U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Baseline Indoor Air Quality Field Study in New US Homes: Hot Humid and Mixed Humid Climates

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Project Summary

Timeline:

Start date: October 1, 2017

Planned end date: March 30, 2020

Key Milestones

1. Obtain IRB Approval; 9/2018
2. Complete Assessments in 8 homes; 12/2018
3. Complete Assessments in 20 homes; 4/2019

Budget:

Total Project $ to Date (March 31, 2019):

- DOE: $263,215
- Cost Share: $18,610

Total Project $:

- DOE: $598,237
- Cost Share: $66,472

Key Partners:

Lawrence Berkeley National Lab
Pacific Northwest National Lab
University of Illinois / Indoor Climate Research

Project Outcomes:

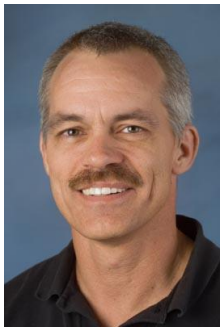
1) Improve understanding of potential health risks in new homes as industry works to achieve MYPP goal of 60% lower energy use.
2) Inform future standards and technology development needed to ensure acceptable IAQ and comfort in very efficiency homes.

Team

- Extensive field testing and monitoring experience.
- Conducted several prior studies involving mechanical ventilation:
  - Investigating failure rates.
  - Quantifying energy impacts.
  - Reducing moisture impacts.
- Train practitioners on mechanical ventilation
  - Energy Rater Training
  - “Measurement and Verification of Whole House Mechanical Ventilation Systems”

Eric Martin

Chuck Withers



Dave Chasar

Jeff Sonne

Tanvir Khan, PhD

Challenge

- Air tightness reduces energy use for thermal conditioning but can increase risks of some IAQ problems.
- Adequate ventilation is necessary – though not always sufficient - for acceptable IAQ.
  - ASHRAE 62.2 sets requirements for ventilation equipment and minimum outdoor air rates in homes.
  - Several states and many home performance programs include mechanical ventilation requirements.
- Limited data indicate deficiencies:
  - many new homes lack general ventilation or kitchen exhaust
  - installed systems commonly don't meet standards
  - Installed systems often not used as intended

Approach

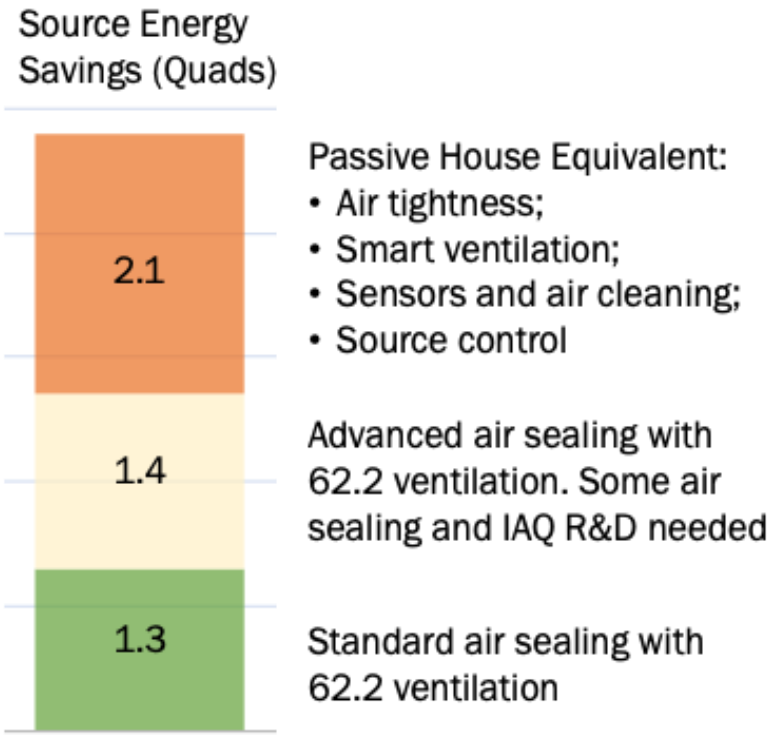
- Conduct field study in varied US climate zones.
- Recruit homes that represent diversity of construction styles and mechanical system designs in each climate zone.
- Visual characterization and performance measurements on site.
- Survey of occupants about activities and perceptions.
- Measurements of pollutants and equipment use over 1 week with windows closed (seasonally appropriate).
- Analyze data to quantify concentrations, emission rates, use and effectiveness of MV, etc.
- *Enhance IAQ data collection protocol to enable a moisture balance to be conducted and calculate an estimated internal moisture generation rate.*

