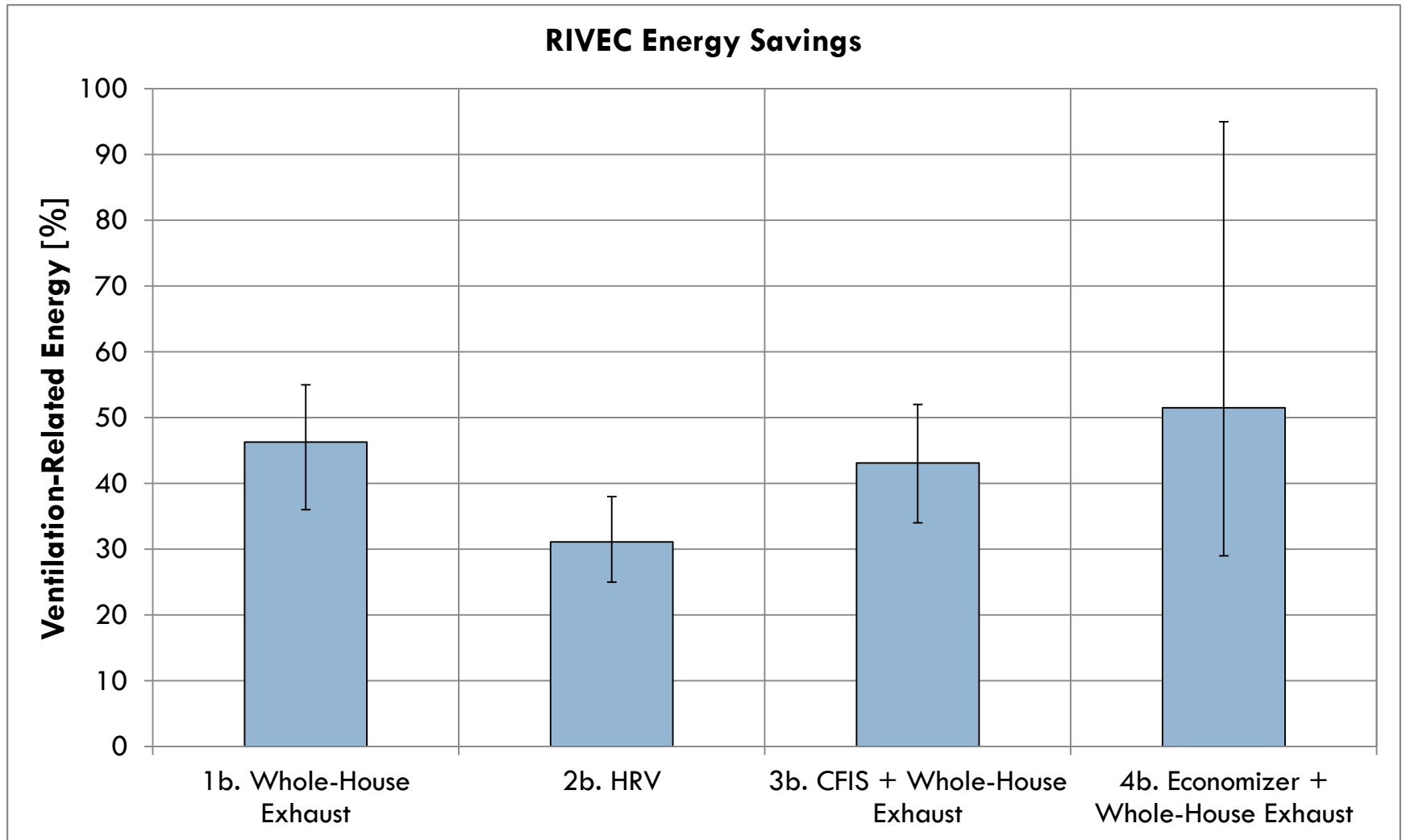
- Changes to require minimum performance and ALLOW credit better performance
 - ASHRAE 62.2 – filtration, smart ventilation
 - RESNET – smart ventilation, diagnostics
 - BPI - diagnostics
 - ACCA - diagnostics
 - ICC
 - CA T24 – energy calc. credits
 - Voluntary standards, e.g., Indoor Air Plus

Thank You! Further Questions?

