# Partnership for Improved Residential Construction

2017 Building Technologies Office Peer Review






**Full-Scale Residential Research Laboratories at FSEC**
**Top**: *Flexible Residential Test Facility*: smart ventilation studies in side-by-side control and experiment houses. **Bottom:** *Manufactured Housing Lab*: experiments with variable capacity HVAC systems.

**Occupied Field Study Houses**
WSU smart ventilation study home in Washington (top, left) and FSEC optimal comfort system study homes on the east (top, right) and west (bottom) coasts of the Florida peninsula.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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**Florida Solar Energy Center, University of Central Florida**

# Project Summary

**Timeline**:

Start date: August 1, 2015

Planned end date: July 31, 2017

**Key Milestones:**

1. Complete setup, begin data collection; December 2015
2. Preliminary evaluation of research questions; July 2016
3. Complete data collection; June 2017

**Budget**:

**Total Project $ to Date (2/23/2017)**:

- DOE: $714,576
- Cost Share: $159,615

**Total Project $:**

- DOE: $1,000,000
- Cost Share: $250,000

**Key Partners**:

| *Comfort Systems* | *Ventilation / IAQ* |
|---|---|
| Unico | Wash. State Univ. |
| Panasonic (heat/cool) | Panasonic (vent) |
| Mitsubishi | Nest Labs |
| Habitat for Humanity | Air Cycler |

**Project Outcome**:

1) *Optimized Comfort Systems* - Demonstrate system approaches for energy efficient management of temperature and relative humidity in low load homes in humid climates. *MYPP goal: 10% heating/cooling energy savings from individual technologies.*

2) *Optimal Ventilation / IAQ* – Demonstrate approaches to optimize delivery of mechanical ventilation in response to variable risk factors. *MYPP goal: 10% heating/cooling energy savings from individual technologies.*

# Purpose and Objectives – Optimized Comfort Systems

**Problem Statement**: Energy efficient home construction and remodeling leads to reduced sensible load, but latent loads remain unchanged. As a result, conventional space cooling equipment runs less, and may no longer manage moisture and comfort adequately.

**Target Market and Audience**:

<u>Target Market:</u> High performance new construction and renovation in humid climates. Cooling energy use = 0.13 Quads (site energy basis).

<u>Audience:</u> Early adopter builders, remodelers and mechanical contractors that need solutions now. Product manufacturers who can provide mass-market solutions.

# Purpose and Objectives – Optimized Comfort Systems

**Impact of Project**: Demonstrate ability of emerging space cooling equipment to maintain RH < 60% with less reliance on supplemental dehumidification, resulting in 10% cooling energy savings and meeting immediate needs of early adopters. Identify desirable operational characteristics that can be used to advance conventional equipment to meet similar, growing needs of mass market. Success also helps enable best practice mechanical ventilation in humid climates.

**Project Outputs:** Project specific data leading to guidance on applicability of emerging systems for early adopters and recommendations for manufacturers to improve performance of both advanced and conventional cooling equipment.

a. Near-term outcomes: Partner builders incorporate innovations as standard.
b. Intermediate outcomes : Increase general humid climate Zero Energy Ready Home (ZERH) compliance and engage manufacturers of conventional equipment to consider solutions.
c. Long-term outcomes: Humid climate HVAC systems become standard product offerings, and considerations for RH control performance included in equipment certification. Seeking similar, regional market transformation as we have seen with use of heat pumps vs. electric resistance, and Energy Star windows.

# Approach – Optimized Comfort Systems

**Approach**: Testing relative humidity (RH) control of variable capacity heat pumps. Systems offer potential for better RH control via ability to vary compressor speed, refrigerant flow, and coil air flow.

- Conducting lab test of centrally ducted system with small duct high velocity distribution (Central Florida – CZ 2a), *Partners: Unico*.
- Conducting field tests of ducted mini-split and ductless multi-split systems (Central Florida – CZ 2a), *Partners: Habitat for Humanity, Mitsubishi, Panasonic*.

**Key Issues**:

- Need for supplemental dehumidification to maintain RH < 60% in low load, mechanically ventilated houses.
- Integration of mechanical ventilation as part of system package.

