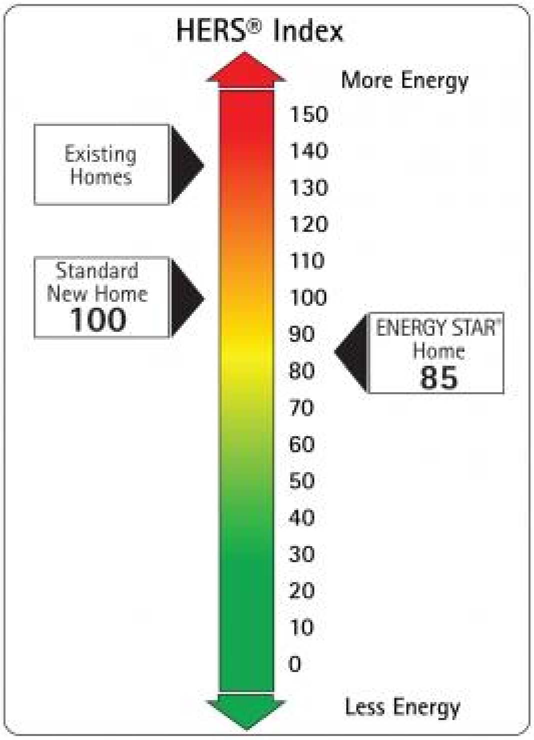
Attachments to Additional Proposed Changes

August 12, 2014

How Is a Home's HERS Index Calculated?

It's time to pull back the curtain to look at the algorithms used to come up with a HERS Index score

POSTED ON JUN 10 2011 BY **MARTIN HOLLADAY, GBA ADVISOR**



It's like golf — the lower the score, the better.

Anyone involved with the Energy Star Homesprogram has probably heard of the HERSIndex, a method of scoring the energy efficiency of a new or existing home. A Web page maintained by the state of Arkansas, for example, explains that the "EPA requires a house qualifying for Energy Star to be built with best practices, tight ducts, and at least 15% more energy efficient than code as shown by a HERS Index score of 85 or less as determined by a HERS Rater."

Knowing that the HERS Index measures a home's energy efficiency is a good starting point. But it's useful to dive a little deeper, to understand how the Index is calculated and exactly what it measures.

Defining the HERS Index

The HERS (Home Energy Rating System) Index was established in 2006 by the Residential Energy Services Network (RESNET), a California-based national association of home energy raters and energy-efficiency mortgage lenders. The lower a home's HERS Index, the more efficient the home.

To calculate a home's HERS Index, a rater uses a computer program — most commonly,REM/Rate. (RESNET has also approved three other software programs for calculating the HERS Index.) After the rater has entered data about the home into the program, REM/Rate compares the home being rated to a "reference home." The reference home is an imaginary home of the same size and shape as the home being rated. In other words, the size of the reference house is not fixed; when a house is being rated, it is always compared to a reference house of the same size as the rated house.

The reference home does not have the same window area or window orientation as the home being rated; instead, the area of the windows in the reference home is assumed to be 18% of the floor area of the rated home. The windows of the reference home are assumed to be evenly distributed on the four orientations of the home.

The reference home is assumed to barely meet the 2006 International Energy Conservation Code; if the home being rated has thicker insulation or better window glazing than the imaginary reference home, those improved specifications will result in a lower (better) HERS Index.

Lighting and appliances are accounted for

The HERS Index accounts for on-site energy production, if any, and energy used for lighting and appliances. The reference home is assigned a budget for lighting and appliances; if the home being rated includes energy-efficient appliances or lighting fixtures, these items can help lower (improve) the home's HERS Index.

The imaginary reference home is assigned a HERS Index of 100. Most existing homes have a HERS Index over 100, since most existing homes fall short of the requirements of the 2006IECC. If a rated home gets a HERS index of 100, it can be expected to use the same amount of energy as a code-minimum home of the same size — a home equipped with "typical" lighting and appliances that are operated according to average American usage patterns.

If a rated home gets a score below 100, it will use less energy than a code-minimum home. A score of 0 corresponds to a net-zero-energy home.

Each 1 point decrease in the HERS Index corresponds to a 1% reduction in energy consumption compared to the imaginary HERS Reference Home. A home with a HERS Index of 70 uses 30% less energy than a code-minimum home of the same size and shape.

"The HERS Index measures the relative performance of your home with respect to a home of equal geometry that is constructed exactly as the HERS reference home is constructed, using a standard set of appliances that are operated according to a standardized set of operating assumptions," explained Philip Fairey, deputy director of the Florida Solar Energy Center. "The reference house has the characteristics of the energy envelope requirements in the IECC. But the IECC addresses only heating, cooling, and hot water, while the HERS index addresses all energy uses."

The HERS Index rewards efficiency, not conservation

The REM/Rate software assumes a certain pattern of appliance use. "A house without a dishwasher is rated as if it had a standard dishwasher," notes Fairey. "The rated home has essentially the same appliances as the reference home, unless the rated home has more appliances. The reference home has one refrigerator. If the rated home has two refrigerators, that can hurt you. The reference home has one clothes dryer and one clothes washer. But you don't get a credit for building a home without a clothes dryer. The software still assumes that a clothes dryer is there, even when one isn't. You'll just end up using less energy than the software would predict."

Although this method of defining the reference house rewards the use of electrically efficient appliances, it does not give full credit to those adopting a simpler way of life. "The HERS Index does not encourage Americans to downscale their lifestyles," says Philip Fairey. "It does not reward conservation; it rewards efficiency."

For Richard Faesy, an energy consultant for Energy Futures Group in Bristol, Vermont, the fact that the HERS Index is conservation-neutral makes him a little uneasy. "It has always rubbed me the wrong way that you could have a 10,000-square-foot 'energy efficient' home," says Faesy. "That's possible because of the way the reference home is set up — in effect, it compares the house to itself. It's an issue that we have tried to tackle in the Vermont green building standards and with LEED for Homes. The philosophy there — and it's a philosophy that came out of Vermont — is, if you have a big home you should have to work harder to achieve the green label." This philosophy is not reflected in the HERS Index.

To Faesy, conservation is not a dirty word. "As we push down towards zero-energy homes, we need to be addressing this issue," he says. "It is not only about how much are you using compared to how much you *could* use — it's also about making some choices to do without."

The HERS Index can't predict energy use

The HERS Index is a useful metric; however, it doesn't tell you how much energy a home will use. Of course, it's a good sign if a home has a low HERS Index — but just because your house has a low HERS Index doesn't mean that your energy bills will be low.

For example, if you have a very big house with a low HERS Index, all you know is that your house will use less energy than the typical very big house. But a huge HERS 70 house can still use more energy than a small HERS 100 house.

A 1997 *Home Energy* magazine article, "Home Energy Rating Systems: Actual Usage May Vary", looked at the HERS rating, a precursor to the HERS Index. Under the old (obsolete) HERS rating system, high scores indicated that a house was energy-efficient, and low scores indicated that a house used a lot of energy — the inverse of the current HERS Index scale. In spite of the fact that the current HERS Index has inverted the scale, the two scoring systems share the same fundamental approach to rating homes.

In the *Home Energy* article, author Jeff Ross Stein wrote, "As a research project for Lawrence Berkeley National Laboratory, Alan Meier and I compared home energy ratings with actual utility billing data for about 500 houses. … In general, we found that HERS can be remarkably accurate at predicting average annual energy costs for groups of homes. Predictions for individual homes were less impressive. Some individual ratings significantly overpredicted or underpredicted energy costs, especially for older homes. Furthermore, there was no clear relationship between the rating score of an individual home and actual energy cost. … Technically, rating scores only measure a house's individual potential for energy improvement; they are not designed to be used to compare different houses in the same way miles-per-gallon ratings are designed to compare cars. However, many consumers and HERS-related financing programs assume that houses with higher [better] scores will have lower energy costs. Unfortunately, houses with higher [better] scores, even when compared to houses of similar size, did not tend to use any less energy than houses with lower [worse] scores. … Occupant behavior is probably the single most significant determinant of actual energy use. HERS have the difficult task of making assumptions based on typical occupant behavior. Reality can easily diverge from these assumptions; predicted energy use or energy cost can be off by 50% or more due to occupant behavior."

According to Philip Fairey, it's unfair to criticize the HERS Index for doing a poor job of predicting energy use. After all, there's more to a home energy rating than the calculation of the HERS Index. "The HERS Index is NOT the only requirement of a Home Energy Rating," Fairey noted in a recent e-mail. "The RESNET Standards quite explicitly specify what is required to be included in a a Home Energy Rating Report, as follows: '303.3.2.3: The estimated annual purchased energy consumption for space heating, space cooling, domestic hot water, and all other energy use, and the total of these four estimates; 303.3.2.4: The estimated annual energy cost for space heating, space cooling, domestic hot water, and all other energy use, and the total of these four estimates.' So, you see, a Home Energy Rating requires not only an estimate of the energy use of the home but also and estimate of the cost of that energy use."

The HERS Index doesn't take occupant behavior into account

Researchers who study residential energy use have long known that occupant behavior explains much of the variation in energy use from one house to another.

Speaking at the March 2011 NESEA conference in Boston, building scientist John Straube noted, “Energy use variation between the lowest and highest energy users — the bottom 10% of users and the top 10% — varies by a factor of 2. A study of 17 identical homes in Oklahoma showed a factor of 3 variation in electricity used for purposes other than space heating or cooling. The high users consumed 3 times as much electricity as the low users. Even in Germany, where we expect everyone to always follow the rules, the ratio of domestic hot water use varies by a factor of 4 from the low-end users to the high-end users. That’s why REM/Rate and HERS Index numbers are just predictions.”

Your actual energy use may vary.

Limitations of the HERS Index

Many energy raters have noted that it’s easier for a large house than a small house to get a low HERS Index.

Duncan Prahl, an energy researcher at IBACOS in Pittsburgh, described the problem in a technical paper, “Analysis of Energy Consumption, Rating Score, and House Size.” Prahl wrote, “One artifact of this method [HERS] is that as houses of a given occupancy get smaller, the energy consumption for space heating and cooling is lowered, and domestic water heating becomes a larger relative component in the final rating score. This is due in part to the fact that as houses get smaller, the ratio of envelope area to floor area increases. This has the tendency to make it more difficult for smaller homes to achieve the same score as a larger home, provided both houses have the same number of bedrooms.”

According to a Boston architect and building envelope consultant who posts comments on the JLC Web forum using the name Ted S., “As the house gets bigger, the HERS rating goes down. I get failing small houses in my state's energy efficiency program all the time, but the bigger ones pass with the same insulation, windows, mechanicals, etc. I'm not supposed to promote that little fact.”

Another criticism of the HERS Index concerns the way that REM/Rate conjures up the reference house. Posting on the Q&A page at the GBA Web site, architect Jesse Thompson wrote, “If we design a house that has 18 bay windows and dormers (chock full of difficult-to-air-seal, difficult-to-thermally-break and difficult-to-insulate construction transitions), that house then only gets compared to a better-built version of that same 18-bay-window-and-dormer house, not a simpler, less-surface-area-to-volume, easier-to-build house that will use less energy by design. So, two buildings with HERS 50 can end up with vastly different energy use, size, constructability, and final energy use. They won’t, in the end, be comparable to each other, even though that is the goal of the tool.”

Other energy rating systems

While the HERS Index attempts to provide a score to describe the energy-use characteristics of a home’s envelope, appliances, and lighting fixtures — an approach sometimes called an “asset value” scoring system — other home-scoring systems use historical energy bills to get a handle on a home’s energy consumption — an approach called an “operational value” scoring system. One example of an operational value scoring system is the EPA Home Energy Yardstick.

In an article discussing the merits of the two different scoring approaches, Philip Fairey and David Goldstein explain that the EPA Home Energy Yardstick is “a web-based statistical analysis tool that compares the reported energy use of a given home against data provided in the 2001 Residential Energy Consumption Survey (RECS) to determine the home’s percentile energy use compared against the reported RECS data, adjusted for climate, number of occupants and house size. … The Yardstick and the HERS Index have completely different (and complementary) uses and purposes. Neither one is necessarily correct or incorrect – they simply measure different things. The Yardstick uses utility bills to characterize the energy use of the home *as it is used by its occupants*. The HERS Index provides *a measure of the relative energy use of the home based on its physical characteristics and a standardized set of operating characteristics*. … An energy rating label based on the previous occupants' energy use habits would say little to nothing about the physical energy attributes of the home and would make it virtually impossible to compare the physical energy attributes of one home against another."

Energy consultant Allison Bailes has reached a similar conclusion to Fairey and Goldstein. In a comment posted on the Q&A page of the GBA site, Bailes wrote, "The HERS protocol looks at the physical parameters of the house and mostly disregards occupant behavior. It uses a set of standard operating conditions so that one house can be compared accurately to another. … The Home Energy Yardstick proposed by the EPA does the opposite. ... It's great information to have, but not the same as the HERS rating at all. The two are complementary systems and would go well together. It's not an either-or situation."

Recent changes to the HERS Index

Because new data on residential energy use for appliances and electricity have become available, RESNET has voted to change some elements of the algorithms used to calculate the HERS Index. "There's an amendment to the RESNET standards that has recently been adopted by the board of directors," Fairey explained. "It changes a number of things in the current standards, which change the results some. Larger homes don't have as big of an energy budget for appliances and miscellaneous energy use as they used to, but reasonable-sized homes — 1,600-square-foot homes and 1,800-square-foot homes — are about where they were before."

The issue of whether the HERS Index should be tweaked and recalibrated as energy use patterns change is contentious. "The HERS standards assume that 10% of a home's lighting energy use is from fluorescent lighting — tubes, CFLs, whatever," Fairey noted. "If incandescents become illegal, I don't know where RESNET would go. These are difficult balancing acts that RESNET has to concern itself with. If you change the basic lighting budget now, within a few minutes, a builder will call you up and ask, 'Why is my house design no longer compliant with Energy Star?' or 'This house used to get a HERS 60, and now I only get 65.' "

According to Fairey, it makes sense to keep changes to the HERS Index to an absolute minimum. "RESNET has not seen a need to increase the efficiency of its reference case," said Fairey. "If anyone wants to raise the bar, it is very easy to do: just aim for a lower HERS Index."

2006 IECC ANNUAL ENERGY COST COMPLIANCE

Building Name:	Sinclair-2012	Date:	February 15, 2012
Owner's Name:	2012 92% & 3 ACH	Builder's Name:	Winchester Homes, Inc.
Property	None	Weather Site:	Baltimore, MD
Address:	Bethesda, , MD 20817	File Name:	Sinclair 2012 with 92% & 3 ACH.blg

Annual Energy Cost ($)

	2006 IECC	As Designed
Heating:	966	587
Cooling:	264	222
Water Heating:	203	206
SubTotal - Used to Determine Compliance:	**1433**	**1016**
Lights & Appliances:	1601	1562
Photovoltaics:	-0	-0
Service Charge:	120	120
Total:	**3154**	**2697** *

Mandatory Requirements:

Minimum Duct Insulation (Design must be equal or higher):	8.0	8.0
Window U-Factor Check (Section 402.6)		
Window U-Factor (Design must be equal or lower):	0.480	0.330

This home MEETS the annual energy cost requirements and verifications of Section 404 of the 2006 International Energy Conservation Code based on a climate zone of 4A. In fact, this home surpasses the requirements by 29.1%.

Name: Randy Melvin Signature:

Organization: Winchester Homes, Inc. Date: February 15, 2012

* Design energy cost is based on the following systems:
- Water Heating: Conventional, Gas, 0.57 EF.
- Cooling: Air conditioner, 48.0 kBtuh, 13.0 SEER.
- Heating: Fuel-fired air distribution, 80.0 kBtuh, 92.0 AFUE.
- Window-to-Floor Area Ratio: 0.07
- Code default: Htg: 0.00036 Clg: 0.00036 SLA

In accordance with IECC, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy cost. Furthermore, the standard reference design HVAC system efficiencies are set to the "prevailing federal minimum standards" as of January, 2009. These standards are subject to change, and software updates should be obtained periodically to ensure the compliance calculations reflect current federal minimum standards.

