Indoor Air Quality

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NSF BEST Center – National Workshop

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Current Work at LBNL

Building America Program - a DOE/National Lab/Industry Partnership

On-line high performance home resources at: buildingamerica.gov

BA Solutions Center has contracting documents & specifications, installation guidance, codes and labeling program info, training videos, etc.

basc.pnnl.gov

- Also supported by California Energy Commission, EPA, & HUD

Building America Education

Energy.gov/eere/building-science-education

ENERGY.GOV
Office of Energy Efficiency & Renewable Energy

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The U.S. Department of Energy's (DOE) Building America program recognizes that the education of future design/construction industry professionals in solid building science principles is critical to widespread development of high performance homes that are energy efficient, healthy, and durable.

In November 2012, DOE met with leaders in the building science community to develop a strategic **Building Science Education Roadmap** that will chart a path for training skilled professionals who apply proven innovations and recognize the value of high performance homes. The roadmap aims to:

Students study moisture building enclosure issues at the Coquitlam Field Test facility in Vancouver, British Columbia. Credit: John Straube

- Increase awareness of high performance home benefits
- Build a solid infrastructure for delivering building science education
- Conduct the **DOE Zero Energy Ready Home Student Design Competition** that complements DOE's Solar Decathlon building competition and emphasizes practical, high performance homes that can be implemented by the home building industry.

Building America Education

“Race to Zero” Student design competition

- Inspire and develop the next generation of building science professionals.
- Advance and enhance building science curriculum in universities.
- Complement the experiential learning benefits provided by the U.S. Department of Energy Solar Decathlon through an additional collegiate competition opportunity

Why is IAQ important?

- Good IAQ an essential part of a high performance home
- Higher performance homes have less air leakage for energy reduction – needs to be balanced against dilution and removal of pollutants
- Current work health focused – odor and moisture still important

Research Issues:	**New Industry Skills:**
Determine the hazards and their health impacts	Ability to identify the hazards and discuss health impacts
Find optimum solutions for health vs. energy	Understand how to optimize health vs. energy
Develop codes and standards for industry	Understand and follow codes and standards
Create new technologies and develop best practices	Understand and use new technologies & best practices

Indoor Hazards: Biological agents

Indoor Hazards: Chemicals

Indoor Hazards: Combustion

What are the most important contaminants?

- We live in a complex soup of many agents
- Combine health effects and exposure to get Disability Adjusted Life Years: DALYs

Top 3:

1. PM2.5
2. Formaldehyde
3. NO_2

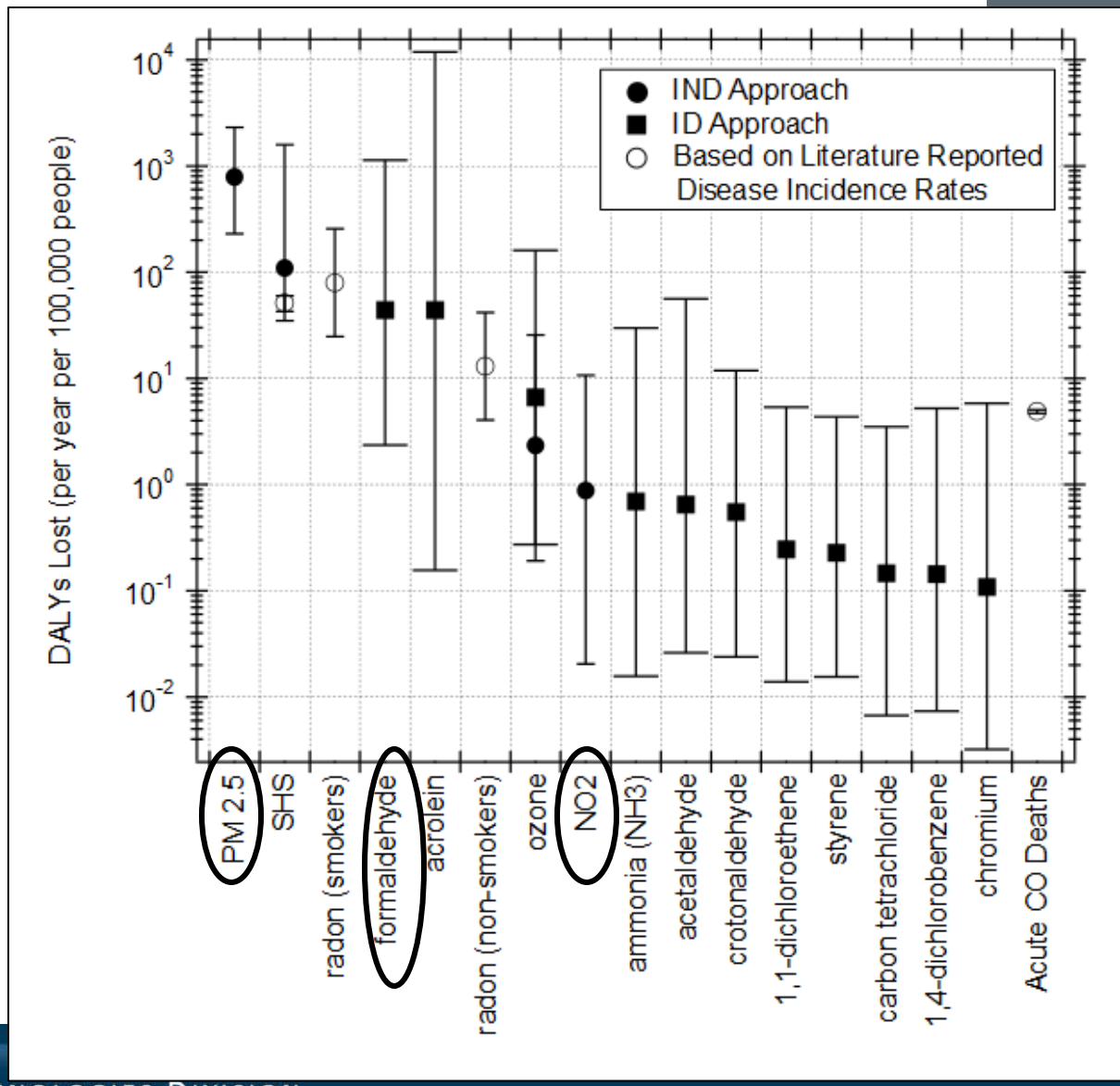


Image source: Logue et al. (2012)