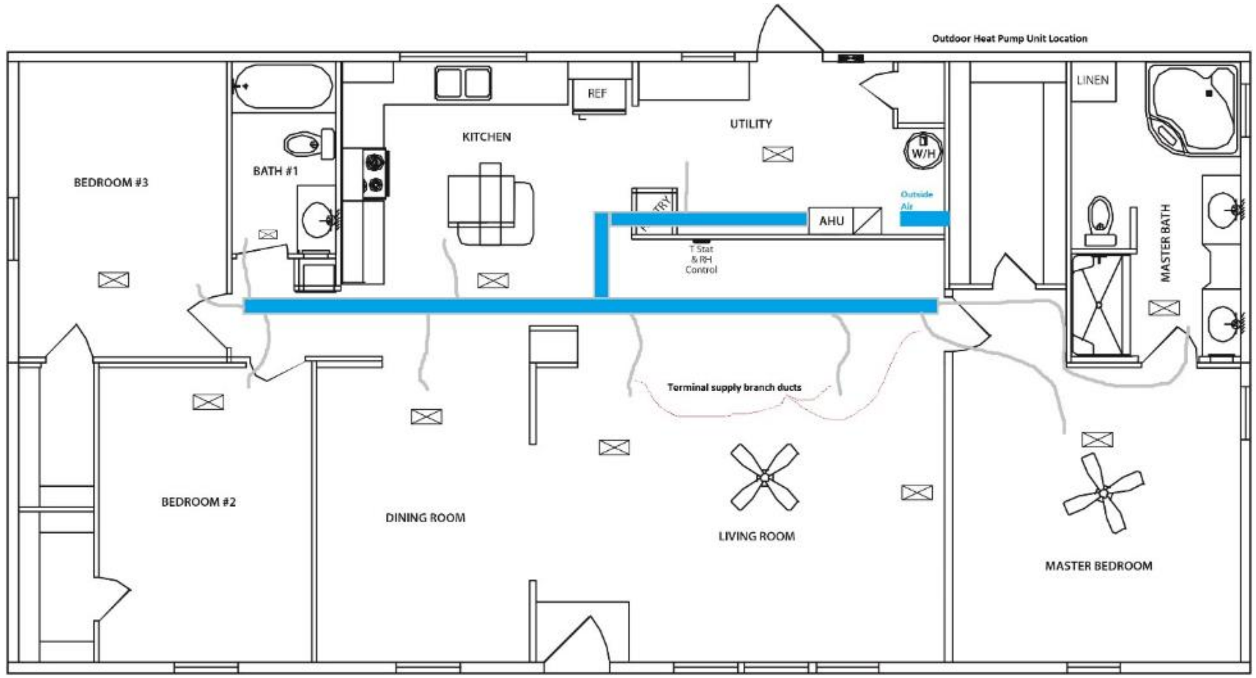
**Distinctive Characteristics**:

- Interior ducts can also be a barrier for ZERH. Approach involves strategies that reduce/eliminate duct losses through use of compact and/or ductless distribution.
- Investigating how distribution strategies perform in terms of evenness of comfort throughout the homes.

