U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Field Studies of Indoor Air Quality in New U.S. Homes

Panelist
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Moderator
Linh Truong – National Renewable Energy Laboratory

July 11, 2018

Building AMERICA
U.S. Department of Energy

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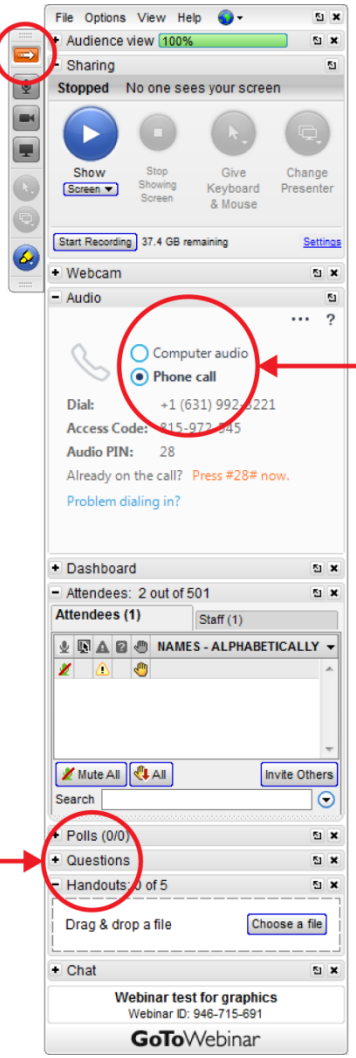

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http://energy.gov/eere/buildings/building-america-meetings#current

Agenda

- ✓**Welcome and Introductory Remarks**
- ✓**Overview of Building America (buildingamerica.gov)**
  - ➢ Linh Truong – National Renewable Energy Laboratory
- ✓**Speaker**
  - ➢ Rengie Chan, Lawrence Berkeley National Laboratory
- ✓**Questions and Answers**
- ✓**Closing Remarks**

Field Studies of Indoor Air Quality in New U.S. Homes

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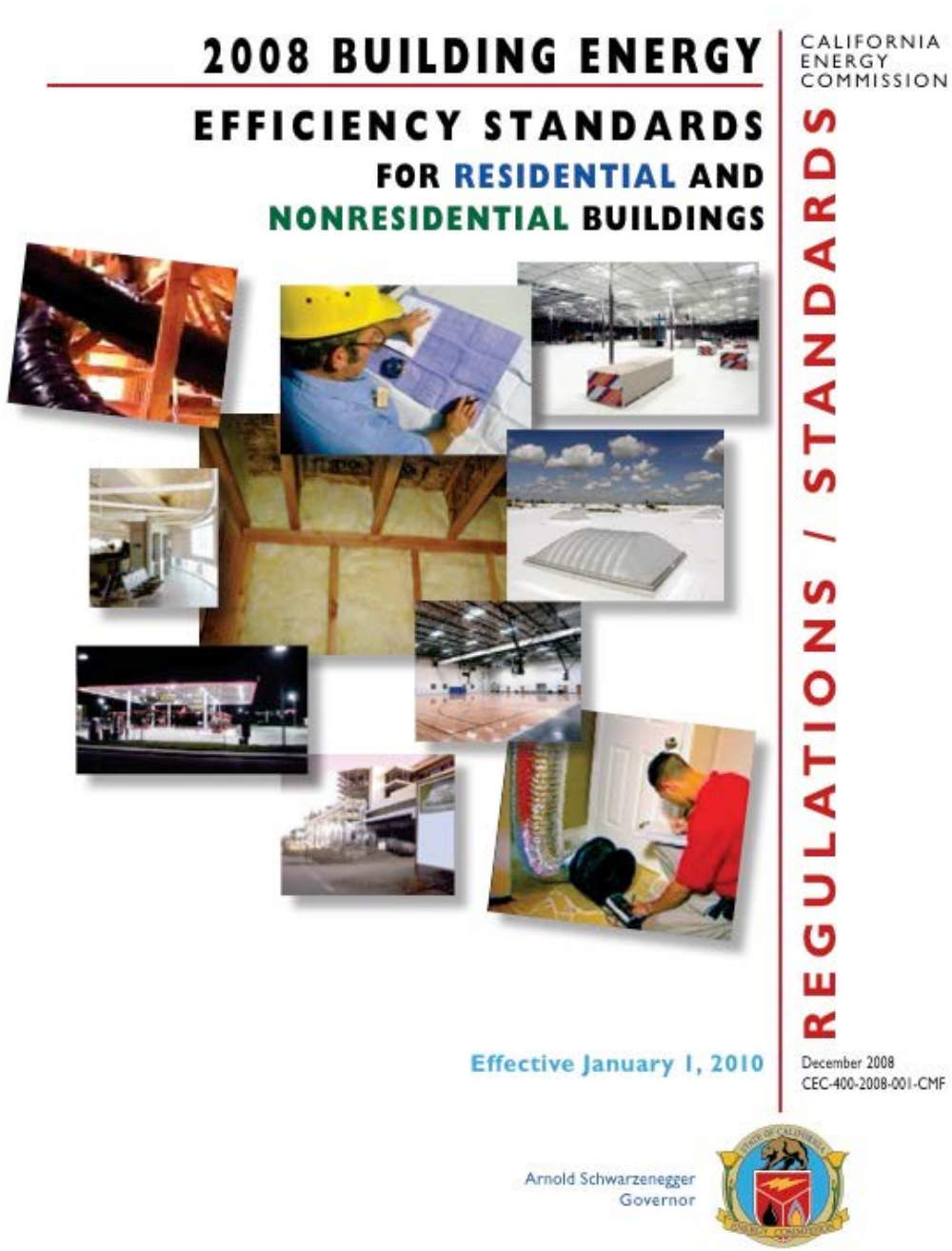
July 11, 2018

Agenda

1. Preliminary results from Healthy Efficient New Gas Homes (HENGH)

   Field study (2016-2018) in 70 new California homes

In 2008, mechanical ventilation requirements were added to California Title 24 to address adverse impacts that could potentially result from air sealing envelopes to reduce infiltration and improve energy efficiency.



Agenda

1. Preliminary results from Healthy Efficient New Gas Homes (HENGH)

   Field study (2016-2018) in 70 new California homes

2. Overview of Building America IAQ New Homes Study

   Field study (2018-2020) in 128 new homes across US

   Field teams: Pacific Northwest National Lab (PNNL)

   Florida Solar Energy Center (FSEC)

   N = 4 climate zones x 32 homes each

Prior California Studies of IAQ and Ventilation

2004-2005 Survey of 1,500 new homes*

- Few open windows in winter; many did not ventilate in other seasons.
- Kitchen and bath ventilation not used regularly

2007-2008 Measurements in 108 new homes** (mostly 1 day)

- 9 of 16 homes with ducted mechanical ventilation had grossly insufficient flow
- Many homes did not use windows for ventilation; 67% below code requirement
- Majority of homes exceeded formaldehyde health guidelines

* Price & Sherman (2006) Ventilation Practices and Household Characteristics in New California Homes

** Offermann (2009) California New Homes Study (CNHS)

US Studies of Ventilation Equipment

Florida Solar Energy Center (FSEC) inspected mechanical ventilation systems in 21 new Florida homes*

- 1-9 ACH_{50}
- 9 of 21 were not operational
- 12 of 21 “capable of operating”

