FLORIDA SOLAR ENERGY CENTER

A Research Institute of the University of Central Florida

Improving Energy Efficiency & Indoor Air Quality in Homes

Subrato Chandra, Ph.D.

Building AMERICA
U.S. Department of Energy
Industrialized Housing Partnership

Acknowledgement

- U.S. Department of Energy, Mr. George James, program manager, Building America who has consistently supported our research
- Colleagues at FSEC and other Building America teams , esp. Philip Fairey, Danny Parker, Neil Moyer, Dr. Joseph Lstiburek and Jim Cummings who have shared their research and ideas with me.

Drivers

- Some physicians blame energy efficient housing for poor IAQ and respiratory health
- IAQ , comfort and durability are generally more important to consumers than energy efficiency (EE)
- Yet, it turns out that EE is a necessary (but not sufficient) condition for good IAQ and comfort
- And, of course, EE is good for our environment as well as our budgets

Presentation Outline

- **FSEC Overview**
- Moisture Problems in HUD code (Mobile) Homes
- Duct Systems Research
- Preventing Dust Mites
- Unvented Attics
- Cool Roofs
- Side-by-side whole house tests

FLORIDA SOLAR ENERGY CENTER

A Research Institute of the University of Central Florida

About 150 Researchers Staff and Students

Hi-Tech Labs

Applied Research

Program Areas

- Energy-Efficient Buildings
- Photovoltaics & Distributed Generation
- Solar Thermal Heating Systems
- Hydrogen and Alternative Fuels
- Education and Training

www.fsec.ucf.edu

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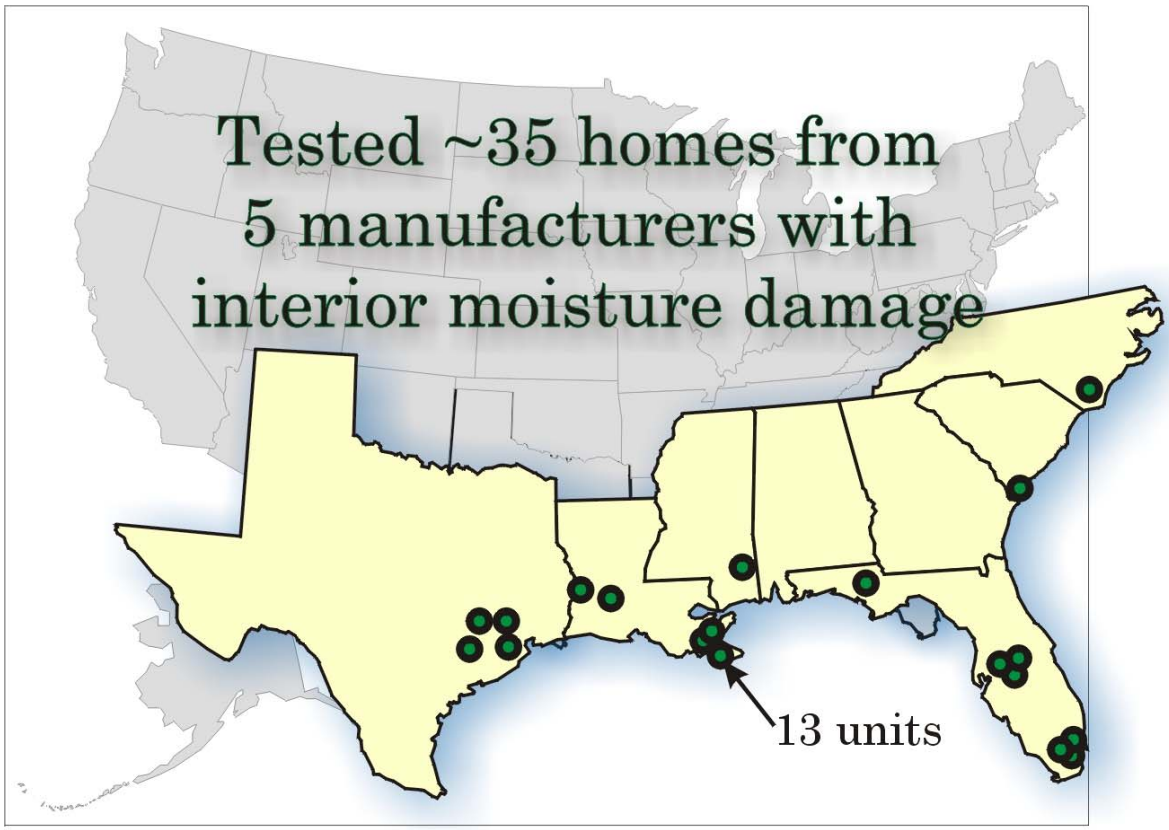
Moisture Problems



- ✓ **Highest priority research item of the HUD code industry**
- ✓ **Collaborating with MHRA**

Moisture Problems

Investigated in the Field

Mold behind vinyl wallpaper

Mold under sink

Moisture Problems

Investigated in the Field

Mold stain on vinyl flooring

Warped vinyl covered flooring

Moisture Problems

Investigated in the Field

Rusted panel box

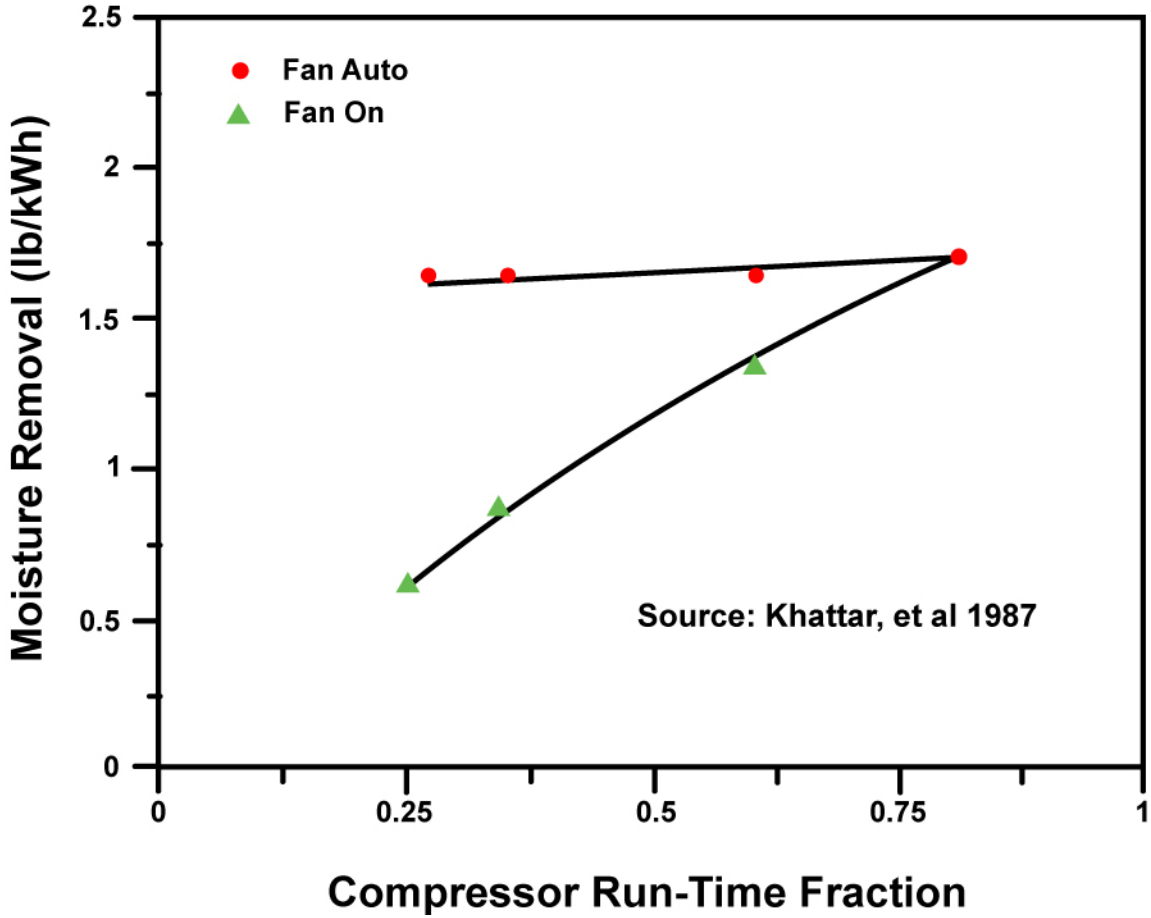
Moldy ceiling

Moisture Problems

- **Leads to energy waste as homeowners lower a/c setpoint to be comfortable (1° lowering of SP = ~10% increase in cooling energy use. Utility bills >$300/mo not uncommon in problem homes.**
- **Causes…**

