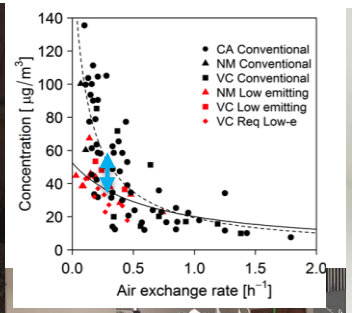
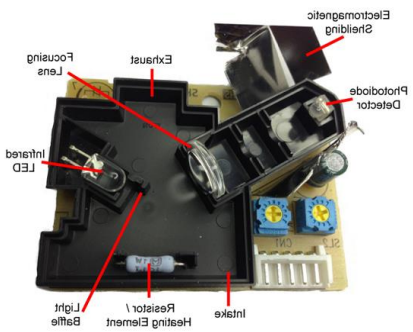
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Healthy Efficient Homes





Lawrence Berkeley National Laboratory

Dr. Iain Walker & Dr. Brett Singer (co-PI)

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Project Summary

Timeline:

Start date: FY16

Planned end date: FY21

Key Milestones

1. Manuscript on Multi-Zone Smart Ventilation Controls submitted to a peer-reviewed archival journal (12/18)
2. Manuscript on Indoor Air Quality in California Homes Built in 2011-2017 with Code-Required Mechanical Ventilation submitted to peer-reviewed archival journal (06/19)
3. Presentations to industry summarizing data collected and preliminary observations from IAQ Study (09/19)

Budget:

Total Project $ to Date:

- DOE: $4.9m
- Cost Share: $4.9

Total Project $:

- DOE: $6.9 m ($1.1-1.2m/yr)
- Cost Share: $6.1 m

Key Partners:

ASHRAE	Air Infil. & Ventilation Ctr
ASTM	Cal Air Resources Board
EPA	Cal Energy Commission
HUD	Home Ventilating Inst.
RESNET	GTI, PG&E, SoCalGas
Aereco	Broan

Project Outcome:

This project will produce innovative technologies, industry guidance and codes and standards that reduce the energy cost of IAQ, and allow the building industry to achieve the 40% energy savings in existing homes and 60% reductions in new homes targeted in the MYPP. This project also seeks to develop technologies to reduce the cost of implementing energy saving IAQ strategies.

Team

Dr. Iain Walker is the PI for this project.

- Codes and standards integration
- Smart ventilation development
- Moisture performance of building envelopes
- Retrofit technologies
- Chair of the national residential building ventilation standard (ASHRAE 62.2) and lead the development of diagnostic standards for RESNET.

Dr. Brett Singer is the co-PI for this project.

- •Internationally recognized expert on IAQ with expertise in exposure science, emissions and source control, air cleaning, field measurements, and controlled environment studies to understand the processes that impact air pollutant exposures in buildings.
- •Leading related CEC study of kitchen ventilation for ZNE homes and CERC IEQ project