# Small Duct High Velocity (SDHV), Variable Capacity Heat Pump

**Lead: Chuck Withers**

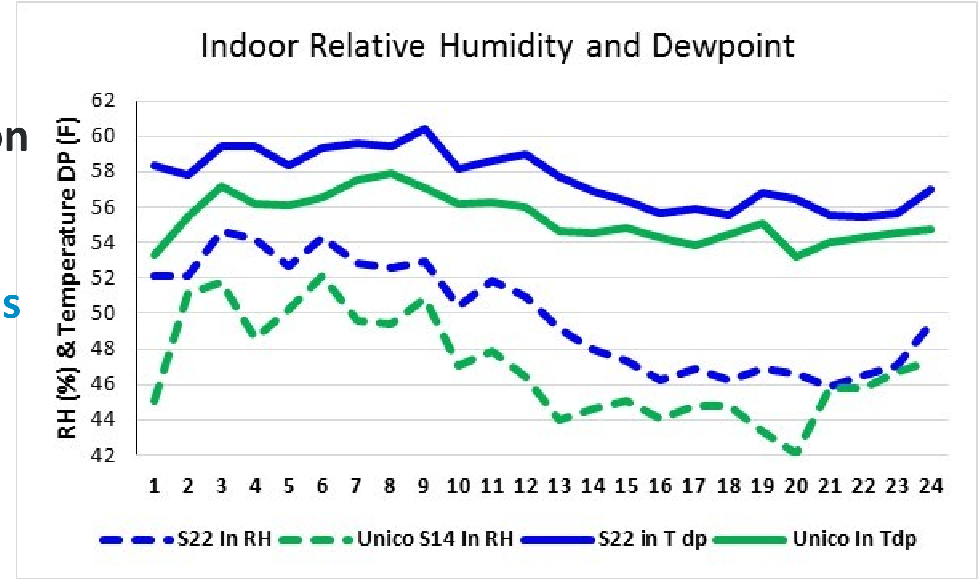





**Supplemental Dehumidification Energy:**

**SEER 22 = 0.44 kWh/d (previous testing)**

**SDHV = 0.22 kWh/d (current testing)**

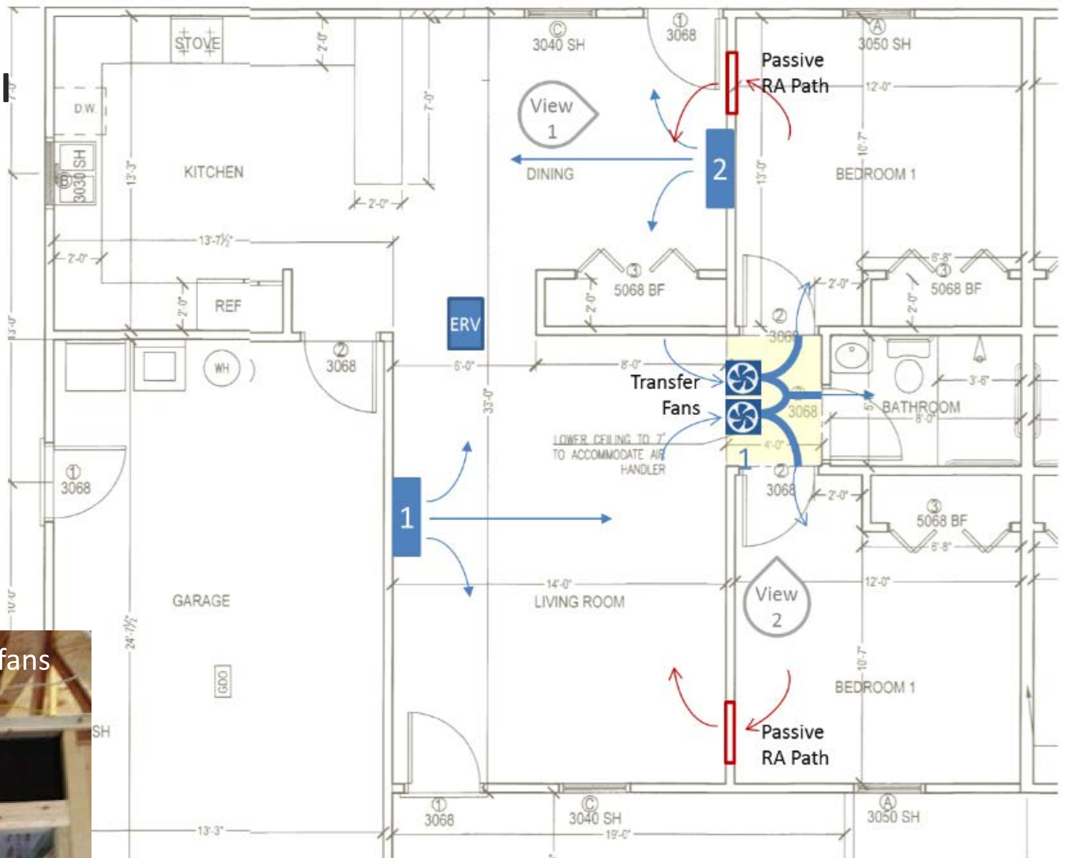


# Ductless Multi-Split

Lead: Janet McIlvaine, Dave Chasar, David Beal

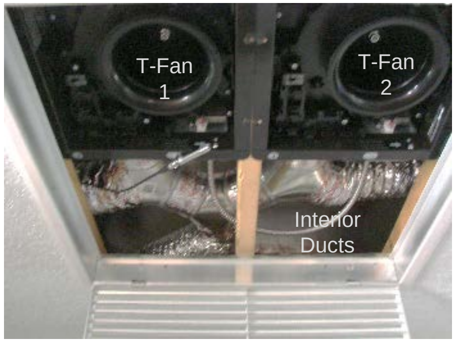
## SE Volusia Habitat for Humanity (Florida)

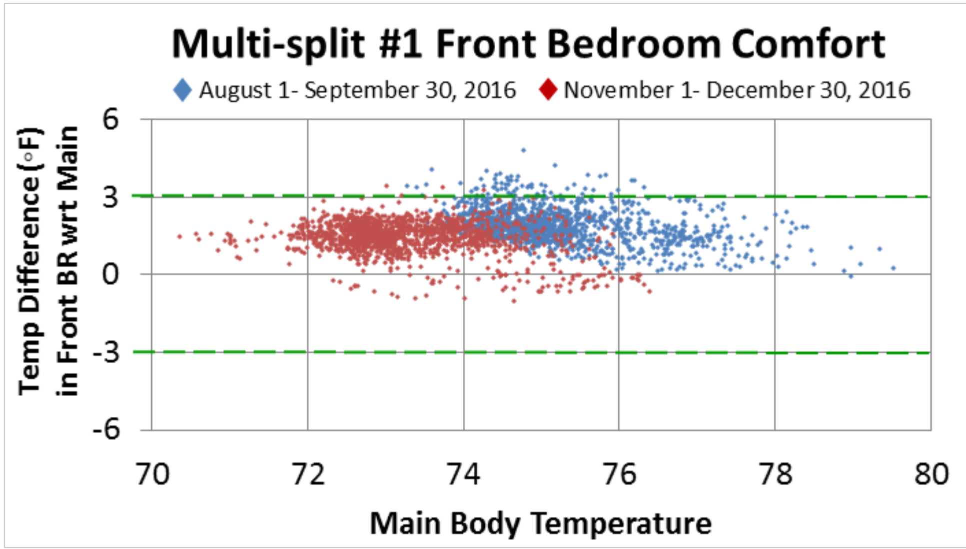
- Duplex (1,075 ft$^2$ per unit)
- Panasonic bundled package
  - 2 fan coil units in main body
  - 2 transfer fans circulate air to BRs
  - ERV for mechanical ventilation









