INDOOR AIR QUALITY IN HIGH PERFORMANCE HOMES

California Energy Commission

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2014 RESNET Building Performance Conference, 02/24-26

Today's Outline

- Intro to IAQ dynamics and pollutants
- Review of past findings in IAQ and efficient homes
- IAQ best practices in efficient homes + recent evidence + recommendations:
  - Source control
  - Task ventilation
  - Dilution ventilation
  - Air cleaning
  - Commissioning
  - Occupant Education
- Resources

What Determines Indoor Pollutant Levels?

- **<u>Outdoor Pollutant levels</u>**

- **<u>Air flow</u>**
  - Natural infiltration
    - weather
    - ELA
    - windows
  - Mechanical Ventilation
    - task ventilation
    - whole house ventilation

- **<u>Indoor Sources</u>**
  - Episodic
    - cooking
    - showering
    - Indoor combustion
  - Intermittent
    - fumigation
    - painting
  - Continuous
    - household furnishings
    - home materials
    - stored products

Indoor Sources: Biological agents

Indoor Sources: Chemicals

Indoor Sources: Combustion

Indoor Sources: Outdoor Air

What is the safe level for each contaminant?

- **Answers are uncertain to non-existent**
- **Policy as much as science: what is risk threshold?**
- **As OSHA sets safety exposure guidelines for worker safety, guidelines are also set for general population/sensitive populations**
- **National and California Ambient Air Quality Standards**
  - CO, NO_2, $PM_{2.5}$, PM_{10}, Ozone, Lead, SO_2
  - Varying averaging times from 1 h to 1 y
  - Set to protect sensitive sub-populations, e.g. **asthmatics**
- **Reference Exposure Levels (RELs) for Toxic Air Contaminants**
  - Level below which **no adverse effects expected**
  - **Acute (hours)** and **Chronic (years to lifetime)**

Identifying Contaminants of Concern

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

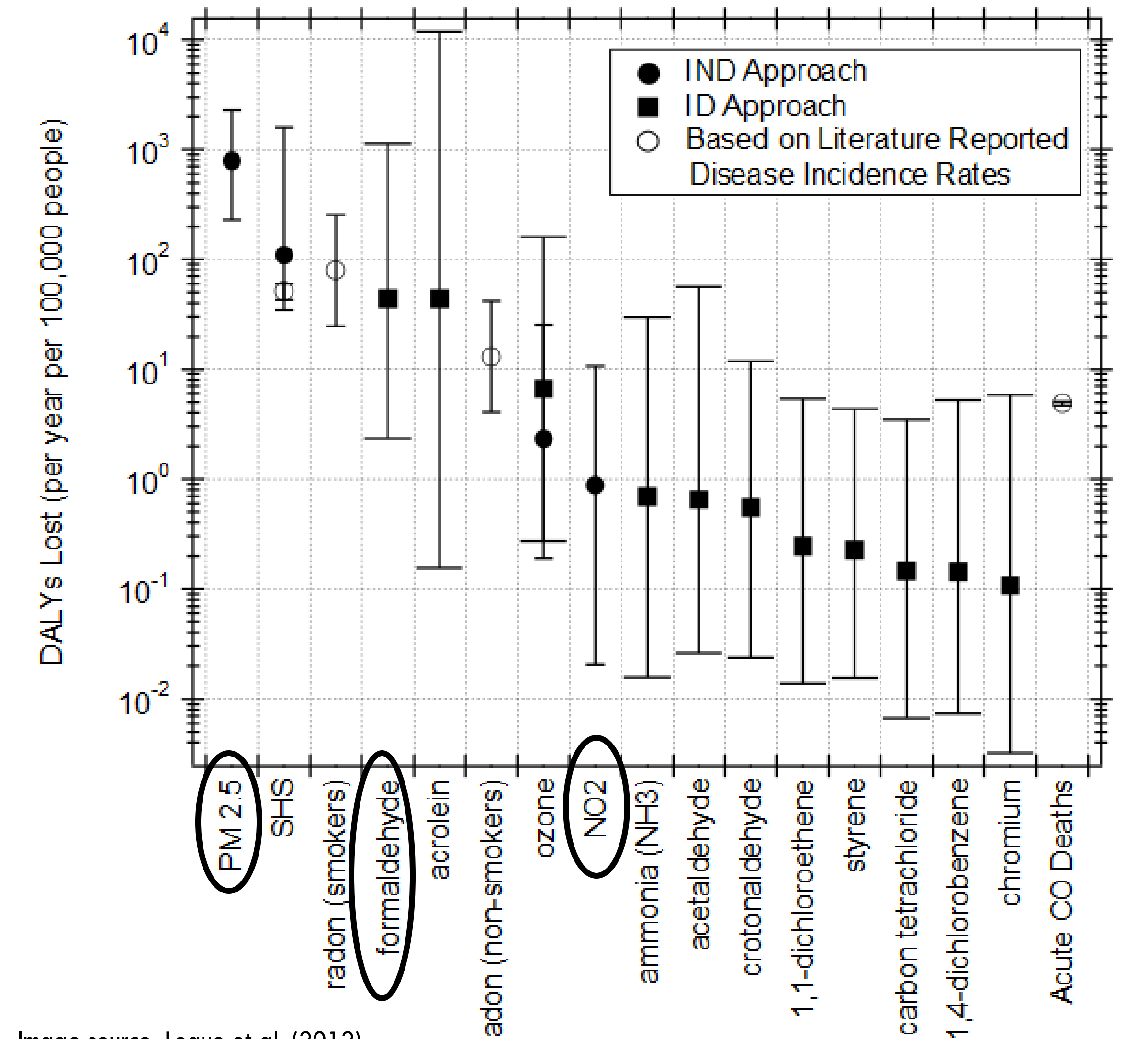


Image source: Logue et al. (2012)

History of IAQ in Energy Efficient Homes—Canada

- Assessments of IAQ in R-2000 and conventional Canadian homes, 1984 ~ Present
  - R-2000 requirements:
    - Airtightness (1.5 ACH_{50})
    - Mechanical ventilation with ERV/HRV
    - Low-emitting materials
    - Commissioning
  - Results:
    - Superior IAQ and energy efficiency can be compatible
    - Equivalent or reduced pollutant concentrations repeatedly measured in R-2000 homes compared to conventional new homes
- This achievement was possible due to a **coordinated national effort, with requirements and specifications that were refined over time, being informed by actual measurements** of pollutants and ventilation parameters in homes that participated in the program.
- Riley & Piersol, 1988; Gusdorf & Hamlin, 1995; Gusdorf & Parekh, 2000; Shaw et al., 2001; Leech et al., 2004
  - See Less (2012) for detailed summary

vs.

History of IAQ in Energy Efficient Homes—U.S.

- Assessments of IAQ in energy efficient homes much less clear in the U.S., due to
  - Uncoordinated efforts
  - Inconsistent definitions of "efficient"
  - Less stringent or optional efficiency requirements
  - Small sample sizes
- Early research suggested efficient homes had increased pollutant levels
  - Hollowell et al., 1978; Berk et al., 1980; Fleischer et al., 1982
- But other, more rigorous studies found similar levels in efficient and conventional homes
  - Offermann et al, 1982; Grimsrud et al., 1988; Harris, 1987; Turk et al., 1988; Hekmat et al., 1986
- Consensus: reduced ventilation was not the most important predictor of high indoor pollutant levels, rather source strength, geographic location and other elements were more important

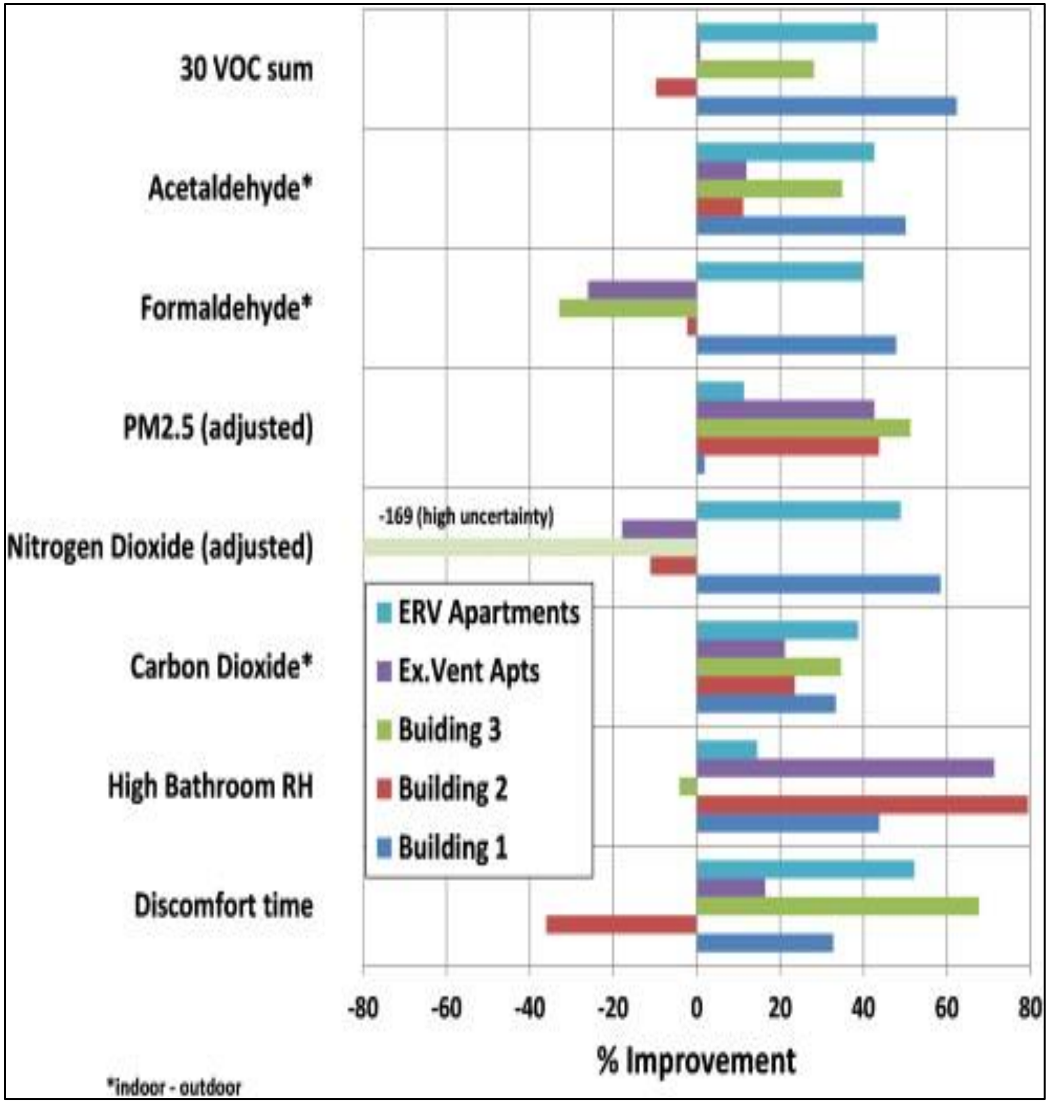
Recent Consensus

- 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
  - Continuous mechanical ventilation results in more consistent air exchange, without under-venting periods
  - Combustion safety testing, sealed combustion appliances, filtration, etc.

