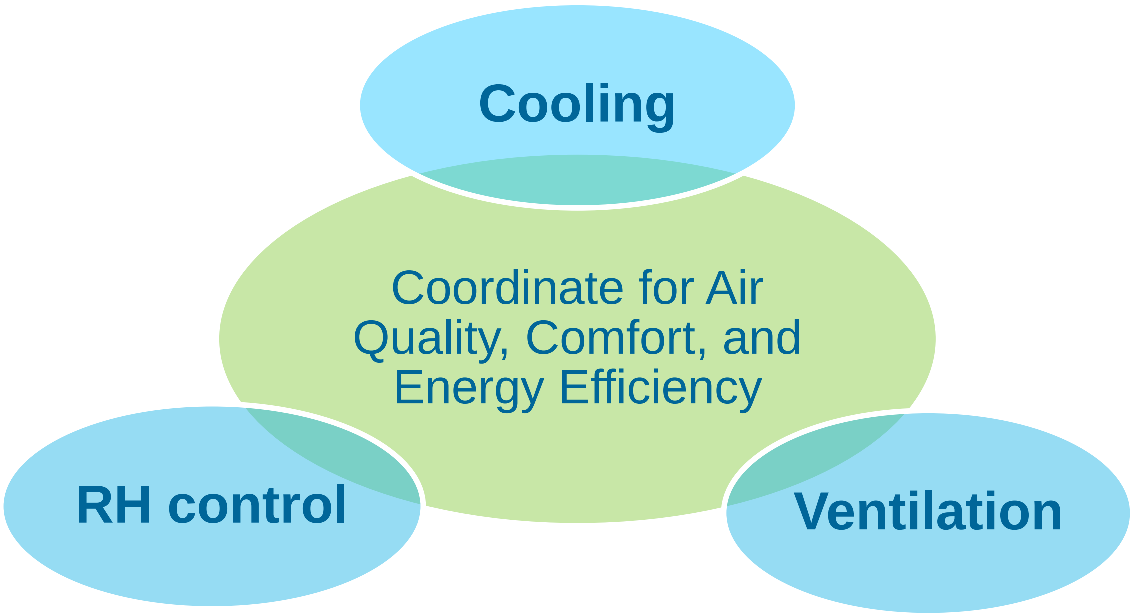
Advanced HVAC Humidity Control Strategies for Hot-Humid Climates



Home Innovation Research Laboratories
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Project Summary

Timeline:

Start date: **September 2017**

Planned end date: **September 2020**

Key Milestones

1. Enrolment of test homes – Spring 2018
2. Initial field results – Fall 2018 / Spring 2019

Key Partners:

Goodman Manufacturing Aprilaire® K. Hovnanian David Weekley Homes Wrightsoft®	ACCA NAHB AB Systems NREL

Budget:

Total Project $ to Date:

- DOE: $298,500
- Cost Share: $78,100 ($35,000 monetary; $43,100 in-kind)

Total Project $:

- DOE: $622,134
- Cost Share: $161,300 ($70,000 monetary, $91,300 in-kind)

Project Outcome:

1. Defined metrics for enhanced dehumidification mode for central AC systems
2. An HVAC control strategy that coordinates and optimizes the operation of the AC and the ventilation systems
3. HVAC design and integration solutions for builders in hot humid climates

Team

Home Innovation RESEARCH LABS™

Goodman Air Conditioning & Heating

NAHB

K. Hovnanian Homes

Building Dreams, Enhancing Lives
David Weekley Homes

ACCA Air Conditioning Contractors of America

Aprilaire®

MiTek WRIGHTSOFT

NREL Transforming ENERGY



Dave Mallay	Nay Shah	Vladimir Kochkin
Research Engineer	Research Engineer	Project Oversight