REM/Design - Residential Energy Analysis Software v12.96

This information does not constitute any warranty of energy cost or savings.

Home Energy Rating Certificate

13513 Moonlight Trail Drive

Silver Spring, MD 20906

5 Stars Plus
Confirmed Rating

Uniform Energy Rating System — **Energy Efficient**

1 Star	1 Star Plus	2 Stars	2 Stars Plus	3 Stars	3 Stars Plus	4 Stars	4 Stars Plus	5 Stars	5 Stars Plus
500-401	400-301	300-251	250-201	200-151	150-101	100-91	90-86	85-71	70 or Less

HERS Index: **55** **Efficient Home Comparison:** **45% Better**

General Information

Conditioned Area: 4569 sq. ft.
Conditioned Volume: 39821 cubic ft.
Bedrooms: 4
HouseType: Single-family detached
Foundation: Conditioned basement

Mechanical Systems Features

Heating: Fuel-fired air distribution, Natural gas, 92.5 AFUE.
Cooling: Air conditioner, Electric, 13.0 SEER.
Water Heating: Conventional, Natural gas, 0.82 EF, 50.0 Gal.
Duct Leakage to Outside: 108.00 CFM.
Ventilation System: None
Programmable Thermostat: Heating: Yes Cooling: Yes

Building Shell Features

Ceiling Flat: R-38
Vaulted Ceiling: NA
Above Grade Walls: R-23, R-15
Foundation Walls: R-13.0
Slab: R-0.0 Edge, R-0.0 Under
Exposed Floor: NA
Window Type: Dbl/LoE/Arg - Vinyl0*******
Infiltration:
Rate: Htg: 1327 Clg: 1327 CFM50
Method: Blower door test

Lights and Appliance Features

Percent Fluorescent Pin-Based: 0.00
Percent Fluorescent CFL: 75.00
Refrigerator (kWh/yr): 459.00
Dishwasher Energy Factor: 0.78
Clothes Dryer Fuel: Electric
Range/Oven Fuel: Natural gas
Ceiling Fan (cfm/Watt): 0.00

The Home Energy Rating Standard Disclosure for this home is available from the rating provider.

REM/Rate - Residential Energy Analysis and Rating Software v12.96

This information does not constitute any warranty of energy cost or savings.

Rating Number: **PR H001**
Certified Energy Rater: Scott Atkinson
Rating Date: June 1, 2011
Rating Ordered For:

Estimated Annual Energy Cost

Confirmed Rating

Use	MMBtu	Cost	Percent
Heating	70.4	$381	23%
Cooling	6.9	$162	10%
Hot Water	15.0	$75	5%
Lights/Appliances	41.5	$892	55%
Photovoltaics	-0.0	$-0	-0%
Service Charges		$120	7%
Total		**$1631**	**100%**

This home meets or exceeds the minimum criteria for all of the following:

2004 International Energy Conservation Code
2006 International Energy Conservation Code
2009 International Energy Conservation Code

HERS Provider
PEG
11130 Fairfax Blvd. Suite 206
Fairfax, Virginia
1-703-934-2777
1-703-934-2775

Certified Energy Rater

4.2.2.4. For non-electric warm furnaces and non-electric boilers, the values in Table 4.2.2.4(1) shall be used for Electric Auxiliary Energy (EAE) in the Reference Home.

Table 4.2.2.4(1) Electric Auxiliary Energy for Fossil Fuel Heating Systems

System Type	Eae
Oil boiler	330
Gas boiler	170
Oil furnace	439 + 5.5*Capacity (kBtu/h)
Gas furnace	149 + 10.3*Capacity (kBtu/h)

4.2.2.5. Lighting, Appliances and Miscellaneous Electric Loads (MELs)

4.2.2.5.1. HERS Reference Home. Lighting, appliance and miscellaneous electric loads in the HERS Reference Home shall be determined in accordance with the values provided in Table 4.2.2.5(1) and Table 4.2.2.5(2), as appropriate, and Equation 4.2-1:

kWh (or therms) per year = a + b*CFA + c*Nbr **(Eq 4.2-1)**

where:

'a', 'b', and 'c' are values provided in Table 4.2.2.5(1) and Table 4.2.2.5(2)
CFA = Conditioned Floor Area
Nbr = number of Bedrooms

4.2.2.5.1.1. Electric Reference Homes. Where the Rated Home has electric appliances, the HERS Reference Home lighting, appliance and miscellaneous loads shall be determined in accordance with the values given in Table 4.2.2.5(1).

Table 4.2.2.5(1) Lighting, Appliance and Miscellaneous Electric Loads in electric HERS Reference Homes

End Use Component[a]	Units	Equation Coefficients		
		a	b	c
Residual MELs	kWh/y		0.91	
Interior lighting	kWh/y	455	0.80	
Exterior lighting	kWh/y	100	0.05	
Refrigerator	kWh/y	637		18
Televisions	kWh/y	413		69
Range/Oven	kWh/y	331		39
Clothes Dryer	kWh/y	524		149
Dish Washer	kWh y	78		31
Clothes Washer	kWh/y	38		10

4.2.2.5.1.2. Reference Homes with Natural Gas Appliances. Where the Rated Home is equipped with natural gas cooking or clothes drying appliances, the

Reference Home cooking and clothes drying loads defined above in Table 4.2.2.5(1) shall be replaced by the natural gas and electric appliance loads provided below in Table 4.2.2.5(2), as applicable.

Table 4.2.2.5(2) Natural Gas Appliance Loads for HERS Reference Homes with gas appliances

End Use Component[a]	Units	Equation Coefficients		
		a	b	c
Range/Oven	Therms/y	22.6		2.7
Range/Oven	kWh/y	22.6		2.7
Clothes Dryer	Therms/y	18.8		5.3
Clothes Dryer	kWh/y	41		11.7

Notes:
(a) Both the natural gas and the electric components shall be included in determining the HERS Reference Home annual energy use for the above appliances.

4.2.2.5.1.3. Garage Lighting. Where the Rated Home includes an enclosed garage, 100 kWh/y shall be added to the energy use of the Reference Home to account for garage lighting.

4.2.2.5.1.4. Ceiling Fans. Where ceiling fans are included in the Rated Home they shall also be included in the Reference Home in accordance with the provisions of Section 4.2.2.5.2.11.

4.2.2.5.2. HERS Rated Homes. The lighting, appliance and miscellaneous electric loads in the HERS Rated Home shall be determined in accordance with Sections 4.2.2.5.2.1 through 4.2.2.5.2.12.

4.2.2.5.2.1. Residual MELs. Residual miscellaneous annual electric energy use in the Rated Home shall be the same as in the HERS Reference Home and shall be calculated as 0.91*CFA.

4.2.2.5.2.2. Interior Lighting. Interior lighting annual energy use in the Rated home shall be determined in accordance with Equation 4.2-2:

$$\mathbf{kWh/y = 0.8*[(4 - 3*qFF_{IL})/3.7]*(455 + 0.8*CFA) + 0.2*(455 + 0.8*CFA)} \quad \textbf{(Eq 4.2-2)}$$

where:

CFA = Conditioned Floor Area

qFF_{IL} = the ratio of the interior Qualifying Light Fixtures to all interior light fixtures in Qualifying Light Fixture Locations.

CE61 – 13

Table C301.1, Table R301.1

Proponent: Jeremiah Williams, U.S. Department of Energy (jeremiah.williams@ee.doe.gov)

THIS IS A 2 PART CODE CHANGE PROPOSAL. PART I WILL BE HEARD BY THE COMMERCIAL ENERGY CONSERVATION CODE DEVELOPMENT COMMITTEE AND PART II WILL BE HEARD BY THE RESIDENTIAL ENERGY CONSERVATION CODE DEVELOPMENT COMMITTEE.

PART I – IECC-COMMERCIAL PROVISIONS

Revise as follows:

TABLE C301.1
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

COLORADO
5B Adams
6B Alamosa
5B Arapahoe
6B Archuleta
4B Baca
5B Bent
5B Boulder
<u>5B Broomfield</u>
6B Chaffee

(Portions of Table not shown remain unchanged)

PART II – IECC-RESIDENTIAL PROVISIONS

Revise as follows:

TABLE R301.1
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

COLORADO
5B Adams
6B Alamosa
5B Arapahoe
6B Archuleta
4B Baca
5B Bent
5B Boulder
<u>5B Broomfield</u>
6B Chaffee

(Portions of Table not shown remain unchanged)

Reason: Broomfield County is a consolidated city-county and a suburb of Denver. Constituted on November 15, 2001, it was apparently missing from the county database(s) used to establish the IECC's county-zone mappings. See http://en.wikipedia.org/wiki/Broomfield, Colorado.

Cost Impact: The code change proposal will not increase the cost of construction.

CE62 – 13

Figure C301.1, Table C301.1, Figure R301.1 (IRC Figure N1101.10), Table R301.1 (IRC Table N1101.10)

Proponent: Shirley Ellis, Energy Systems Laboratory, Texas A&M Engineering Experiment Station, Texas A&M University System (shirleyellis@tamu.edu)

THIS IS A 2 PART CODE CHANGE PROPOSAL. PART I WILL BE HEARD BY THE COMMERCIAL ENERGY CONSERVATION CODE DEVELOPMENT COMMITTEE AND PART II WILL BE HEARD BY THE RESIDENTIAL ENERGY CONSERVATION CODE DEVELOPMENT COMMITTEE.

PART I – IECC-COMMERCIAL PROVISIONS

Revise as follows: End the Warm-Humid white line at the line separating the Dry (B) and Moist (A) moisture zones.

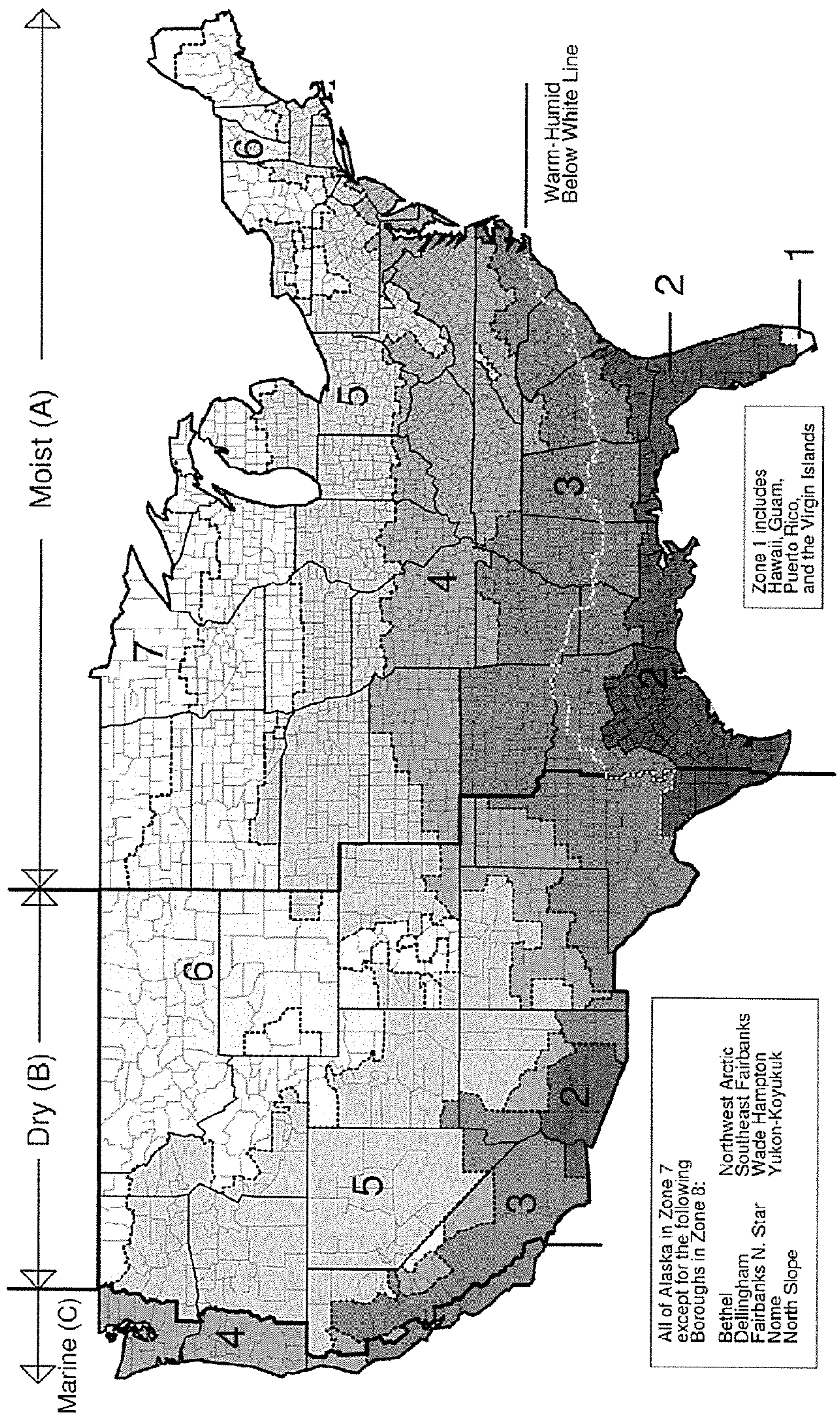

Marine (C)
Dry (B)
Moist (A)
Warm-Humid
Below White Line
Zone 1 includes
Hawaii, Guam,
Puerto Rico,
and the Virgin Islands
All of Alaska in Zone 7
except for the following
Boroughs in Zone 8:
Bethel
Dellingham
Fairbanks N. Star
Nome
North Slope
Northwest Arctic
Southeast Fairbanks
Wade Hampton
Yukon-Koyukuk

FIGURE C301.1
CLIMATE ZONES

Revise as follows: Remove the asterisk (*) from the following Counties, thereby removing the warm-humid location designation.

TABLE C301.1
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

TEXAS

Bandera*
Dimmit*
Edwards*
Frio*
Kinney*
La Salle*
Maverick*
Medina*
Real*
Uvalde*
Val Verde*
Webb*
Zapata*
Zavala*

PART II – IECC-RESIDENTIAL PROVISIONS

Revise as follows: End the Warm-Humid white line at the line separating the Dry (B) and Moist (A) moisture zones.

