Performance-Based IAQ and Optimized Ventilation

Southface
Bryant Hains – Principal Investigator
404-604-3627
bhains@southface.org

Project Summary

Timeline:

Start date: 10/1/2016

Planned end date: 9/30/2019

Key Milestones

1. Sensor Packages assembled and tested; 1/1/2018
2. Test Plan Accepted by DOE; 4/1/2018

Budget:

Total Project $ to Date:

- DOE: $456,227
- Cost Share: $149,790

Total Project $:

- DOE: $661,417
- Cost Share: $214,134

Key Partners:

Emory University
UL Environment
Broan/Venmar
Beazer Homes
Senseware

Project Outcome:

Field validation, using low cost Indoor Air Quality (IAQ) sensors, of a smart ventilation system that can help low-load homes in humid environments maintain acceptable indoor humidity conditions while providing adequate ventilation according to ASHRAE 62.2.

Team

Team Contributions:

- Southface to function as prime, performing all installations, monitoring, and testing of homes, reporting, administrative activities
- Beazer homes to supply Energy Star certified homes
- Senseware to provide IAQ sensor packages, data acquisition, wireless cloud-based IoT platform
- Broan/Venmar to supply ERVs and engineers helping to analyze ERV performance data
- Emory University Rollins School of Public Health helping to analyze the IAQ and comfort data
- UL Environment helping to test for and analyze sensor drift data

Technical Advisors:

- Lieko Earle, Ph.D., LBNL
- Brett Singer, Ph.D., NREL

Challenge

- Building air tightness is crucial to lowering the energy use of homes, but mechanical ventilation is necessary to provide optimal IAQ
- However, resistance to mechanical ventilation is one of the reasons for builder push-back on increasing building enclosure air tightness requirements for state energy codes, as seen in Florida in 2015 and in Georgia in 2017.
- Builders are resistant to cost increases, but, perhaps more importantly, they fear the introduction of humidity from outside, especially in the hot-humid climate.

- **Smart Ventilation solutions that minimize indoor humidity at an acceptable cost to production builders have the potential to overcome this barrier while providing the important IAQ benefits necessary for occupant health.**

Approach

- Field validation, using low cost IAQ sensors, of a smart ventilation system that can help low-load homes in humid environments maintain acceptable indoor humidity conditions while providing adequate ventilation according to ASHRAE 62.2.
- Collect field data for one year in 4 Charleston new construction homes in order to determine the differences in occupant comfort, IAQ, and HVAC energy consumption when toggling bi-weekly between an ERV operating continuously and an ERV operating with smart, time-varying humidity control logic.
  - Measuring : T, RH, CO_2, PM2.5, and Radon

- **This will address some of the builders' concerns and answer the question of whether the smart control logic helps with occupant comfort and the creation of a more acceptable indoor environment.**

Impact

This project will Validate/Demonstrate Smart Ventilation and Real-Time Controls as part of the “Smart ventilation technology solutions” area of Roadmap C: Optimal Ventilation and IAQ Solutions.

Smart ERV, compared to other technologies:

Technology Option	Installed Cost	Notes
Central Fan Integrated System (CFIS)	$680	No tempering of OA, humidity concerns, uses AHU blower
Ventilating Dehumidifier	$3,250	High Price
Standard ERV	$1,200	“Continuous Mode” in this project
Broan ERVS100S Smart ERV	$1,200	“Smart Mode” in this project

Progress

- Collaborated with IoT company Senseware to select low-cost IAQ sensors for a sensor package
  - Senseware IAQ package now commercially available

- Collaborated with Broan/Venmar to modify their smart ERV model ERVS100S to remotely toggle between "Smart" and "Continuous" modes using the Senseware platform

Progress

- Collaborated with NREL to modify BEopt program to include CFIS and smart ERV modeling capabilities
  - CFIS modeling capability now publicly available

Release Notes

BEopt Version 2.8 contains a number of new capabilities. New features include:

- Central fan integrated supply (CFIS) mechanical ventilation type
- Ducted mini-split heat pump (MSHP) options
- New Kiva ground heat transfer model
- Updated to EnergyPlus v8.8
- New version of DView