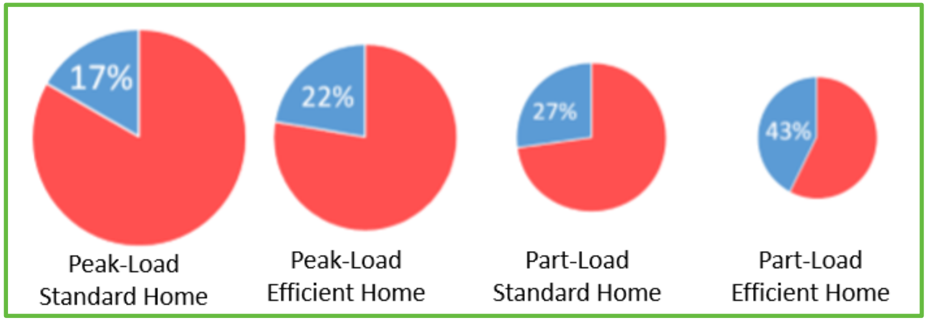
Gary Ehrlich	Ryan Kennett	Jim Hoffner Dean Potter	Derek Holtman Mike Funk
NAHB	Goodman Mfg.	K. Hovnanian Homes	David Weekley Homes

Armin Rudd	Scott Grefsheim	Glenn Hourahan, P.E.	Bill Wright
AB Systems	Aprilaire®	ACCA	Wrightsoft®

Challenge

Problem Definition:

1. For new homes equipped with whole-house mechanical ventilation, managing indoor humidity in hot-humid climates is one of the top issues for builders of all sizes and types.
2. AC systems are rated and designed to COOL and dehumidification will take care of itself
3. Builders are often reluctant to install supplemental dehumidifiers because of cost, durability, maintenance, integration with the rest of the HVAC, occupant operation, other factors
4. Ventilation can create comfort issues
5. Energy efficient homes may be more prone to higher RH levels if humidity control is not addressed



Example latent loads as a percentage of total loads

Fragmented Value Chain:

1. Risk transfer – who is responsible?
2. Communication barriers – who is the decision maker?
3. System integration
4. Quality control: design and installation