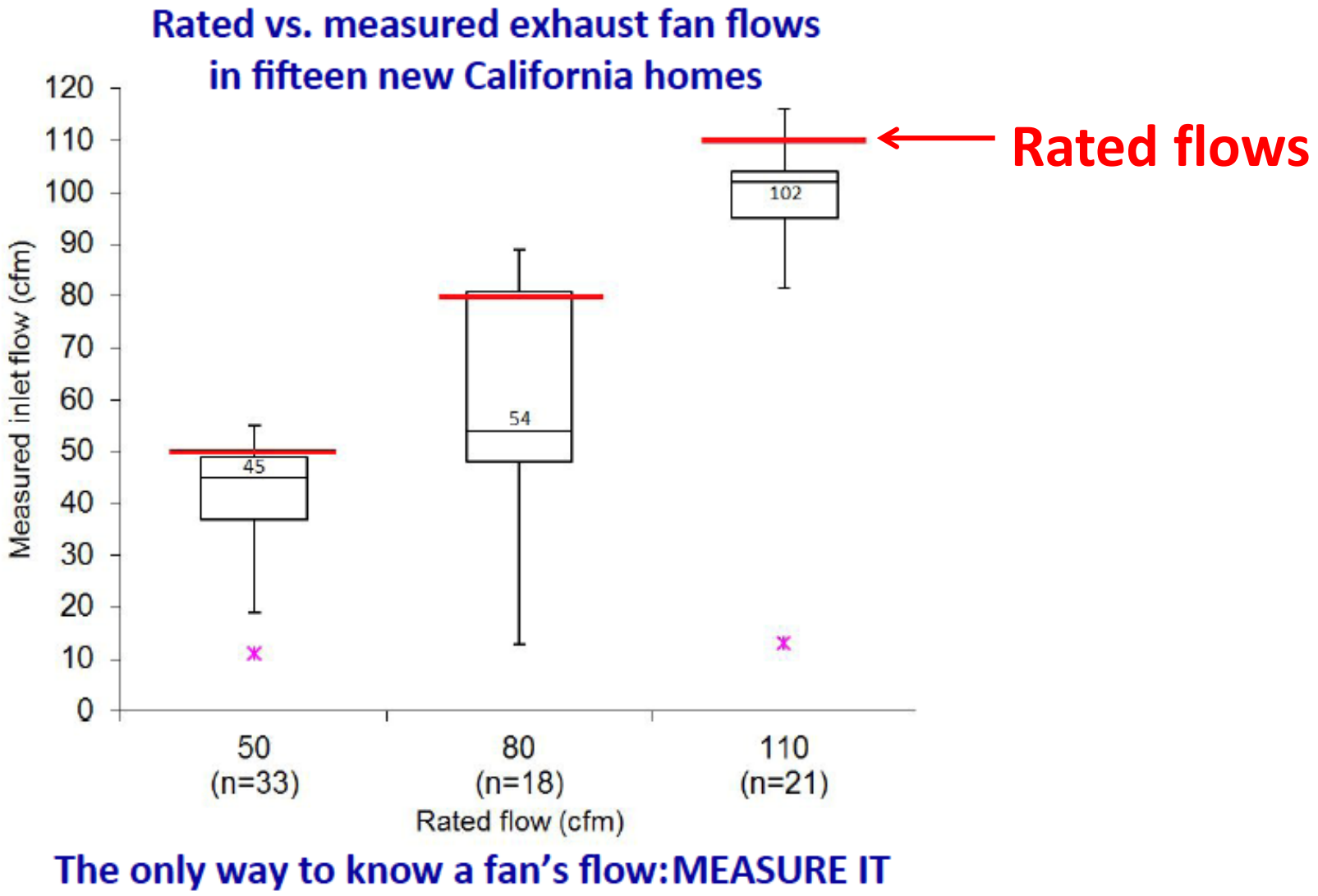
  Only 3 had ventilation airflows close to design targets

  2 of the 3 disabled by occupants

LBNL measured airflows in 15 new homes

* Sonne et al. (2015) Investigation of the effectiveness and failure rates of whole-house mechanical ventilation systems in Florida

LBNL Study of Ventilation System Airflows

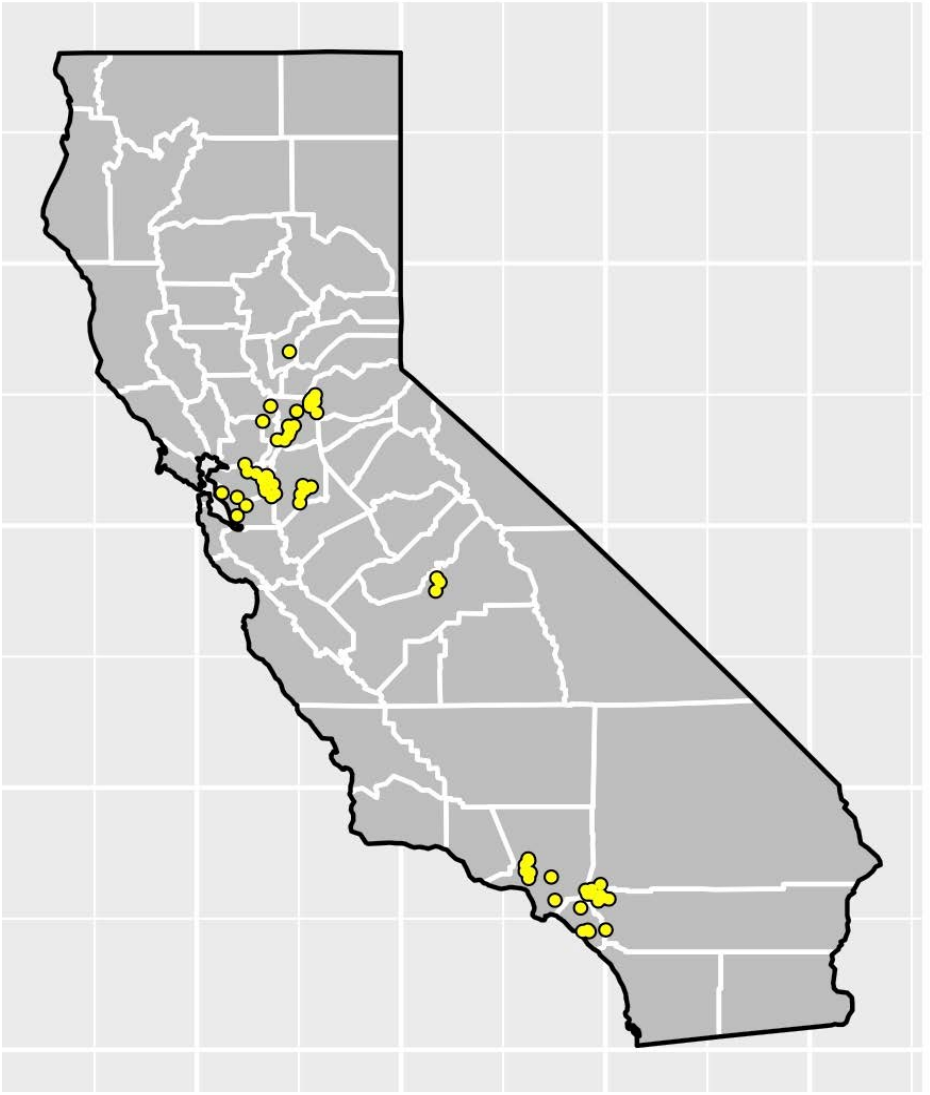


Stratton C. et al. 2012. Measuring Residential Ventilation System Airflows: Part 2 - Field Evaluation of Airflow Meter Devices and System Flow Verification. LBNL-5982E.

Healthy Efficient New Gas Homes (HENGH)

Field Study (2016–2018) of 70 New Homes

- All homes have mechanical ventilation
  - Whole house ventilation [ON]
  - Bathroom exhaust fan
  - Kitchen range hood exhaust to outside
- Indoor air quality, occupant activities and ventilation use monitored for one week in each home