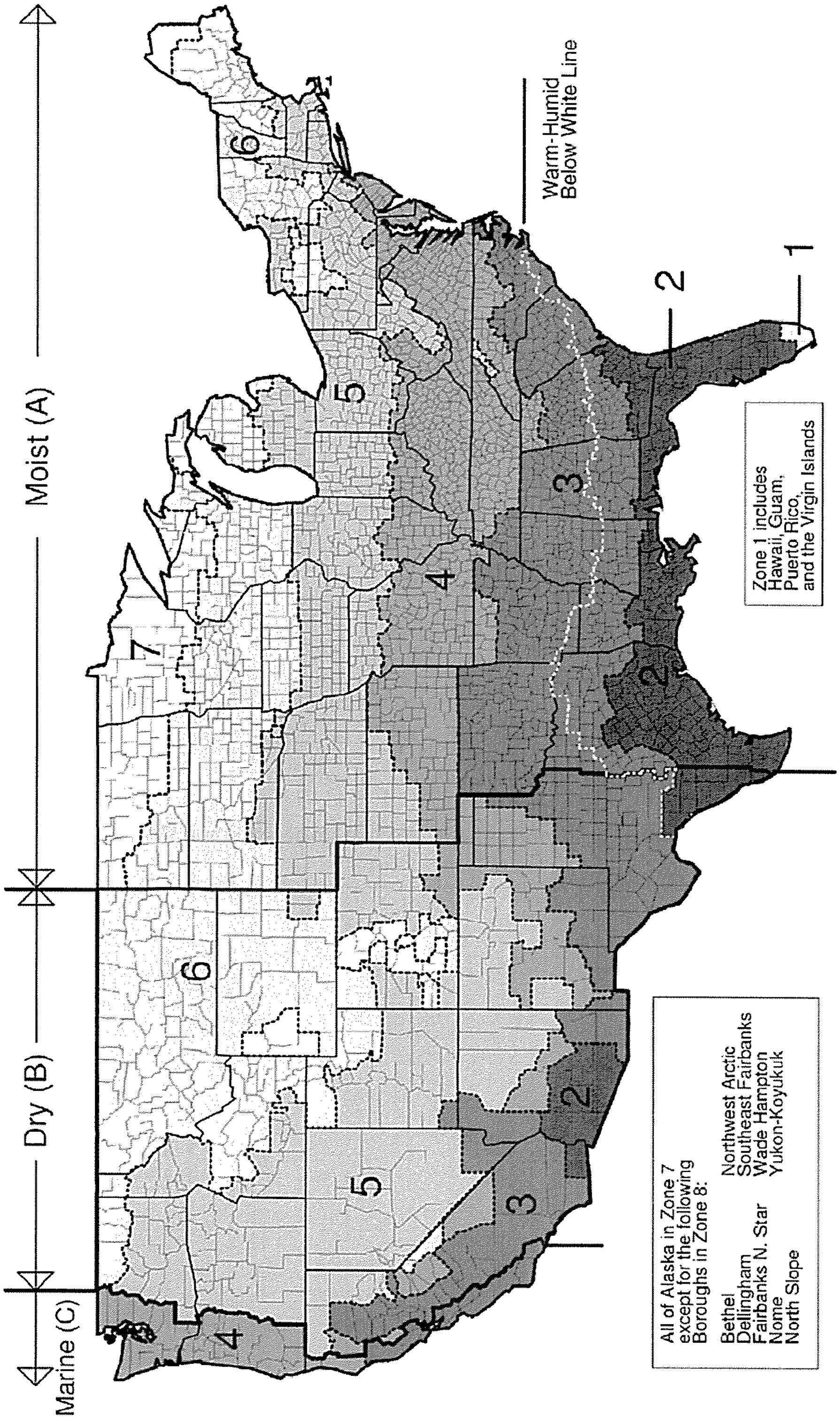


FIGURE R301.1 (N1101.10)
CLIMATE ZONES

Revise as follows: Remove the asterisk (*) from the following Counties, thereby removing the warm-humid location designation.

TABLE R301.1 (N1101.10)
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

TEXAS

Bandera*
Dimmit*
Edwards*
Frio*
Kinney*
La Salle*
Maverick*
Medina*
Real*
Uvalde*
Val Verde*
Webb*
Zapata*
Zavala*

Reason: These 14 counties are in the Dry (B) moisture zone and therefore do not need to meet the requirements for Warm-Humid locations. This is based on the following studies *Calculation of Precipitation Data and Climate Zones for ASHRAE Standard 169, Prepared by: Sonia Zhang and Didier Thevenard* and *Numerical Logics Inc. and Steve Cornick National Research Council of Canada.* ASHRAE Std 169 is also working on revisions to these Figures and Tables based on the above studies.

Cost Impact: The code change proposal will not increase the cost of construction.

CE62-13
PART I – IECC-COMMERCIAL PROVISIONS

Public Hearing:	Committee:	AS	AM	D
	Assembly:	ASF	AMF	DF

PART II – IECC-RESIDENTIAL PROVISIONS

Public Hearing:	Committee:	AS	AM	D
	Assembly:	ASF	AMF	DF

C301.1-EC-ELLIS.doc

Taylor, Ryan - 902

INDOOR AIR QUALITY IN HIGH PERFORMANCE HOMES

By: Brennan Less & Iain Walker, LBNL Residential Building Systems

2014 RESNET Building Performance Conference, 02/24-26

California Energy Commission

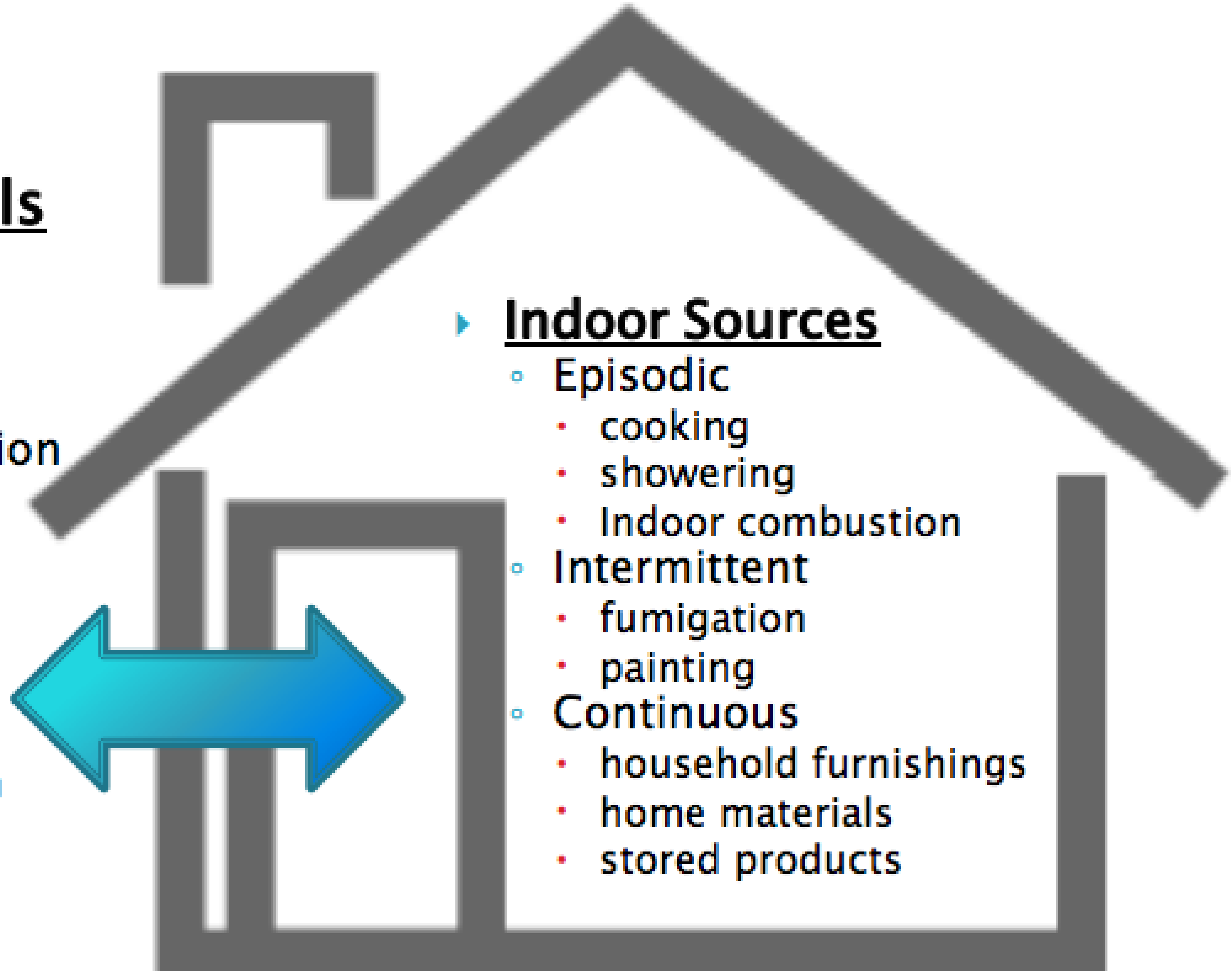
Today's Outline

- 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?

- **Outdoor Pollutant levels**

- **Air flow**
  - Natural infiltration
    - weather
    - ELA
    - windows
  - Mechanical Ventilation
    - task ventilation
    - whole house ventilation



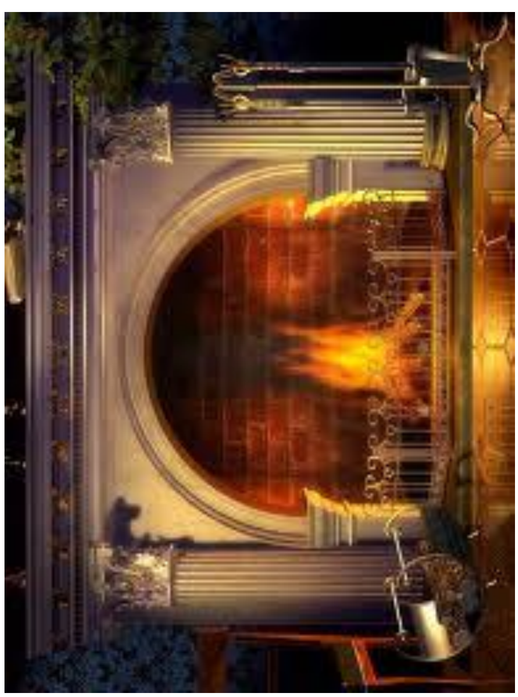
- **Indoor Sources**
  - Episodic
    - cooking
    - showering
    - Indoor combustion
  - Intermittent
    - fumigation
    - painting
  - Continuous
    - household furnishings
    - home materials
    - stored products

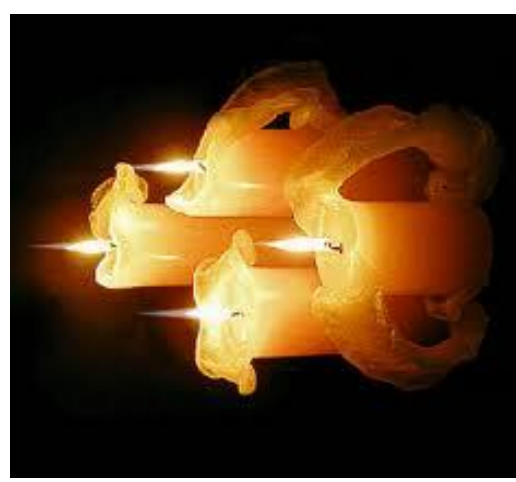
3

Indoor Sources: Biological agents

Indoor Sources: Chemicals

Indoor Sources: Combustion





Indoor Sources: Outdoor Air

What is the safe level for each contaminant?

8

- **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

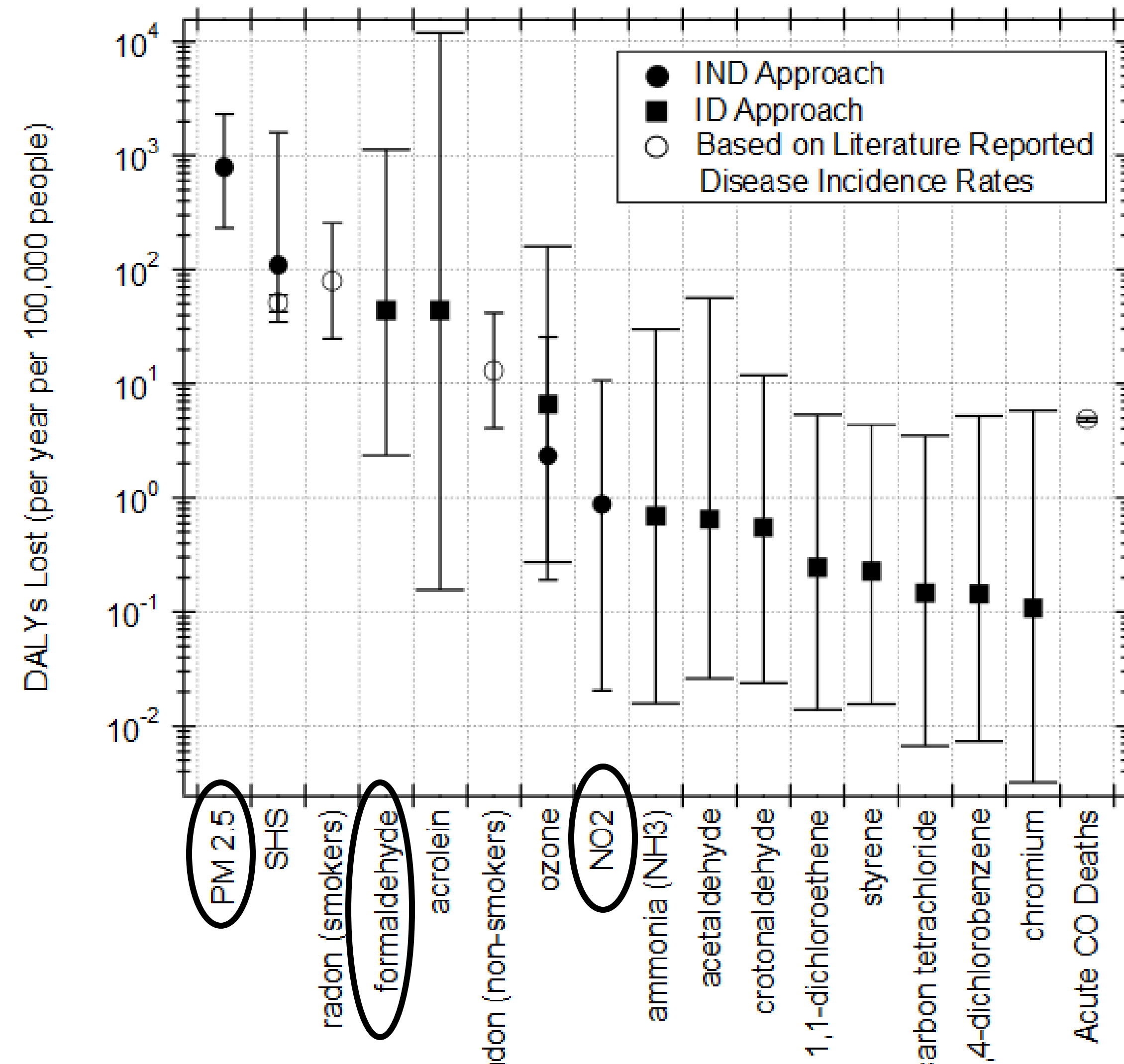


Image source: Logue et al. (2012)