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Smart Ventilation Energy Savings

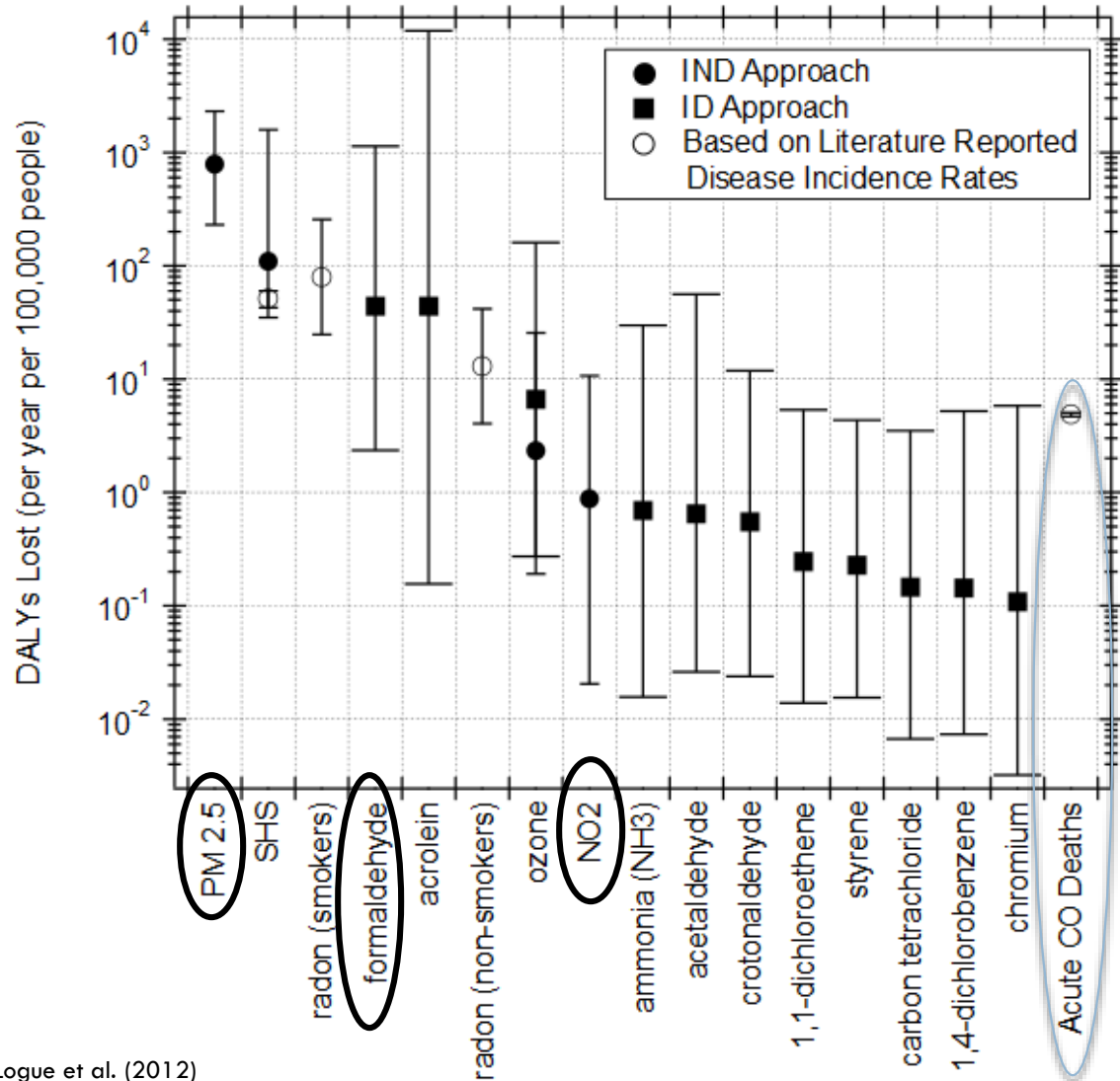


Identifying Contaminants of Concern

- What are common?
- What is the health impact? Disability Adjusted Life Years: DALYs