Outdoor Sources

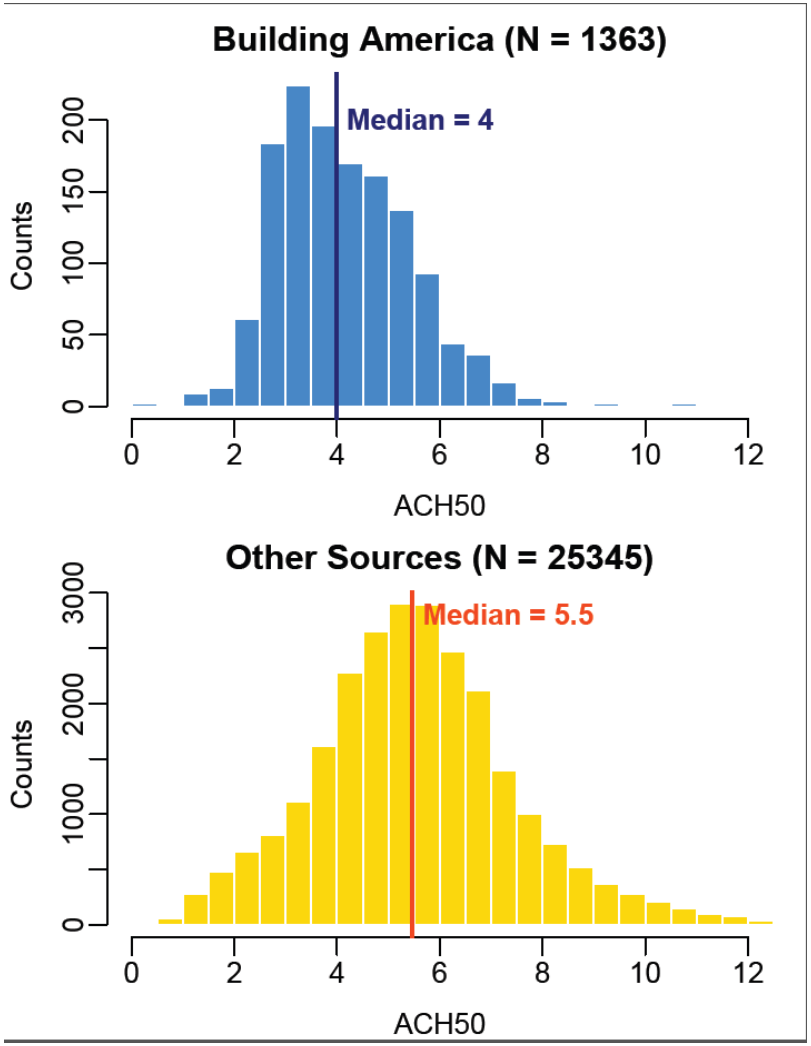
More Ventilation is not always better

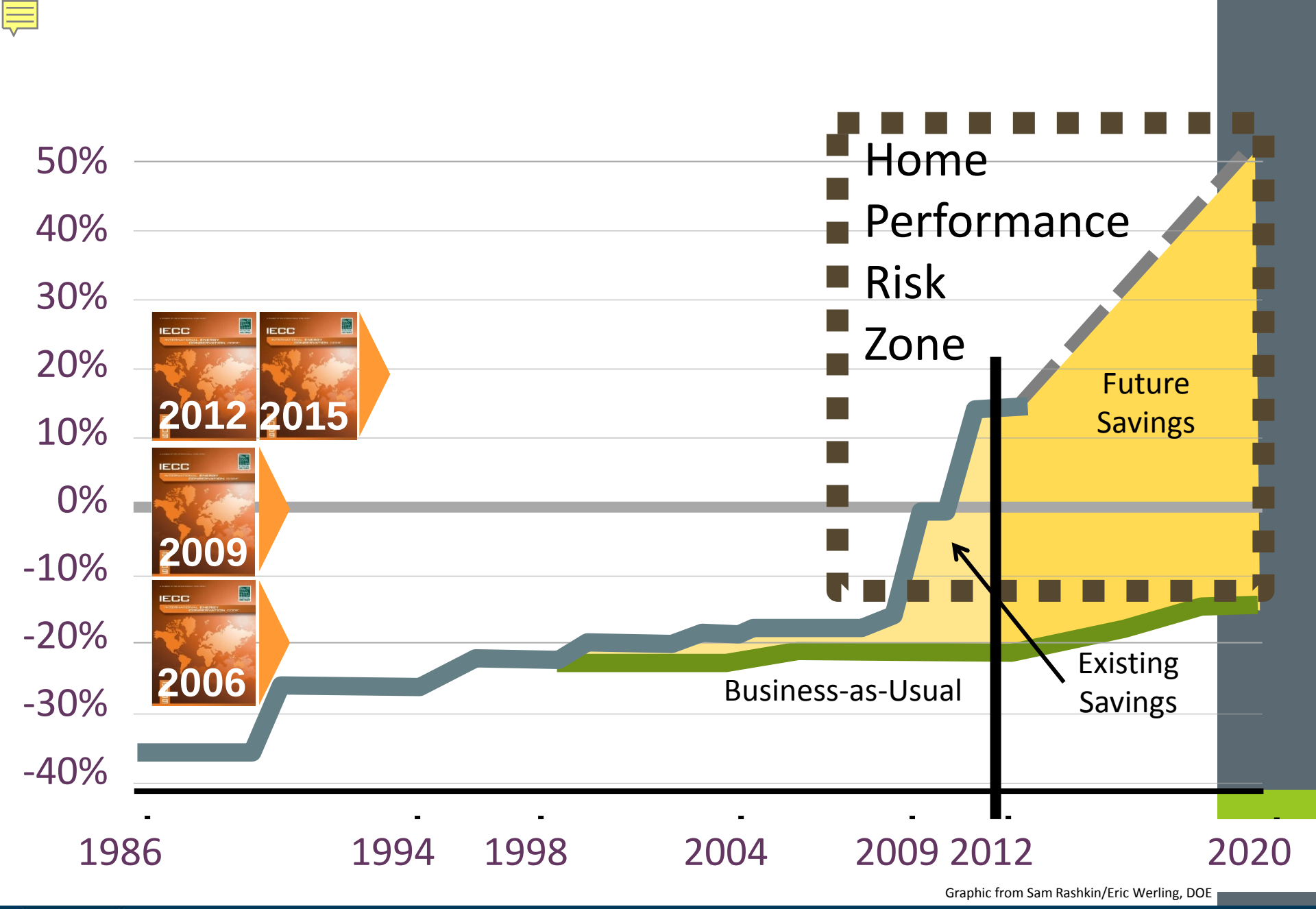
- Outdoor pollutants (e.g. ozone, $PM_{2.5}$) pose a serious health risk

- Certain times of day elevated levels of pollutants in outdoor air
- If outside air worse than indoor air negative energy & health benefit
- Shelter in place for rare outdoor air events – gas well blow out, chemical factory explosion, etc.

Houses getting tighter

- LBNL Air Leakage Database > 120,000 air leakage tests
- Mechanical ventilation becoming more important as homes get tighter for energy reduction and comfort
- 2012 IECC requires <3 ACH50
- R2000 requires <1.5 ACH50





Graphic from Sam Rashkin/Eric Werling, DOE

Indoor Source Control

- Current LBNL/DOE/BA activities:
  - Kitchen ventilation: cooking generates moisture, PM2.5, acrolein, NO2, etc.
  - Spilling combustion appliances (mostly a CO issue)
  - High performance filtration

- Other relevant issues:
  - Bathroom exhaust: moisture removal (+ cleaning products)
  - Reduce Emissions: e.g., formaldehyde legislation in place in CA and soon will be Federal
  - Radon – already a well developed Radon control industry with good technical approaches – studied by LBNL 25-30 years ago