- Used UL Environment's chambers to baseline the low-cost sensor packages' performance prior to deployment
  - Will test again after the year-long deployment to check for sensor drift

Progress

- All 4 houses have been performance tested, have sensors and monitors installed, and the ERVs are online, switching bi-weekly
- House relative locations:

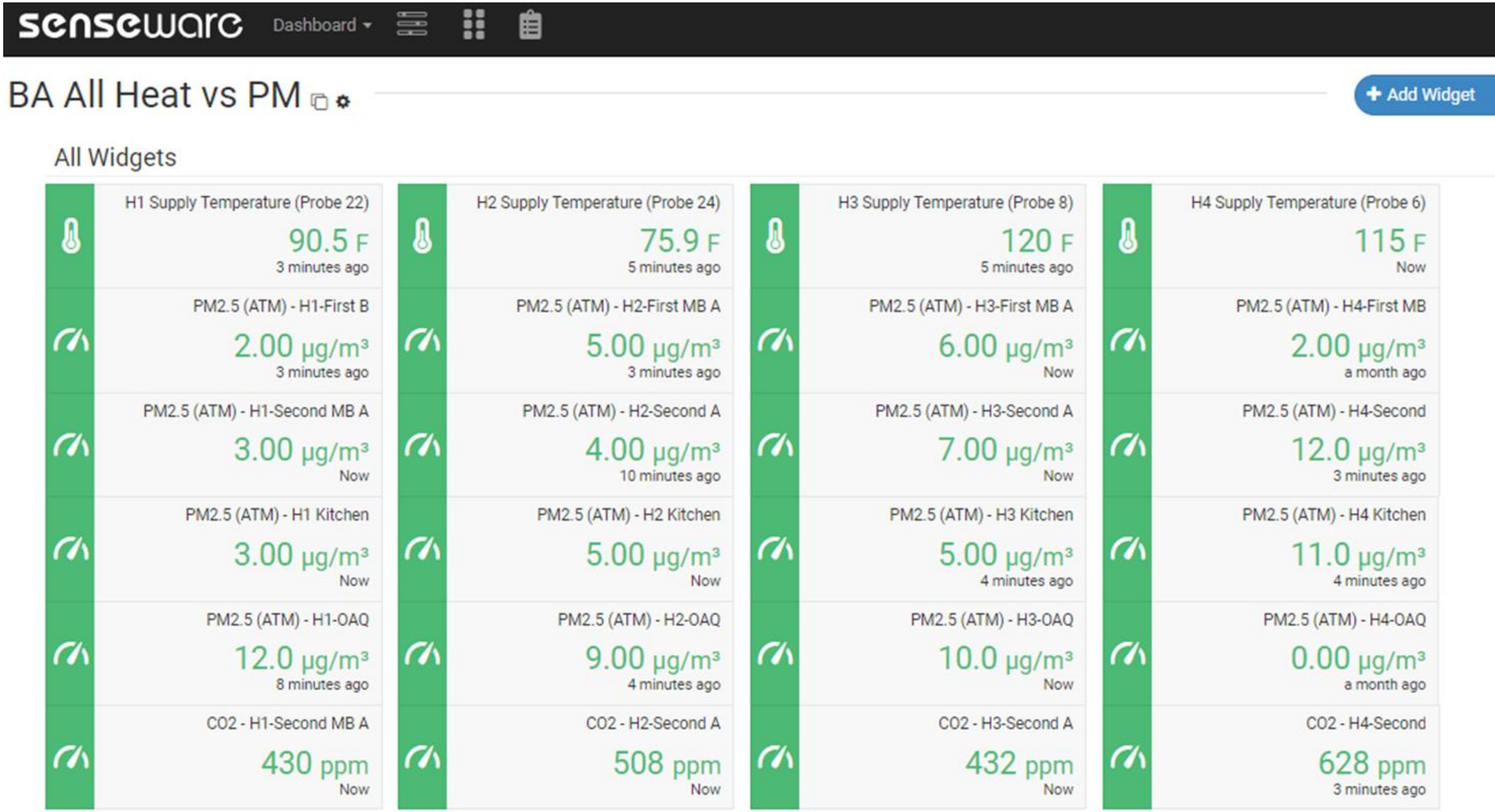
Progress

- Senseware controls and T/RH probes installed in ERV ductwork

- Senseware IAQ sensor package placed in the kitchen area

Progress

- Senseware platform example:



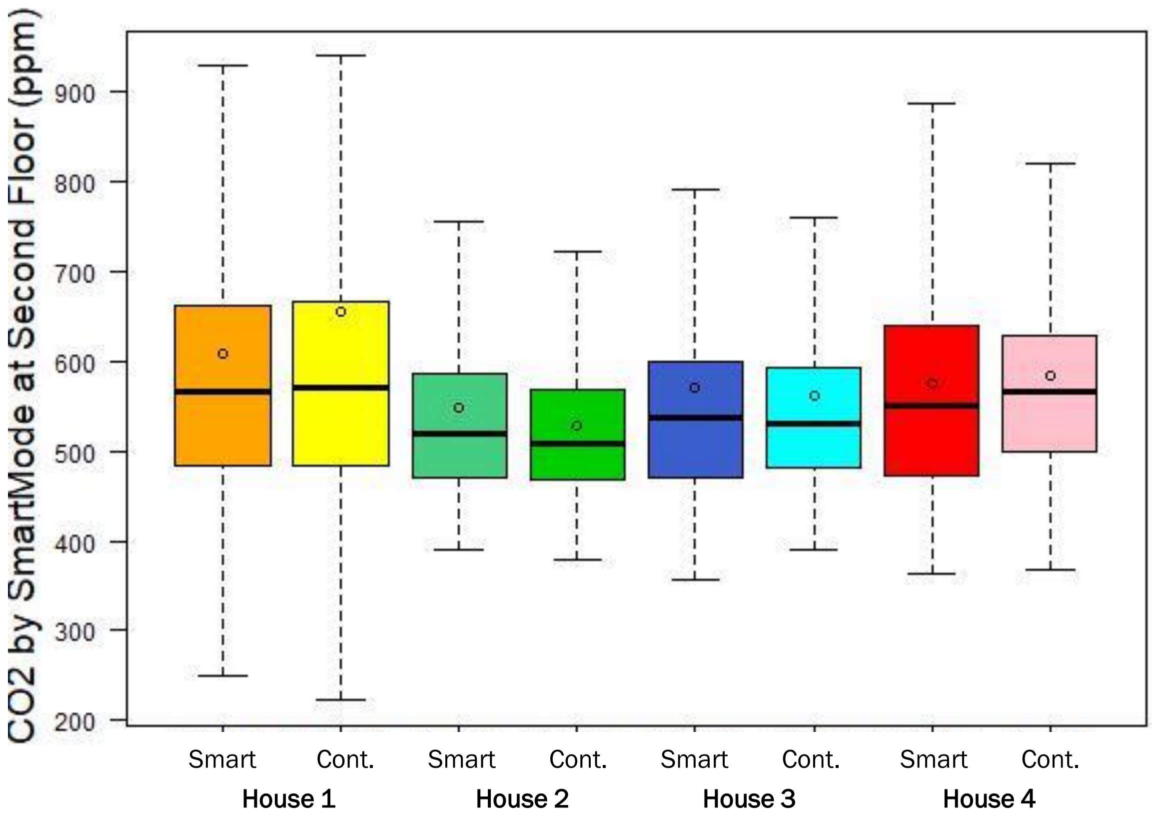
Progress

- QAQC on the Co-located Sensors:

Pollutant	Household #	Micro Environment	Device A (Avg. ± Std. Dev.)	Device B (Avg. ± Std. Dev.)	Absolute Precision	Relative Precision (%)
$PM_{2.5}$	Household 1	First Floor	7.4±11.2	8.6±11.5	1.7	21.8
$PM_{2.5}$	Household 2	First Floor	13.0±24.6	12.6±25.9	2.3	17.7
$PM_{2.5}$	Household 3	First Floor	14.0±19.2	15.7±22.2	2.9	19.4
$PM_{2.5}$	Household 1	Second Floor	7.9±9.5	7.9±9.3	1.8	23
$PM_{2.5}$	Household 2	Second Floor	11.7±24.9	11.9±22.5	4.3	36.6
$PM_{2.5}$	Household 3	Second Floor	13.6±21.0	13.8±21.9	2.8	20
CO_2	Household 1	First Floor	521.79±113.6	533.2±123.1	16.7	3.2
CO_2	Household 2	First Floor	670.73±207.76	680.1±213.1	16.5	2.4
CO_2	Household 3	First Floor	678.36±202.66	668.7±197.7	11.7	1.7
CO_2	Household 1	Second Floor	686.4±517.7	572.1±126.3	364.0	57.8
CO_2	Household 2	Second Floor	552.8±143.47	558.4±140.7	19.8	3.6
CO_2	Household 3	Second Floor	562.73±151.37	569.3±155.0	10.8	1.9

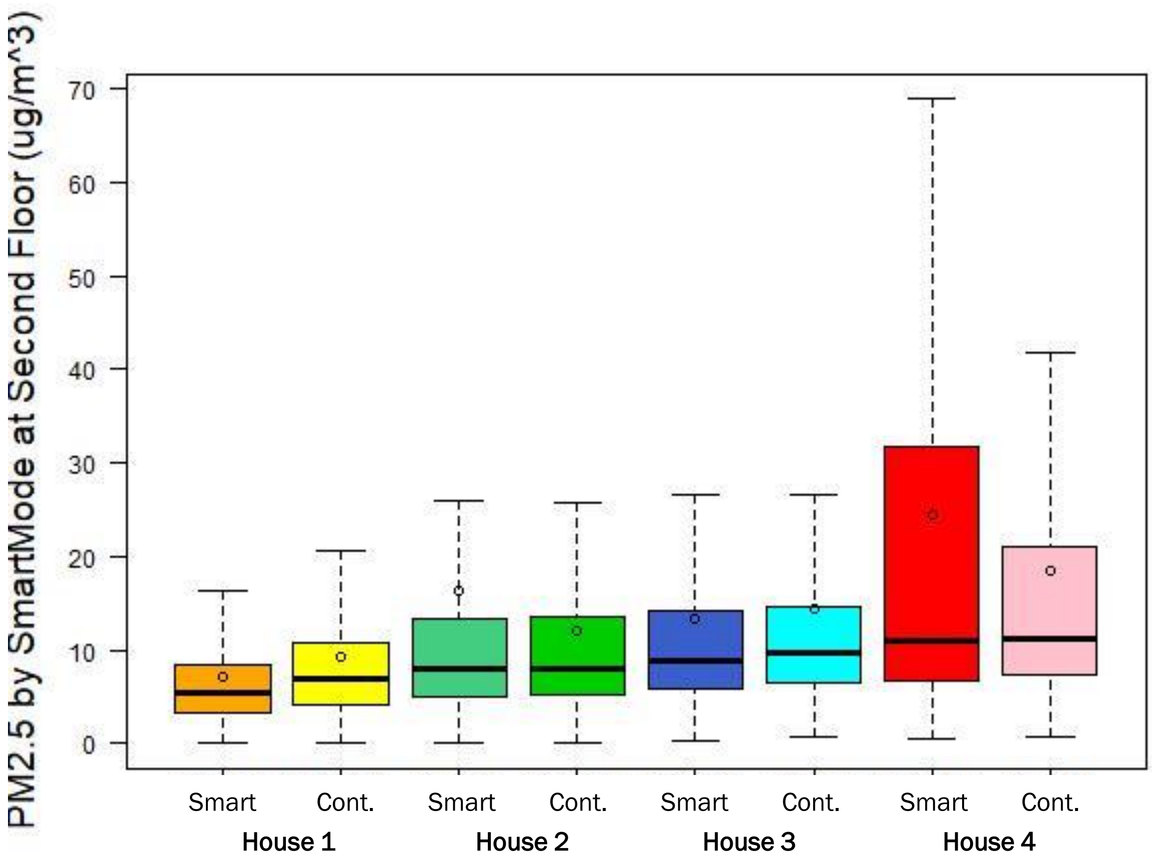
Progress

- CO_2 Concentrations on Second floor, Smart vs. Continuous mode



Progress

- PM2.5 Concentrations on Second floor, Smart vs. Continuous mode



Progress

Multivariate Linear Mixed Regression Modeling Initial Results

$$PM2.5 \sim \beta_1(\text{ERV Mode}) + \beta_2(\text{Outdoor}) + \beta_3(\text{Microenvironment}) + \beta_4(\text{Temp.}) + \beta_5(\text{Humidity}) + \beta_6(\text{House \#})$$