Top 3:

1. PM_{2.5}
2. Formaldehyde
3. NO₂



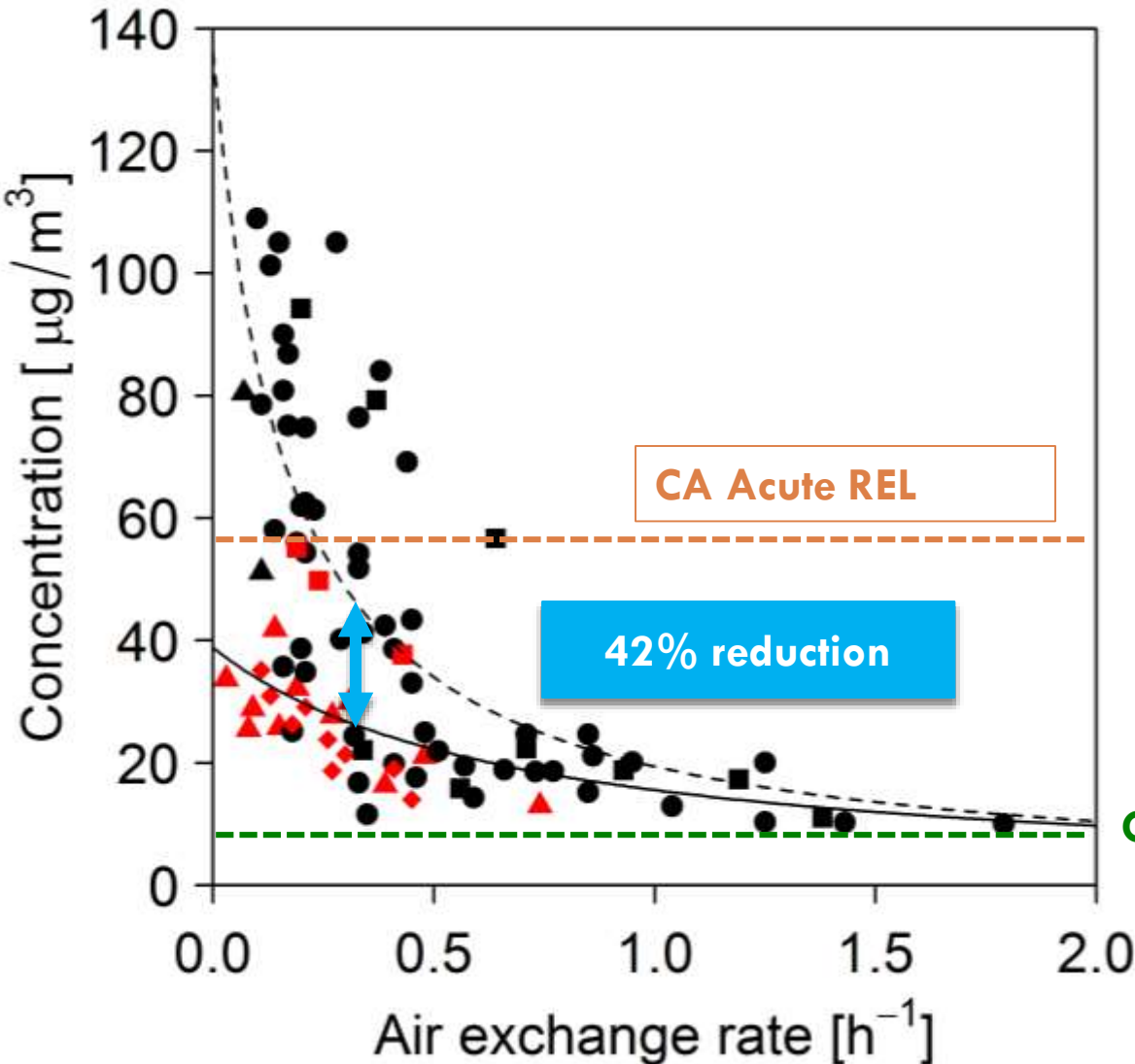
Recent Consensus

- Energy efficient homes have **BETTER** IAQ
 - Sealed crawlspaces were shown to reduce crawlspace moisture levels, mold and spore transmission to inside home (Coulter et al., 2007)
 - Increased airtightness reduces the transport of pollutants from attached garages (Emmerich et al., 2003)
 - Tighter ducts limit transport from attics, crawlspaces and garages
 - Mechanical ventilation results in more consistent air exchange, without under-venting periods
 - Combustion safety testing, sealed combustion appliances, filtration, etc.