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

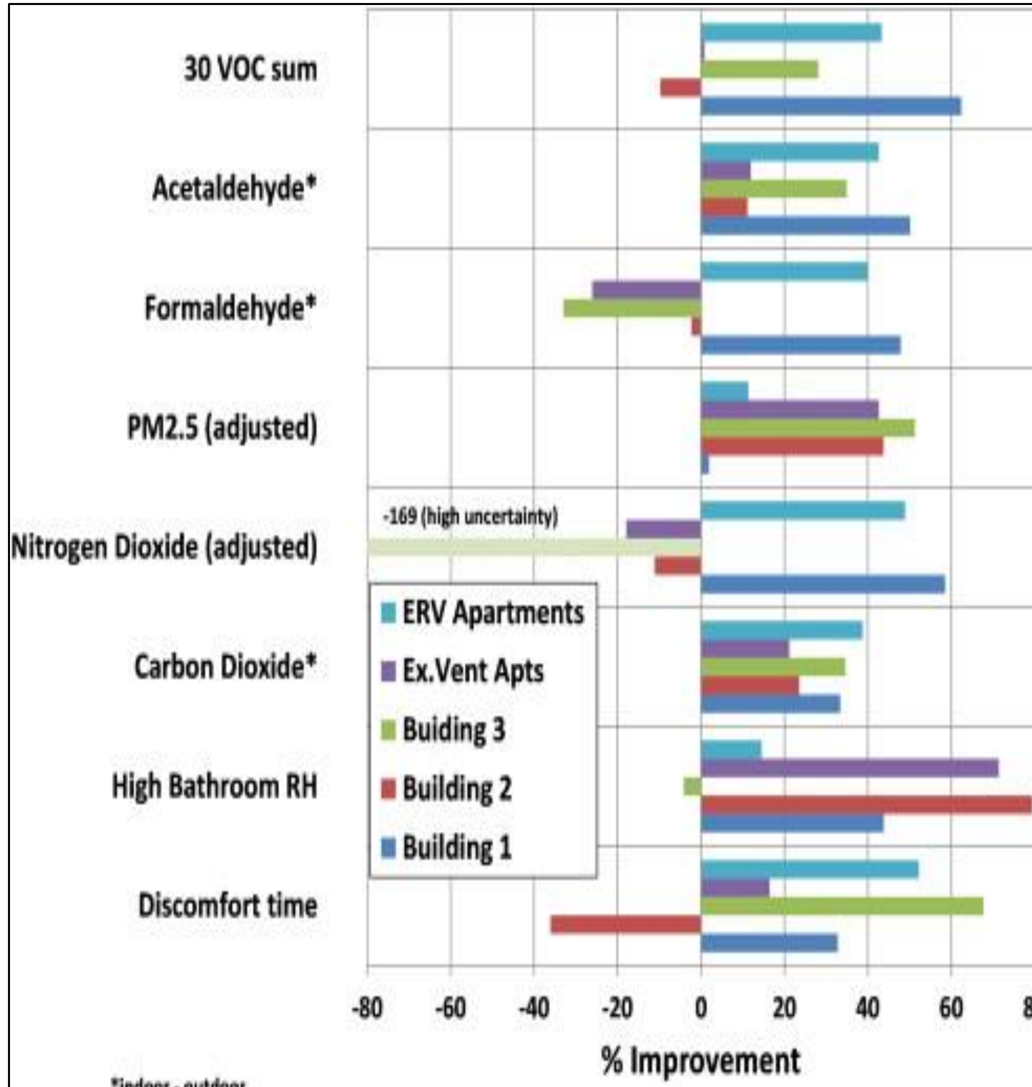
Recent Consensus

- 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)

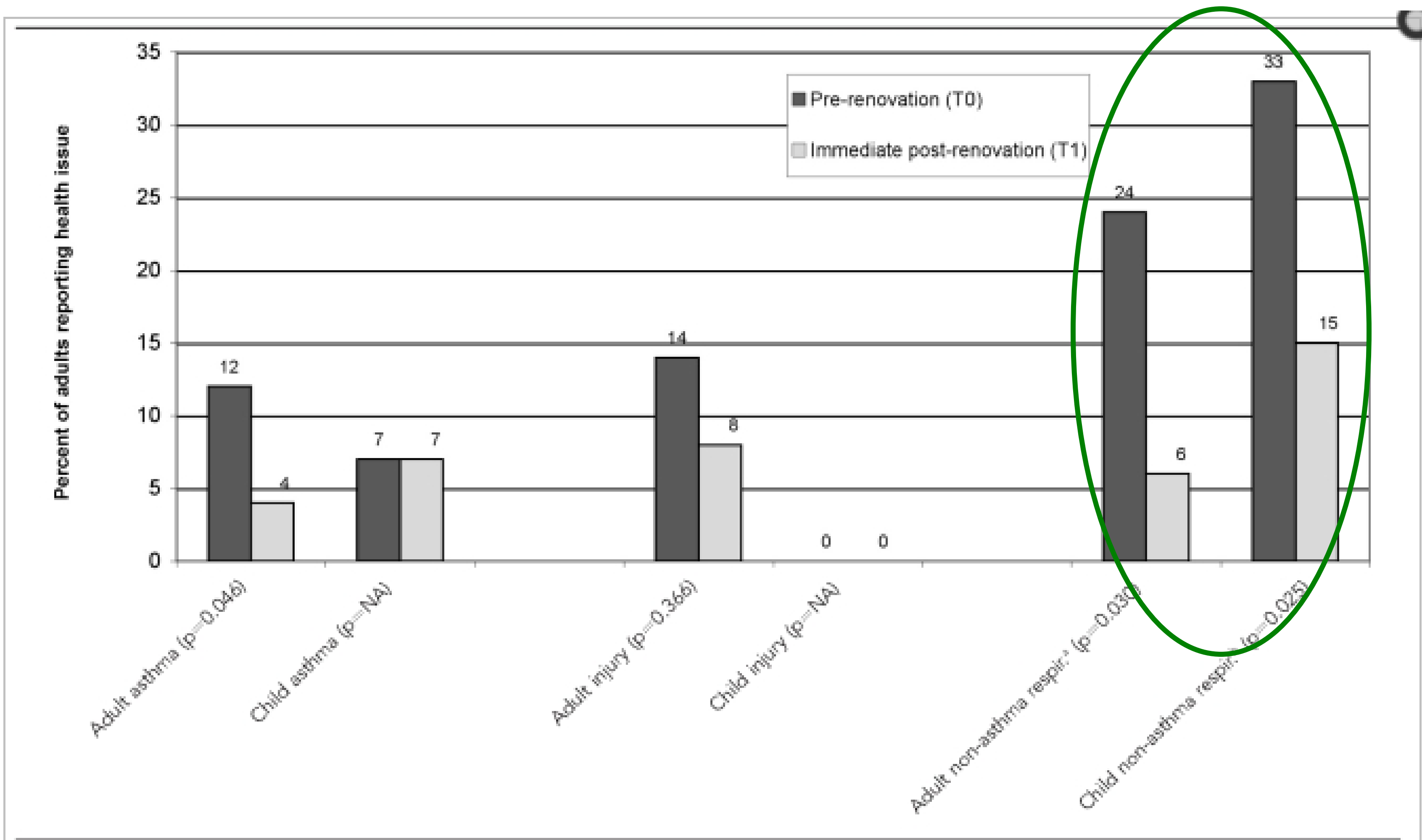
General improvement in IEQ in 16, low-income multifamily retrofitted residences (Norris et al., 2012)

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?

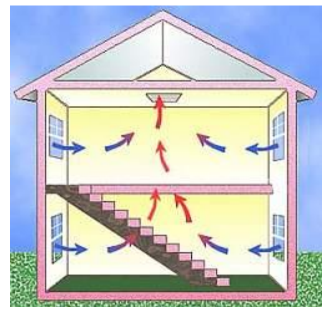
Is that all I need to do?

Principles for Achieving Good IAQ in High Performance Homes

Source Control

Formaldehyde std for comp-wood (CARB)

