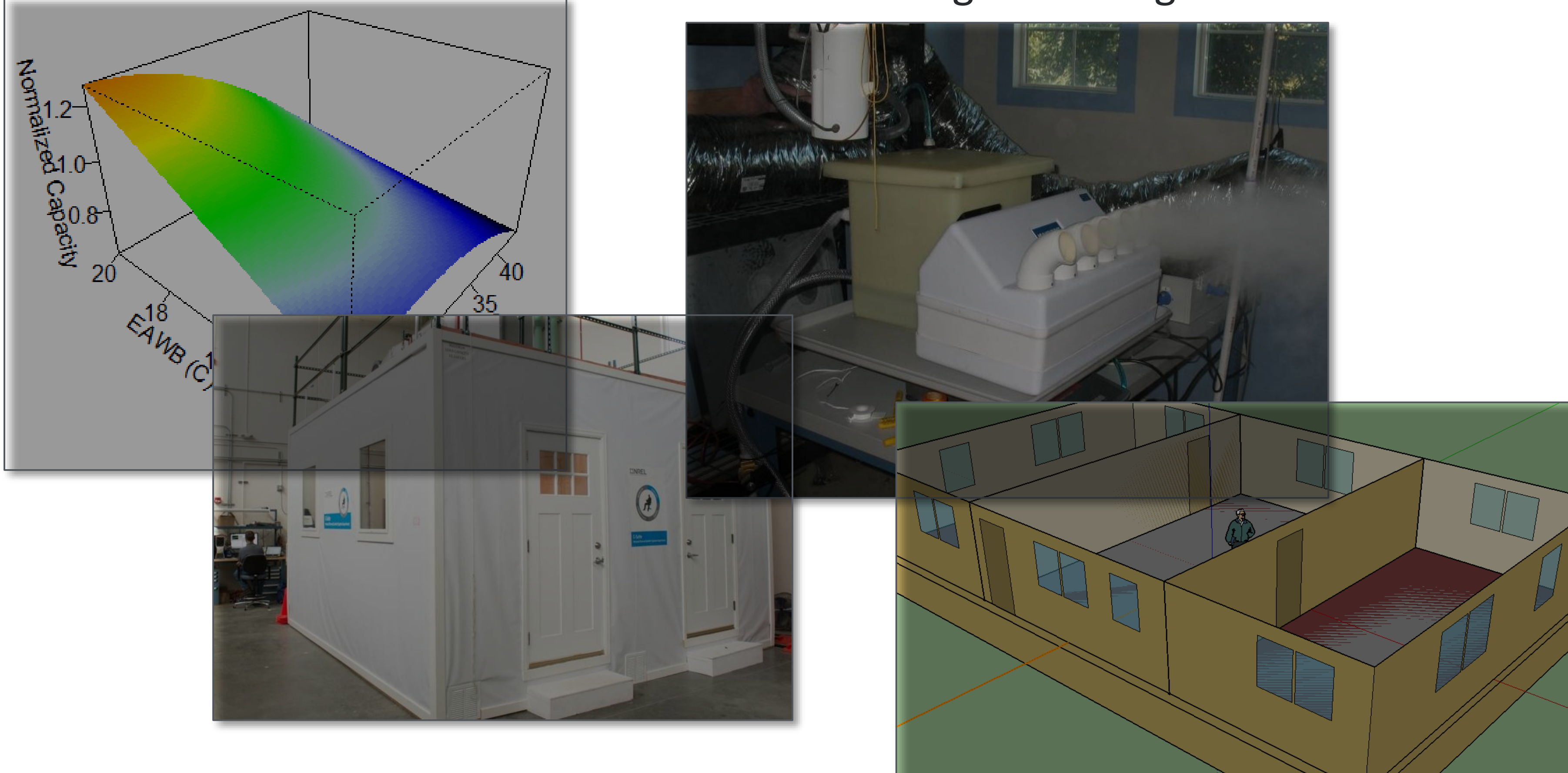
Advanced Technical Solutions for Zero Energy Ready Homes and BA Roadmap Support

2016 Building Technologies Office Peer Review



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Project Summary

Timeline:

Start date: 10/1/2015

Planned end date: 9/30/2017

Key Milestones:

1. 12/18/2015: Technical update presentation on multi-zone modeling and equipment
2. 4/15/2016: White paper documenting performance of variable-speed air conditioner damper system
3. 9/30/2016: Multi-zone model calibration and zoning recommendations for low-load homes

DOE Budget (Comfort Solutions):

- FY2015: $325,000
- FY2016: $400,000
- Total Future DOE $: TBD

Key Partners:

- Building America teams
- Unico

Project Outcome:

- Annual simulation and design tools to ensure year-round humidity control and well-distributed comfort
- Optimal space conditioning solution packages for low-load homes, which includes:
  - Sensible load control
  - Latent load control
  - Comfort distribution

Purpose and Objectives

Problem Statement:

- High-performance, low-load homes face unique space conditioning challenges that are not adequately addressed by current HVAC design practices
- Equipment suitable for optimal performance in low-load homes is not commonly utilized

Low-load home comfort systems must address:

1. Effective part-load temperature and humidity control during all occupied times
2. Effective air distribution and temperature control throughout all occupied spaces

Project Goal: Ensure HVAC designers and builders have the tools necessary to design and install optimal comfort solutions that address the needs of high-performance, low-load homes.