Builder

HVAC Designer

OEM

Ventilator Provider

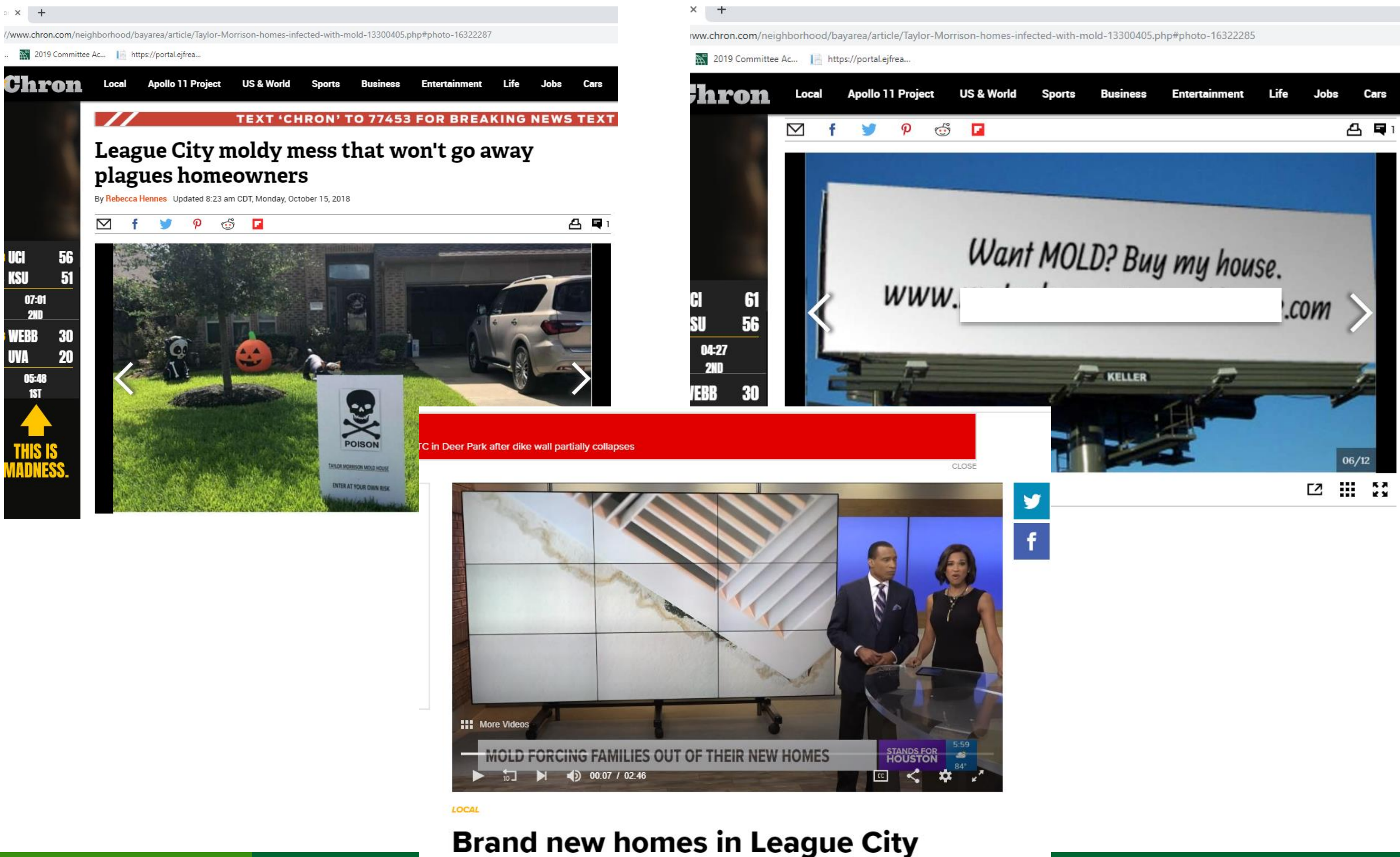
Control Providers

T-stat Provider

HVAC Trades

Challenge

- Very Recent Moisture Issues in Hot-Humid Markets



Approach

- Develop and validate a coordinated humidity and ventilation control strategy for central ducted systems that improves comfort and energy performance in hot-humid climates:
  - Identify metrics for enhanced AC dehumidification mode
  - Develop a control protocol for coordinating ventilation operation with AC operation
  - Identify limitations of the strategy and offer solutions for add-on supplemental dehumidification
  - Conduct modeling (partner – NREL)

- Metrics for optimization and coordination:
  - Indoor humidity at or below 60% RH
  - Part-time load conditions
  - Energy consumption (AC, ventilation, distribution)
  - Functionality (distribution; comfort; control)
  - Cost to install and operate

