Building America

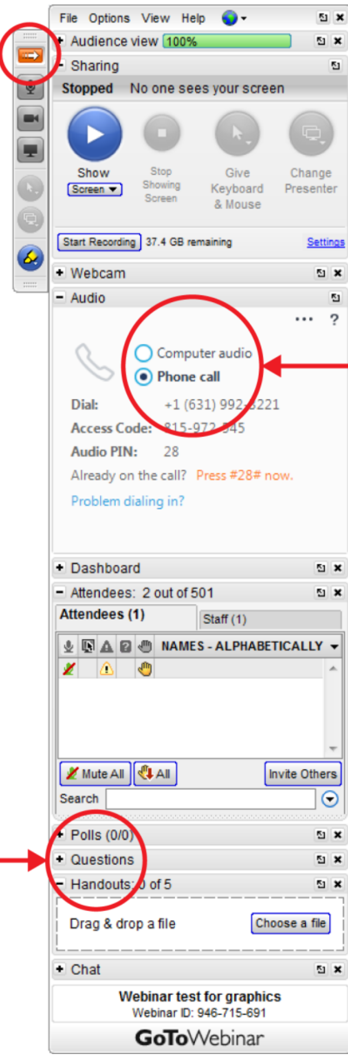
Quarterly Team Project Update

August 8, 2017

U.S. Department of Energy
Eric Werling
Lena Burkett

National Renewable Energy Laboratory
Stacey Rothgeb

Open and close your control panel



2 Audio Options:
Use telephone to dial into the call
OR
Use your computer's microphone & speakers ("VoIP")*

**If you are using the Mic and Speakers (VoIP) option, please make sure your computer has a microphone and it is enabled.*

Submit text questions

Up Next…

FLORIDA SOLAR ENERGY CENTER®

A Research Institute of the University of Central Florida

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Creating Energy Independence

FY '15 BAPIRC Project Conclusions

Variable Capacity Comfort Systems for Low Load Homes
Smart Mechanical Ventilation Systems

August 8, 2017

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Ductless Multi-Split / Ducted Mini-Split

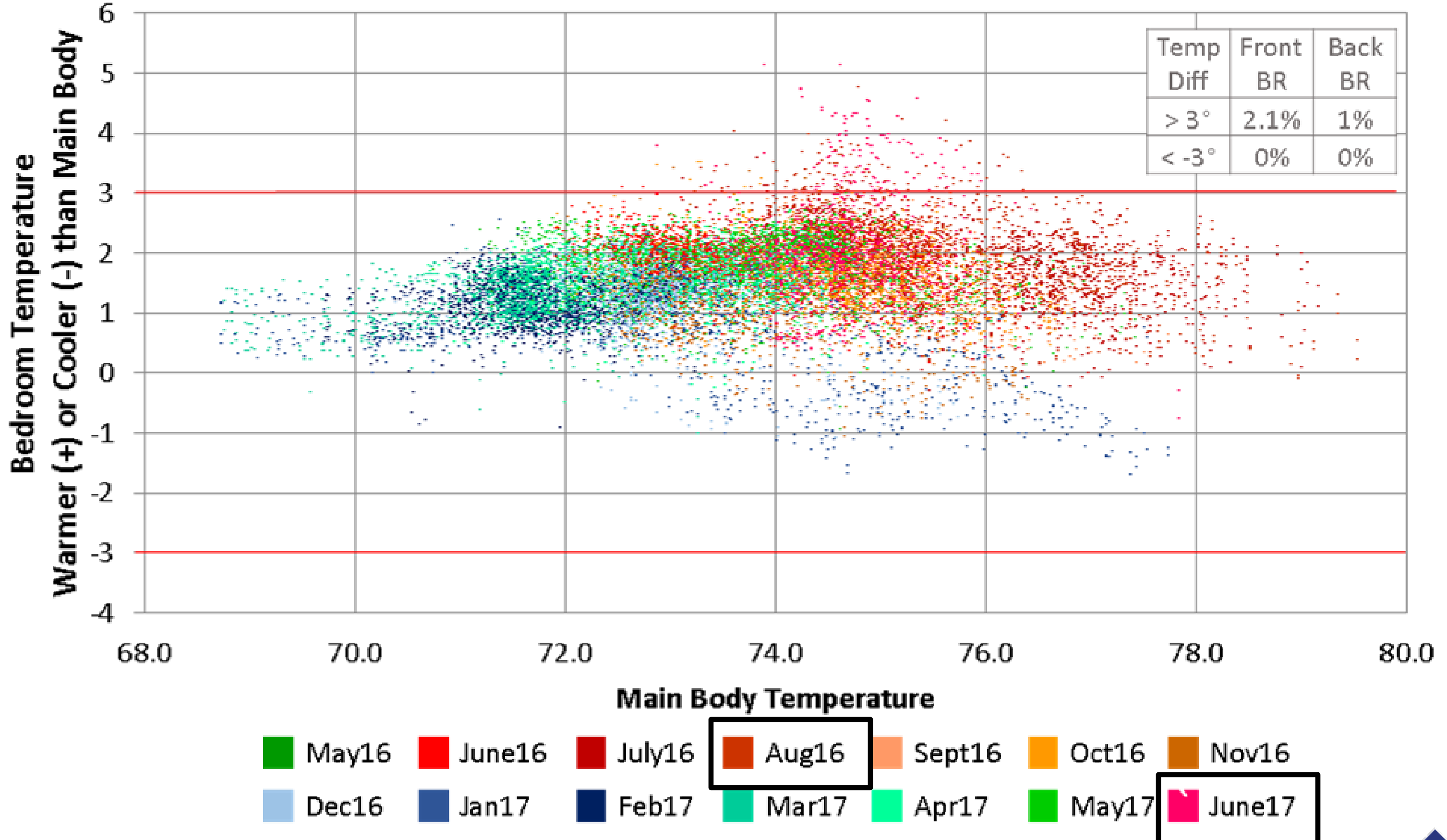
SE Volusia Habitat for Humanity (Florida – HERS 48)

- Duplex (1,075 ft^2 per unit)
- Cooling Peak = 11,323 Btu/h
- Panasonic bundled package
  - Multi-split (19 kBtu/h) with 2 fan coil units in main body (9 kBtu/h each) SEER 22
  - 2 transfer fans circulate air to BRs
  - ERV for mechanical ventilation (82% of 62.2-2010 33 cfm)

South Sarasota Habitat for Humanity (Florida – HERS 51)

- 3 single family detached houses (1,290 ft^2)
- Cooling Peak = 12,242 Btu/h
- Mitsubishi mini-split with cassette AHU (15k Btu/h) SEER 15.5
  - Fully ducted supply and return
  - Unvented attic
  - Hybrid supply/exhaust system for mechanical ventilation (80-130% of 62.2-2010 43 cfm)

Temp Distribution Adequate with Transfer Fans (when used as designed)

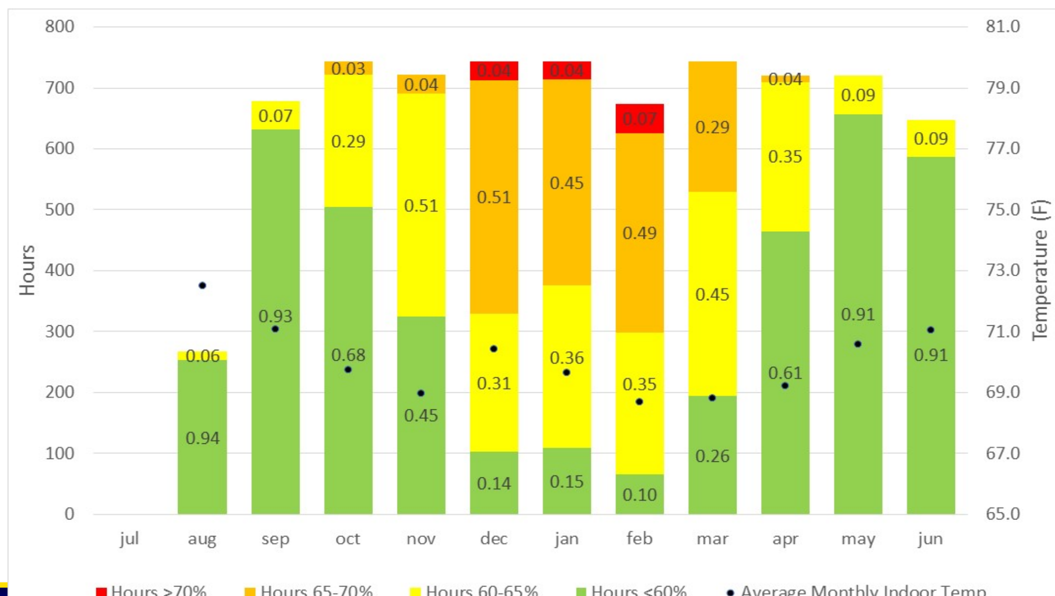


Temp Diff	Front BR	Back BR
> 3°	2.1%	1%
< -3°	0%	0%

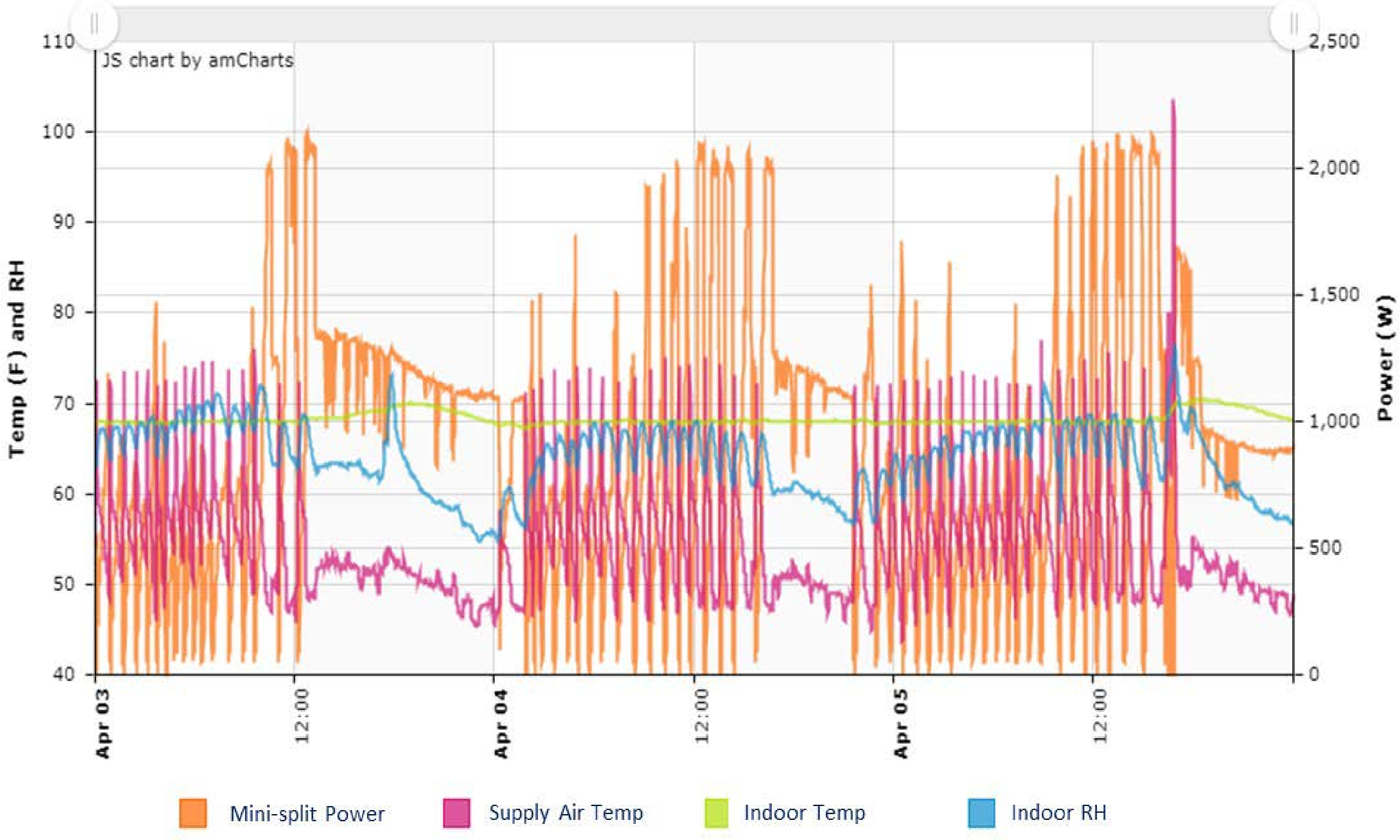
Inconsistent Indoor RH Control

Multi-Split

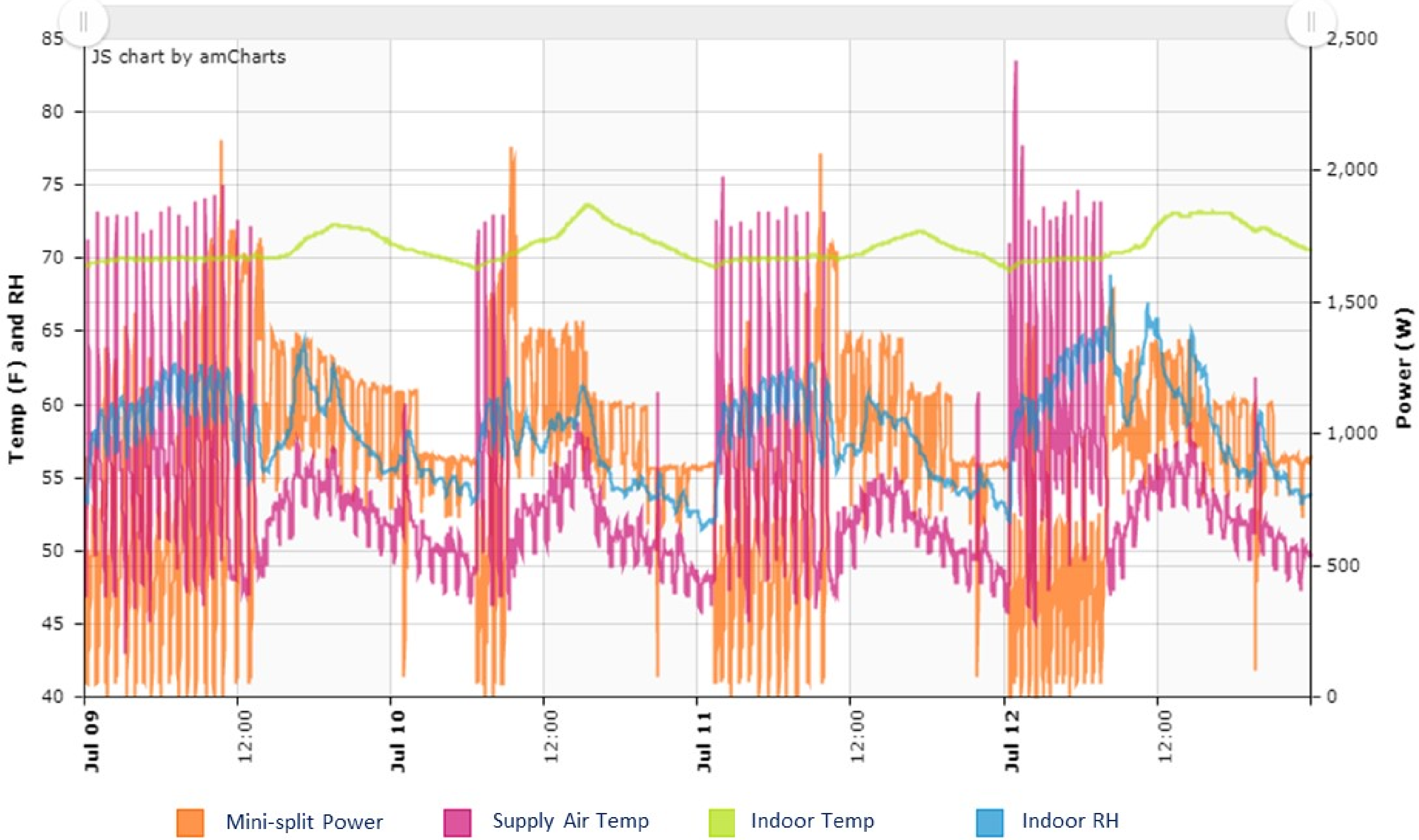
Mini-Split



Inconsistent Indoor RH Control (SS2 mini-split low load cycling)



