FLORIDA SOLAR ENERGY CENTER

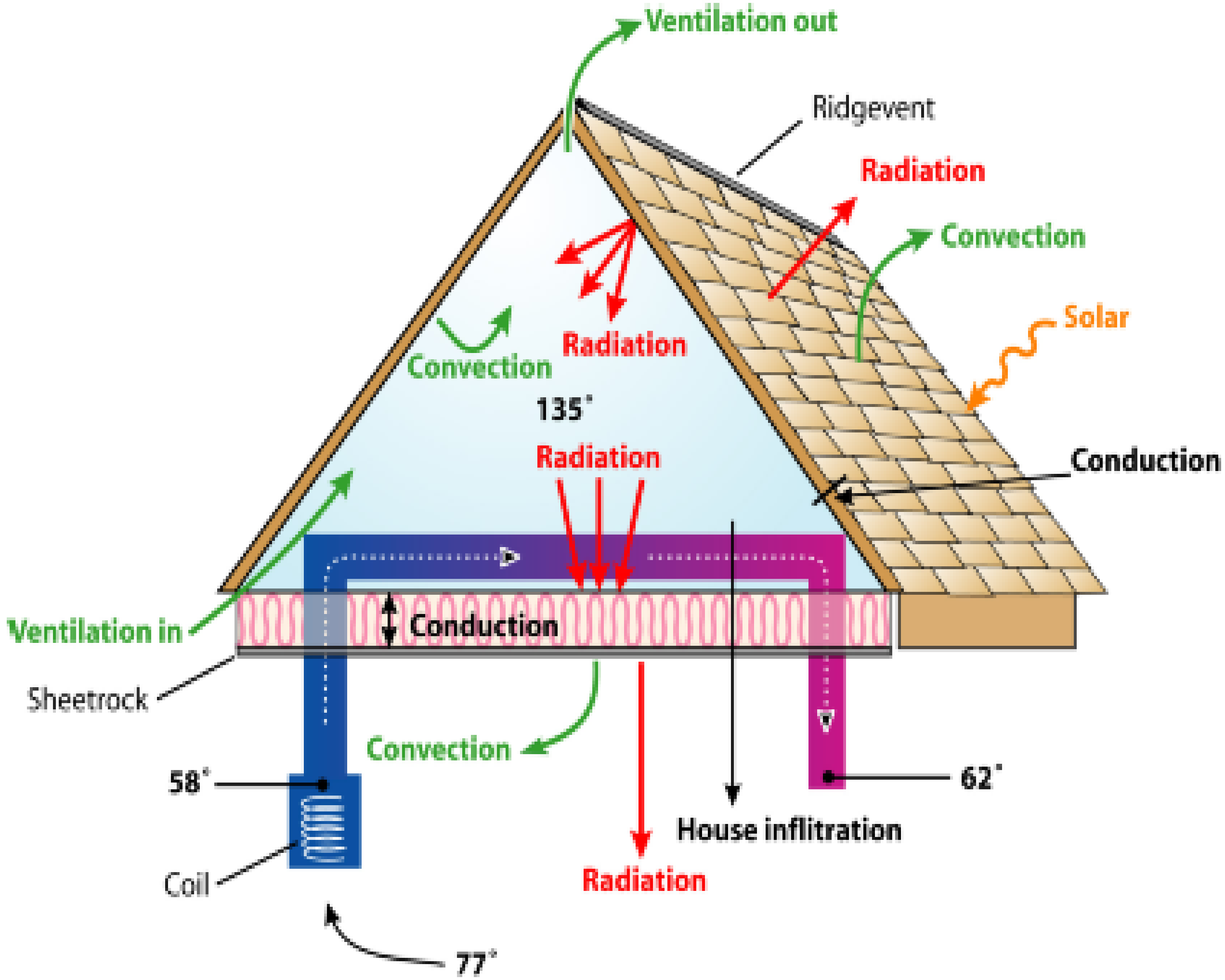
A Research Institute of the University of Central Florida

Ten Years of Cool Roofing Research at the Florida Solar Energy Center

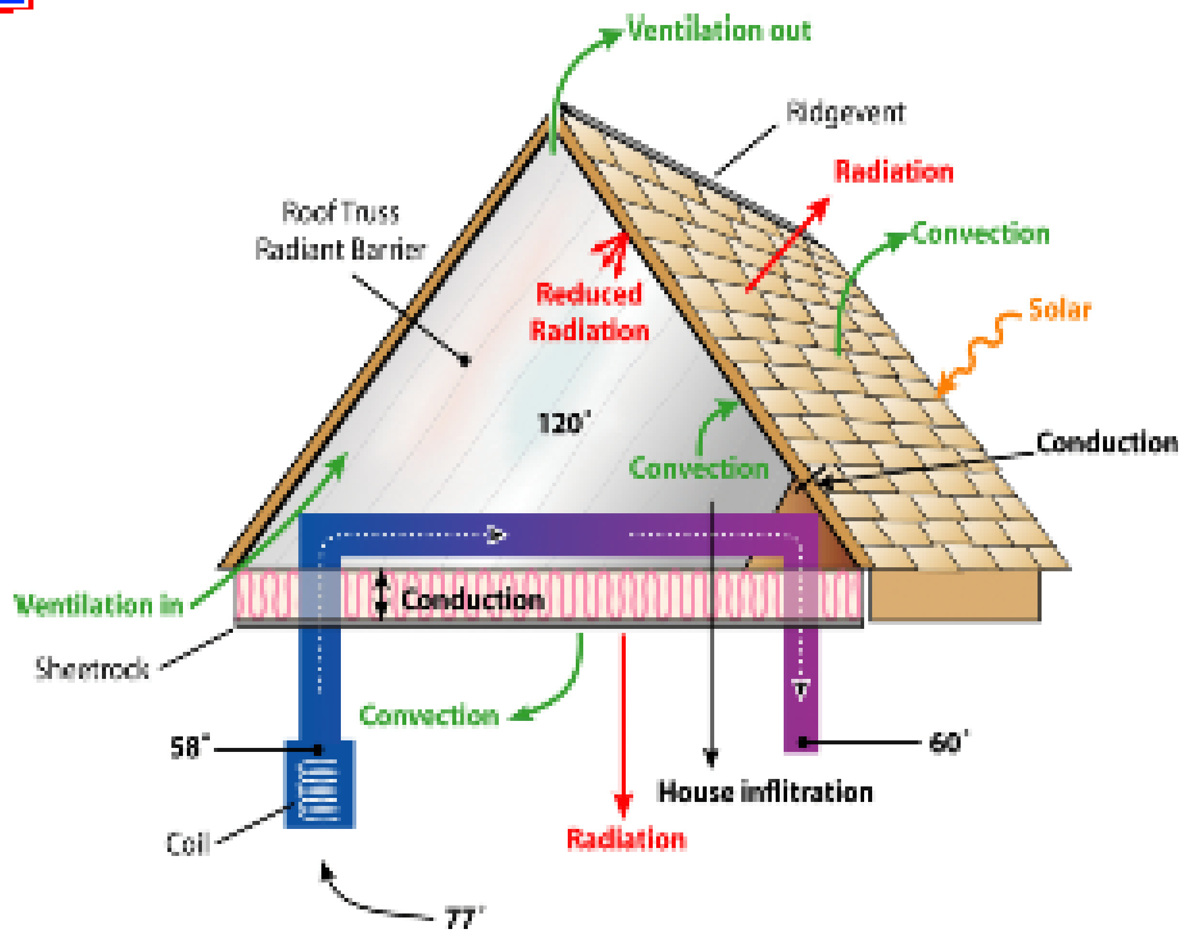
Danny Parker

Consortium for Energy Efficiency
Workshop on Cool Roofing
San Francisco, December 2005