Homes Built With Low-Emitting Materials Have Lower Formaldehyde Concentrations (Hult et al., 2014)

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- **Conventional Materials**
 - 54 CA homes from California New Home Survey (2-5 years old) (Offermann, 2009)
- **Low-Emitting Materials (LBNL Study)**
 - 11 New Mexico LEED/Indoor airPLUS homes
 - CARB compliant wood products

CA Chronic REL

LBNL Field Study in High Performance Homes (Less, 2012)

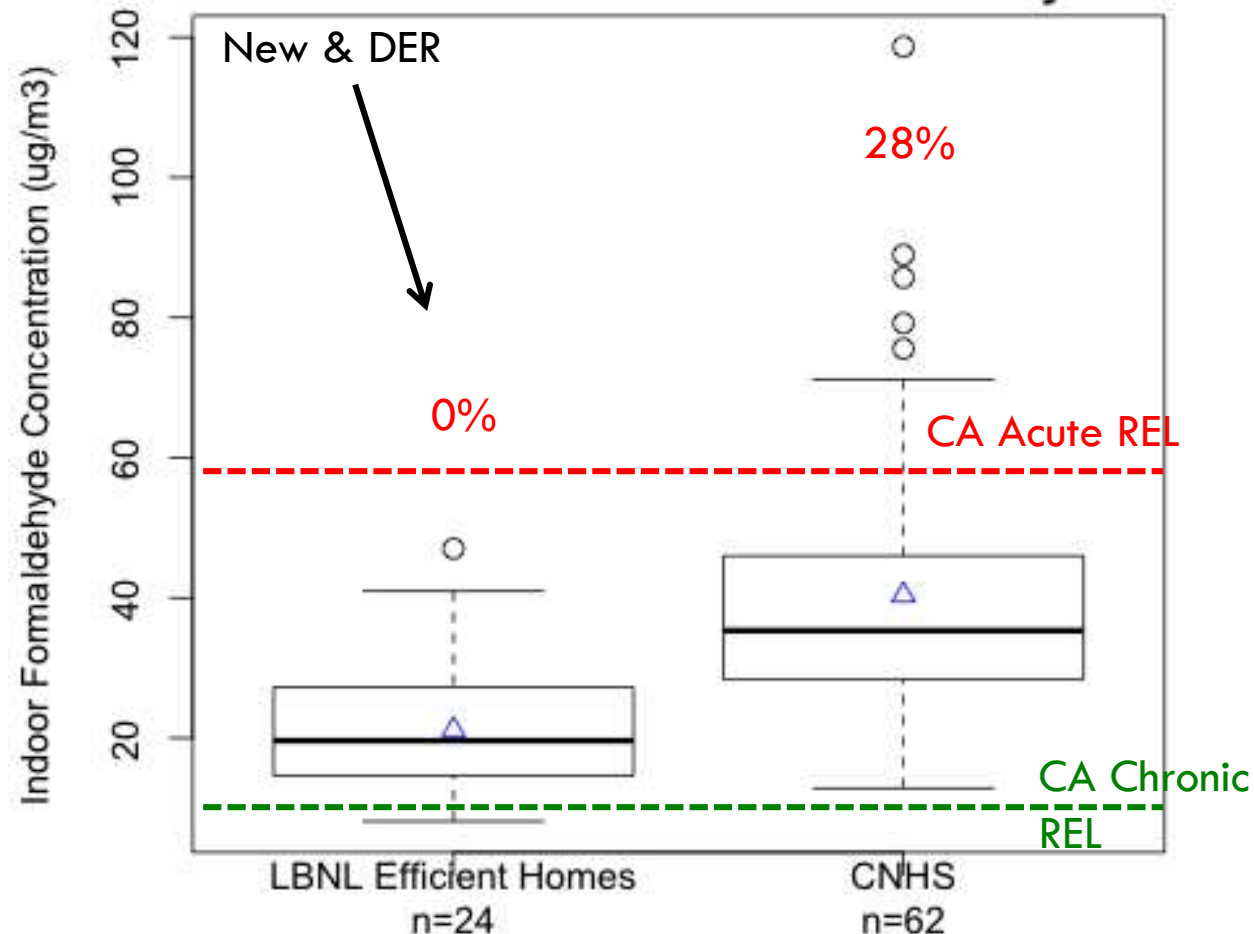
Median levels were ~44% lower than in CNHS