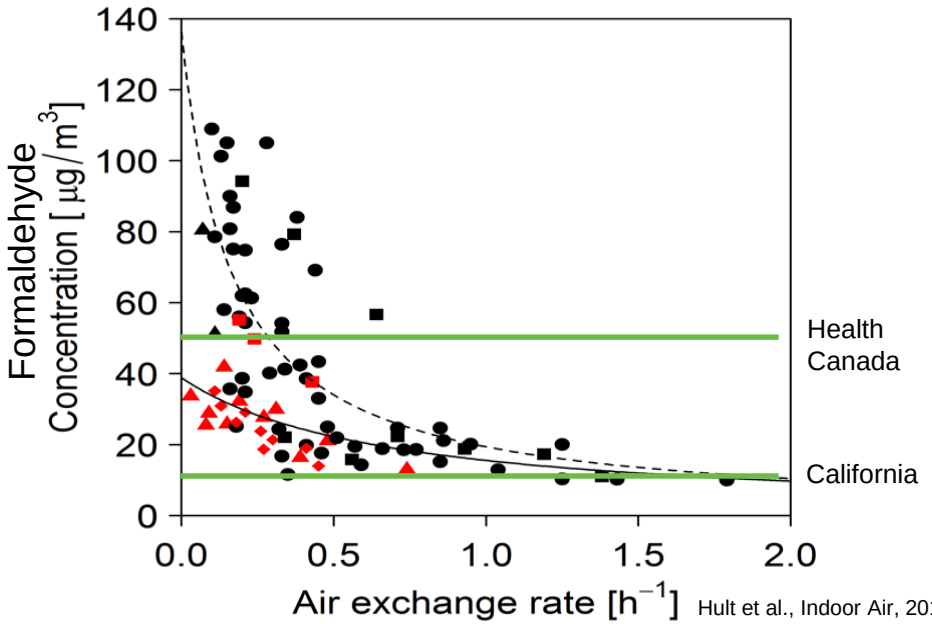
Dr. Rengie Chan

- Field IAQ measurement
- Created building performance database
- Analysis of IAQ data to inform policy

Mr. Brennan Less

- Field measurements
- Simulations
- Smart ventilation strategies
- Deep retrofits

Challenge



Hult et al., Indoor Air, 2015

Problem Definition:

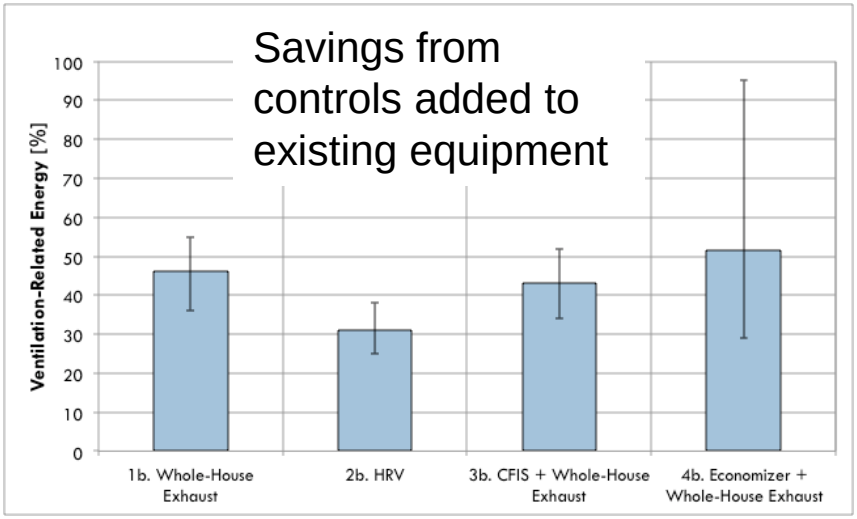
- Concerns about IAQ and moisture problems are a market barrier for airtight energy efficient homes
- Energy and cost of providing IAQ needs to be reduced

- Ventilation to provide acceptable IAQ is about 1/3 of residential building heating/cooling load – even more in high performance buildings with low envelope losses.
- Reducing the energy used for ventilation to provide IAQ to achieve the RBI goals of high performance homes that 40% energy savings in existing homes and 60% reductions in new homes targeted in the MYPP.
- Lower-cost energy savings approaches for IAQ adaptable to existing buildings are necessary to achieve RBI energy savings targets. Target: HRV/ERV performance at half the cost.
- There is a paucity of information on IAQ in homes that is needed to develop new technologies

Approach: develop and evaluate technologies

- **Home IAQ Performance.** Field measurements of contaminants & ventilation system performance to show where we should spend IAQ efforts & focus for technology development.
- **Smart ventilation technologies** to control IAQ equipment (fans, filters etc.).
  - *Equivalent exposure* allows time shifting: lower temperature differences, occupancy, operation of other fans, grid-integrated peak-shifting.
  - Retrofittable.
  - Alternative to high-cost and complex systems.
- **Targeted pollutant solutions:** technologies for source reduction & task ventilation.