Attic Thermal Processes

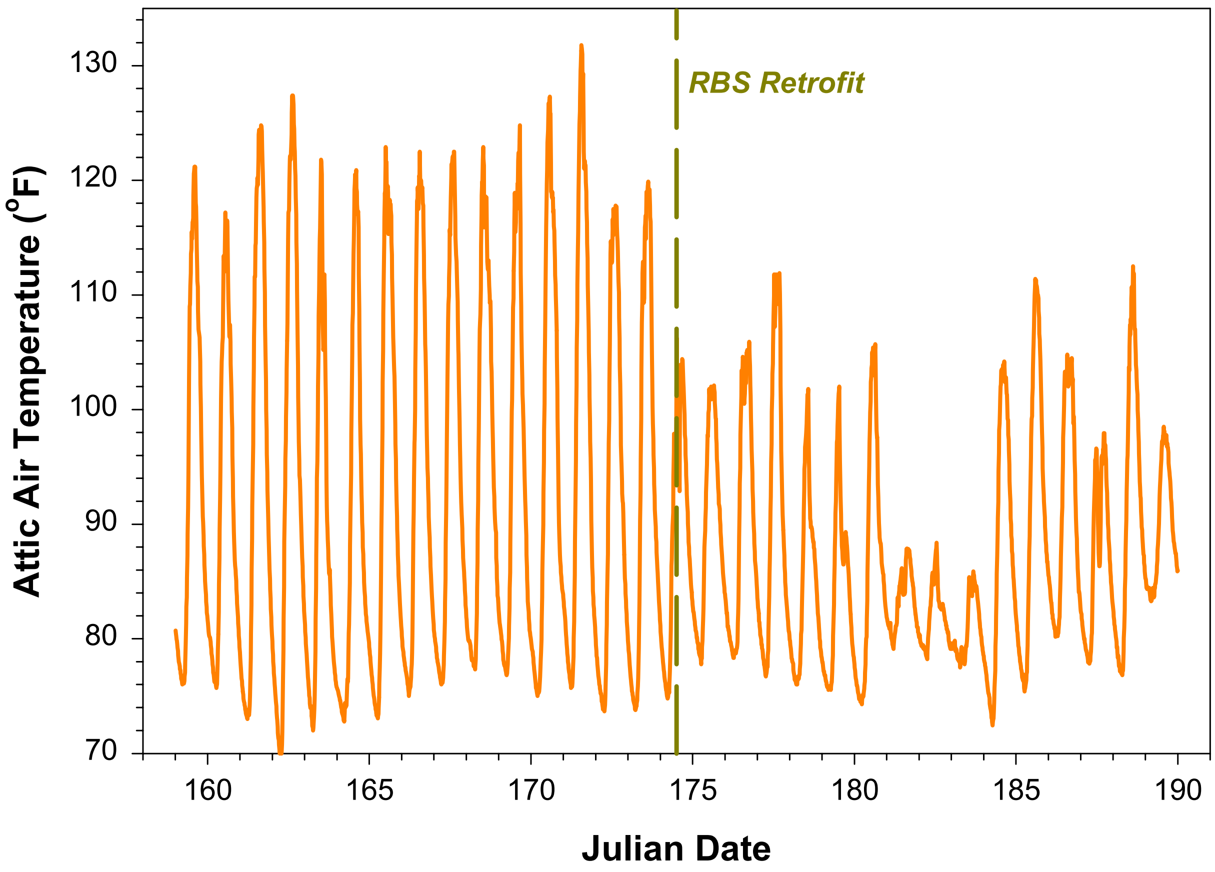


Altered attic heat transfer mechanisms; Radiant Barrier

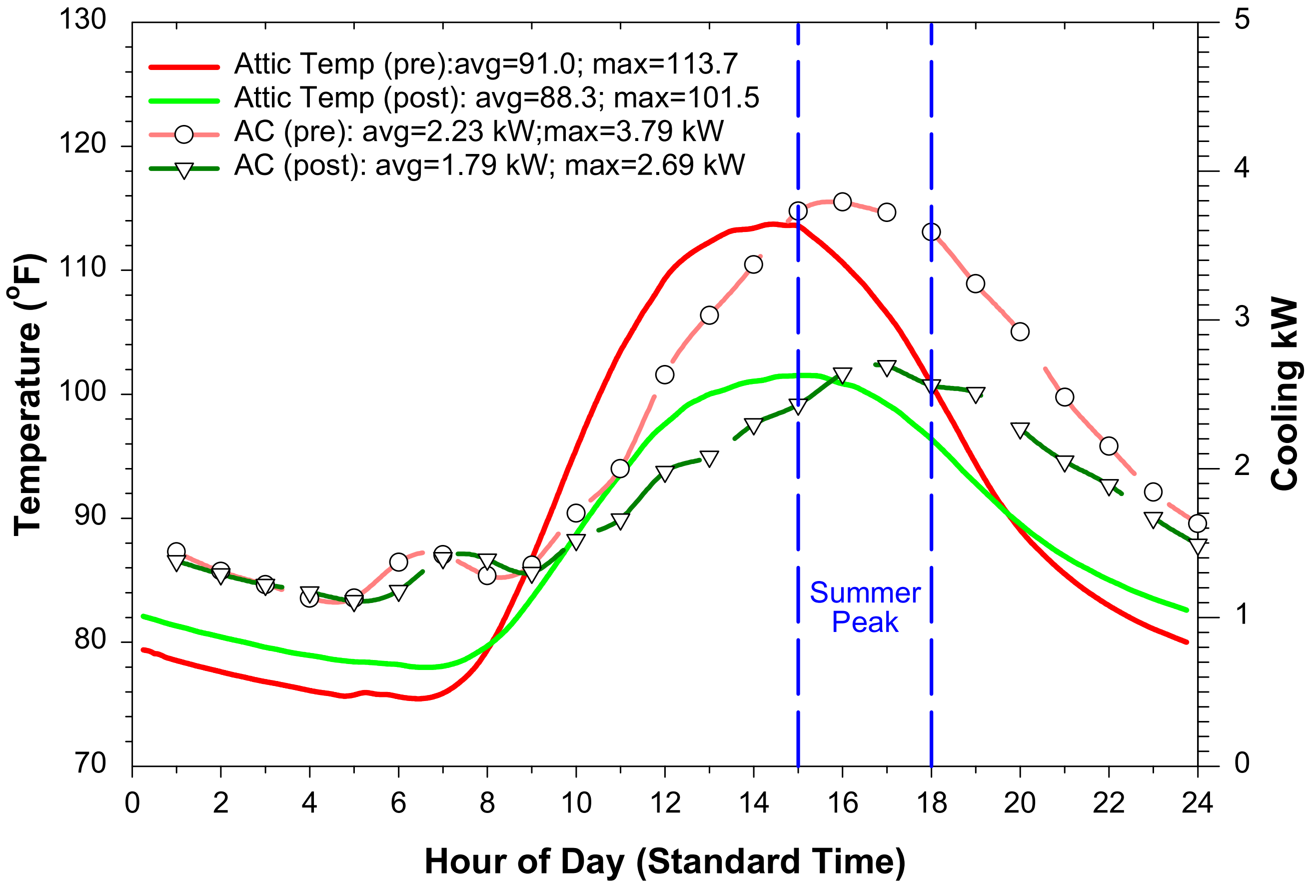


Radiant Barrier Pilot Project

Site #199 attic temp before and after retrofit – June 22, 2000



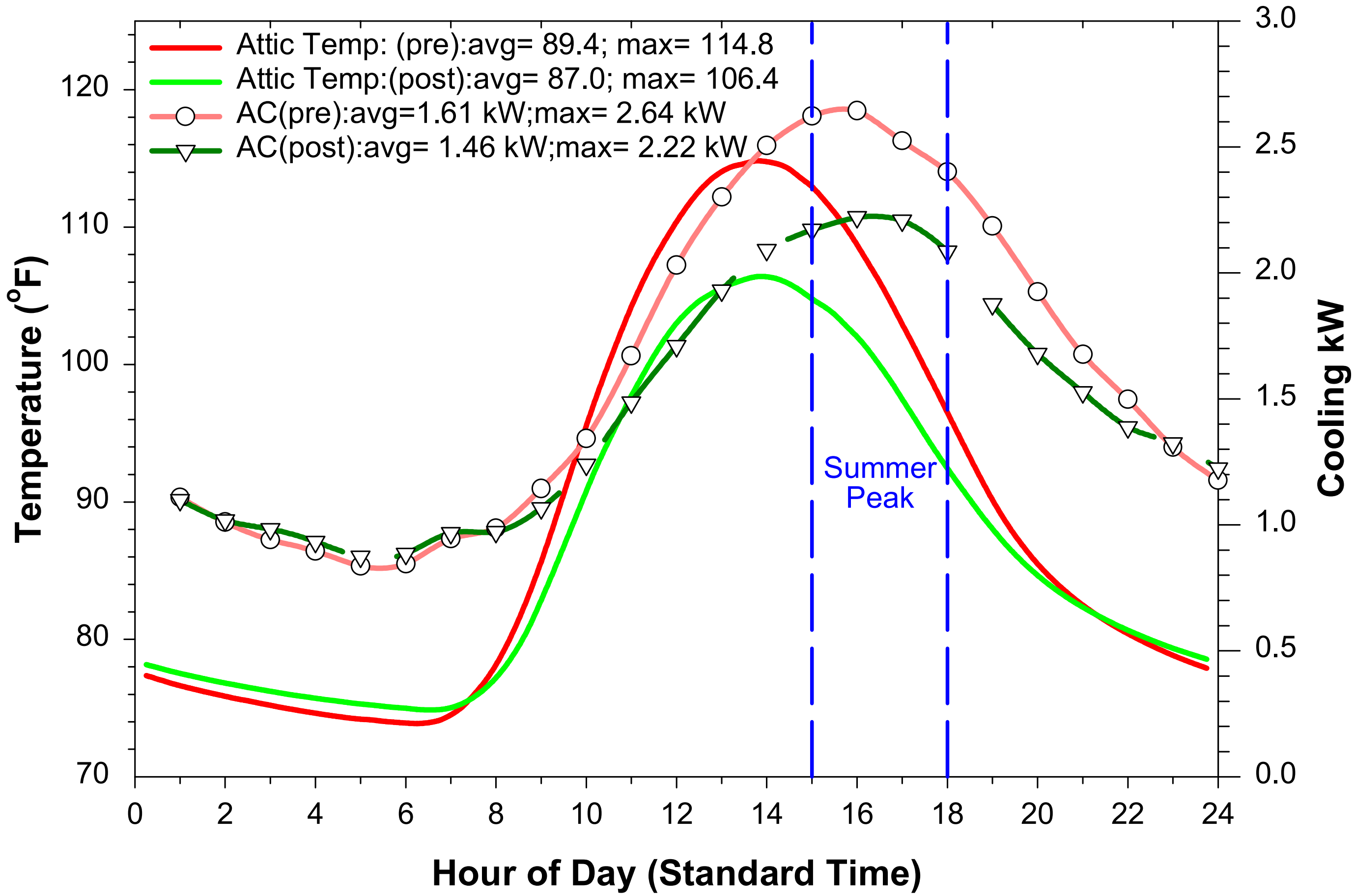
Site #199 RBS retrofit impact on attic air temp and AC cooling demand



Overall Results: 9 Sites

- Average cooling energy savings: 3.6 kWh/day (9.3%)
- Peak demand reduction; 420 W (16%)
- 8.4^{o} drop in avg. max daily attic temp.
- Improved load shape: most reduction during day; nighttime demand elevated
- Improvements to customer comfort

RBS impact on summer attic air temp and AC cooling demand in eight homes