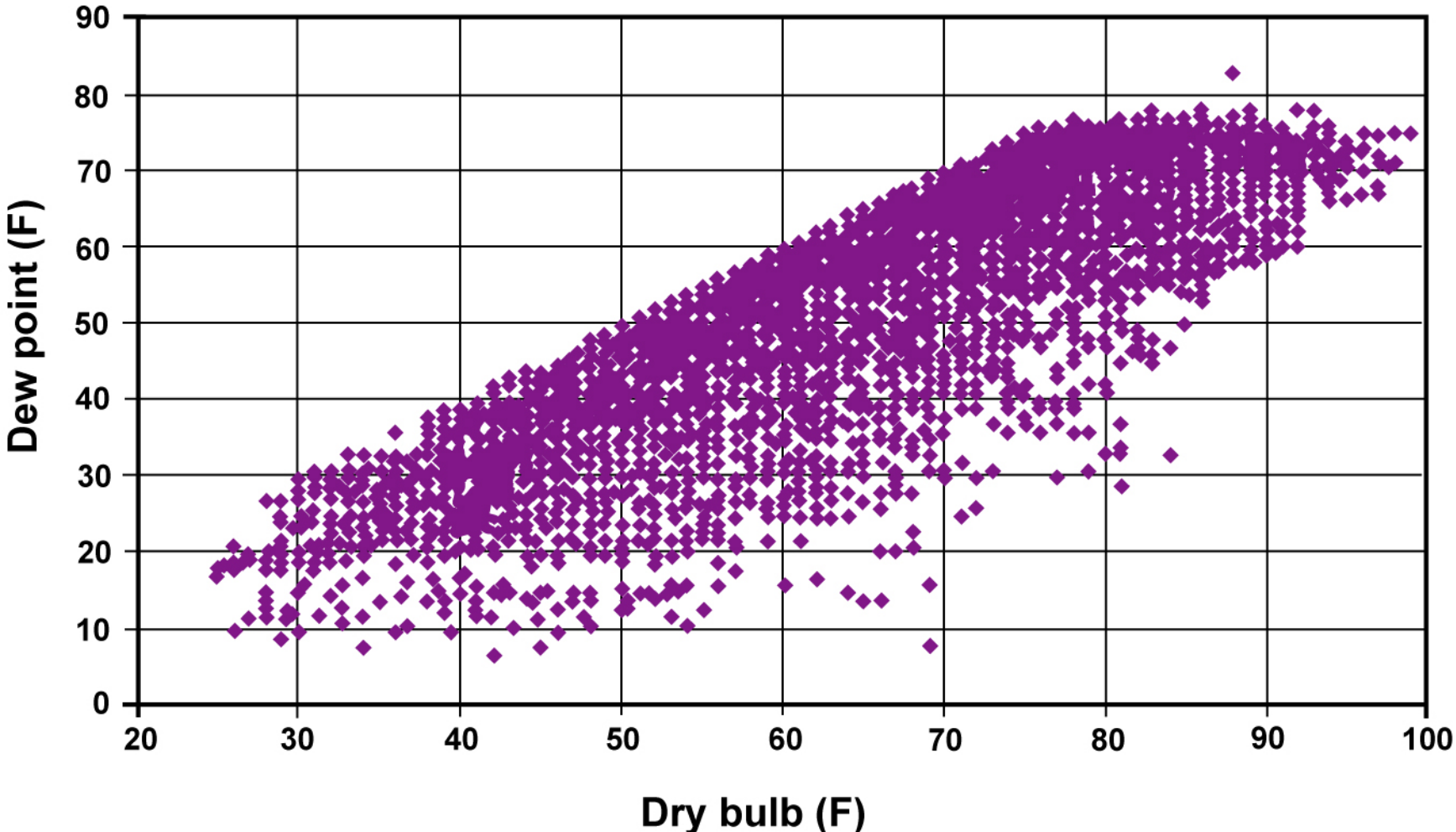
Increased RH w/ fan always on

Fan On vs Auto



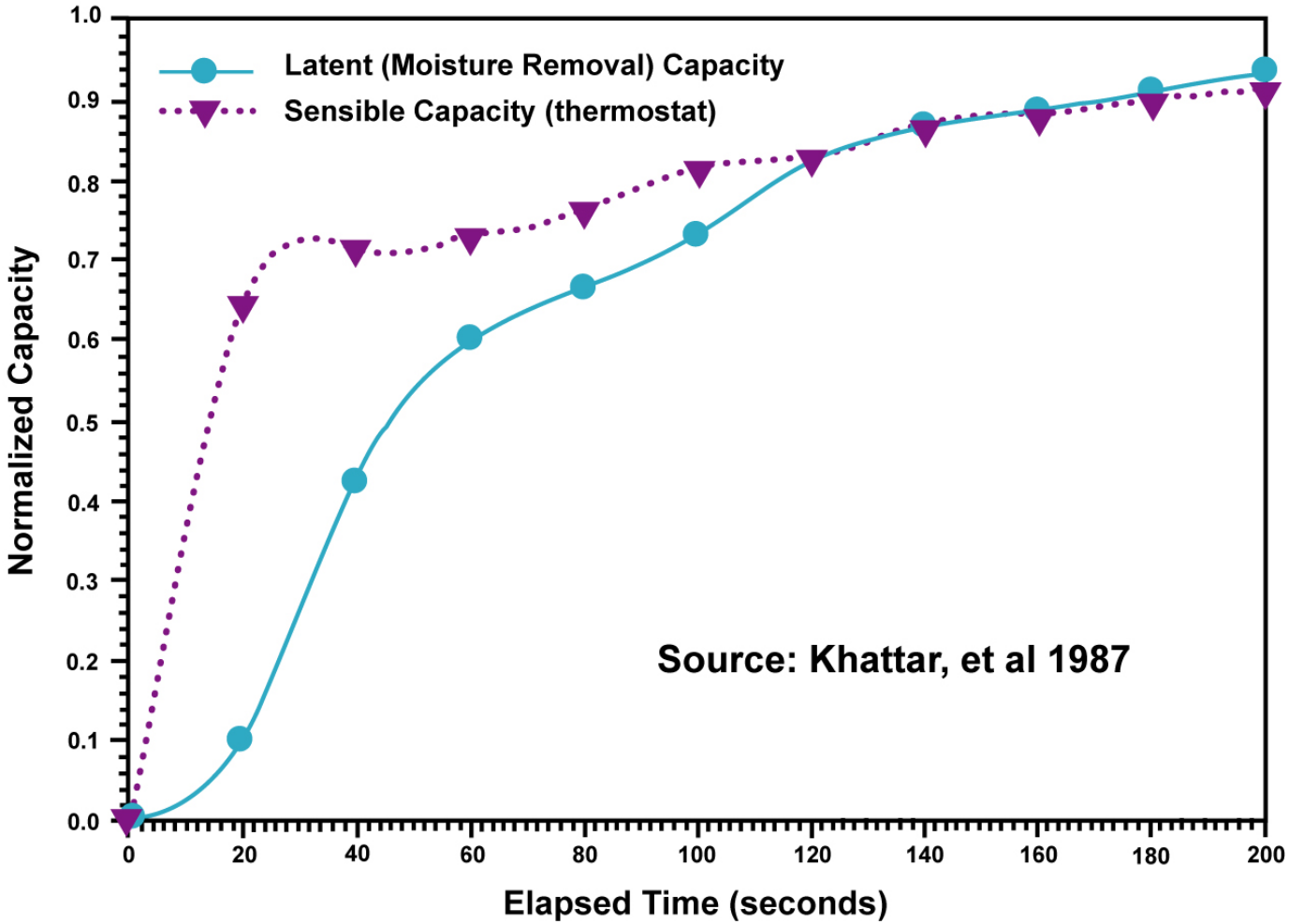
Thermostat set below dewpt.

Hourly Weather Data for Mobile, Alabama



Oversized A/C

Impact of Air Conditioner Cycle Length on Humidity Removal



Causes- Contd..

- Negative pressures coupled with vinyl wall papers
- Negative pressures arise from leaky supply ducts or interior door closures
- Poorly vented crawlspaces
- Lack of ground covers
- Other causes (leaks, poor flashing)
- Winter time problems

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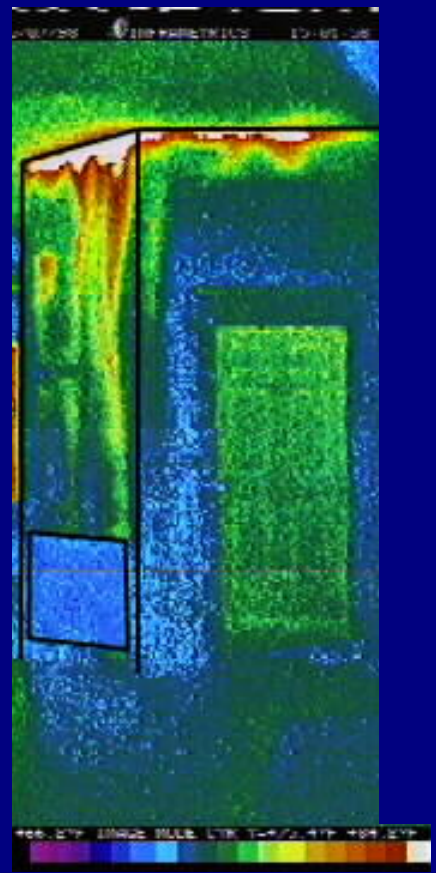
Duct Systems Research



Duct Construction

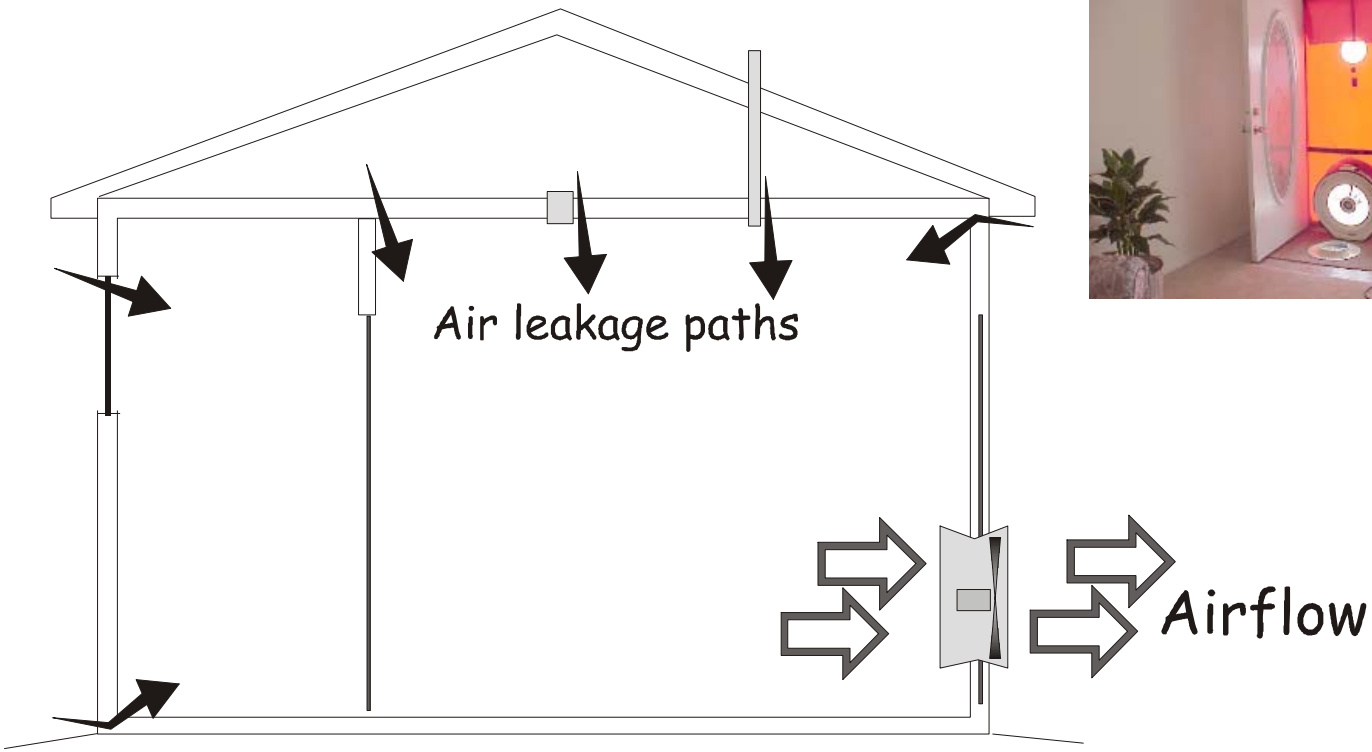
Before:
Tape failure at duct joint led to condensation, mold, and decay.

After:
Mastic and mesh duct sealing improves IAQ and energy efficiency.