Inconsistent Indoor RH Control (SS2 mini-split variable supply air temp)

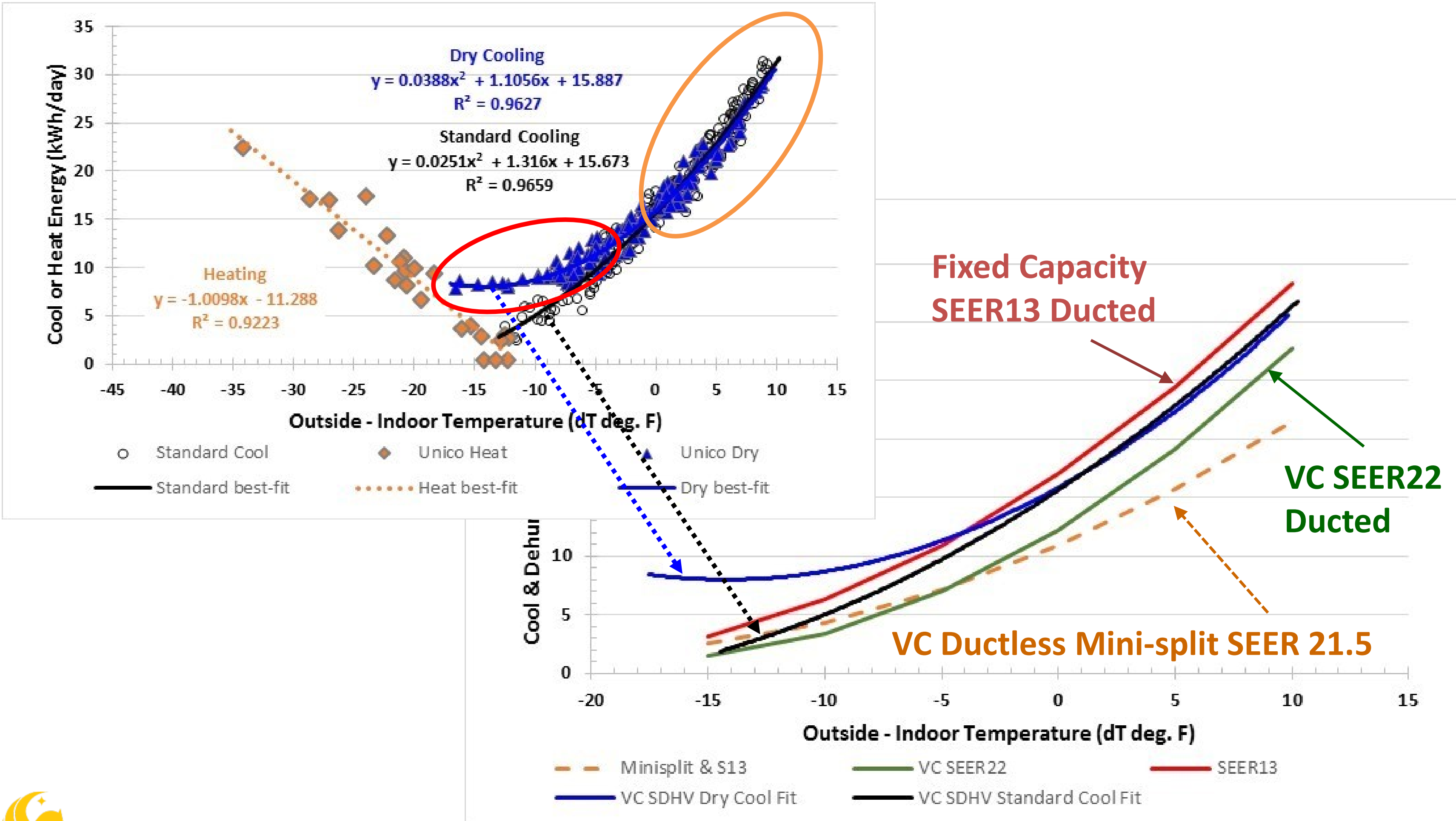


Small Duct High Velocity (SDHV)

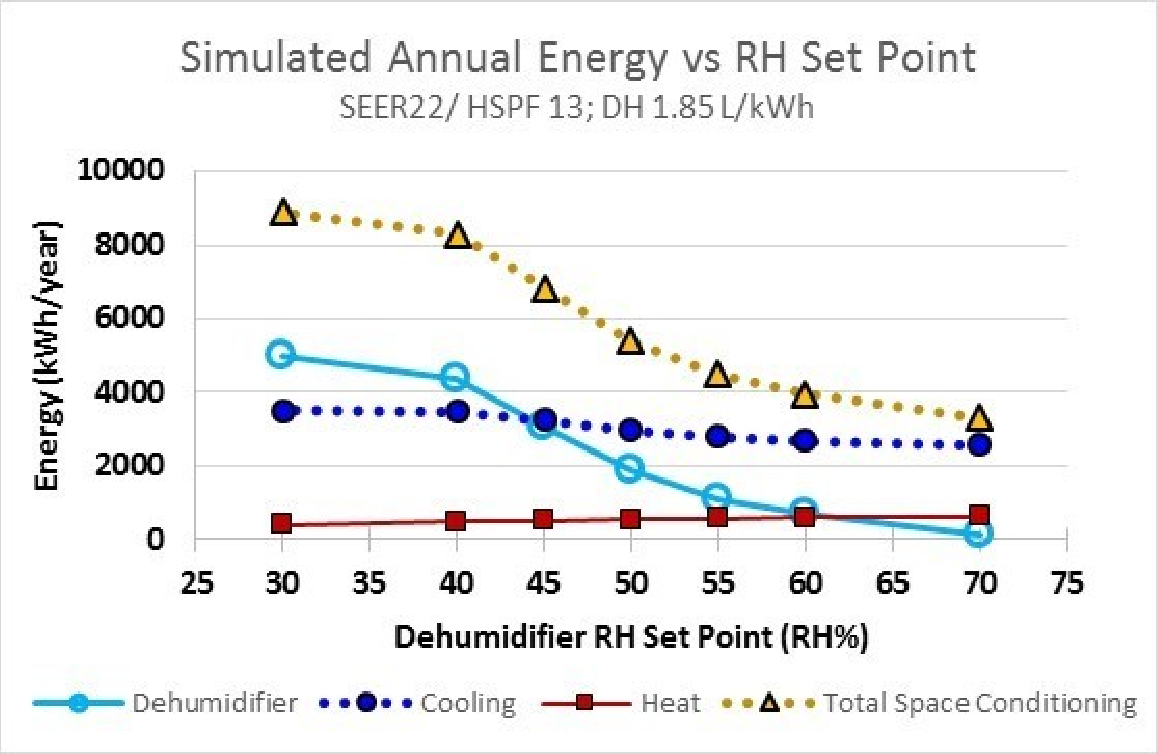
FSEC Manufactured Housing Lab

- 1,600 ft^2, 4.5 ACH50
- Cooling Peak = 18,200 Btu/h
- Continuous mechanical ventilation supplied to utility room (100% of 62.2-2016 57 cfm)
- Unico iSeries heat pump (SEER 14) 29.2 kBtu/h cooling capacity
- Stand alone supp. Dehumidifier located living room set to 60% RH.

MH Lab Space Conditioning Energy



Annual Dehumidifier Energy Should Also be Considered in Equipment Selection



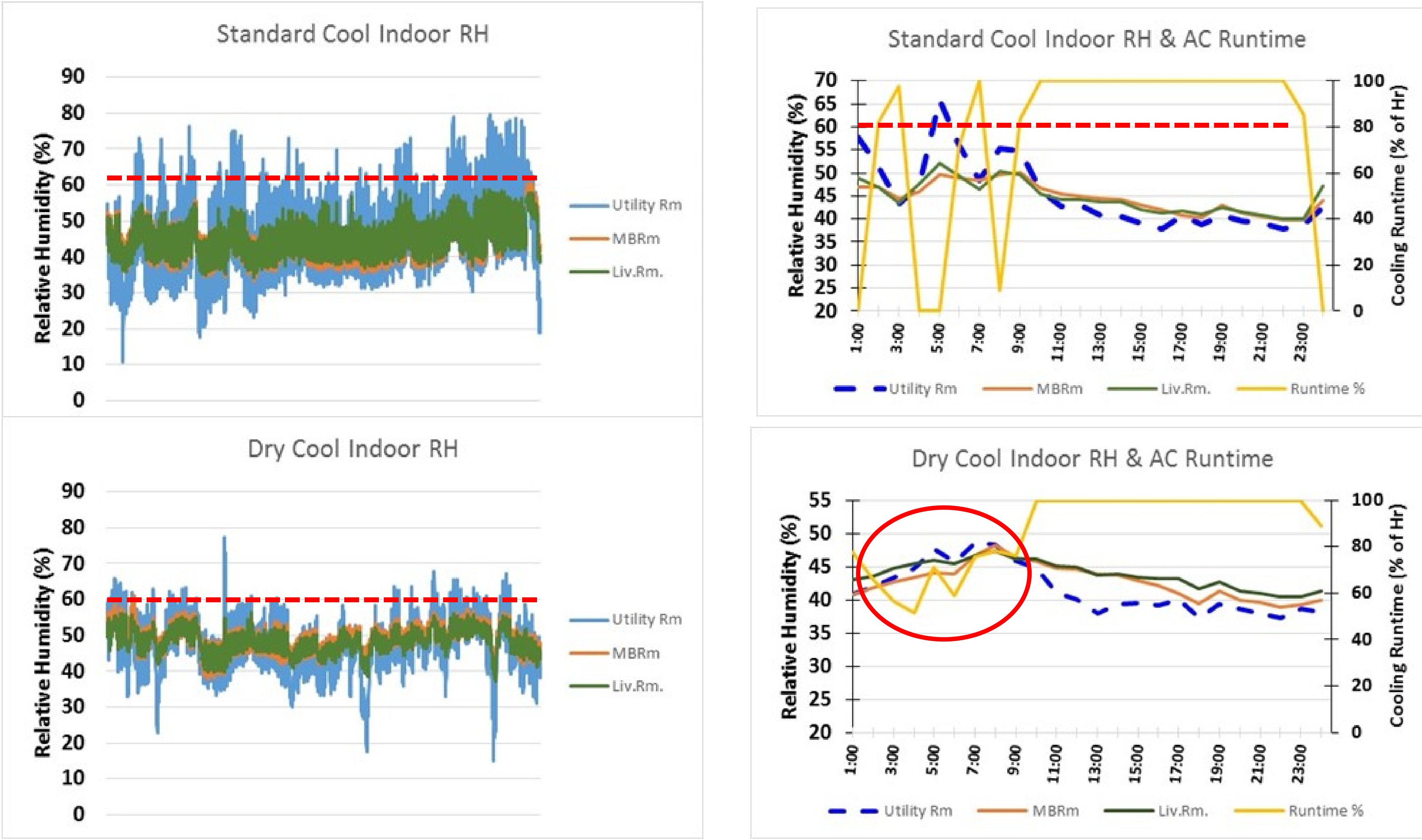
Simulated space conditioning energy in the MHL with SEER 22 heat pump and supplemental dehumidification.

AHU Power

Test Configuration	Fan Max. Watts	Fan Standby Watts	Fan Watts (min-max)	Fan cfm/W runtime (min-max)	Whr/day Incl. standby	Duct dP in wc (Pa)	Avg. Airflow CFM (min-max)	Runtime Hrs/day
Unico SDHV VC SEER14	184	8	57 (12-184)	5.51 (2.7-25.5)	1365	0.41 (103)	340 (300-550)	18.2
2 ton VC SEER22	160	25	73 (56-160)	9.7 (6.2-28.1)	1760	0.08 (21)	726 (590-990)	19.6

- SEER13 SDHV *fan efficiency* 43% lower than SEER22 VC- BUT
- SDHV AHU *daily energy* 22% <u>LOWER </u>than SEER22; because-
  - SDHV standby power 68% lower
  - SDHV operates at lower CFM
- SDHV meets load by SAT 9°F colder

House Lab Indoor RH Control



Indoor RH Control Conclusions

- Indoor RH levels vary based on a number of factors:
  - Mechanical ventilation rates
  - Occupant activities
  - Operational characteristics of air conditioning
- Variable capacity systems have great potential to help control indoor RH:
  - Need to maintain colder coil during low load and decrease SHR.
  - Need to utilize lowest capacity consistently over longer periods during low load to avoid 1) cycling and 2) overcooling.
  - Coil airflow needs to be able to operate at the low end of the operational range to achieve these objectives.
  - Cooling should prioritize efficiency over RH in *Standard Mode*
  - Prioritize RH control over efficiency in *Dry Mode*
  - Use and RH sensor to intelligently move between modes.

Smart Mechanical Ventilation Research

- *Seasonal Temperature Based Smart Ventilation Control (STSVC)*: Shift ventilation away from seasonal time periods that have large indoor-outdoor temperature differences.

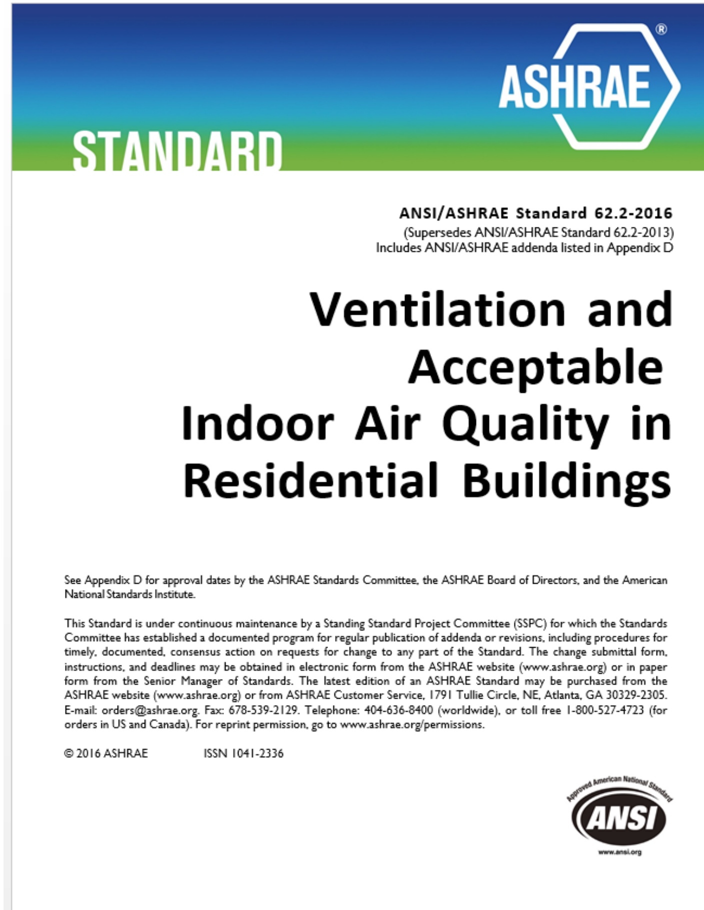
- *Occupancy Based Smart Ventilation Control (OSVC)*: Vary operation of a mechanical ventilation fan in response to whether the home is occupied or vacant.

- *Real Time Weather Based Smart Ventilation Control (RTWSV):* Vary mechanical ventilation airflow with an algorithm that interprets measurements of current and 24-hour historical outdoor temperature and moisture.

- *Commercialization Activities:* Engage manufacturers and other stakeholders to catalyze product development.

ASHRAE 62.2-2016 Appendix C

- Procedures for evaluation of time-varying ventilation
- Occupant exposure to pollutants relative to continuous ventilation.
- Average (annual) relative exposure = 1 (chronic exposure).
- Peak exposure < 5 for any time step (acute exposure).