IAQ Monitoring

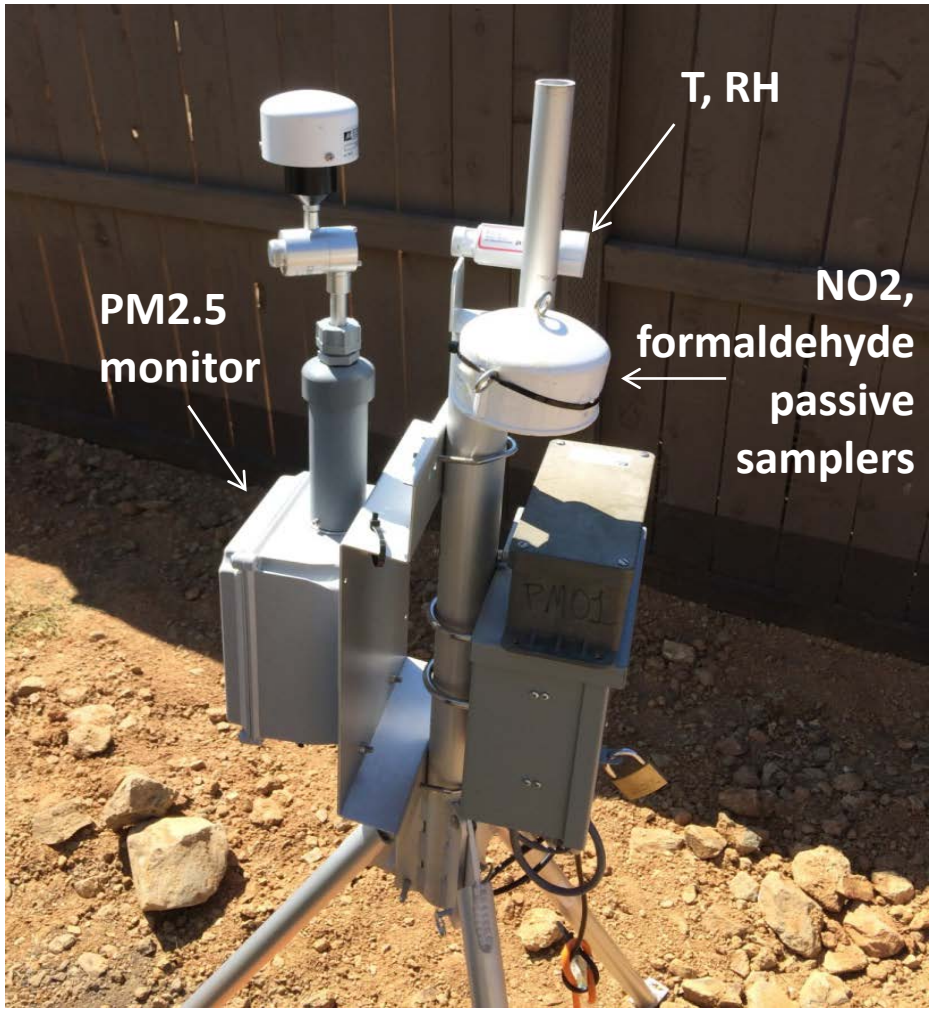
PM2.5

CO_2
T,
RH

NO_2

Formaldehyde

Concurrent Outdoor Monitoring

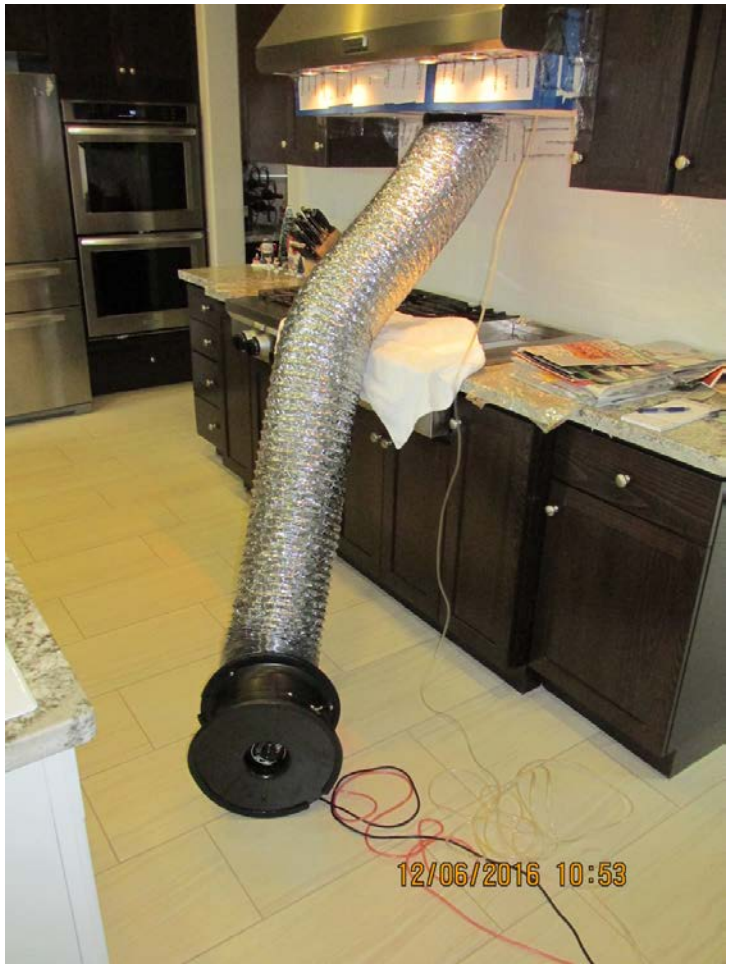


Diagnostic Testing

Envelope and Duct Leakage

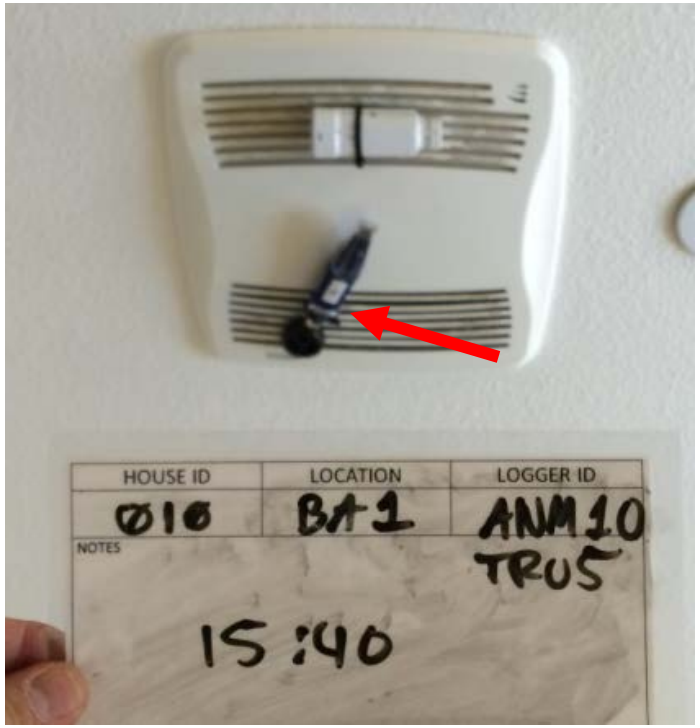
Exhaust Fan Airflow

Range Hood Airflow



Activity Monitoring

Range hood use

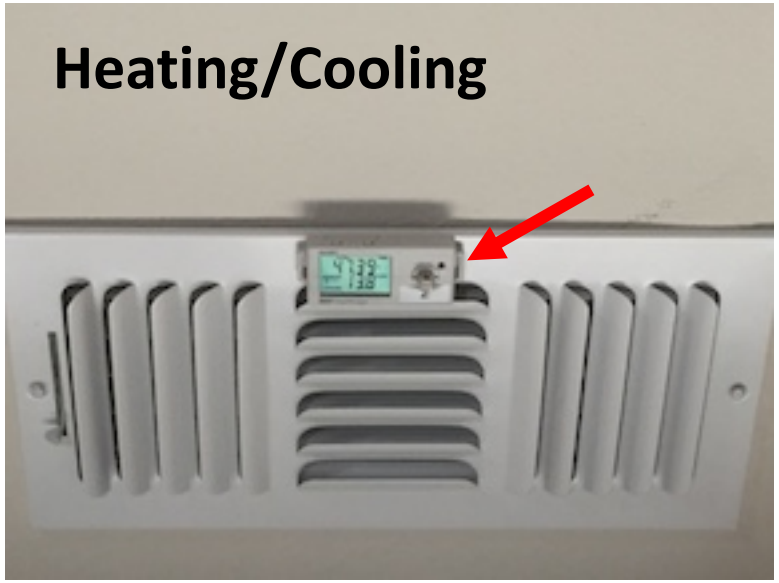


Exhaust fan use

Cooking (cooktop, oven)

Activity Monitoring

External door use (patio, garage)



Clothes dryer

Occupant Survey and Activity Log

B. Air Quality In and Around Your Home

7. To what extent are you satisfied or dissatisfied with the indoor air quality in your home?

Very Dissatisfied				Neutral				Very Satisfied
☐	☐	☐	☐	☒	☐	☐	☐	☐

8. How would you rate the outdoor air quality near where you live?

Very Poor				Neutral				Excellent
☒	☐	☐	☐	☐	☐	☐	☐	☐

9. How would you rate your home in protecting you from outdoor air pollution?

Very Ineffective				Neutral				Very Effective
☐	☐	☐	☒	☐	☐	☐	☐	☐

C. Comfort Level in Your Home

10. In winter, how often is the temperature in your home uncomfortable to any occupants because some room(s) are too hot or too cold?

	Never	Few times a year	Few times in a month	Few times a week	Every day
Too hot in some room(s).	☒	☐	☐	☐	☐
Too cold in some room(s).	☐	☐	☐	☒	☐

11. In summer, how often is the temperature in your home uncomfortable to any occupants because some room(s) are too hot or too cold?