In FY2016, this project will characterize zoning equipment options, improve moisture modeling in low-load homes, and analyze/develop zoning best practice recommendations for low-load homes.

Target Market and Audience: Residential HVAC designers, home builders, residential equipment manufacturers

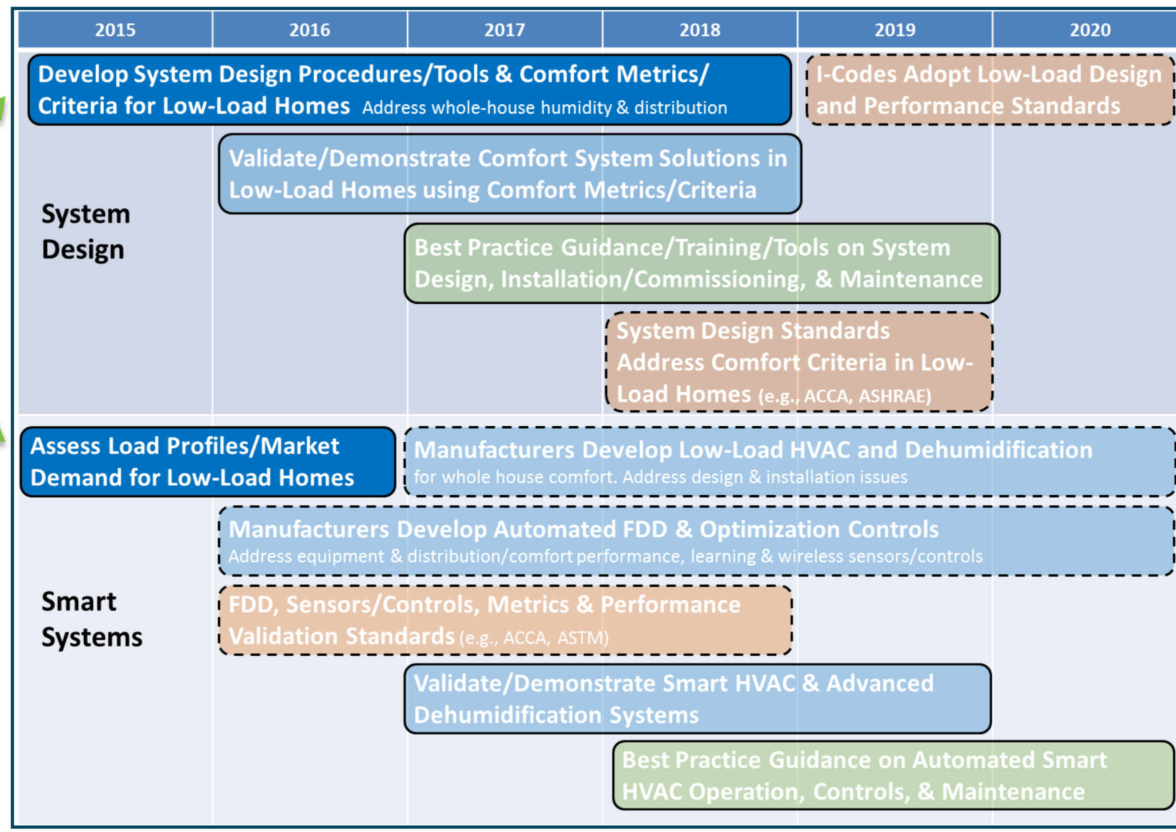
Impact of Project

Three phases:

- Short term: Development and adoption of design tools that ensure year-round, well-distributed comfort
- Mid term: Builder adoption of optimal low-load home space conditioning solutions
- Long term: Improvements in codes and standards efficiency requirements

Overall Approach:

Use the RBI *Research-to-Market Roadmap for Optimal Comfort Systems for Low-Load Homes* **as a guide**.