ASHRAE
STANDARD

ANSI/ASHRAE Standard 62.2-2016
(Supersedes ANSI/ASHRAE Standard 62.2-2013)
Includes ANSI/ASHRAE addenda listed in Appendix D

Ventilation and Acceptable Indoor Air Quality in Residential Buildings

See Appendix D for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Senior Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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Approved American National Standard
ANSI
www.ansi.org

FSEC

Howard Residence, Olympia, WA

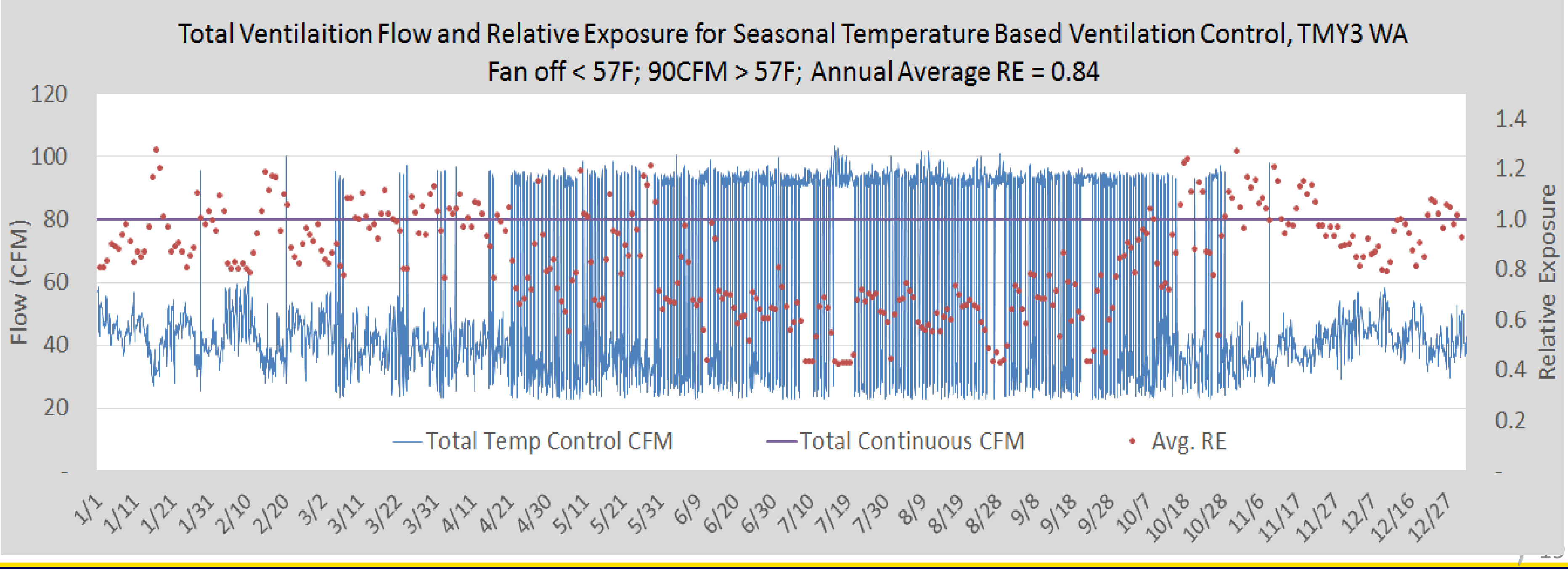
- 1,640 sqft occupied existing home.
- Deep energy retrofit in 2010.
- HERS 63, SEER 25 DHP, 5 ACH 50
- Bathroom exhaust fan for whole house ventilation.
- ASHRAE 62.2-2016

$Q_{total} = Q_{fan} + Q_{inf} = 80$ cfm

$Q_{fan} = 40$ cfm

Seasonal Temperature SVC

- Flip-flop experiments
- 2 weeks: 40 cfm fan;
- 2 weeks: T_{out}<57 ºF, 0 cfm fan ; T_{out}>57 ºF, 90 cfm fan

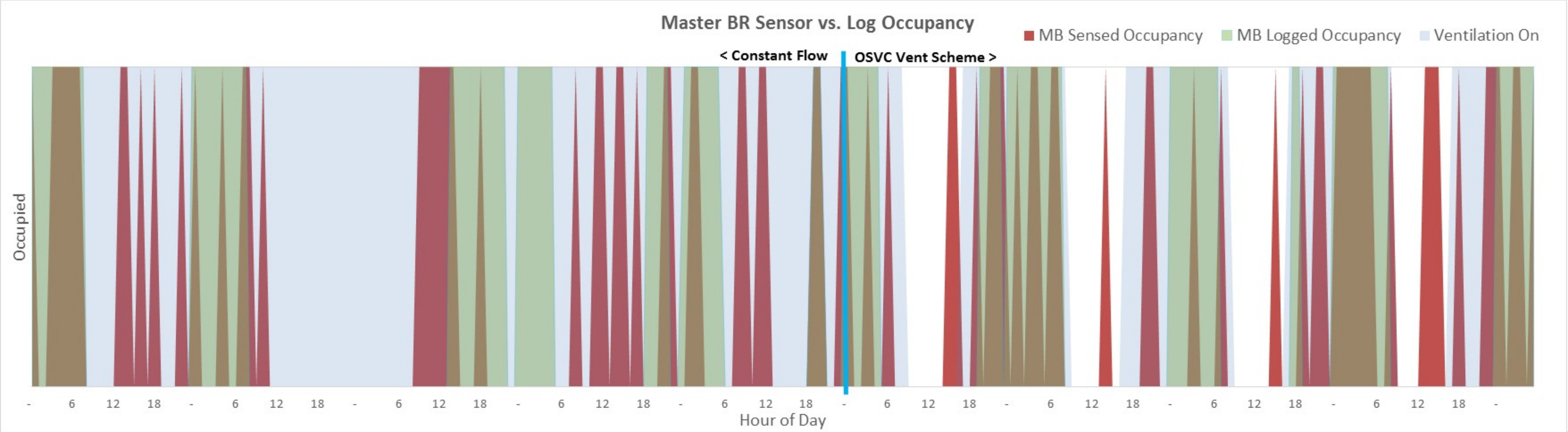


Seasonal Temperature SVC Results

- 10% annual space conditioning energy savings (230 kWh, modeled).
- T_{out}<57 ºF, CO_2 12% higher with STSVC (748 ppm); T_{out}>57 ºF, CO_2 8% higher with STSVC (567 ppm)
- Indoor RH remained largely between 40% and 60%, slightly more moisture indoors during STSVC.

Occupancy SVC Experiments

- Weekly flip-flop: 40 cfm fan and
- 5:00pm – 9:00am; 40 cfm fan
  9:00am – 5:00pm; 0 cfm fan
- Not ASHRAE 62.2 compliant.
- CO_2 11% higher with OSVC (747ppm); VOC 6% lower with OSVC (marginal significance).



Occupancy SVC Simulations

- Implications of modification to pollutant emission rate assumptions in ASHRAE 62.2.

$Q_{tot} = 0.03A_{floor} + 7.5(N_{br} + 1)$ - When occupied (Q$_{fan}$ = 40 cfm)

$Q_{tot} = 0.03A_{floor}$ - When unoccupied (Q$_{fan}$ = 10 cfm)

- Results in a 3-9% increase in relative exposure over current assumptions.
- Modeled energy savings vary (1%-10%) based on:
  - How away hours line up with climate specific ventilation load.
  - Amount of total ventilation flow reduction achieved (balanced vs. unbalanced and interactive effects).

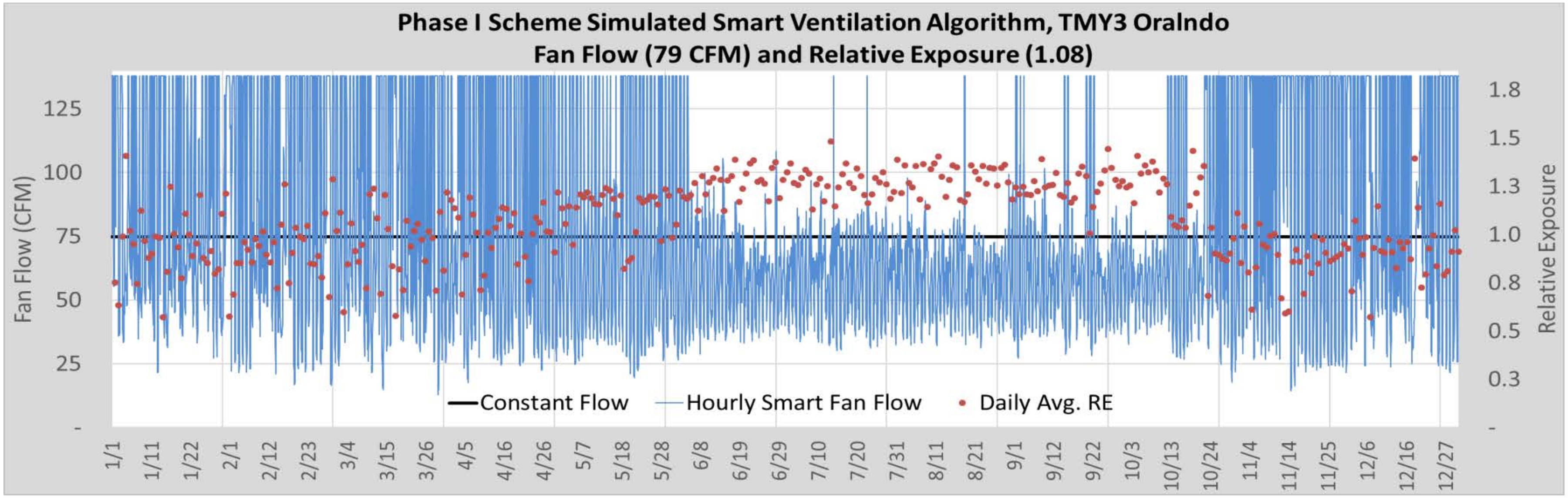
Real Time Weather SVC

$$RSS = \sqrt{(\Delta T * X_T)^2 + (\Delta W * X_W)^2}$$

Hourly Fan Flow = (Target Fan Flow * (Average RSS_1:RSS_{23}/RSS_{24})

Period (defined by hourly outdoor T)	Parameter	Phase I Scheme Values
Cooling	Outdoor temp range for cooling period target Cooling period target fan flow	> 71.5°F 55 cfm
Heating	Outdoor temp range for heating period target Heating period target fan flow	< 60°F 75 cfm
Floating	Outdoor temp range for floating period target Floating period target fan flow	<= 71.5°F; >= 60°F 138 cfm (fan limit)
All	Indoor temperature Delta-temperature weight (X_T) Indoor moisture (W) Delta-moisture weight (W_W)	64.4°F 2 $12 g/m^3$ 1

Phase I Simulated Results



FSEC

Phase I Simulated Results

Season/ Period	Sensible (kBtu/h)			Latent (lbs/h)			Fan Energy (Average Watts)			Average	
	Fixed	Smart	% Δ	Fixed	Smart	% Δ	Fixed	Smart	% Δ	Flow (cfm)	RE
Summer[a]	0.25	0.05	79%	0.94	0.78	16%	40	28	29%	65	1.22
Cooling[b]	0.32	0.17	47%	0.84	0.66	22%	40	23	42%	53	1.29
Heating[b]	(1.46)	(1.19)	18%	(0.56)	(0.47)	17%	40	27	31%	64	1.09
Floating[b]	(0.75)	(1.37)	-82%	0.18	0.32	-81%	40	59	-47%	136	0.66
Annual										79	1.08

Season/ Period	Sensible			Latent			Fan			Total	
	Fixed (kWh)	Smart (kWh)	Savings (kWh)	Fixed (kWh)	Smart (kWh)	Savings (kWh)	Fixed (kWh)	Smart (kWh)	Savings (kWh)	Savings (kWh)	Savings %
Summer[a]	160	46	114	397	331	65	175	124	51	230	32%
Cooling[b]	206	109	97	405	317	88	199	101	98	283	35%
Heating[b]	649	532	116				48	120	(72)	45	6%
Floating[b]							102	257	(156)	(156)	-153%
Annual	854	641	213	405	317	88	349	478	(130)	172	11%