Targets

- 32 homes/zone
- 16 w/ mech vent
- 8 get 2-week test
- 15 internal moist.

Impact

Tighter US homes will use 3 Quads less source energy per year[1]



California study found acceptable IAQ in newish homes with MV

Mean indoor concentration	CA homes pre-MV	CA homes with MV
Formaldehyde	36.3 ppb	19.8 ppb
$PM_{2.5}$	13.3 µg/m^3	8.3 µg/m^3
NO_2	5.4 ppb	6.1 ppb

Since 2012, IECC requires dwelling unit mechanical ventilation (DUMV).

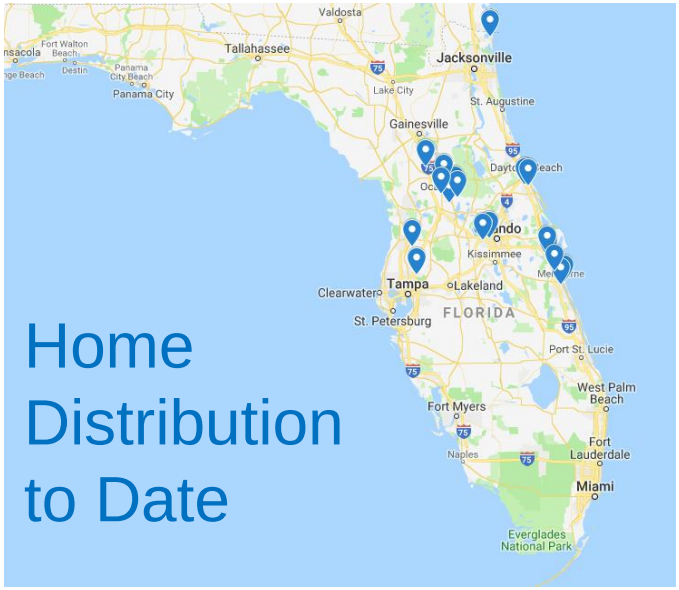
Kitchen exhaust still not required.

Some states requiring DUMV only for tightest homes, e.g. <3 ACH50.

Field data will inform future revisions to industry standards.

Progress – Sampling and Recruitment Strategy

- Identified regional home characteristics to qualify sample using data from EIA RECS, NREL Restock, RESNET, NAHB, US Census.
- FSEC Energy Rated Home Database used as primary source of recruitment records, with ~50,000 qualifying homes.
- Recently augmented recruitment records with data from RESNET National Registry.



Recruitment Website

Recruitment Postcard

Progress – Data collection complete in 18 homes in central and north Florida.