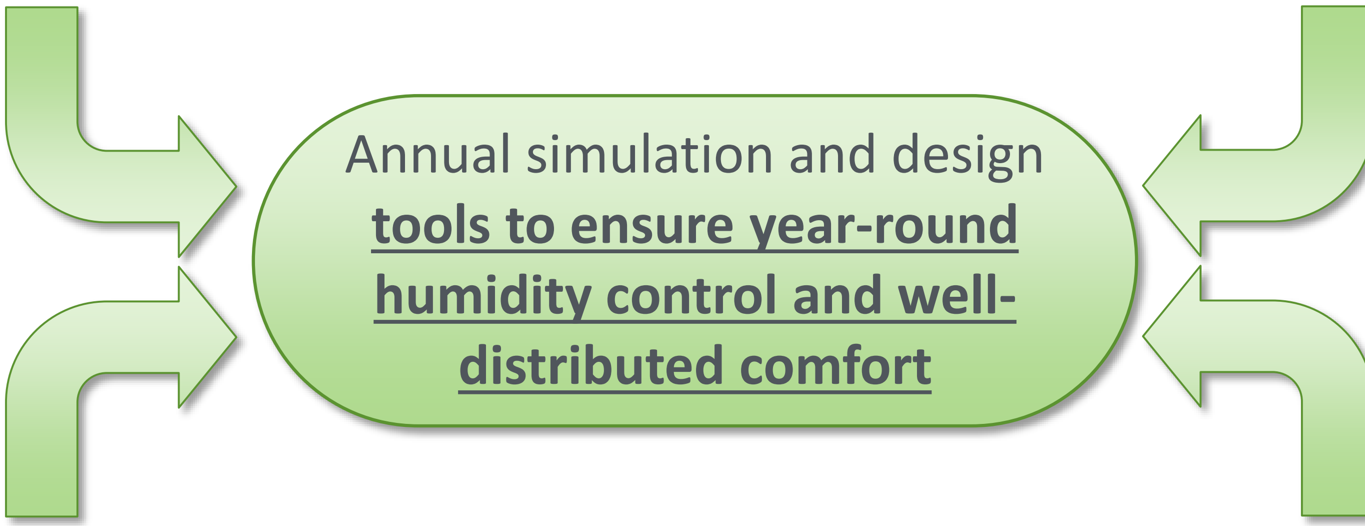
Research Subtasks

Dehumidification System Design

- Robust dehumidification design methods are required to prevent high indoor humidity

Improved Moisture Modeling

- Moisture buffering of building materials and assemblies is critical to predicting indoor humidity



Achieving Distributed Comfort

- Variable-speed air handlers coupled with zone controlled dampers are an attractive solution for low-load homes

Multi-Zone Modeling Capability

- Multi-zone models are needed to ensure well-distributed comfort and assess the ability of space-conditioning systems to meet occupant comfort expectations

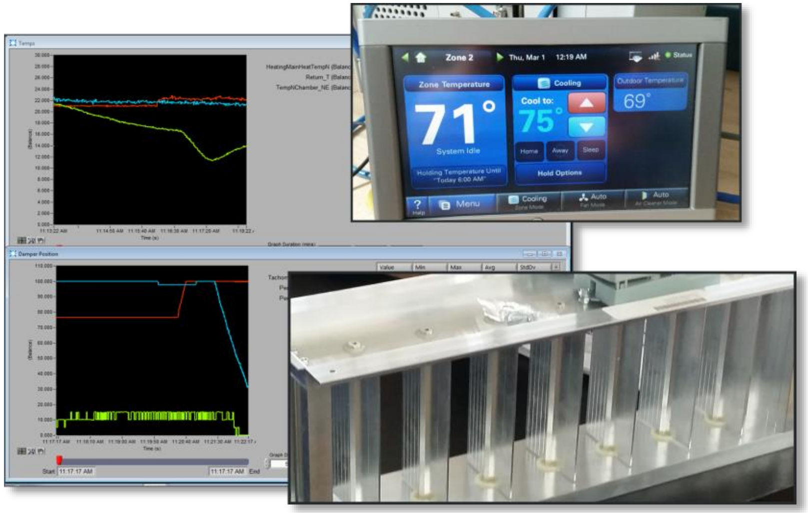
Research Subtasks

Dehumidification System Design

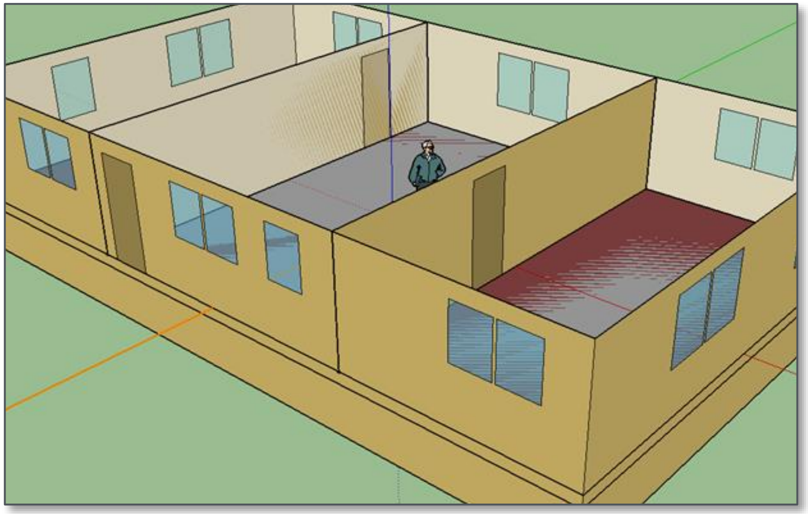
Dehumidifier Sizing Chart (pints/day)					
Conditions in Your Space	Square Footage of Your Space				
	300 sq. ft.	500 sq. ft.	700 sq. ft.	1000 sq. ft.	1500 sq. ft.
Slightly Damp Space feels damp and has the occasional musty smell. 50-60% Humidity	30	40-45	50	60	70
Moderately Damp Space often feels damp and often smells musty. 60-70% Humidity	30	40-4			
Very Damp Space feels wet, smells musty; damp spots appear on walls and floors. 70-85% Humidity	40	50			
Wet Space feels wet, smells must; seepage appears on walls and floors; may have mold growth. 85-100% Humidity	40-45	50-6			

Improved Moisture Modeling

Achieving Distributed Comfort



Multi-Zone Modeling Capability



Dehumidification System Design: Approach

Background:

- Residential HVAC designers/installers lack methods to appropriately design supplemental dehumidification systems
- Current manufacturer guidelines don't account for house characteristics such as insulation and infiltration/ventilation levels

Approach:

1. Study procedures for residential cooling and heating load calculation and equipment sizing (ACCA Manuals J&S)
2. Identify likely dehumidification design conditions for residential applications
3. Develop and implement dehumidification load calculations
4. Test calculations for various house types and climates by comparing results to EnergyPlus annual simulations