$PM2.5$: Indoor PM2.5 Concentration

Coefficients

β_1 : Influence of ERV Mode

β_2 : Influence of Outdoor PM2.5 Concentration

β_3 : Influence of Microenvironment (individual sensors throughout house)

β_4 : Influence of Temperature

β_5 : Influence of Humidity

β_6 : Influence of House #

Progress

Multivariate Linear Mixed Regression Modeling Initial Results

$$PM2.5 \sim \beta_1(\text{ERV Mode}) + \beta_2(\text{Outdoor}) + \beta_3(\text{Microenvironment}) + \beta_4(\text{Temp.}) + \beta_5(\text{Humidity}) + \beta_6(\text{House \#})$$

Compared to Continuous mode, periods when the ERV operated in Smart mode:

- Exhibited reduced indoor PM levels during periods with little to no indoor PM source generation (i.e., 11 pm to 5 am)
- Exhibited slightly elevated indoor PM levels during periods when indoor PM sources were more common (i.e., 3 pm to 8 pm)
- Both of these observed trends are consistent with the expected lower ACH rate in Smart mode.
- However, results should be interpreted cautiously, given the relatively limited operating period for several of the test homes.

Stakeholder Engagement

Currently in monitoring/initial analysis phase of the project

- Collaboration with Beazer and Broan to implement lessons learned
- Constant engagement with homeowners about comfort, other issues
- Engagement with NREL and LBNL engineers throughout test plan and analysis design
- Engagement with NREL engineers to add CFIS and Smart ERV modeling capabilities to BEopt
- Collaboration with Senseware to select sensors for their IAQ package and troubleshoot their platform and sensor packages
- Working with:
  - Broan/Venmar engineers to analyze ERV performance data
  - Emory University Rollins School of Public Health to analyze the IAQ data
  - UL Environment to analyze IAQ and sensor drift data

Remaining Project Work

- Continue monitoring, ERV mode toggling, and quarterly check-ins
- Continue analyses:
  - Occupant comfort and comfort metrics (in partnership with Emory)
  - IAQ (in partnership with Emory)
  - ERV performance analysis (in partnership with Venmar)
- Retrieval of sensors and home Test-out
- Post-monitoring period sensor drift analysis at UL Environment
- Sharing of results with stakeholders to improve their products and homes
- Develop actionable guidance for builders and designers on smart ventilation solutions

Thank You

Southface
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REFERENCE SLIDES

Project Budget

Project Budget: $661,417 Federal / $214,134 Cost Share
Variances: None
Cost to Date: $456,227 / $661,417 = 69% through March 25, 2018
Additional Funding: None

Budget History					
10/1/2016 – FY 2018 (past)		FY 2019 (current)		FY 2020 – 9/30/2019 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$437,642	$143,790	$18,585	$6,000	$205,190	$64,344

Project Plan and Schedule

- Project Start: 10/1/2016
- Project End: 9/30/2019
- No-Cost extension required after 1 year, due to delays in sensor development, IRB approval, Test Plan approval, new home construction
- Change in Principal Investigator to Bryant Hains on 8/28/2017
- Currently in final Budget Period, no more Go/no-go's
- Remaining Work:
    - Monitoring, check-ins
    - Test-out
    - Sensor drift testing
    - Data Analysis
    - Final reporting
- Remaining Milestone:
    - Identify differences in occupant comfort, T/RH, and HVAC energy consumption between smart and continuous ERV operation strategies and whether there is a measureable difference in IAQ pollutant levels between the two strategies