Laboratory Evaluation

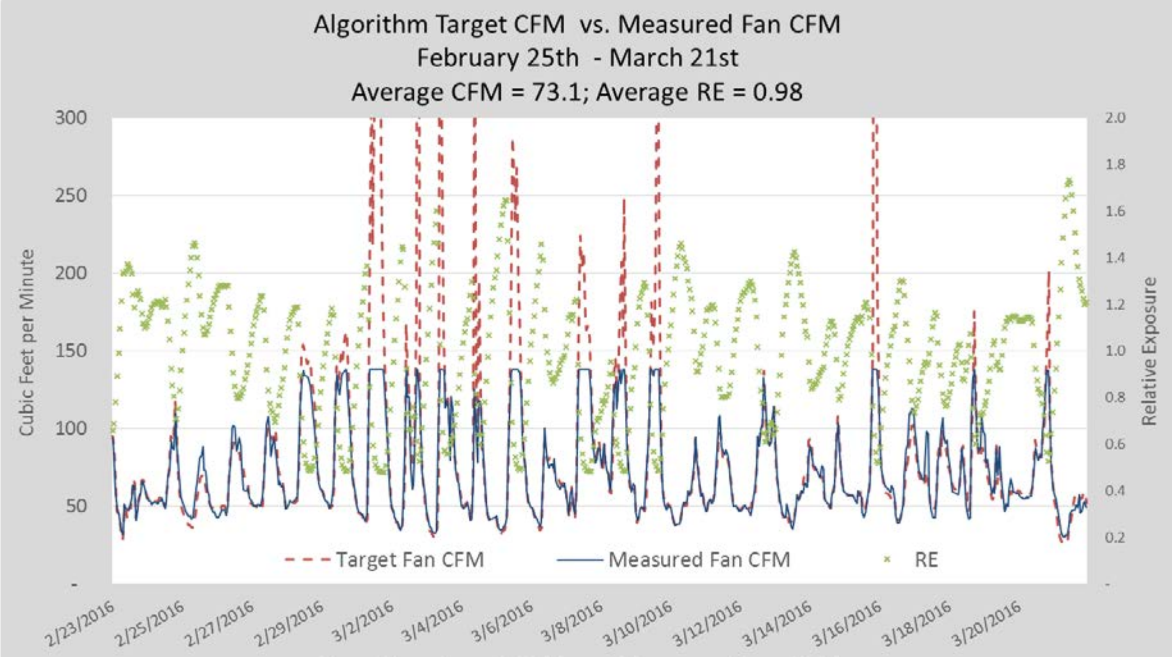
FSEC FRTF Labs

- 1,536 ft^2, 2.2 ACH50
- Supply ventilation
- ASHRAE 62.2-2016

$Q_{total} = Q_{fan} + \phi Q_{inf} = 76.1$ cfm

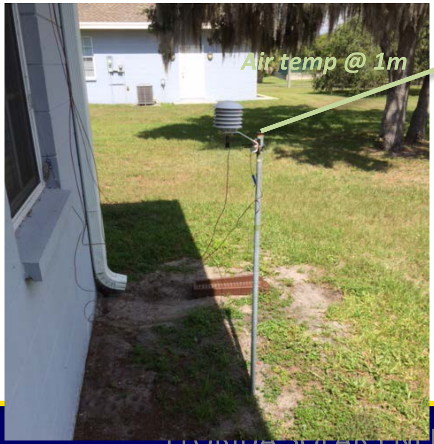
$\phi = 1$, $Q_{fan} = 66$ cfm

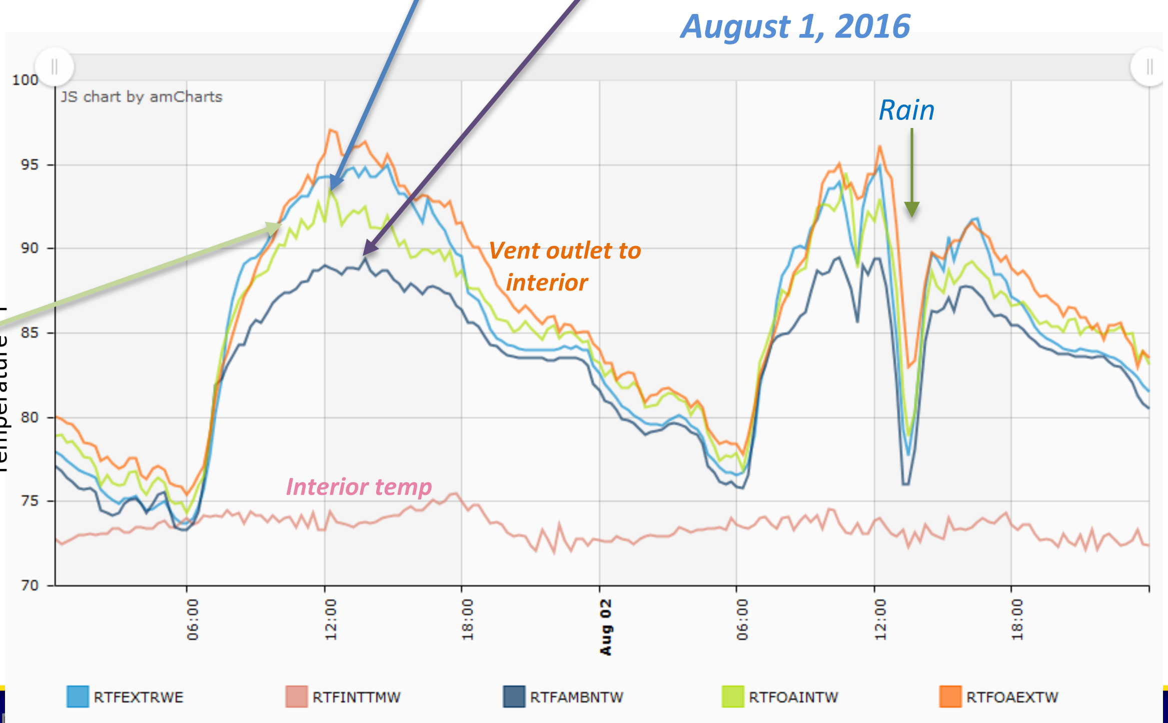
$\phi \neq 1$, $Q_{fan} = 75$ cfm



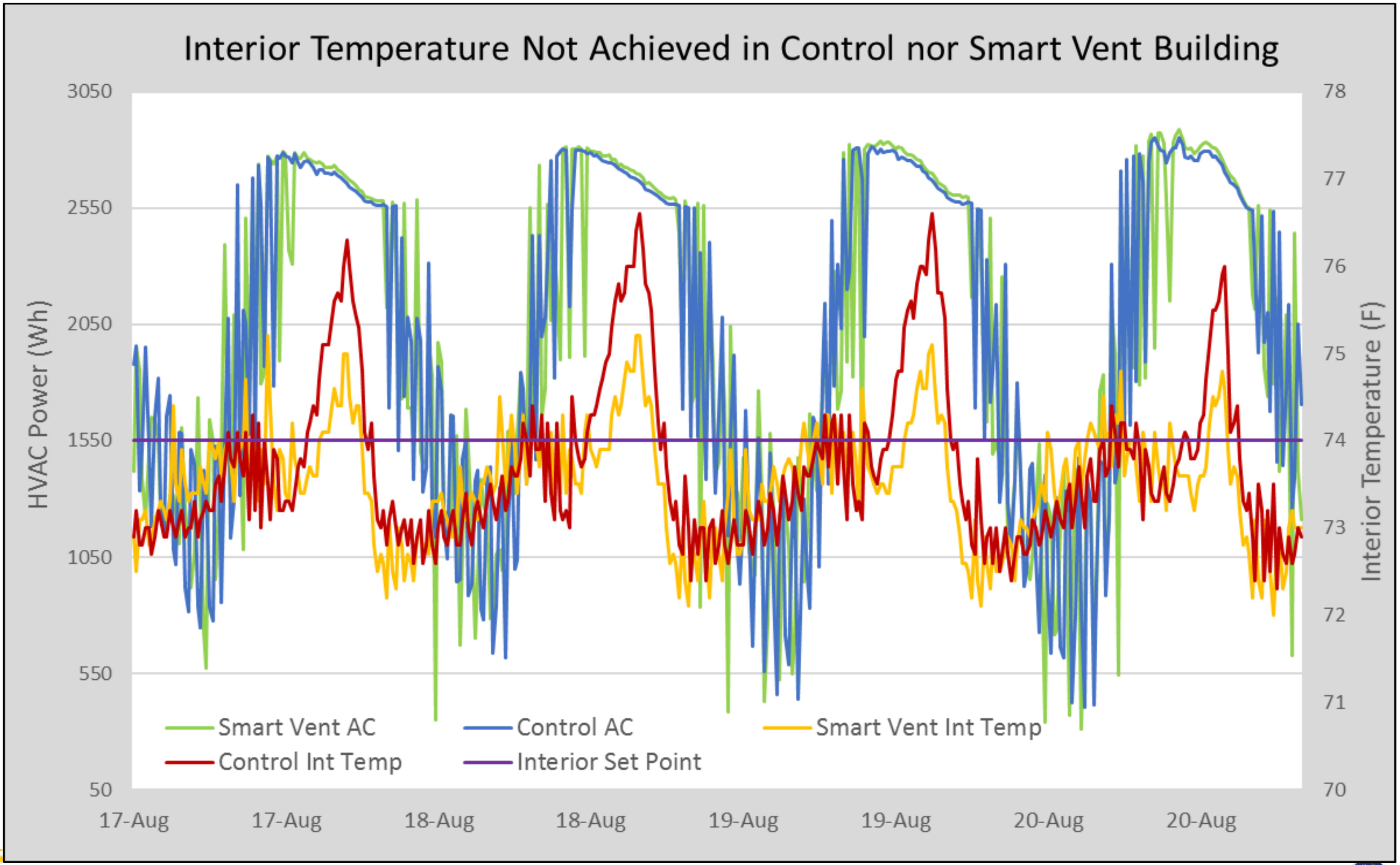
Lesson Learned: Temp. Variation

- Potential to use broadband weather to drive Smart Vent, but…
- Air temperature in summer at 15 ft height 3-4 °F lower than air temperature at soffit inlet
- Increase not coming from attic; evidence of wall related heat
- Air temperature is higher near ground and varies with time of day
- Ideal summer ventilation outdoor target temp not 75, but ~65 °F





Lesson Learned: AC Sizing and Peak Load

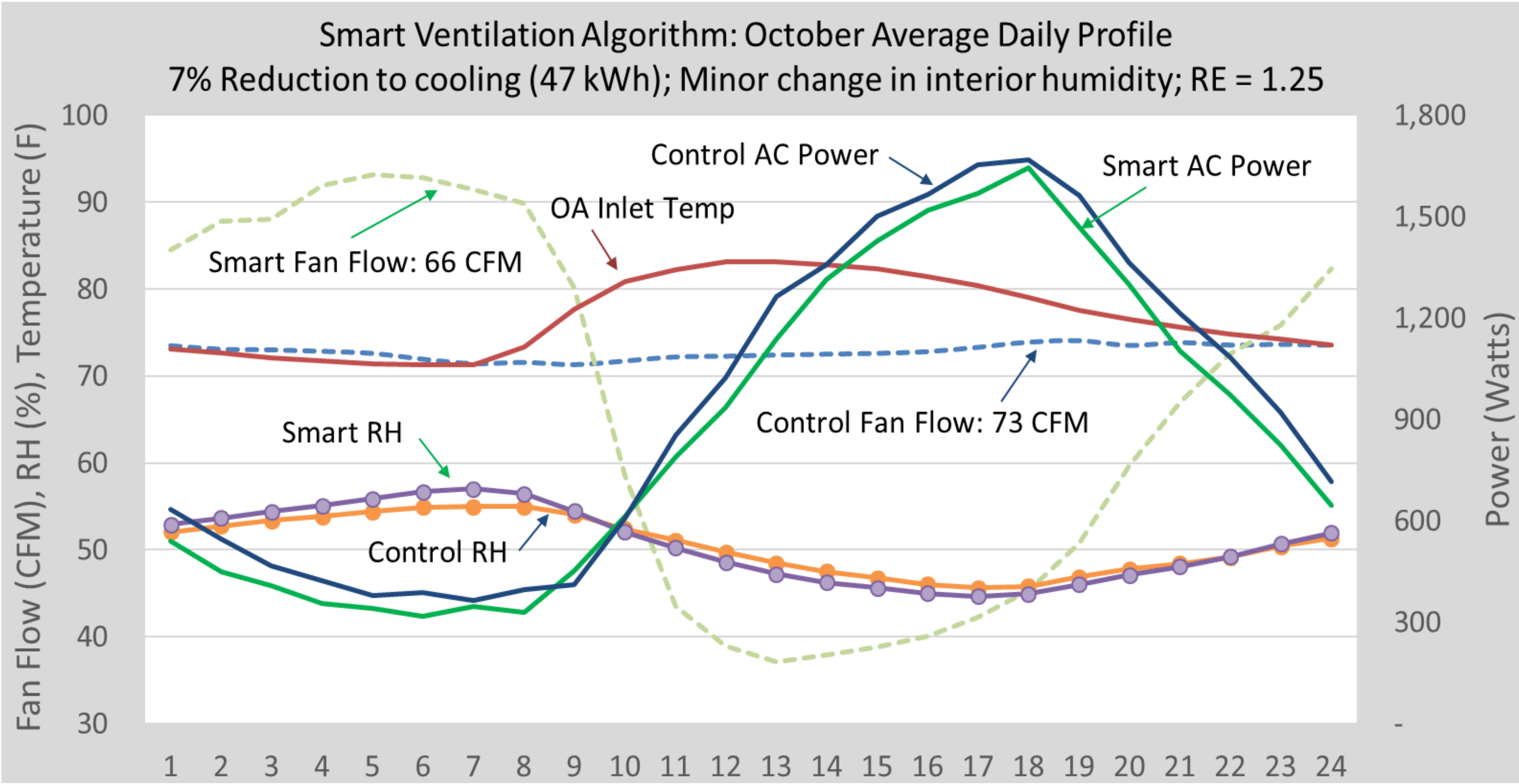


Phase I Experimental Results

Month	Cooling Energy (kWh)			Fan Energy (kWh)			Total (kWh)			
	Fixed	Smart	Savings	Fixed	Smart	Savings	Fixed	Smart	Savings	% Savings
Aug	1,312	1,295	16	29	18	11	1,340	1,313	27	2%
Sep	1,011	1,013	(2)	29	18	10	1,039	1,031	8	1%
Oct	671	624	47	29	21	8	700	645	55	8%
Nov	295	246	49	29	25	3	324	271	53	16%
Dec	286	234	52	29	27	2	314	261	53	17%
Jan	300	248	53	29	25	3	329	273	56	17%
Avg	**646**	**610**	**36**	**29**	**22**	**6**	**674**	**632**	**42**	**6.2%**

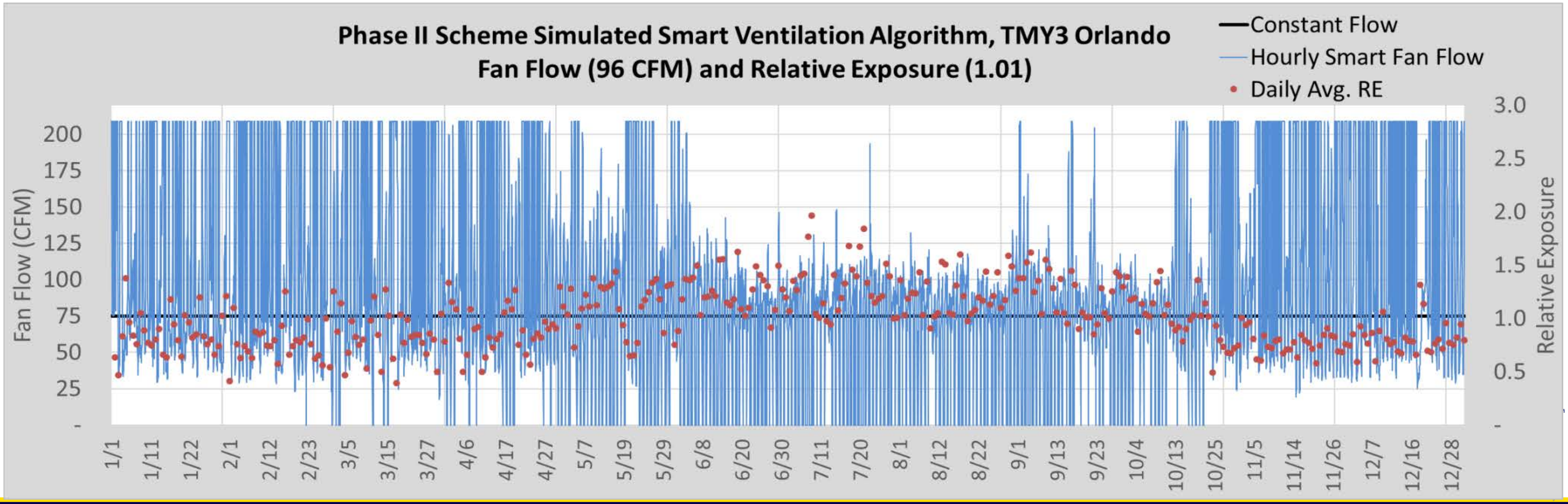
Month	Smart Flow (cfm)	Smart RE	Outdoor OA Inlet T	Control Indoor T	Smart Vent Indoor T	Outdoor OA Inlet DP	Control Indoor RH	Smart Vent Indoor RH
Aug	57	1.33	84.4	73.6	73.6	75.5	52.1	51.2
Sep	59	1.31	81.5	73.6	73.9	73.5	53.1	53.9
Oct	66	1.25	76.8	74.2	74.1	65.8	50.5	50.6
Nov	82	1.08	70.3	74.0	74.1	60.0	50.9	53.3
Dec	87	1.03	69.6	73.9	73.9	61.0	54.0	56.2
Jan	82	1.06	65.3	74.3	73.9	54.0	48.3	52.8

Phase I Experimental Results



Phase II

Period	Parameter	Phase I Scheme Values	Phase II Scheme Values
Cooling	Outdoor temp for cooling period target Cooling period target fan flow Outdoor temperature for fan override	> 71.5°F 55 cfm n/a	> 71.5°F 75 cfm >= 88°F
Heating	Outdoor temp for heating period target Heating period target fan flow	< 60°F 75 cfm	< 50°F 75 cfm
Floating	Outdoor temp for floating period target Floating period target fan flow Outdoor W to adjust floating period target Floating period target adjusted for W	<= 71.5°F; >= 60°F 138 cfm (fan limit) n/a n/a	<= 71.5°F; >=50°F 209 cfm (fan limit) >= 15g/m3 75 cfm
All	Indoor temperature (T) Delta-temperature weight (X_T) Indoor moisture (W) Delta-moisture weight (X_W)	64.4°F 2 12g/m3 1	64.4°F 2 12g/m3 1



Phase I vs. Phase II Simulated Results

Season/ Period	Sensible (kBtu/h)			Latent (lbs/h)			Fan Energy (Average Watts)			Average	
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Annual										79	1.08

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	Fixed	Smart	% Δ	Fixed	Smart	% Δ	Fixed	Smart	% Δ	Flow (cfm)	RE
Summer[a]	0.25	(0.08)	133%	0.94	0.90	4%	40	41	-3%	76	1.19
Cooling[b]	0.32	0.09	73%	0.84	0.76	9%	40	33	16%	61	1.24
Heating[b]	(1.46)	(1.20)	18%	(0.56)	(0.47)	17%	40	35	13%	64	1.04
Floating[b]	(0.75)	(1.89)	-152%	0.18	0.25	-42%	40	98	-145%	179	0.53
Annual										96	1.01

Phase I vs. Phase II Experimental Results

Phase I

Month	Cooling Energy (kWh)			Fan Energy (kWh)			Total (kWh)			
	Fixed	Smart	Savings	Fixed	Smart	Savings	Fixed	Smart	Savings	% Savings
Aug	1,312	1,295	16	29	18	11	1,340	1,313	27	2%
Sep	1,011	1,013	(2)	29	18	10	1,039	1,031	8	1%
Oct	671	624	47	29	21	8	700	645	55	8%

Phase II

Month	Cooling Energy (kWh)			Fan Energy (kWh)			Total Energy (kWh)			
	Fixed	Smart	Savings	Fixed	Smart	Savings	Fixed	Smart	Savings	% Savings
May	719	630	89	29	36	(7)	748	666	82	11%
Jun	822	749	73	29	20	8	851	770	81	9.5%
Jul	1,011	924	87	29	26	2	1,040	950	89	8.6%

Smart Ventilation Conclusions

- 10% space conditioning energy savings can be achieved with a variety of methods.
  - Potential for greater savings with enthalpy exchange and optimization of fan energy.
- Greater control = greater complexity = greater system cost. Benefits need to justify costs.
- Limited availability of controls, systems, and design tools in the marketplace currently.
- BA involvement in ASHRAE 62.2 will accelerate commercialization and use of smart vent systems
  - Appendix C, User Manual, occupancy discussion, upcoming IAQ study
- Commercialization considerations
  - Device integration to reduce cost, fault detection, code/ratings credit, commissioning.