- No homes exceeded acute REL versus 28%
- Estimated emissions rates were 40% lower than in new CA homes

23 of 24 of homes reported use of **healthy, low-emitting** building and finish materials

- Also lower emissions from existing, non-replaced materials in retrofits
- CARB regulations

Comparison of Winter Indoor Formaldehyde Levels
LBNL High Performance Homes
Versus California New Homes Study



Source Control—Combustion & Cooking Emissions



- Moisture & CO₂
- NO₂ and formaldehyde
- Ultrafine particles & CO



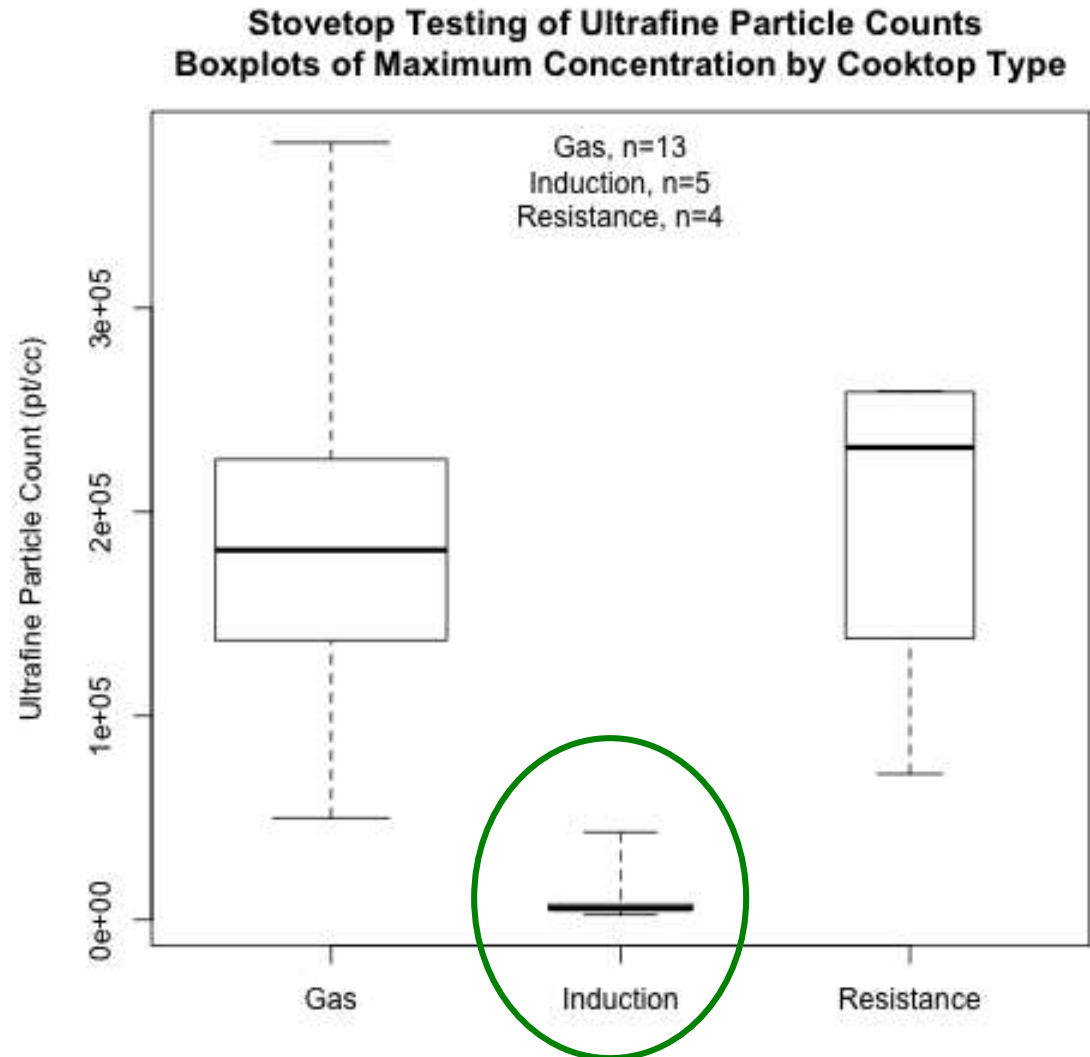
- Ultrafine particles



- Ultrafine particle
- VOCs including acrolein
- Moisture and odors

Ultrafine Particles (UFP) from Cooktop Test in 24 High Performance CA Homes (Less, 2012)

- Performed water boiling test in each test home, and measured UFP ($\#/cm^3$) on nearby countertop
 - No range hoods!
- Similar peak 1-minute concentrations between gas (181k) and electric resistance cooktops (232k)
- Induction electric levels were MUCH lower (5k)