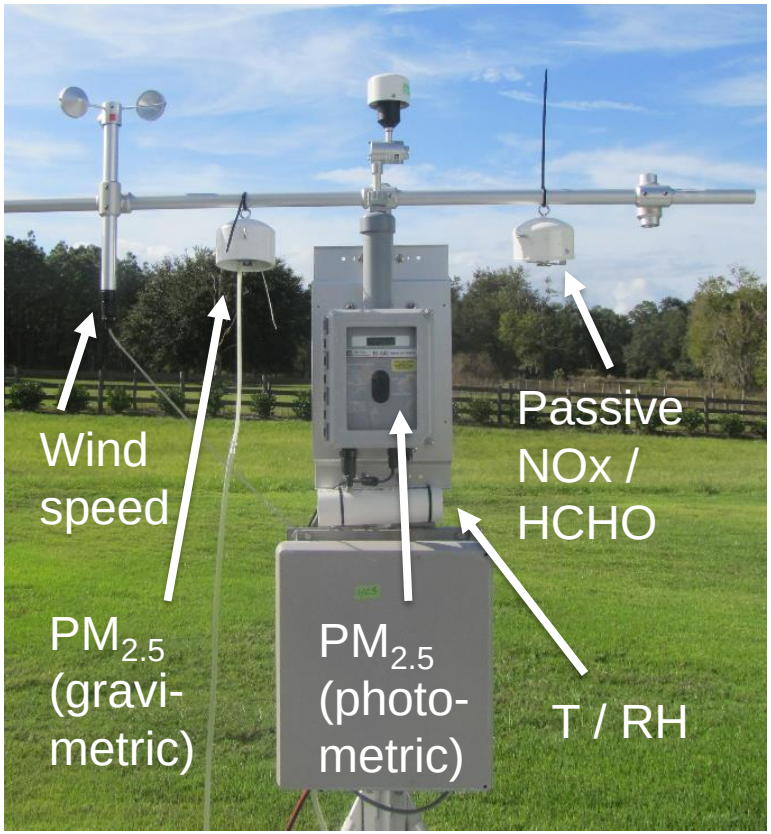
Home #	County	Year Built	SQFT	Stories	People	HERS Index	Whole House Mech Vent
401	Brevard	2015	2032	1	2	54	N
402	Brevard	2018	2670	2	3	N/A	N
403	Brevard	2016	2104	1	4	52	N
404	Brevard	2014	2003	1	6	N/A	N
405	Lake	2017	2146	1	3	-13	Y
406	Marion	2017	2128	1	2	65	N
407	Lake	2017	3541	1	2	14	Y
408	Nassau	2016	3150	2	3	N/A	N
409	Lake	2017	2725	1	2	55	N
410	Orange	2017	3869	2	2	57	N
411	Hillsborough	2017	1495	1	6	59	N
412	Orange	2016	3574	2	4	54	N
413	Pasco	2017	3737	1	2	54	N
414	Volusia	2018	2900	1	4	N/A	N
415	Volusia	2015	1500	1	5	54	Y
416	Lake	2016	1750	1	2	52	Y
417	Lake	2016	3372	1	2	54	N
418	Brevard	2017	3107	1	5	50	Y

Homes 405-418 targeted as having whole house mechanical ventilation, but properly designed and operating systems found in only 5 of those homes .

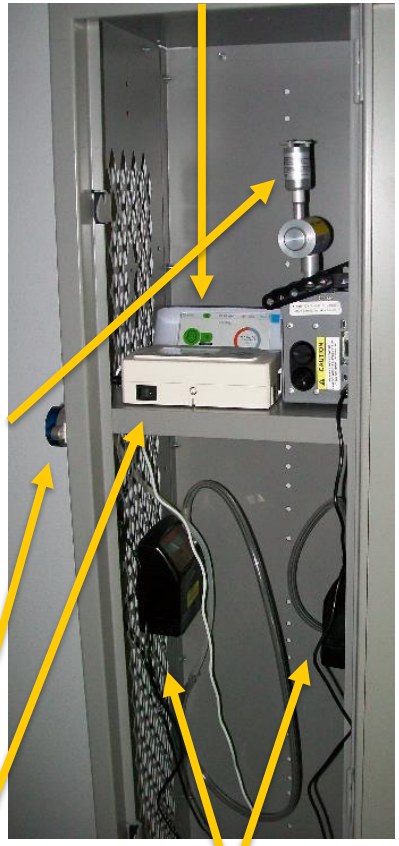
Blue text indicates homes with two weeks of data.