Recent CA study (Norris et al., 2012)

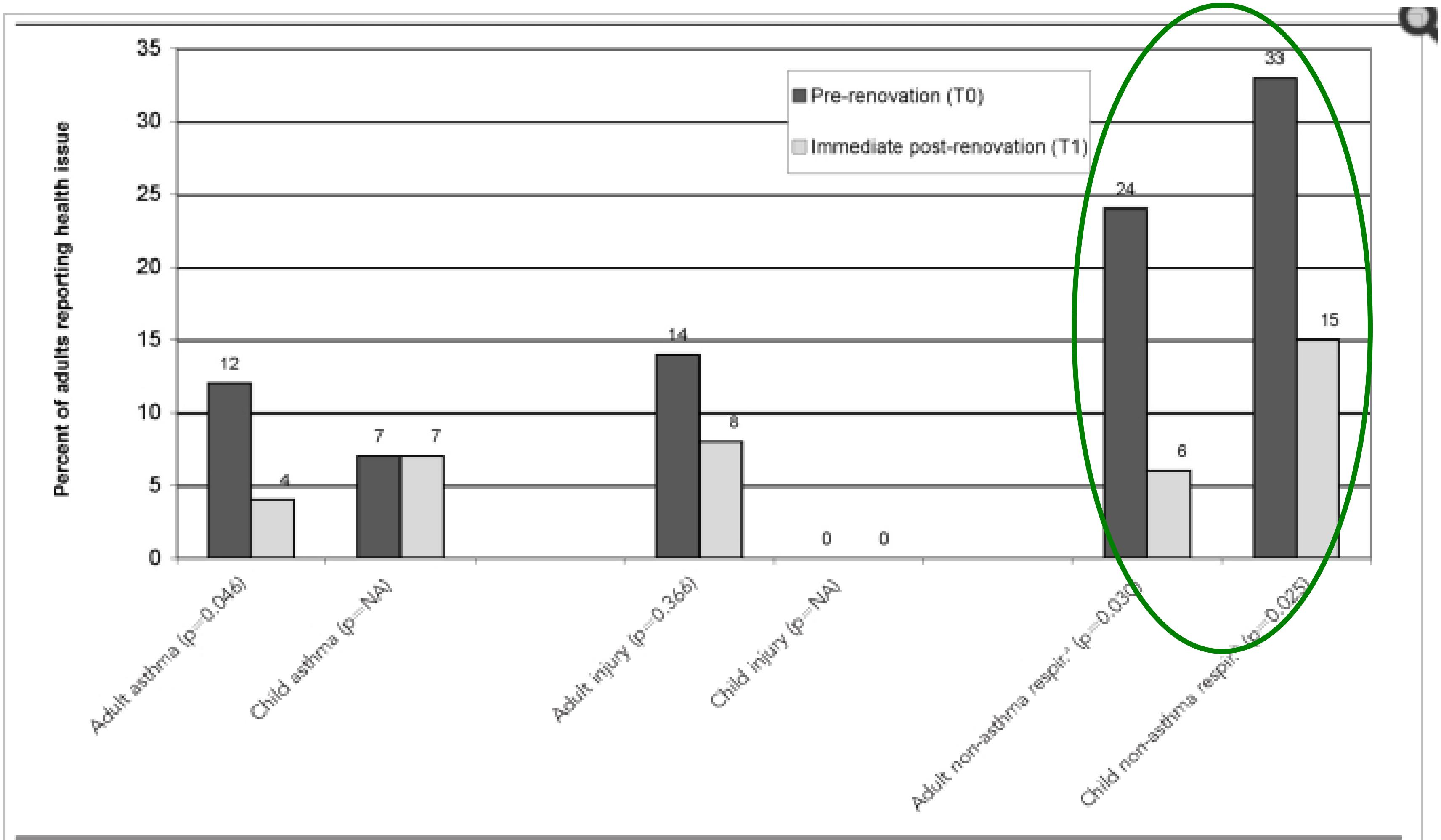
General improvement in IEQ in 16, low-income multifamily retrofitted residences (Norris et al., 2012)

Larger decreases in pollutants levels linked with larger increases in ventilation rates.



3 Renovated Multifamily homes in Montana

(Breysse et al., 2011)



Summary of recent IAQ studies

- Failure to follow best practices—ventilation, source control, occupant education—may lead to increases in pollutant levels and health effects
  - Tohn, 2012; Wilson et al., 2013; Emmerich, Howard-Reed, & Gupte, 2005; Milner et al., 2014; Offermann, 2009
- Substantial evidence suggests that with careful design and operation, high performance homes may improve occupant health and reduce pollutant levels (albeit with some inconsistency).
  - Breysse et al., 2011; Jacobs, 2013; Leech et al., 2004; Kovesi et al., 2009; Weichenthal et al., 2013; Norris et al., 2012
- We lack comprehensive pollutant measurement data in current best-practice, high performance homes

“BUILD TIGHT, VENTILATE RIGHT”

But what the heck does that mean?!?

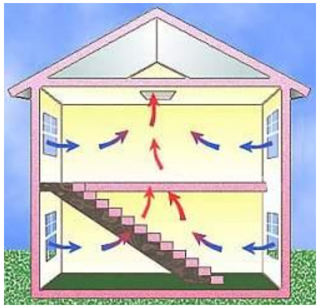
How tight?
Ventilate how much?
Where and with what?
Is that all I need to do?

Principles for Achieving Good IAQ in High Performance Homes

<u>Source Control</u>

Formaldehyde std for comp-wood (CARB)

<u>General & Task Ventilation</u>



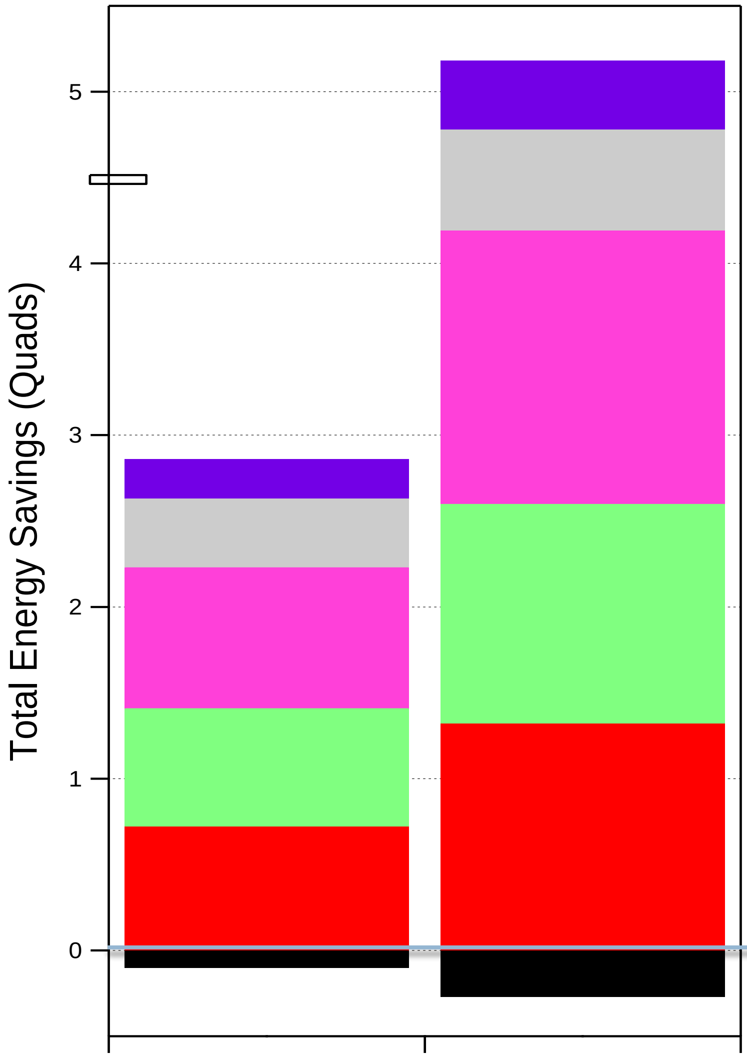
Occupant Education

<u>Filtration/ Air cleaning</u>

Commissioning

Big Rewards for Airtightening, But Returns Diminish

Site Energy **Source Energy**



Passive house (0.6 ACH_{50})

R2000 standard (1.5 ACH_{50})

If all housing stock met IECC (2012) airtightness standard (3 or 5 ACH_{50})

Maximize improvement in airtightness (about 50%)

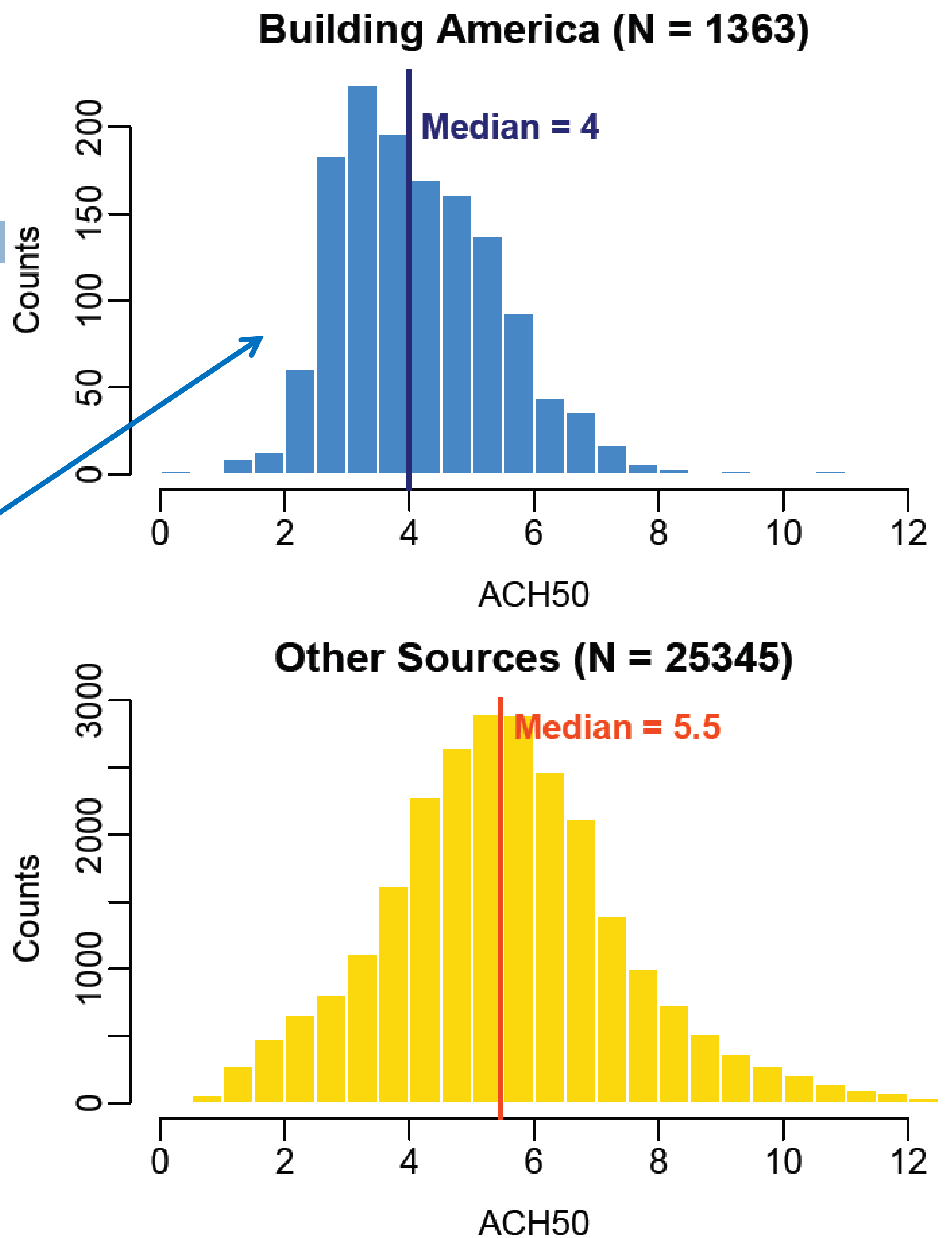
Average improvement in airtightness (about 25%)