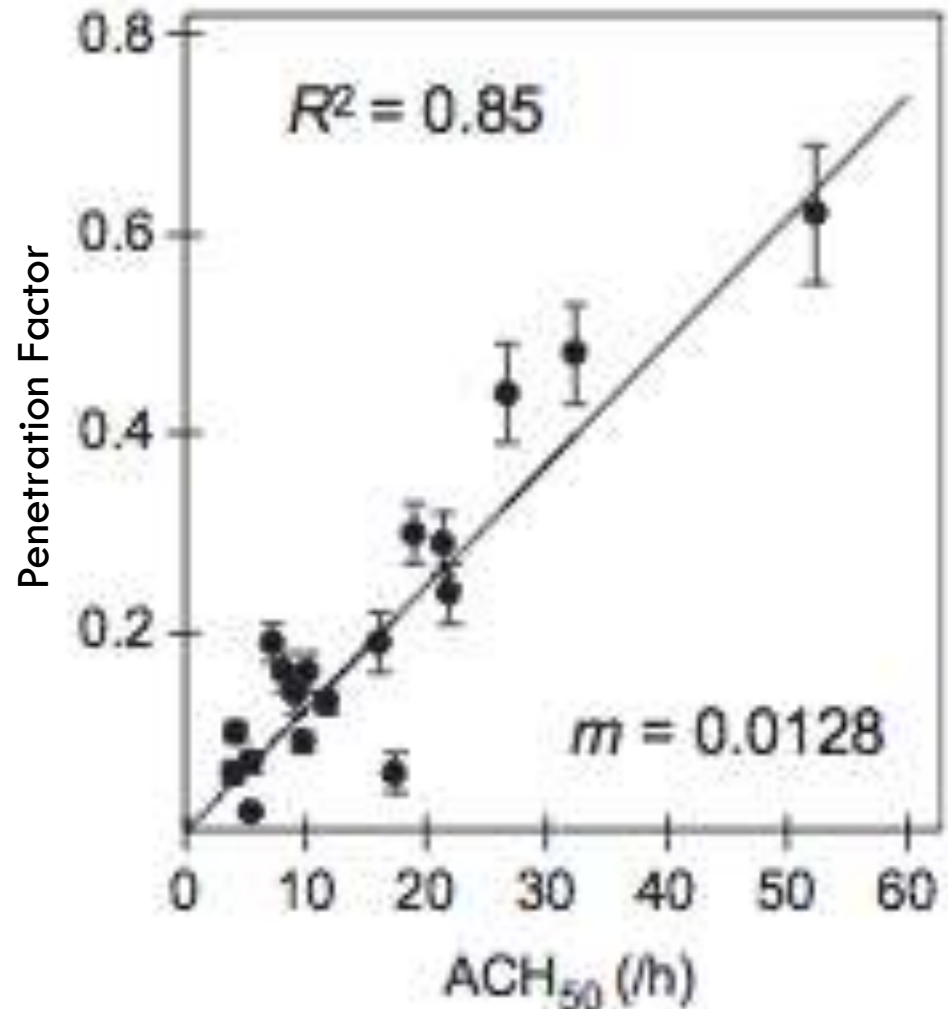


Kitchen Ventilation Recommendations

- Install range hoods vented to outside
 - Hood **covers all burners**
 - Hood is **not flat bottomed**
 - Airflow of **200 cfm**—MEASURED
 - **Quiet** operation, NOT just on low speed—HARD TO KNOW
 - **Short** duct runs with **smooth** pipe and few turns (basis of EPA Energy Star spec)
 - Look for *future* inclusion of Capture Efficiency in ratings and requirements in 62.2
- Provide ducted make-up air in VERY airtight homes or in systems with high flows (200 cfm in 1.5 ACH50 home ~ 10 Pa – is this OK?)
- Meet ASHRAE 62.2 general kitchen ventilation requirement
- Occupant Education or Automation?
 - Need to get people to use their range hoods
 - Automation is available, but not the greatest

An Airtight Envelope Filters **Outdoor** Particles

- Field testing of envelope penetration of **submicron** particles (Stephens & Siegel, 2012)
- Tight homes are good particle filters for **Exhaust** ventilation:
 - $1.5 \text{ ACH}_{50} = 2\%$ penetration = MERV16
- Need data for larger particles: PM_{2.5}