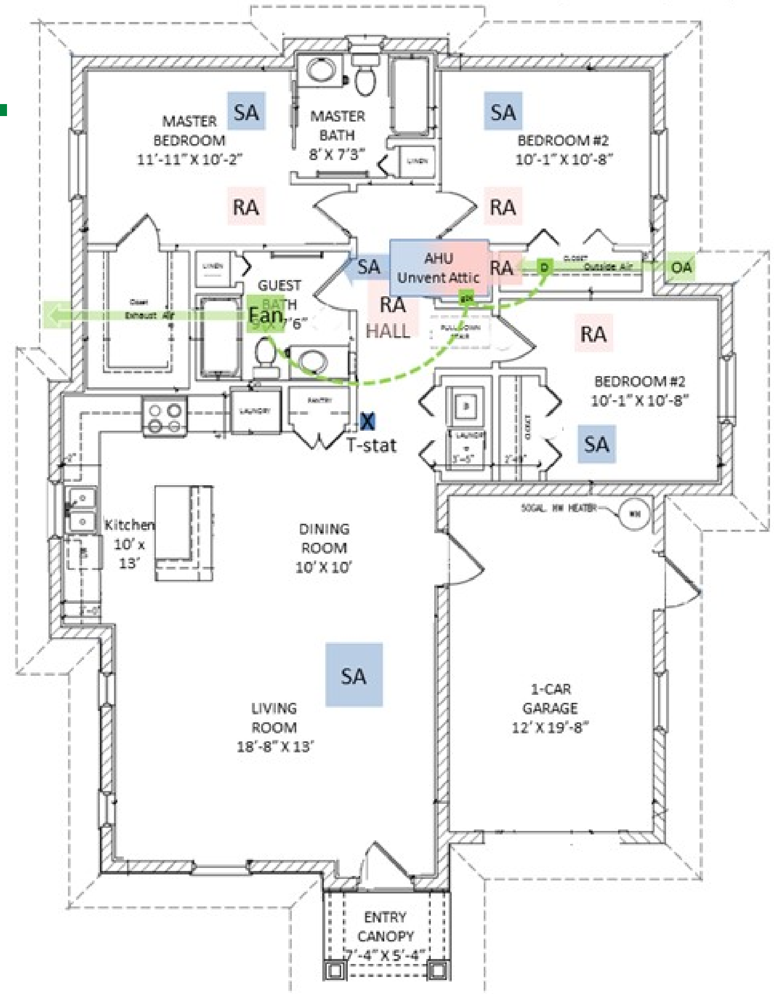



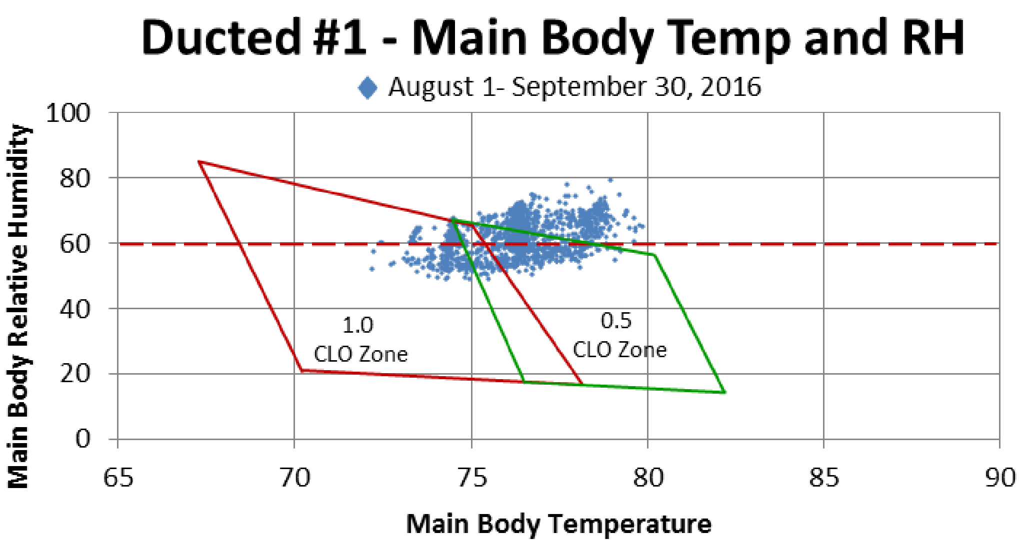
# Ducted Mini-Split

**Lead: Janet McIlvaine, Dave Chasar, David Beal**

### South Sarasota Habitat for Humanity (Florida)

- 2 single family detached houses (1,290 $ft^2$ per unit)
- Mitsubishi mini-split with cassette AHU
  - Fully ducted supply and return
  - Unvented attic
  - Hybrid supply/exhaust system for mechanical ventilation.




# Progress / Accomplishments – Optimized Comfort Systems

**Accomplishments**:

1) Ductless systems with transfer fans distribute comfort within ACCA Manual RS guidelines (bedrooms ± 3$^{o}$F from set point) for > 95% of all hours for all months.
2) Small duct, high velocity central system able to maintain RH < 60% with only incidental need for supplemental dehumidification (50% less than previous SEER 22 system tested), due to consistently low cfm/ton. Dry mode requires no dehumid.
3) Variable capacity systems tested do not appear to operate at lowest stated capacities for extended periods (>15 minutes). Mini/Multi systems often default to high coil temp.
4) 3 of 4 Mini/multi-split homes have 50-70% of cooling hours > 60% RH; 25-35% of cooling hours > 65% RH.

**Market Impact**: Partner Habitat affiliates have transitioned to the ducted mini-split system as standard, with ~30 homes built to date. Accelerating impact by:

1. Engaging with 3 equipment manufactures to identify and implement modifications to improve performance.
2. Engaging builders/contractors through conferences, focused training activities.
3. Working together with Habitat and manufacturers as they develop and standardize regional HVAC packages available through Gifts in Kind program.

**Awards/Recognition**: Partner Habitat affiliates have won DOE Housing Innovation Awards in 2014, 2015, and 2016.

# Purpose and Objectives – Optimal Ventilation / IAQ

**Problem Statement**: Mechanical ventilation is a critical component of a comprehensive strategy for good IAQ. However, the potential for continuous delivery of outdoor air to impact energy use and comfort presents a barrier to installation and operation of compliant systems.

**Target Market and Audience**:

Target Market: High performance new construction and renovation in all climates. Heating/cooling energy use = 1.46 Quads (site energy basis).