Enhanced Dehumidification

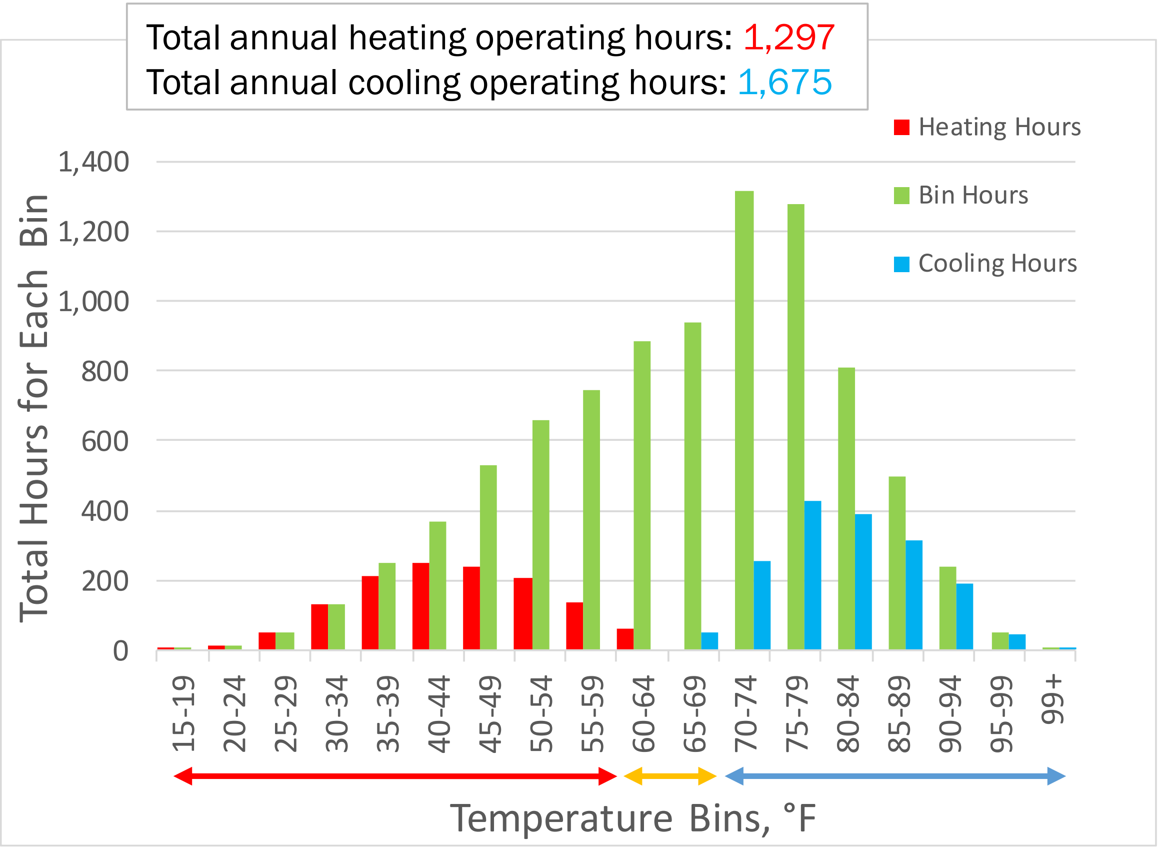
- *Goal = reduce the sensible heat ratio (SHR) when additional humidity control is needed*
  - Use advanced controls with a standard central heat pump or furnace/AC
    - Variable-speed ECM drive (not multi-speed)
    - Thermal Expansion Valve (TXV)
  - Operate at **full** compressor capacity
  - Establish the min air flow for the equipment to operate without freezing the evaporator (indoor) coil or damaging the system
  - Mode selection based on interior RH level either at onset or during the AC cycle
  - Thermostat, dead-band selected to maximize humidity control with minimal over-cooling
  - Optimize ramping profile during cooling to improve humidity control and minimize re-humidification at end of cycle

Prioritized Ventilation

- Outdoor air is ducted into return plenum at the air handler (supply type ventilation)
  - Outside air is conditioned during on-cycle and is always filtered and distributed
- Dedicated ventilation fan, ASHRAE 62.2-2010 capable
- Maximize ventilation **time and rate** during on-cycles
  - Double the continuous rate during on-cycle
  - Ventilate during off-cycles at reduced rate and only when a 4-hour target has not been met
- Maximum ventilation rate at 10% of HVAC system air flow
- Use “Smart Ventilation” during mild/favorable weather
- Relying on the air handler fan for distribution
  - Circulation (off-cycle) mode at 25% of normal AC air flow

Approach

❑ Prioritized Ventilation – Example Savannah GA



- During heating season on-cycle ventilation provides 95% of 62.2-2010 rate
- During cooling season on-cycle ventilation provides 80% of 62.2-2010 rate
- Over 12 months, combined on-cycle ventilation at twice continuous rate and off-cycle ventilation at half rate meet 62.2-2010

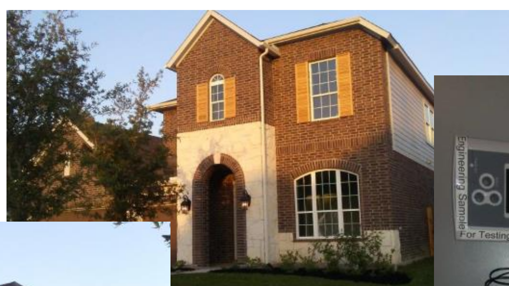
Impact

- Facilitate Builder Transition to High-Performance Homes
- Evaluate the limitations of and the potential for relying on a central HVAC system for maintaining humidity and comfort in energy efficient homes
- Allow builders to rely on the existing infrastructure for HVAC design and installation – simplify the transition while improving performance – finding the "sweet spot"
- Develop metrics for standardizing enhanced dehumidification mode across OEMs
- Develop metrics for control protocols for coordination of equipment operation: AC, furnace, ventilator, zones, thermostat