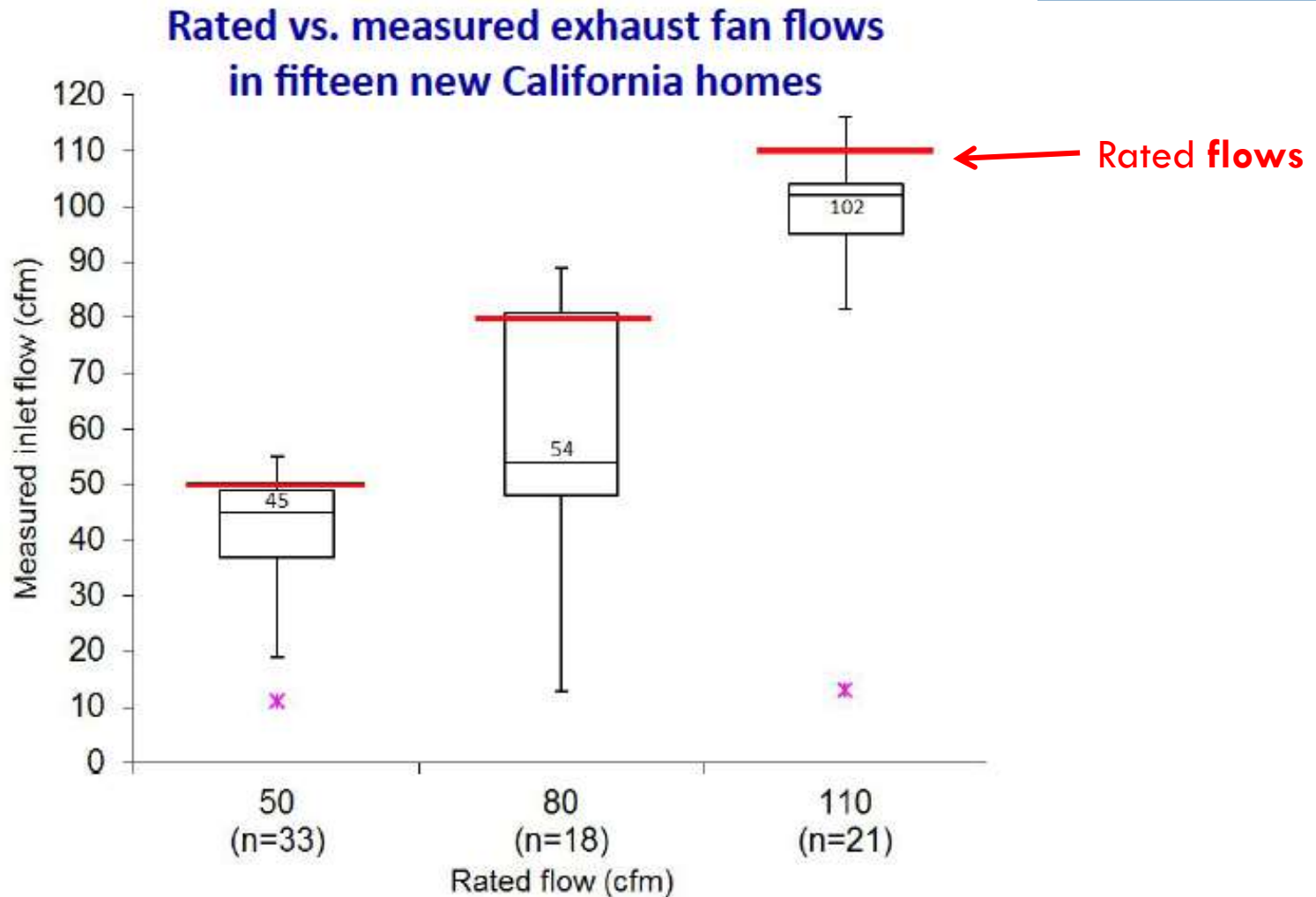


Field Survey of 60 Canadian HRVs (Hill, 1998)

- Cores and filters “**clean**” in ~**50%** of homes
 - ▣ <10% “clean” when five years or older
- 7 homes had **inlets clogged** with debris
- 7% of HRVs were simply **not operational** due to component failure
- 29% of systems were out of balance (supply vs. exhaust) by **>40%**
 - ▣ Excessive depressurization and back drafting concerns
- Occupant knowledge of system was largely unrelated to performance, level of maintenance, etc.



Ventilation Measurements in 15 New CA Homes (Stratton, Walker, & Wray, 2012)



The only way to know a fan's flow: MEASURE IT

Faults Observed in CA High Performance Home Ventilation Systems (Less, 2012)

- 5 of 9 ERV/HRV found to have some substantial problem
 - ▣ Low airflows
 - ▣ Failed duct connections
 - ▣ Improperly installed duct connections (recirculating ERV)
 - ▣ Erratic control of variable speed systems
 - ▣ Clogged fresh air intake on ERV
 - ▣ Not operating continuously, inactive for months

- Similar faults are found in other studies (Balvers et al., 2012; Hill, 1998; Offermann, 2009)