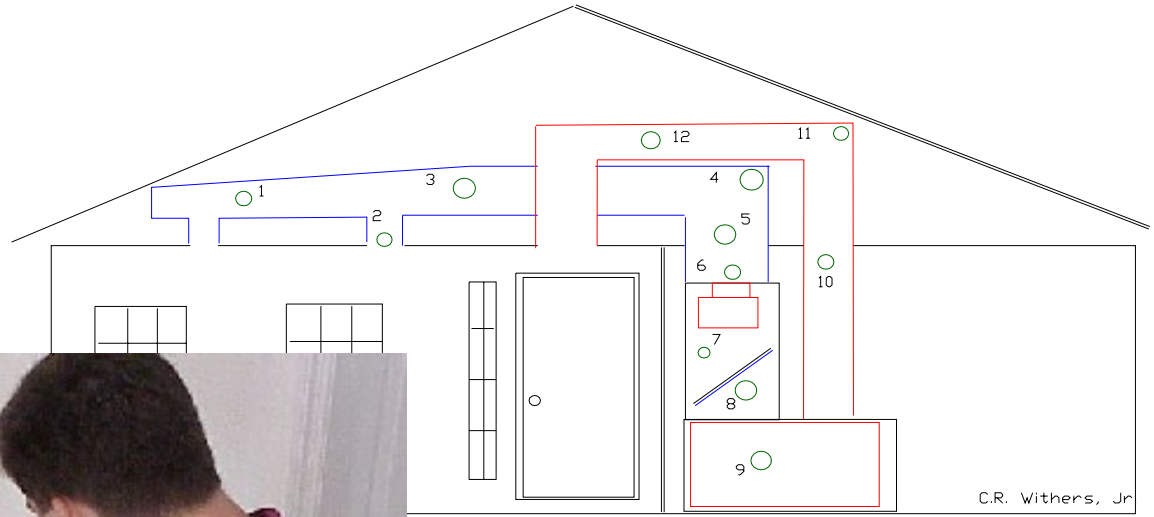
Gap around boot

- The gap above drywall needs to be sealed to meet air tightness criteria

Blower Door Testing



Duct Air Tightness Testing



Calibrated fan measures air leak rate at 25 Pascals while the air conditioner is off and vents are temporarily sealed.

Return Air Transfers

- Need about 50 square inches per 100 cfm of supply air (door undercut counts towards above)
- Pressure difference across closed bedroom door <3Pa
- Various ways to do it
- Locate clothes dryers in uncond spaces or room with a operable window

Return air Pathways

- Closet returns and pathway through walls are also possible

Pathway to air handler

Jump duct

Air tight ducts

- Enhance comfort and reduce energy bills
- Eliminate negative pressure and consequent dust, pollen and mold problems
- Reduce system size
- Code credit available if system is tested
- Most cost effective item

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Dust Mite – Blomia Tropicalis

Dust Mite Allergens

- Primary cause of asthma in humid climates
- Fecal particles ~5 to 10 μm
- Heavier than air, cannot be filtered
- Do not live in ducts

Dust Mite Allergen Control Methods

- Control Methods
  - Covers on mattresses and pillows
  - Hot water (130ºF) washing
  - Exhaustive vacuuming
  - Dehumidification
  - Avoid deep pile carpets and heavy drapes
- Acaracides, Air Filters and Denaturants of Limited Value

Research Study

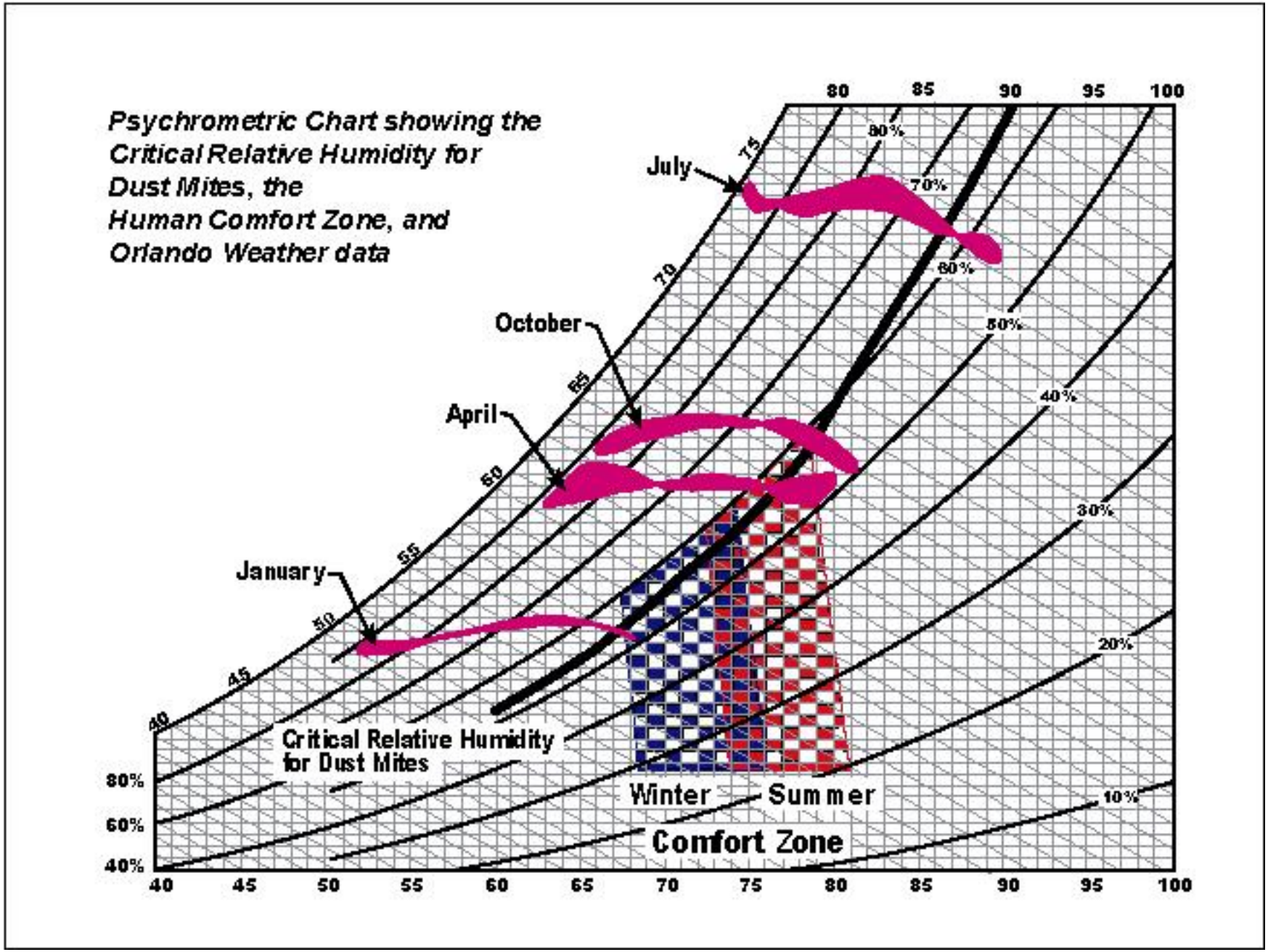
- We conducted an experimental study in collaboration with the USF medical school and with the assistance of ALA affiliates in FL, AL and LA

Goal

Prevent dust mite allergens in new homes with wall-to-wall carpets

NOT

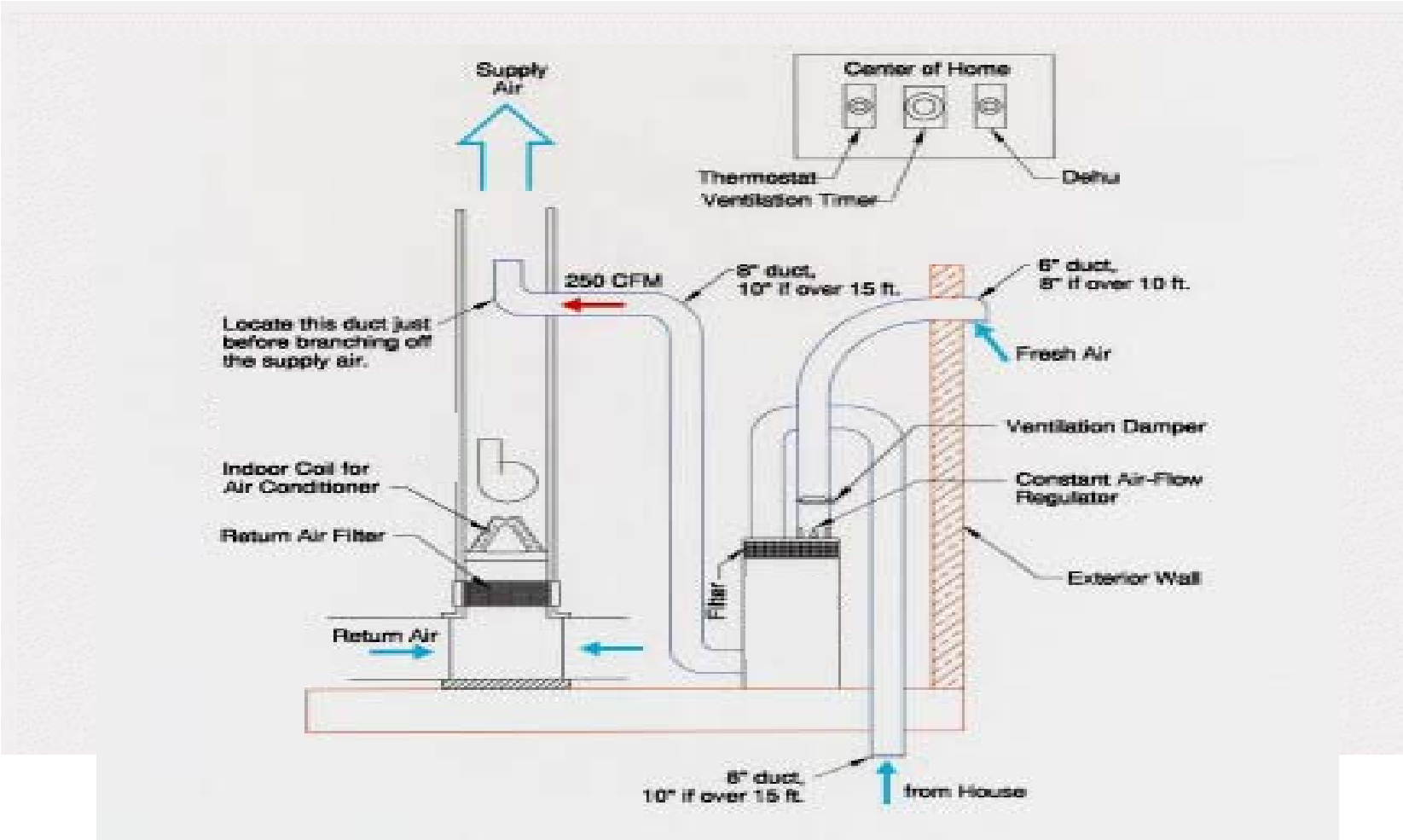
Eliminating allergens from infested homes (a harder problem)


Psychrometric Chart showing the Critical Relative Humidity for Dust Mites, the Human Comfort Zone, and Orlando Weather data
July
October
April
January
Critical Relative Humidity for Dust Mites
Winter
Summer
Comfort Zone
80
85
90
95
100
75
70
65
60
55
50
45
40
90%
70%
60%
50%
40%
30%
20%
10%
80%
60%
40%

Procedure

- Test houses (mostly ALA Health Houses) were built with central dehumidification and ventilation
- Thorough vacuum cleaning (central vac once/wk or good upright twice/wk) was done on some test and control homes
- Five pairs of test and control homes were studied during 1996-98

