Energy Efficient Options for Residential Space Conditioning in Hot, Humid Climates

ASHRAE Annual Meeting, Seminar 37

June 24, 2008

Hugh I Henderson, Jr., P.E.

CDH Energy Corp.

Cazenovia, NY

www.cdhenergy.com

Project

- "Closing the Gap: Getting Full Performance from Residential Central Air Conditioners"
  - Task 4 - Develop New Climate-Sensitive Air Conditioner (Henderson, Shirey, Raustad)
- Sponsored by NASEO, FSEC, NYSERDA, and others

AC Optimized for Humid Climates

- Historically, Conventional AC Systems have appeared to be Sufficient for Homes:
  - slightly lower air supply flows
  - never operate in constant fan mode
  - humidity typically maintained below 60% RH
- But Several Factors are Driving the Need for Humid Climate Features
  - More efficient building envelopes
  - Continuous ventilation as per ASHRAE 62.2

Humid Climate Issues

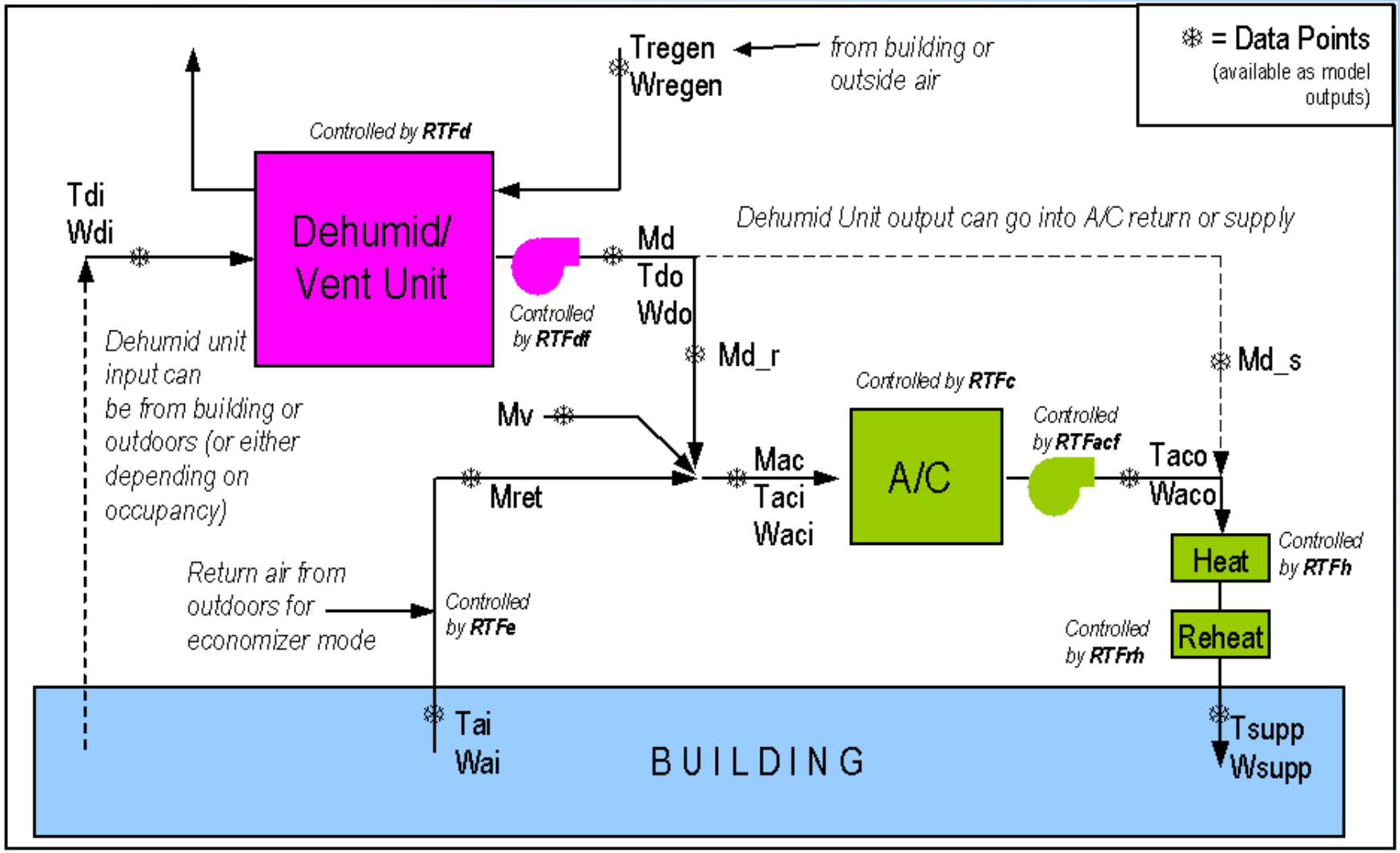
- Is adequate humidity control provided?
  - Precise control?.. 50% RH…below 60% RH
- What in the impact of Continuous Ventilation?
  - “normal” infiltration
  - Continuous ventilation per ASHRAE 62.2
- When does high humidity occur?
  - Night or day?...Summer or swing seasons?
- Is explicit dehumidification required?
  - Or can AC enhancements help