Reflective Roof Retrofits

Experiments: 1993 - 1998

Dark roofed attics can reach 130 - 140EF on summer afternoons. A white color will reflect much of this heat back to the sky. Reducing the temperature in the attic is doubly important because of the presence of the cooling ducts.

Pre-post experiments in 19 homes:

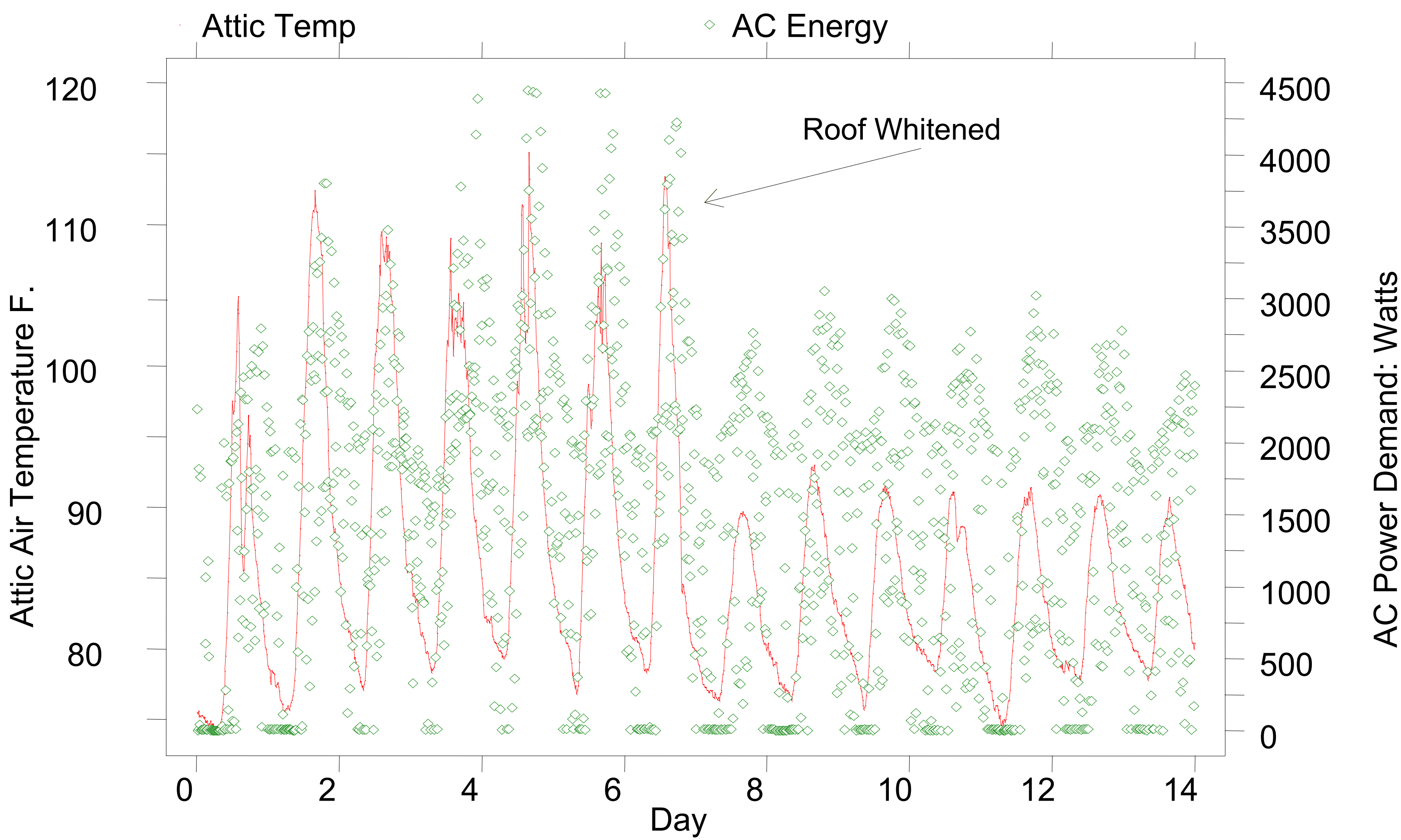
- 19 % average reduction in cooling energy use
- 23 % average reduction in peak demand

Reference:

Parker, D.S., Chandra, S., Barkaszi, S.F. and Beal, D.J., 1995B. "Measured Cooling Energy Savings from Reflective Roofing Systems in Florida: Field and Laboratory Results," Thermal Performance of the Exterior Envelopes of Buildings VI, p. 489, December 4 _ 8, 1995, Clearwater, FL.