	Never	Few times a year	Few times a month	Few times a week	Every day
Too hot in some room(s).	☐	☐	☐	☒	☐
Too cold in some room(s).	☒	☐	☐	☐	☐

Healthy Efficient New California Homes Study
Occupancy and Indoor Activities Data Log

Instructions: Please fill out this data log each day, or on the following day.

Please enter you estimates. If you are unsure vide your best guess.
Do not list nes of any people.

Code number for home 13

Day 1: Date 11-30-16 Date completed 11-30-16

	Midnight to 7am	7am to 11am	11am to 1pm	1pm to 5 pm	5pm to 9pm	9pm to Midnight
Number of people in home	2	4	4	2	2	2
Cooktop use Number of minutes	0	30	0	0	.45	0
Oven use Number of minutes	0	0	0	0	0	0
BBQ/outdoor grill Number of minutes	0	0	0	0	0	0
Vacuuming Number of minutes	0	0	0	.25	0	0
Window Use Number of minutes	0	0	0	0	45min 0	0
Other notable* indoor/outdoor events	3 aircleaners 24/7			carpet & floor clean		0

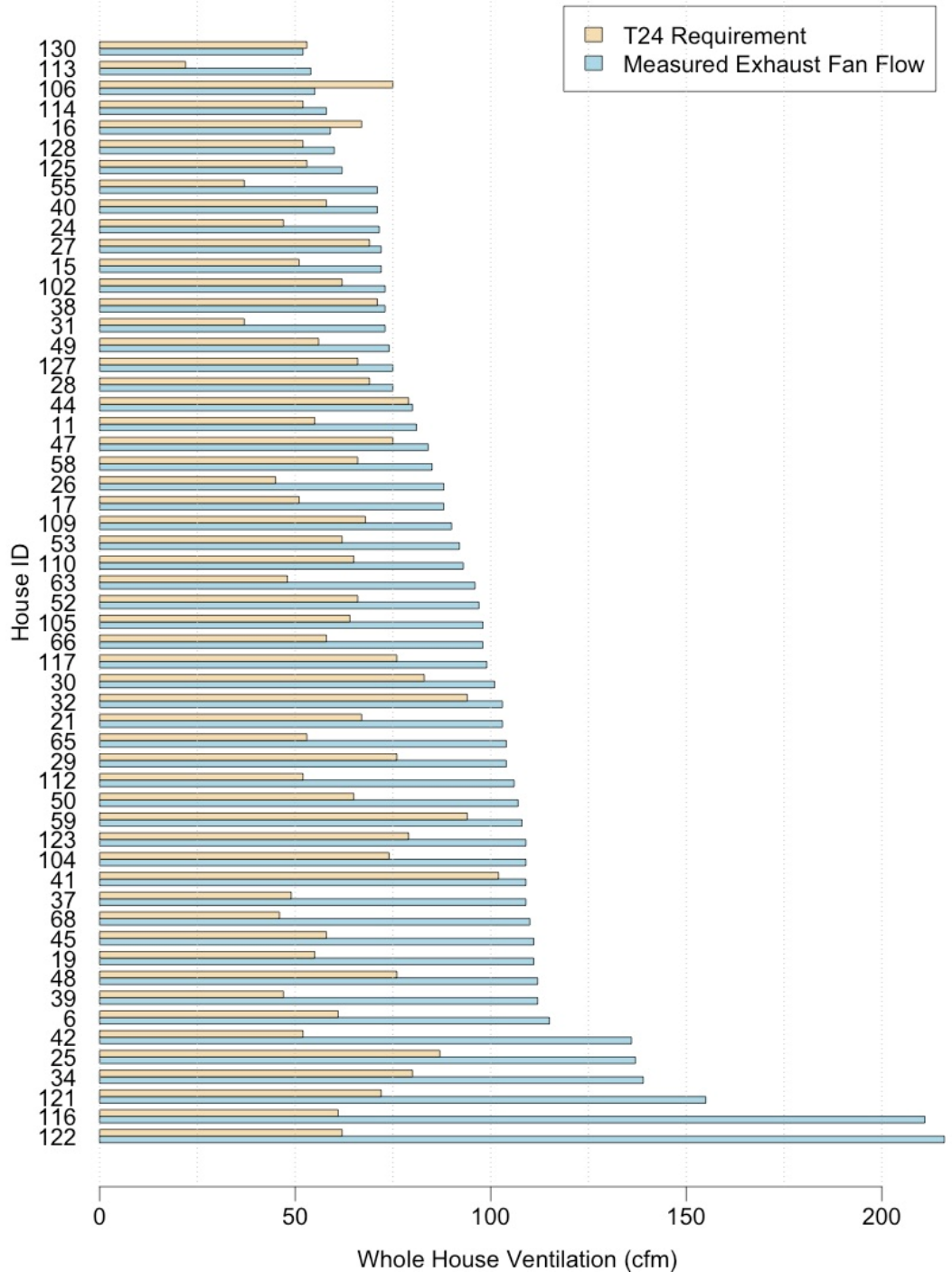
*For example, use of fireplace, candle, air freshener, air cleaner, humidifier, unusual outdoor air quality (wood smoke, wildfire), and so on.

Whole-House Mechanical Ventilation

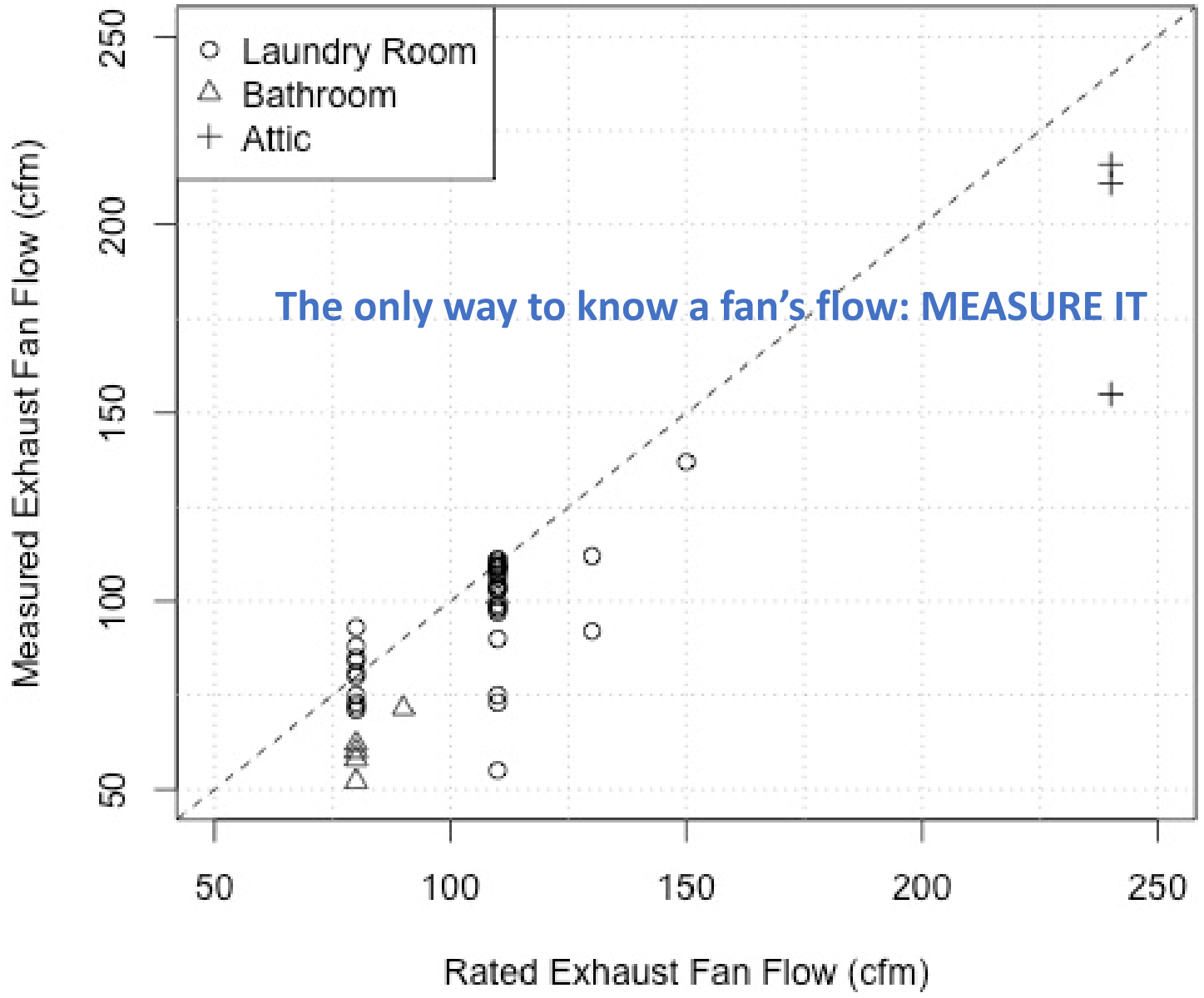
In most cases, the measured airflow of the exhaust fan exceeded the required whole-dwelling ventilation needs.