Key Issues: Whole-house dehumidification systems are typically oversized leading to significant added cost, decreasing adoption rates

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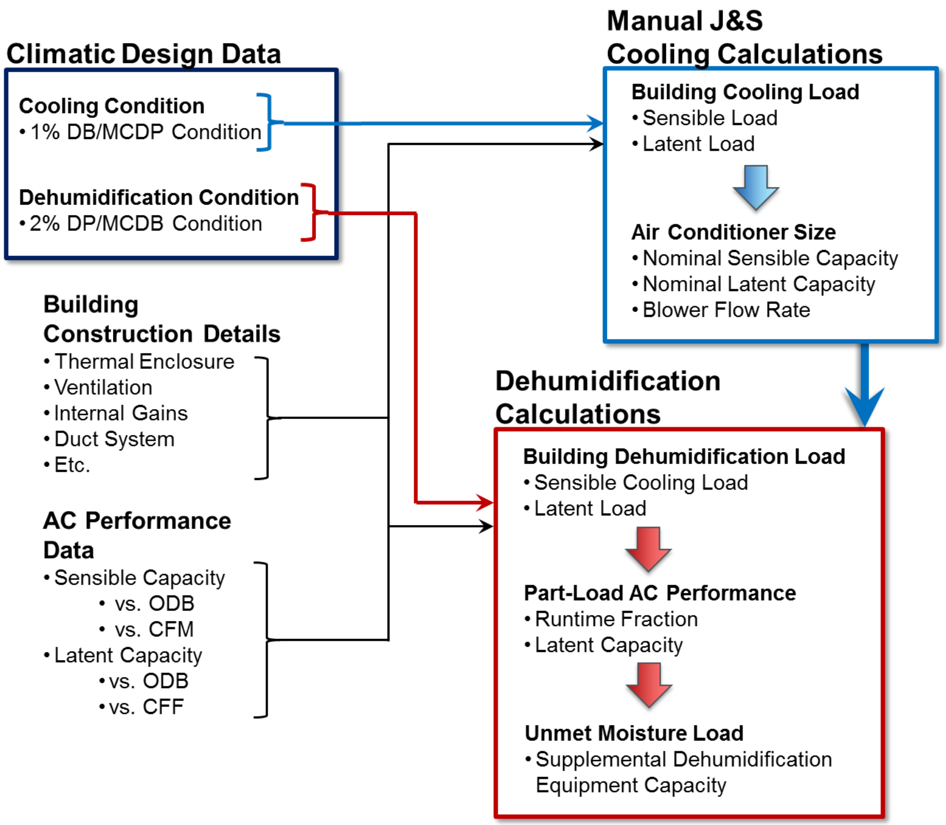
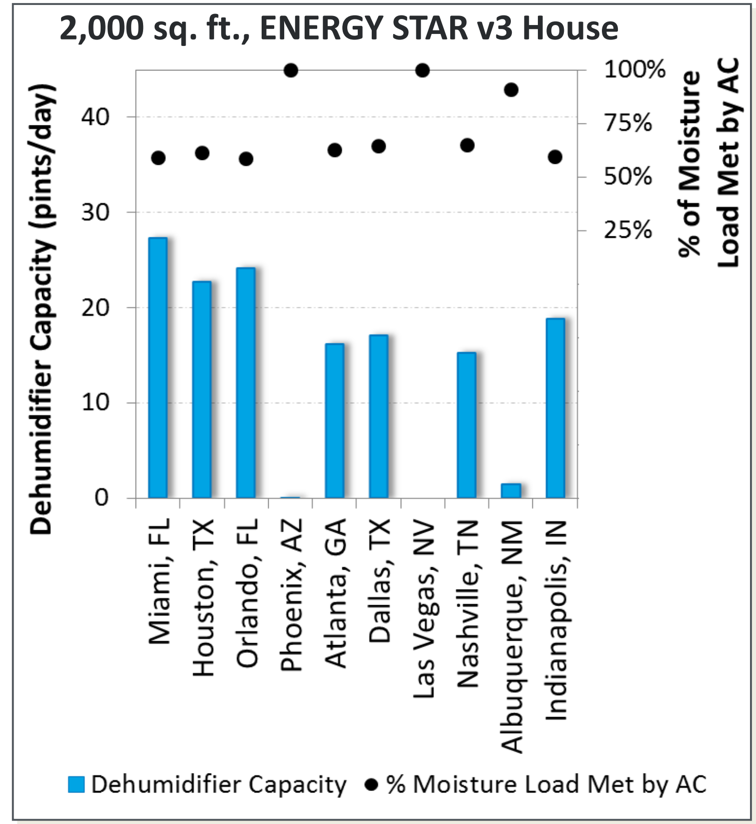
Dehumidification System Design: Results

Accomplishments: Validated, robust approach to designing whole-house dehumidification systems