Analysis Approach

- Use TRNSYS-based simulations to evaluate impacts
  - TRNSYS 16 using TRNBuild/Type 56
  - Driven by TMY2 weather data
  - moisture capacitance model (**N** x air mass)
  - Infiltration & ventilation
- Incorporate detailed HVAC components
  - AC coil, Dehumidifiers, ERVs, reheat
- Incorporate HVAC/building control interactions and part load affects
  - Latent degradation

Simulation Framework

based on model from Henderson and Sand (2003)



Model Enhancements

Implemented for this Project

- Sherman-Grimsrud infiltration model
- Duct air leakage & conduction model
- Newest latent degradation models from Shirey & Henderson (2006)
  - Constant and AUTO fan modes
  - Impact of different fan control strategies
- HVAC humidity and vent control strategies
  - Fan delays, lower fan speeds, overcooling

Simulated House

2,000 sq ft, 4 bedrooms, slab on grade

- HERS Reference House (from 2006 RESNET)
  - Good building envelope
  - Duct leakage (80% DE)
  - Normal infiltration (SLA = 0.00048)

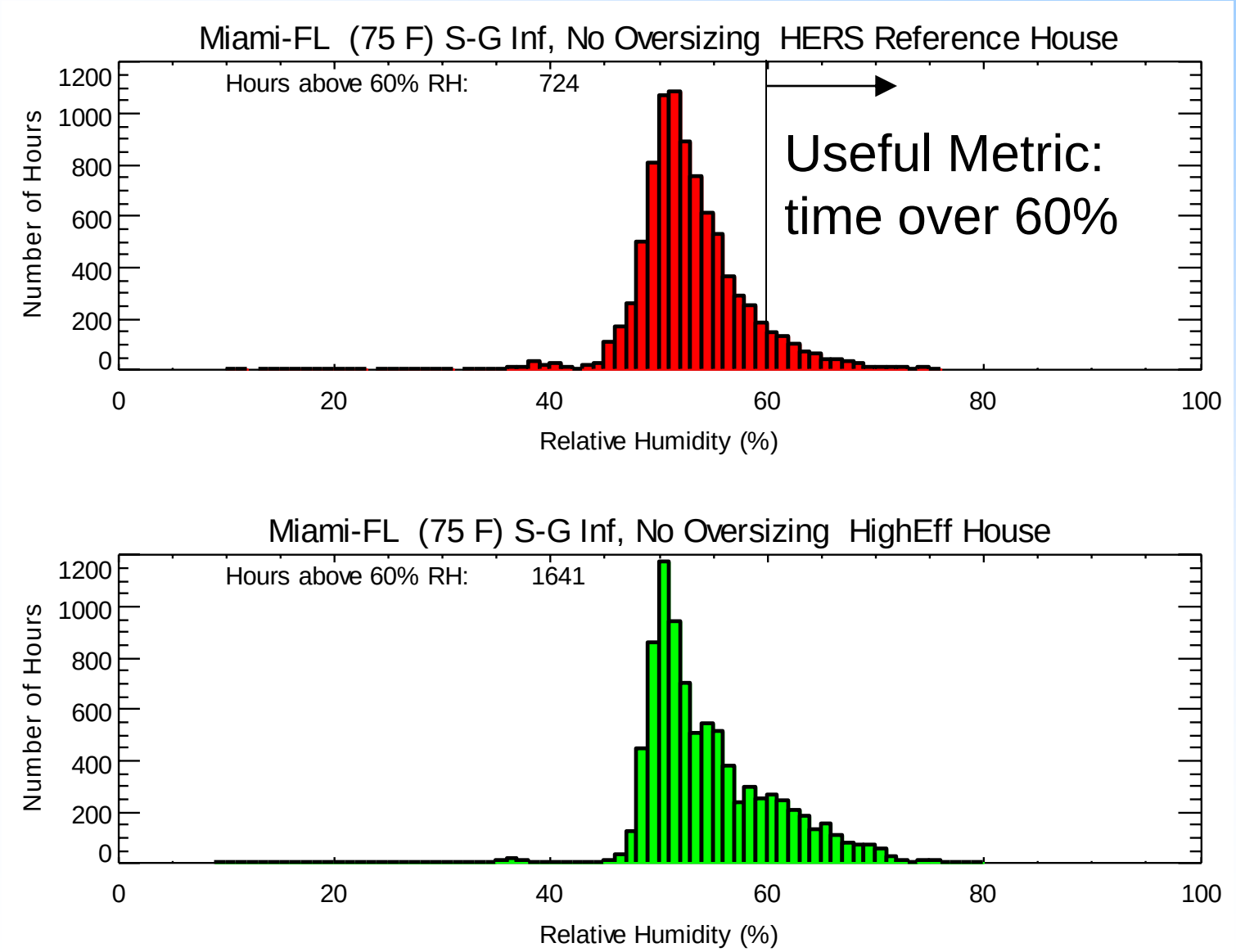
- "High Efficiency" House (30-40% better)
  - "tax credit" home
  - more insulation, better windows
  - No duct leakage
  - 36% less infiltration (SLA = 0.000307)