Dark Gray vs. White?

Big Differences Seen…



FPL Demonstration Project: Ft. Myers, FL

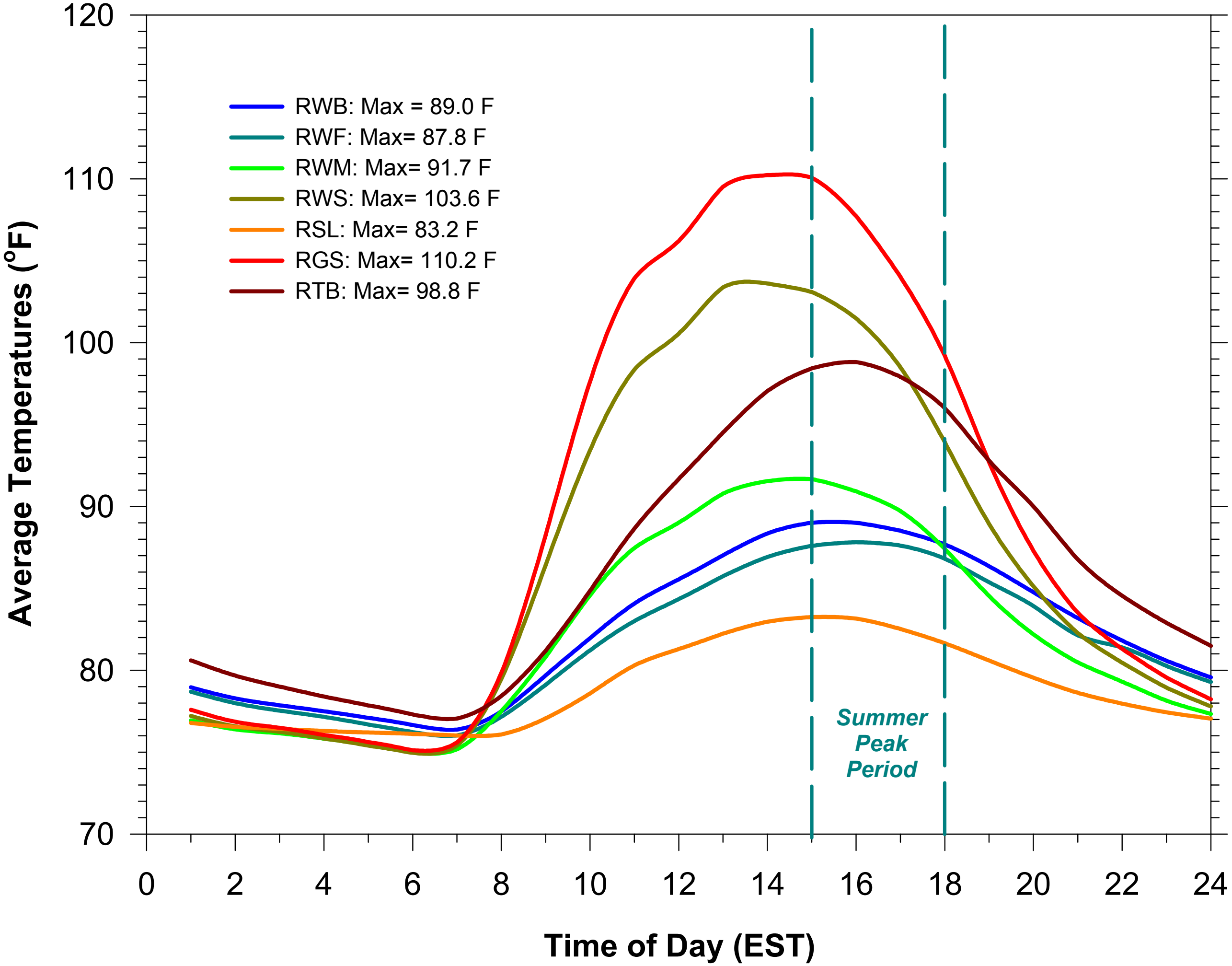
Study Homes: RGS, RWM, RWB, RWF



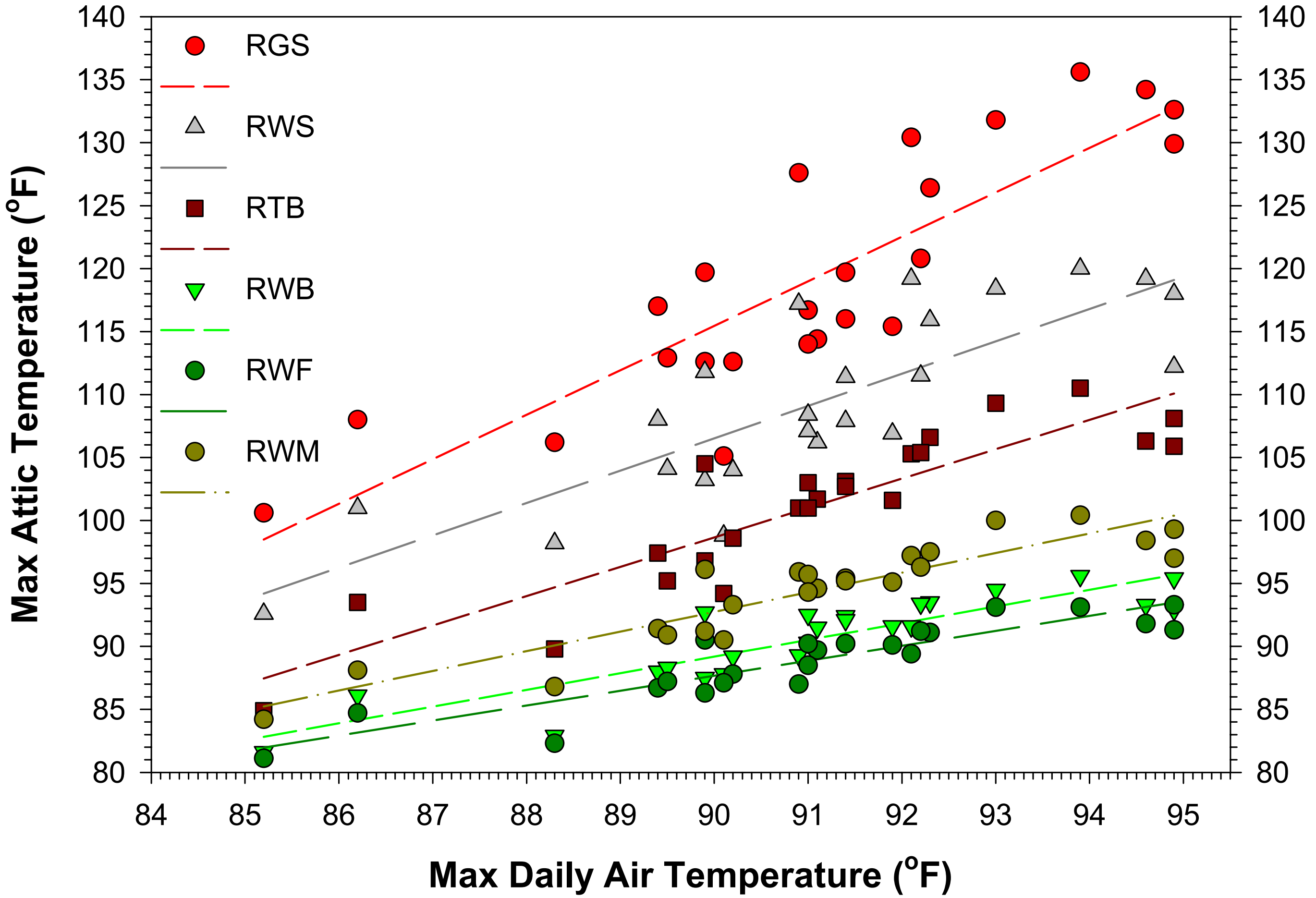

Study Homes: RTB, RWS, RSL

Detailed Instrumentation

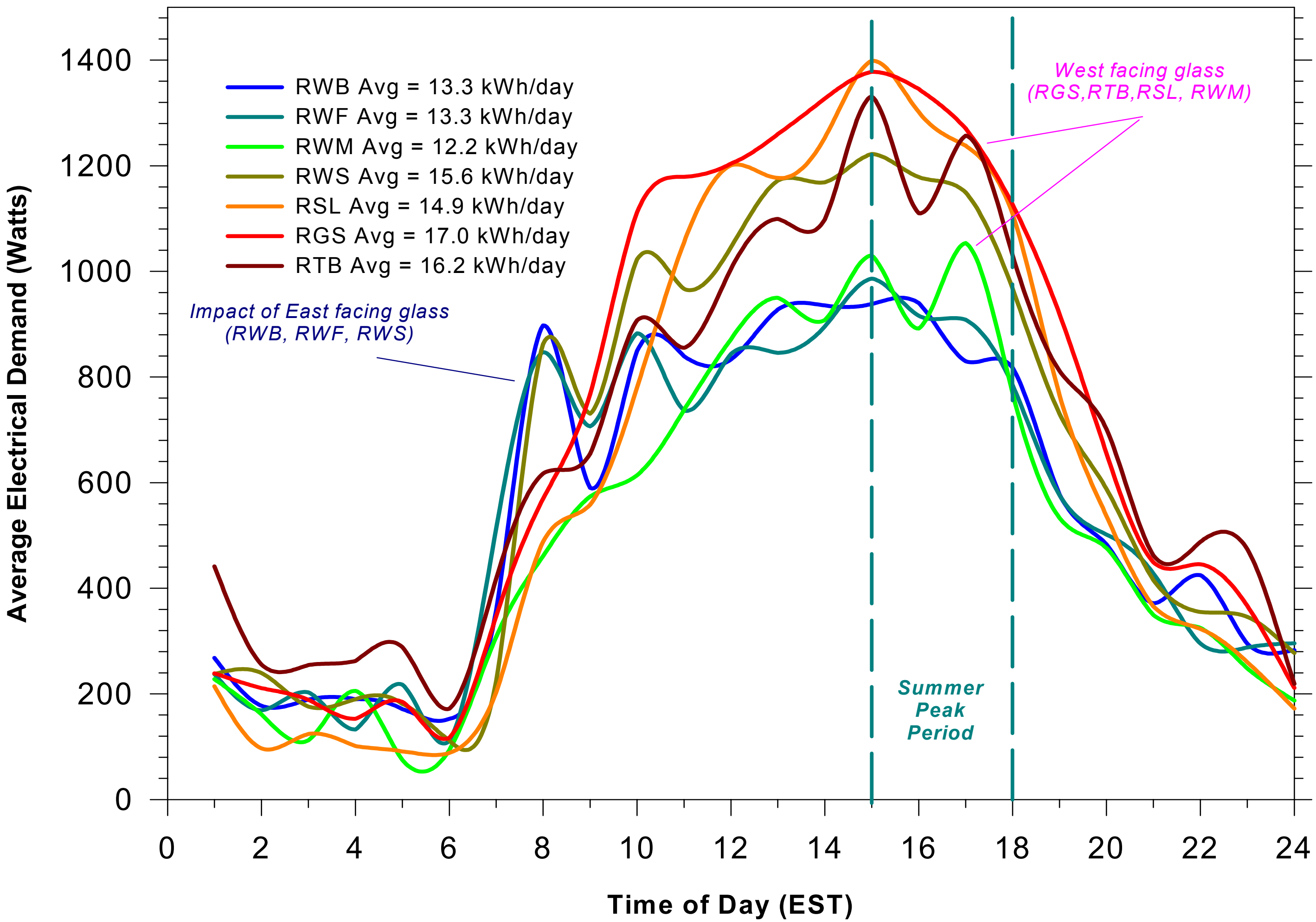
Attic Air Temps



Influence on Peak Attic Temperatures