Market Impact: Publication pending, thus market impact will occur in the future

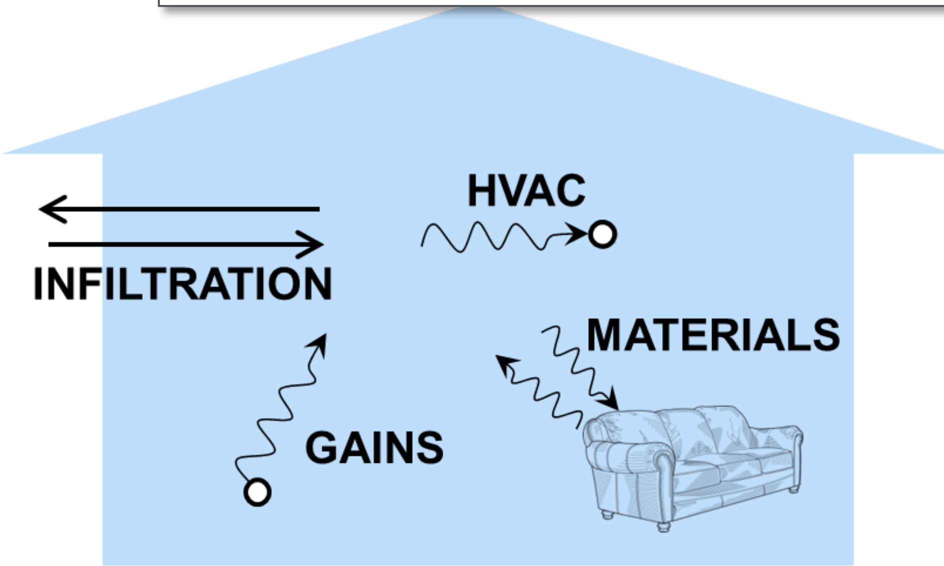
Your report has helped with discussions we're having with respect to dehumidification in high performance homes. It's been very helpful.

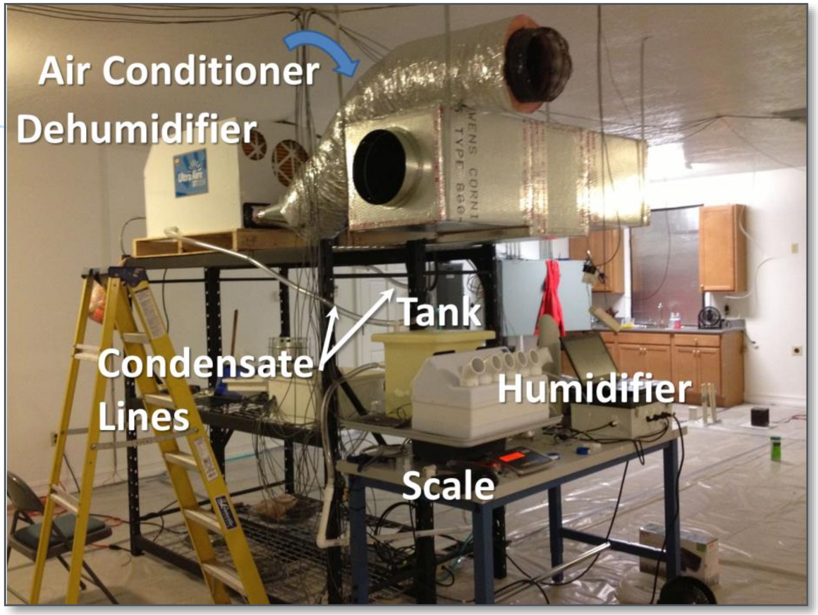
-from a leading US HVAC equipment manufacturer

Moisture-Buffering Model Inputs: Approach

Approach:

$$\dot{m}_{v,MATERIALS} = \rho V \frac{d\omega}{dt} - \dot{m}_{v,INFILTRATION} + \dot{m}_{v,HVAC} - \dot{m}_{v,GAINS}$$





Key Issues:

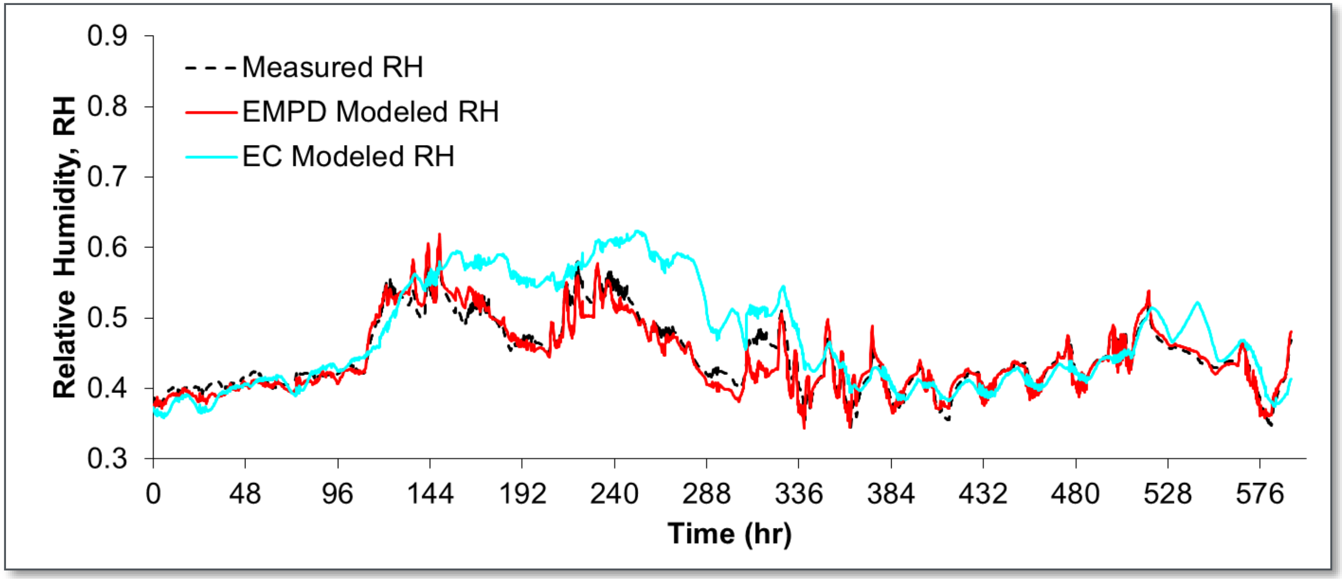
- Measurement uncertainty associated with infiltration and distribution system losses
- Determining a generalized set of model inputs (**FY16 activity**)