General & Task Ventilation

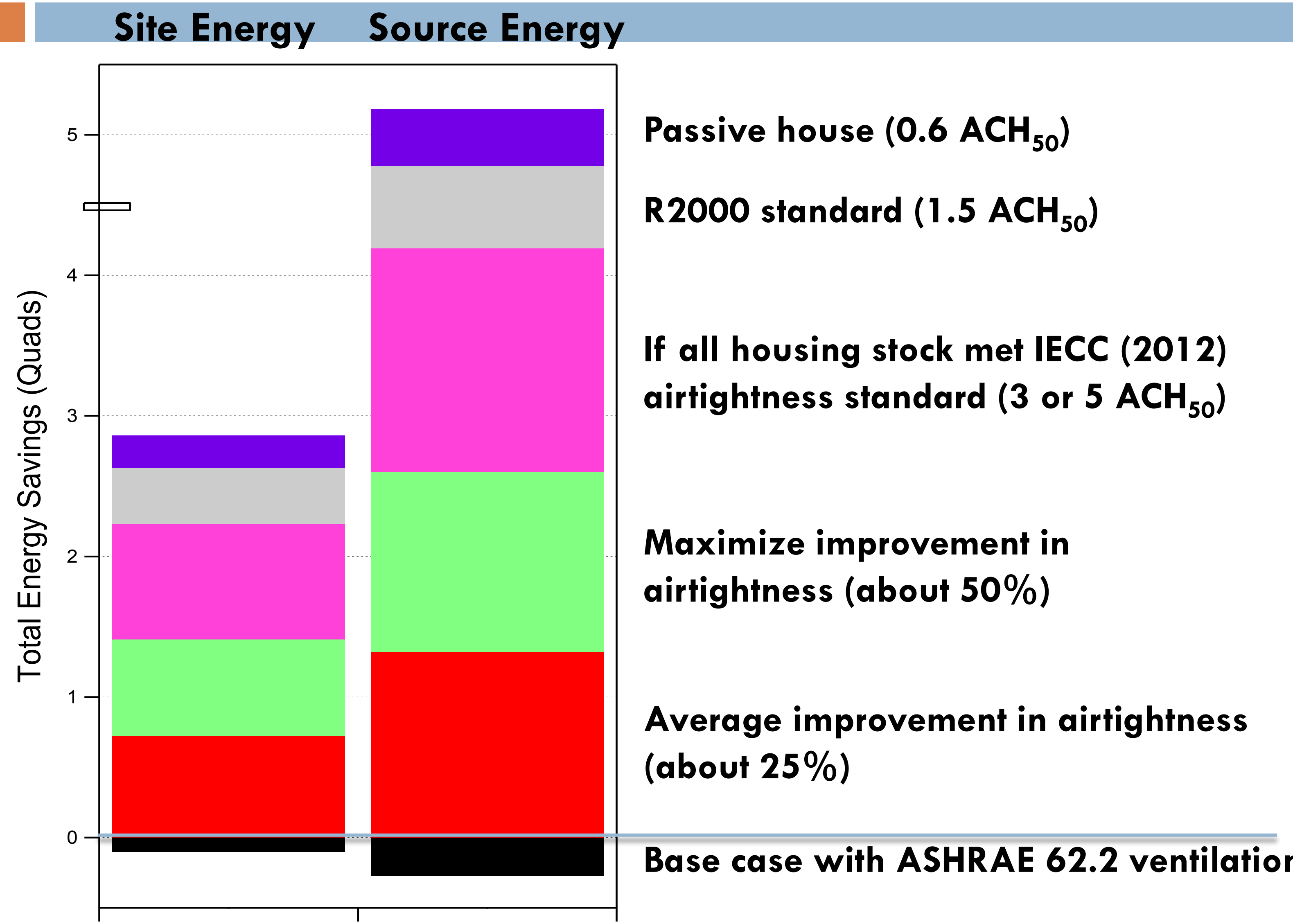


Occupant Education

Filtration/ Air cleaning

Commissioning

Big Rewards for Airtightening, But Returns Diminish

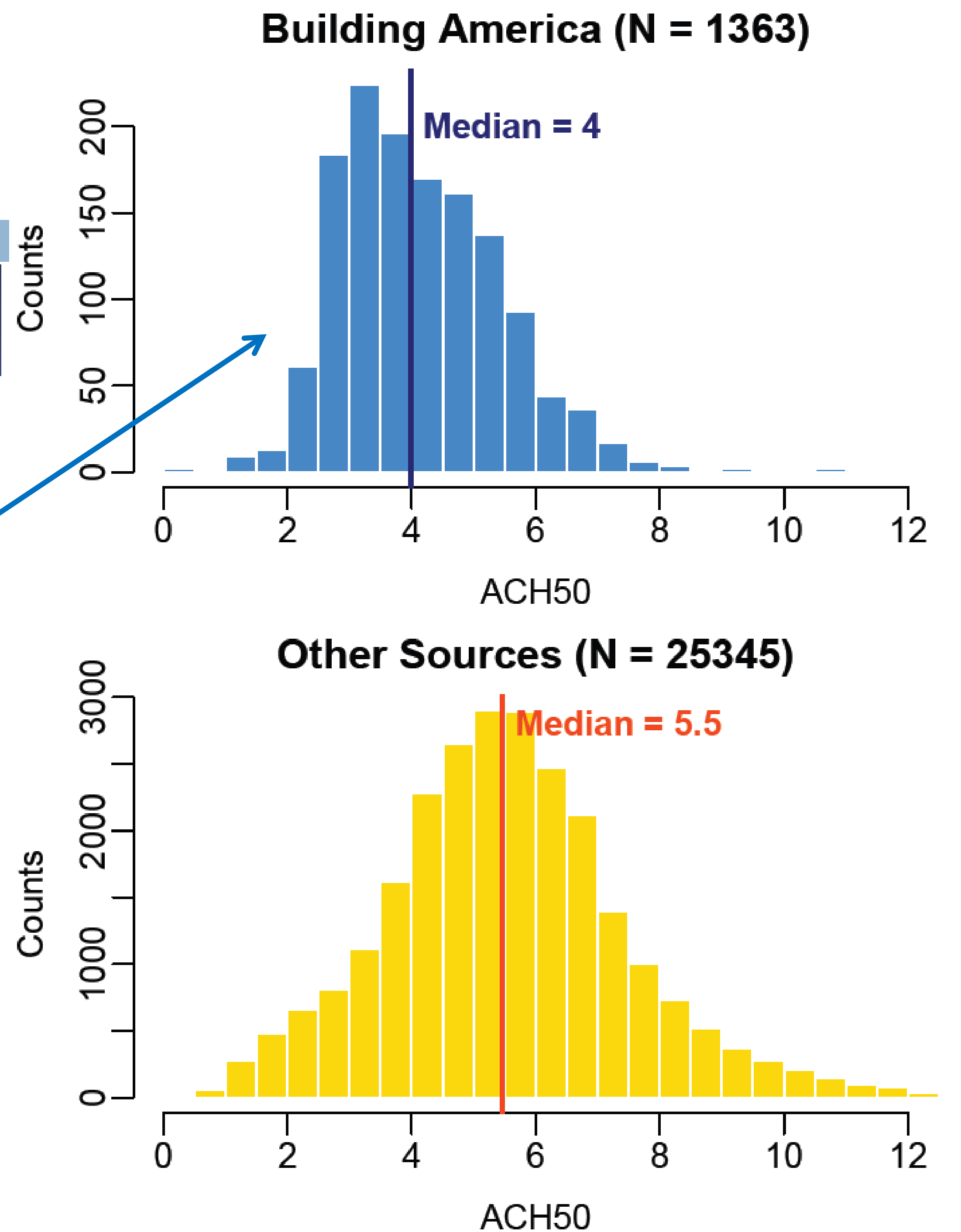


Slide courtesy Rengie Chan, LBNL

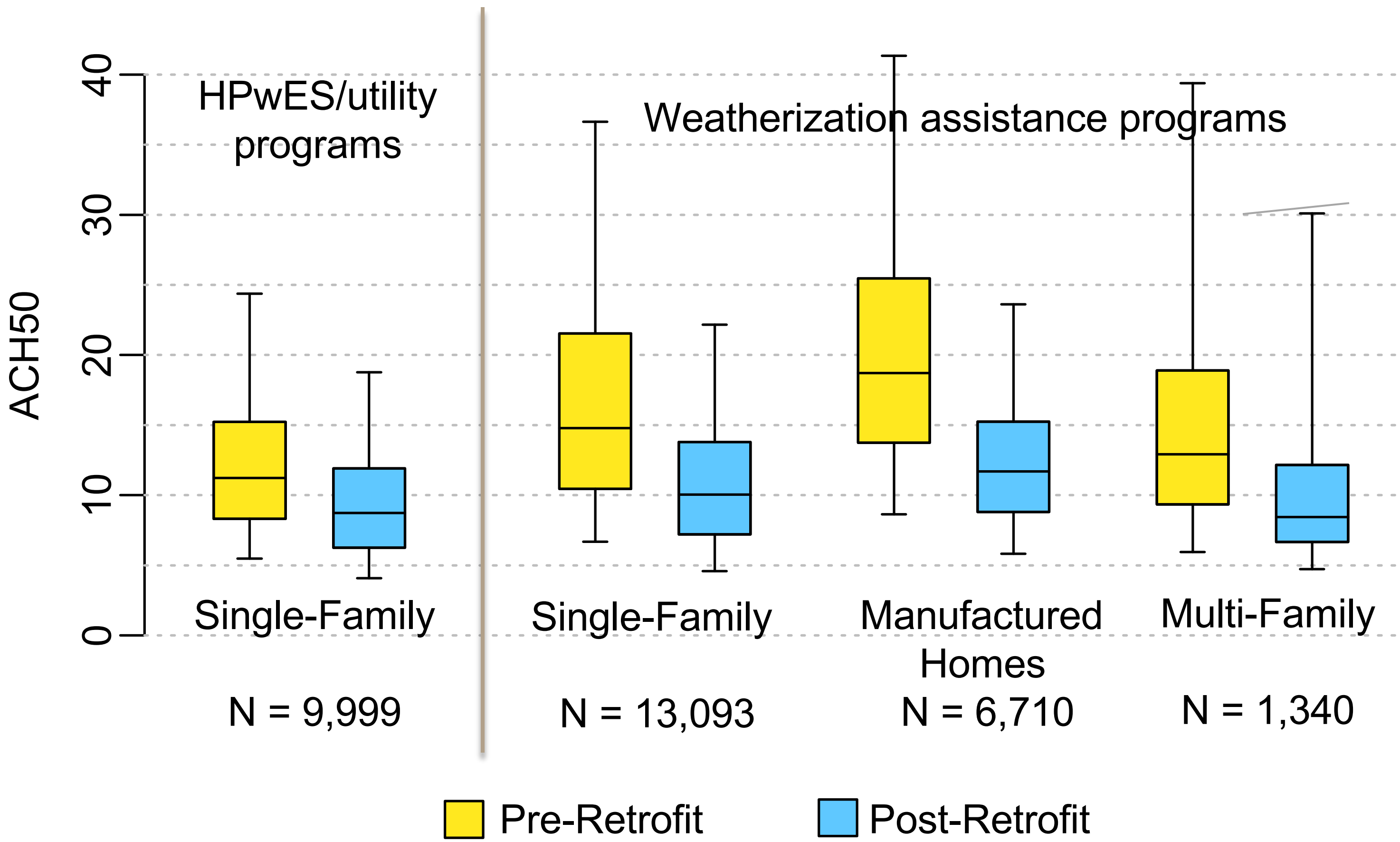
Airtightness in New Homes

Residential Diagnostics Database

High Performance Homes, 27% More Airtight On Average



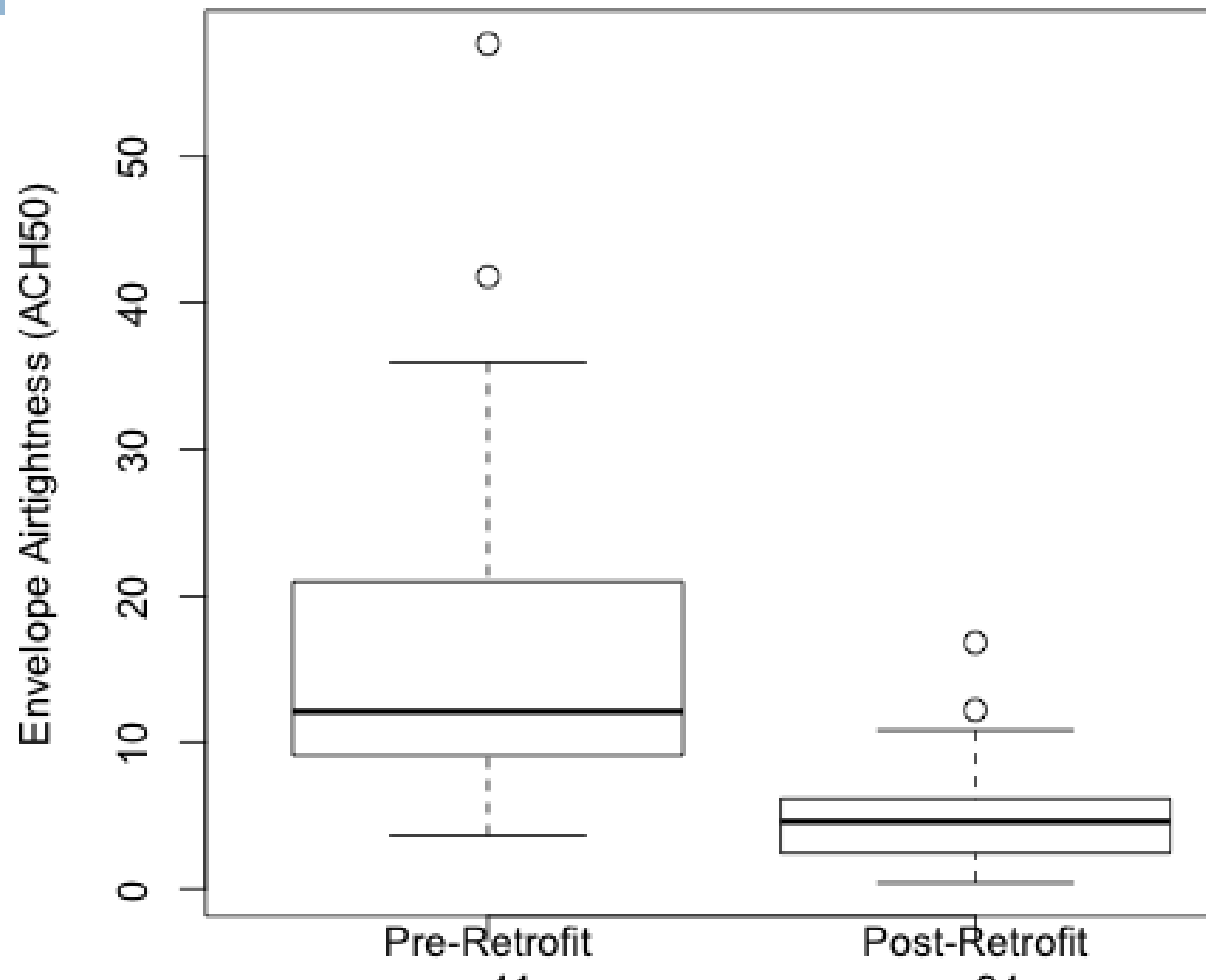
Airtightness in Retrofit Homes (LBNL ResDB)



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

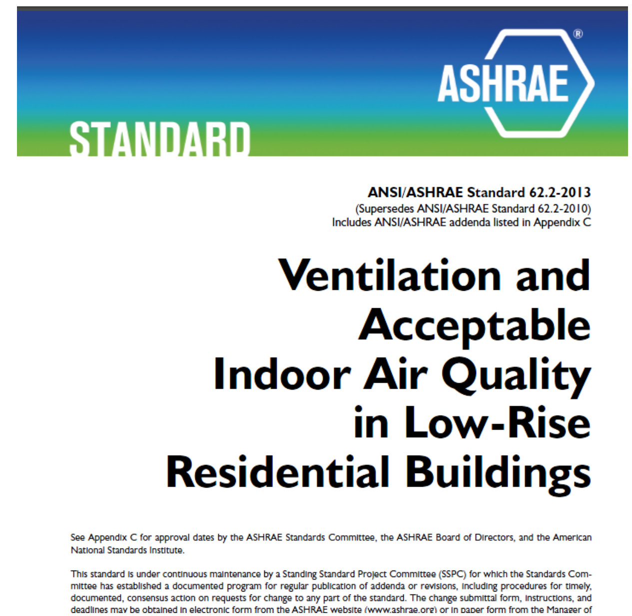
Mean = 4.7

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

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

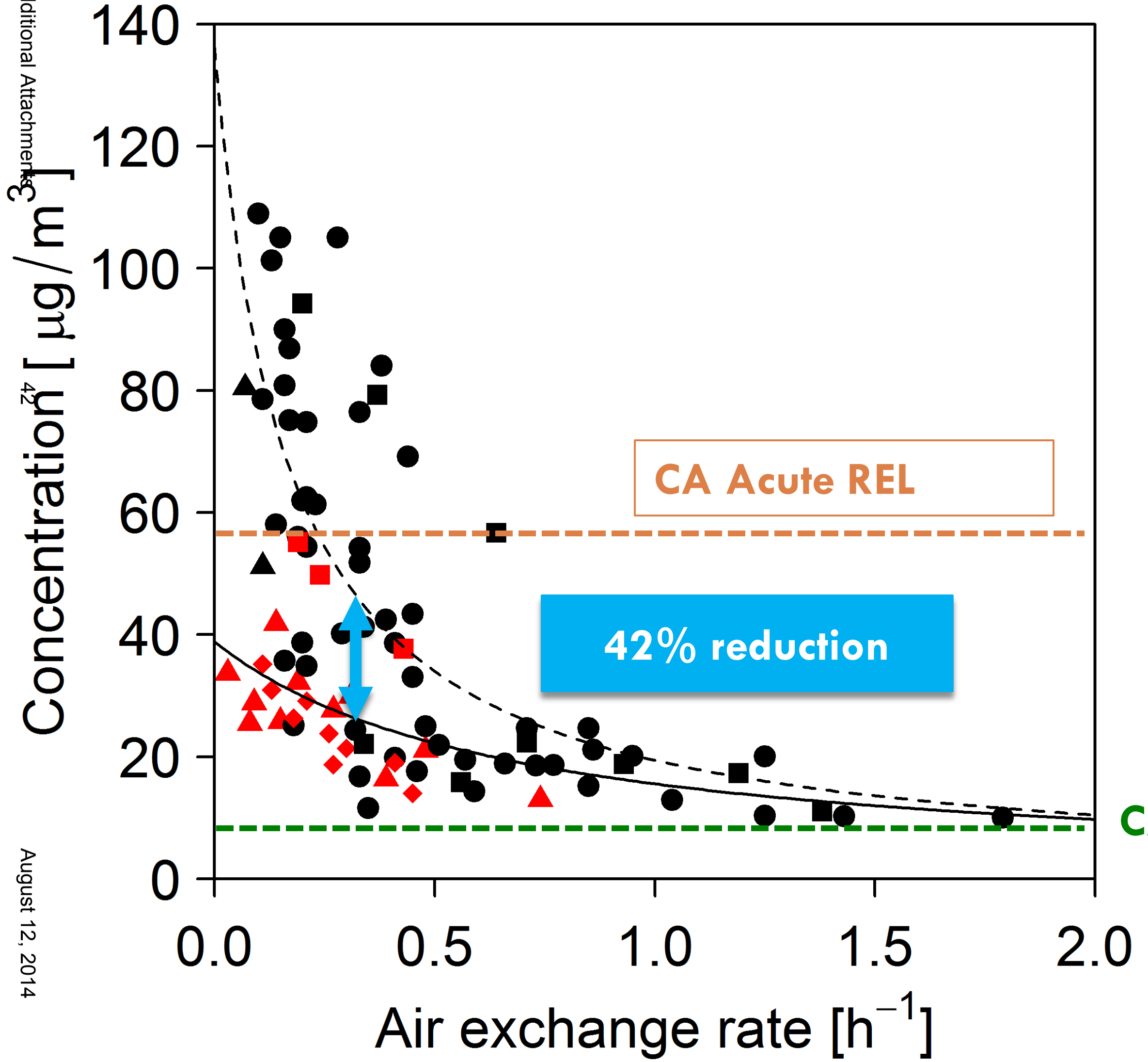
California Department of Public Health CDPH

OEHHA Office of Environmental Health Hazard Assessment

CA Formaldehyde limits and regulation

California Air Resources Board

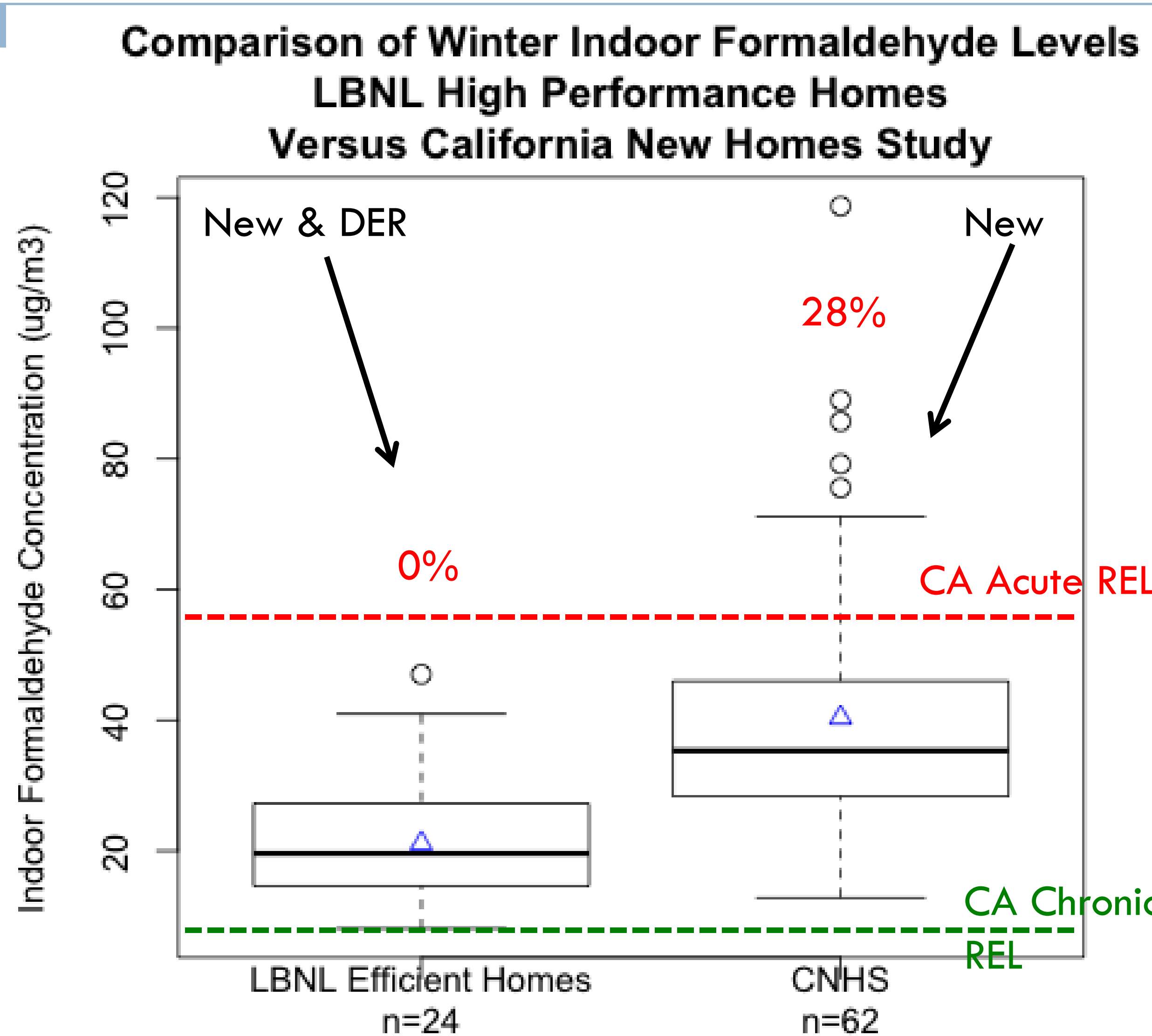
Homes Built With Low-Emitting Materials Have Lower Formaldehyde Concentrations