Base case with ASHRAE 62.2 ventilation

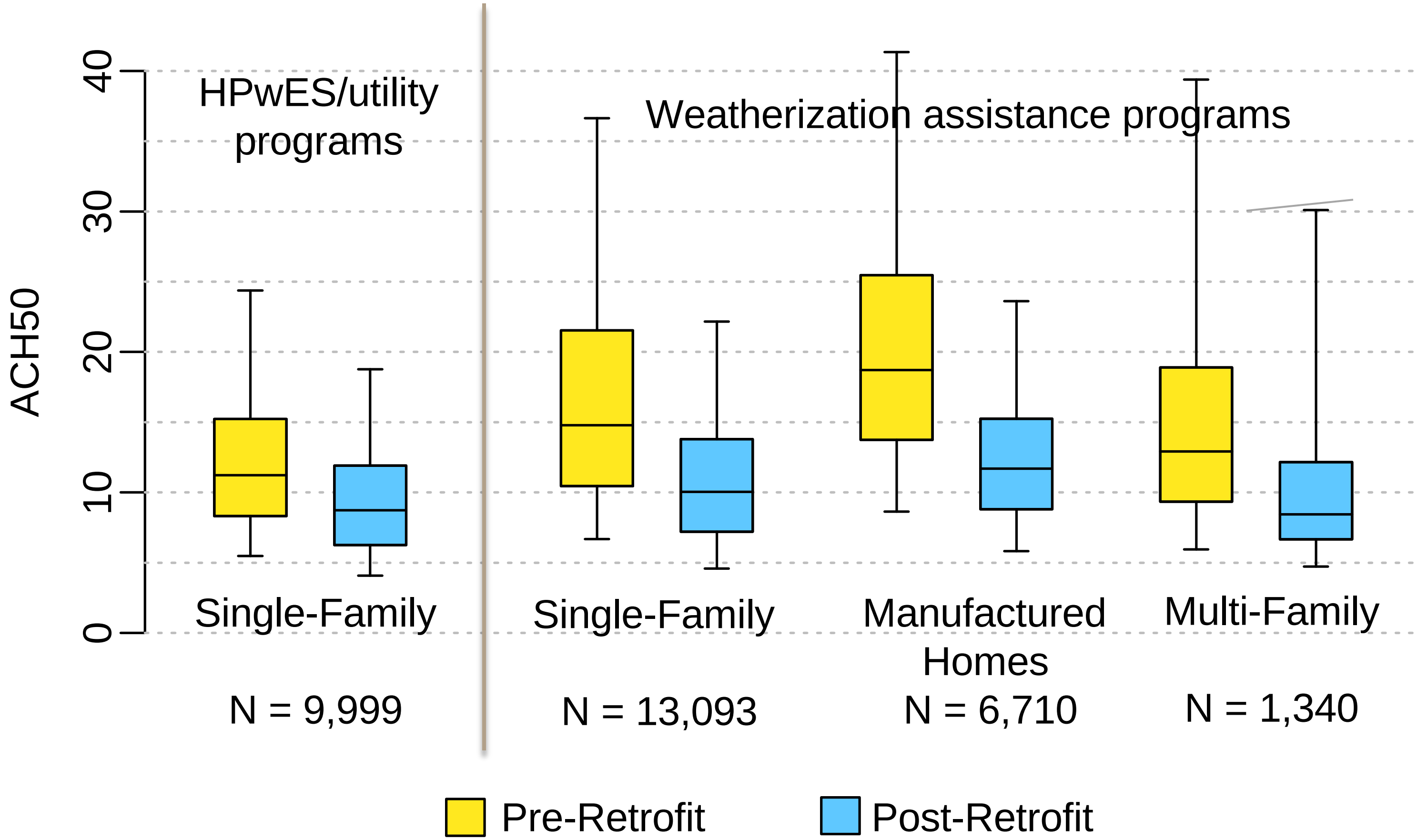
Slide courtesy Rengie Chan, LBNL

Airtightness in New Homes

High Performance Homes, 27% More Airtight On Average



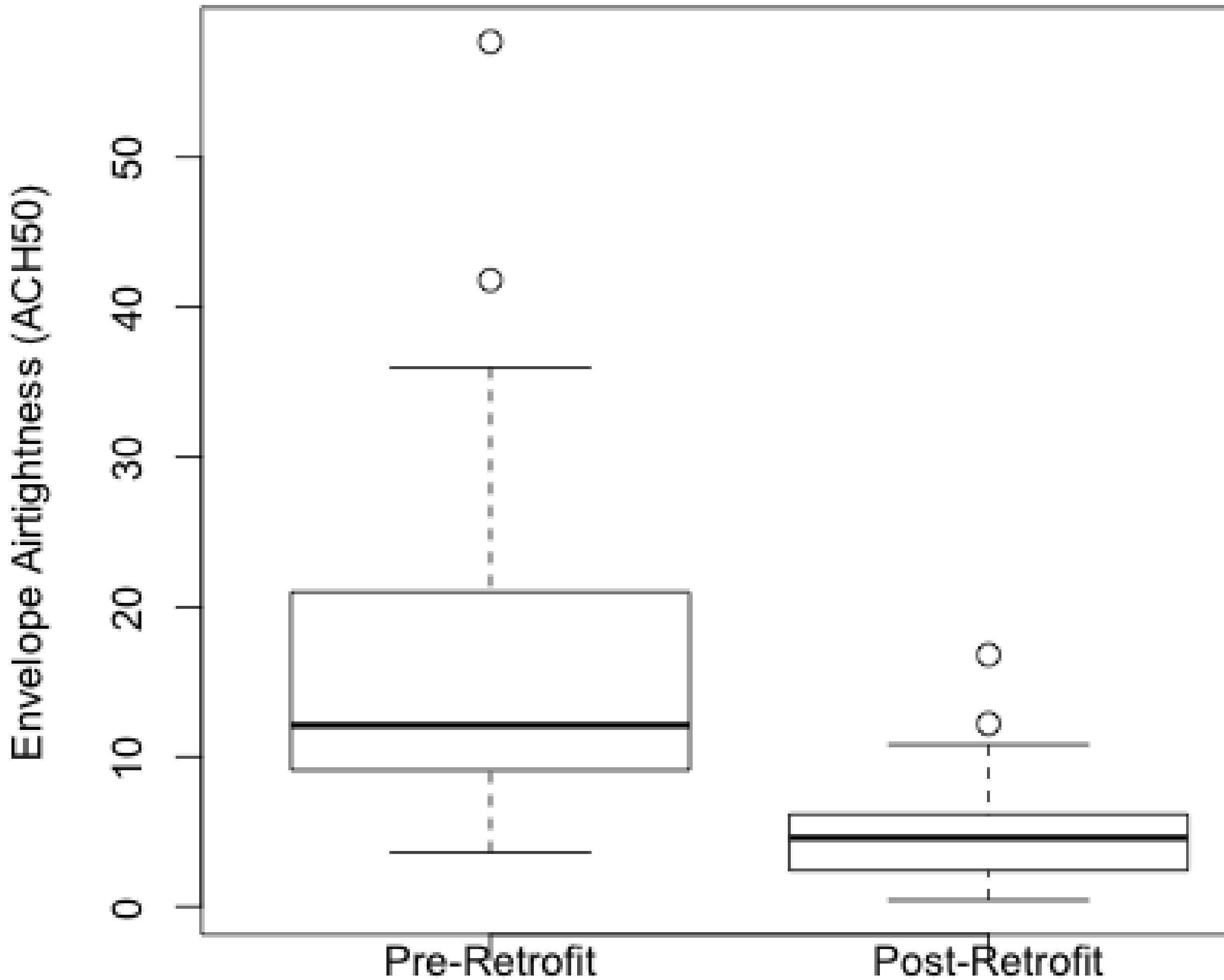
Airtightness in Retrofit Homes (LBNL ResDB)



Median Reduction:	-20%	-30%	-35%	-28%

Airtightness in U.S. Deep Energy Retrofits (DERs)

- Summary from LBNL review of available DER literature
- **63% average leakage reduction**
  - **Example: 12 to 5 ACH_{50}**
- **NOT VENTILATED RIGHT!**
  - 71% mech vented in 103 projects
  - **Only 47% vented in 47 non-Cold climate projects**



Mean = 16.1

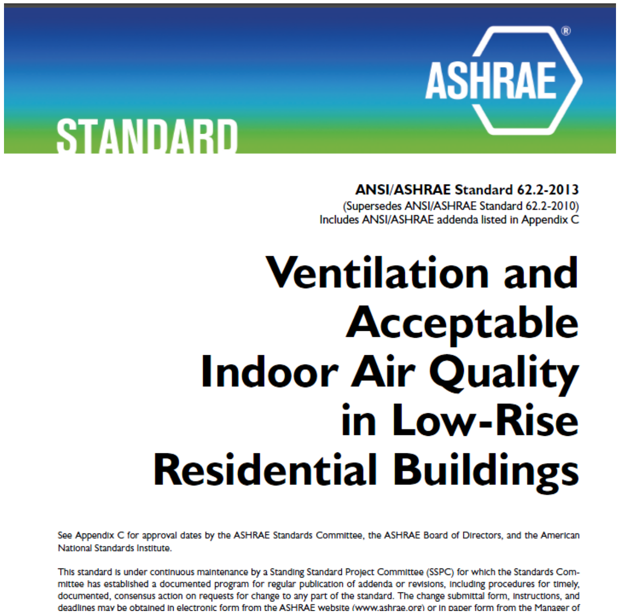
Mean = 4.7

So… How Tight Is Tight Enough?

- New homes
  - 3 ACH_{50} captures ~80% of savings
  - 1.5 ACH_{50} good high performance target
    - Achievable: <0.6 ACH_{50}
- Retrofit
  - >50% reduction
  - <5 ACH_{50}

How Much Ventilation?

- Minimum requirement: ASHRAE 62.2-2013
  - Whole house flow—with blower door credit (not in MF)
  - Local exhaust in kitchens and bathrooms
  - Duct leak limits, minimum filtration
  - Compartmentalization 0.2 cfm50 per square foot of all surfaces
  - Existing home allowances for local exhaust
  - Requires CO alarm
  - Measure air flows
- "Good" = anything "better" than this minimum
  - Better does not always mean more (outdoor pollutants)



STANDARD

ASHRAE

ANSI/ASHRAE Standard 62.2-2013
(Supersedes ANSI/ASHRAE Standard 62.2-2010)
Includes ANSI/ASHRAE addenda listed in Appendix C

Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

See Appendix C for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Manager of

Source Control

- Formaldehyde & VOCs
  - What's in the house structure
    - Building materials
    - Furniture
    - Consumer products
- Combustion and cooking
  - Local exhaust
  - Choice of equipment
- Moisture and odors
  - Local Exhaust