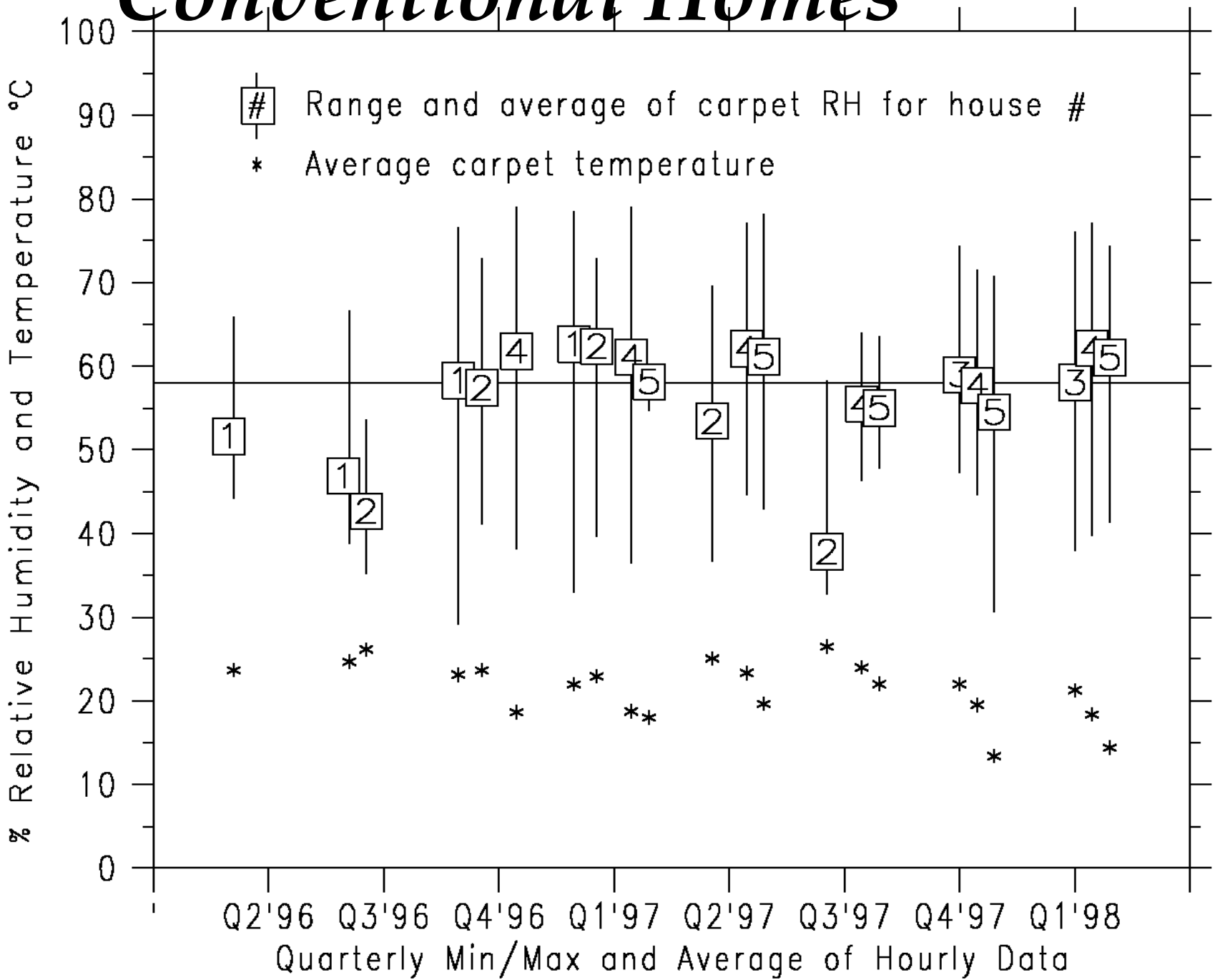
Central Dehumidification and ventilation system

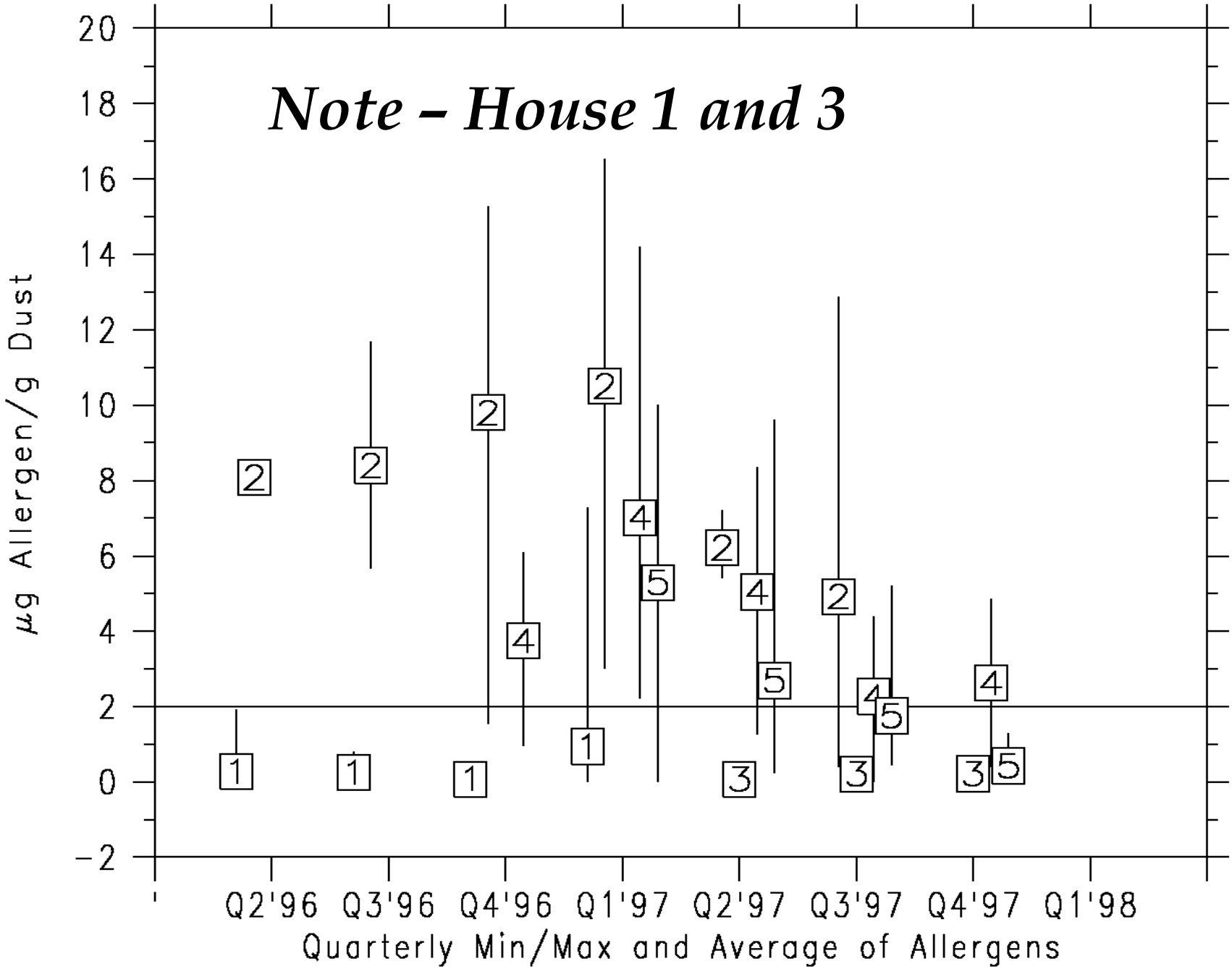


Results

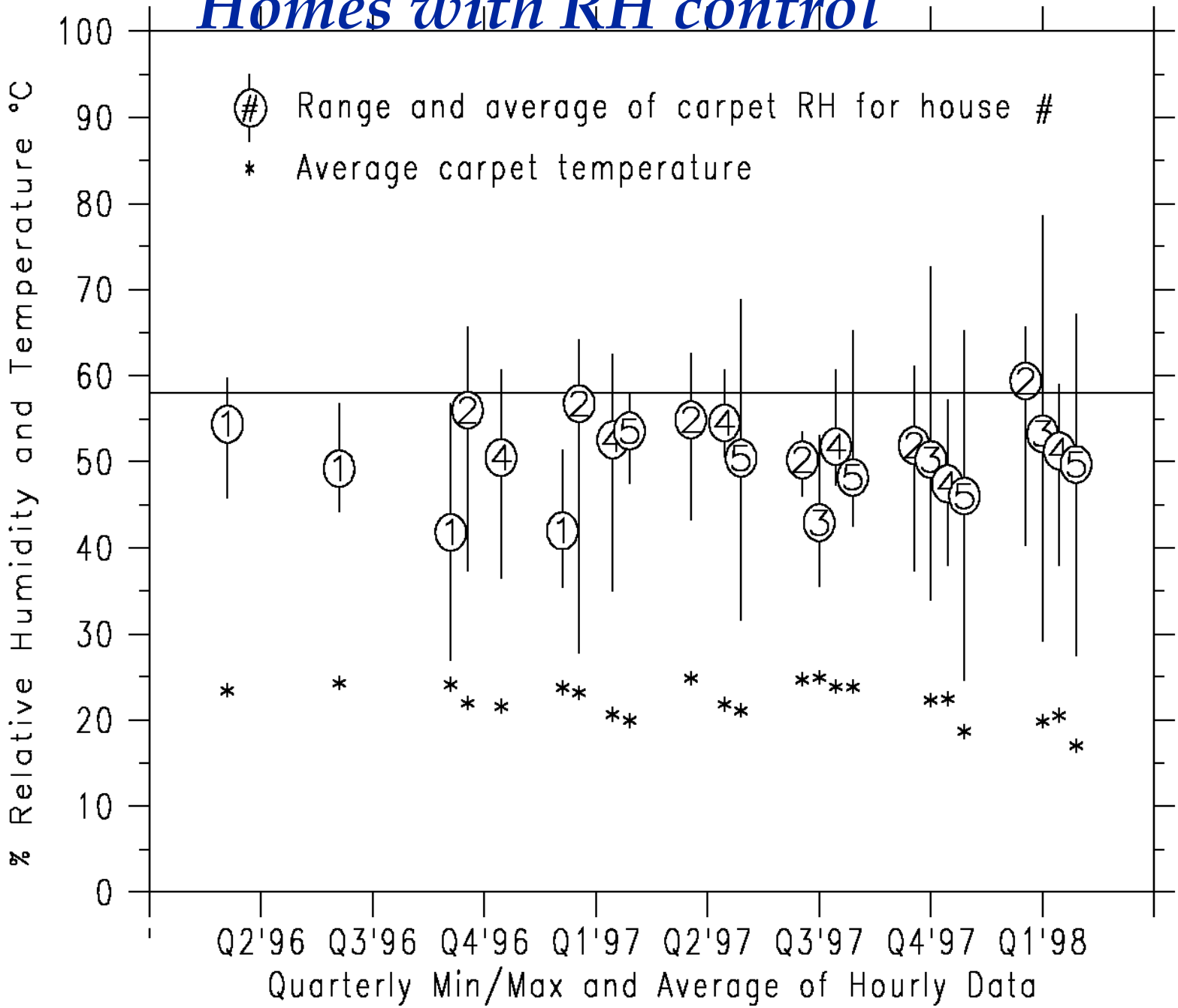
- Presented at ASHRAE IAQ ‘2001 as a peer reviewed paper.