- **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



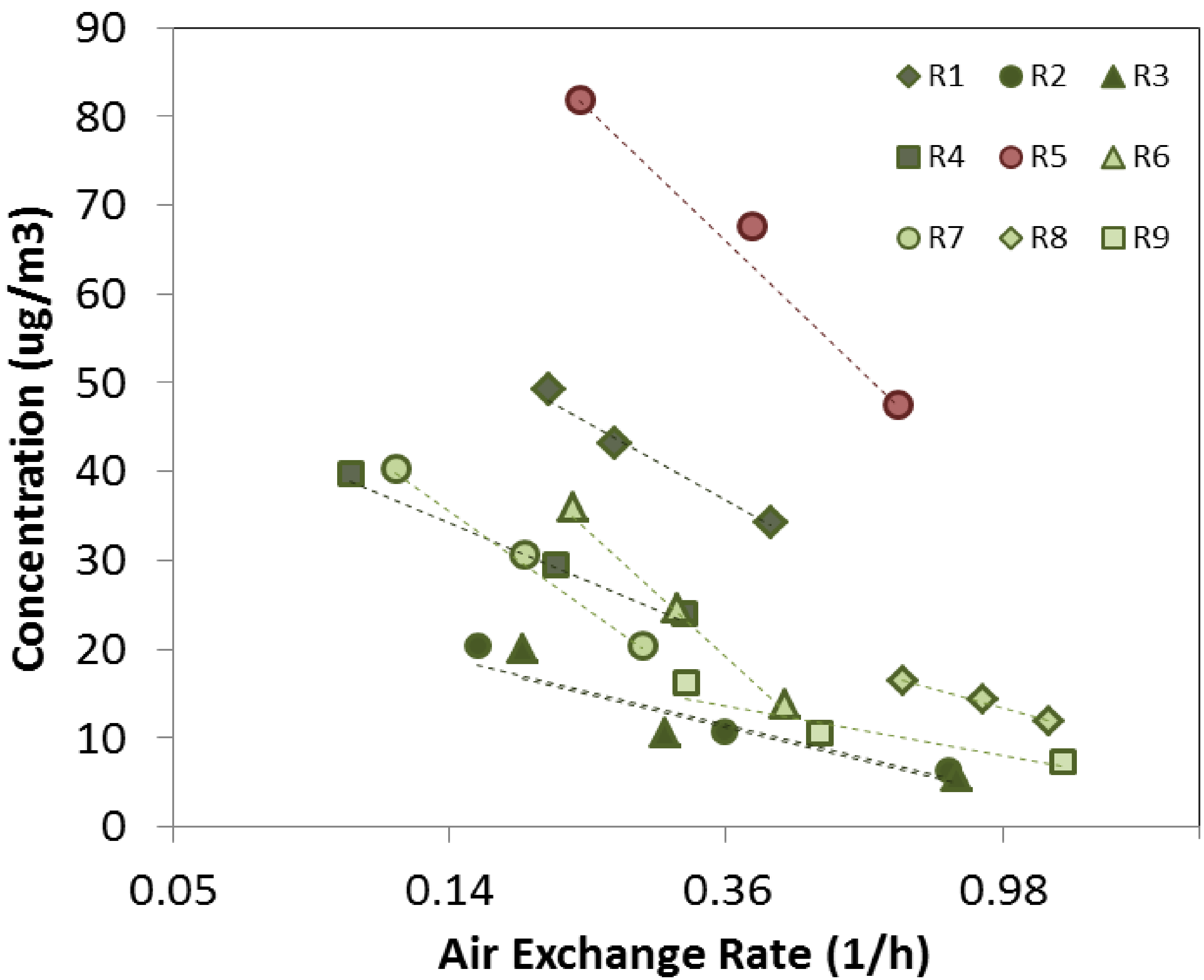
LBNL Formaldehyde/VOC Ventilation Intervention Study (Willem et al. 2013)

- 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**

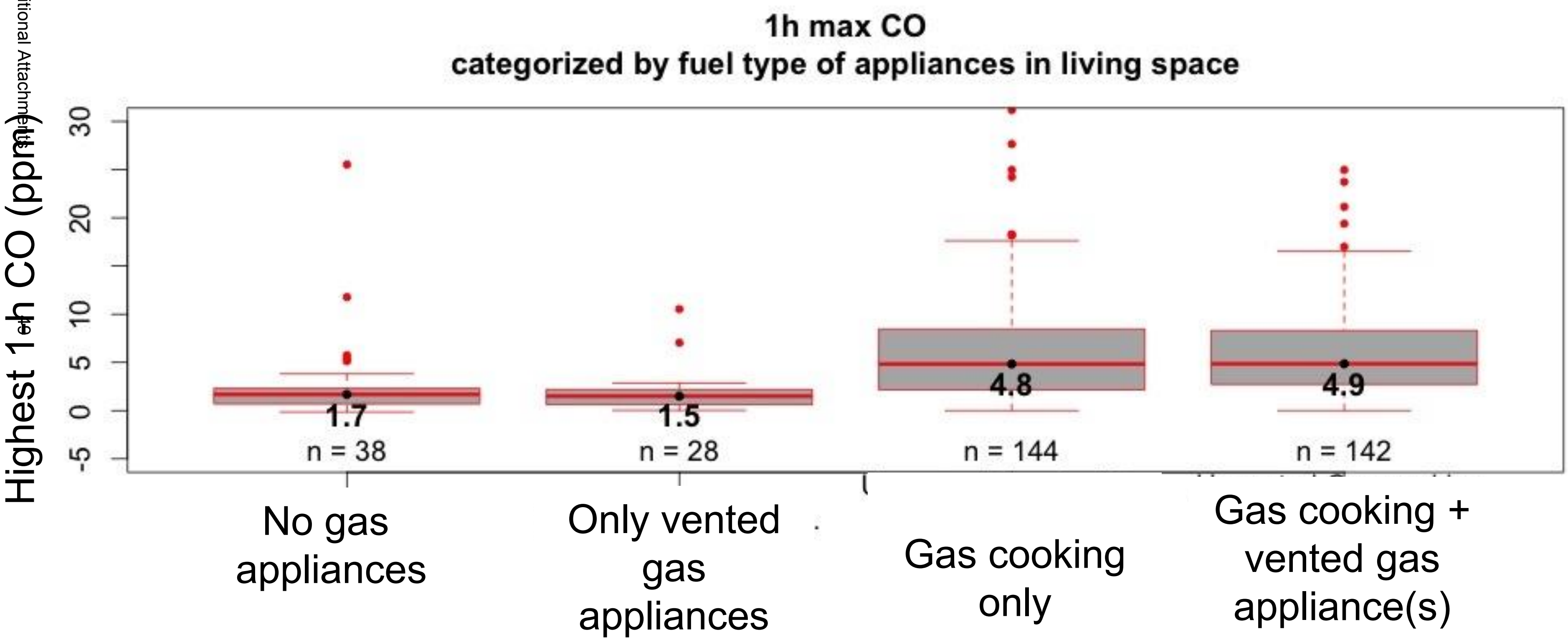
Source Control—Combustion & Cooking Emissions

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

- Ultrafine particles

- Ultrafine particle
- VOCs including acrolein
- Moisture and odors

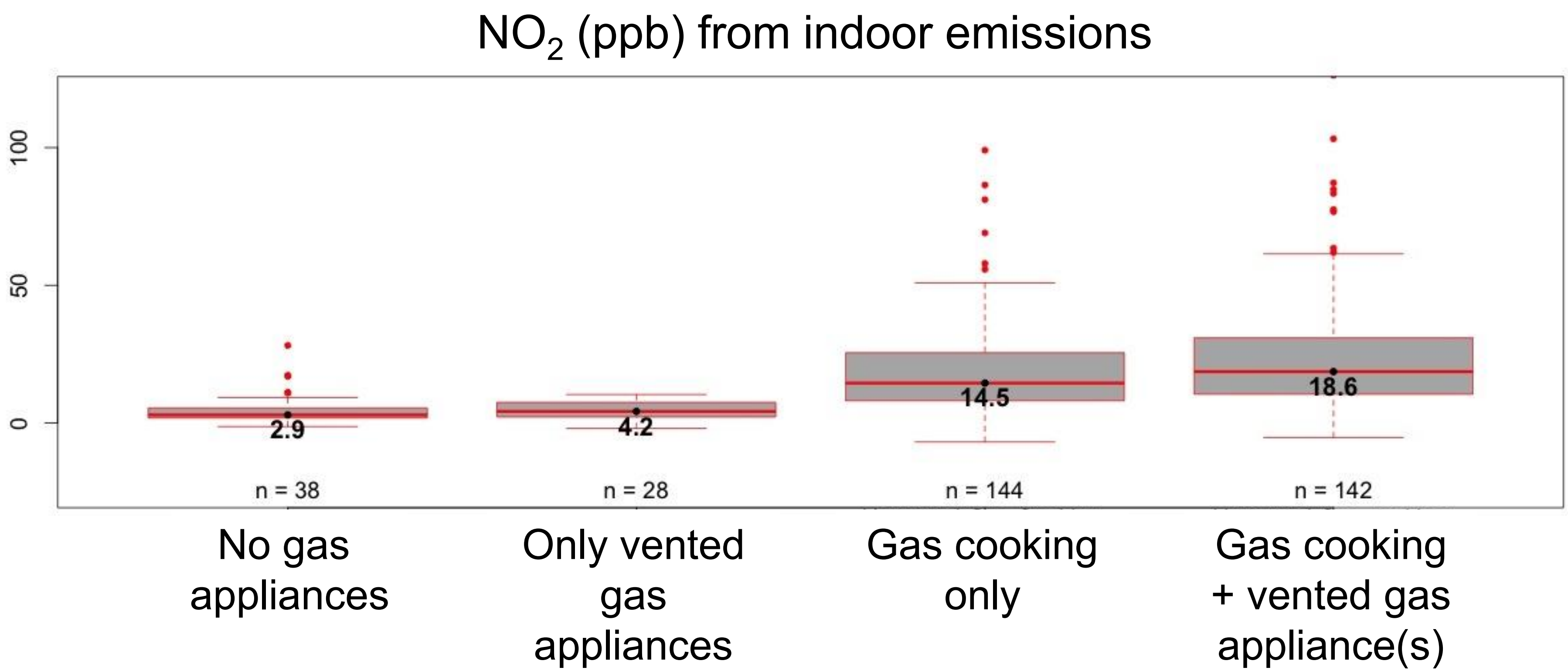
Wait, I Thought Furnaces and Water Heaters Were the Sources of Dangerous Indoor Combustion Pollutants…