Source Control—Cooking

- Moisture & CO_2
- NO_2 and formaldehyde
- Particles & CO

- Particles

- Particles
- VOCs including acrolein
- Moisture and odors

Removing cooking pollutants

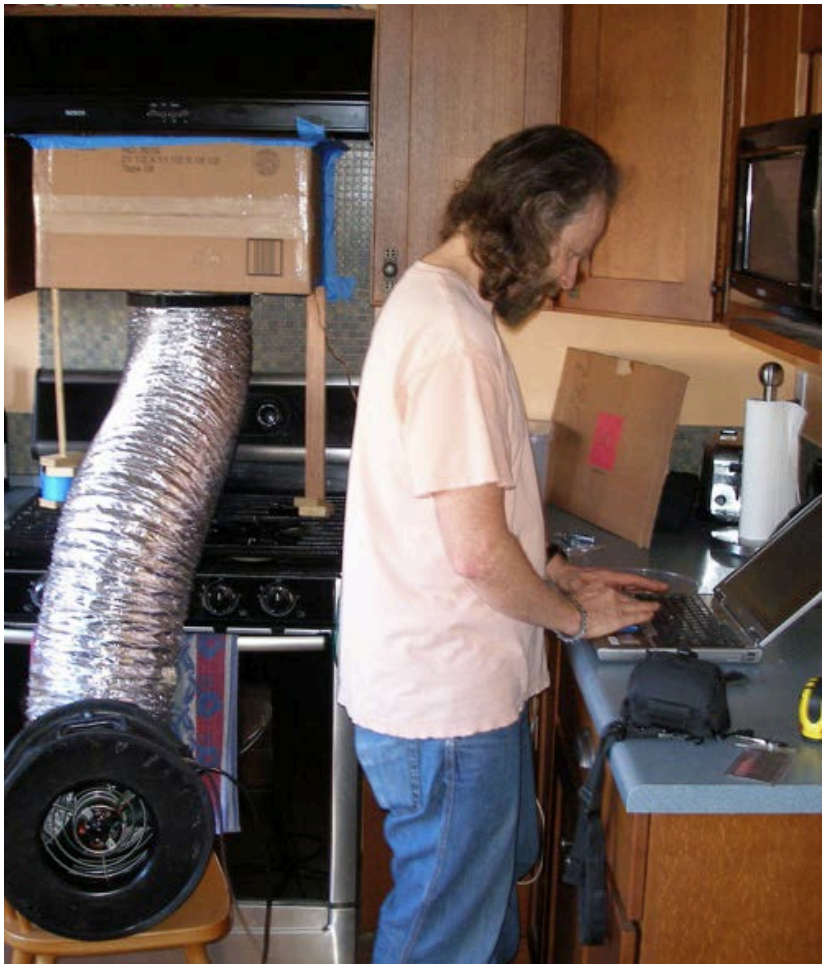
The effectiveness of range hoods at capturing cooking pollutants is called capture efficiency.

LBNL Currently developing ASTM test method with manufacturers – laboratory rating NOT “in-home”