Conventional Homes

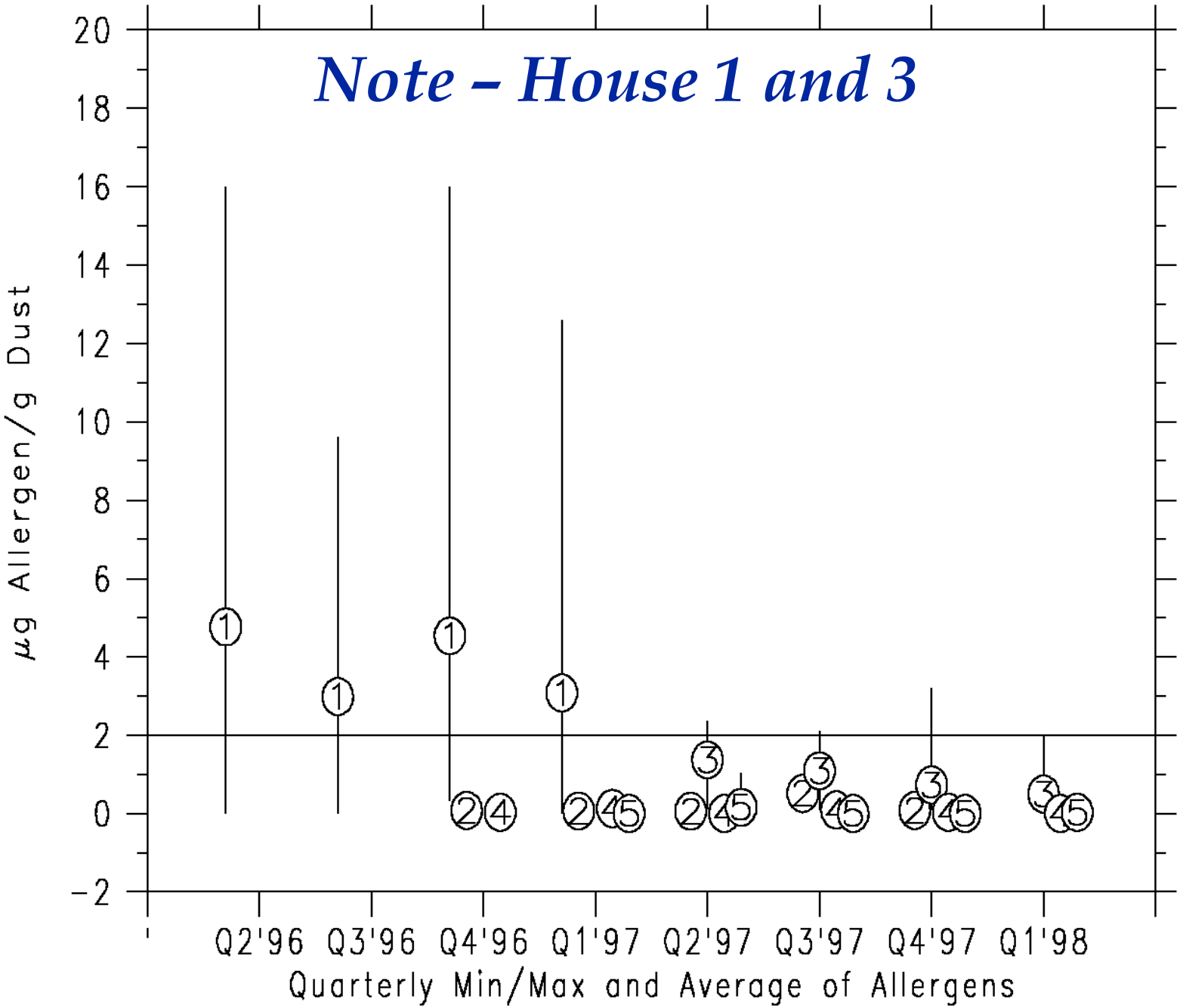



Note – House 1 and 3
µg Allergen/g Dust
20
18
16
14
12
10
8
6
4
2
0
−2
Q2'96
Q3'96
Q4'96
Q1'97
Q2'97
Q3'97
Q4'97
Q1'98
Quarterly Min/Max and Average of Allergens

Homes with RH control



Note – House 1 and 3



Conclusions

- Thorough vacuuming and central dehumidification can prevent allergens in new housing with wall to wall carpeting
- Thorough vacuuming alone may be quite effective and is worthy of further study

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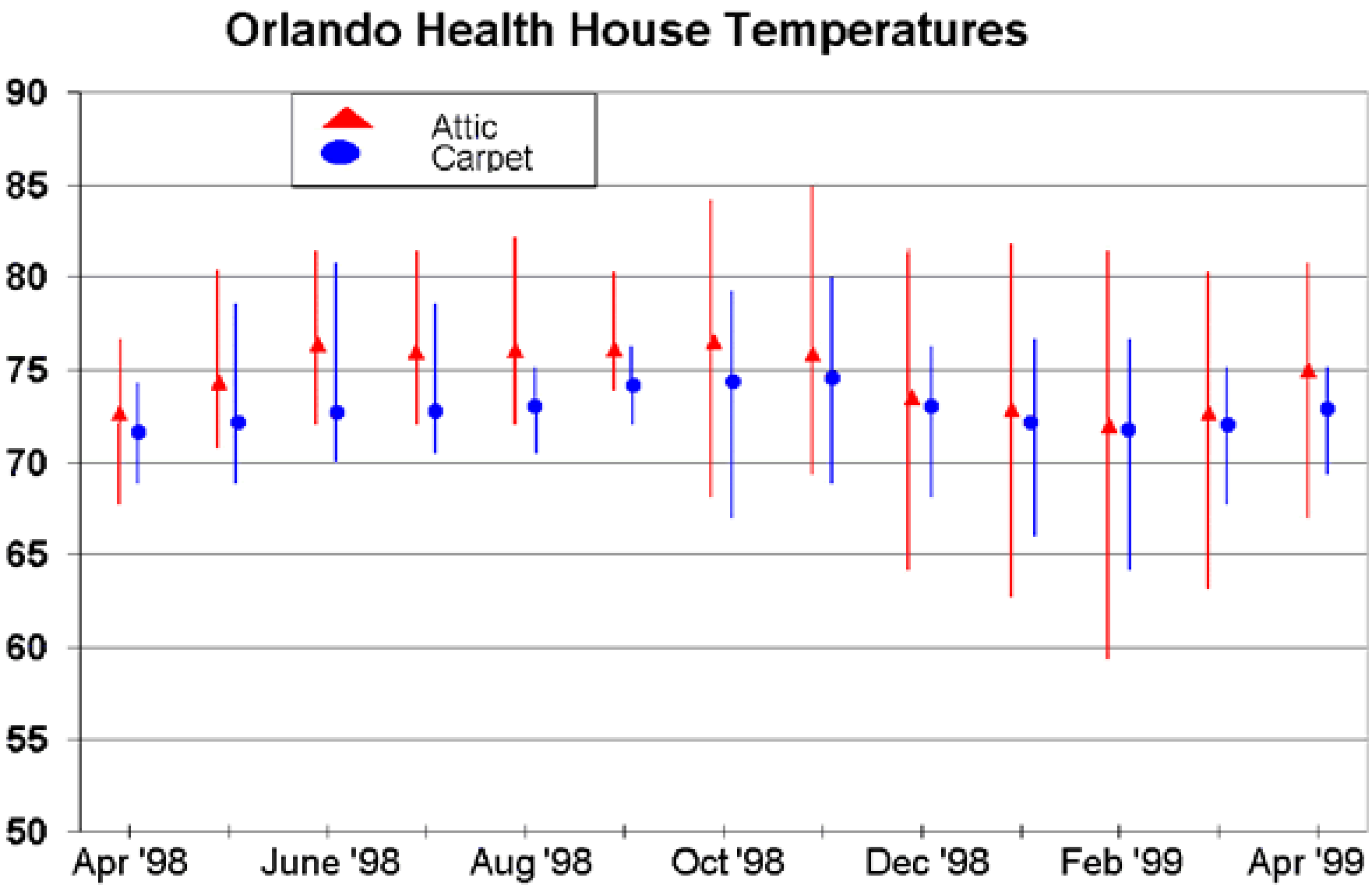
Unvented Attics

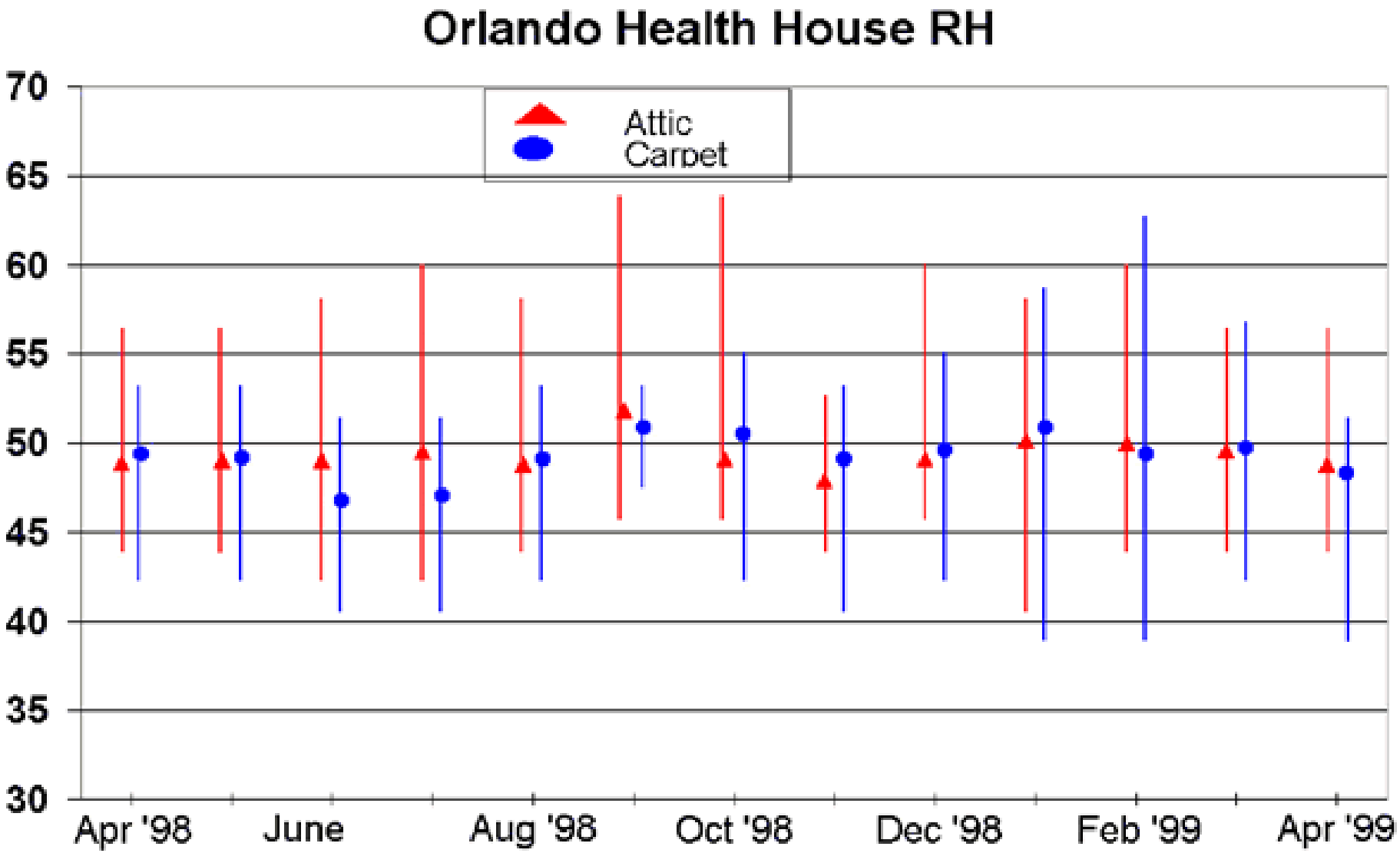
- Good strategy for increasing energy efficiency especially for tile and metal roofs, as ducts get located inside the thermal boundary
- Side by side tests show 5% to 10% savings over vented attics