Avg. Cooling over Unoccupied Period



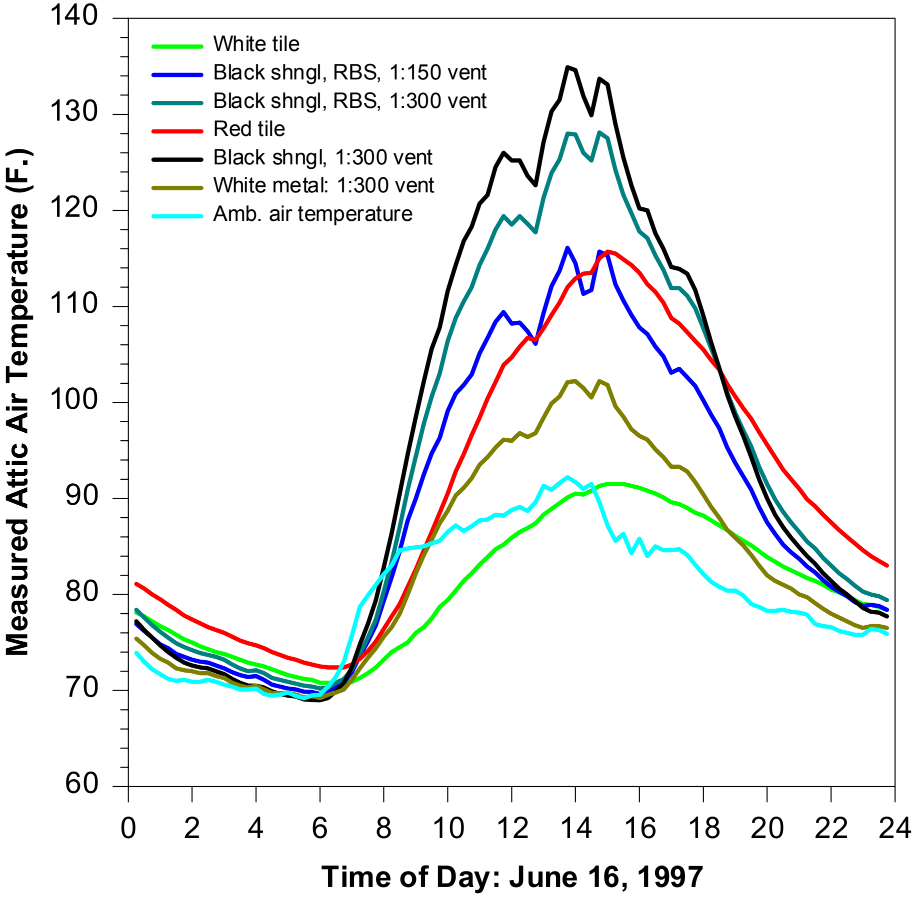
Final Results Summary: Best Estimates

Table 21
Summary of Normalized Savings and Demand Reductions from Regression Estimates

	Cooling Savings		Peak Demand Reduction	
Case Description	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 South Florida homes detailed in Appendix H.