Progress – Protocol Implementation, Air Quality Monitoring

Outdoor Location:



Primary Central Indoor Location:



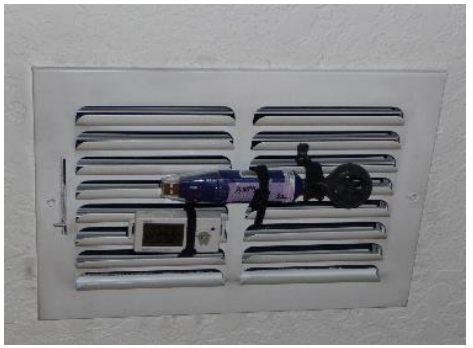
Master Bedroom: T/RH, $PM_{2.5}$, HCHO, CO_2
Secondary Central Indoor Location: T/RH, $PM_{2.5}$, CO_2

Progress – Protocol Implementation, Activity Monitoring

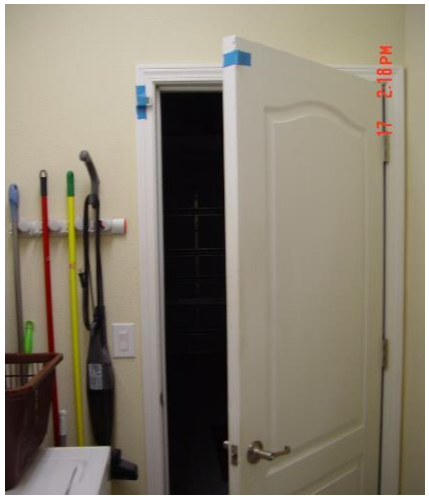
Clothes Dryer Use

Bath Fan Use

Range Hood Use



Heating/Cooling Runtime



Door Use: Garage, Master Bedroom, Patio

Cooking

WH Ventilation Runtime

Condensate Production (For Internal Moisture)

Homeowners also complete a survey and a daily activity log.

Progress – Protocol Implementation, Air Flow Testing

Whole House Ventilation, Dryer: Powered Flow Hood.

Bathroom Exhaust: Exhaust fan flow box.

Kitchen range hood: Custom flow box/duct blaster.

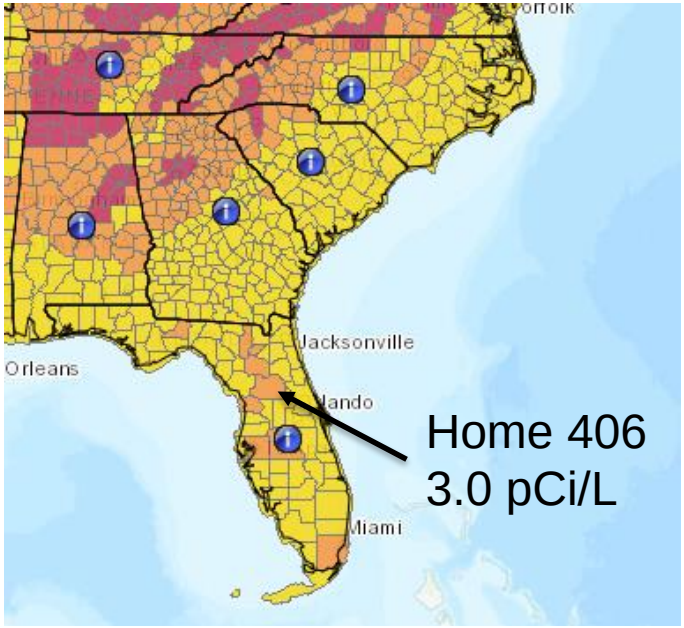
Enclosure and duct leakage: Delta Q.

Whole House Air Exchange: SF6 Tracer Gas (For Internal Moisture)

Air handler flow: Flow plate.

Progress – Preliminary Air Quality Results, Homes 401-408

- Formaldehyde above Cal EPA threshold.
- $PM_{2.5}$ indoor lower than or equal to outdoor, only 2 out of 8 are close to outdoor US EPA threshold.
- 4 out of 8 homes are all electric. One home with high NO_2 has recirculating over the range microwave.
- CO_2 and HCHO lower homes with whole house mechanical ventilation.