Progress

- Worked with Goodman to develop an enhanced dehumidification protocol/controls, Winter 2018
- Developed a ventilation protocol with Aprilaire, Summer 2018
- Conducted test house design reviews of ACCA Manual J/S/D with Wrightsoft and HVAC partners, Spring 2018
- Commissioned and instrumented systems at 3 test homes: Houston 1-stage & 2-stage AC, Savannah 1-stage HP (Fall 2018)



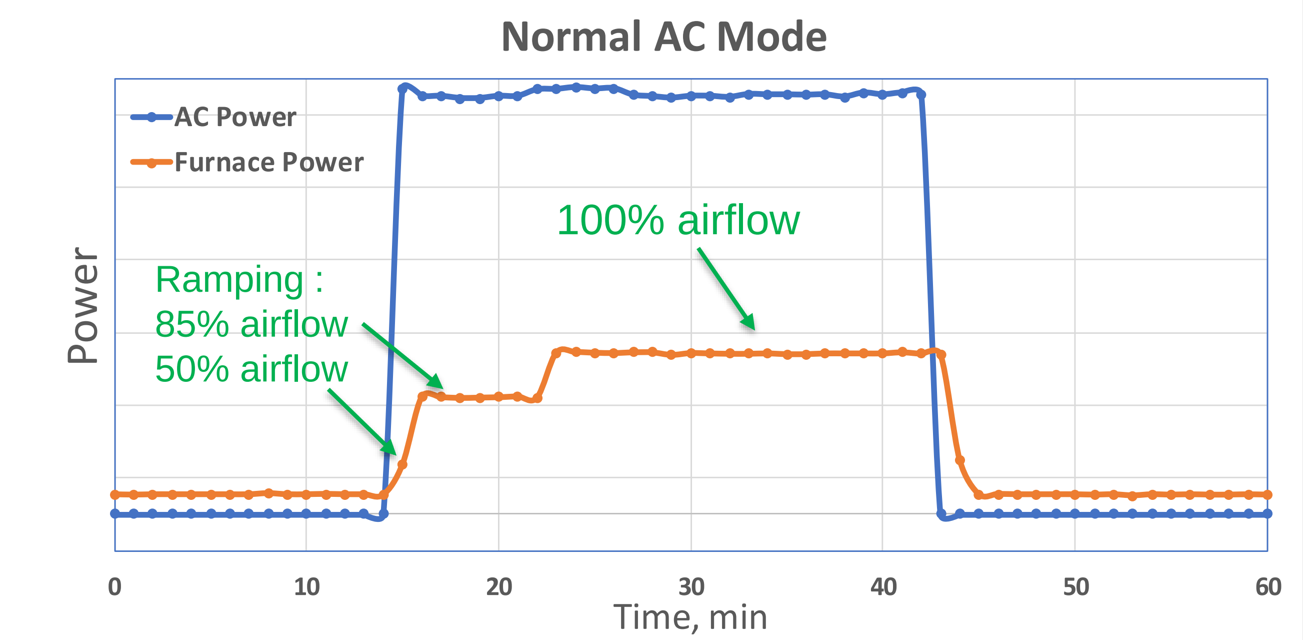


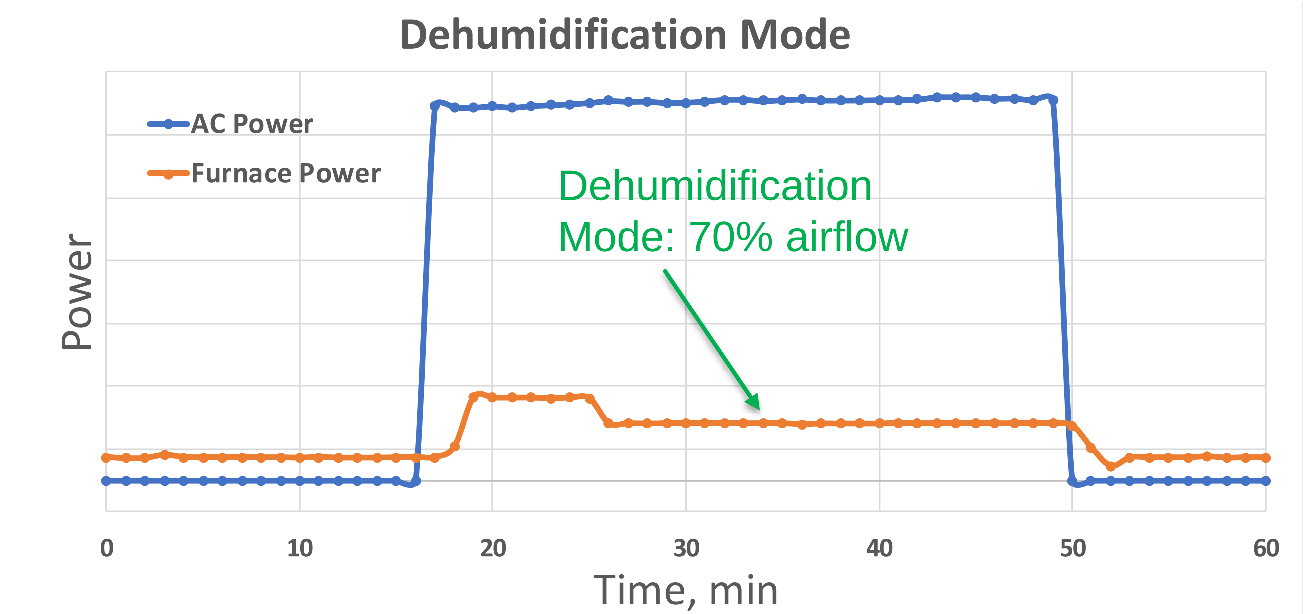


Progress

- **Sample Measured Refrigerant Performance Characteristics in Dehumidification Mode**