Audience: Product manufacturers for commercialization of solutions; ASHRAE Standard 62.2, ZERH / Energy Star, and codes to enable adoption of solutions; and builders and contractors for implementation of solutions.

# Purpose and Objectives – Optimal Ventilation / IAQ

**Impact of Project**: Demonstrate ability of smart ventilation systems to better manage energy and comfort risks, while ensuring compliant acute and chronic exposure to pollutants. Success will lead to increased market penetration, increased effectiveness of installed systems, and 10% heating/cooling energy savings.

**Project Outputs:** Project specific data leading to commercialization of smart ventilation systems and guidance for compliant operation.

a. <u>Near-term outcomes</u>: Single variable systems operated in compliant fashion.
b. <u>Intermediate outcomes</u> : Multi-variable systems and advanced single variable systems available commercially. Enables increased penetration of ZERH, Energy Star, etc.
c. <u>Long-term outcomes</u>: Combined with improvement of low-cost IAQ sensors, apply smart ventilation principles to performance based IAQ standards and mechanical ventilation systems. Risks related to delivery of outdoor air no longer a barrier to adoption of mechanical ventilation and compliant operation.

# Approach – Optimal Ventilation / IAQ

**Approach**: Testing smart mechanical ventilation systems that vary outdoor air flow in response to various risk factors.

- Lab test of system varying relative exposure (flow) real time, proportional to outdoor temperature and relative humidity (Central FL, CZ 2a – hot humid).
- Field test of system delivering two levels of flow in response to 1) outdoor temperature and 2) occupancy (Washington, CZ 4c - marine), *Partners: Panasonic, Nest Labs.*
- Field test of hybrid supply (CFIS)/exhaust system (Central Florida, CZ 2a – hot humid), *Partners: Habitat for Humanity, AirCycler*.