- Continuous exhaust (N=55)
- Intermittent exhaust (N=9)
- Continuous inline fan connected to central forced air system (N=4)
- Supply ventilation provided by central fan integrated system with a motorized damper (N=2)

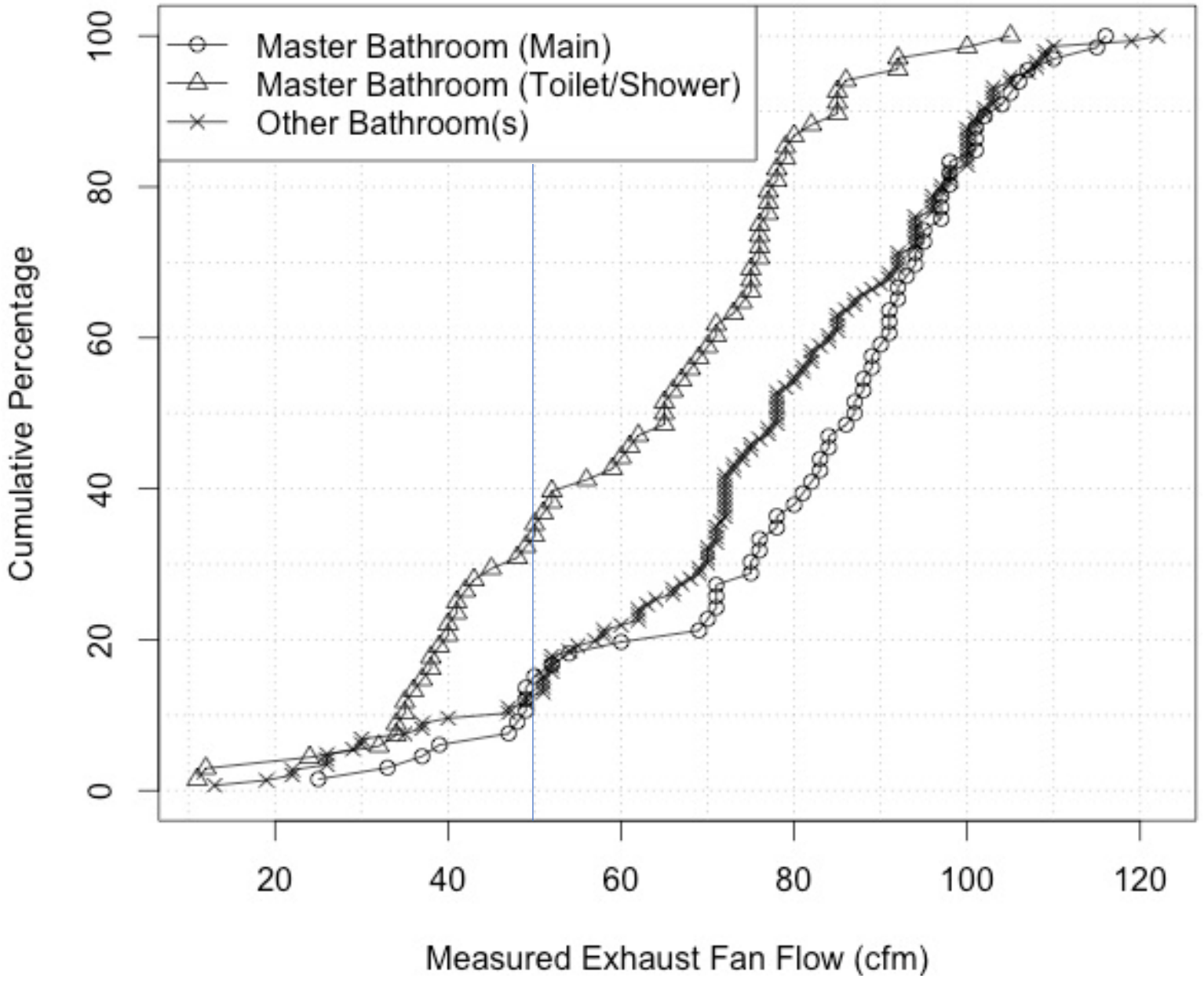
Comparison of measured exhaust fan flow and Title 24 mechanical ventilation requirement (N=56)



Rated versus measured exhaust fan airflows (N=56)

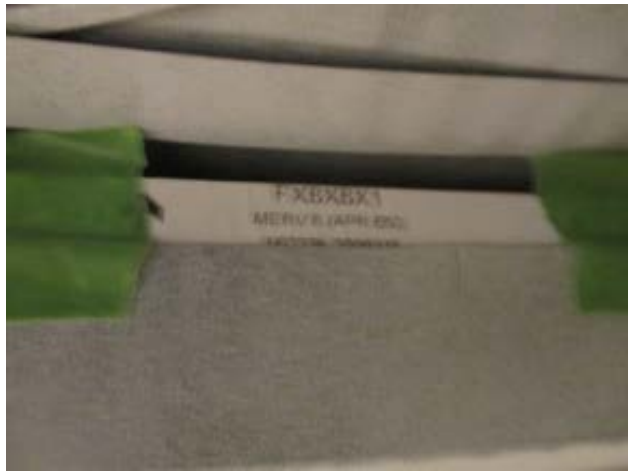


Bathroom exhaust fans mostly meeting 50 cfm airflow requirement (intermittent)



Supply Ventilation

Supply Ventilation Air Filter



Only **1** in **4** homes with whole-house ventilation system running as found.

Whole-House Ventilation Control	Controller Labelled?	% On As-Found
On/Off Switch	No (N=42)	5%
	Yes (N=12)	58%
Programmable Controller	No (N=10)	50%
Thermostat	No (N=2)	0%
Breaker Panel	No (N=1)	100%
No Controller	No (N=3)	100%

Whole House Ventilation Control. Leave on except for severe outdoor air quality.

To maintain minimum levels of outside air ventilation required by the State of California, this fan should be on at all times when the building is occupied, unless there is outdoor air contamination.

Continuous Duty

ASHRAE Guideline 24

Manual switches associated with a whole-building ventilation system should have a clear label such as,

*"**This controls the ventilation system of the home. Leave on except for severe outdoor contamination.**"*