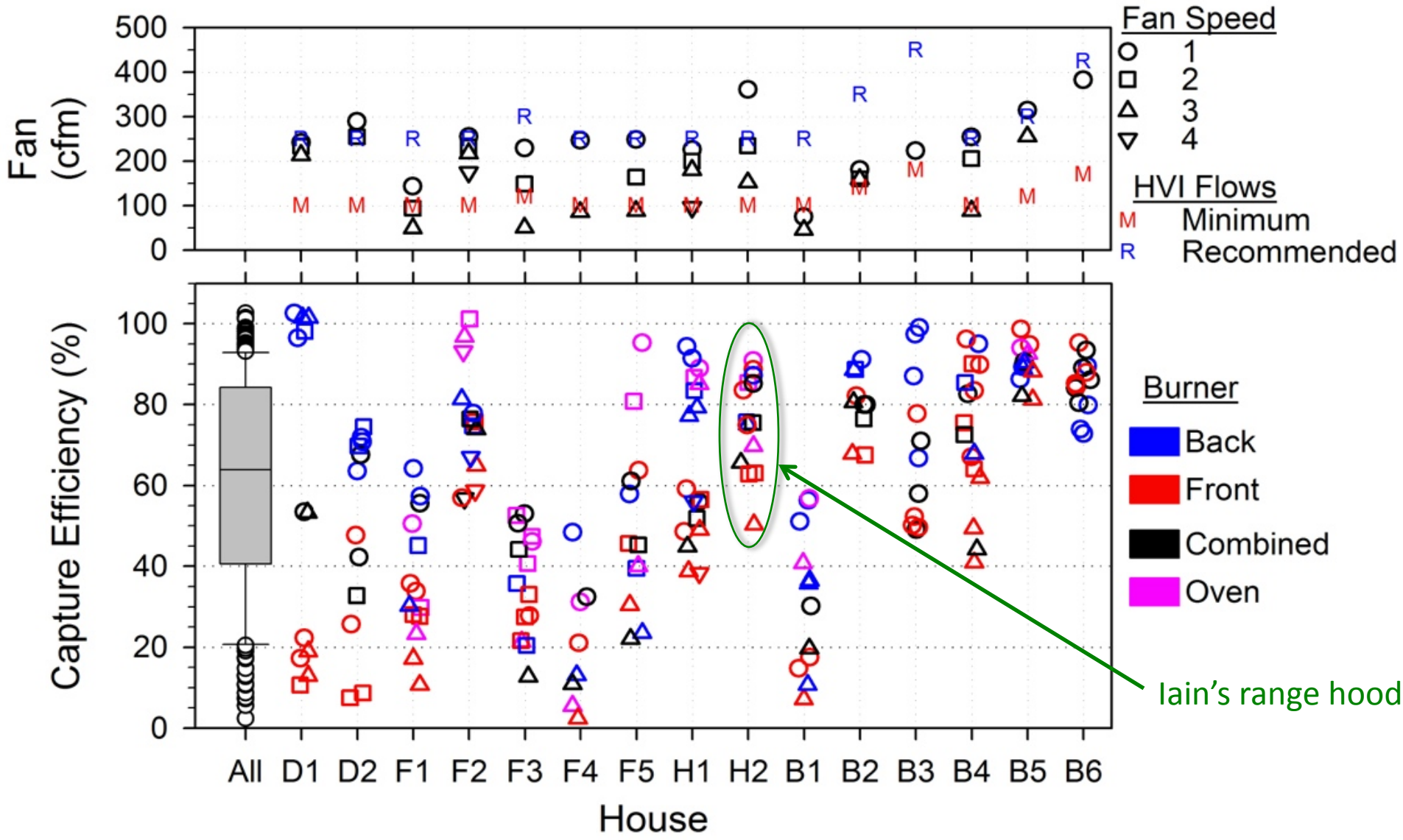
Testing in Homes

Sampling CO2 from gas burners

Measuring air flows with active flow hood



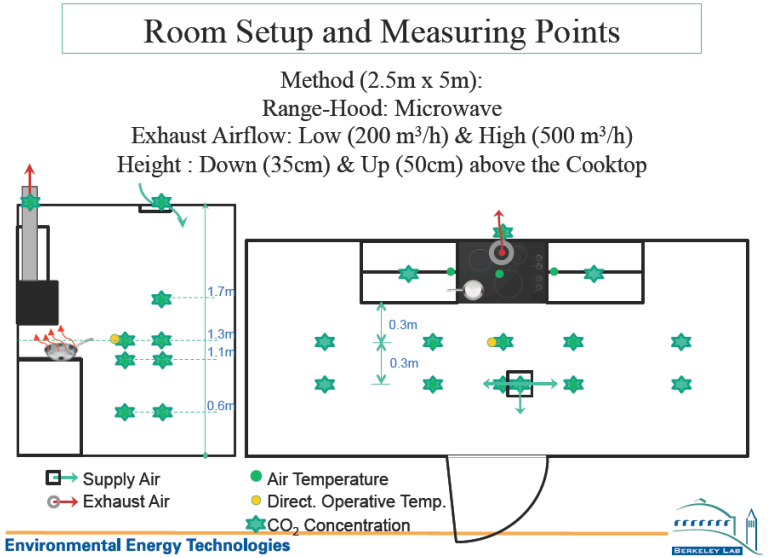
In-Home Performance Varies



Kitchen Ventilation

- Lab experiments to support standard test for effectiveness rating and investigate equivalence of low exhaust flow, recirculating air cleaning devices
- Work with manufacturers on product improvements
- Create guidance on best practices – includes European AIVC collaboration

LBNL Kitchen and Range Hood Lab



Kitchen Ventilation Recommendations

- Install range hoods vented to outside
  - Hood **covers all burners**
  - Hood is **not flat bottomed**
  - Airflow of **200 cfm**—MEASURED
  - 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
- Need to evaluate efficacy of recirculating hoods with charcoal filters
  - Not all contaminants removed
  - How good is combinations of charcoal filter + general kitchen ventilation for moisture?
- Automation? More complex … but we **know** it works..

Source Control - Combustion Safety: Carbon Monoxide

Sources: non-direct vented gas burning appliances: furnaces, water heaters (ovens?)

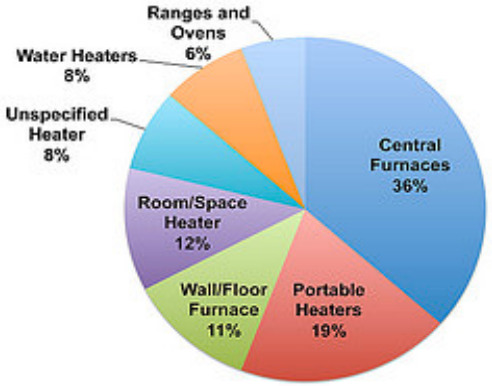
Poor combustion leads to CO production

Tight home plus depressurization from exhaust fans (kitchen, bathroom, clothes dryer), other appliances and fireplaces leads to combustion products coming into home instead of up the flue