Up Next…

Project Updates

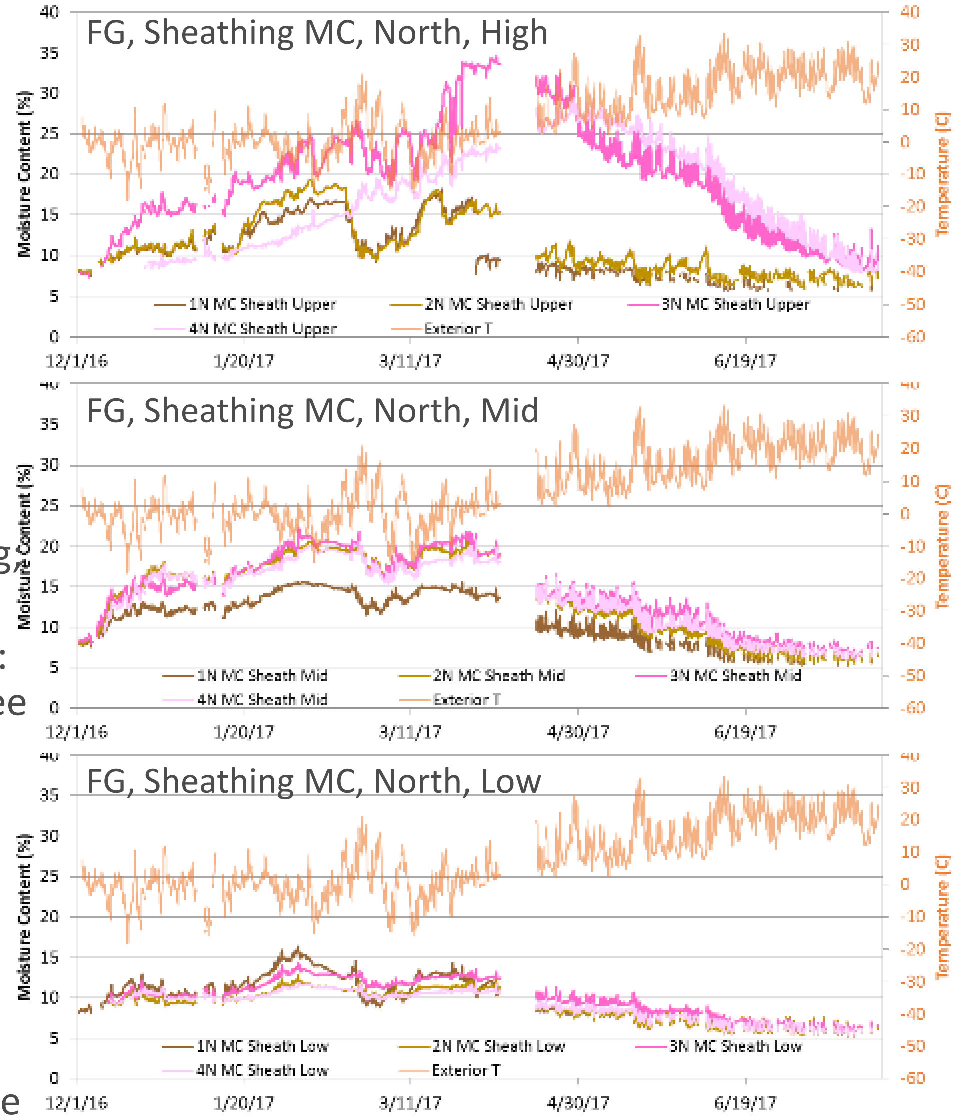
Monitoring of Unvented Roofs with Diffusion Vents and Interior Vapor Control in a Cold Climate

Team and Partners	Topic Area
Building Science Corporation w/ DuPont, Owens Corning, Cosella-Dörken, K. Hovnanian Homes	Topic 1: High Performance Moisture Managed Envelopes

- Interior vapor control membrane on attics with fibrous insulation (non-SPF)
- Enables affordable insulation solution for attics, bringing the HVAC equipment into the conditioned space
- New Construction Field Test
- Variables: fiberglass/cellulose, interior vapor control, diffusion vent at ridge
- Data collected December 2016-July 2017
- Up to 3 winters of data

Monitoring of Unvented Roofs with Diffusion Vents and Interior Vapor Control in a Cold Climate: Results to Date

- In fibrous insulation roofs, interior-sourced moisture accumulates at peak/ridge
- At non-DV ridges: high RHs, high wood moisture contents (25-30%+), condensation measured (non-diffusion vent roofs)
- Diffusion vent controls this moisture accumulation at ridge
- At lower parts of roof, sheathing moisture levels controlled (slightly over 20% MC)
- Inward moisture drives: variable-permeance ("smart") vapor retarders allow inward drying; fixed 1 perm VB has accumulation
- Mold index (per ASHRAE Std. 160) calculated: remain below 1 ("pass"), but only first of three winter conditions
- Safest experimental roofs: combine diffusion vent and variable-perm vapor retarder
- Code compliant (ccSPF + cellulose, §R806.4) roof has much drier behavior than experimental fibrous insulation roofs (lower risk assembly)
- Two more winters: high RH, induce air leakage

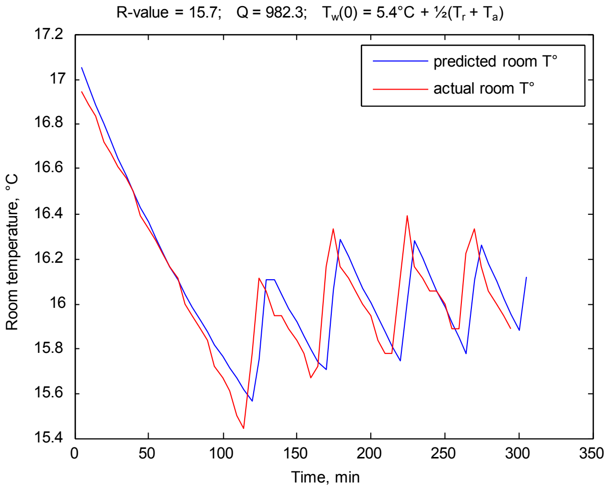


Roof	Short Name
1	FG-VB-DV
2	FG-SVR-DV
3	FG-VB-nDV
4	FG-SVR-nDV

Physics-based Interval Data Models to Automate and Scale Home Energy Performance Evaluations – August 2017 Update

Team and Partners	Topic Area
Fraunhofer USA, Inc. with Eversource, National Grid, Holyoke Gas & Electric	Performance Measurement (2016)

Develop a highly scalable tool that automatically and remotely analyzes communicating thermostat (CT) and interval meter data to identify household-specific retrofit opportunities to reduce heating energy consumption, quantify expected retrofit energy savings, and validate post-retrofit energy performance.



Success Metrics: Develop & validate approach that correctly identifies households with the target retrofit opportunities with 1) at least 75% classification accuracy and 2) +/-25% accuracy in predicting retrofit energy savings, to significantly increase the uptake of the target retrofit measures while reducing program recruitment costs per retrofit project. Success metrics include doubling the rate of onsite energy audits in partner utility programs for the target households identified by the tool.

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

Project Approach and Progress

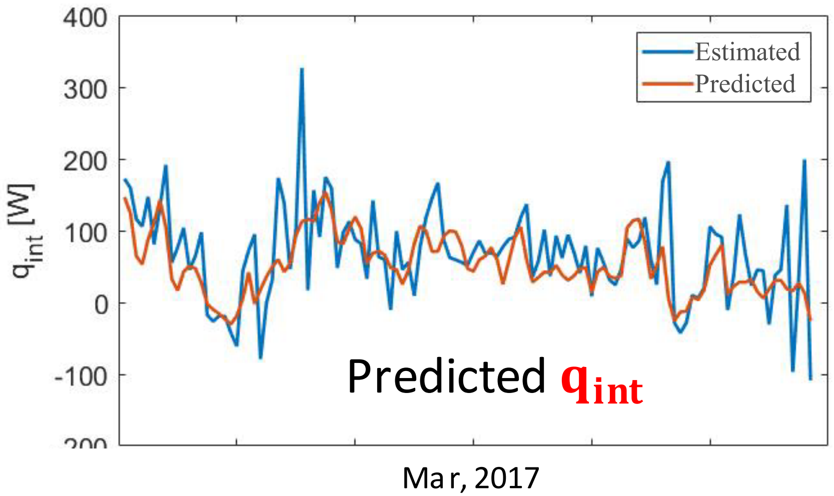
- Develop coarse-grained gray-box models
  - Connect CT data & home thermal parameters
- Leverage existing and new utility data
  - ~80 homes: CT data, home assessments, interval gas and electric meter data
  - Several hundred homes: CT data + home energy evaluations
- Apply to homes/systems of increasing application complexity over project life
  - Regular gas furnaces to condensing boilers
  - Single-zone to multi-zone homes
- Apply Machine Learning to increase accuracy
- Use models to:
  - Estimate home thermal parameters
  - Characterize home-specific classes of retrofit opportunities (e.g., insulation upgrade)
  - Predict home-specific retrofit energy savings

Data Acquisition Progress Update:

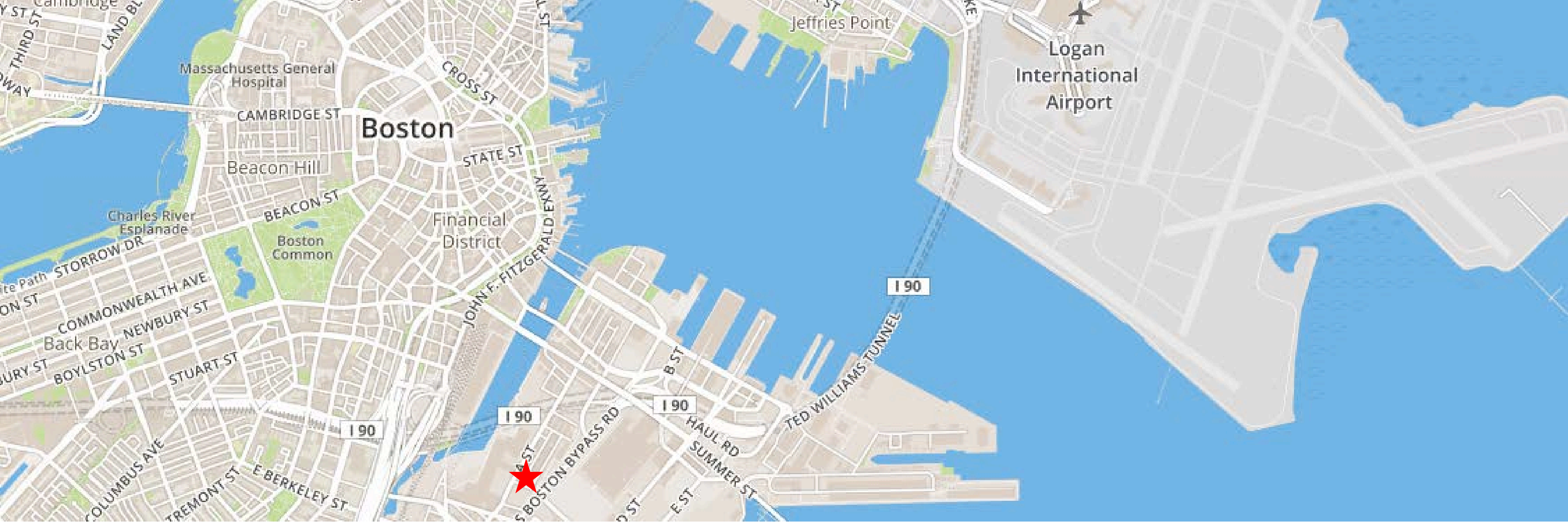
- Obtained CT- and home-assessment data for 60+ homes with gas furnaces
- Problems in data quality being addressed

Technical Progress update:

- Two sets of algorithms developed for home thermal parameter estimation from nighttime CT data
- Machine learning for external (e.g., solar irradiation) and internal (e.g., human activity) heat loads



Estimated by gray-box model vs. predicted by machine learning internal heat gains for a home



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Energy Savings with Acceptable IAQ through Improved Air Flow Control

Team and Partners	Topic Area
Gas Technology Institute, University of Illinois, Midwest Energy Efficiency Alliance, Chitwood Energy Management, National Center for Healthy Housing	Optimal Ventilation & IAQ Solutions (2015)

- This project will develop an integrated assessment that will measure the impact of controlled HVAC duct losses and system flow, infiltration, and ventilation options on IAQ and energy savings.
- Field tests of 20 control homes and 20 treatment homes, conducted in cooperation with field practitioners.
- Energy measurements and multiple IAQ measurements including CO2, radon, formaldehyde, humidity
- Guidance for delivering residential retrofits including both good IAQ and energy savings.

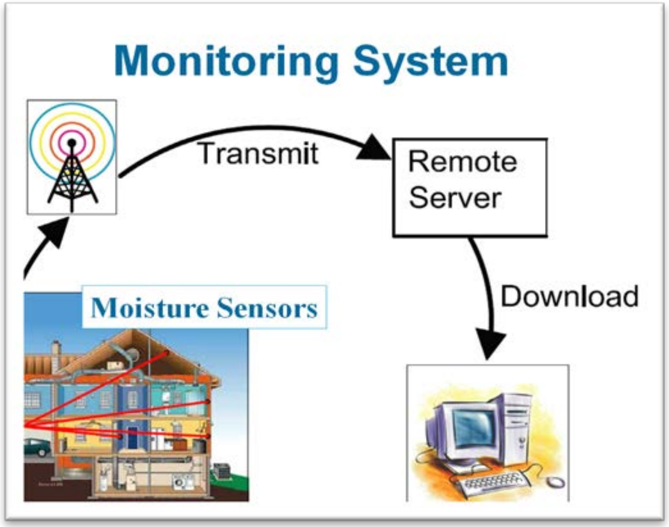
Success Metrics: Through systematic management of airflows, provide improved energy savings with the same IAQ or improved IAQ with the same energy savings.

Field Test Site Recruiting Status

- Home monitoring started in Q1’17 following Field Test Plan approval in Q4’16
  - Only able to recruit three homes in Winter 2016-17 due to late start and lead contractor prospect base not meeting eligibility requirements
- Recruited and trained two more home performance contractor teams in Q2’17 (total of three)
- Home performance contractors reached out to a broad audience in Q1-Q2’17
  - Homeowners, Chamber of Commerce, various building departments, firehouses, other raters and insulation contractors
  - A number of homeowners expressed interest but could not be enrolled due to not meeting test plan eligibility requirements
- Exploring opportunities to optimize the test plan and other tactics to increase enrollment

Moisture Performance of High-R Wall Systems

Team and Partners	Topic Area
Home Innovation Research Labs w/ American Chemistry Council, NAHB, USDA Forest Products Lab, VSI	High Performance Moisture Managed Building Envelopes (2015)



Goal: Study moisture performance of high-R walls (>R-20) in occupied high performance homes across different climate zones. Improve builders' confidence and facilitate transition to high-R walls.

Success Metrics: Measured and modeled performance of high-R walls and design guidance to ensure durability of high performance walls.

Extended Plate and Beam (EP&B) Wall System

Team and Partners	Topic Area
Home Innovation Research Labs, Inc. w/ American Chemistry Council, Forest Products Laboratory, The Dow Chemical Company, Builder Partners: Arn McIntyre Construction, Kevin L. Smith Construction	High Performance Moisture Managed Envelopes (2015)

Goal: Study the constructability and structural/moisture performance of high-R walls with rigid foam insulation interior to the wood structural sheathing

Success Metrics: Efficient, cost-effective, durable wall assembly to meet and exceed new IECC targets

Attic Retrofits Using Nail-Base Insulated Panels

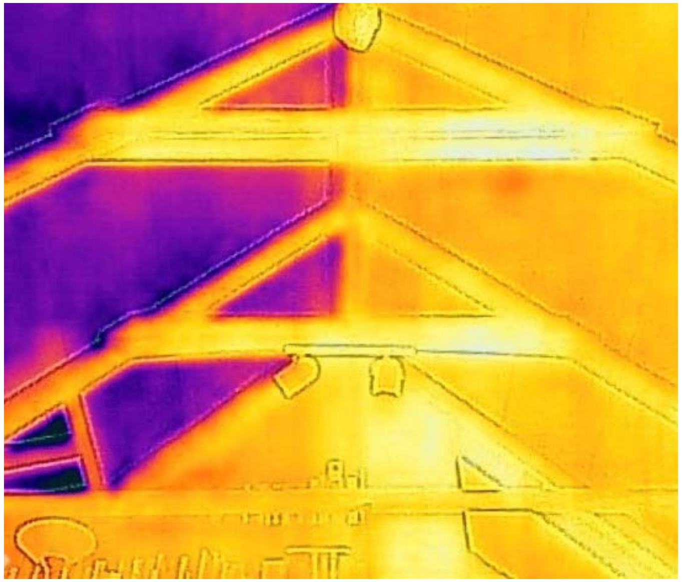
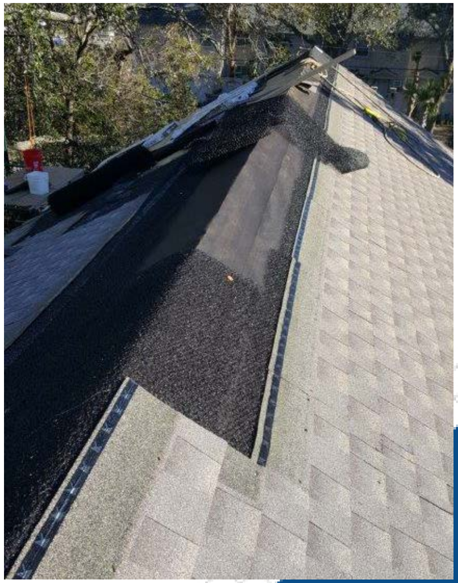
Team and Partners	Topic Area
Home Innovation Research Labs, Inc. w/ SIPA, ACC, APA, Dow, DuPont, Owens Corning	High Performance Moisture Managed Building Envelopes (2015)

Purpose: Develop and demonstrate a roof/attic energy retrofit solution using retrofit panels for existing homes where traditional attic insulation approaches are not effective or feasible.