**Key Issues**:

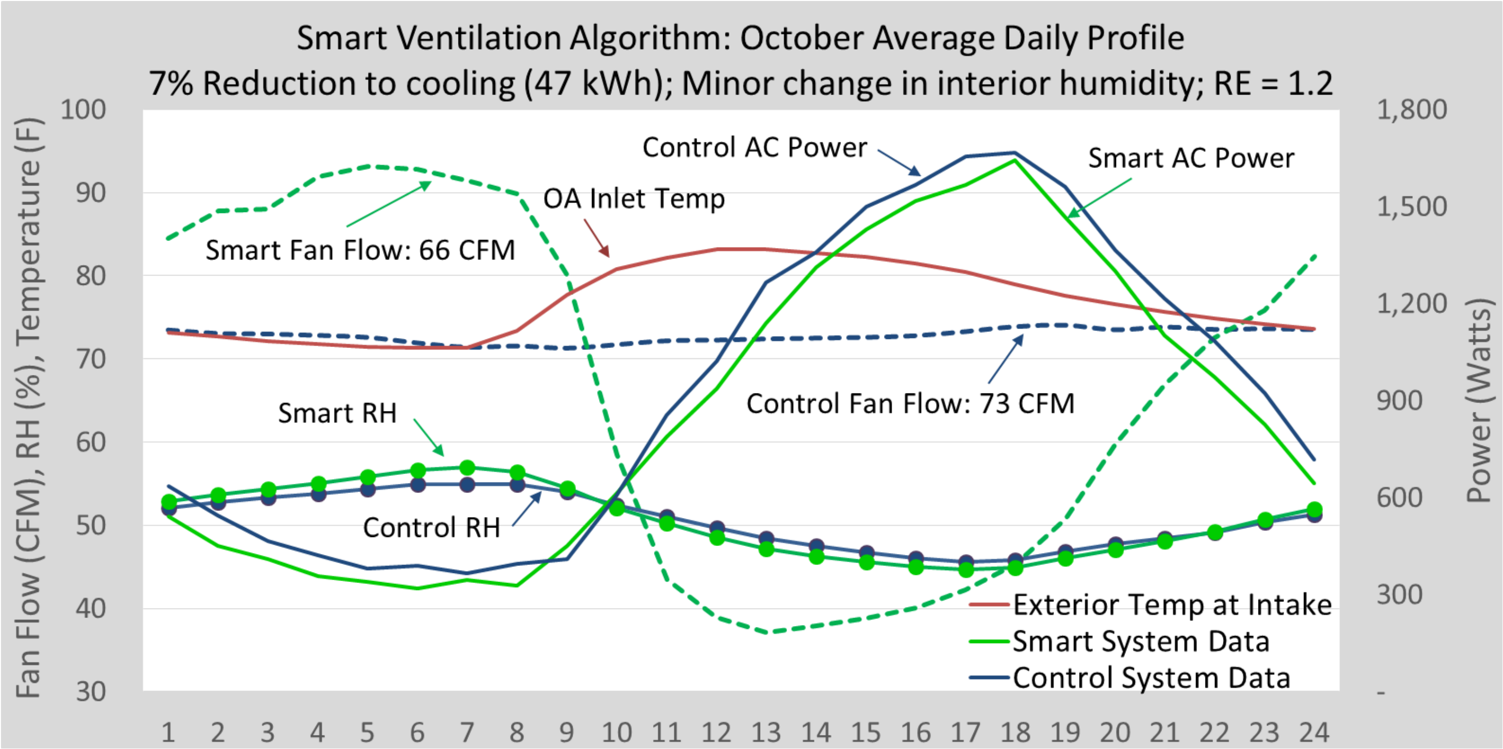
- Deliver improved (or equivalent) comfort, while consuming less (or an equivalent amount of) energy, compared to continuous ventilation.
- Deliver relative exposure to pollutants in accordance with ASHRAE 62.2-2016.

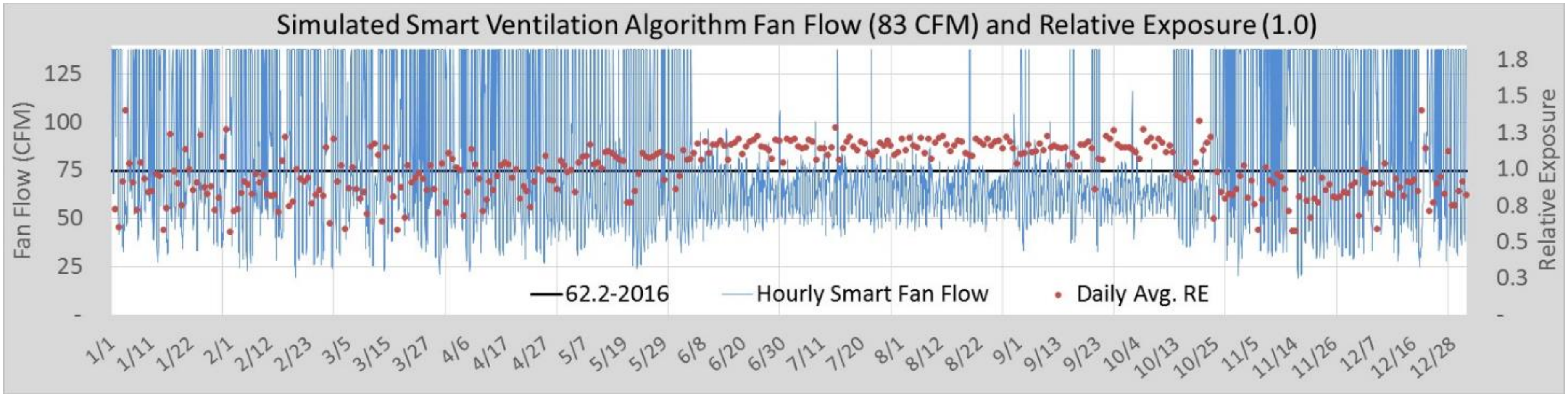
**Distinctive Characteristics**:

- Engaging ventilation equipment manufacturers and other stakeholders, including ASHRAE Standard 62.2 committee, to enable market penetration.

# Smart Ventilation Algorithm Lab Test

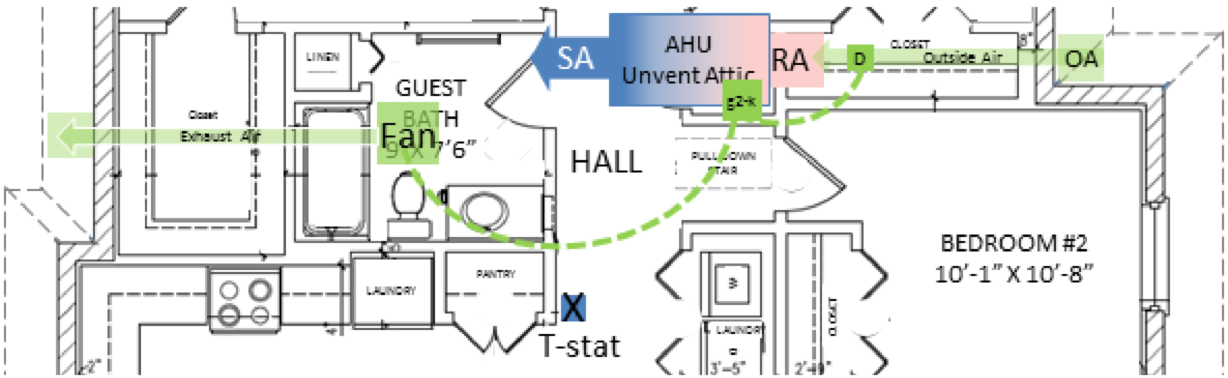
Lead: Danny Parker, Karen Sutherland



# Hybrid Supply/Exhaust Ventilation Field Test (Florida)

- System prioritizes central fan integrated supply (CFIS) ventilation when actively heating/cooling.
- Balance needed for ASHRAE 62.2 compliance made up with efficient exhaust fan.
- Will ASHRAE 62.2 compliance be achieved if mini-split causes CFIS flow to vary?





# Temperature/Occupancy Controlled Ventilation Field Test (WA)

**Lead: Michael Lubliner, WSU**

- Deep Energy Retrofit. Exhaust ventilation. ACH50 = 5.
- Investigating resulting indoor comfort, indoor air quality, and energy impacts among 40 cfm continuous exhaust ventilation and:
    - 0 cfm when outdoor temperature < 57F, 90 cfm when outdoor temp > 57F, taking advantage of stack induced natural ventilation.
    - 0 cfm when unoccupied, 40 cfm when occupied.

# Progress / Accomplishments – Optimal Ventilation / IAQ

**Accomplishments**:

1) Smart ventilation algorithm delivering 1.3 kWh/d cooling energy savings = 6.3% average monthly cooling energy savings (ranging from 1-18%). Minor indoor RH impacts.
2) Temperature based ventilation control estimated to save 9% heating energy (230 kWh/y) with no indoor RH impacts.
3) Hybrid supply/exhaust system provides relative exposure <1 when mated with variable capacity heat pump.
4) Started dialogue within ASHRAE 62.2 related to relationship between occupancy and pollutant emission rates, potentially enabling additional energy savings and/or IAQ improvement.

**Market Impact**: Partner Habitat affiliate has built ~6 homes with the hybrid supply/exhaust system. Accelerating impact by:

1. Providing input to/review of ASHRAE 62.2 user manual containing examples of applications involving compliant, smart ventilation systems.
2. Engaging manufacturers and other stakeholders to identify commercialization issues and remaining gaps including system costs, commissioning, fault detection, and interoperability of components across communication platforms.
3. Investigating use of measurements from low cost IAQ sensors (TVOC, $CO_2$) as a surrogate for occupancy. Participating in Energy Star Web Connected Thermostat efforts to enable smart ventilation control.