Current Practice for evaluating CO is poor:

- Excessively conservative hazard threshold fails many homes with miniscule or no risk
- Failures require expensive, unnecessary mitigations or limit air sealing
- Complex and time consuming procedures

Home CO poisoning

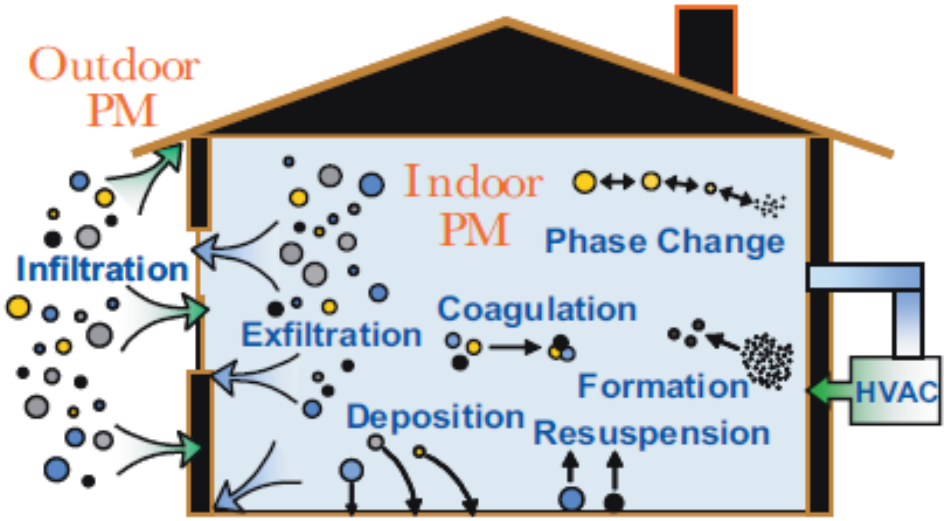


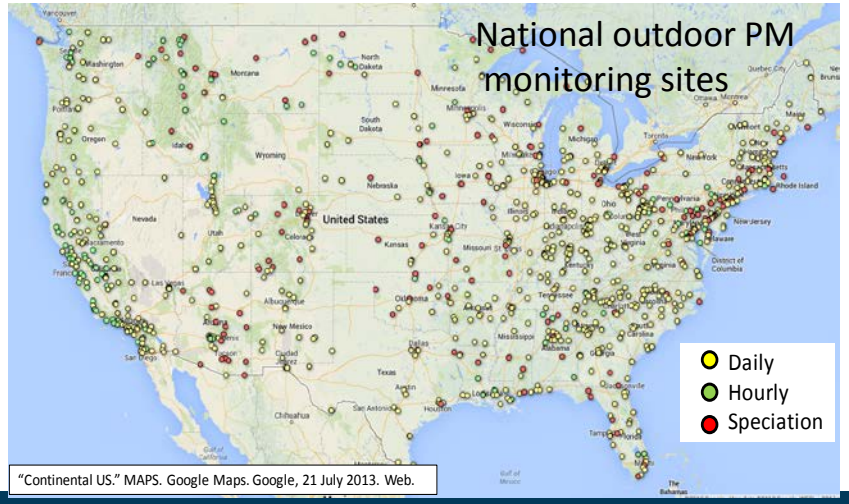
Combustion Safety Testing

- Key test components for reducing risk:
  - Visual inspection of appliance and vent system
  - CO test
  - Draft test
- In existing field studies burner cleaning and repair plus repair of poor venting resolved most problems
- Collaborative effort with industry: AHRI, GTI, NFPA and other Building America Teams & researchers
- We are working with standards and training organizations (Building Performance Institute, RESNET, ACCA, AHRI, GTI) to change combustion safety testing training and requirements

High Performance Filtration

- Examine tradeoff between equipment costs, energy use and health improvements
  - Allow tradeoffs in standards – proposed language for ASHRAE 62.2
  - Technical background for requirements in codes and standards for minimum filter requirements