Success metrics: Heating and cooling energy savings of at least 10%; improved comfort; monitored data that confirms acceptable moisture levels.

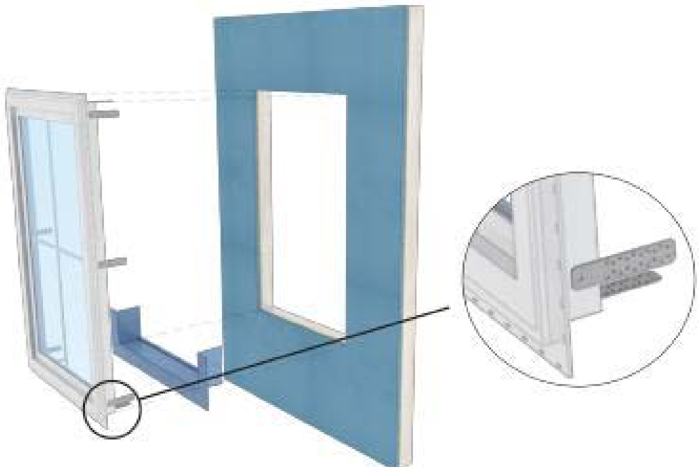
Attic Retrofits Using Nail-Base Insulated Panels



Structural Support of Windows in Walls with Continuous Insulation

Partners	Topic Area
Home Innovation Research Labs, Inc. American Chemistry Council American Architectural Manufacturers Association	Topic 1: High Performance Moisture Managed Envelopes (2016)



- Identify code compliant solutions for window installation in walls with continuous insulation (CI)
- Evaluate the structural performance of walls with windows of varying shapes and sizes, insulation thicknesses, and installation methods.

<u>Success Metrics:</u> Structural performance validation of window installation methods for walls with continuous insulation will provide data & justification for additional methods to be included in industry (AAMA) guidance & IRC code provisions. Results will enable increased use of continuous insulation, which is highly effective at raising overall R-value, eliminating thermal bridging, and mitigating moisture issues.

Integrated Design: A High Performance Solution for Affordable Housing

Team and Partners	Topic Area
The Levy Partnership, Inc.	Envelope, Comfort, and IAQ (2015)

- Develop a high performance Integrated Design for affordable housing (Habitat for Humanity and factory-built)
- Combine a high performance enclosure, ductless mini-split heat pump, transfer fans and ventilation
- Monitor 3 test homes, occupied and unoccupied, for 1 year+
- TRNSYS and BEopt models calibrated to field data

Success Metrics: Reduce space conditioning energy use by 50% relative to IECC 2009 in Habitat and factory built homes in mixed-humid and cold climates

Worcester Habitat Home Under Construction

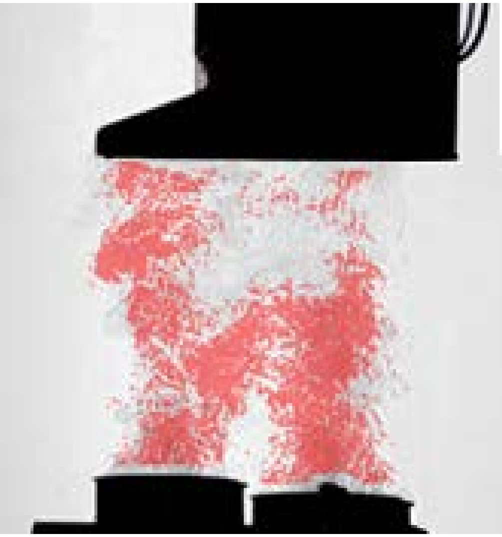
ARIES Collaborative

Advanced Residential Integrated Energy Solutions

Development of the Industry's First Smart Range Hood

Team and Partners	Topic Area
Newport Partners w/ Broan-NuTone	Optimal Ventilation & IAQ Solutions (2016)

- Kitchens are the primary source of the most harmful pollutants generated in the home.
- Kitchen range hoods are seldom used and can be ineffective.
- Develop a Smart Range Hood that senses pollutants, with automatic operation.
- Improve residential IAQ, extend lives, and save billions of dollars in health-related costs annually.



Success Metrics: "Smart" range hood developed & validated that is very quiet (≤ 1 sone), up to 5 times more efficient than ENERGY STAR, and near 100% capture efficiency, at a target price point competitive with the intermediate market. Enables tighter homes, ZERH specs, & better IAQ by addressing major indoor pollutant source.

Project Summary: Smart Range Hood Development

Timeline:

Start date: October 1, 2016

Planned end date: September 30, 2019

Key Milestones

1. M1.1: Sensor & pollutant spec table; 1/16/17
2. M1.2: Identify and acquire sensors; 3/31/17
3. GNG: Develop control logic model; 6/30/17

Project Outcome:

Develop, test, and demonstrate the industry's first Smart Range Hood.

Project Goal:

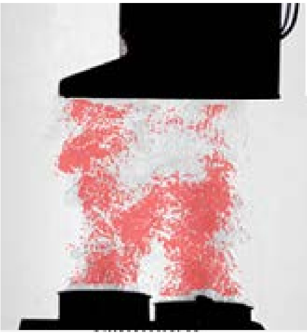
Integrate smart features in future, commercially available range hoods.

Key Partners:

Newport Partners L.L.C.

BROAN NuTone

Provide whole house mechanical ventilation → Sense key pollutants → Operate Automatically and Efficiently → Improve Capture Efficiency → Reduce Noise → Provide Homeowner Feedback and Recommendations



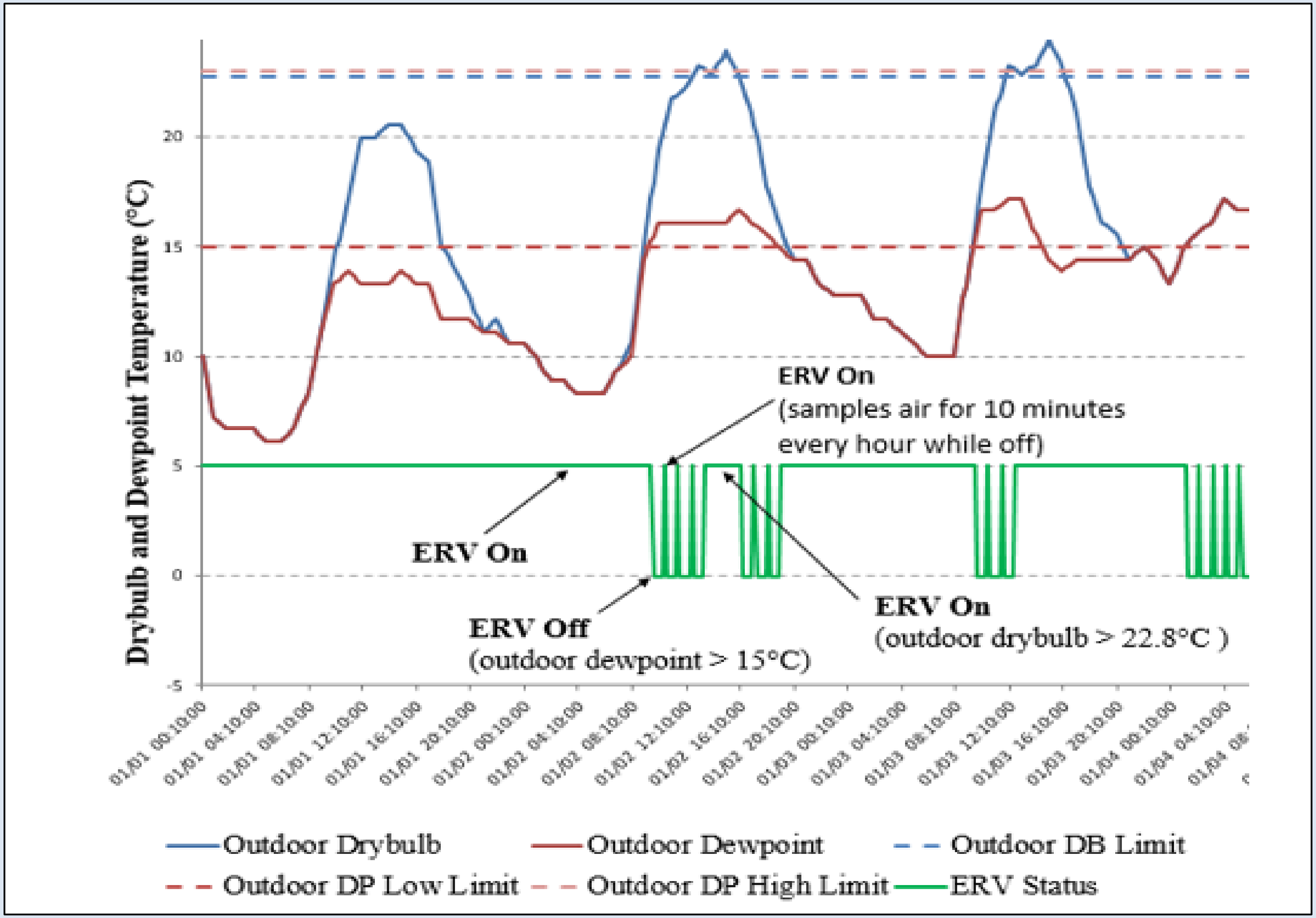
Performance-Based IAQ and Optimized Ventilation

Team and Partners	Topic Area
Southface Energy Institute w/ Underwriters Laboratory, Beazer Homes, Illinois Sustainable Technology Center, Venmar, Kerley Family Homes	Optimal Ventilation & IAQ Solutions (2016)

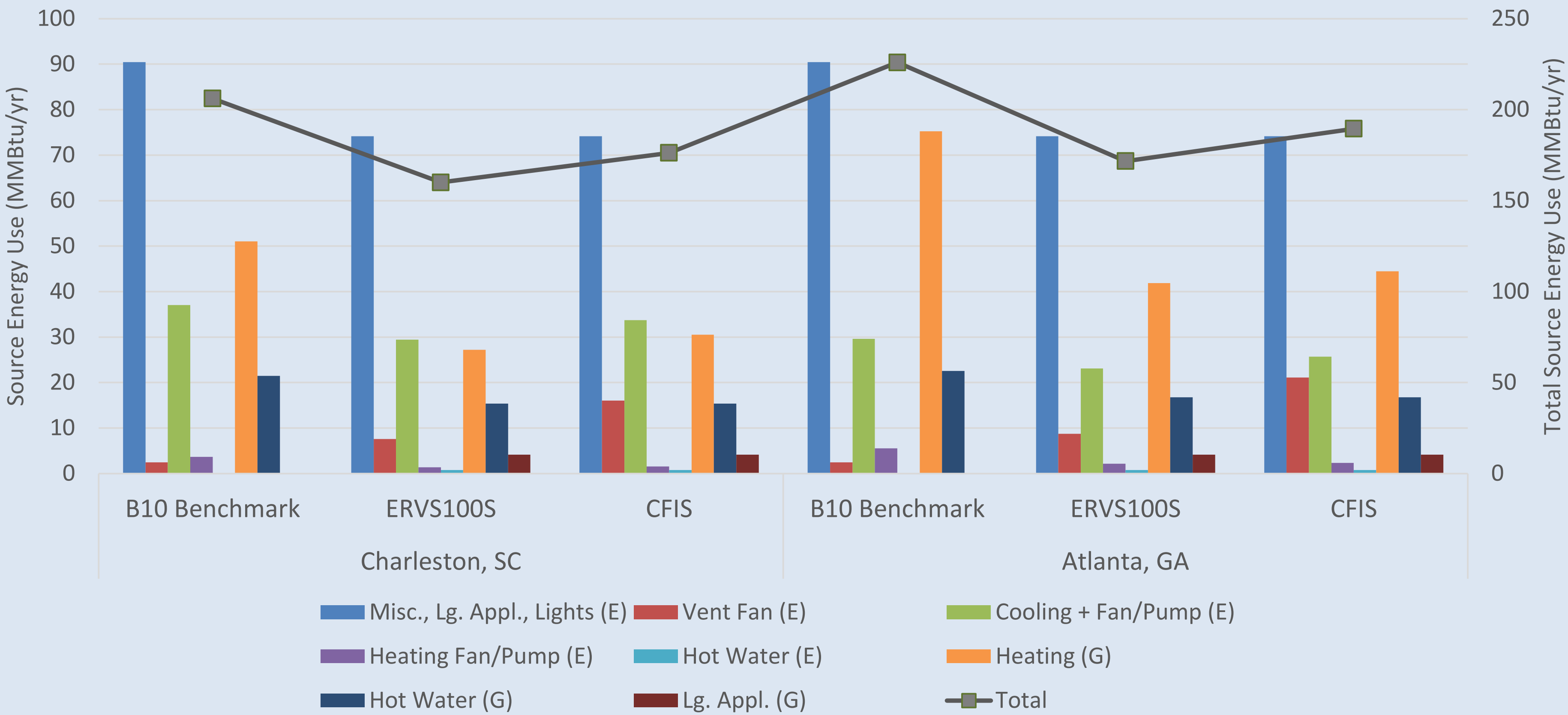
- Develop assessment protocol incorporating low-cost IAQ sensors: PM2.5, CO_2, O_3, TVOC, and radon sensors
- Benchmark IAQ metrics in new and existing homes
- Smart ERV field tests in real-world homes to evaluate impact on IAQ and energy consumption
- Pilot LBNL-developed IAQ Score in test homes

Success Metrics: Develop & validate a performance-based protocol for assessing indoor air quality (IAQ) in homes and inexpensive smart ERV solution that can achieve average annual HVAC energy cost savings of approximately $100 compared to central fan integrated supply systems, and ~50% reduction of ventilation related latent loads compared to supply or exhaust strategies.

BEopt Customization

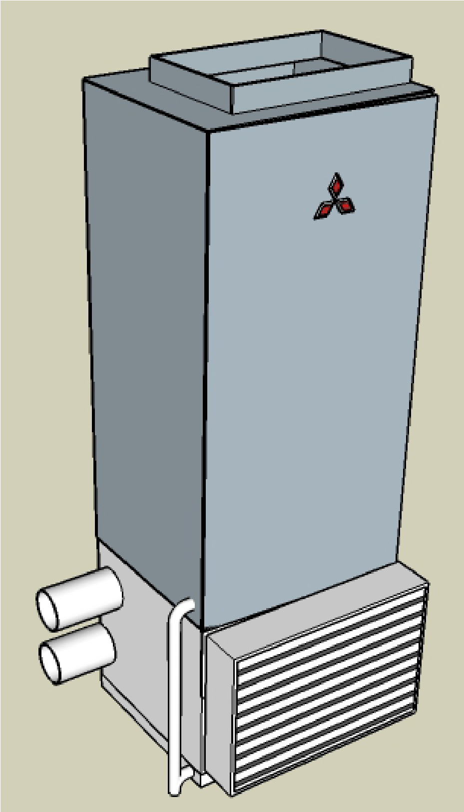


End-Use Source Energy Consumption



Ventilation Integrated Comfort System (VICS)

Team and Partners	Topic Area
Steven Winter Associates, Inc. w/ Mitsubishi	Optimal Comfort Systems and Optimal Ventilation & IAQ Solutions (2016)



- Development of integrated E/HRV for heat pump
- Variable speed fans for low energy and high controllability
- Test and demonstrate in unoccupied and occupied homes
- Lower cost and better performance than most balanced, heat recovery ventilation options.