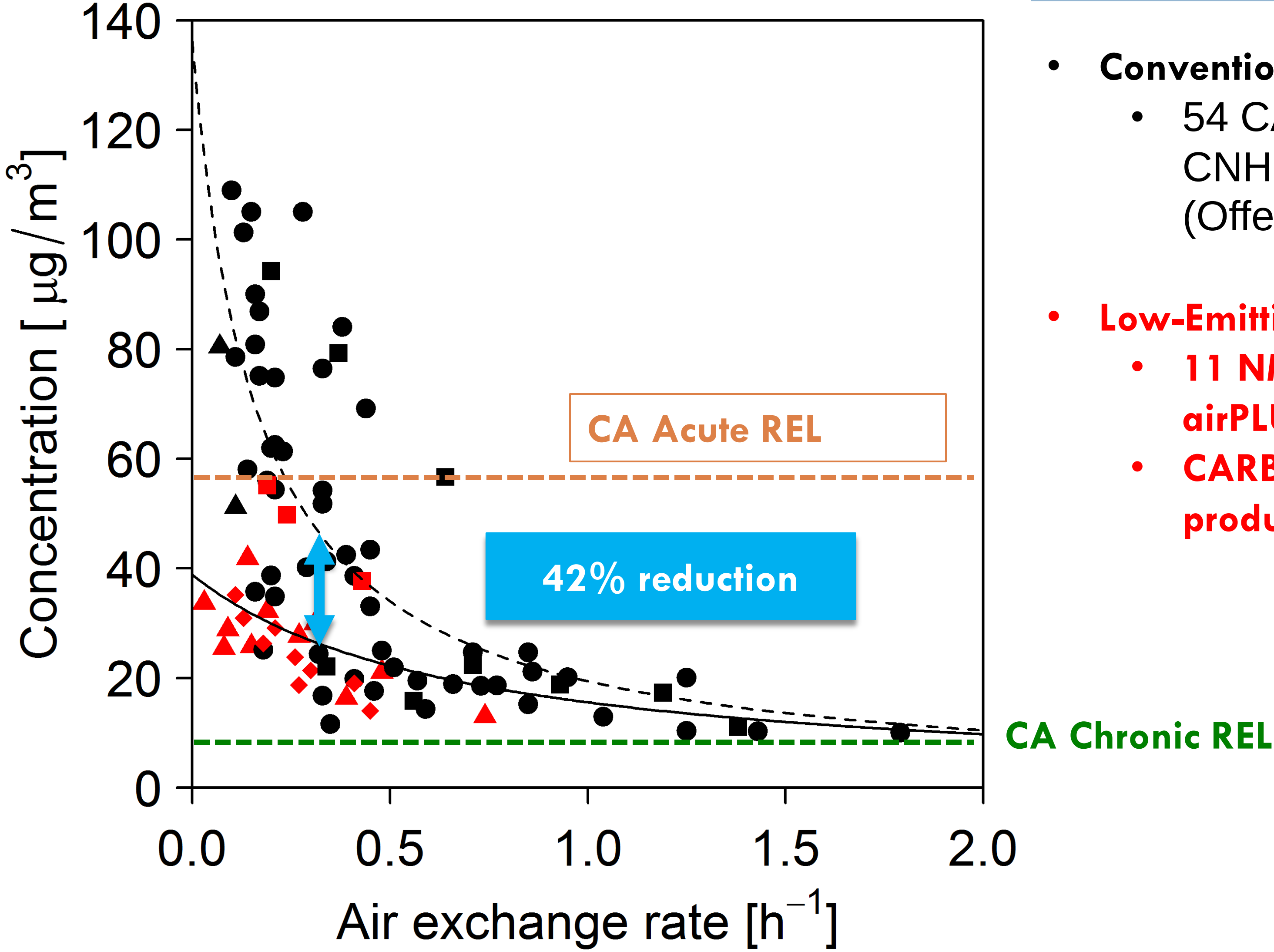
California Department of Public Health CDPH

OEHHA Office of Environmental Health Hazard Assessment

CA Formaldehyde limits and regulation

California Air Resources Board

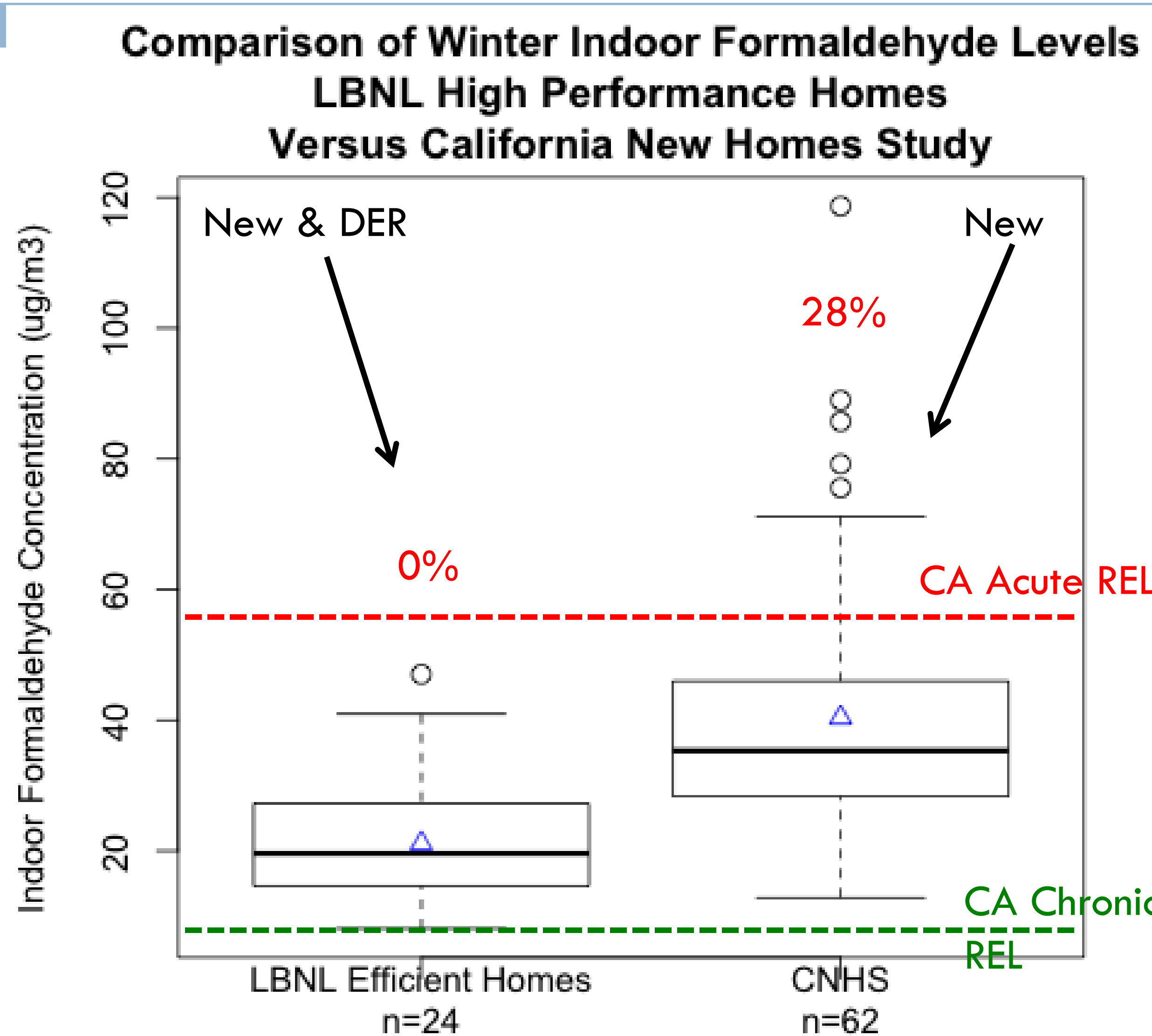
Homes Built With Low-Emitting Materials Have Lower Formaldehyde Concentrations



- **Conventional Materials**
  - 54 CA homes from CNHS (2-5 years old) (Offermann, 2009)
- **Low-Emitting Materials**
  - **11 NM LEED/Indoor airPLUS homes**
  - **CARB compliant wood products**

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



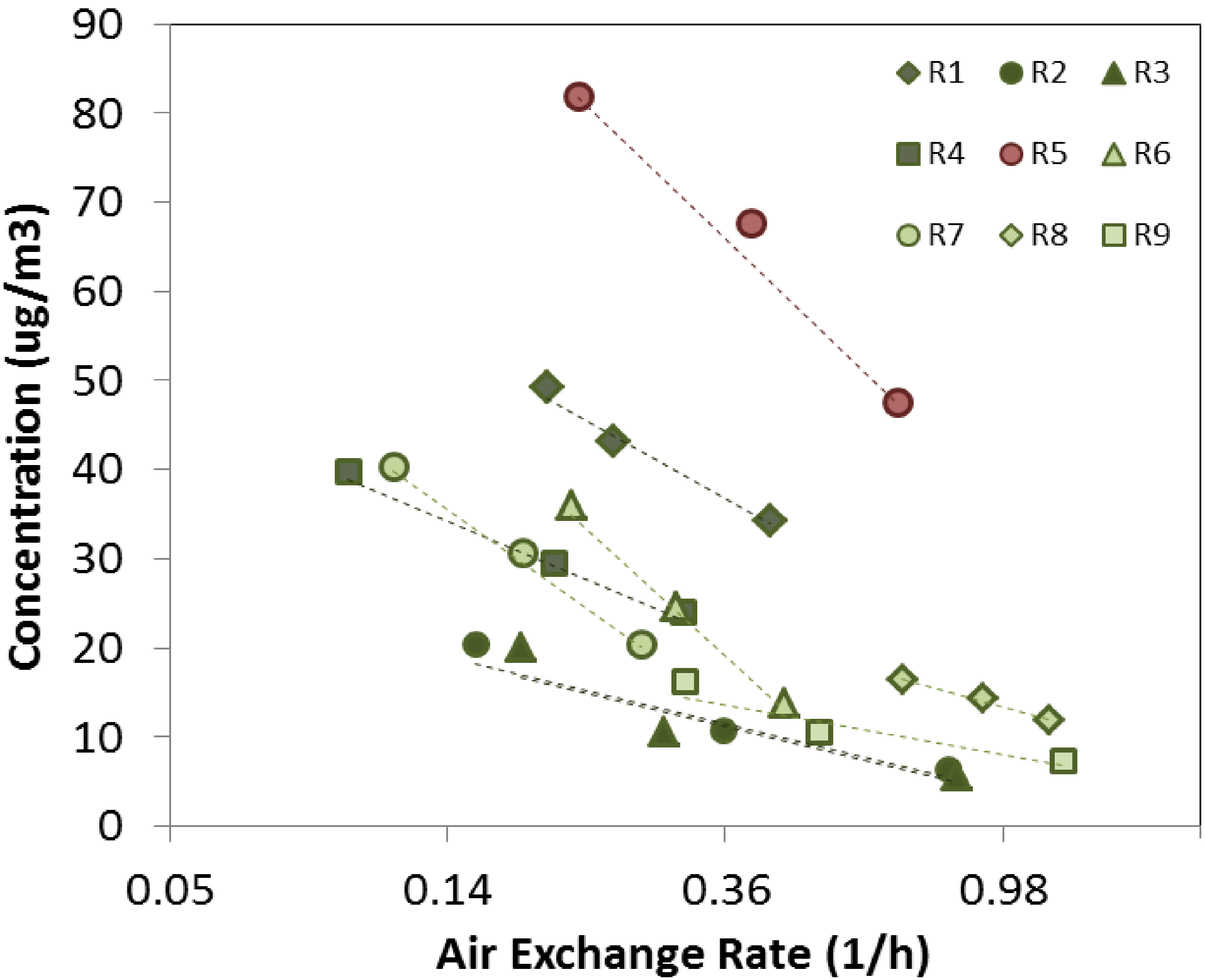
LBNL Formaldehyde/VOC Ventilation Intervention Study (Willem et al. 2013)

- Vary AER in 9 homes; other parameters fixed
  - Materials
  - Temperature
  - Rel. Humidity
  - Season
- AER control via mechanical ventilation
- Measure AER & concentrations, calculate emissions

	Age (yrs)	Floor area (ft^2)	ACH 50	Low-emitting Material#
R1	2.0	2100	1.2	1,2,3
R2	1.5	150	4.0	1,2,3
R3	1.5	150	4.0	1,2,3
R4	0.3	1475	0.6	1,2,3
R5	7.5	1300	4.3	-
R6	0.8	1570	1.0	2,3
R7	1.0	2260	0.7	2,3
R8	2.5	1600	1.0	2
R9	2.5	3440	4.0	2

#1= Wood products compliant with CA Title 17 or low- or no- formaldehyde standards,
2= Wet surface finishing certified as low-emitting,
3= Carpet materials and backing low-emitting.