  - Measured at 70% of system airflow (245 CFM/ton – 30% reduction from 350 CFM/ton or 37% of typical 400 CFM/ton)
  - Goodman's Design Engineer and Regional Technical Manager measured and determined acceptable performance
  - Calculated sensible heat ratio (SHR) at measured conditions was 62% (0.62) representing a significant increase in latent capacity compared to typical SHR of 80% in normal AC mode
  - A 60% airflow was evaluated and deemed too marginal for consistent reliable operation

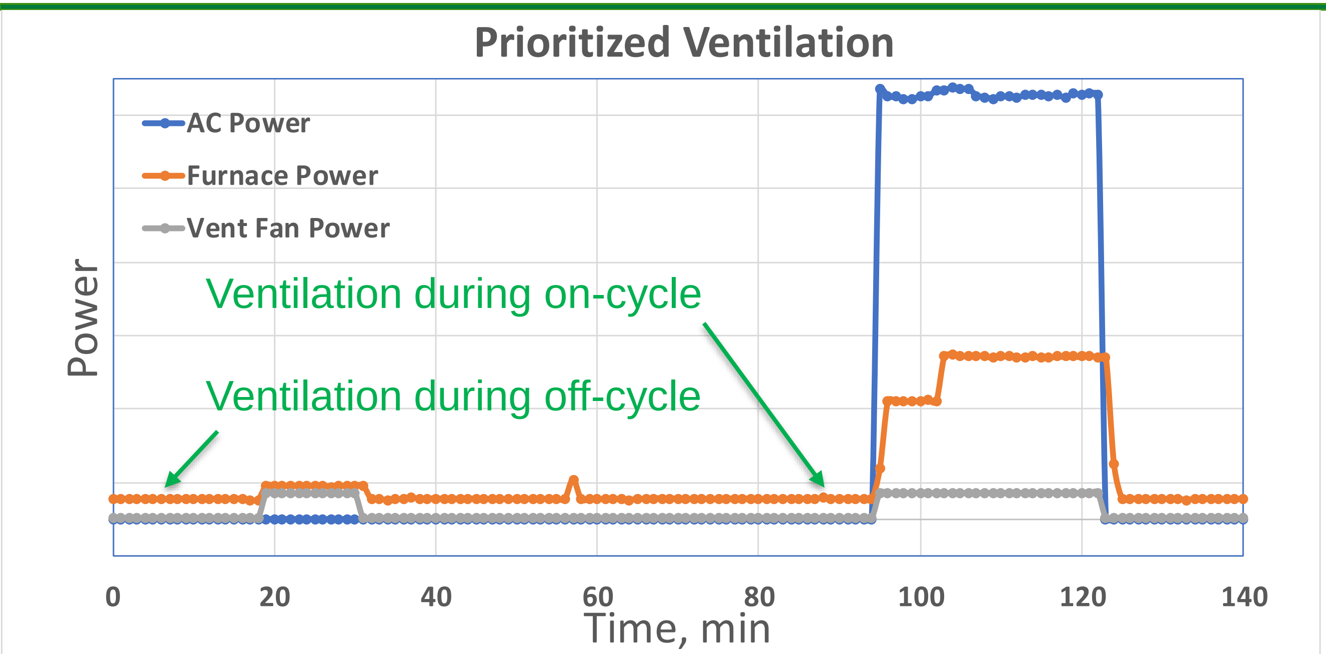
Enhanced Dehumidification: Sample Field Data