Distinctive Characteristics: Measures, in-situ, moisture adsorption of building materials and assemblies

Moisture-Buffering Model Inputs: Results

Accomplishments:

- Collected moisture-buffering field data for two residences and developed accurate Effective Moisture Penetration Depth (EMPD) model inputs



- Identified seven existing datasets for developing and validating a generalized EMPD moisture buffering model
- Working towards a validated, generalized model for FY16 milestone

Market Impact: Improved EnergyPlus EMPD model has been used by several researchers. Market impact will grow in the future as model usage increases.

Achieving Distributed Comfort: Approach

Key Steps:

1. Identify attractive equipment options likely to achieve well-distributed comfort in low-load homes
2. Study EnergyPlus technology model inputs
3. Identify equipment performance data needs
4. Conduct laboratory and/or field tests to collect required data
5. Generate model inputs and validate EnergyPlus model using laboratory and/or field test data
6. Identify and pursue product innovation path opportunities

Identified Equipment:

– Zone-to-zone transfer fans: field test characterization by Building America teams

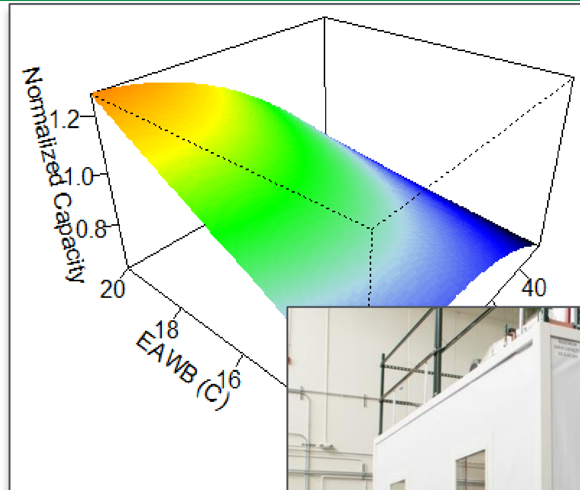
– Small-duct, high velocity system heat pump: performance mapping by partner company and field demonstration by Building America team

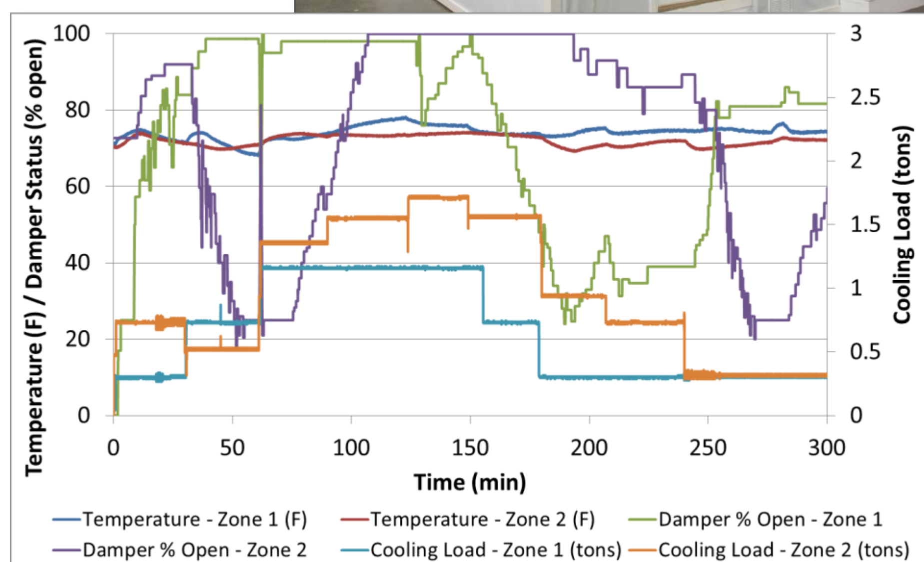
– **Variable-speed, damper system**: FY16 laboratory characterization

Achieving Distributed Comfort: Progress

Accomplishments:

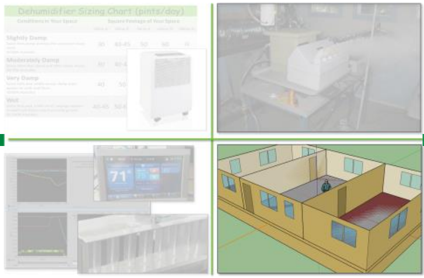
- Worked with partner company to performance map two, small duct high velocity, variable-speed heat pumps
- Installed and characterized a two zone damper system with a variable speed air conditioner (with focus on distributed thermal comfort)
- Drafted white paper to meet project deliverable





Market Impact: Impact will result from having models to predict the distributed comfort reducing low-load home market barriers

Multi-Zone Building Modeling: Background



Background: Why multi-zone simulations?