Lower Concentration with Increased AER in Each Study Home



May - Sep 2011
Age: 0.3 - 2.5 y
N = 9 homes

Formaldehyde and Ventilation Control

- Increasing ventilation rates in residences decreases the indoor formaldehyde concentration
- BUT ventilating is 20-60% less effective at reducing short-term formaldehyde concentrations than a constant emission rate model would suggest
  - Over longer term, ventilation increases the emission rate which depletes sources faster
- Other pollutants do NOT necessarily respond similarly
  - Acetaldehyde results (and those for most other VOCs) were consistent with traditional, constant emission rate model Willem et al. (2013)

Building Material Source Control Recommendations

- Use 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
- NOTES
  - Building materials are NOT the only sources of indoor chemicals/VOCs
    - Instruct occupants about personal care products, candle/incense use, cleaning products, furniture, etc.
  - **Federal formaldehyde regulations (CFR S.1660, not yet implemented) will drastically reduce formaldehyde levels emitted from manufactured wood products**

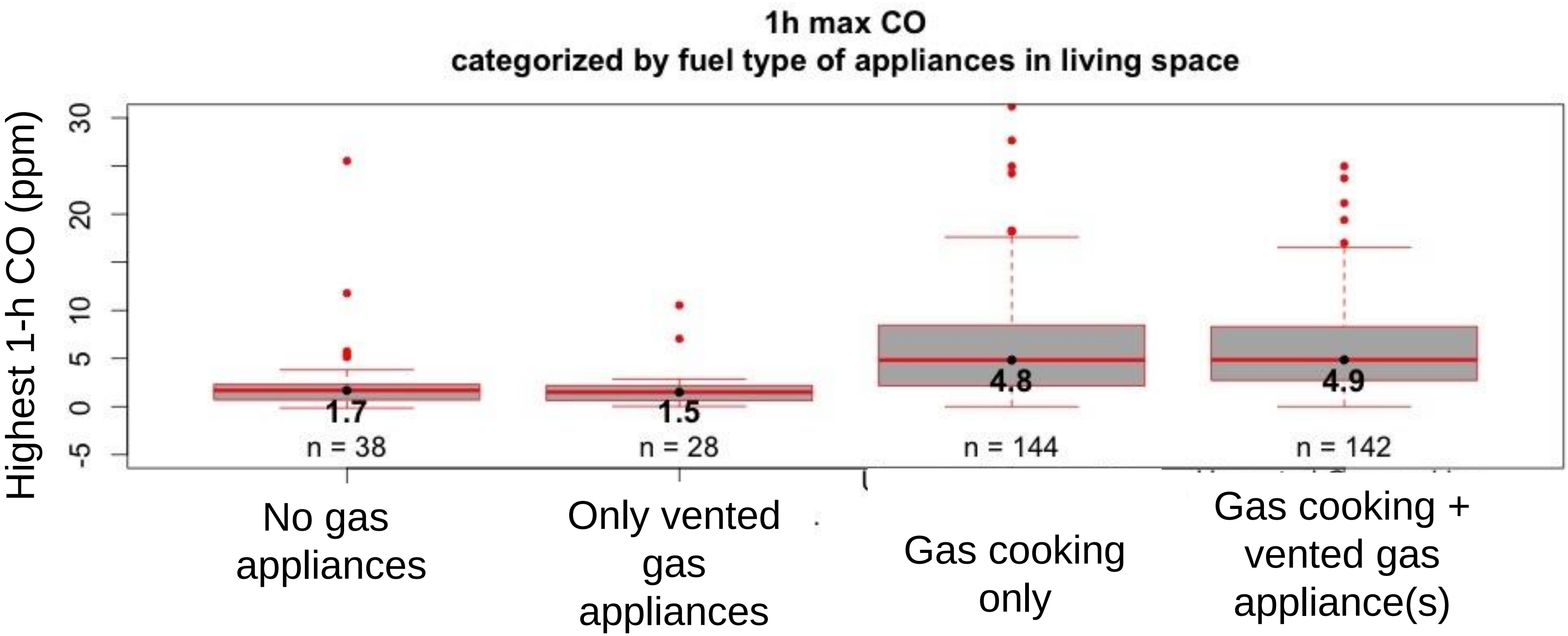
Source Control—Combustion & Cooking Emissions

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

- Ultrafine particles

- Ultrafine particle
- VOCs including acrolein
- Moisture and odors

Wait, I Thought Furnaces and Water Heaters Were the Sources of Dangerous Indoor Combustion Pollutants…

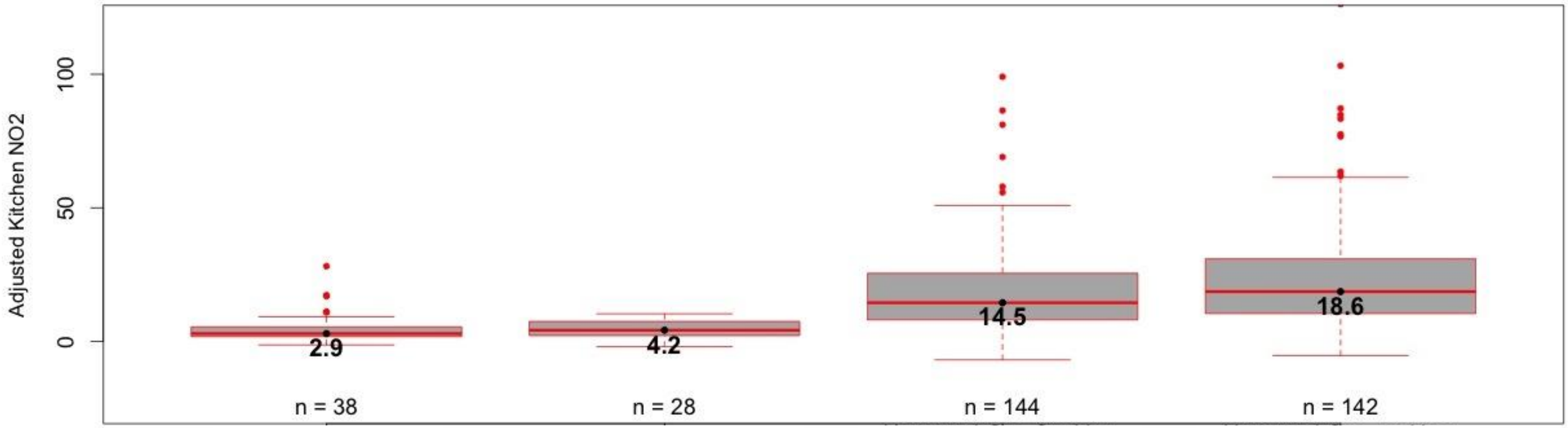


Measured concentrations indoors over a 6-day period in winter 2011-2013

Mullen et al. 2012; Mullen et al. 2013 (LBNL reports; manuscript in preparation)

Cooking Burners Are the Largest NO_2 Source in California Homes

NO_2 (ppb) from indoor emissions



No gas appliances

Only vented gas appliances

Gas cooking only

Gas cooking + vented gas appliance(s)

Measured concentrations indoors minus estimated contribution from outdoors

Mullen et al. 2012; Mullen et al. 2013 (LBNL reports; manuscript in preparation)

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)

Nitrogen Dioxide (NO_2) in High Performance CA Homes with Gas Cooking and Standing Pilot Lights (Less, 2012)

- Six-day average **NO_2 levels were 240% higher in gas-cooking kitchens (n=15) than electric kitchens (n=8)** (13.1 vs. 5.4 ppb)
  - **BUT** Average was still <1/2 the CA outdoor annual standard (30 ppb)
- Historic gas ranges with **standing pilot lights** contributed to higher levels in three homes (2 DERs, 1 new)
  - 60, 30, and 20 ppb.
- Notably, NO_2 levels were **substantially lower than those found in other large CA home surveys** (averages from 25-28 ppb) (Spengler et al., 1994; Lee et al., 2002):
  - Lower outdoor concentrations, no smoking, newer gas cooking appliances with lower pollutant emission rates, and enhanced kitchen ventilation

Combustion and Cooking Source Control Recommendations for Tight Homes

- Install a range hood and **use it**
- Consider use of non-combustion AND efficient heat sources
  - Induction electric cooking
  - Heat pumps
- If heating with gas, use direct-vented, sealed combustion equipment
- Avoid standing pilot lights, mostly on vintage gas ranges

Kitchen Exhaust Performance

- Capture Efficiency
  - Fraction of emitted pollutants removed by hood
  - May differ by burner design and actual cooking activity

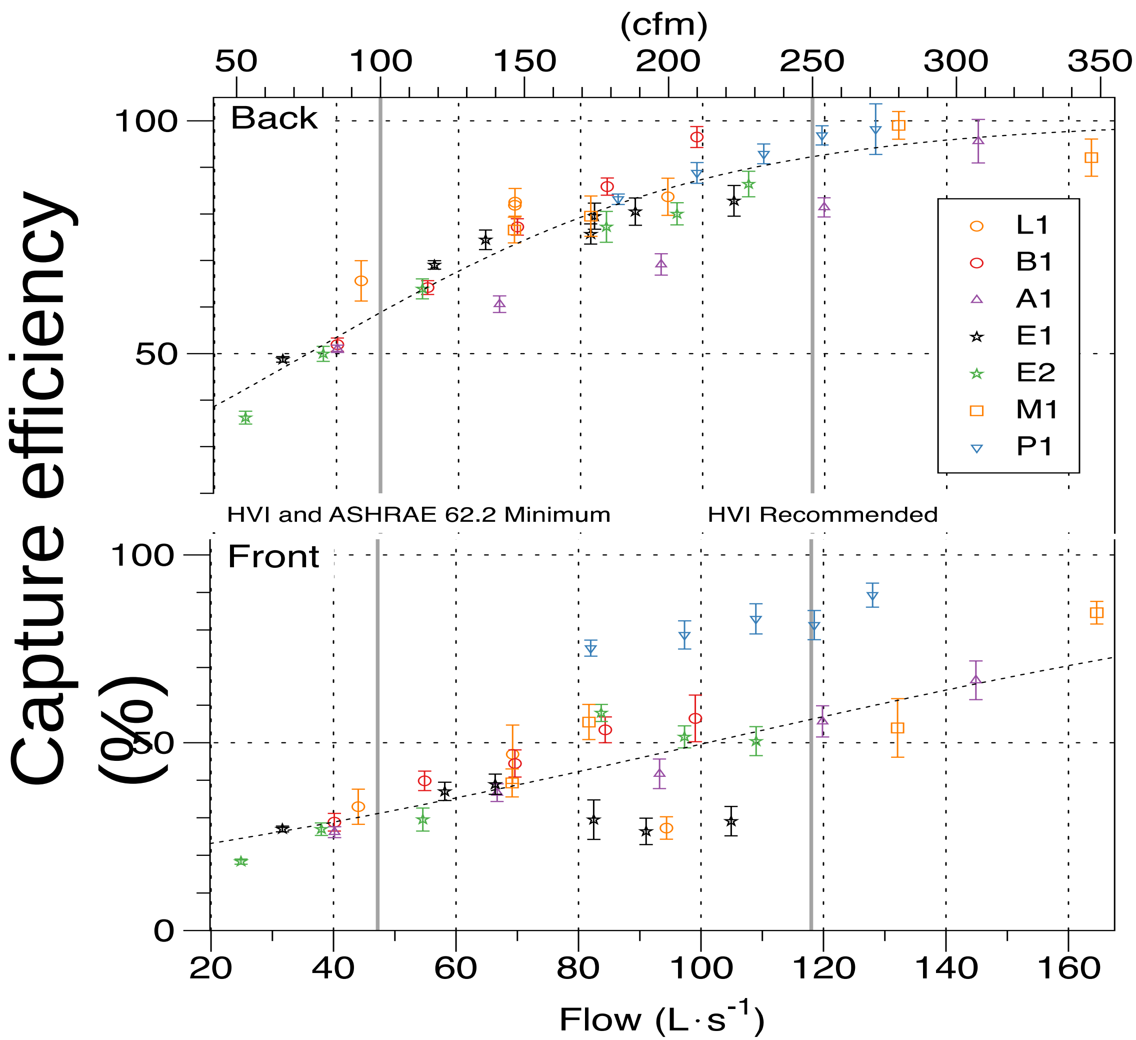
LBNL Laboratory Performance Study

- 7 devices
  - L1: Low-cost hood, $40
  - B1: Basic, quiet hood, $150
  - A1: 62.2-compliant, $250
  - E1: Energy Star, $300
  - E2: Energy Star, $350
  - M1: Microwave, $350
  - P1: Performance, $650

Measurements:

- Fan curves (flow vs. P)
- Capture Efficiency
  - Front burners
  - Back burners
  - Oven
- Fan Power

Capture Efficiency—Lab Results



- Reference Flows:
  - 100 cfm
    - 60% back
    - 30% oven, front
  - 200 cfm
    - ~80% back
    - 40-80% oven
    - 25-80% front