Parameter	Threshold	Median	Range
Formaldehyde (ppb)	7	27	16 - 47
$PM_{2.5}$ IN (ug/m^3)	12	6	1-8
$PM_{2.5}$ OUT (ug/m^3)	12	5	4-15
NO_2 (ppb)	53	7	<1 - 33
CO_2 (ppm)	1,000	834	515 - 1599
Radon (pCi/L)	4	1	0.05 – 3.0

EPA Radon Zones
Zone 1
Zone 2
Zone 3

Progress – Ventilation System Characterization

Home #	Expected Whole House Vent	As Found Whole House Vent
405	ERV	ERV has good flow but misducted, no enthalpy exchange.
406	Supply	Functioning with good flow, but flow largely locked out at TStat.
407	Supply	Non-functioning - thermostat incompatible. Low flow.
409	Intermittent Exh.	Compliant fan. Simple on/off, non-labeled switch.
410	Ventilating DH	Turned off. Outside air damper will not open, no flow.
411	Continuous Exh.	Compliant fan. Non-labeled switch + non-functioning supply.
412	Continuous Exh.	Non-Compliant fan. Non-labeled switch + non-functioning supply.
413	Intermittent Exh.	Compliant fan, non-compliant switch + mystery switch (damper?).
414	Ventilating DH	Low flow. Outside air damper miswired, opens only when high RH.
415	ERV	Working!
416	ERV	Good flow but questionable ducting (return to return).
417	Ventilating DH?	Supply, switched off.
418	ERV	Working!

Colored text indicates kitchen and/or bath (or both) ventilation non-compliant.

Progress – Internal Moisture Generation

- **Developed analytical solution to moisture balance model that includes 2-layer effective moisture penetration depth (EMPD) model for moisture buffering.**
- **Conducted some initial validation of model using lab home data.**
  - Without measured humidity ratio in the moisture buffering layers (shallow and deep), need to estimate model coefficients based on area of buffering material, mass transfer coefficients and surface temperature.
  - NREL previously conducted experiments in FSEC labs to determine coefficients on a whole house basis.
- **Secured co-funding from ASHRAE for additional lab validation and to expand field sample from 15 - 45 homes.**
- **Tracer gas testing and condensate production data able to be collected in most every home.**
- **Working on using snapshot tracer gas data to calibrate natural infiltration model.**

Stakeholder Engagement

- Lawrence Berkeley Lab has been coordinating a Technical Advisory Committee consisting of indoor air quality experts from a number of organizations for input on protocol development.
- Early in the project FSEC hosted a 2-day meeting to gain input on protocol development and application. Representatives in attendance from:
  - Washington State University
  - The Energy Conservatory
  - Haywood Score
- Results are expected to inform future standards and technology development needed to ensure acceptable IAQ and comfort in very efficient new homes. Stakeholders include:
  - Ventilation standards (ASHRAE 62.2)
  - Enclosure and equipment design standards (ASHRAE 160)
  - Practitioners designing and building homes to those standards (architects, engineers, builders, and contractors)

Remaining Project Work

- Recruitment and data collection in other southeastern states.
- Original schedule calls for data collection to be complete by October 2019.
- Institutional Review Board (IRB) approval caused ~ 6 month delay to field work early in project.
- Remaining data collection likely to continue into middle of FY20.
- Characterizing whole house mechanical ventilation systems continues to be time consuming, but provides valuable information about failure mechanisms.
- Data analysis and presentation/publication of results.

Thank You

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REFERENCE SLIDES

Project Budget

Project Budget: Budget Period 1 funds spent on protocol development, IRB approval, instrument acquisition, and some recruitment and data collection. Budget Period 2 funds primarily spent on recruitment and data collection, as well as reporting.

Variances: An additional $27,457 was approved for additional interaction with IRB and expanded field data collection protocol.

Cost to Date: 42% of the budget has been expended to date (3/31/2019).

Additional Funding: No additional funding has been received from other sources.

Budget History			
October 2017– December 2018 (Budget Period 1 - past)		January 2019– March 2020 (planned)	
DOE	Cost-share	DOE	Cost-share
$250,341	$27,817	$347,896	$38,655

Project Plan and Schedule

Institutional Review Board protocol review and approval for research with human subjects took longer than expected.