Flexible Roof Facility



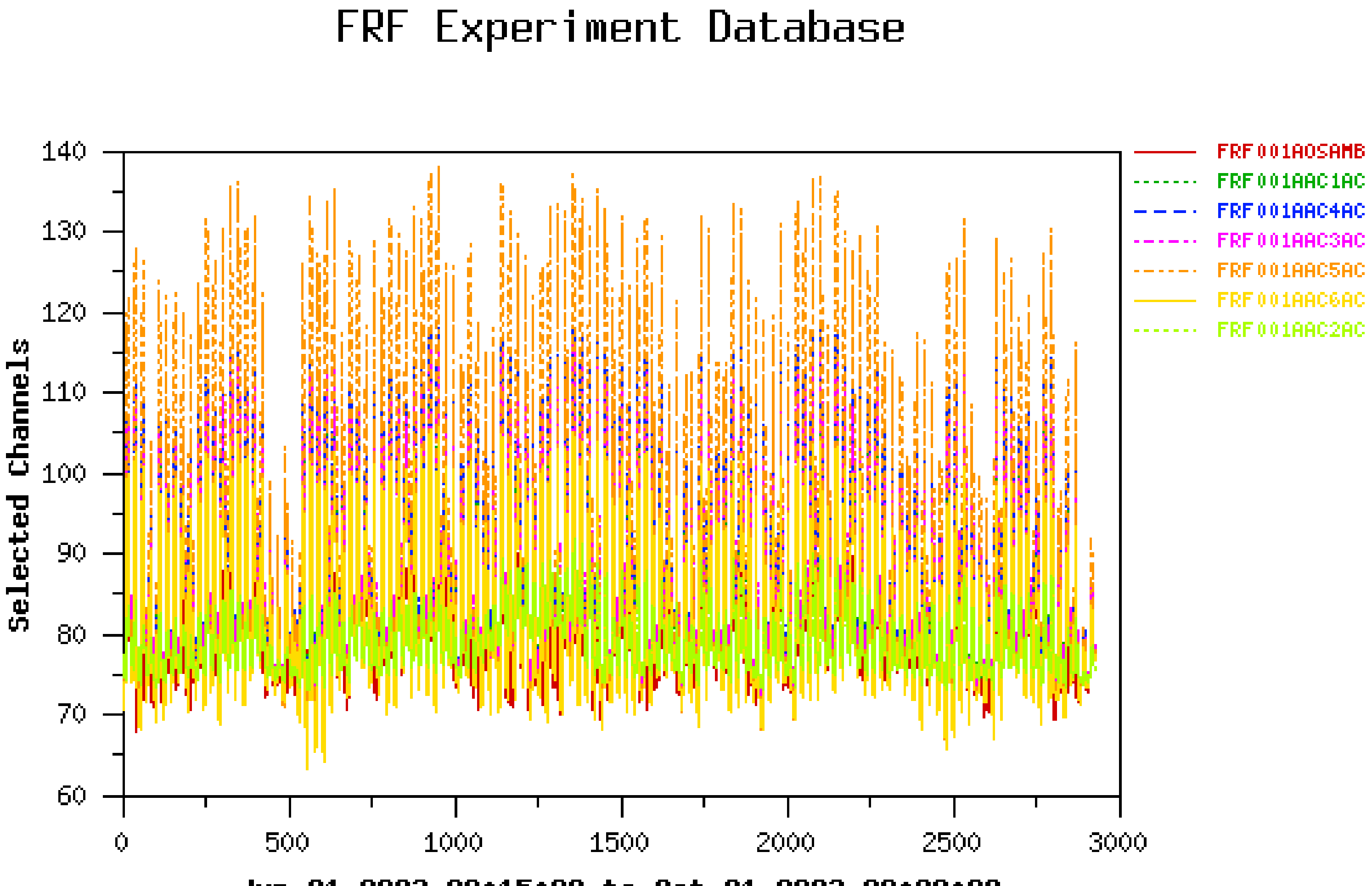
FRF Roof/Attic Testing

- Roofs/Ventilation
- Cool roofing systems
- Measured heat flux
- Attic air temperature
- Weather conditions
- Summer 2002-2003: Unfinished vs. Finished metal roofing systems
- Long-term testing of unfinished metals
  - Emittance/reflectance

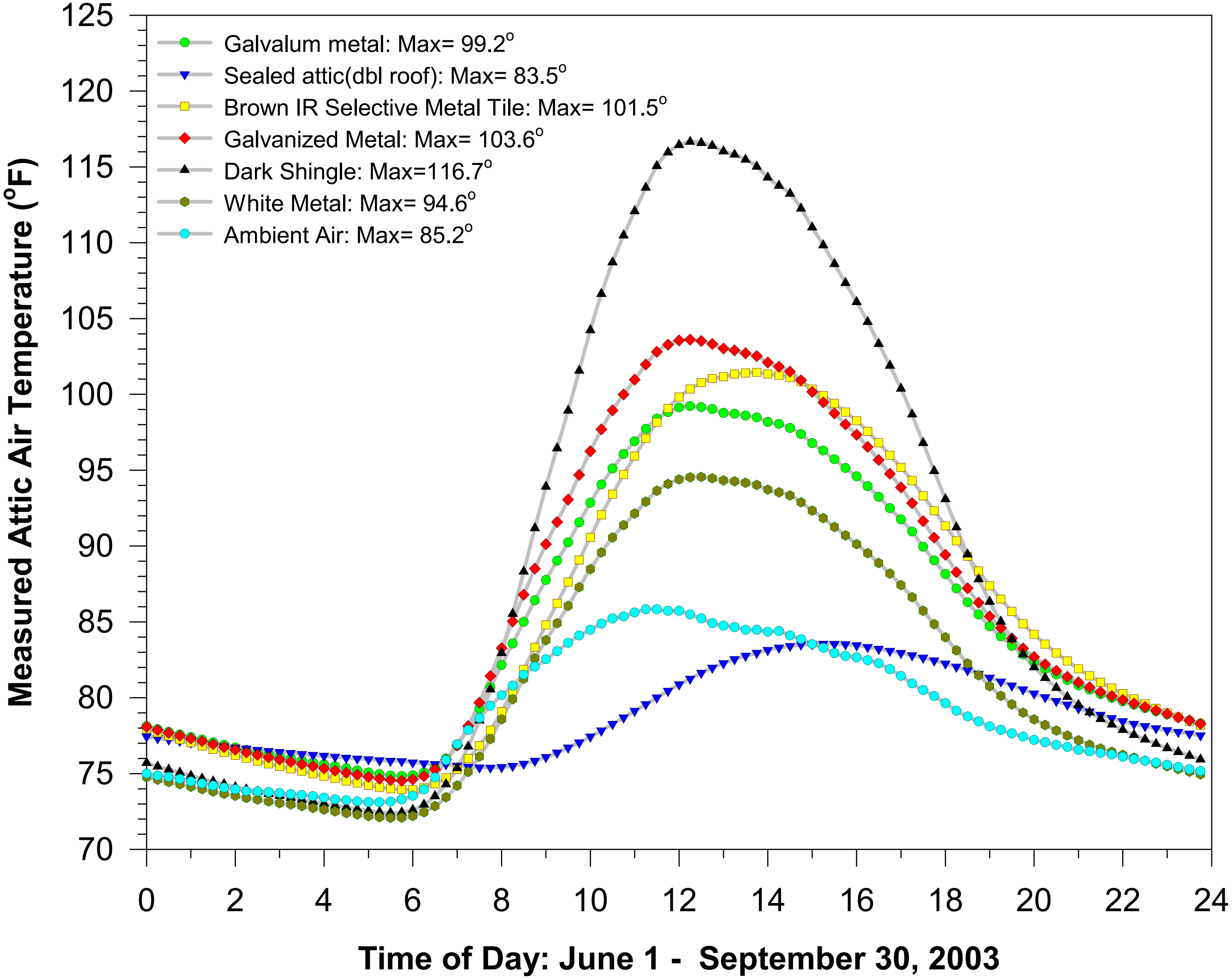
FRF Testing 2003

- Metal Roofing long term exposure
  - Unfinished Galvanized
  - Unfinished Galvalume
  - IR Reflective Metal shingles
  - White metal roof
  - Control= Dark shingles