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

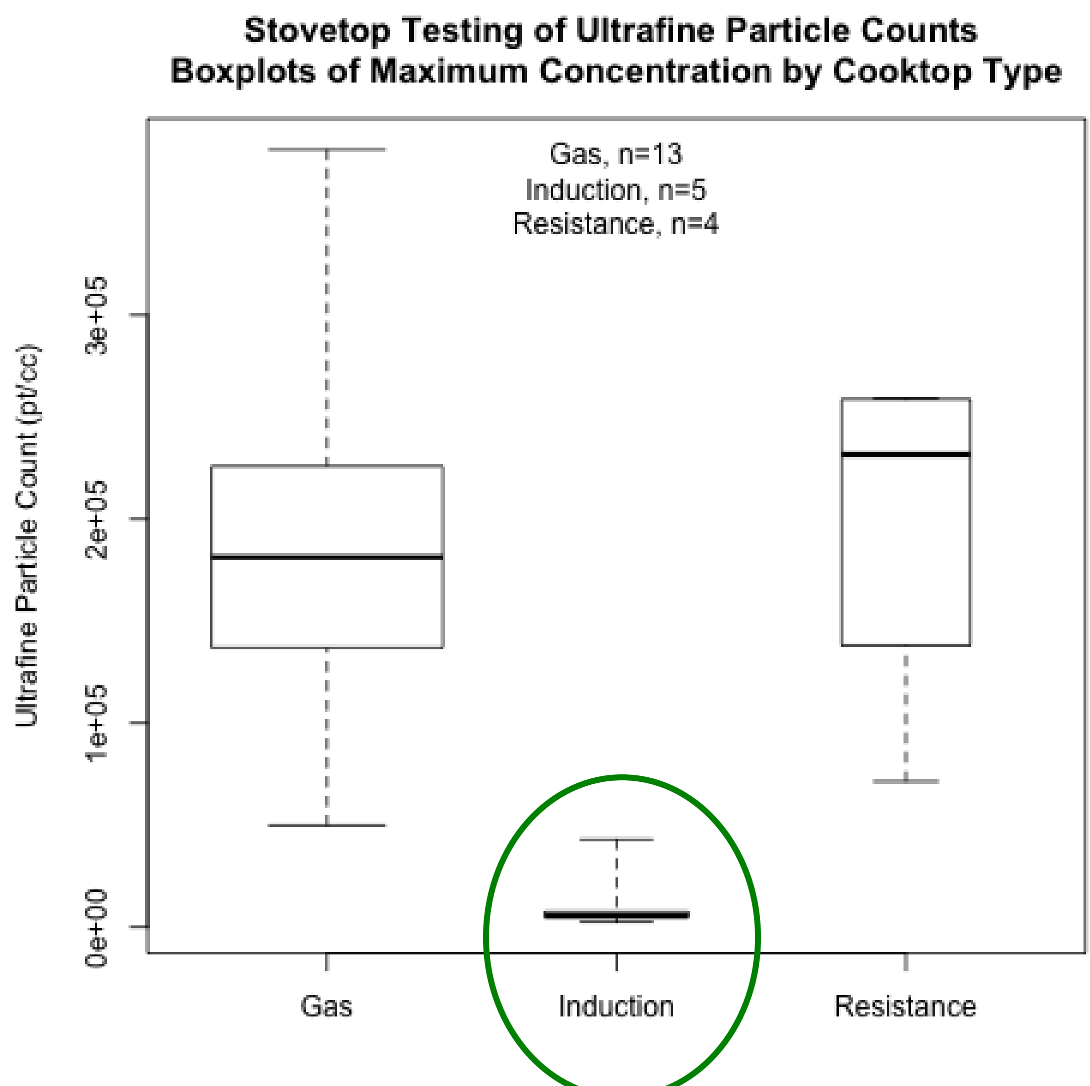


Measured concentrations indoors minus estimated contribution from outdoors

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

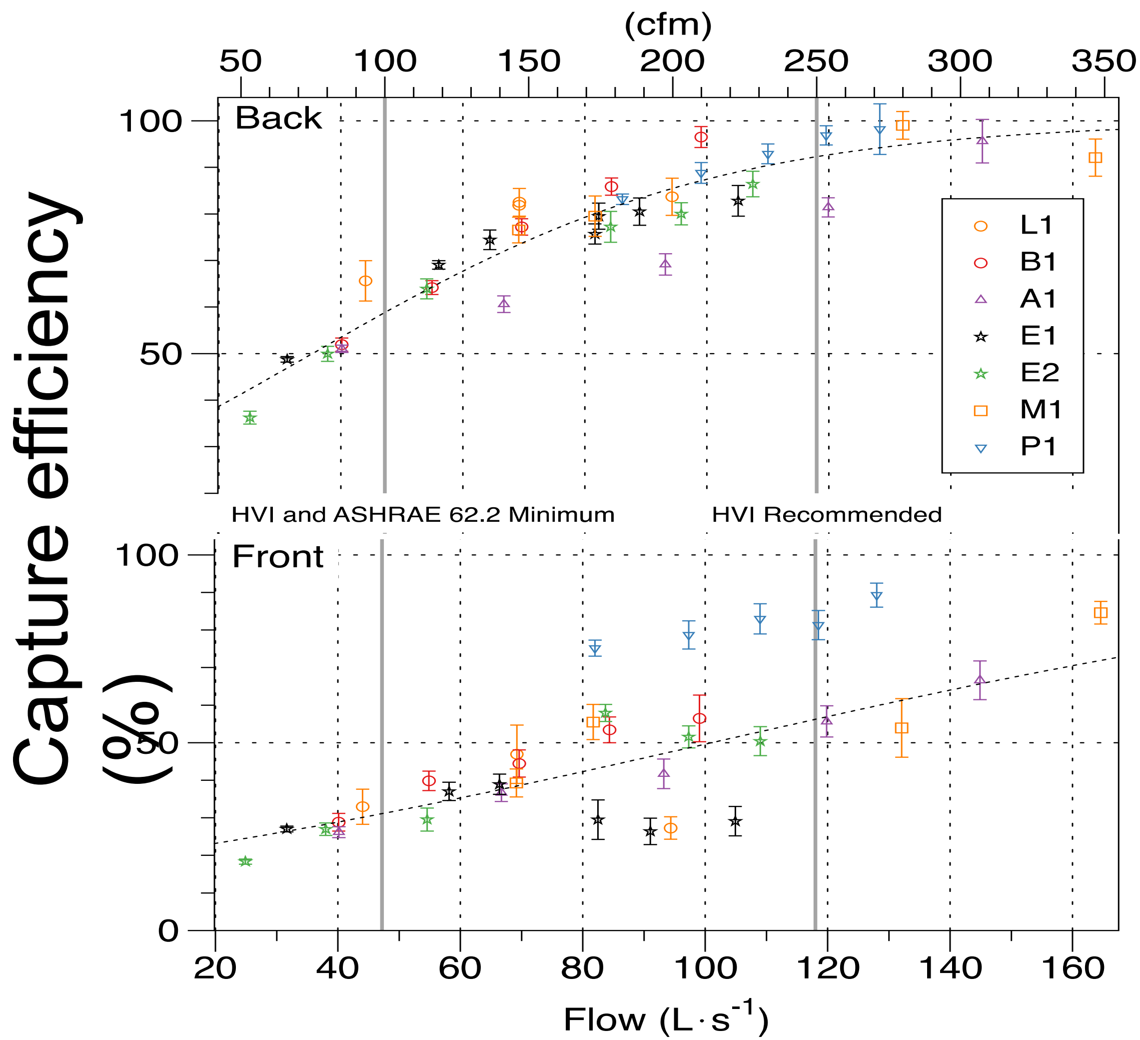
LBNL Laboratory Performance Study

- 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

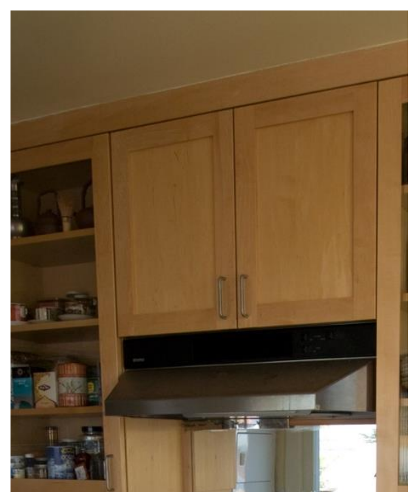
Capture Efficiency—Lab Results

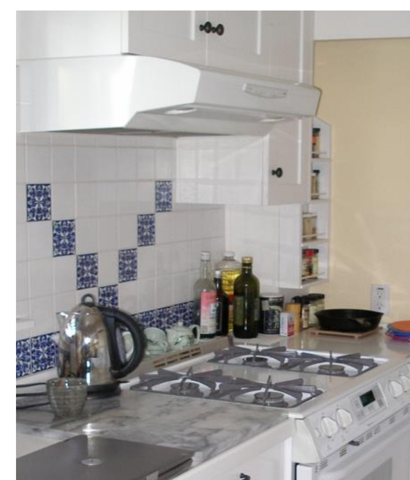


- Reference Flows:
  - 100 cfm
    - 60% back
    - 30% oven, front
  - 200 cfm
    - ~80% back
    - 40-80% oven
    - 25-80% front

LBNL In-Home Performance Study

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

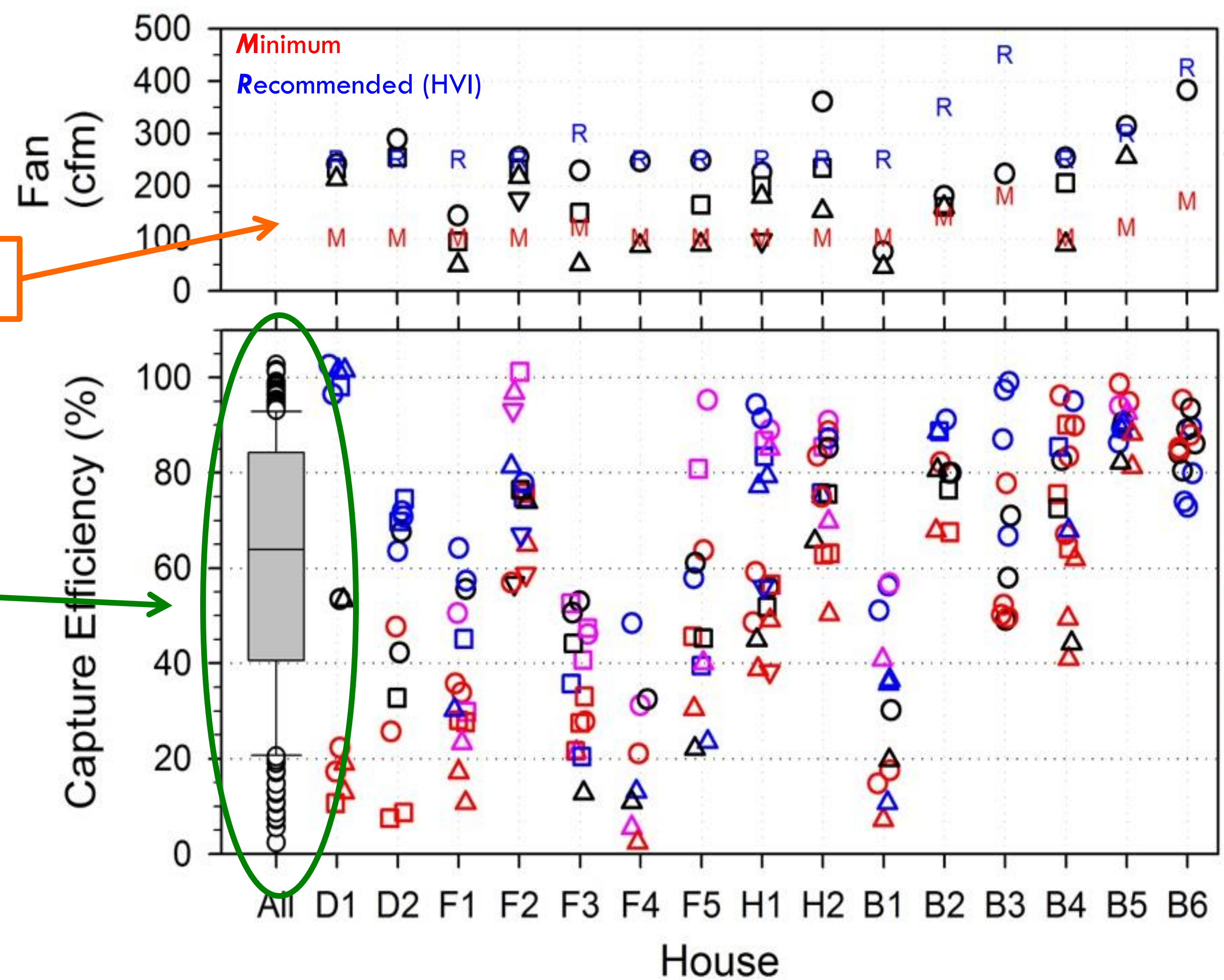




Capture Efficiency—Field Results

Installed flow < Rated flow

~65% Overall Capture Efficiency

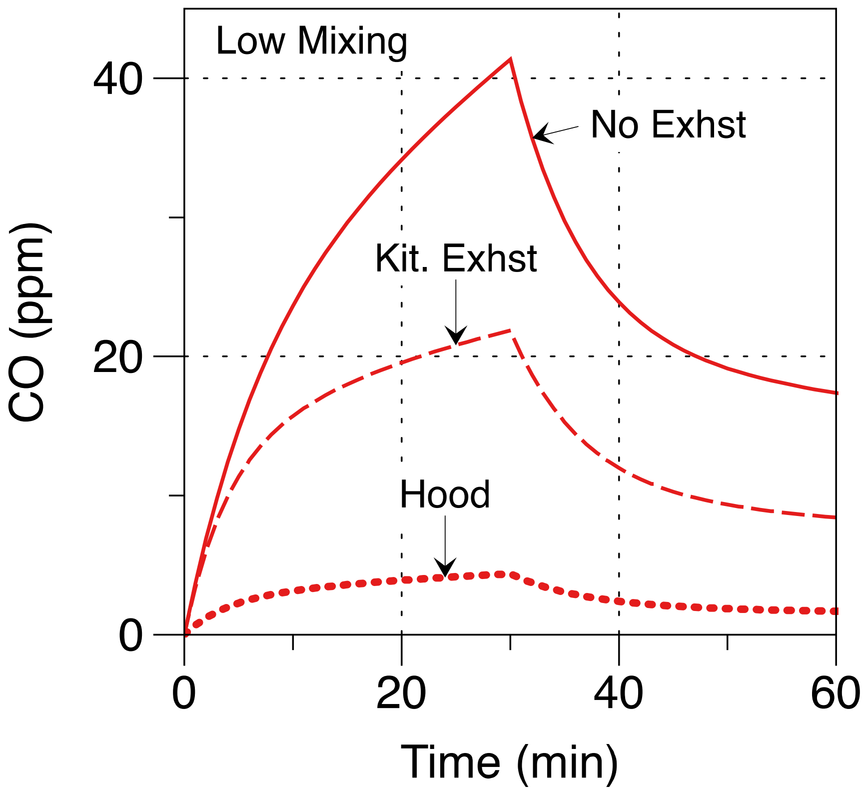


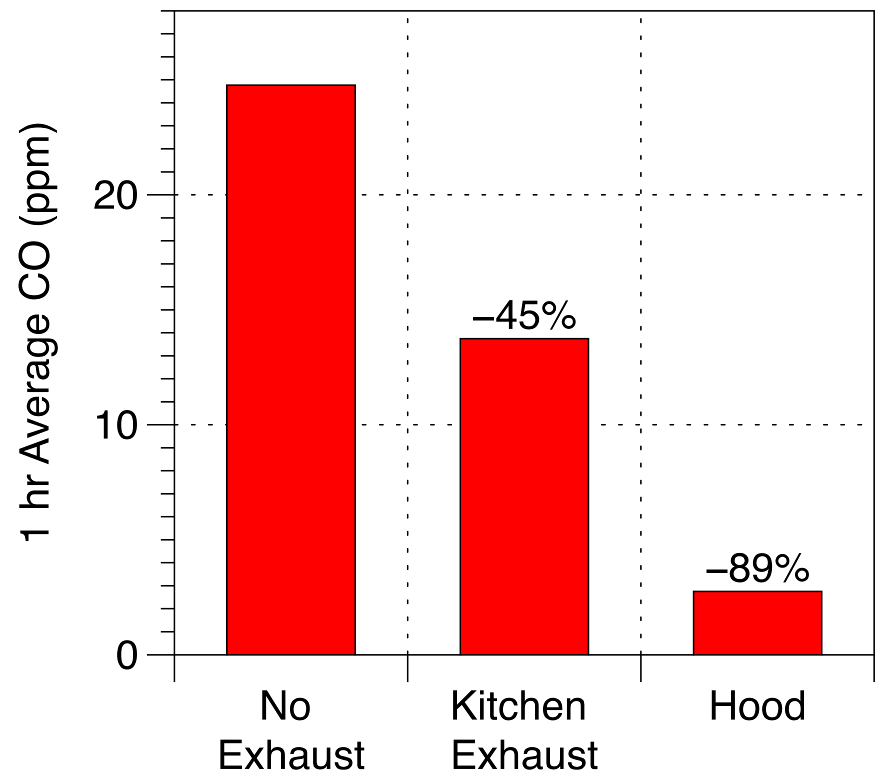
Kitchen Ventilation in Passive House Construction

- 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

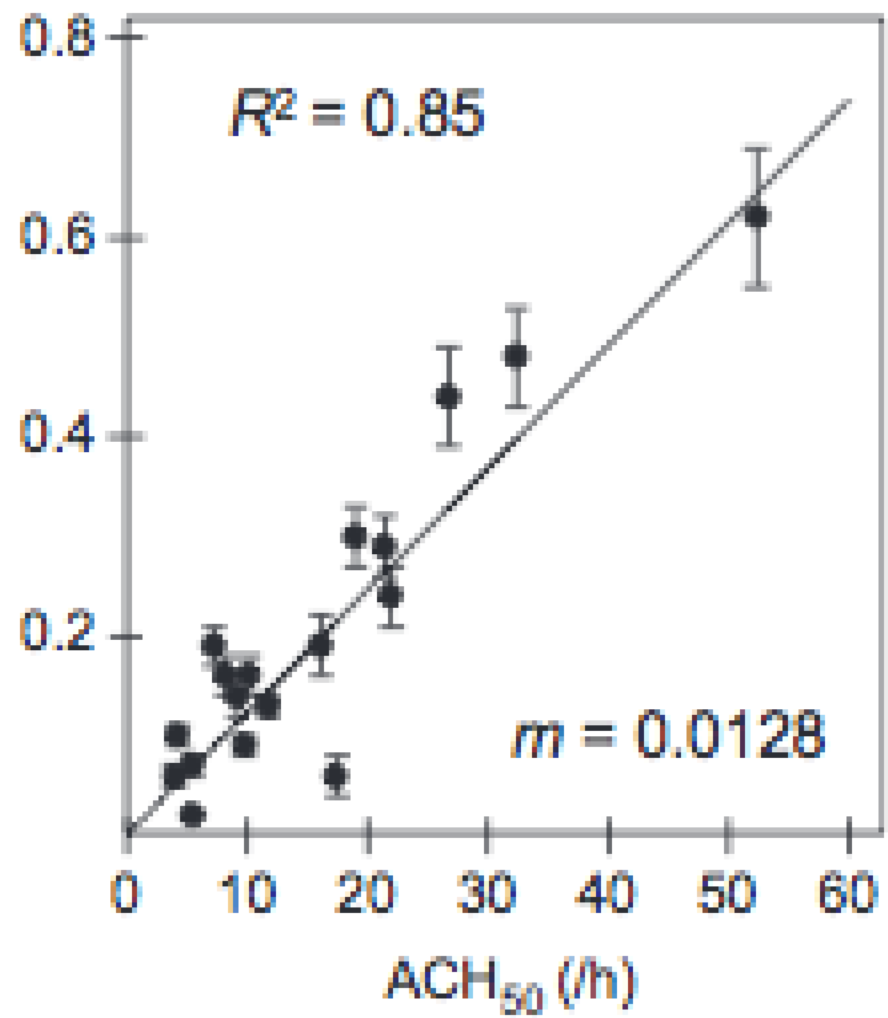
- Install range hoods vented to outside
  - Hood **covers all burners**
  - Hood is **not flat bottomed**
  - Airflow of **200 cfm**—MEASURED
  - **Quiet** operation, NOT just on low speed—HARD TO KNOW
  - **Short** duct runs with **smooth** pipe and few turns (basis of new EPA spec)
  - Look for *future* 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