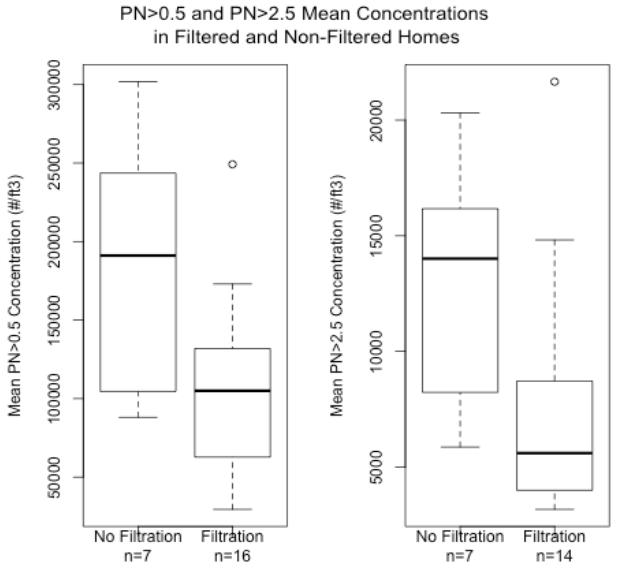


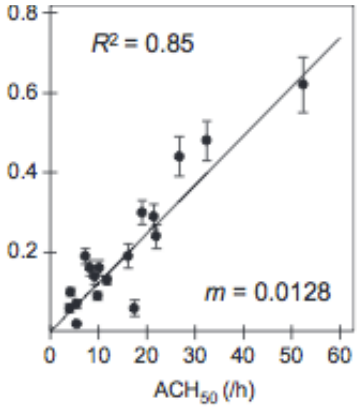
Source Control - Filtration

Combine modeling with field data

Recommendations:

- Central forced air system and supply ventilation At least MERV 13 preferably MERV14 or greater
- Need to limit air flow resistance – get it included in filter rating and labeling
- Tight homes are good particle filters for ***Exhaust*** ventilation:
  - 1.5 ACH_{50} = 2% penetration = MERV16





Whole house ventilation

- For everything else that isn't a fixed source
- Has biggest energy impact – always operating
- LBNL research on "***Smart Ventilation***":
  - Use control systems to:
  - Sense operation of other fans and account for their contribution
  - Time shift ventilation to
    - Ventilate when temperature differences are smallest
    - Avoid peak times when energy grid loads are highest
    - Reduce ingress of outdoor pollutants by not ventilating when outdoor concentrations are high
  - Account for unoccupied times
  - Limit peak exposure
  - Include natural infiltration

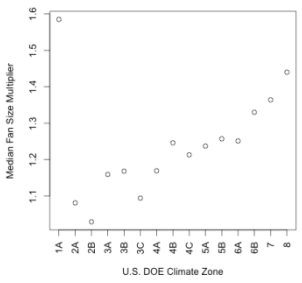
Residential Integrated VEntilation Controller: RIVEC

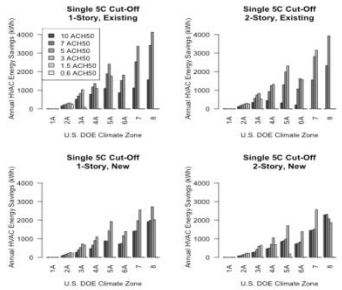
- Uses continuously calculated relative dose and exposure to control the whole house ventilation fan
- Deliberately turns off whole house ventilation at peak times
- Senses operation of other fans and includes their air flows in the relative dose and exposure calculations

Smart Ventilation

Demonstrated 40% savings with a simple timer control

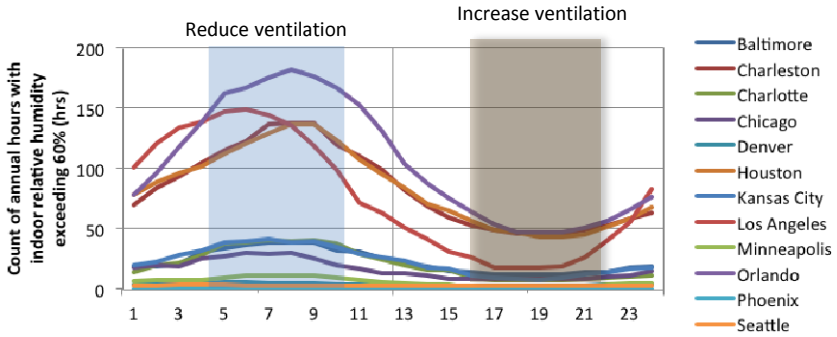
- Developing new controls based on outdoor air temperature





Control Options:
1. Fixed 5C
2. Vary by climate
3. Vary using infiltration calculation

- Developing new controls for reducing impact of outdoor humidity in humid climates



Shift ventilation to less humid times
Based on outdoor humidity and/or timers

Commissioning—Why It's So Important in Airtight Homes

- If IAQ system fails, there is no natural infiltration backup
- Faults are **common** in all system types
- Measurement methods and equipment are inconsistent
- LBNL developing new equipment and test standards for rating test equipment

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 (testo417)

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

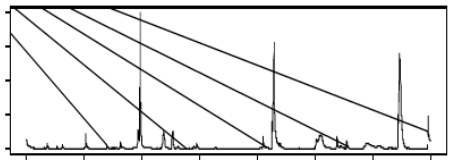
IEQ Valuation

Develop IEQ/IAQ Scoring Tool
Like an energy score – something builders can sell

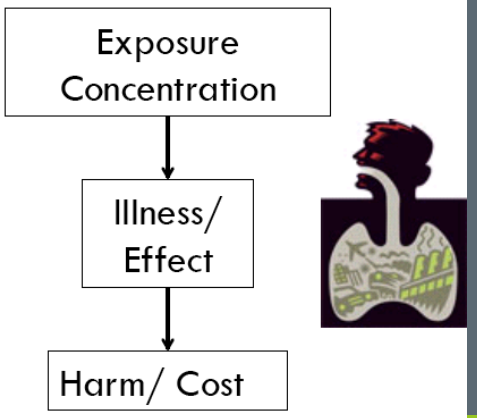
1. Develop the metrics to quantify IEQ/IAQ performance
2. Develop method to combine several metrics into one score
3. Apply prototype scoring tool to high performance and conventional homes