Attic Temps over Summer



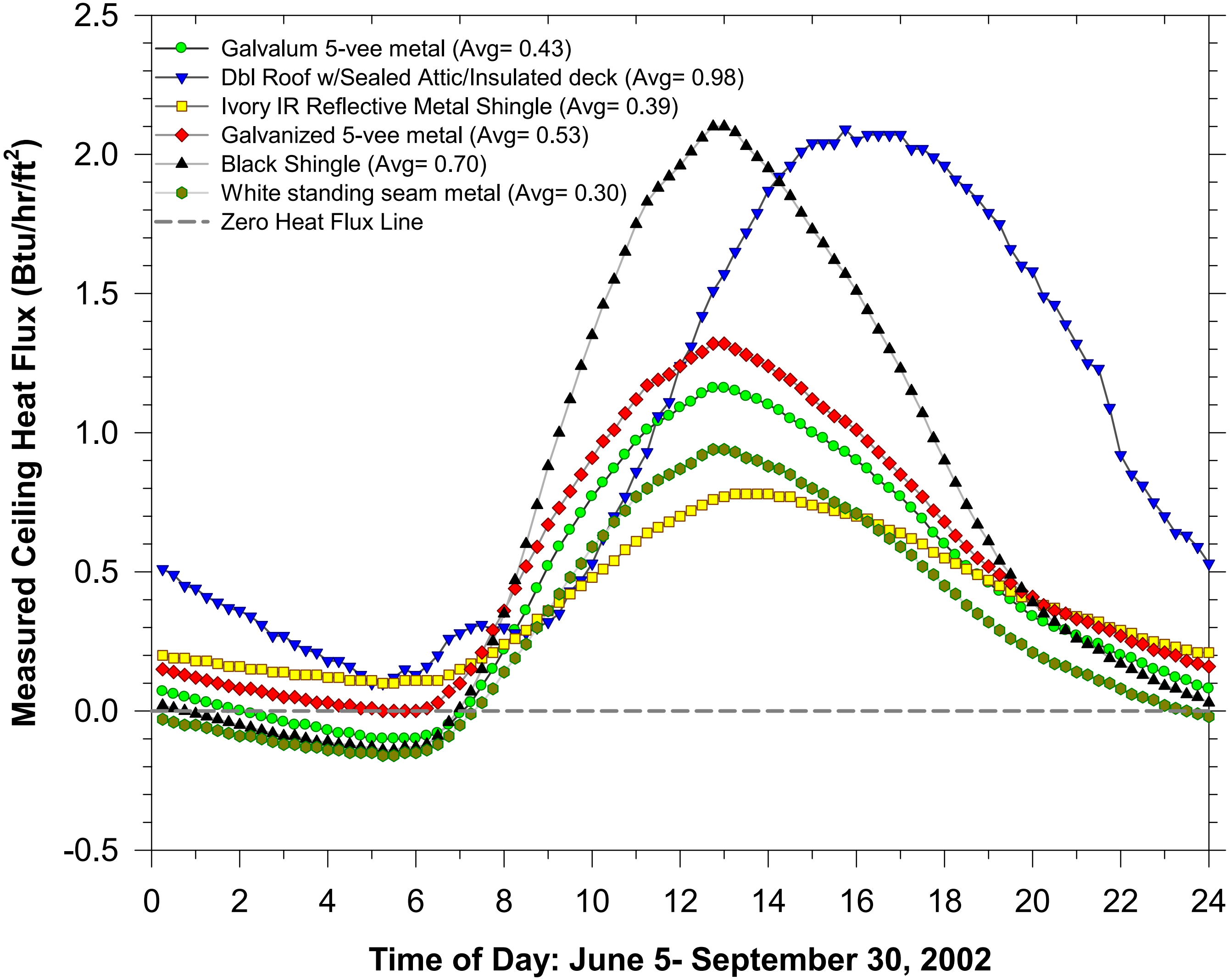
Average Temps Over Summer



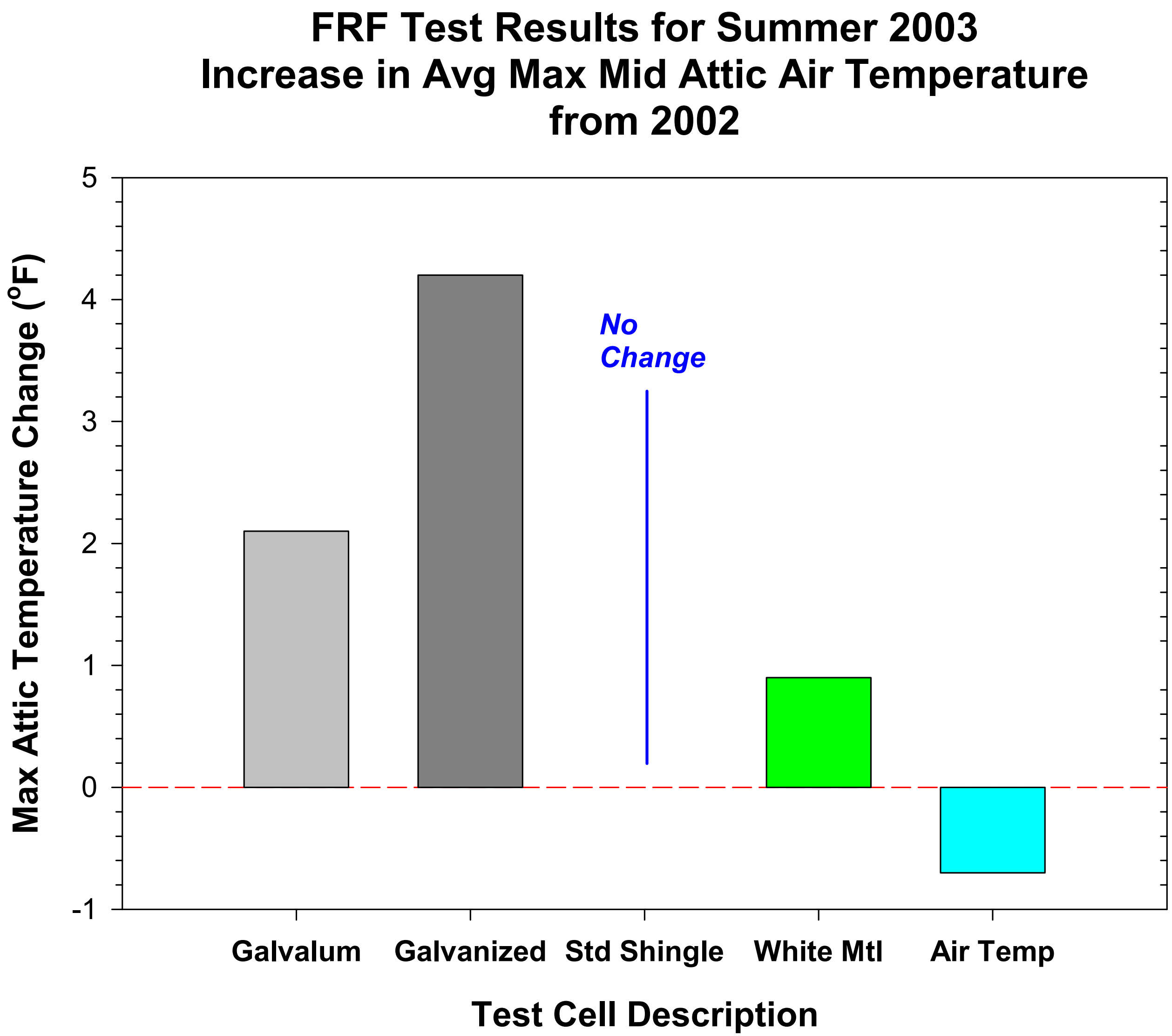
Max Attic Temperatures

- *Galvalume* Metal
  - 111 °F
- Dbl Roof, sealed
  - 85 °F
- IR Reflective Shingle
  - 106 °F
- Galvanized Metal
  - 114 °F
- Black Shingle (Control)
  - 140 °F
- White Metal Panel
  - 104 °F
- Outdoor Air Temp= 95 °F