- High-performance, low-load homes look less like single zone buildings and more like multi-zone buildings
- Necessary to evaluate HVAC system delivery of thermal comfort
- Necessary to compare alternative space conditioning systems
- Prerequisite to developing comfort metrics/scores

Expected Outcomes:

- Utilize EnergyPlus/Open Studio to simultaneously assess energy and thermal comfort performance of various space conditioning systems
- Develop simulation and design tools ensuring year-round, well-distributed temperature and humidity control

Key Issues: Modeling complexities associated with multi-zone simulations:

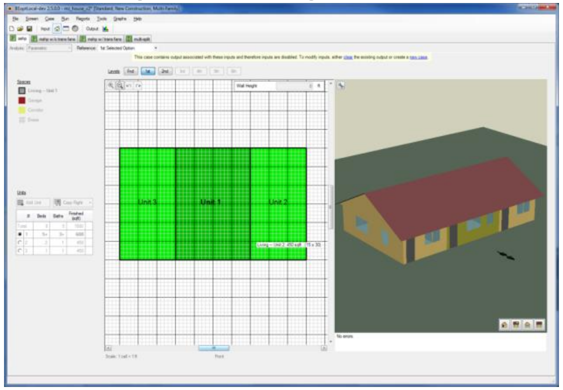
- Distribution of internal gains
- Distribution systems
- Infiltration & inter-zonal air mixing
- Point-source equipment
- Occupant behavior (doors, etc.)

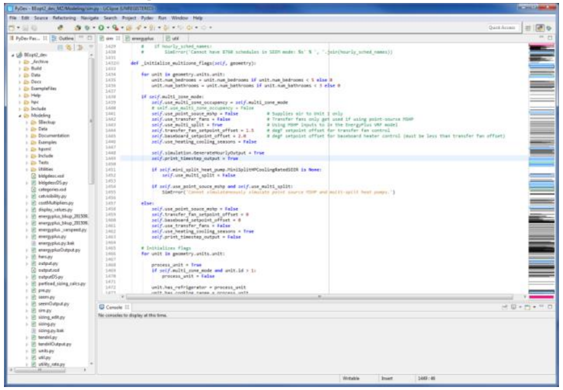
Multi-Zone Building Modeling: Approach

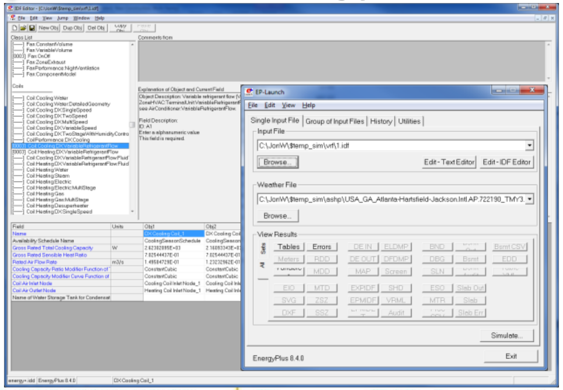
1. Study and assess advanced EnergyPlus/Open Studio multi-zone models and inputs (Airflow Network, EMPD, etc.)
2. Develop EnergyPlus model inputs for multi-zone building and equipment models
3. Validate multi-zone model utilizing DOE Building America and national laboratory field test data
4. Write Open Studio/EnergyPlus measures to simplify the multi-zone modeling process