Simulated Cases

- Different Climates
  - Miami, Jacksonville, Houston, Atlanta, Fort Worth, Wilmington-NC, Sterling-VA
- Different Cooling Set Points
  - 75F and 78F
- Infiltration vs. Constant Ventilation
  - Infiltration by Sherman-Grimsrud
  - Constant Ventilation = 97.5 cfm, 0.3656 ACH
    - Explicit: 57.5 cfm (2,000 sq ft, 4 bedrooms)
    - Implicit: 40 cfm (0.02 x floor area)

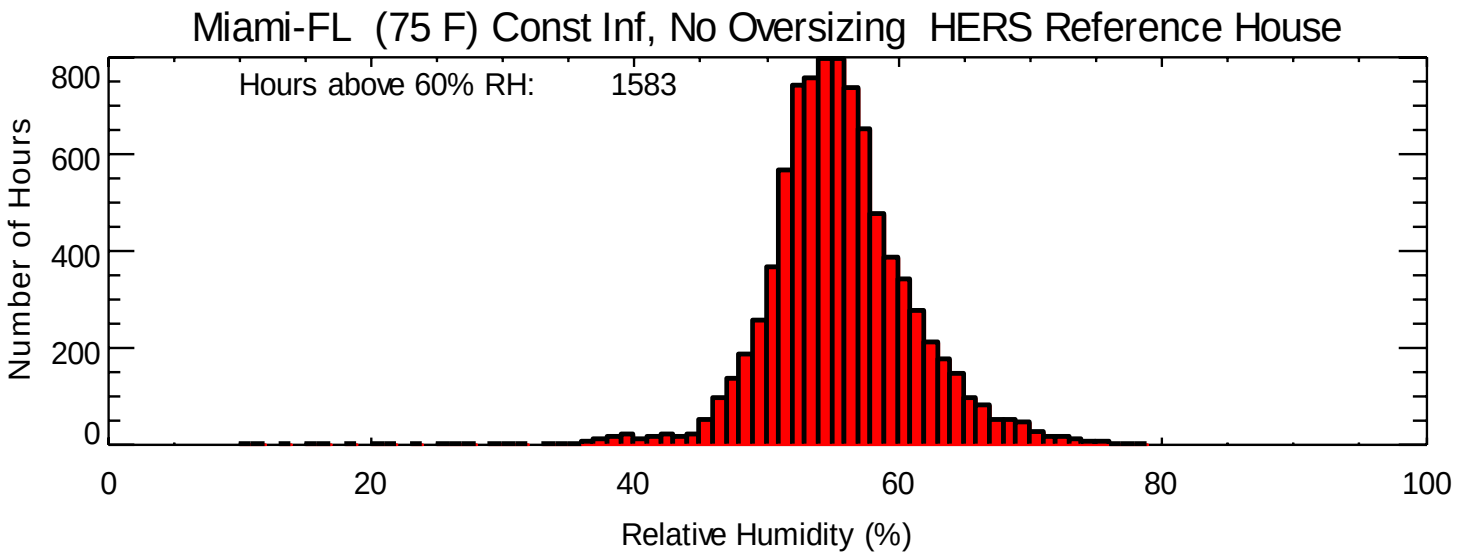