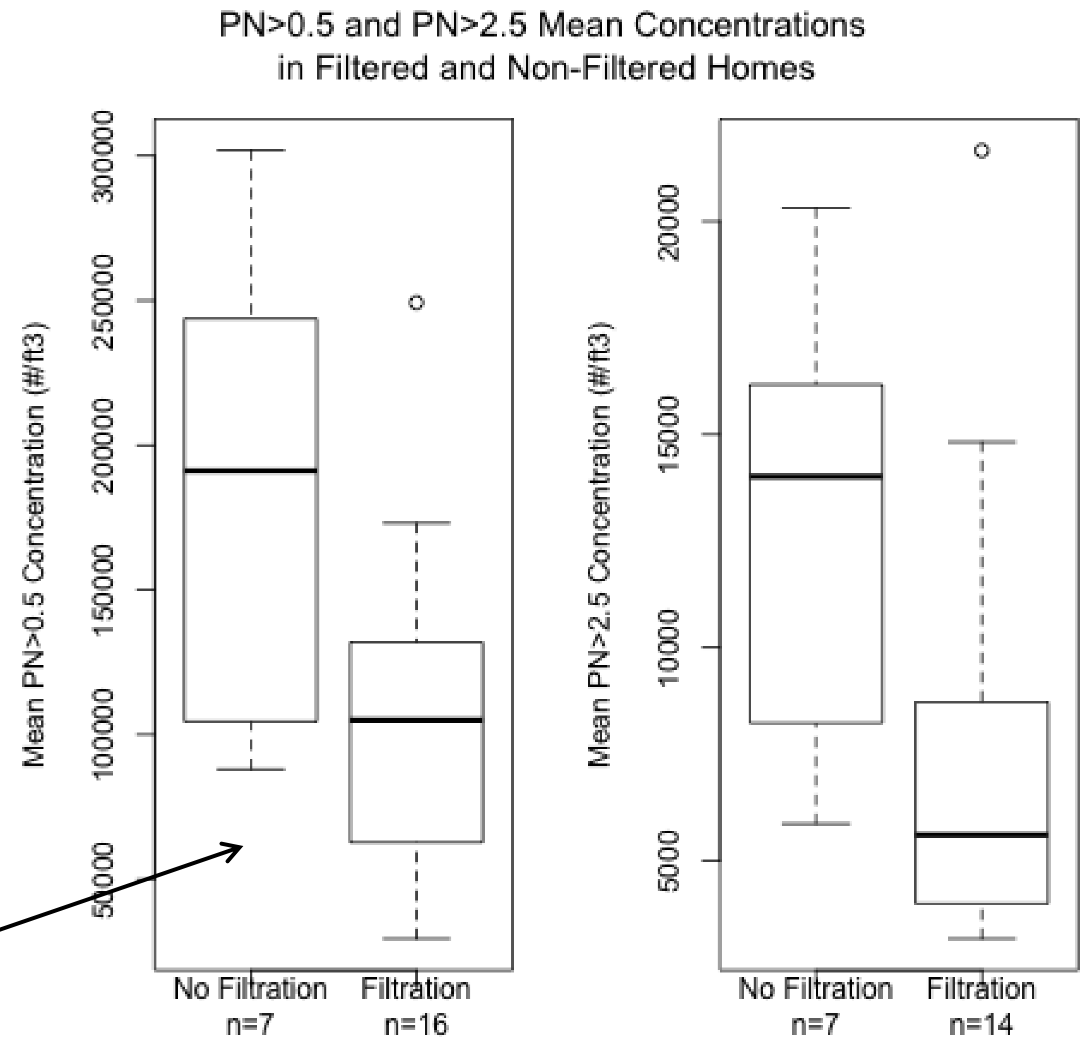
- Field testing of particle penetration of submicron particles (Stephens & Siegel, 2012)
- Tight homes are good particle filters for ***Exhaust*** ventilation:
  - 1.5 ACH_{50} = 2% penetration = MERV16
- BUT particles passing through HRV/ERV or supply vent are NOT filtered by envelope!



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)

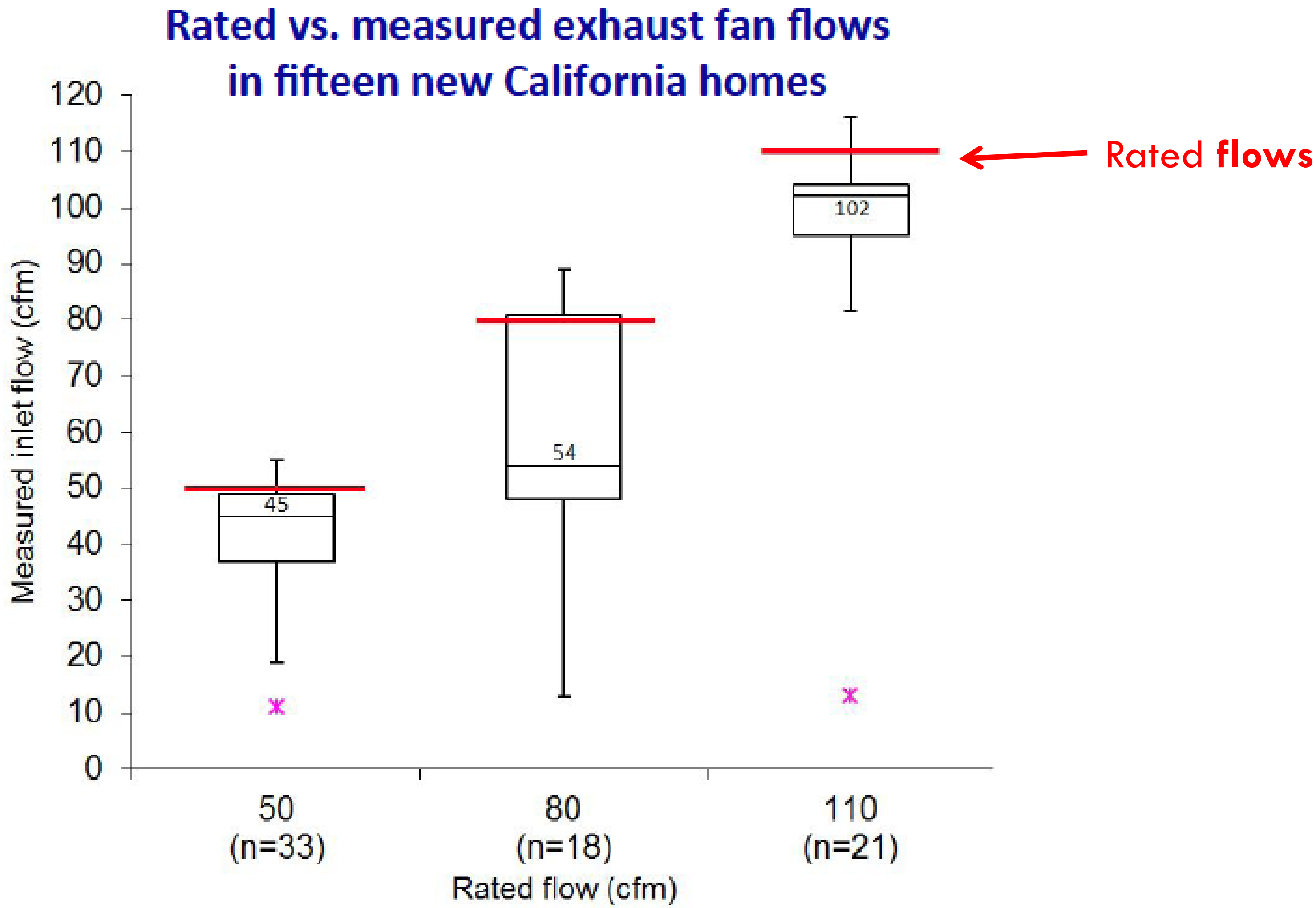
testo 417 Vane Anemometer (testo 417)

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

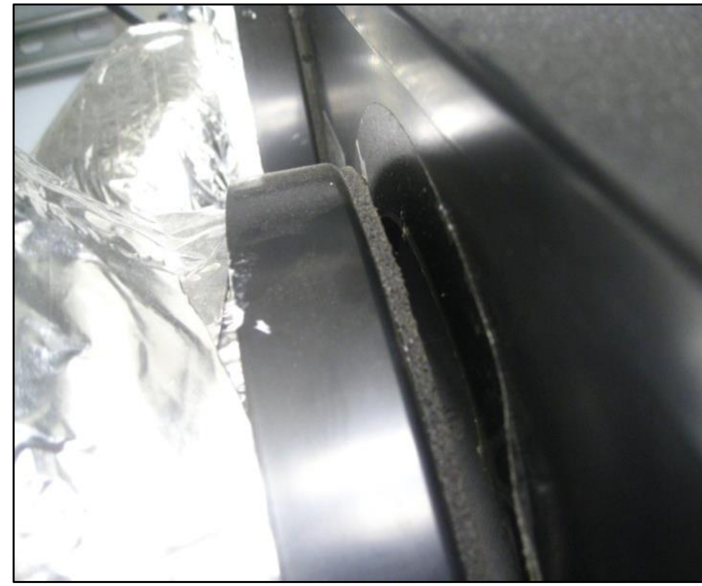
Ventilation Measurements in 15 New CA Homes, Comparison to ASHRAE 62.2-2007 Flow Requirements

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)

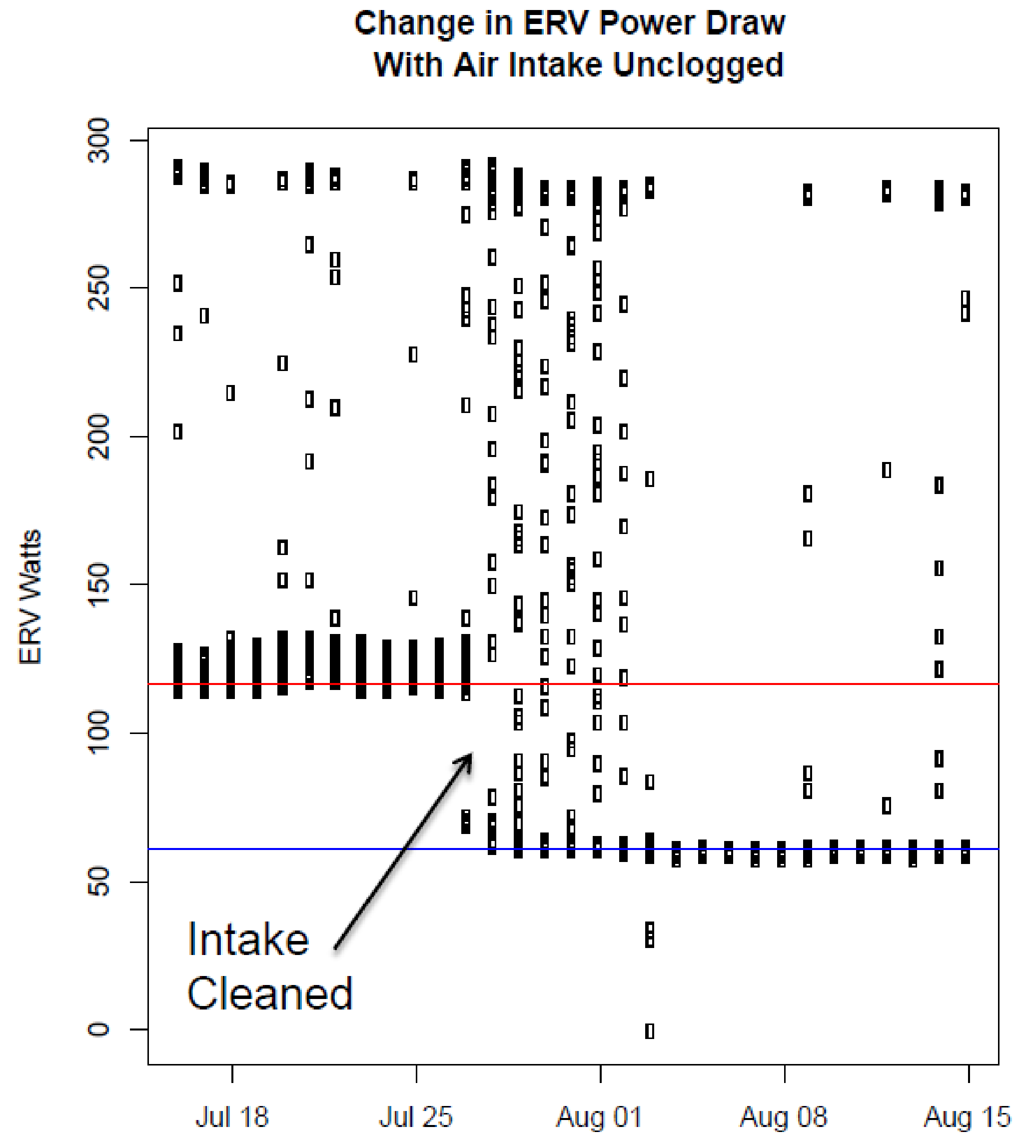
- 5 of 9 ERV/HRV found to have some substantial problem
  - Low airflows
  - Failed duct connections
  - Improperly installed duct connections (recirculating ERV)
  - Erratic control of variable speed systems
  - Clogged fresh air intake on ERV
  - Not operating continuously, inactive for months



- 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:

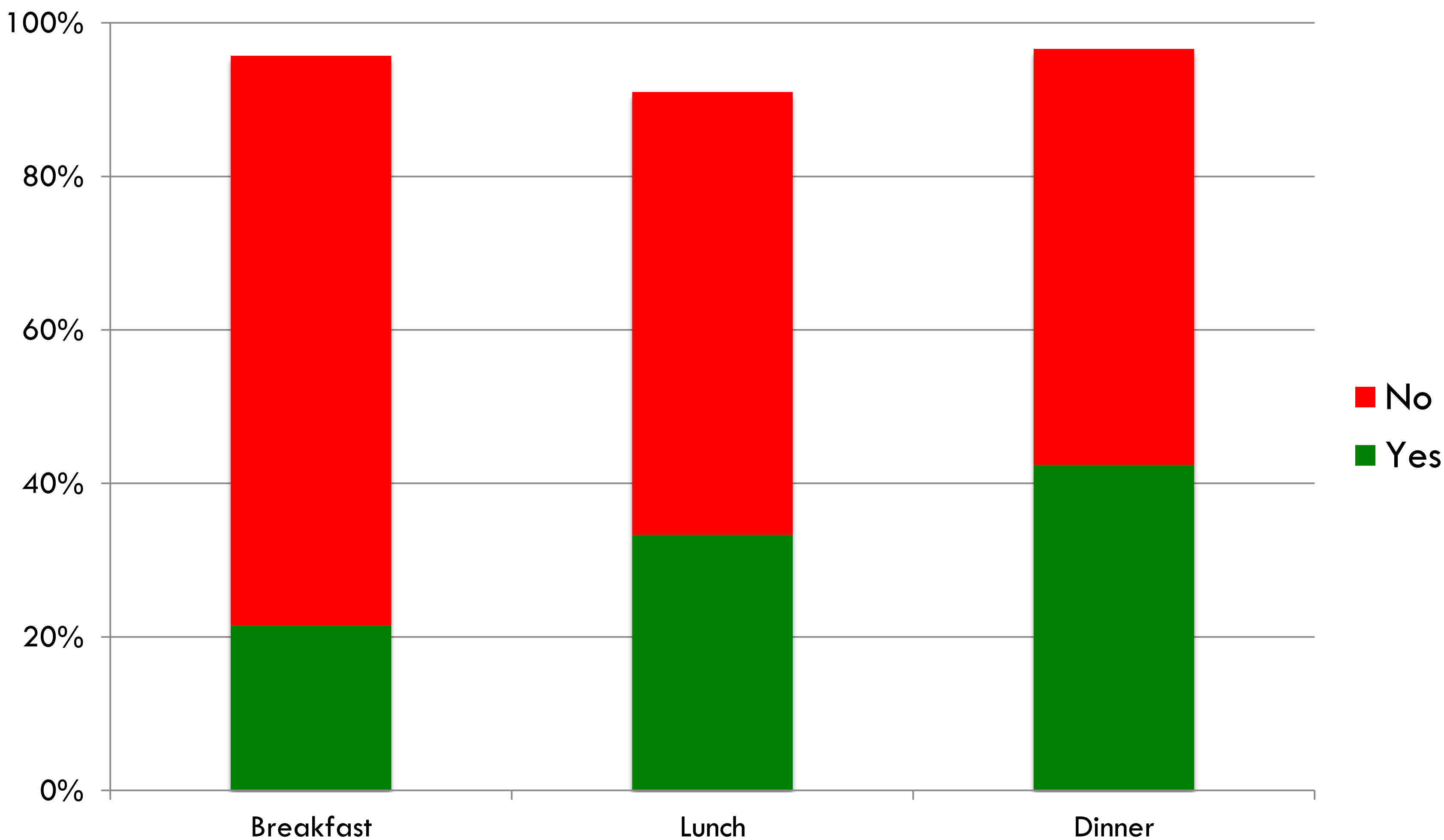
63% of participants in IAQ study either didn't use or didn't have kitchen exhaust

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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