Mean Indoor Concentration	Ventilated Homes	Unventilated Homes
Formaldehyde	19.8 ppb	36.3 ppb
$PM_{2.5}$	8.3 μg/m^3	13.3 μg/m^3
NO_2	6.1 ppb	5.4 ppb

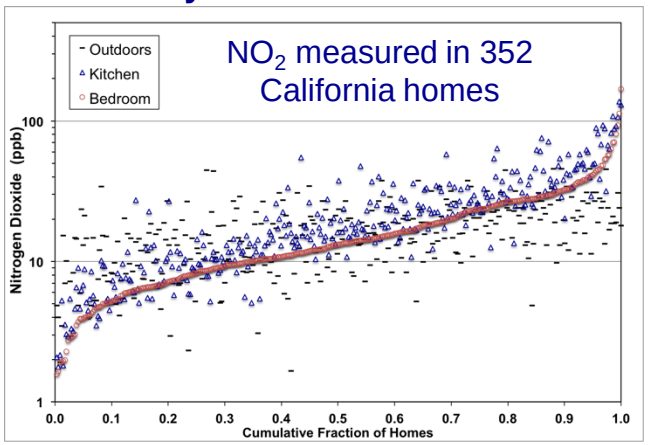


Evaluating automatic range hood controls with Broan

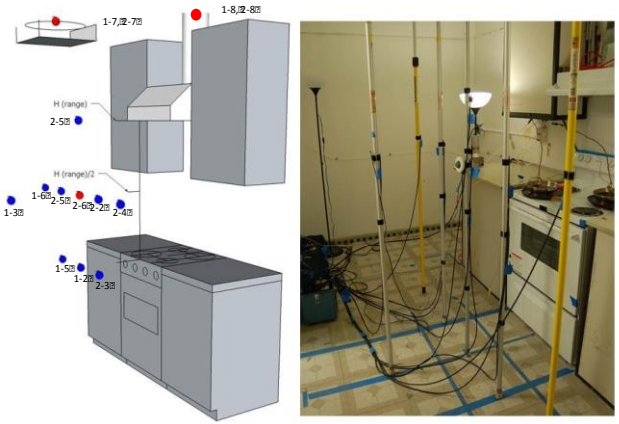
Approach: Solutions based on field, lab and simulation data

Laboratory experiments

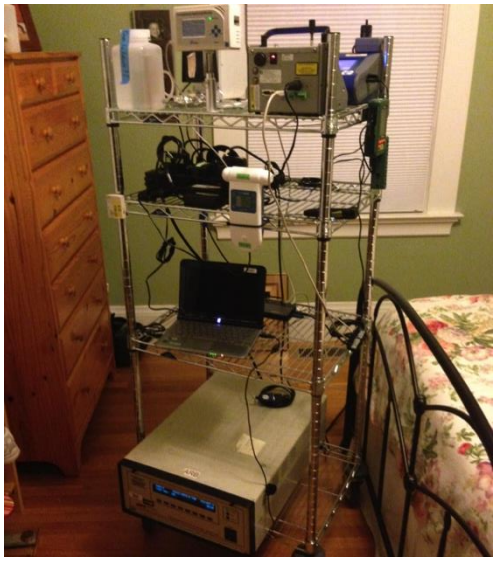
Surveys and data collection



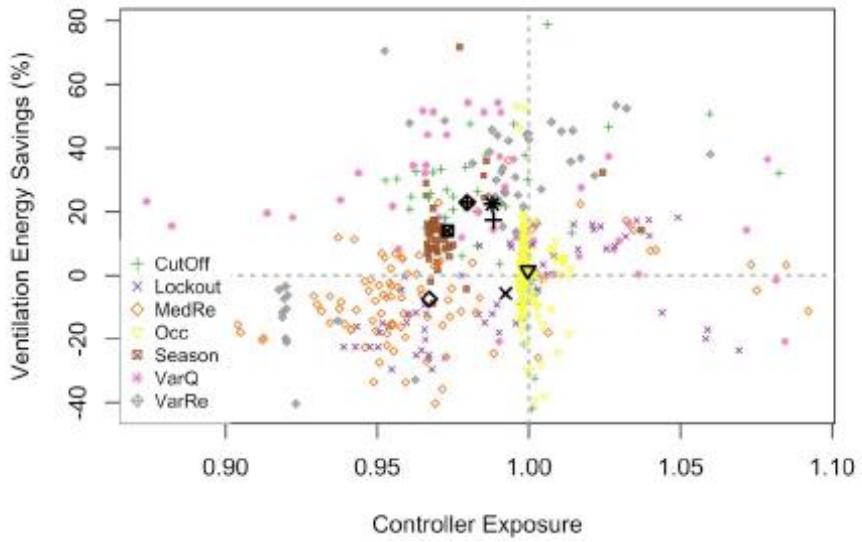
Test method development



Controlled experiments in homes



Analysis & Simulations – extend results beyond field and lab conditions



Impact

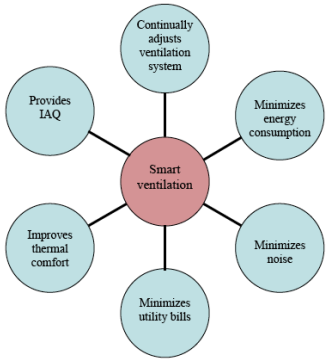
Industry engagement (2016-present)