LBNL In-Home Performance Study

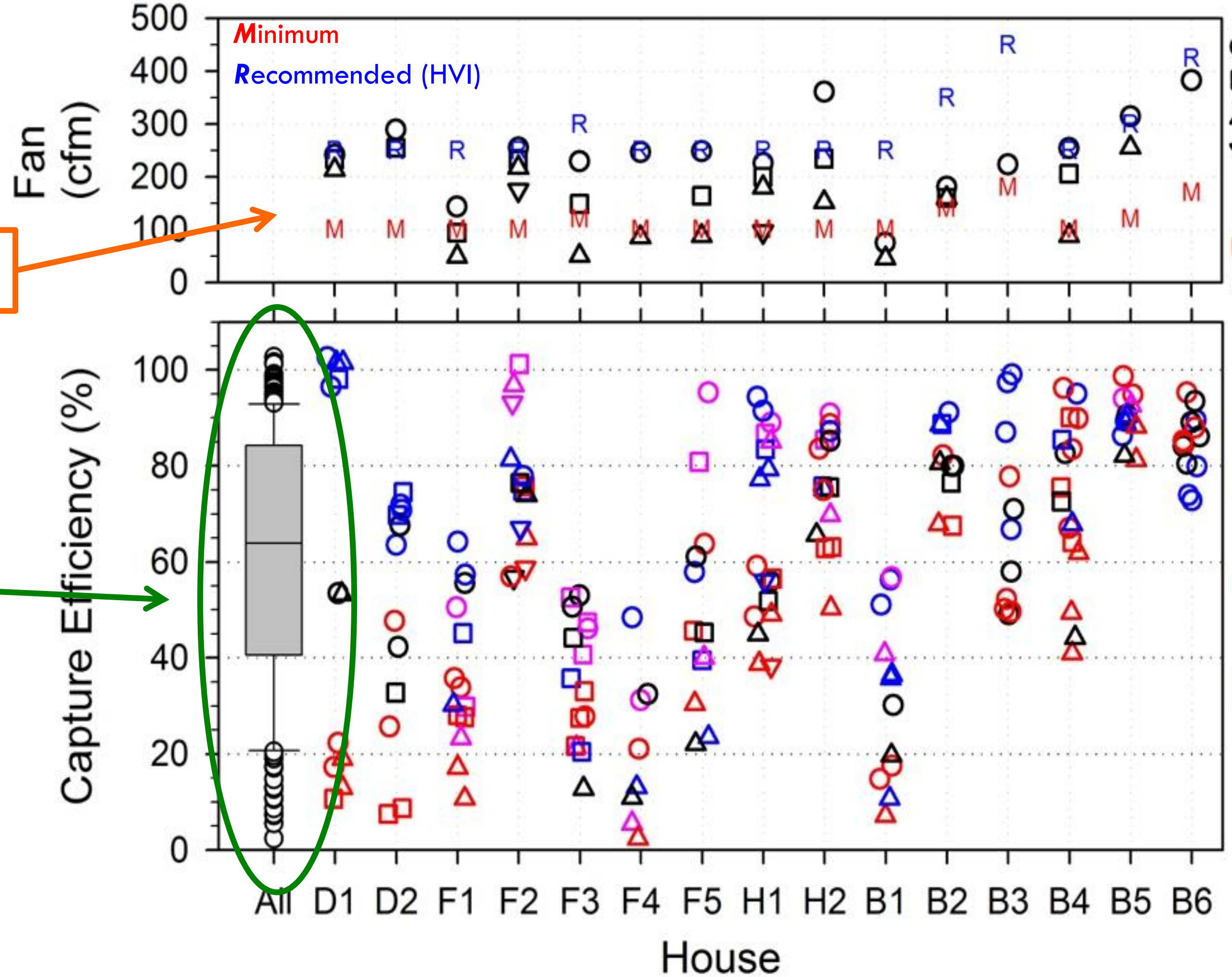
- 15 devices
- Cooktops
  - Pots with water
  - Front, back, diagonal
- Ovens
  - 425 F, door closed
  - Cool between tests




Capture Efficiency—Field Results

Installed flow < Rated flow

~65% Overall Capture Efficiency

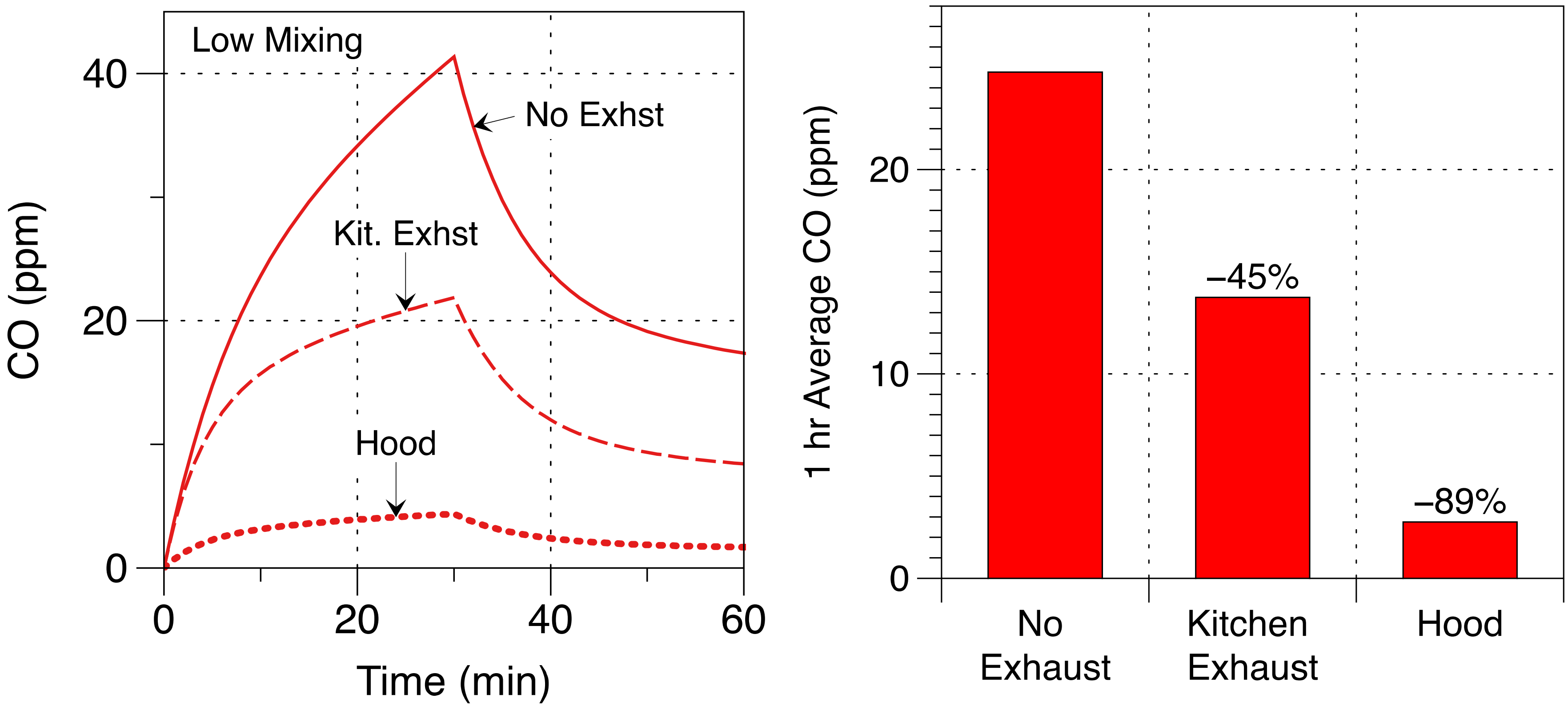


Kitchen Ventilation in Passive House Construction

- Typical kitchen ventilation set-up:
  - Recirculating range hood with charcoal filter (for odor)
  - Continuous ERV/HRV exhaust, 35 cfm requirement
- NOT generally 62.2 compliant
  - 5 ACH per kitchen volume
  - Only 35 cfm!
- May increase chronic exposure
  - Two, gas-cooking, PH-style homes in Less (2012) had 6-day NO_2 levels near or above CA outdoor standard

Are Range Hoods Really Much Better Than General Kitchen Ventilation? **YES!**

Exhaust Fan Flows = 200cfm (hood or kitchen)
Capture Efficiency = 80%



CO concentration in the **SEPARATE KITCHEN**

Kitchen Ventilation Recommendations

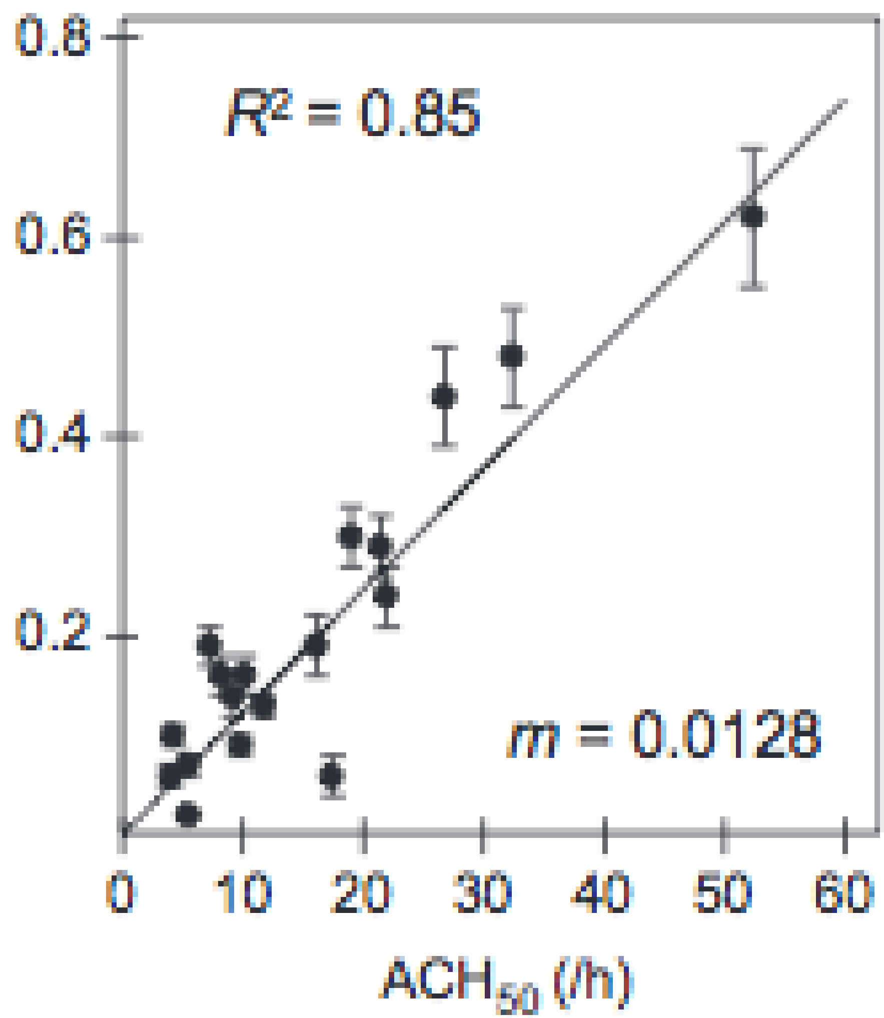
- Install range hoods vented to outside
  - Hood **covers all burners**
  - Hood is **not flat bottomed**
  - Airflow of **200 cfm**—MEASURED
  - **Quiet** operation, NOT just on low speed—HARD TO KNOW
  - **Short** duct runs with **smooth** pipe and few turns (basis of new EPA spec)
  - Look for *future* inclusion of Capture Efficiency in fan ratings
- 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?)
- Avoid microwave range hoods
- Do not use low-flow continuous ventilation in kitchen ceiling
- Occupant Education or Automation?
  - Need to get people to use their range hoods
  - Automation is available, but not the greatest