Distinctive Process: Efficient workflow leverages existing capability

1. Export BEopt MF XML → **2. Scripts Generate E+ File** → **3. Run EnergyPlus**

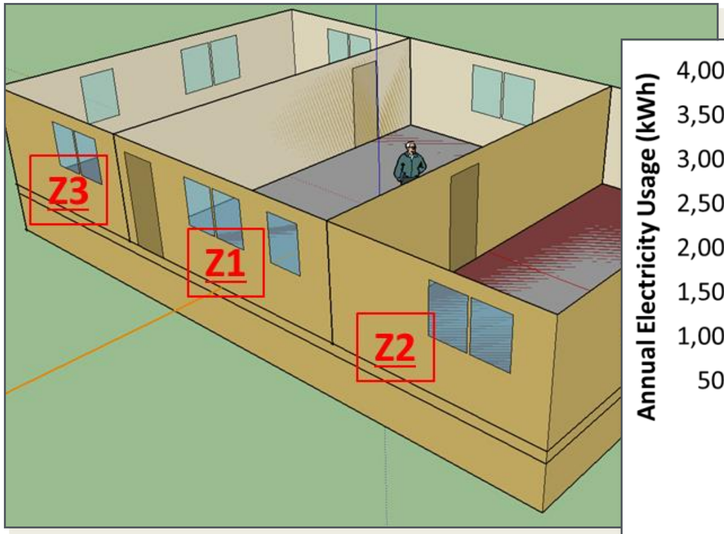


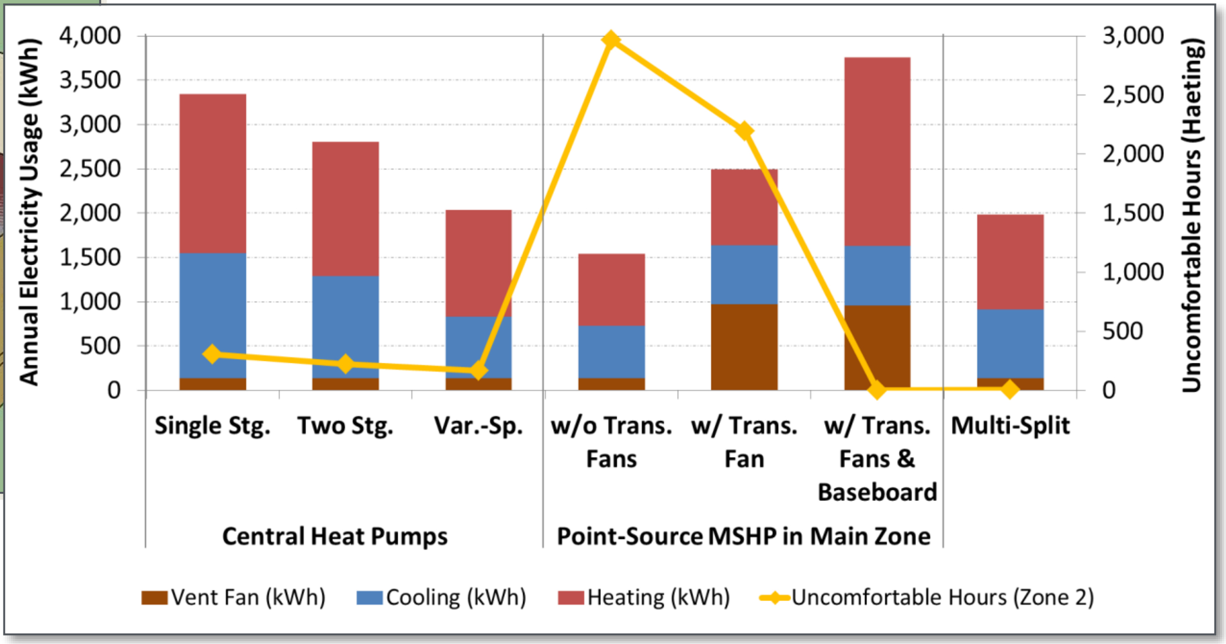




Multi-Zone Building Modeling: Accomplishments

Example Results: Simulated 1,500 sq. ft., IECC 2009 house with various space conditioning systems in Atlanta, GA





Validation Steps:

1. Identify field test data suitable for multi-zone model validation. Reach out to project PIs regarding data sharing, support, etc. (**completed**)
2. Construct model and validate buffer space temperatures (**completed**)
3. Validate inter-zonal air flow rates and zone temperatures
4. Confirm performance of distributed comfort

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Project Integration and Collaboration

Project Integration: NREL staff meets regularly to discuss progress towards project milestones

Partners, Subcontractors, and Collaborators:

- Manufacturer partner – NREL provides recommended test matrices and data analysis. Routine email and phone conversations, as needed. (*Partner*)
- Building America teams – Discussion of issues, field test data, lessons learned and future opportunities. (*Partner*)

Communications:

- Dehumidification System Design approach was presented at the Energy & Environmental Building Alliance (EEBA) Excellence in Building Conference & Expo
- Moisture buffering field test results were published in *Energy and Buildings* and the approach was presented at Buildings XII conference
- Other research efforts have not been presented

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Next Steps and Future Plans

Next Steps and Future Plans:

- Report on dehumidification load calculations will be published and circulated to industry
- Variable-speed, multi-zone damper system will be modeled and validated in EnergyPlus/Open Studio
- A generalized moisture buffering model will be developed and validated
- Multi-zone model will be validated using Building America team field test results
- Annual simulations will be run to determine optimal zone configurations and system design for low-load homes

REFERENCE SLIDES

Project Budget

Project Budget: $325,000 – FY15
$400,000 – FY16
Variances: None. Project is being executed to plan.
Cost to Date: $576,000

Budget History					
FY 2015 (past)		FY 2016 (current)		FY 2017 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$325,000	$0	$400,00	$0*	$400,000**	$0

Additional Funding:
* Modest in-kind contribution from manufacturer partner providing performance testing of small-duct, high velocity heat pumps
** Subject to appropriations and AOP planning cycle

Project Plan and Schedule

Project start date: 10/1/2015 Project planned completion date: 9/30/2017

Key Milestones:

- Go/No-Go to continue into FY17 based on sufficient progress towards project objectives, 7/16/2016
- Deliver White Paper on multi-zone model validation and zoning recommendations for low-load homes, 9/30/2016

Project is on schedule and expected to complete successfully

Project Schedule												
Project Start: 10/1/2015	(blue)	Completed Work										
Projected End: 9/30/2017	(dark blue)	Active Task (in progress work)										
	(red ◆)	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												
Q3 Milestone: White paper on peak latent loads	Completed	Completed	Completed ◆									
Q4 Milestone: Paper on moisture buffering field test		Completed	Completed	Completed ◆								
Current/Future Work												
Q1 Milestone: Presentation on multi-zone modeling			Completed	Completed	Active ◆							
Q3 Milestone: Paper on zone damper system test					Active	Active	Active ◆					
Q4 Milestone: Paper on generalized buffering model							Active	Active ◆				
SMART Milestone: Paper on multi-zone model validation						Active	Active	Active ◆				