Unvented Attic allows ductwork and storage area in semi conditioned space

- Use vapor retardant roofing paper on shingle roofs
- Do not seal ceiling holes
- Do not use ICAT can light

1997 Orlando Health House
4 Tons a/c for 3,600 SF (zoned)


Orlando Health House Temperatures
Attic
Carpet
90
85
80
75
70
65
60
55
50
Apr '98
June '98
Aug '98
Oct '98
Dec '98
Feb '99
Apr '99


Orlando Health House RH
Attic
Carpet
70
65
60
55
50
45
40
35
30
Apr '98
June
Aug '98
Oct '98
Dec '98
Feb '99
Apr '99

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Cool Roofs

- 7 Habitat Homes in SW Florida

• Standard dark shingles with standard ventilation (RGS)

• Light colored shingles with standard ventilation (RWS)

• Terra cotta direct nailed S-tile roof (RTB)

• White S-tile roof (RWB)

• White flat tile roof (RWF)

• White metal 5-vee roof (RWM)

• Standard dark shingles with R-19 sprayed insulation on roof decking and unvented attic (RSL)

7 Habitat Homes

A/C Energy Use

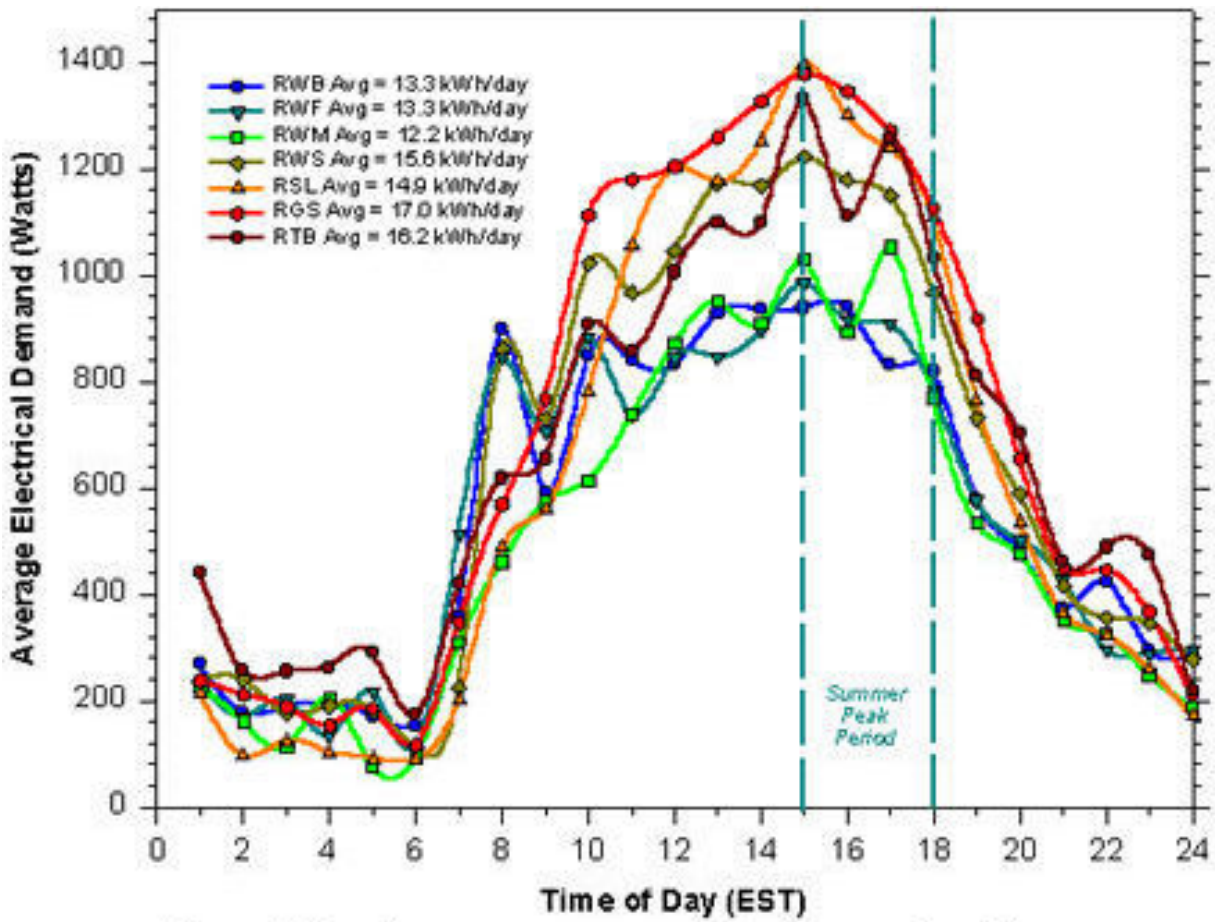


Figure E-4. Average space cooling demand profiles over the unoccupied period.

Cool Roof Results

Case Description	Cooling Savings		Peak Demand Reduction	
	kWh	Percent	kW	Percent
RGS (Control)	0	0%	0	0%
RWS (White Shingle)	300	4%	0.48	17%
RSL (Sealed Attic)	620	9%	0.13	5%
RTB (Terra Cotta Tile)	180	3%	0.36	13%
RWB (White S-Tile)	1,380	20%	0.92	32%
RWF (White Flat Tile)	1,200	17%	0.98	34%
RWM (White Metal)	1,610	23%	0.79	28%

* Percentages relative to typical values for average sized detached S. FL homes

Attic Radiant Barrier Study

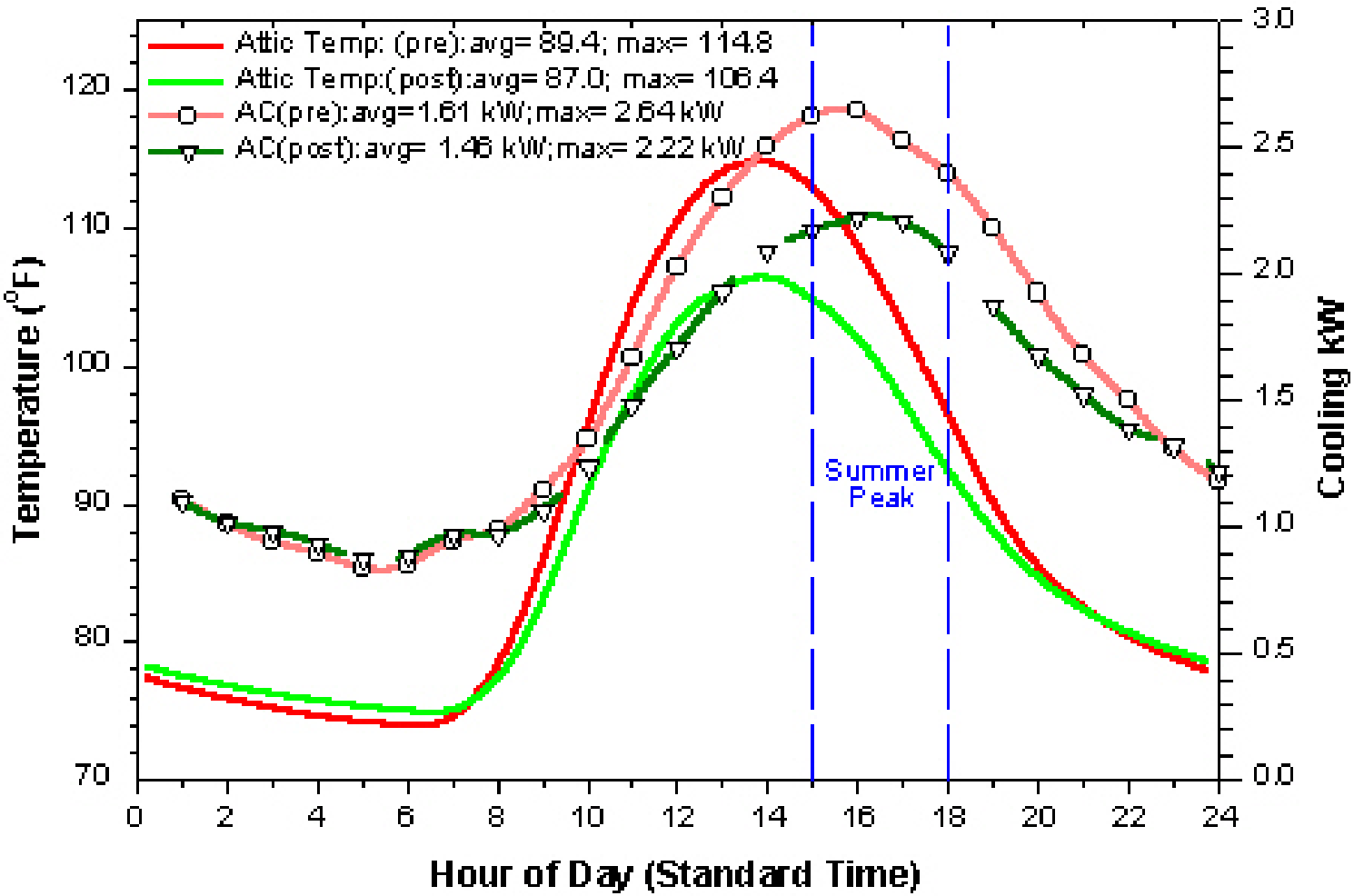
Before and after tests on 9 homes

Site #199 pre-retrofit

Site #199 post-retrofit

Results – 9% Savings

Occupied homes



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NC A&T State U.