Air Cleaning—Filtration

- Sources of Indoor Particles:
  - Outdoor sources (agriculture, diesel exhaust)
    - Removal by envelope or filters on air inlets
  - Indoor sources (cooking, activity)
    - Dilution or filters

An Airtight Envelope Filters **Outdoor** Particles

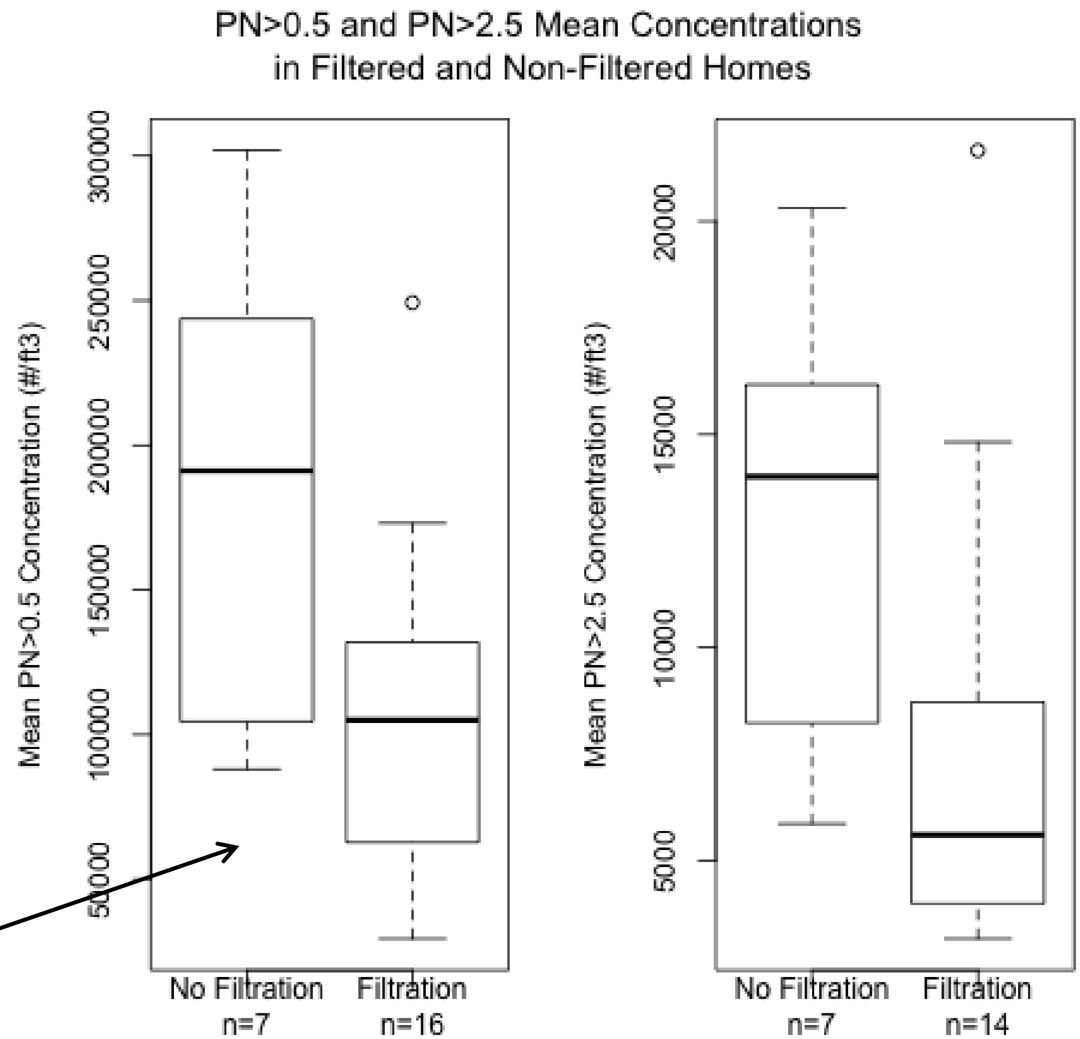
- Field testing of particle penetration of submicron particles (Stephens & Siegel, 2012)
- Tight homes are good particle filters for ***Exhaust*** ventilation:
  - 1.5 ACH_{50} = 2% penetration = MERV16
- BUT particles passing through HRV/ERV or supply vent are NOT filtered by envelope!



Filtration in High Performance CA Homes (Less, 2012)

Filters in Central Forced Air System and ventilation systems.

Unfiltered homes typically hydronically or point-source heated



Six-day averages

Filtration Recommendations

- Consider the quality of your outdoor, “fresh” air
  - Highways and other major roadways
  - Industry
  - Agriculture
- **Airtight envelope provides filtration** and removal of infiltrating particles
- Supply ventilation should be:
  - Minimum **MERV 13** to remove >90% 1-3 micron particles
  - **MERV 14** and up to remove sub-micron particles
- Central forced air system for indoor sources
  - At least MERV 13 preferably MERV14 or greater
  - Operate central systems continuously on low speed (ECM motor)
  - Consider stand-alone filtration in non-forced air homes
- Gas filtration possible—but little field data to give specific recommendations

Commissioning—Why It's So Important in Airtight Homes

- If IAQ system fails, there is no natural infiltration backup
- Unfortunately, faults are **common** in all system types

TSI/Alnor Balometer® Flow Capture Hood ABT701 (ABT701)

Observator DIFF Automatic Air Volume Flow Meter (DIFF)

TSI/Alnor Balometer® Flow Capture Hood EBT721 (EBT721)

Energy Conservatory - Exhaust Fan Flow Meter (TECEFM)

The Energy Conservatory – FlowBlaster™ (TECFB)

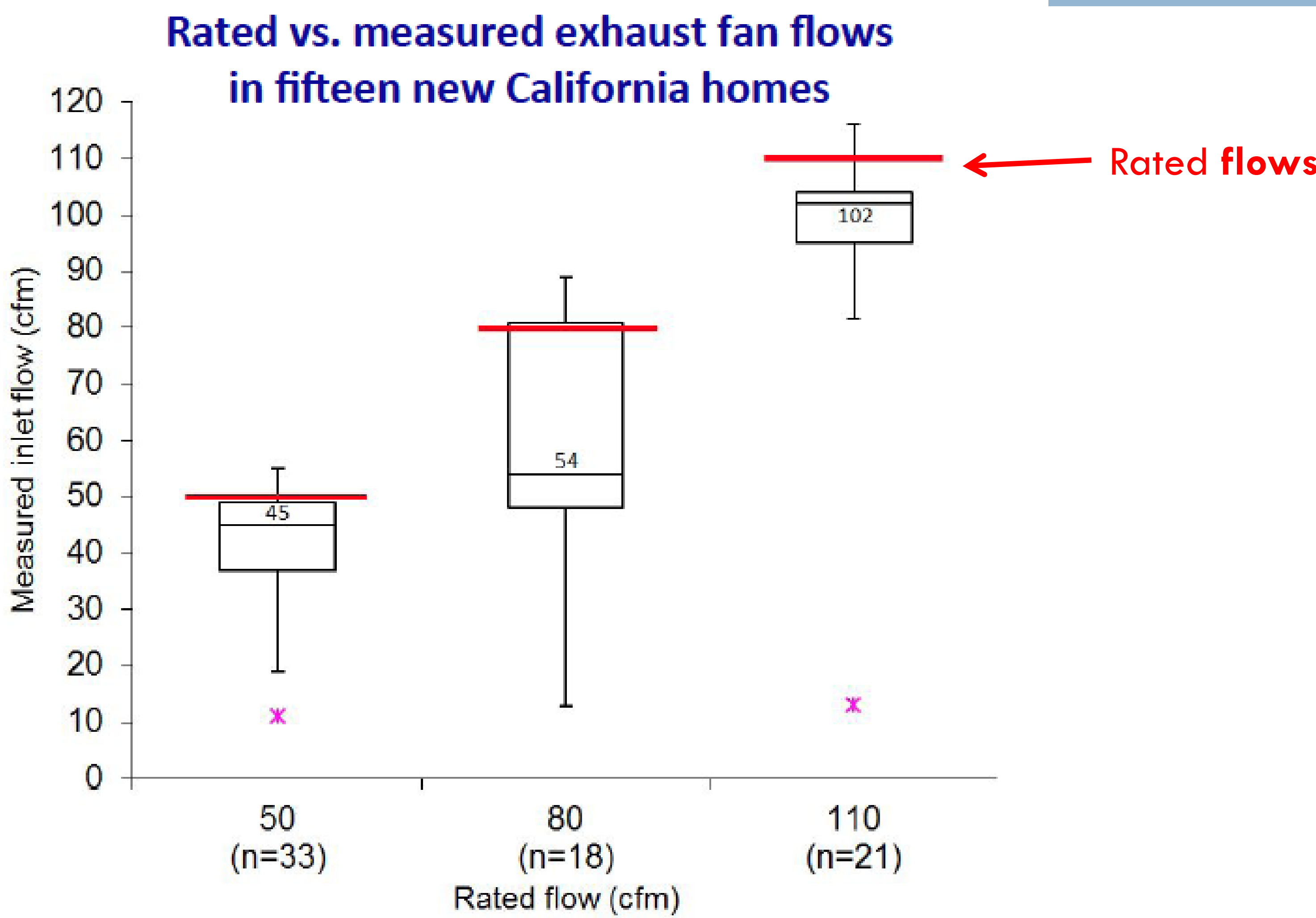
testo 417 Vane Anemometer (testo 417)

Figure 1: The six commercially available flow hoods evaluated for this study

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

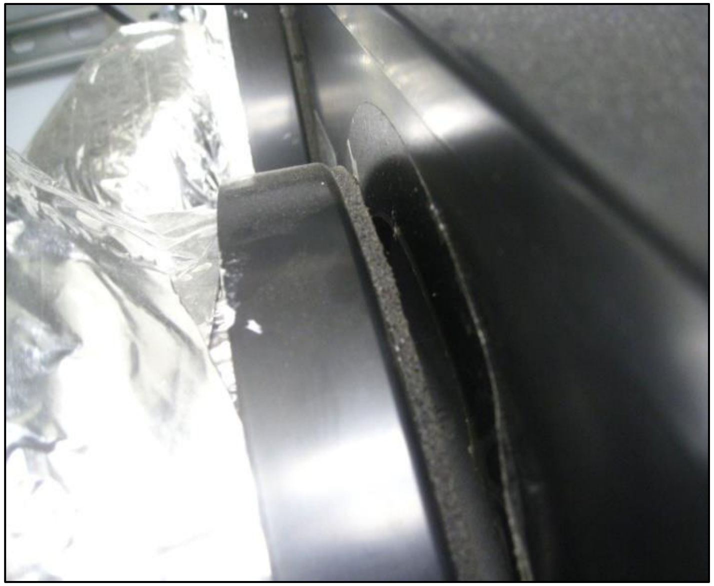
Ventilation Measurements in 15 New CA Homes, Comparison to ASHRAE 62.2-2007 Flow Requirements

Home ID	continuous whole building ventilation	intermittent local kitchen exhaust	continuous local kitchen exhaust	intermittent local bathroom exhaust				continuous local bathroom exhaust		
				Bath 1	Bath 2	Bath 3	Bath 4	Bath 1	Bath 2	Bath 3
FH1	P	P		F	P	P				
FH2	P	NM		F	P	P				
FH3	P	NM		F	F	P	F			
FH4	P	NM		P	P	P				
FH5	F	P		P	P	F				
FH6	P	NM						P	P	
FH7	P	NM						P	P	
FH8	P	NM		F	F	P				
FH9	P	NM		P	F	F				
FH10	P	NM		P	F	F	F			
FH11	F	NM		F	P	P				
FH12	P	P		P	P	F				
FH13	P		F					F	NM	F
FH14	P	NM		F	P	P				
FH15	P	P		P	P	P				