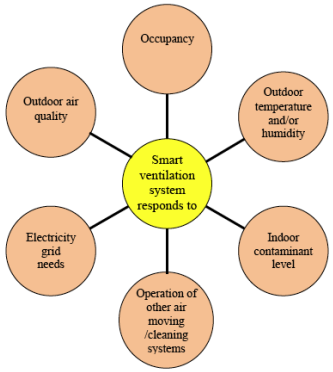
- New industry consensus standards: RESNET 380 (diagnostics) & ASTM E3087(Range Hood capture efficiency)
- Existing industry consensus standards: ASHRAE 62.2, ASTM 3087, RESNET 301 & 380, Home Ventilating Institute Range Hood Ratings, CGSB M149, California Title 24
- 14 peer-reviewed journal articles + 28 conference papers
- More than 70 Workshops/invited talks/papers at industry conferences
  - RESNET, ASHRAE, Indoor Air, Home Performance Coalition, ISIAQ, Air Infiltration and Ventilation Center, Energy and Environmental Building Alliance, Pro-Clima (New Zealand), National Air Filtration Association, Dry Climate Forum, Building America Webinars, Better Buildings Residential Network, US EPA Workshops, Home Ventilating Institute, Home Chemistry Workshop, ACEEE Conference on Health, Environment, and Energy, NEHA Healthy Homes Conference, Passive House Conference
- Cofunding/additional work:
  - California Energy Commission (Smart Ventilation, measured contaminants, kitchen ventilation), Dwyer (air flow diagnostics), Broan (automatic range hoods), ComEd (retrofitting homes), Aereco (smart ventilation)

Impact

Smart ventilation technologies

- Reduced market confusion and enabled manufacturers to get credit with international definition of Smart Ventilation (with AIVC)





- New products coming to market from Broan, Panasonic, Air King, Honeywell, Aprilaire and others
- New occupancy-based control strategies

Sensors & Controls

- Led to other work in US (Ohio state and others) and internationally (via our involvement with the Air Infiltration and Ventilation Center, an IEA Annex) on low-cost approaches to sensing IAQ and potential to lower energy used for IAQ in homes
- Better sensors now being used by some manufacturers based on results of LBNL study
- Building America developing evaluation test method

Impact

National IAQ Study in New Homes

- CEC Co-sponsored project in CA has informed the development of the Building America New Home IAQ project in other climates
- Generating data to support industry standard such as ASHAE 62.2 and high performance home programs, e.g., EPA EnergyStar, Passive House
- Identified labeling as a key area for improvement – led to new labeling requirements from Home Ventilating Institute (HVI) and California Energy Commission

Kitchen ventilation

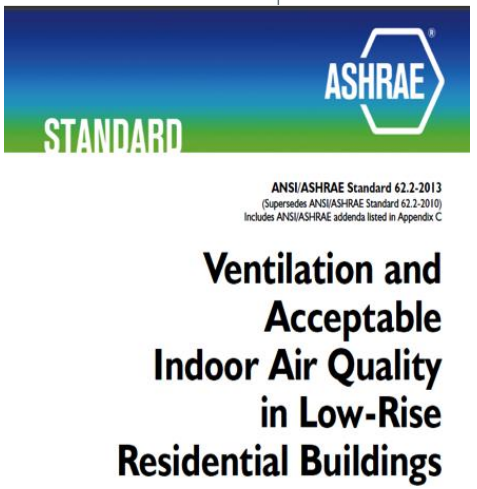
- HVI to add Capture Efficiency ratings – manufacturers will be publishing ratings by end of 2019
- Galvanized national and international awareness/interest: HVI, Broan, Texas A&M, TNO, University of Nottingham
- Broan developing automated range hood tested in LBNL FlexLab