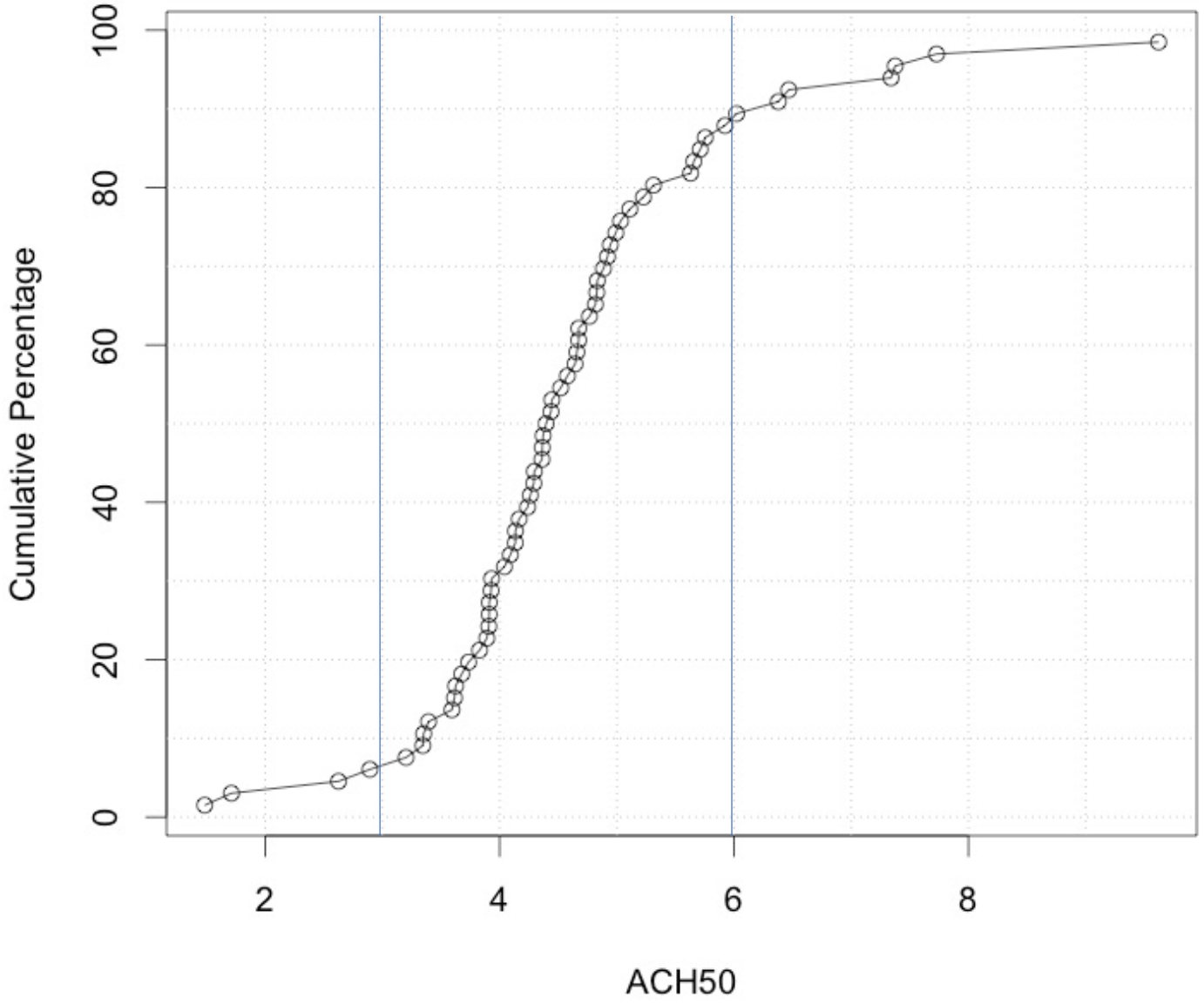
In addition, guidance on operations and maintenance procedures should be provided to occupants.


Keep fan
"ON" at
all times
except in
case of
outdoor air
contamination
or if home
is vacant
for more
than 7 days
05/24/2017 12:37

DeltaQ Test – Envelope and Duct Leakage Results

Envelope Leakage

- Most homes between 3 and 6 ACH50
- Only 4 out of 70 homes <3 ACH50, IECC 2018 requirement



Duct Leakage

Duct Leakage (DeltaQ*)	% of 70 Homes
<50 CFM	25%
50–100 CFM	30%
100–200 CFM	31%
>200 CFM	**14%**

*DeltaQ test measures duct leakage at working pressure, not at 25 Pa.

Data from HERS registry (CF-6R)

21 of 23 homes reported duct leakage measured at 25 Pa ranging between 50 and 100 CFM.

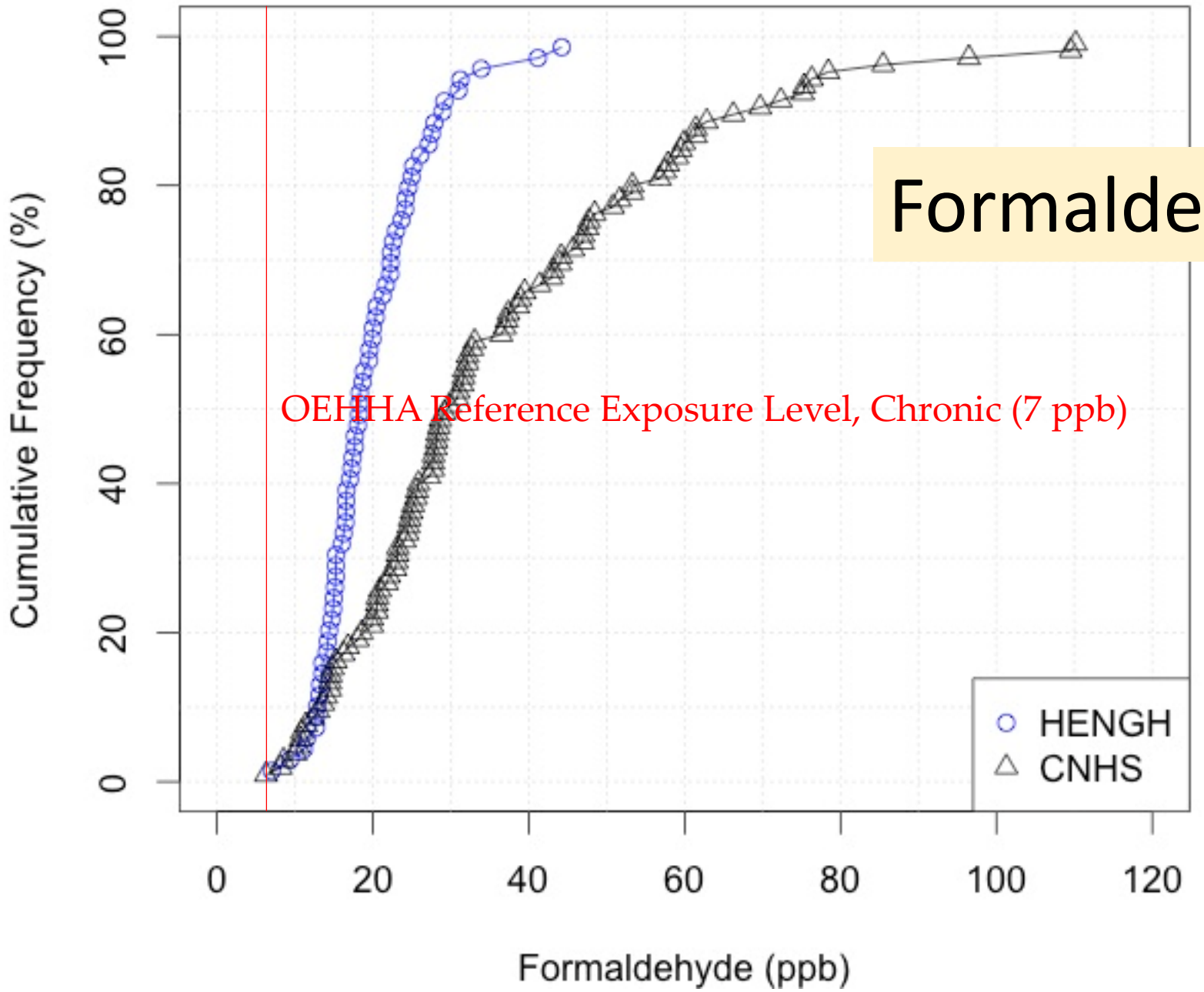
Indoor Air Quality Results

Comparisons of formaldehyde, $PM_{2.5}$, and NO_2 with a prior study of new homes in California suggest that contaminant levels are lower than measured from about 10 years ago.

Mean Indoor Concentration	HENGH	California New Home Study* (Offermann 2009)
Formaldehyde	19.8 ppb	36.3 ppb
$PM_{2.5}$	8.3 $\mu g/m^3$	13.3 $\mu g/m^3$
NO_2	6.1 ppb	5.4 ppb

*Almost all homes (98%) use electric ranges for cooking.