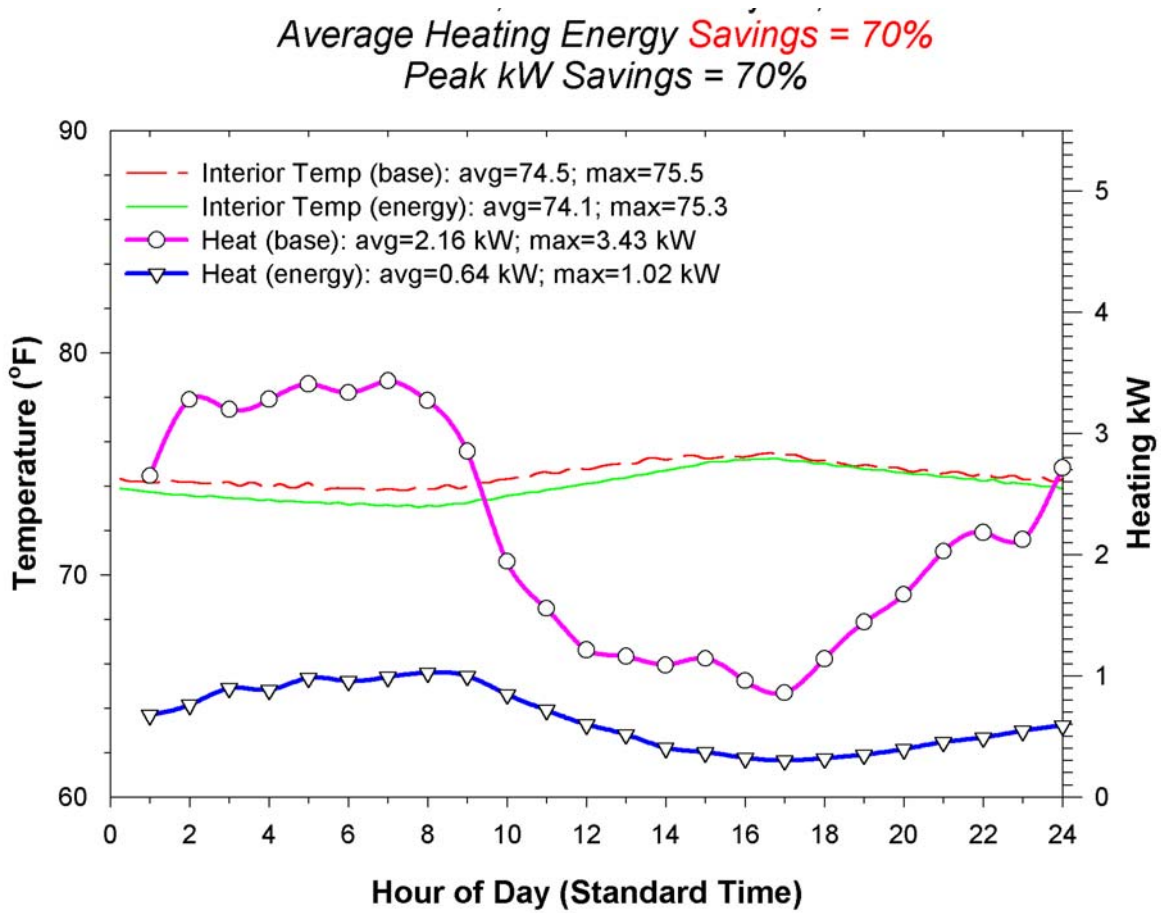
Greensboro, N.C.

- Side-by-side homes
- Simulated occupancy
- 1528 sq. ft.

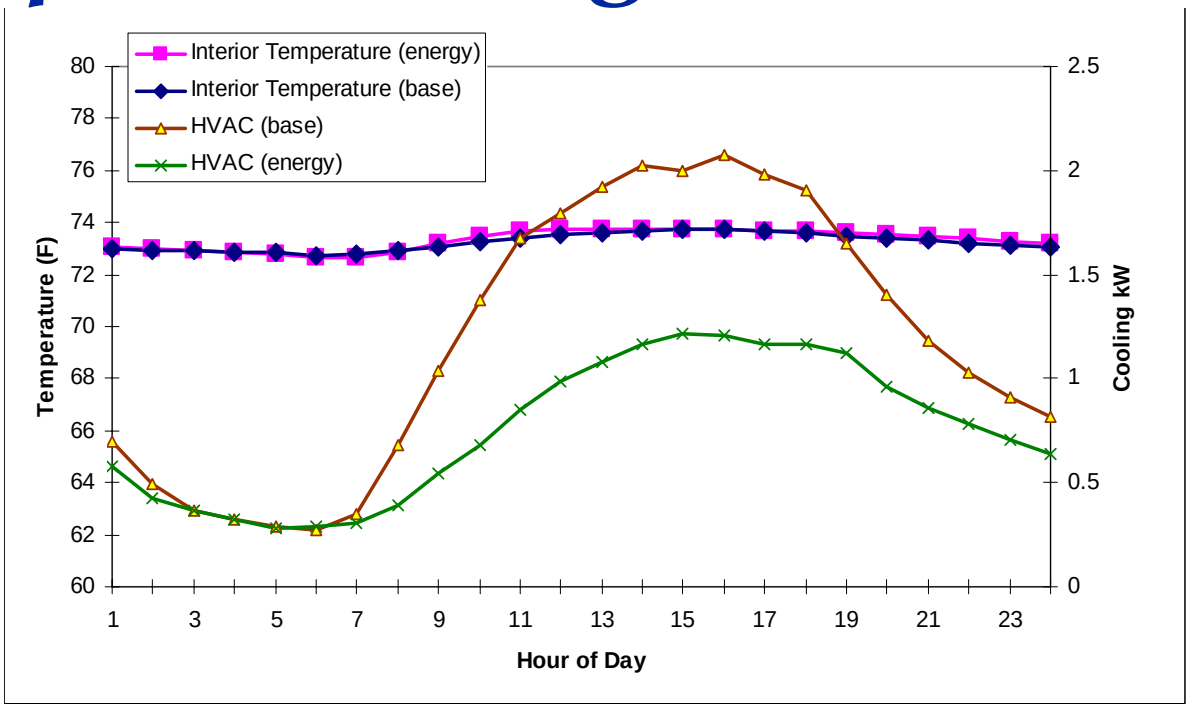
Features

Characteristic	Standard	Building America
Floor/wall/ceiling insulation	R-11/11/20	R-22/13/33 + RBS
Windows	single/storm	low-E
Ducts	taped	mastic
HVAC type	SEER 10+ strip	SEER 12 heat pump
A/C HVAC size (tons)	3.0	2.0
Water heater	electric	solar

Heating Season Results (Nov'01 – Feb '02)