Relative Humidity Histogram

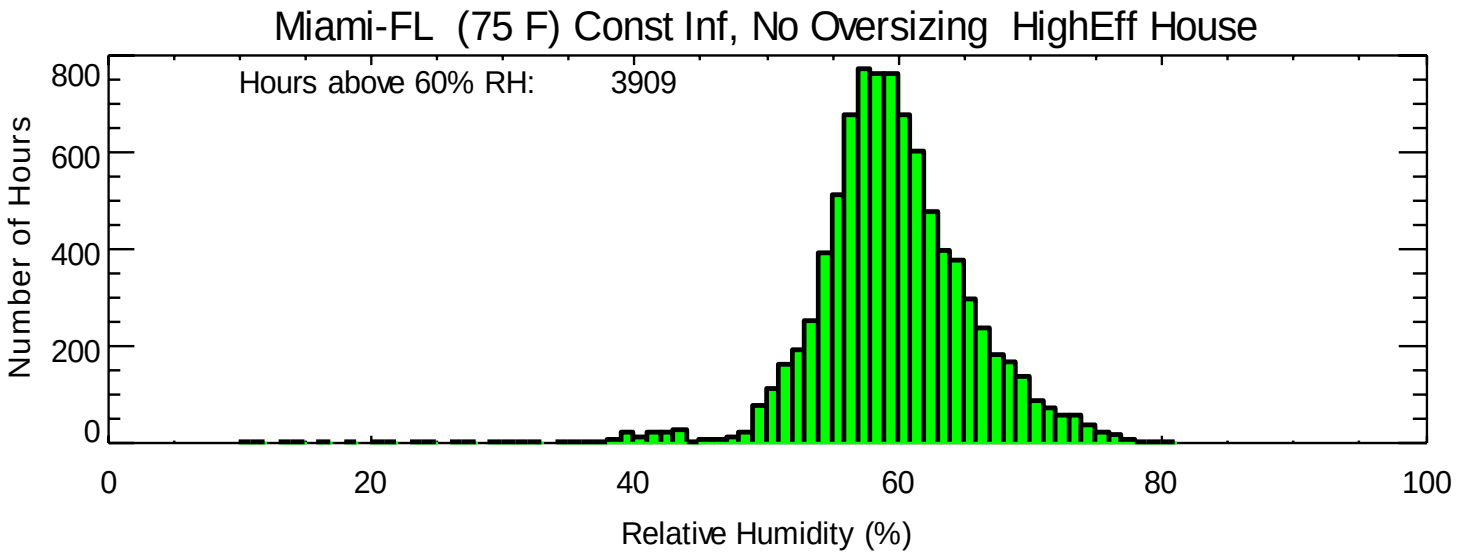
75F, Miami, S-G Infiltration



Relative Humidity Histogram

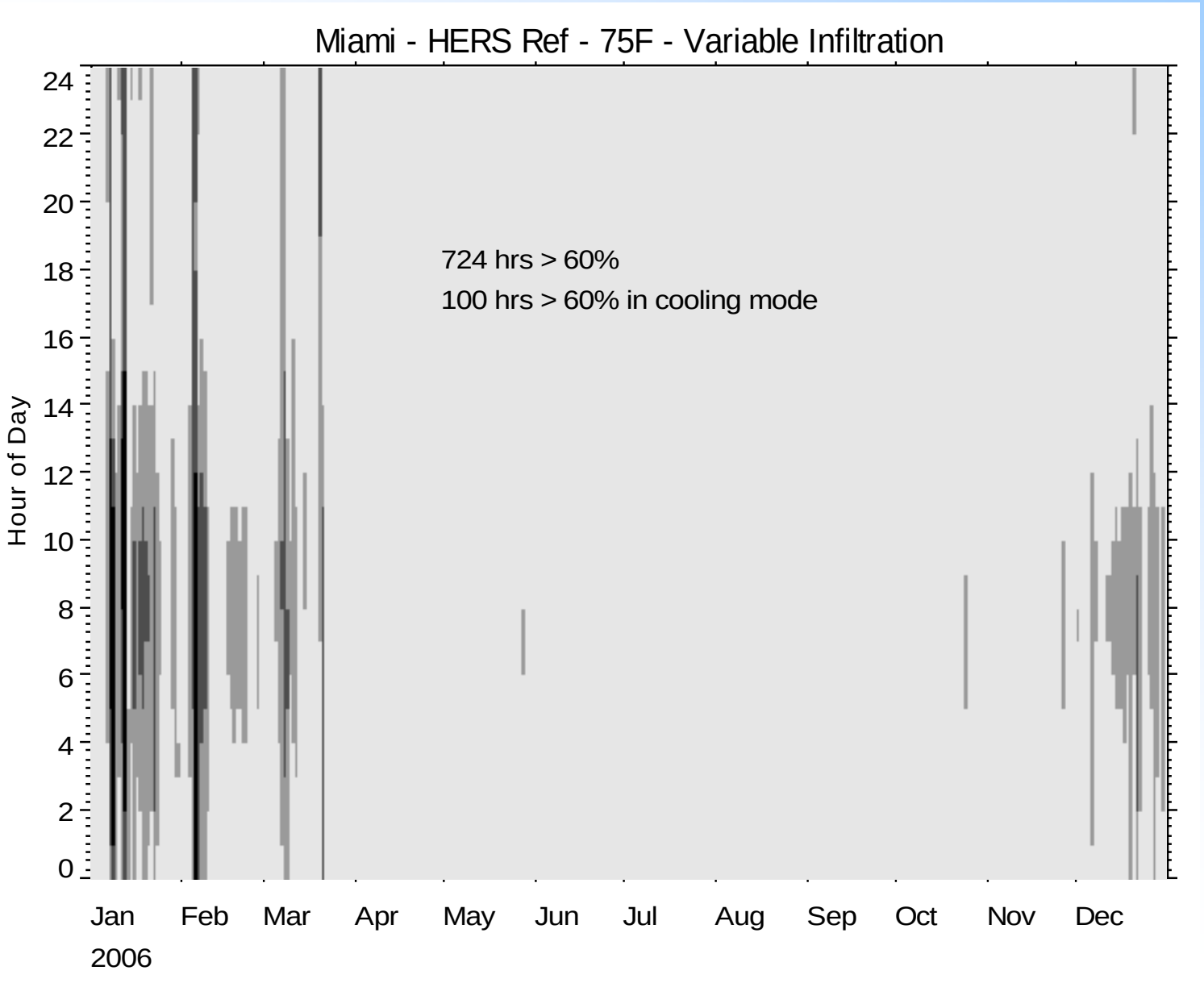
75F, Miami, Constant vent





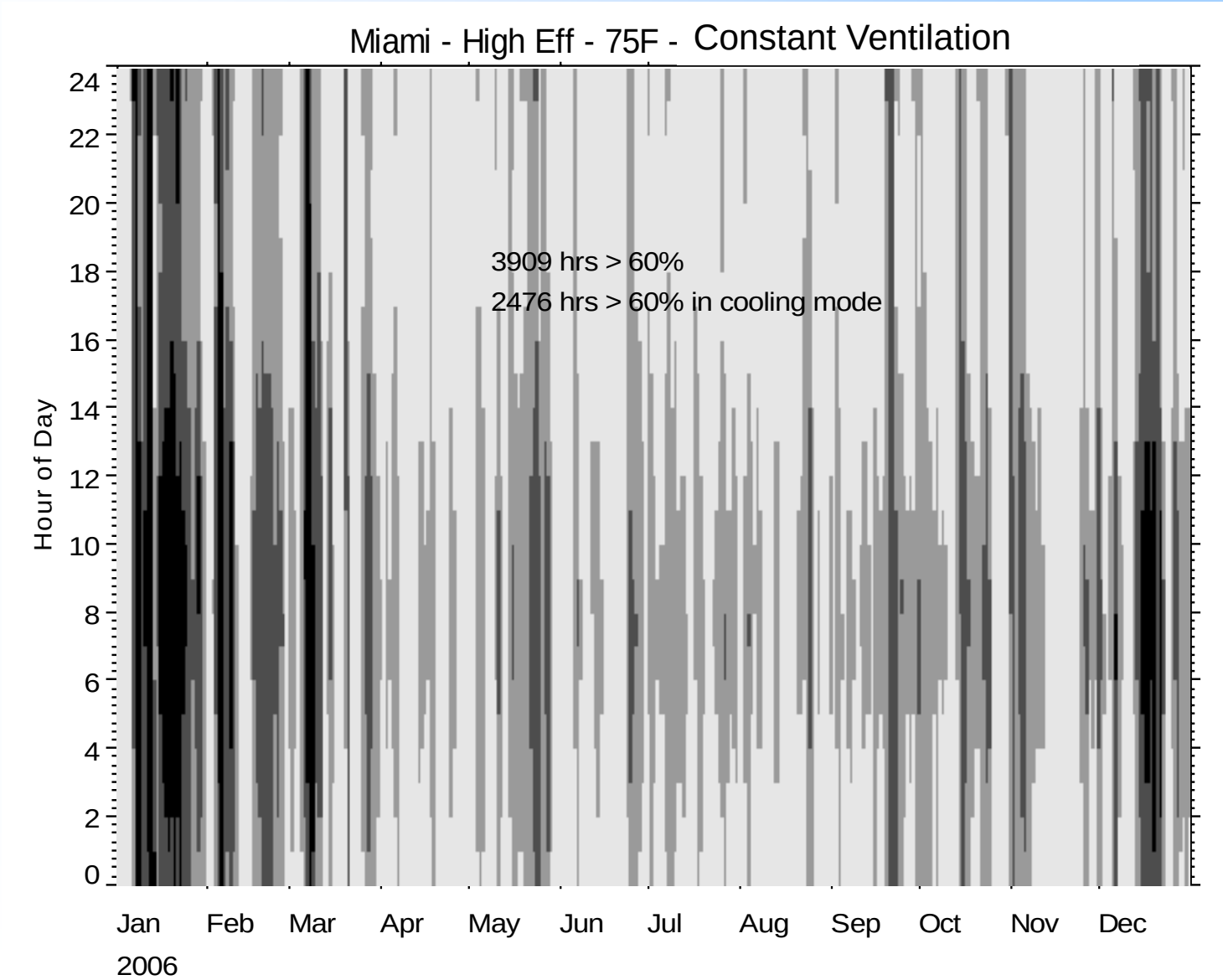
When Does High Humidity Occur?

Hours above: 60, 65, 70% RH



With Continuous Vent & Eff House

Hours above: 60, 65, 70% RH



Humidity Impacts in Different Cities