Progress – Test Method Development

- Revised Standard: Diagnostics for home energy ratings (RESNET 380)
  - Added multifamily test procedures and improved other procedures

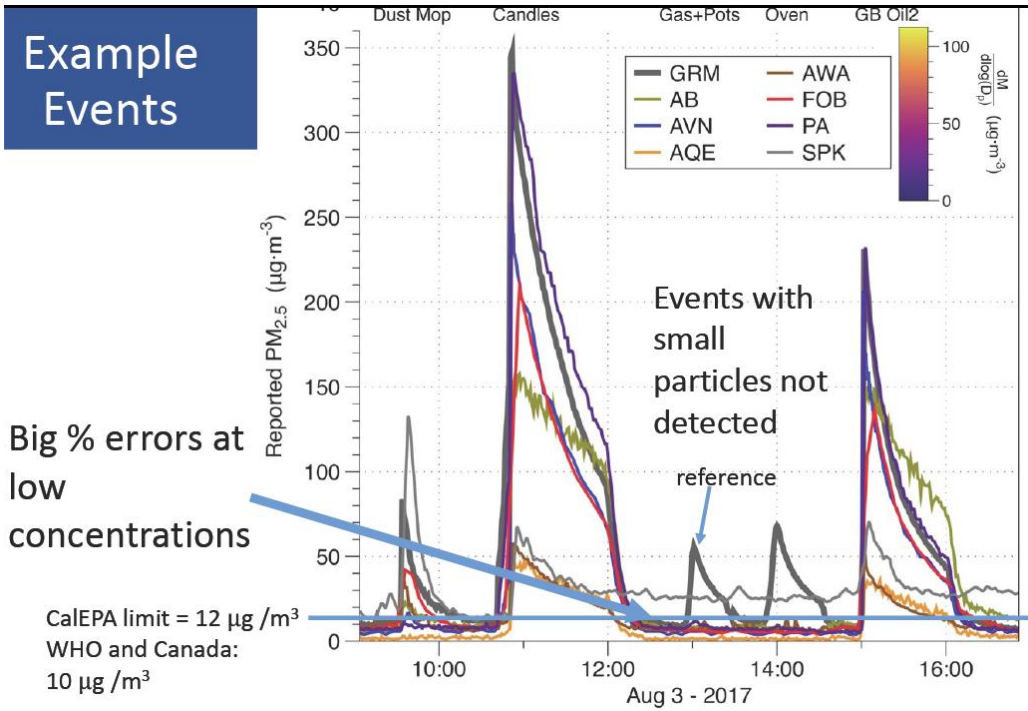
- Adding multifamily requirements to ASHRAE 62.2. Working on ASHRAE IAQ Position Document.

- Incorporating Range Hood Test Method into HVI testing procedures. Potential to reduce energy required for kitchen ventilation 50%.



Progress – Low Cost IAQ monitors

- Collaboration with manufacturers leading to use of better sensors
- Collaboration with Ohio State, CETIAT (France) and AIVC (international webinars)
  - Studies agree that:
  - Most events detected
  - .. But some sensors better than others
  - Not good enough a low concentrations for ventilation controls
- Technical Assistance to BA team partner Newport Ventures developing standardized rating/test method



Progress: Smart Ventilation – Occupancy Control

- Accounting for building materials (e.g., formaldehyde) severely restricts savings
- Advanced controls, such as pre-occupancy flushing, can offer improved savings