# Project Integration and Collaboration

**Project Integration**: Collaborating and coordinating with:

- Builders and contractors (local Habitat affiliates and Habitat International) to assist with validation and adoption of innovations.
- Voluntary programs (Zero Energy Ready Home) to communicate potential solutions to barriers and enable adoption by leading building professionals.
- Industry standard organizations (ASHRAE 62.2) to inform the market on best practice.
- HVAC manufacturers to develop and commercialize mass market solutions (Including some not yet mentioned: Trane, Honeywell, Aprilaire, QuFresh).

**Partners, Subcontractors, and Collaborators**:

- Subcontractor: WSU – Leads smart ventilation activities related to occupancy, marine/cold climates, and commercialization.
- Partners: Panasonic, Nest, Energy Conservatory, Unico, Mitsubishi, AirCycler, and Habitat for Humanity.
- Collaborators: LBL, PARR Building America Team, NREL

**Communications**:

- Expert meeting, conference papers, and panel sessions on smart ventilation.
- Education of local, regional, and national Habitat stakeholders through roundtables, conferences, and webinars.

# Next Steps and Future Plans (current scope / future)

**Optimized Comfort Systems**:

- Implement RH control enhancement in homes with Mitsubishi ducted mini-split. Discussing similar enhancements with Panasonic and Unico.
- Adjust transfer fan air flow in homes with ductless multi-split.
- Perform simulations to quantify impact of supplemental dehumidifier energy at RH set points < 60%.
- Engage with EnergyStar HVAC certification on inclusion of criteria for RH control performance.

**Optimal Ventilation/IAQ**:

- Continue dialogue on occupancy control within ASHRAE 62.2. Simulate energy savings potential with large scale occupancy data from Nest Labs.
- Analyze data on interior conditions in occupancy controlled residence and correlate data from multiple, low cost IAQ monitors against tracked occupancy.
- Adjust smart vent algorithm parameters in Florida lab to ensure compliant relative exposure, shift emphasis to RH control.
- Hybrid supply/exhaust system: Determine if fraction supplied by exhaust increases proportionally as outdoor dew point decreases, and if expected energy savings are being realized.
- Engage with ASHRAE 62.2 regarding acceptable occupancy detection and IAQ sensors, and requirements for fault detection and alerts.

# REFERENCE SLIDES

# Project Budget

**Project Budget**: FY 2016 funds primarily spent on experimental set up and preliminary data collection. FY 2017 funds primarily spent on final data collection and reporting.

**Variances**: Original deliverables planned for March 2017, but early delays in one task enable data collection to continue through June 2017 with deliverable reports planned for July 2017.

**Cost to Date**: 70% of the budget has been expended to date (as of 2/23/2017).

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

| Budget History | | | | | |
|---|---|---|---|---|---|
| August 2015– FY 2016 (past) | | FY 2017-July 2017 (current/planned) | | FY 2018 (N/A) | |
| DOE | Cost-share | DOE | Cost-share | DOE | Cost-share |
| $514,523 | $124,371 | $485,477 | $125,629 | $0 | $0 |

# Project Plan and Schedule

- Initiation date: 8/1/2015. Project planned completion date: 7/31/2017.
- Original builder partner for Florida smart ventilation field measurements dropped from project.  Change in builder partner and system type prevented “complete set-up” milestone for this task only from being achieved on original date of 12/2015.
- Go/no-go decision points evaluated preliminary results in 7/2016.

| Project Schedule | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Project Start: August 2015 | Completed Work | | | | | | | | | | | |
| Projected End: July 2017 | Active Task (in progress work) | | | | | | | | | | | |
| | Milestone/Deliverable (Originally Planned) | | | | | | | | | | | |
| | Milestone/Deliverable (Actual) | | | | | | | | | | | |
| | FY2015 | | | | FY2016 | | | | FY2017 | | | |
| Task | 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) |
| **Past Work** | | | | | | | | | | | | |
| Q4 Milestone: Approval of Experimental Plan | | | | | | | | | | | | |
| Q1 Milestone: Complete Set-Up / Instrumentation | | | | | | | | | | | | |
| Q2 Milestone: Smart Vent Expert Meeting | | | | | | | | | | | | |
| Q3 Milestone: Complete Cost Comparisons | | | | | | | | | | | | |
| Q4 Milestone: Evaluate Research Questions | | | | | | | | | | | | |
| **Current/Future Work** | | | | | | | | | | | | |
| Q3 Milestone: Complete Data Collection | | | | | | | | | | | | |
| Q4 Milestone: Deliver Final Report | | | | | | | | | | | | |