Formaldehyde



Formaldehyde Emission Standards

California Environmental Protection Agency | AIR RESOURCES BOARD

FREQUENTLY ASKED QUESTIONS FOR CONSUMERS

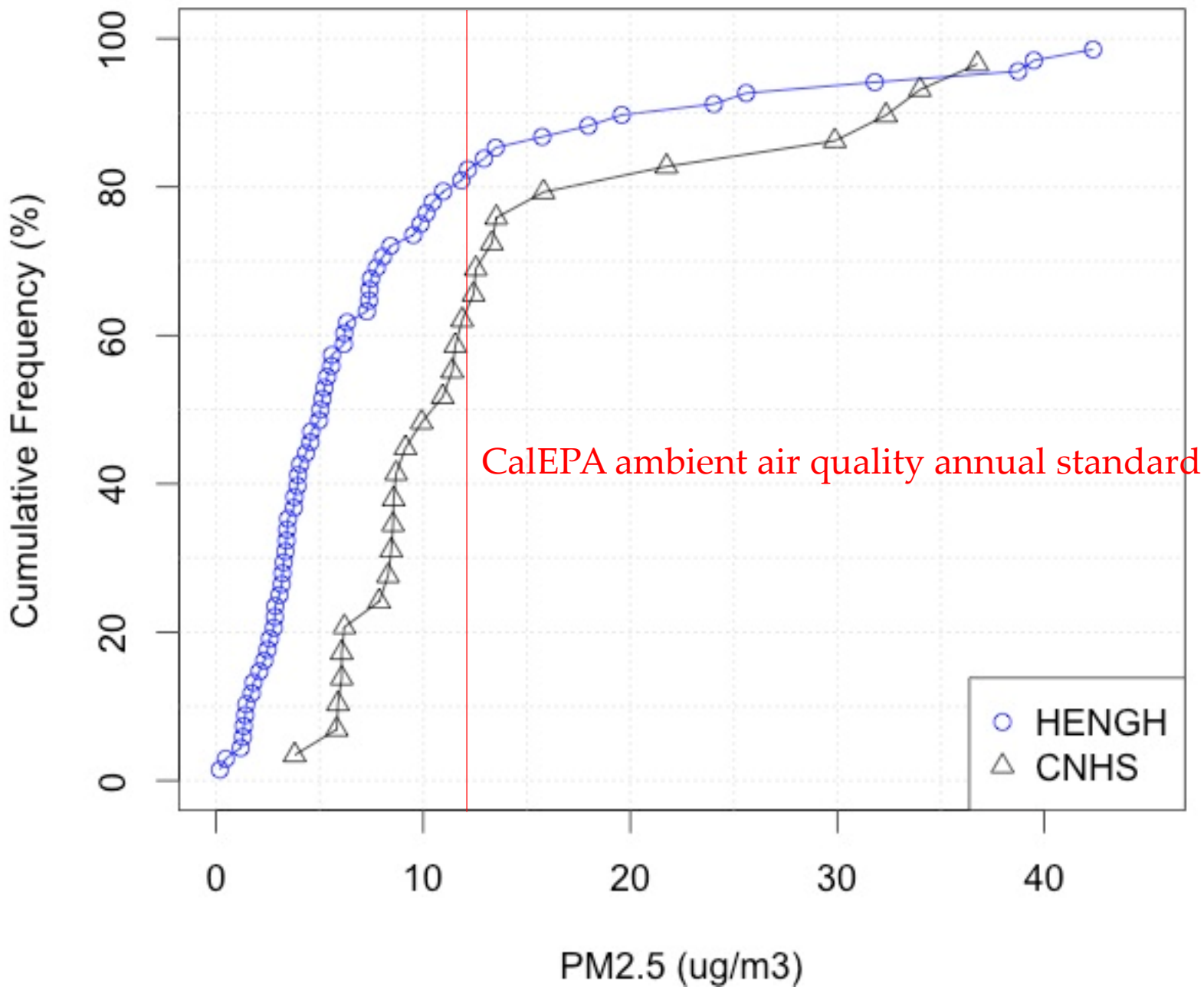
REDUCING FORMALDEHYDE EMISSIONS FROM

Composite Wood Products

The ATCM to control formaldehyde emissions from composite wood products became effective January 1, 2009.

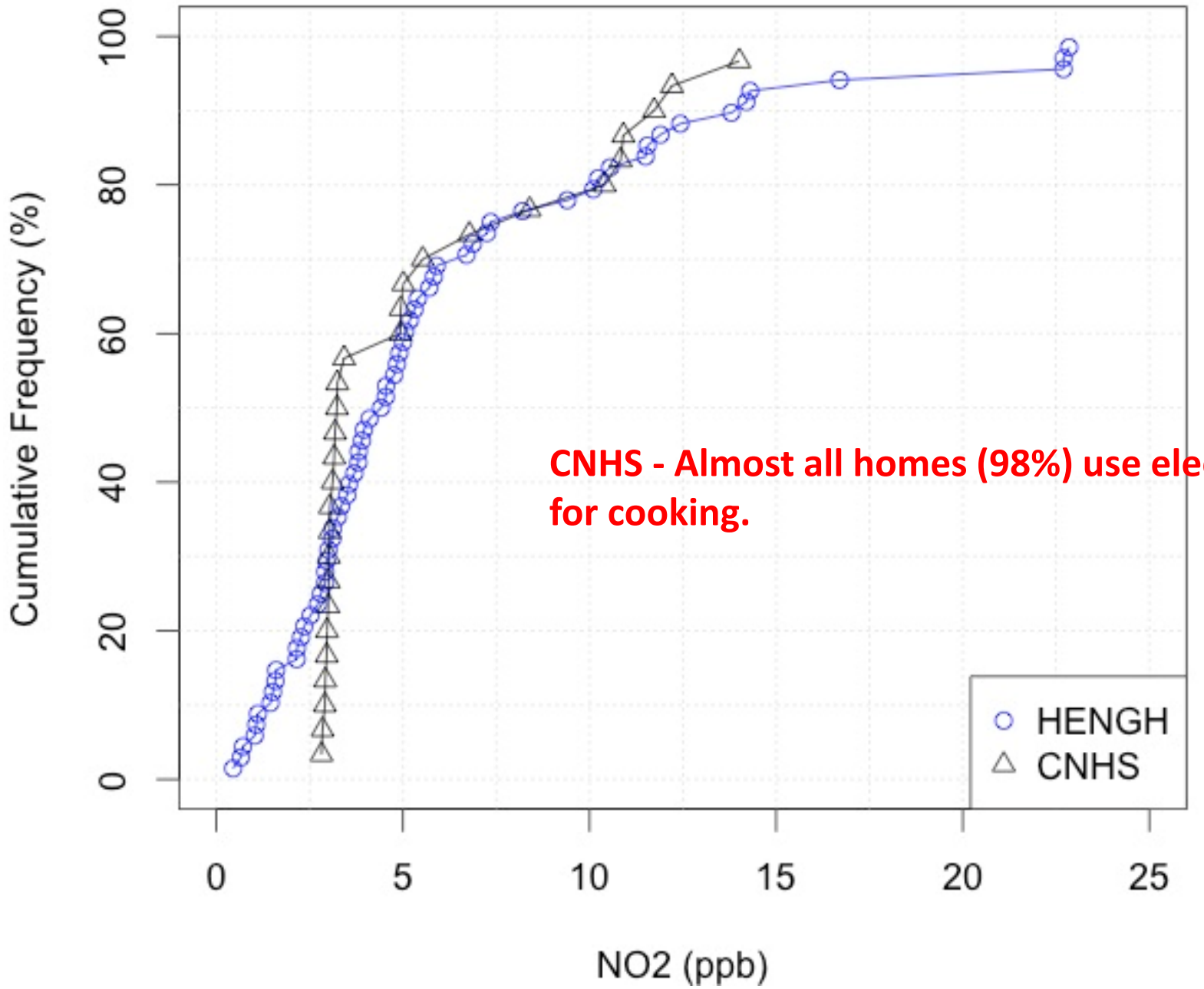
https://www.arb.ca.gov/toxics/compwood/compwood.htm

