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)
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:**

<table>
<thead>
<tr>
<th>ASHRAE</th>
<th>Air Infil. &amp; Ventilation Ctr</th>
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<tbody>
<tr>
<td>ASTM</td>
<td>Cal Air Resources Board</td>
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<tr>
<td>EPA</td>
<td>Cal Energy Commission</td>
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<tr>
<td>HUD</td>
<td>Home Ventilating Inst.</td>
</tr>
<tr>
<td>RESNET</td>
<td>GTI, PG&amp;E, SoCalGas</td>
</tr>
<tr>
<td>Aereco</td>
<td>Broan</td>
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**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**

**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.

  – *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.

• **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.

• **Targeted pollutant solutions:** technologies for source reduction & task ventilation.

<table>
<thead>
<tr>
<th>Mean Indoor Concentration</th>
<th>Ventilated Homes</th>
<th>Unventilated Homes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formaldehyde</td>
<td>19.8 ppb</td>
<td>36.3 ppb</td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>8.3 µg/m$^3$</td>
<td>13.3 µg/m$^3$</td>
</tr>
<tr>
<td>NO$_2$</td>
<td>6.1 ppb</td>
<td>5.4 ppb</td>
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</table>

Savings from controls added to existing equipment

Evaluating automatic range hood controls with Broan
Approach: Solutions based on field, lab and simulation data

Laboratory experiments

Surveys and data collection

NO\textsubscript{2} measured in 352 California homes

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
- 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 by 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
- Tight energy efficient homes offer lower savings – greatest potential in retrofit
Seasonal shifting gives biggest savings – up to 80% of ventilation load

Optimum strategy climate and envelope leakage dependent

Median Ventilation Site Energy Savings by State, VarQ Smart Controller
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

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard</th>
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<tbody>
<tr>
<td>Formaldehyde (ppb)</td>
<td>26</td>
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<tr>
<td>PM2.5 (μg/m³)</td>
<td>5.6</td>
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<tr>
<td>NO₂ (ppb)</td>
<td>3.8</td>
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<tr>
<td>CO₂ (ppm)</td>
<td>625</td>
<td>1000</td>
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<tr>
<td>CO₂ bedroom (ppm)</td>
<td>725</td>
<td>1000</td>
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Stakeholder Engagement

Industry

Standards

Utilities and Related

Leadership roles:
- 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

Practitioner Journals

Presentations to Industry & Practitioners

- ASHRAE
- EEBA
- Home Performance Coalition
- Indoor Air Quality Association
- PHius
- RESNET
- Forum on Dry Climate
- National Air Filtration Association
- ACEEE
- AIVC
- International Society of Indoor Air Quality and Climate
- 12th REHVA World Congress
- 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

LBNL
Dr. Iain Walker, Scientist
(510) 486 4692 iswalker@lbl.gov
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): $1.5m
- 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

<table>
<thead>
<tr>
<th>FY16– FY 2018 (past)</th>
<th>FY 2019 (current)</th>
<th>FY 2020 – FY21 (planned)</th>
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<tbody>
<tr>
<td>DOE</td>
<td>Cost-share</td>
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<td>$3.8m</td>
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**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

<table>
<thead>
<tr>
<th>Task</th>
<th>FY2017</th>
<th>FY2018</th>
<th>FY2019</th>
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<tbody>
<tr>
<td></td>
<td>Q1 (Oct-Dec)</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
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<tr>
<td>Scientific guidance &amp; technical support to BA program and stakeholders</td>
<td>![Green](Completed Work)</td>
<td>![Green](Completed Work)</td>
<td>![Green](Completed Work)</td>
</tr>
<tr>
<td>C&amp;S I: ASTM range hood method, RESNET 380, ASHRAE 62.2, CA T24, etc.</td>
<td>![Green](Completed Work)</td>
<td>![Green](Completed Work)</td>
<td>![Green](Completed Work)</td>
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<tr>
<td>Smart ventilation: temp control, occupancy control, aux fan credits, eval low-cost monitors</td>
<td>![Green](Completed Work)</td>
<td>![Green](Completed Work)</td>
<td>![Green](Completed Work)</td>
</tr>
<tr>
<td>New Home Field Study</td>
<td>![Green](Completed Work)</td>
<td>![Green](Completed Work)</td>
<td>![Green](Completed Work)</td>
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<tr>
<td>Technical support to Building America teams (FOA awardees)</td>
<td>![Green](Completed Work)</td>
<td>![Green](Completed Work)</td>
<td>![Green](Completed Work)</td>
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