Success Metrics: Develop, validate, & demonstrate VICS, to reduce up-front cost $1,000-$2,000 compared to separate E/HRV. Save 400-800 kWh/year compared to exhaust only ventilation. Enables balanced ventilation, better IAQ, & RH control in tight homes at lower cost.

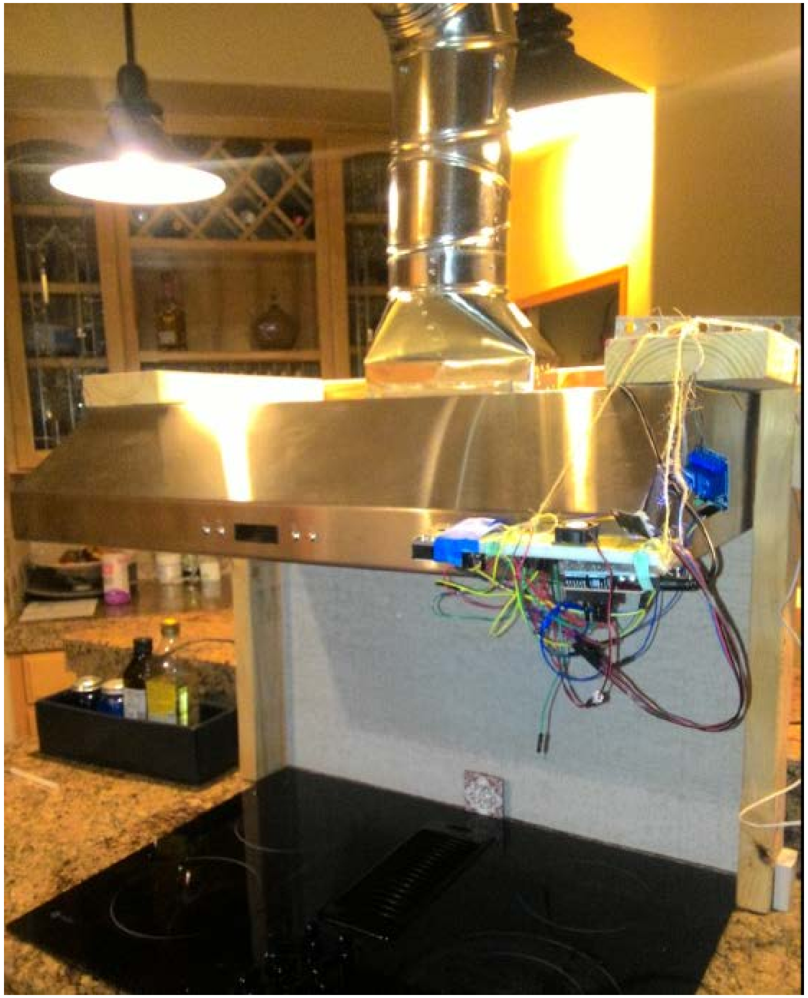
Phase I Results

- Duct restrictions to outdoor air and supply air were imposed on the VICS. In addition, different MERV filters were evaluated.
- In nearly all scenarios, except the most restrictive test conditions for OA and supply ductwork, the VICS achieves desired flow rates
- AHU fan is configured for constant torque, therefore large restrictions (equivalent to 200' of ducting) impose physical limitations on the VICS and reduce flow rates
- These tests are important to determine how ducting configuration will impact the operation of the VICS

AHU Fan Speed	OA duct Restriction	Supply Duct Restriction	OA Supply Air Flow	Exhaust Air Flow	Distribution Supply Air Flow	Power
-	IN.W.G.	IN.W.G.	CFM	CFM	CFM	Watts
Low	0.08	0.10	121	120	257	40
High	0.08	0.10	121	120	482	107
Low	0.24	0.30	89	90	217	34
High	0.24	0.30	122	118	417	98

Status

1. **Proof of Concept finalized**
   A. Senses PM2.5, IRT, humidity
   B. Varies speed in response to sensed pollutants/conditions
   C. Highly responsive
      1. ON within ~15 seconds of gas range turning on
      2. ON within ~2 minutes of electric range turning on
2. **Broan working on Gen1 prototype development**
   A. Migrate logic to different language
   B. Test and simulate broader range of cooking scenarios
3. **Horizon**
   A. Gen1 prototype due 9/30
   B. Test plan due 9/30



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

Affordable, Solid Panel “Perfect Wall" System

Team and Partners	Topic Area
NorthernSTAR **University of Minnesota**	**Topic 1: Moisture Risk Management and High-Performance Envelope Systems**

Research Project Update – Quarter 4

- Developed two complete MonoPath house designs (bid sets)
- Completed modeling for ZERH, energy, and moisture performance
- Began construction of Twin Cities - Habitat for Humanity home
  - new enclosure contractor/builder was trained with this house
  - panel erection observed by other partners and potential builders
  - structure completed in 2 days; dried-in and secure in 8 days
- Partners onboard to build eight more houses by winter
  - bringing on a new community/building partner

Project Partners:
MonoPath
Twin Cities Habitat for Humanity
Urban Homeworks
Thrive Builders (Denver, CO)
City of Minneapolis
Building Knowledge, Inc
Huber Engineered Woods & Unico

Up Next…

BERKELEY LAB

BERKELEY LAB
LAWRENCE BERKELEY NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

Building America New Home IAQ Study

Brett Singer
Iain Walker

August 08, 2017

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Motivating Questions

What is the indoor air quality in new homes with/out mechanical ventilation?

- What ventilation equipment is provided in new U.S. homes designed (or not) to comply with ASHRAE 62.2?
- What are airflows as installed?
- Do designs and performance vary by climate zone?
- Are there discernible differences in indoor air quality between homes that meet / don't meet 62.2?
- How do people use ventilation? Is it discernibly relatable to IAQ?

BACKGROUND

Ventilation and IAQ in California New Homes

- Air tightness reduces infiltration and dilution of indoor emitted contaminants
- CEC concerned that people don't reliably use windows.

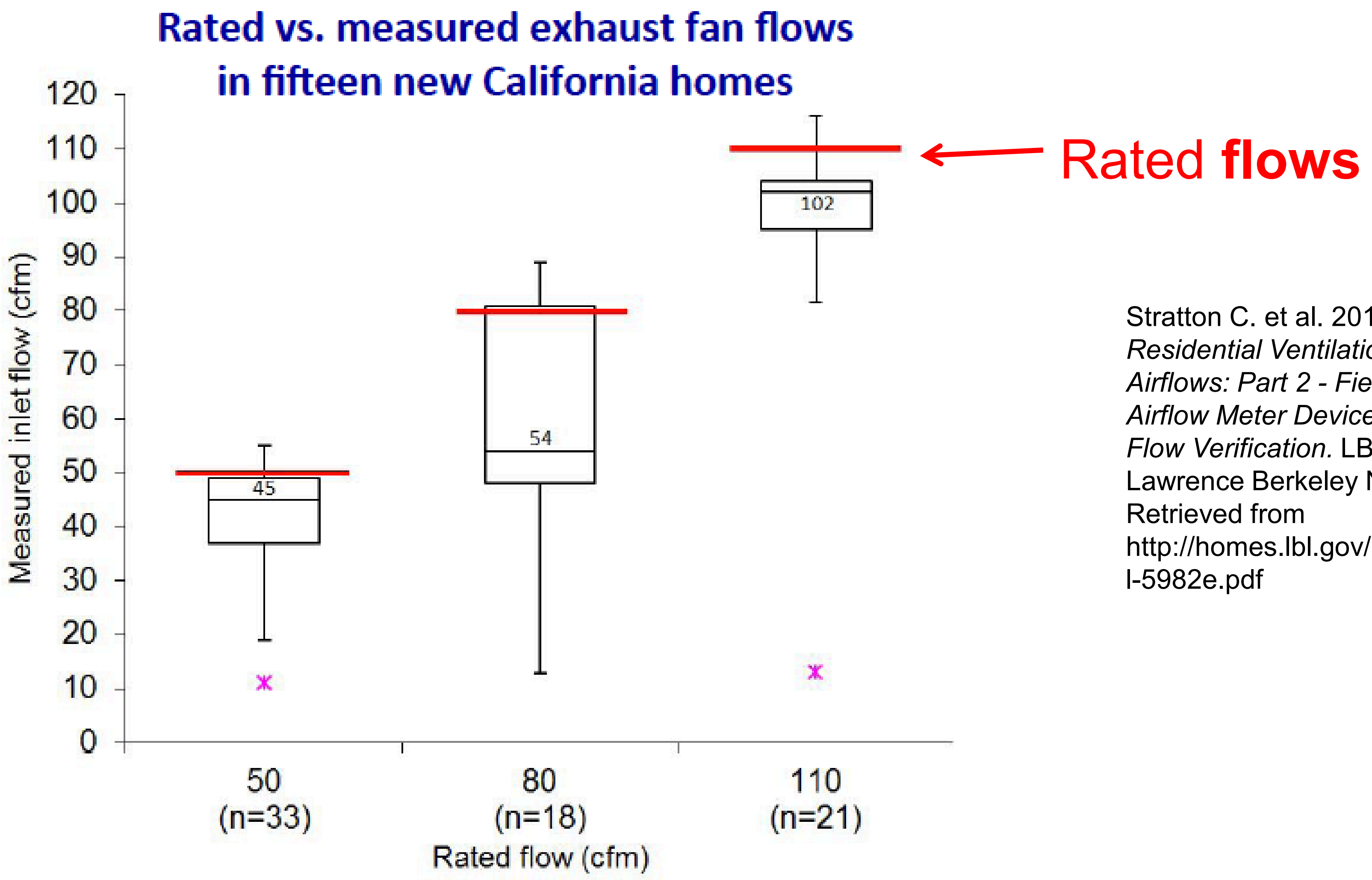
- 2004-05: survey of ~1500 new homes (Price & Sherman, 2006)
  - Few open windows in winter; many did not ventilate in other seasons.
  - Kitchen and bath ventilation not used regularly
- 2007-08: measurements in 108 homes – mostly 1 day (Offermann 2009)
  - 9 of 16 homes with ducted mechanical ventilation had grossly insufficient flow
  - Many homes did not use windows for ventilation; 67% below code requirement
  - Majority of homes exceeded formaldehyde health guidelines

US Studies of Ventilation Equipment

- FSEC inspected MV systems in 21 new Florida homes*
  - 1-9 ACH_{50}
  - Only 3 of 21 had ventilation airflows close to design targets
  - 2 of the 3 disabled by occupants
  - 12 of 21 ‘capable of operating’
  - I9 of 21 were not operational
- LBNL measured airflows in 15 new homes

*Sonne et al. 2015.

US Studies of Ventilation Equipment



The only way to know a fan's flow: MEASURE IT

Stratton C. et al. 2012. *Measuring Residential Ventilation System Airflows: Part 2 - Field Evaluation of Airflow Meter Devices and System Flow Verification.* LBNL-5982E. Lawrence Berkeley National Lab. Retrieved from http://homes.lbl.gov/sites/all/files/lbnl-5982e.pdf

Austrian Study (Wallner et al. 2015)

- IAQ and occupant health in new Austrian homes with/out MV.

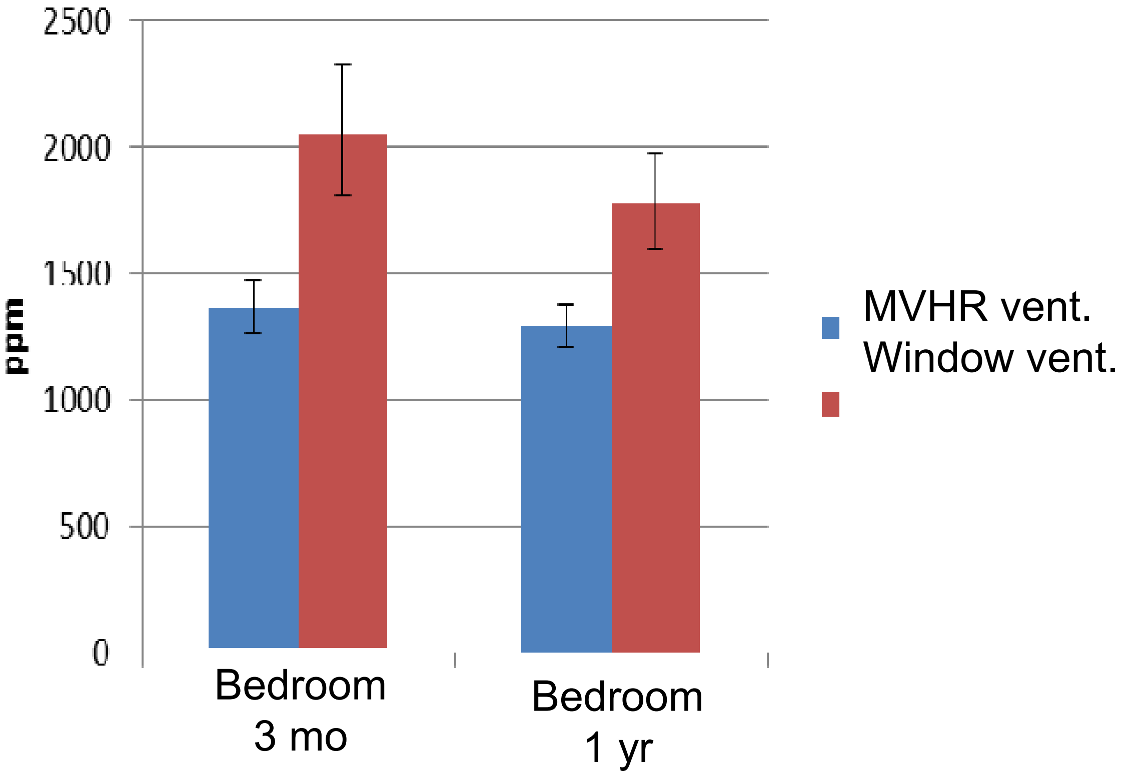
62 Homes with mechanical ventilation system w HR (MVHR) = Testgroup (T)
61 Homes without mechanical ventilation (only window) = Controlgroup (K)
In both groups the ratio SFH/MFH ~ 70/30

Two field measurement appointments in ea. Home:
- 3 months (+/- 3 weeks) after move-in
- 1 year (+/- 3 weeks) after move-in