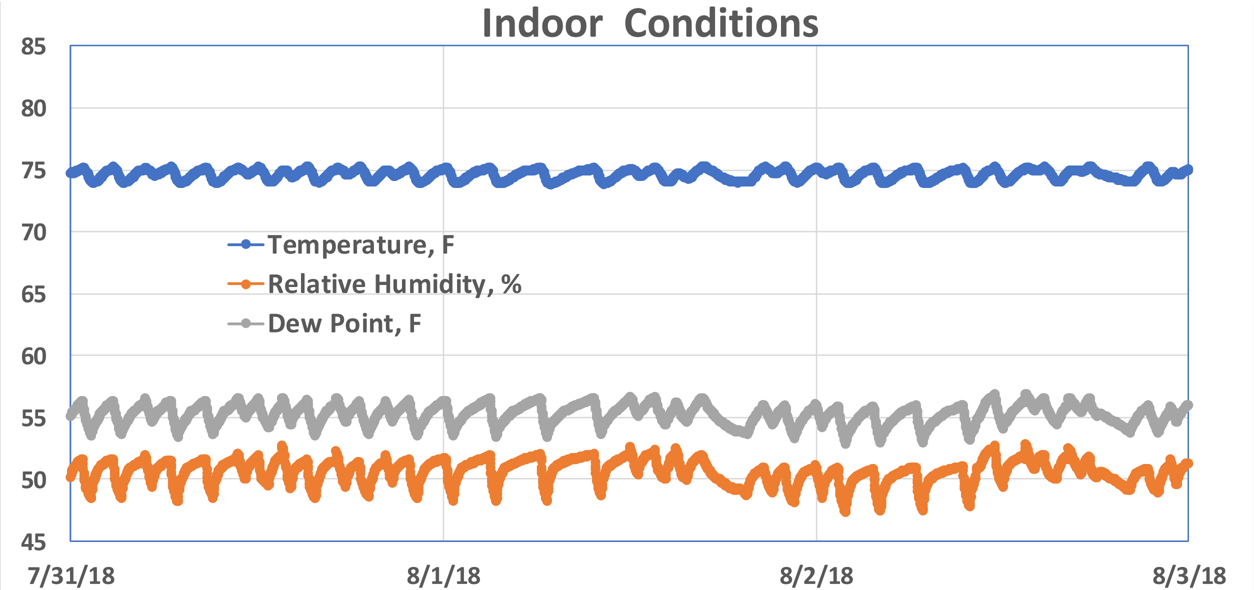


- Ramping profile maximizes latent performance for normal AC mode
- Dehumidification mode kicks in when indoor humidity exceeded a specified trigger (e.g., 55%)
- Next design iteration will update the ramping profile for dehumidification mode

Prioritized Ventilation and Indoor Conditions: Sample Field Data



- Ventilation during on-cycle: air handler operates at normal airflow
- Ventilation during off-cycle: air handler operates at 25% of normal airflow