Using HERS Reference and High Efficiency House for each City

S-G Infiltration

		Hours above 60 % RH	
		HERS Ref	High Eff
75 F	Miami-FL	724	1,641
	Jacksonville-FL	622	976
	Atlanta-GA	193	73
	Sterling-VA	46	-
	Houston-TX	1017	1,400
	Fort_Worth-TX	131	29
	Wilmington-NC	588	253
78 F	Miami-FL	1667	2,699
	Jacksonville-FL	1153	1,768
	Atlanta-GA	385	118
	Sterling-VA	119	5
	Houston-TX	1535	2,040
	Fort_Worth-TX	305	51
	Wilmington-NC	974	468

Constant Ventilation

		Hours above 60 % RH	
		HERS Ref	High Eff
75 F	Miami-FL	1,583	3,909
	Jacksonville-FL	1,391	2,833
	Atlanta-GA	384	355
	Sterling-VA	268	342
	Houston-TX	1,557	2,623
	Fort_Worth-TX	216	191
	Wilmington-NC	1,384	1,750
78 F	Miami-FL	2,473	4,592
	Jacksonville-FL	1,954	3,297
	Atlanta-GA	563	449
	Sterling-VA	318	299
	Houston-TX	1,991	2,955
	Fort_Worth-TX	385	263
	Wilmington-NC	1,772	1,841

Can AC Control Enhancements Help?