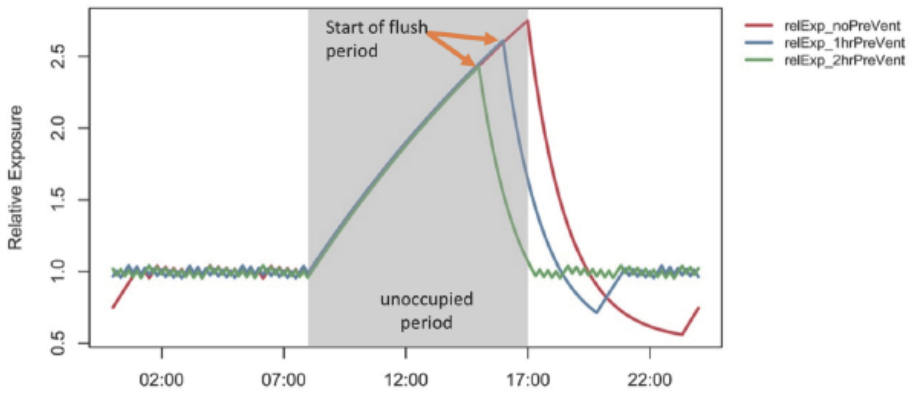
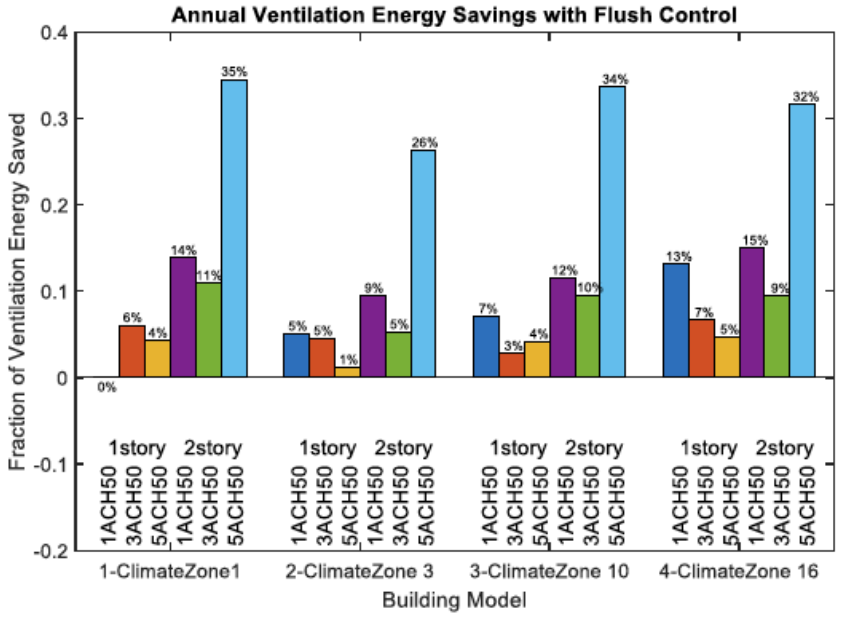


Figure 2. Relative exposure with no, one- and two-hour pre-occupancy flush out periods. Unoccupied period highlighted in light grey. Reproduced from Less & Walker (2017).