Resources

□ Healthy Products

- Environmental Working Group
 - <http://www.ewg.org/>
- Healthy Building Network—Pharos Database
 - <http://www.pharosproject.net/>
- Good Guide
 - <http://www.goodguide.com/>
- BuildingGreen chemical avoidance guidance
 - http://www2.buildinggreen.com/guidance/Avoid-Toxic-Chemicals-in-Buildings?ip_login_no_cache=7212a98a1b9d960554b417acc51531a3
- Health Product Declaration
 - <http://hpdcollaborative.org/>

□ Overall Design

- Building America
 - <http://energy.gov/eere/buildings/building-america-bringing-building-innovations-market>
- Energy Star Indoor airPLUS
 - <http://www.epa.gov/indoorairplus/>
- EPA Moisture Control Design Guide
 - <http://www.epa.gov/iaq/pdfs/moisture-control.pdf>
- Healthy Indoor Environmental Protocols for Home Energy Upgrades
 - http://www.epa.gov/iaq/pdfs/epa_retrofit_protocols.pdf
- HUD Healthy Homes
 - http://portal.hud.gov/hudportal/HUD?src=/program_offices/healthy_homes
 - <http://www.buildingscience.com/documents/guides-and-manuals/gm-read-this-before-you-design-build-renovate>
- National Center for Healthy Housing
 - <http://www.nchh.org/>