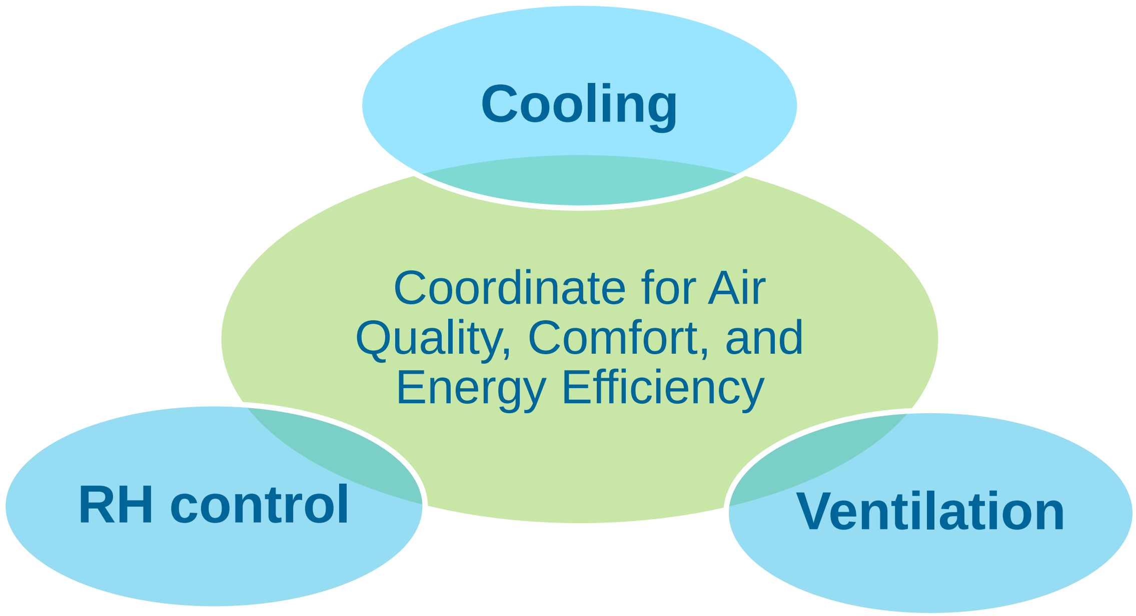
- RH is maintained at below 53% during this window

Stakeholder Engagement

- “Baked” into the project from the beginning
- Key to success of the overall effort
- Stakeholders contributing cash, time, expertise, products
- The project was kicked off with two face-to-face meetings between the OEM (Goodman) and builder representatives
- Engaged during design, installation, commissioning
- Initial results have been reviewed with Goodman and builders
- Stakeholders will help with application and dissemination of results

Remaining Project Work

- Continue monitoring of three instrumented homes
- Enroll two additional test homes using an updated system design
- Engage with ACCA and AHRI on increasing transparency of the latent capacity of the equipment
- Finalize a set of standardized metrics for enhanced dehumidification mode
- Finalize control protocols for coordination of equipment operation: AC, furnace, ventilation, zones, thermostat, and supplemental dehumidification
- Develop resources for builders to facilitate decision making process on selecting a humidity control strategy



Thank You

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REFERENCE SLIDES

Project Budget

Project Budget: See Table below
Variances: None
Cost to Date: See Table below
Additional Funding: None

Budget History					
FY 2017 – FY 2018 (past)		FY 2019 (current)		FY 2020 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$227,074	$68,870	$213,572	$47,530	$181,487	$44,900

Project Plan and Schedule

Project Schedule		
Project Start: 09-15-2017		Completed Work
Projected End: 09-14-2020		Active Task (in progress work)
		Milestone/Deliverable (Originally Planned)
		Milestone/Deliverable (Actual)

	FY17	FY2018				FY2019				FY2020			
Advanced HVAC Humidity Control for Hot-Humid Climates	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)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work													
2.0 Establish the Project Team													
3.0 Establish the Research Plan													
4.1 Modeling Analysis													
4.2 Develop Prototype HVAC Design													
5.1 Install and Instrument Prototype System													
5.2 Develop Updated Design													
5.3 Enroll test houses for Updated HVAC Design													
6.0 Develop Draft Latent Efficiency Rating Protocol													
GO/NO-GO Decision Point													
Current/Future Work													
7.0 Interim Results Update													
8.0 Install and Instrument the Updated HVAC Design													
9.0 Evaluate Results													
10.0 Develop Best Practices and Design Guidance													