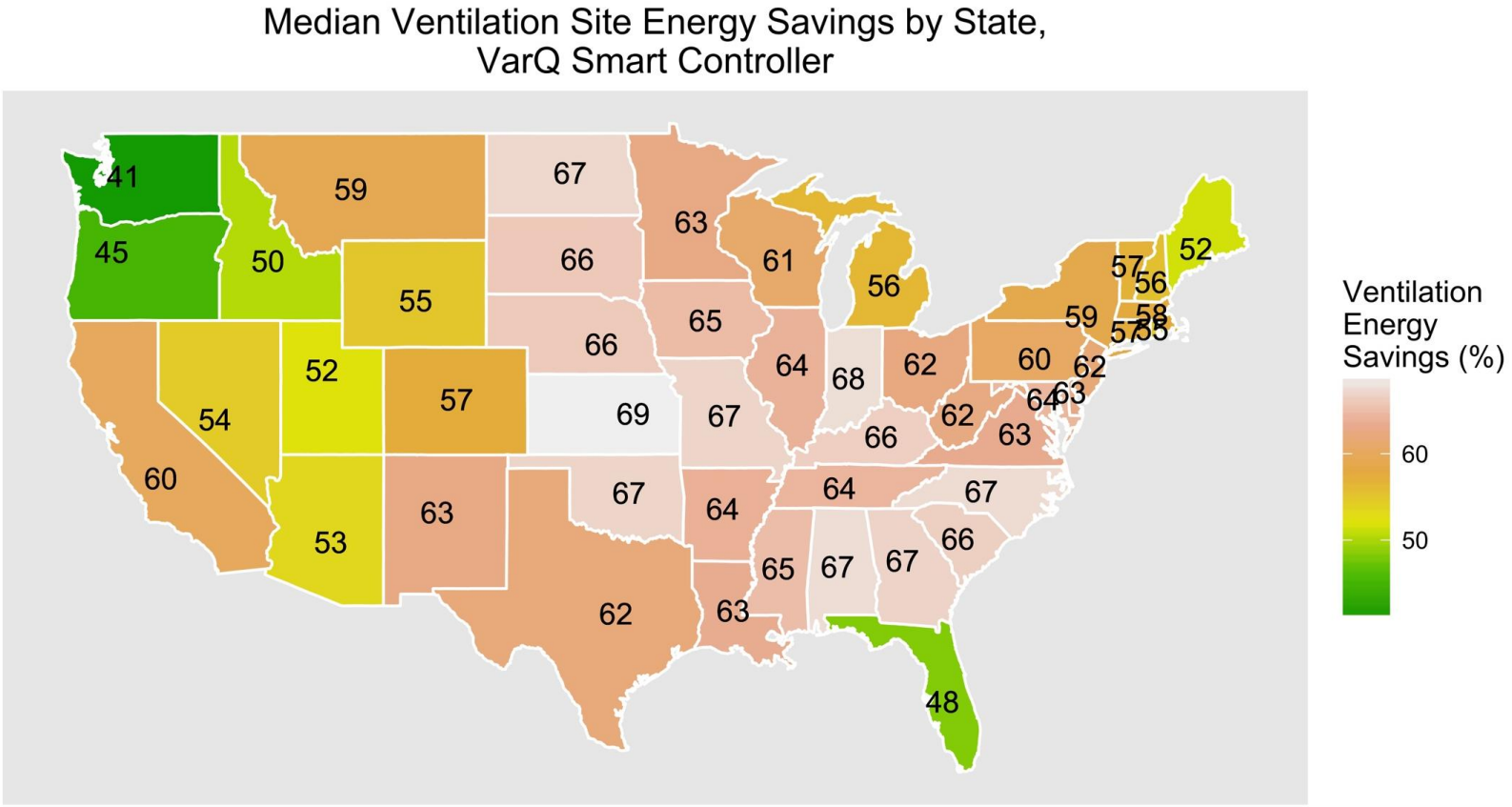
- Tight energy efficient homes offer lower savings – greatest potential in retrofit



Progress: Smart Ventilation – Temperature Control

Seasonal shifting gives biggest savings – up to 80% of ventilation load

Optimum strategy climate and envelope leakage dependent



Progress: Field study - Baselining Home IAQ

- **Completed CEC co-funded California study**
- **Building America New Home study active -**
- **Key results from California study:**
  - 50% more ventilation flow that minimum requirement (ASHRAE 62.2
  - Ventilated homes have contaminants at acceptable levels
  - Poor labeling leads to non-operation

	Mean	Standard
Formaldehyde (ppb)	26	7 OEHHA 40 Canada 80 WHO
PM2.5 (µg/m^3)	5.6	12
NO_2 (ppb)	3.8	53
CO_2 (ppm)	625	1000
CO_2 bedroom (ppm)	725	1000

Stakeholder Engagement

Industry

BROAN NuTone

AERECO air on demand

QUFRESH

Panasonic

Air King Ventilation Products

MITSUBISHI ELECTRIC COOLING & HEATING

Standards

HVI HOME VENTILATING INSTITUTE

CALIFORNIA ENERGY COMMISSION

ASTM INTERNATIONAL

ASHRAE

RESNET RESIDENTIAL ENERGY SERVICES NETWORK

ACCA

Utilities and Related

Southern California Gas Company

gti GAS TECHNOLOGY INSTITUTE

PG&E Pacific Gas and Electric Company

Leadership roles:

- ASHRAE: Lead ASHRAE Residential Ventilation Standard 62.2, develop ASHRAE IAQ Position document
- RESNET: Lead development of RESNET Std 380 on diagnostics
- ASTM: Lead standards development for Range Hoods, Air Leakage testing
- HVI: technical support to add range hood performance ratings
- AIVC: International definition of smart ventilation, kitchen ventilation, low-cost sensors