PM2.5



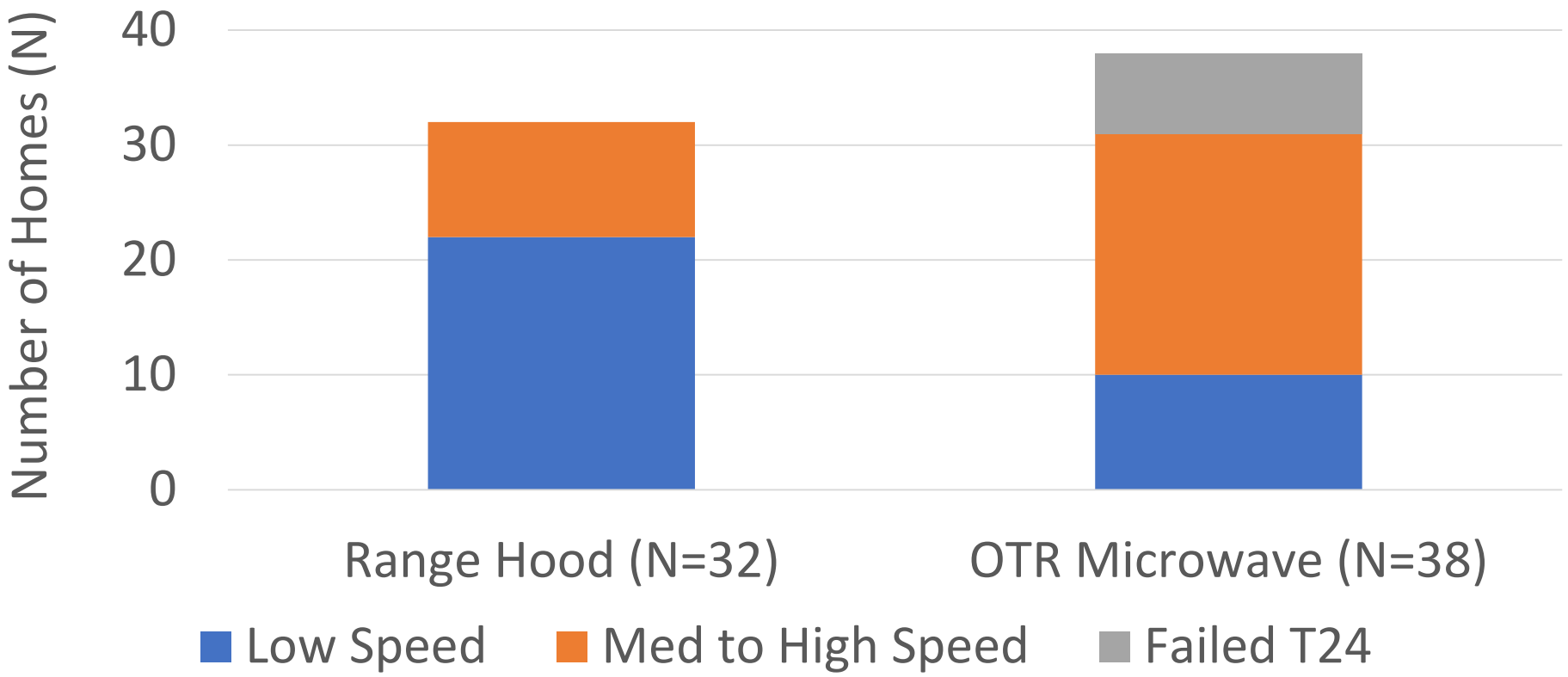
CalEPA ambient air quality annual standard = 12 ug/m^3

NO2



CNHS - Almost all homes (98%) use electric ranges for cooking.

HENGH – All kitchen range hood exhaust to outside, most met Title 24 (100 cfm)



HENGH – Particle Filtration

- Exhaust ventilation in homes with reasonably tight building envelope
- Medium to high efficiency air filters

MERV Rating	Number of Air Filters (N=112)
6 - 7	4
8	57
10	18
11	22
12	1
13	9
14	1

Other Results

- AER
  - Comparison with CNHS that 2/3 of homes with overall AER below 0.35/h
- Time-resolved formaldehyde and NO2
  - Formaldehyde levels during occupied versus unoccupied
  - NO2 from cooking, with and without range hood use
- CO2
  - Overnight concentrations in excess of 1100 ppm in some homes
- T, RH
  - Comparison with self-reported comfort satisfaction

Problems Affecting Occupant Comfort a Few Times per Week or More Frequently	Field Study (N=70)	HENGH Survey (N=2271)
Too hot in summer	31%	41%
Too cold in winter	29%	20%
Not enough air movement	21%	18%
Too hot in winter	14%	10%
Indoor air too dry	9%	11%
Too cold in summer	4%	9%
Too much air movement	1%	5%
Musty odor	1%	3%
Indoor air too damp	1%	2%

Building America IAQ New Home Study

- Collect IAQ data in 32 homes each in four climate zones
  - Portland, OR
  - Boulder/Denver, CO
  - Southeast: FL, AL, GA, NC, SC
- Regional variations in system designs, performance, and occupant behaviors

Building America
U.S. Department of Energy

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Motivating Questions

- What is the IAQ in new homes with/out mechanical ventilation?
- What ventilation equipment is provided in new U.S. homes designed (or not) to comply with ASHRAE 62.2?
- What are airflows as installed?
- Do designs and performance vary by climate zone?
- Are there discernible differences in IAQ between homes that meet / don’t meet 62.2?
- How do people use ventilation? Is it discernibly relatable to IAQ?

Study Scope

- Characterization
  - Envelope & duct airtightness
  - MV equipment – rated and measured flows
- One-Week Monitoring
  - Use of ventilation equipment and natural ventilation
  - Time-resolved pollutant concentrations & environmental parameters
    - $PM_{2.5}$, formaldehyde, CO_2, T, RH
  - Time-integrated
    - NO_2, $PM_{2.5}$ mass (filter)

In addition to HENGH

- SVOCs
- Radon
- T/RH in attic, basement, crawlspace
- Consumer-grade IAQ sensor

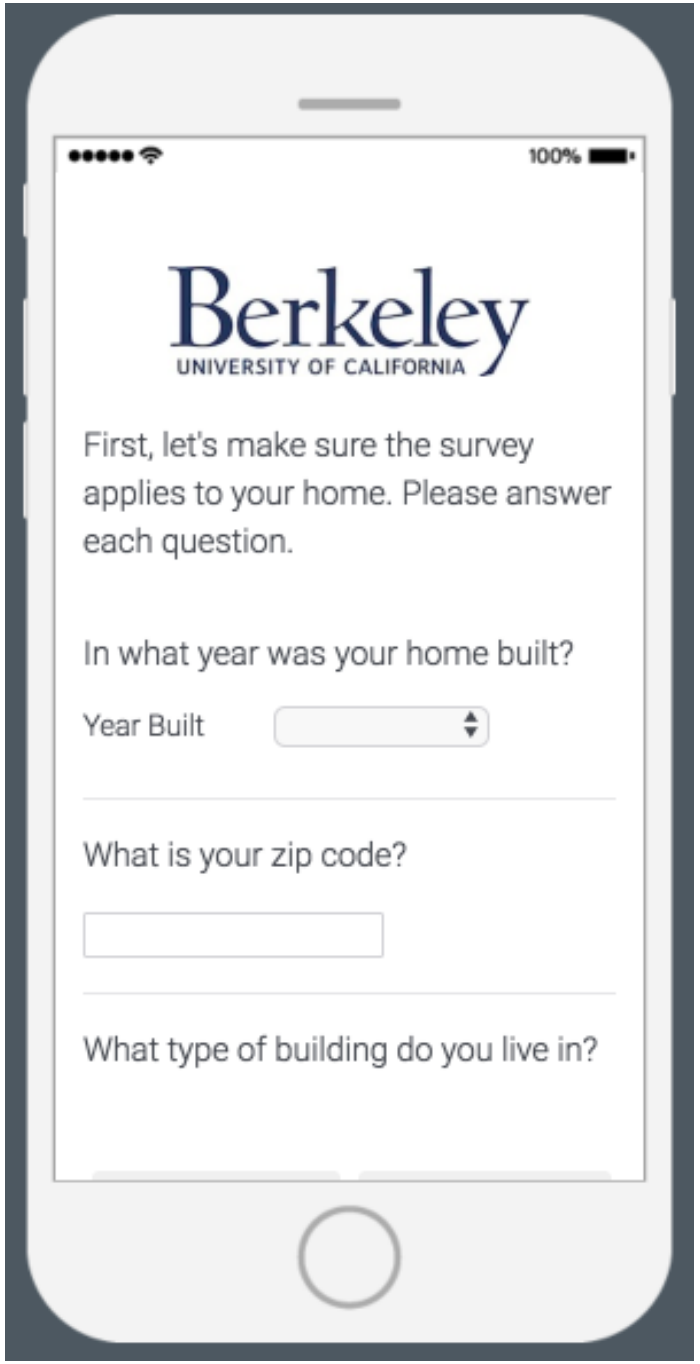
Analysis Plan

- Investigate associations of humidity and contaminants with controls
  - ASHRAE 62.2 compliant mechanical ventilation
  - Envelope air tightness
  - Mechanical system commissioning
  - Other factors (low-emitting materials, ventilation system use, etc.
- Characterize variations of equipment, usage, and IAQ by climate zone & home type

Berkeley Lab Indoor Air Quality Survey

Our goal is to learn how people like you ***feel*** about your home environment and about the factors that can affect your indoor air quality, or "IAQ".

The survey asks about your satisfaction, perceptions, activities and product use. There are also questions about your home and household.



The data from these studies will inform builders and manufacturers, as well as industry ventilation standards and code provisions, to better protect **indoor air quality** and **health** as building infiltration is reduced to **save energy**.

Field Studies of Indoor Air Quality in New U.S. Homes

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Q&A Session

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