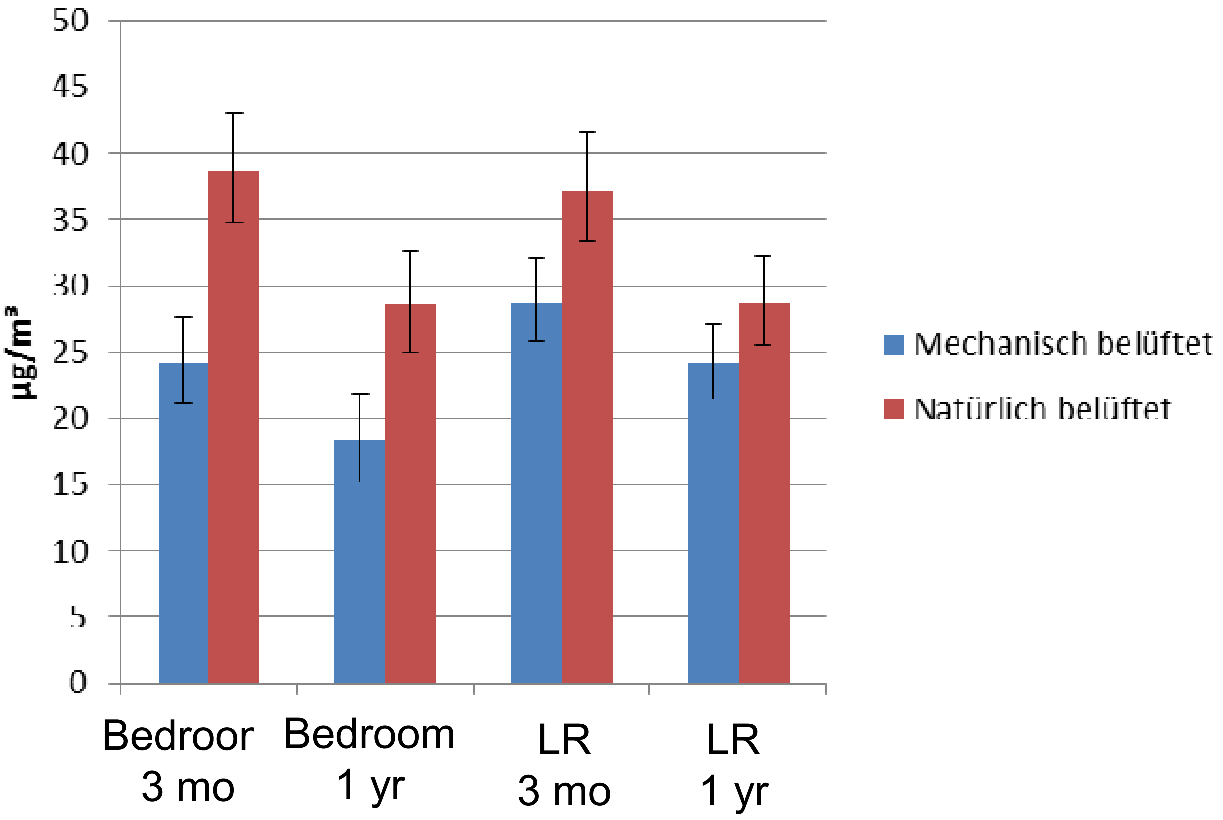
Measurement/survey:
- VOC's: sorption tubes (Anasorb 747) with GC-MS
- Aldehydes: sorption tubes (DNPH) with HPLC
- Mould spores: based on EN ISO 16000-16 / VDI 4300 Blatt 10
- Dust mites allergenes (Der p1 and Der f1): vacuum selected surfaces -> ELISA test
- Radon: ÖNORM S 5280-1
- CO_2, Temperatur, R.H.
- Interview of all occupants (>16yrs age) on medical and comfort/hygenic aspects
- In Testgroup (MVHR) additionally: air exchange rate / supply air flow and noise level

Austrian Study Results

CO2: Maximum of gliding hourly average

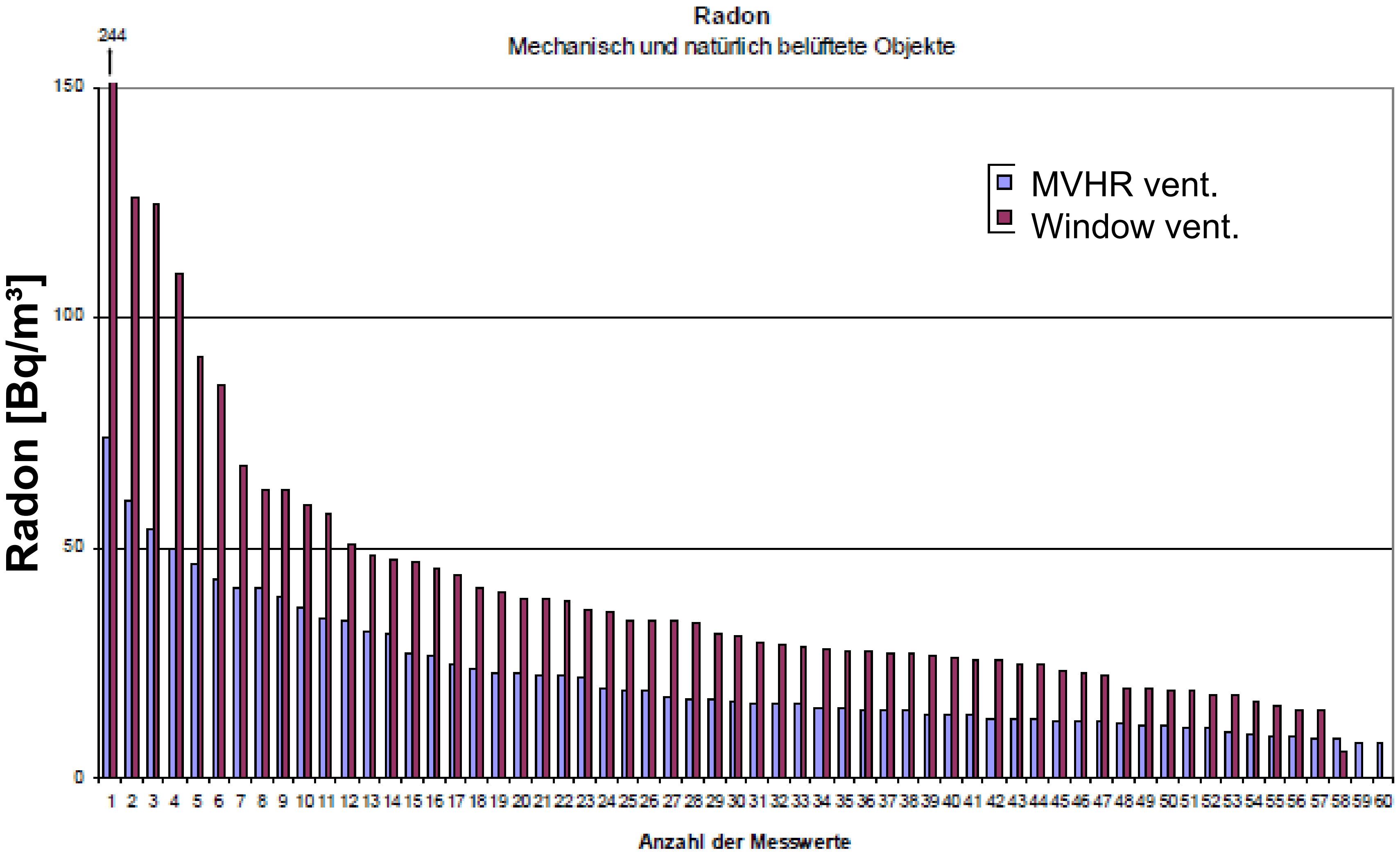


Formaldehyde



Tappler, P., Hutter, H.-P., Hengsberger, H., & Ringer, W. (2014). *Lüftung 3.0 - Bewohnergesundheit und Raumluftqualität in neu errichteten, energieeffizienten Wohnhäusern*. Vienna: Institut für Baubiologie und Bauökologie. Retrieved from http://innenraumanalytik.at/pdfs/lueftung_2014.pdf

Austrian Study Results - Radon



Tappler, P., Hutter, H.-P., Hengsberger, H., & Ringer, W. (2014). *Lüftung 3.0 - Bewohnergesundheit und Raumluftqualität in neu errichteten, energieeffizienten Wohnhäusern*. Vienna: Institut für Baubiologie und Bauökologie. Retrieved from http://innenraumanalytik.at/pdfs/lueftung_2014.pdf

Canadian IVAIRE study*

- Measurements in homes of 83 asthmatic children over 2 years
  - 43 received HRV or ERV; 40 controls
  - Heating season AER increased 0.17/h to 0.34/h with MV
    - Control group increased 0.18 to 0.21/h
  - Contaminants + T/RH – measured in child's bedroom and/or living room
    - CO_2 – time resolved
    - Formaldehyde, speciated VOCs, NO_2 - integrated
    - Mold spores and allergens - integrated
  - Survey for symptoms, medication use, hospital visits

*Aubin et al. 2013, Lajoie et al. 2015

IVAIRE Results

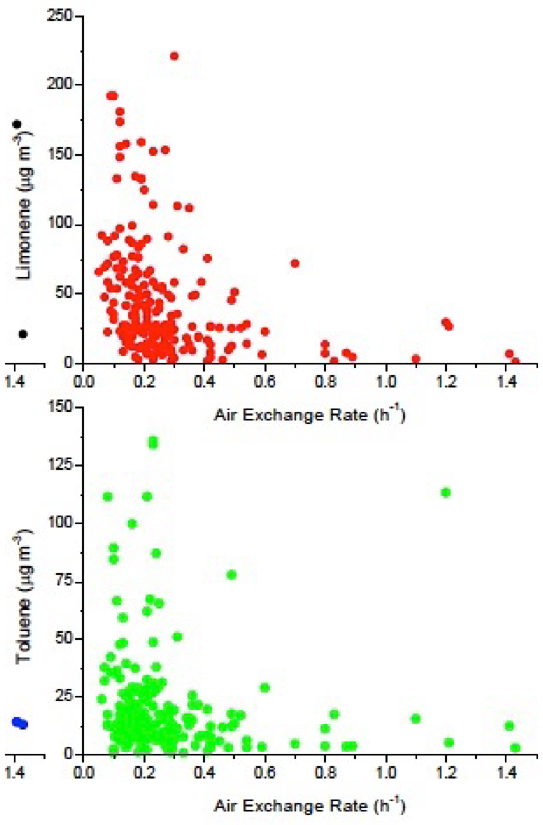


Table 1: Median concentrations of selected IAQ relevant parameters measured during the heating season before and after the intervention for the control and intervention groups.

Parameter	Cohort	Pre-Intervention	Post–Intervention
CO_2 (24-hr, ppm)	Control	1020	1027
	Intervention	899	770*
Formaldehyde ($\mu g\ m^{-3}$)	Control	35.9	36.0
	Intervention	34.3	24.1*
Airborne Mould Spores (DG18, CFU m^{-3})	Control	69	55
	Intervention	57	35*
Decane ($\mu g\ m^{-3}$)	Control	5.2	6.3
	Intervention	5.7	3.3*
Ethyl Acetate ($\mu g\ m^{-3}$)	Control	7.8	7.6
	Intervention	10.9	5.5*
α-pinene ($\mu g\ m^{-3}$)	Control	10.6	8.3
	Intervention	13.3	5.9*

Healthy Efficient New Gas* Homes (HENGH) Study

- Investigate impacts of 2008 building code that required MV
- Web-based survey of ventilation use and IAQ satisfaction
- Characterize MV system designs & installed performance (airflows)
- Monitor use of ventilation equipment; daily survey of activities
- Measure contaminant concentrations
  - CO_2, Est. $PM_{2.5}$, NO_2/NO_X, Aldehydes
- Target of 70 homes monitored for ~7 days, including weekend

*Focus on homes with gas appliances b/c funds from utility surcharge

VIAQNUSH Measurements

- Measurements
  - humidity and contaminant concentrations
  - ventilation equipment use
  - activities that impact contaminant emissions and removal
- Characterize homes and ventilation equipment

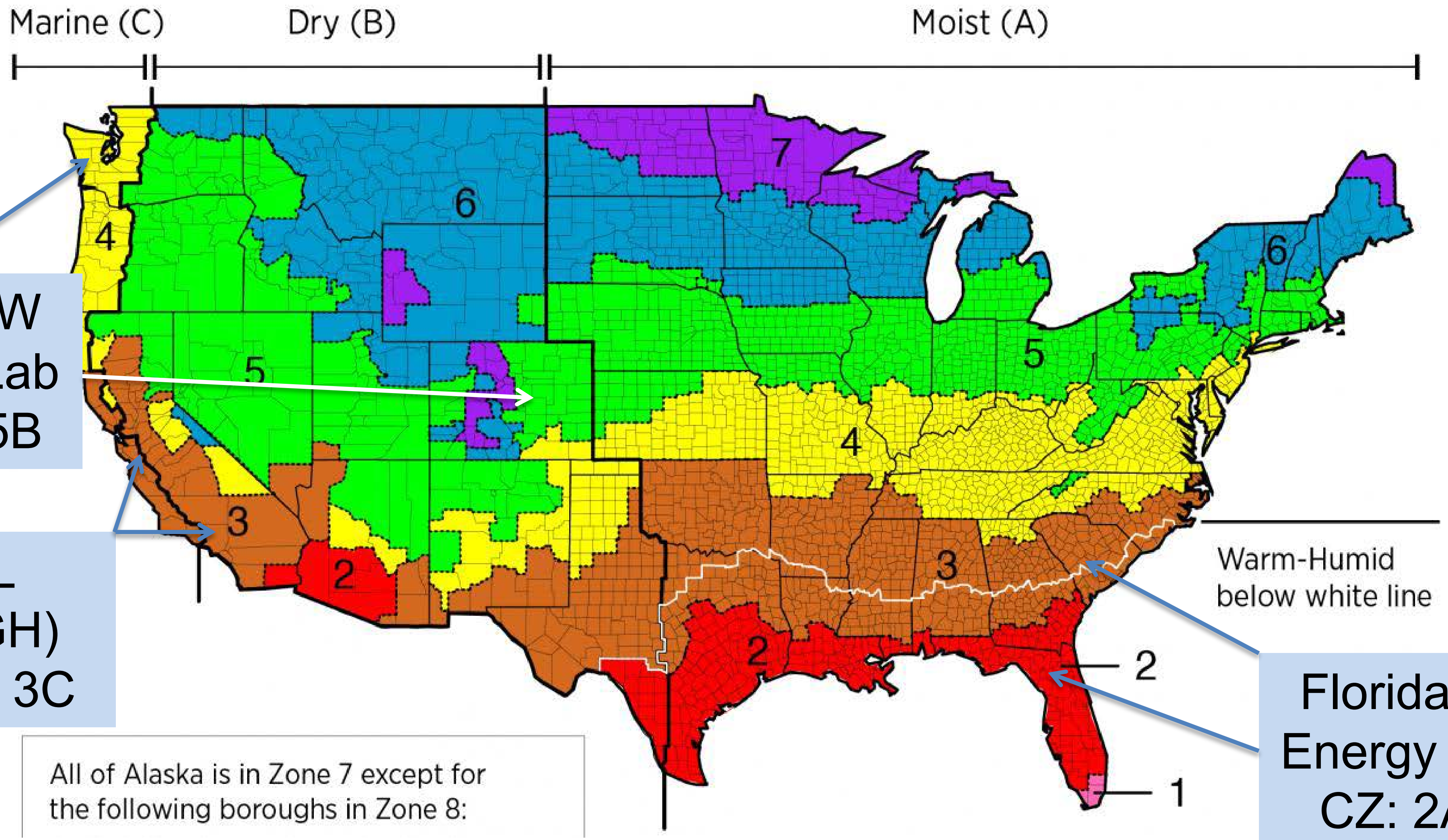
VIAQNUSH Analysis

- Investigate associations of humidity and contaminants with controls
  - ASHRAE 62.2 compliant mechanical ventilation,
  - envelope air tightness
  - mechanical system commissioning
  - other factors (low-emitting materials, ventilation system use, etc.
- Variations of equipment, usage, and IAQ by climate zone & home type

Scope of Study

- 4 Climate Zones
- Target ~32-36 homes per CZ: 50% with 62.2-compliant MV
  - Characterize home, mechanical equipment
  - Survey of occupants
  - Monitor ventilation, IAQ, activities for ~1 week
  - Repeat monitoring in ~8-9 homes with/out MV operating

Study Teams



Pacific NW National Lab
CZ: 4C, 5B

LBNL (HENGH)
CZ: 3B, 3C

Florida Solar Energy Center
CZ: 2A, 3A

Scope of Study - Measurements

- Characterization
  - Envelope & duct airtightness
  - MV equipment – rated and measured flows
- Measurements
  - Use of ventilation equipment and natural ventilation
  - Time-resolved pollutant concentrations & environmental parameters
    - $PM_{2.5}$ indicator in central indoor and outdoor
    - CO_2, T, RH in central and bedrooms
    - Low-cost monitors (specifics TBD)
  - Time-integrated
    - NO_2, NO_X and aldehydes in central indoor and outdoor
    - $PM_{2.5}$ mass (filter) in central indoor and outdoor

Technical Advisors, Stakeholders and Schedule

- Technical Advisory Committee
  - ~20 invited in late July, expect 10-15
  - Experts in ventilation, IAQ, residential field studies
- Stakeholders
  - Planning to present study plan and updates on progress to wide range of industry stakeholders (details TBD)
- Schedule
  - Currently negotiating agreements, final budgets, etc.
  - Fall: TAC review; Refine methods as needed; IRB review
  - Jan: start recruiting
  - Feb: Target start of field monitoring

Roles

- Study design
  - LBNL designed core field study procedures
  - Teams proposed enhancements
  - TAC will review; LBNL & teams will coordinate revisions
  - Human subjects review by central DOE IRB
- Implementation
  - Teams / subcontractors will recruit homes, collect field data & samples
  - LBNL will create central database
  - Teams upload data and sample results to central database
  - Teams analyze data collected in their regions for primary results
  - LBNL analyzes all data for comprehensive findings

References

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