Acute Exposure

- Near instant effect
- Exposure period is considered a day or less
- Effects can clear up or be permanent
- Ex. carbon monoxide in homes



Impact Assessment



Codes and Standards

Codes and Standards

ASHRAE 62.2: National Residential Ventilation Standard

- Long term guidance towards more health –related basis
- Make standard more flexible to allow smart ventilation controls
- Target specific pollutants – Particle Filtration

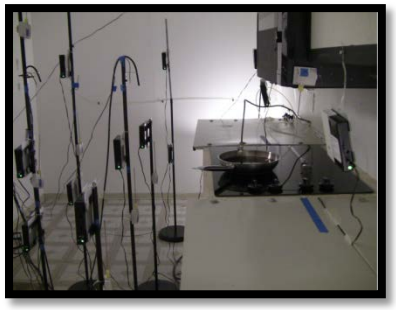
RESNET: Home Energy Scoring

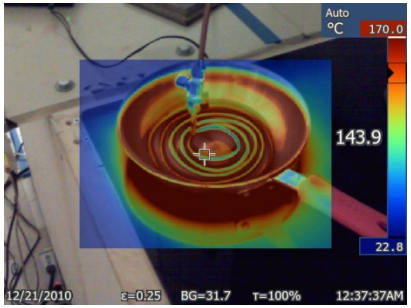
- Revisions to RESNET core Standard and ongoing interpretations and additions
- New Standard for Testing Air Leakage of Building Enclosures, Air Leakage of Heating and Cooling Air Distribution Systems, and ***Airflow of Mechanical Ventilation Systems***

Codes and Standards

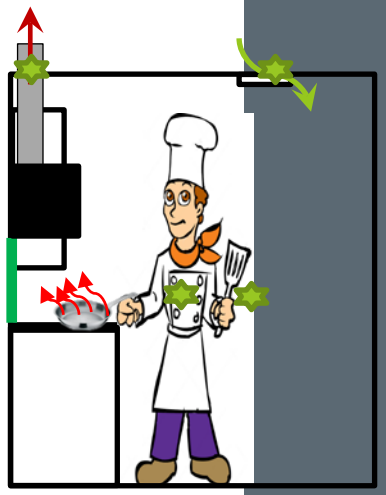
Two new ASTM standards:

1. Range Hood Capture Efficiency

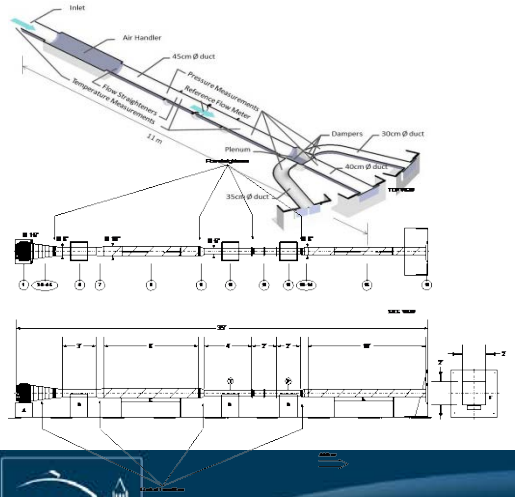




$$CE = \frac{C_{exhaust} - C_{room}}{C_{exhaust} - C_{inlet}}$$



2. Rating Air Flow Measurement Diagnostic Equipment



http://indoorair.lbl.gov/range-hood-roundup.html

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Inside Information: RANGE HOOD ROUNDUP

Berkeley Lab scientists have spent decades investigating how everyday activities affect indoor air quality. We study pollutant sources in homes and develop effective controls. Our recent study found that cooking without proper kitchen ventilation often produces air pollutant levels in homes that exceed outdoor air quality standards.

We need your help to learn more. Berkeley Lab's Range Hood Roundup is gathering information about cooking patterns and kitchen ventilation in U.S. homes. Please join our science team by completing a short survey. We will use the information you provide – along with data from thousands of others across the country – to develop recommendations for improving indoor air quality and health through better building codes and product standards.

The survey has 10-12 questions depending on the equipment in your home. It should take just a few minutes.

Thank You!

INDOOR AIR AND YOUR HEALTH

Berkeley Lab Citizen Science Survey

BECOME A CITIZEN SCIENTIST:
TAKE THE SURVEY

indoorair.lbl.gov

Info about LBNL IAQ research