Cooling Season Results (May – Aug'02) 36% avg, 42% peak savings

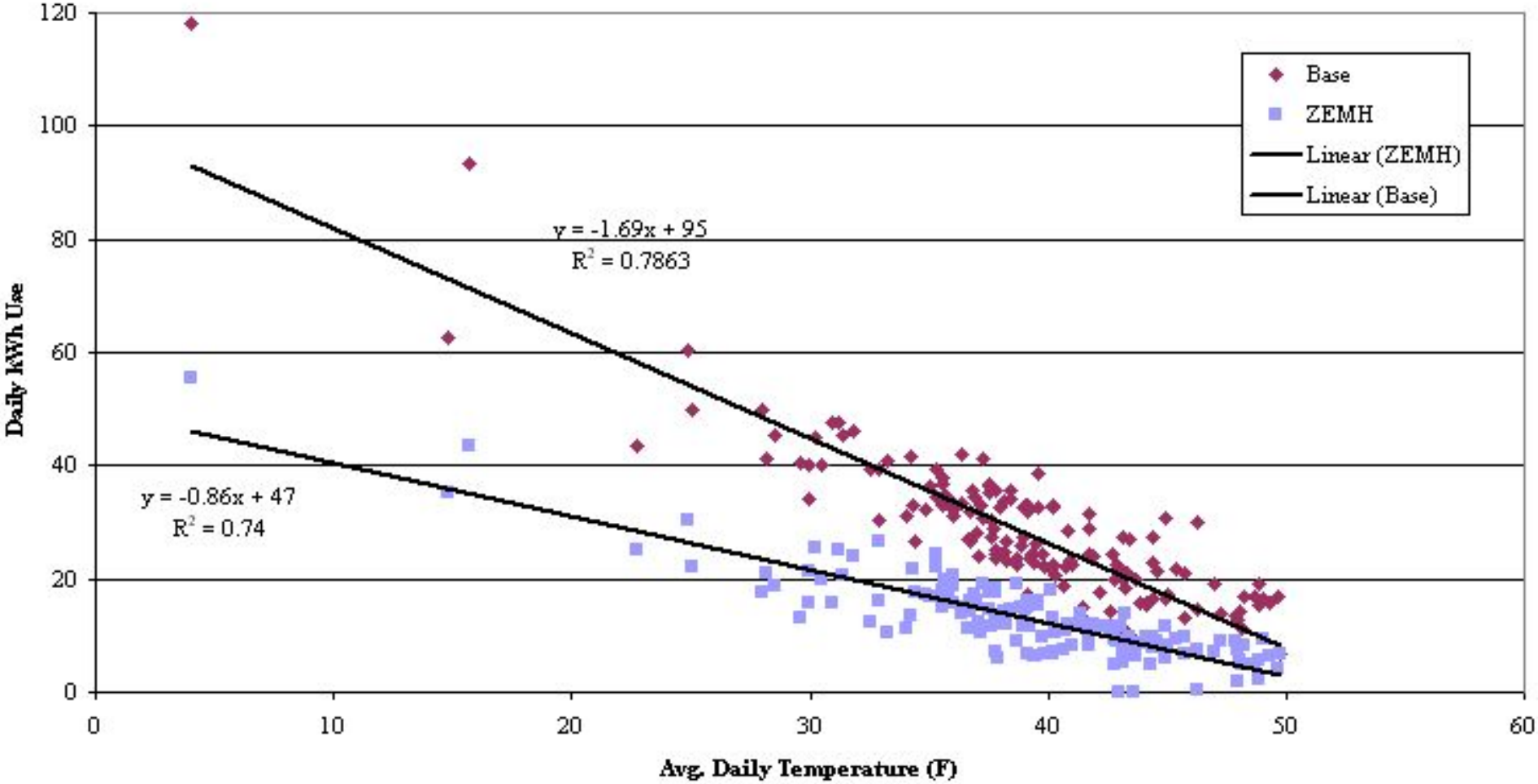


Nez Perce Facility

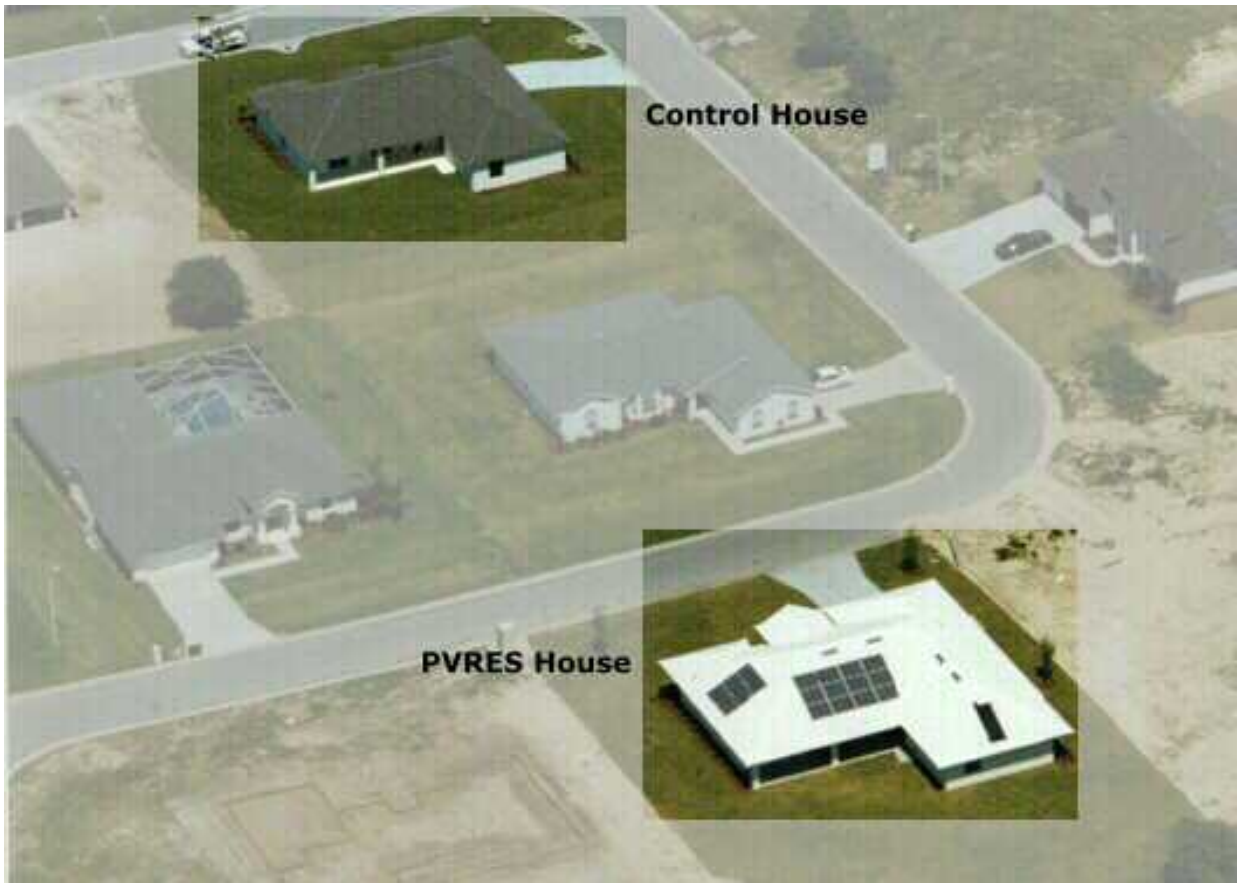
Lewiston, Idaho

- PV + Solar DHW + Energy Efficiency
- Funded by BPA
- BAIHP technical assistance thru WSU

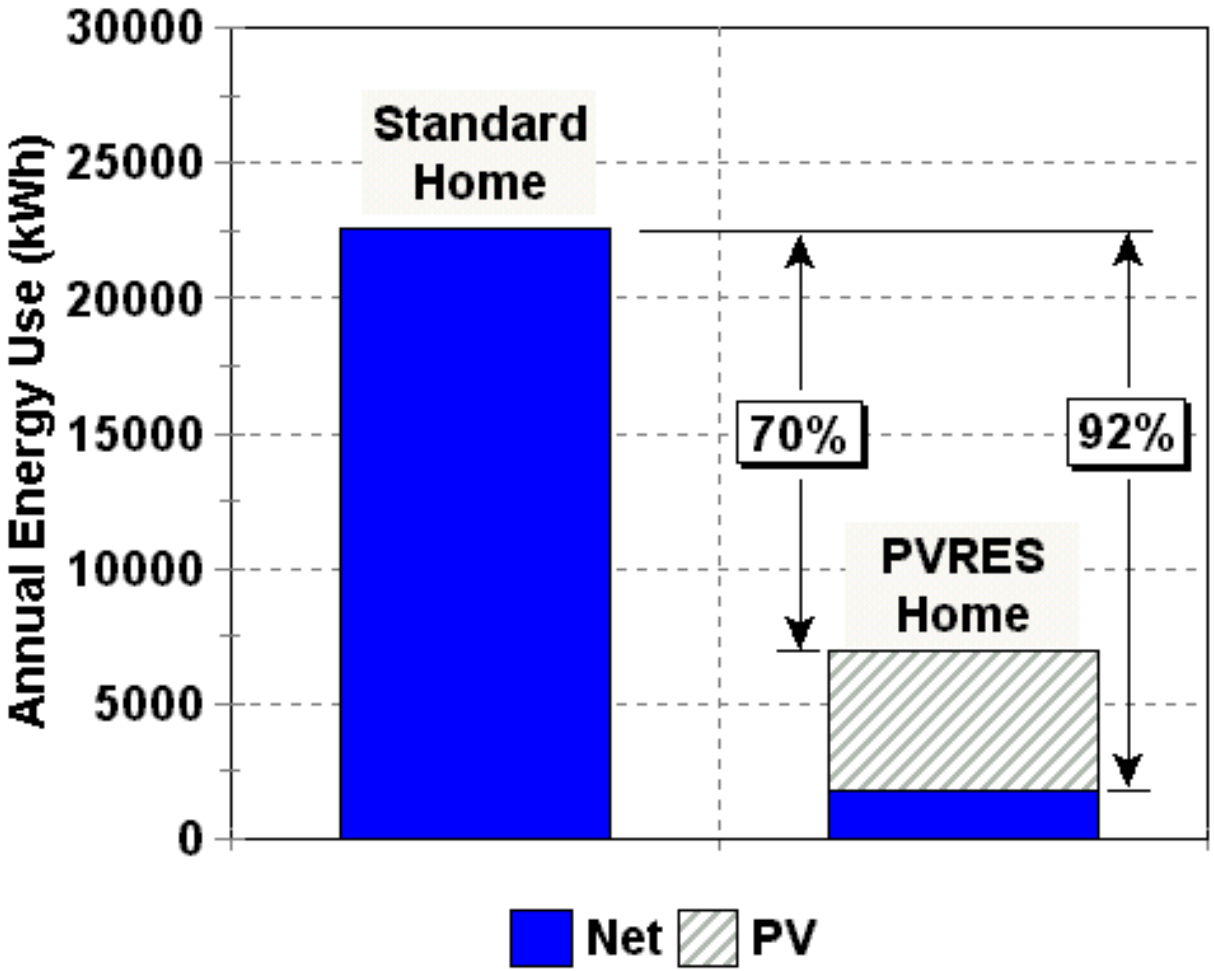
Figure 4 - Regression Analysis of Daily Space Heating Use vs. Outside Temperature



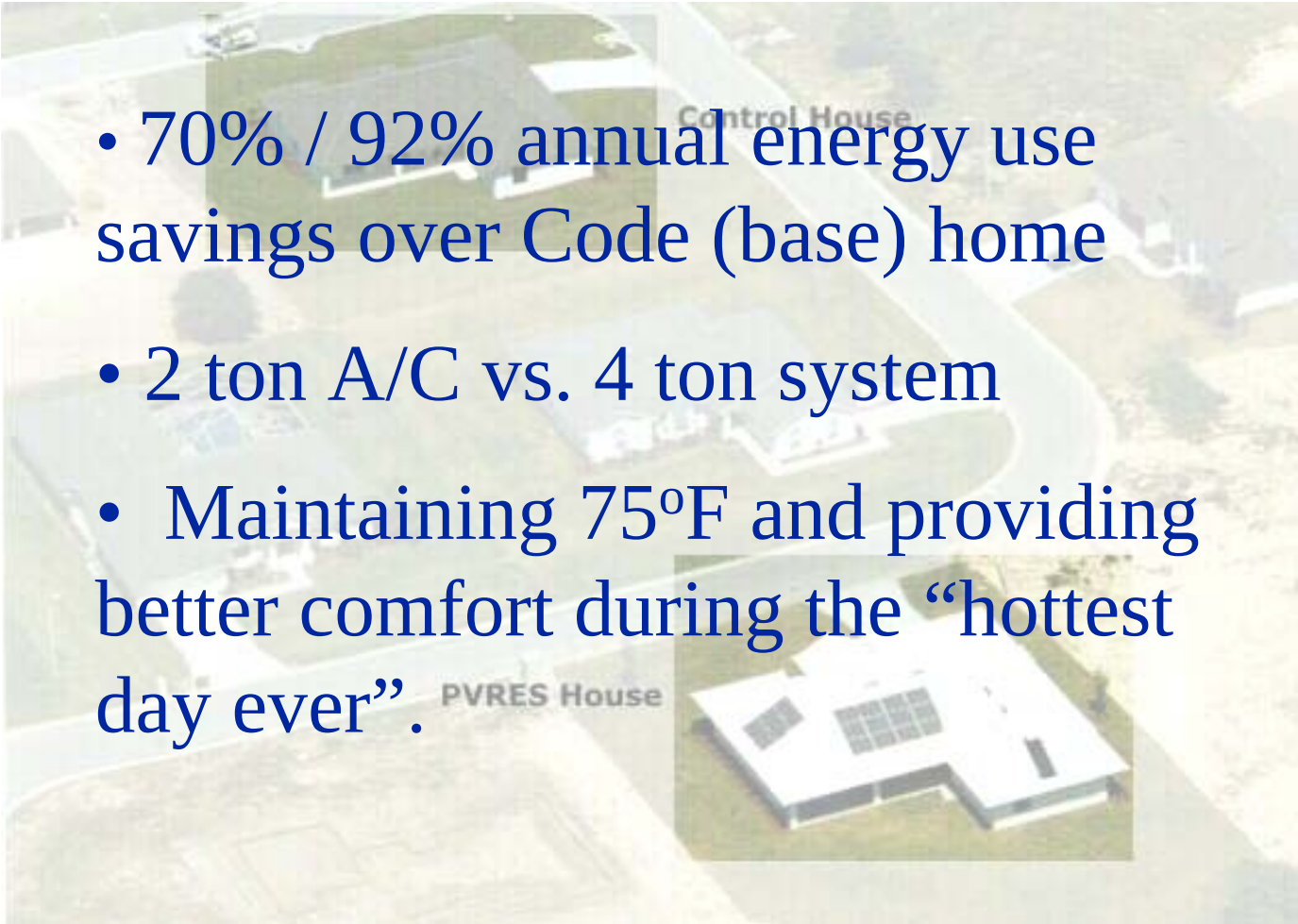
Lakeland Houses



Annual Energy Use



Putting it all Together



- 70% / 92% annual energy use savings over Code (base) home
- 2 ton A/C vs. 4 ton system
- Maintaining 75°F and providing better comfort during the “hottest day ever”.

Thank You!