Stakeholder Engagement

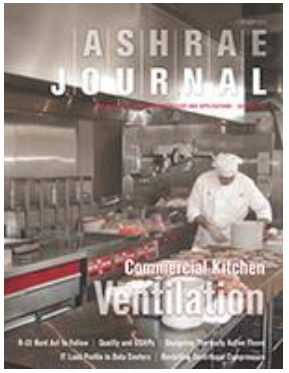
Scientific Journals

ehp ENVIRONMENTAL HEALTH PERSPECTIVES

Environmental Science & Technology

INDOOR AIR
International Journal of Indoor Environment and Health

Practitioner Journals



Presentations to Industry & Practitioners

ASHRAE

EEBA

Home Performance Coalition

INDOOR AIR QUALITY ASSOCIATION

PHIUS
Passive House Institute US

RESNET
RESIDENTIAL ENERGY SERVICES NETWORK

FORUM ON DRY CLIMATE
HOME PERFORMANCE

International Society of Indoor Air Quality and Climate

AIVC Air Infiltration and Ventilation Centre

12TH REHVA WORLD CONGRESS CLIMA2016

NAFA National Air Filtration Association
The Source for Expertise, Education & Standards in Air Filtration

ACEEE
American Council for an Energy-Efficient Economy

ISIAQ INTERNATIONAL SOCIETY OF INDOOR AIR QUALITY AND CLIMATE

Remaining Project Work

FY19:

- Continue to develop smart ventilation algorithms
  - Multi zone/multi-family approaches
  - Low-cost applications for existing/simple systems
- Complete New Home IAQ study with BA teams
- Range Hood Capture Efficiency Test in HVI listings
- Metrics & test methods for automatic and recirculating range hoods

Beyond FY19:

- Grid-integration and Commercial/institutional building applications for smart ventilation
- Range Hood Capture Efficiency in ASHRAE 62.2
- Tech support to get smart ventilation credit in codes & standards
- Smart homes – develop and evaluate sensors & controls to enable good IAQ with greater energy savings
- Low-cost combined IAQ and energy retrofits for low-income housing

Thank You

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REFERENCE SLIDES

Project Budget

Project Budget: : $1.1m FY19
Variances: No variances from planned budget
Cost to Date: $3.8m
Additional Funding:

EPA/HUD support for HEH Program $300K/y
CEC: Healthy Efficient New Gas Homes (FY15–FY18): $1.25m
CEC: Smart Ventilation in Advanced California Homes (FY16–FY19): $1.5 m
CEC: Effective Kitchen Ventilation in Zero Net Energy Homes (FY18-FY20): $1m
Aereco: Smart Ventilation in Advanced California Homes (FY16–FY19): $300k
Dwyer: Advanced Flow Hood Performance Verification (FY18): $100k
ComEd: Residential Retrofits, Energy and Health (FY19-20): $240k
Broan: Automatic Range Hoods (FY19): $50k

Budget History

FY16– FY 2018 (past)		FY 2019 (current)		FY 2020 – FY21 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$3.8m	$3.1m	$1.1m	$1.8m	$2.0m	$1.2m

Project Plan and Schedule

- Project original initiation: 10/2016
- Project planned completion: 09/2021
- Schedule and Milestones: Manuscript on Multi-Zone Smart Ventilation Controls submitted to a peer-reviewed archival journal (12/2018), Beta version of IAQ Scoring Tool provided to partners for review and initial field testing (03/2019), Manuscript on Indoor Air Quality in California Homes Built in 2011-2017 with Code-Required Mechanical Ventilation submitted to peer-reviewed archival journal (06/2019), Presentation summarizing data collected and preliminary observations from IAQ Study (09/2019). Go/no-go: Building America IAQ Field Study data analysis (07/2019)
- Current and future work: develop smart ventilation control strategies, compile baseline IAQ data, study IAQ sensors, update codes and standards

Project Schedule

Project Start: FY17

Projected End: FY19

Completed Work

Active Task (in progress work)

Milestone/Deliverable (Originally Planned)

Milestone/Deliverable (Actual)

Task	FY2017				FY2018				FY2019			
	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Scientific guidance & technical support to BA program and stakeholders	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
C&SI: ASTM range hood method, RESNET 380, ASHRAE 62.2, CA T24, etc.			◆	◆			◆	◆				◆
Smart ventilation: temp control, occupancy control, aux fan credits, eval low-cost monitors				◆				◆	◆			
New Home Field Study					◆			◆			◆	◆
Technical support to Building America teams (FOA awardees)				◆				◆				◆