HERS Reference, 75F, Miami, Constant vent

Miami	Hours above 60% RH (hrs)	AC Runtime (hrs)	AC Electric Use (kWh)	Supply Fan Electric Use (kWh)	Total HVAC Electric Use[1] (kWh)	Relative Energy Use (%)
Base Case	1,583	2,166	5,201	859	6,411	100%
Over Cooling by 3F	1,070	2,314	5,533	918	6,801	106%
80% Supply Airflow	1,251	2,223	5,281	821	6,451	101%

Notes:
Overcooling proportional to how much RH exceeds 55% set point
Lower supply air flow activated when humidity exceeds 55% set point

Other Dehumidification Options

- Dehumidifier (DH)
  - Conventional, stand-alone (2.6 pint/kWh)
  - Ducted high-efficiency (5.4 pints/kWh)

- Enthalpy wheel/ERV
  - heat recovery & dehumidification (74%, 0.5 W/cfm)
- AC with Condenser Reheat
  - 50% of condenser capacity after evap coil; activated when space drops 0.5F
- Other Dehumidification Options
  - Evap coil with low temperature Desiccant (hybrid)
  - AC with Heat Pipes
  - Mini MAU (like commercial units)

Results for Dehumidification Options

HERS Reference, 75F, Miami, Constant vent

Miami	Hours above 60% RH (hrs)	AC Runtime (hrs)	Dehumid Runtime (hrs)	AC Electric Use (kWh)	Supply Fan Electric Use (kWh)	Mech. Exh. Fan Use (kWh)	DH Unit Electric Use (kWh)	DH FAN Electric Use (kWh)	Total Electric Use (kWh)	Relative Energy Use (%)
Conventional AC	1,583	2,166	-	5,201	859	350	-	-	6,411	100%
Standalone Dehum (75 pint)	-	2,294	1,083	5,480	908	350	1,189	-	7,927	124%
High Efficiency DH	-	2,248	859	5,374	890	350	628	-	7,243	113%
Mini MAU (0.2 tons, 288 cfm/ton)	77	2,269	2,410	5,418	898	-	449	353	7,471	117%
Mini MAU (0.3 tons, 192 cfm/ton)	34	2,271	1,905	5,421	898	-	502	353	7,527	117%
Hybrid Desiccant/DX	-	2,046	897	4,898	813	350	777	69	6,976	109%
Conv AC (AUTO) w/ ERV (CONST)	1,201	1,563	7,135	3,830	621	-	205	252	5,161	80%
AC with HP HX	675	2,478	-	5,644	1,122	350	-	-	7,116	111%
Condenser Reheat System	-	2,635	-	6,212	1,042	350	-	-	7,603	119%

- Proper humidity control increases energy use by as much as
  - 24% for conventional DH, 13% for efficient DH
  - 19% for condenser reheat
- ERV efficient but does not control humidity

Results for High Efficiency House

High Eff House, 75F, Miami, Constant vent

Miami	Hours above 60% RH (hrs)	AC Runtime (hrs)	Dehumid Runtime (hrs)	AC Electric Use (kWh)	Supply Fan Electric Use (kWh)	Mech. Exh. Fan Use (kWh)	DH Unit Electric Use (kWh)	DH FAN Electric Use (kWh)	Total Electric Use (kWh)	Relative Energy Use (%)
Conventional AC	3,909	2,170	-	3,187	520	350	-	-	4,057	100%
Standalone Dehum (75 pint)	-	2,592	1,486	3,738	620	350	1,640	-	6,348	156%
High Efficiency DH	-	2,476	1,206	3,581	592	350	888	-	5,411	133%
Mini MAU (0.2 tons, 288 cfm/ton)	6	2,551	3,508	3,680	610	-	673	353	5,667	140%
Mini MAU (0.3 tons, 192 cfm/ton)	5	2,559	2,604	3,692	612	-	708	353	5,718	141%
Hybrid Desiccant/DX	-	1,859	1,425	2,713	446	350	1,240	110	4,968	122%
Conv AC (AUTO) w/ ERV (CONST)	1,726	1,445	6,984	2,152	347	-	201	252	3,203	79%
AC with HP HX	1,583	2,596	-	3,571	710	350	-	-	4,631	114%
Condenser Reheat System	-	3,344	-	4,664	799	350	-	-	5,813	143%

- Proper humidity control increases energy use by as much as
  - 56% for conventional DH, 33% for efficient DH
  - 43% for condenser reheat

Summary

- Humidity exceeds 60% RH for 500-1000 hrs per year for typical house in humid climate
- Can expect nearly twice the high RH hours for:
  - higher efficiency building envelopes
  - Continuous ventilation per ASHRAE 62.2
- Humidity is high at part load conditions:
  - early mornings and swing seasons
  - when no cooling is required
  - almost never at peak conditions
- It takes 10-50% more energy to properly control humidity
  - Conventional DH and Condenser Reheat about the same
  - Best technologies have about half energy penalty