P – Passed, F – Failed, NM – Not Measurable

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

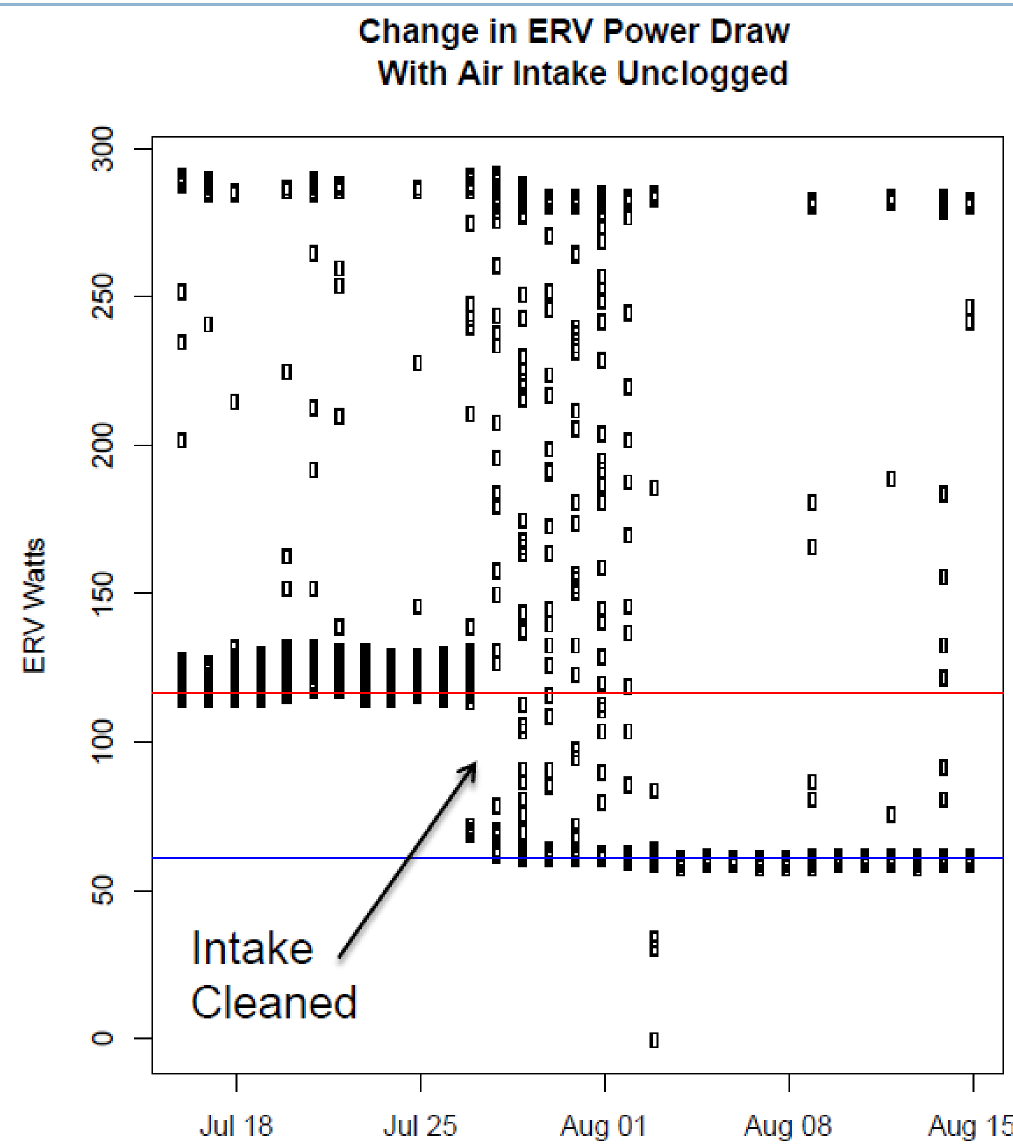
- 5 of 9 ERV/HRV found to have some substantial problem
  - Low airflows
  - Failed duct connections
  - Improperly installed duct connections (recirculating ERV)
  - Erratic control of variable speed systems
  - Clogged fresh air intake on ERV
  - Not operating continuously, inactive for months



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

Clogging Ventilation Inlets and Continuous Commissioning/Maintenance

- Clogged ERV inlet in Passive House Retrofit (Less, Fisher, & Walker, 2012)
- Average power on low:
  - Clogged = 117 watts
  - Cleaned = 61 watts
  - **Gives a clear fault detection signal (ECM motor)**
- Once cleaned, the same thing began to happen again…**ongoing maintenance need**



Difficult to Commission Systems, I

Figure 12: None of the flow hoods would fit into the space adjacent to this bathroom ERV inlet; it went unmeasured

Figure 13: Only the smallest flow hoods could measure this ERV outlet set between floor joists

Figure 14: The refrigerator has to be pulled out to measure this kitchen ERV inlet, and even then, the uneven surface prevented measurement with most of the flow hoods

Figure 15: The ledge and uneven surface adjacent to this ERV outlet terminal made its flow difficult to measure

Difficult to Commission Systems, II

Figure 16: We located FH6's range hood outlet (circled) on its roof, but for safety reasons did not try to measure its flow

Figure 17: The dimensions and irregular surface of this typical microwave-integrated range hood in FH2 makes inlet flow measurements difficult

Commissioning Recommendations

- Carefully commission ALL ventilation equipment
  - Particularly important in airtight homes, with minimal natural air exchange
- Design systems with maintenance and commissioning in mind
  - Easy access to inlets and outlets
    - Particularly important for ERV/HRV, range hoods, & CFIS
  - More complex systems require much greater commissioning time and effort ($$$)

Occupant Education—Link Between Design and Operation

- Occupants do not understand IAQ risks in airtight homes
  - Ventilation system operation
  - Maintenance schedule or maintenance contract
  - Use of kitchen ventilation
- Occupants DO NOT know when systems are not operating properly

Kitchen Exhaust Use in Cal. IAQ study:

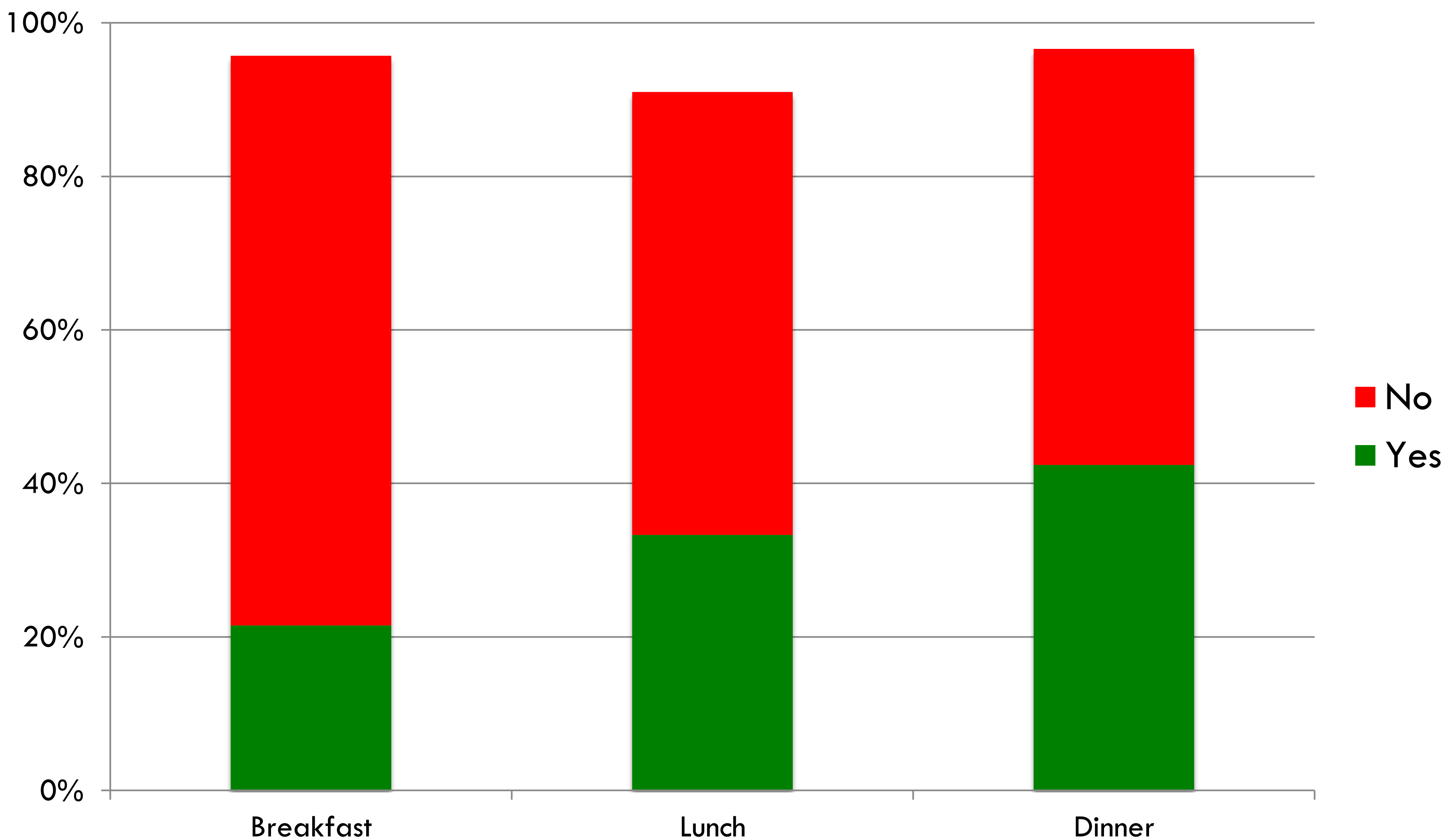
63% of participants in IAQ study either didn't use or didn't have kitchen exhaust

Self-reported usage	Number	Percent
Most times (>75%) when cooktop or oven used	44	13%
Most times when cooktop used, but not oven	39	11%
About half the time	45	13%
Infrequently, only when needed	113	32%
Never	35	10%
No exhaust fan	73	21%

Mullen et al. (2012) LBNL-5970E

Web-Based Cooking Survey: Range Hood Used When Cooking in Previous 24 Hr?

Klug et al. (2011) LBNL-5028E



Likelihood of range hood use increased with amount of cooking.

Why Are Kitchen Exhaust Fans Not Used?

Reasons for NOT using exhaust system	Number	% of n=193 using <50% of time
Don't think about it	31	16%
Not needed	92	48%
Too noisy	40	21%
Wastes energy	3	<2%
Doesn't work	19	10%
Open window instead	17	9%
Other reasons	7	<4%
No reason selected or don't know	23	12%

Mullen et al. (2012) LBNL-5970E

Occupants and Maintenance in Canadian HRVs—Education Only Goes So Far

- Canadian HRV (Hill, 1998) study found occupants were “educated” about their system
- **BUT** less than half comprehended:
  - Maintenance needs
  - Requirement for central fan operation with HRV
  - Location of components requiring maintenance
    - Problem was worst in tract homes, where occupants were given little or no explanation or training

Education Recommendations

- BETTER than education may be:
  - **Simple, robust systems**
  - **Requiring little to no maintenance**
  - **Have built-in automated fault detection**
  - **Service contracts for ventilation equipment**
- Provide occupants with owner's manuals, as required in LEED for Homes, EPA Indoor airPLUS, etc.
  - Including testing and commissioning results + ALL product literature, organized clearly, etc.
- Educate yourselves, so that you can better inform occupants of risks, system interactions, and life-style changes (candle/incense use, toxic cleaners, etc.)
  - Range hood use is a big opportunity

Overall IAQ Recommendations

- Use low-emitting materials
- Encourage occupants to consider safety of consumer products
- ASHRAE 62.2 is a minimum
- Pick good range hoods (maybe automatic)
- Commission everything
- Use at least MERV 13 filters on central forced air and supply air ventilation
- For health:
  - Focus on particles, formaldehyde, cooking and other unvented combustion
- Talk to occupants/owners –
  - Main Hazards: combustion, cleaning products, formaldehyde

Thanks You! Further Questions?

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- Residential Building Systems Group, LBNL:
  - http://homes.lbl.gov/

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/

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