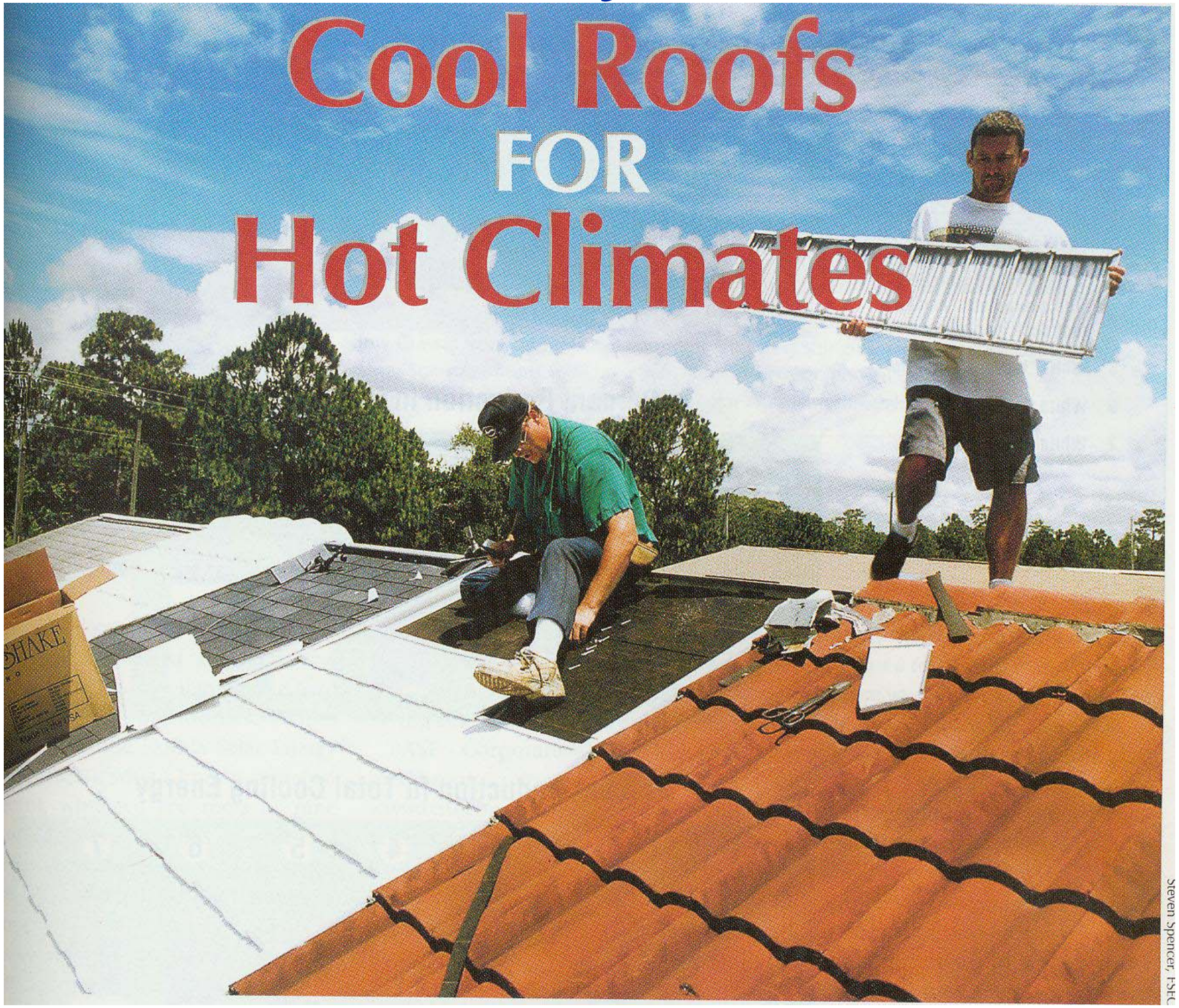
Ceiling Flux…Different Story



Change in Performance



Journal of Light Construction, June 2003



Information to the public…

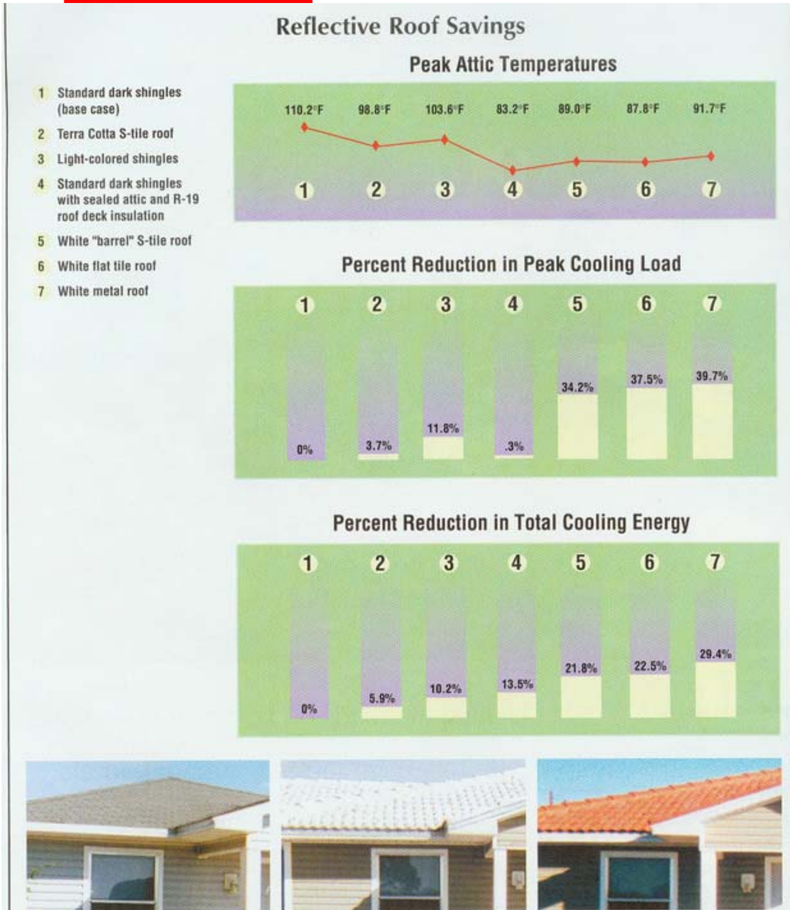
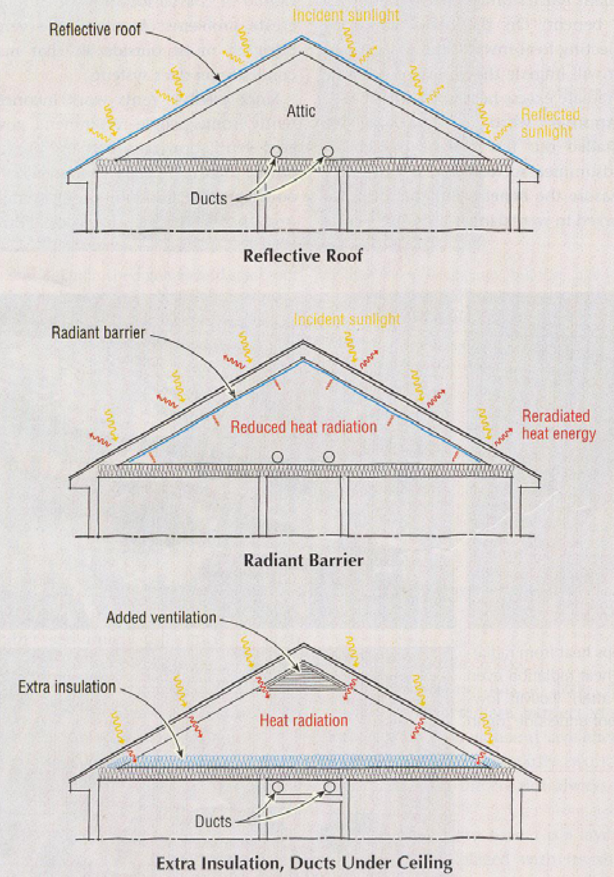


Figure 1. Florida Solar Energy Center researchers compared the air-conditioning power use of seven identically built houses with different roof coverings. Reflective roofing dramatically reduced total power use (bottom chart) and had an even greater effect on peak A/C power demand (middle chart). Insulating the roof deck and sealing the attic, without using a reflective roof, cut total energy use somewhat but did not reduce peak cooling loads noticeably.

Options for Stopping Rooftop Heat Gain



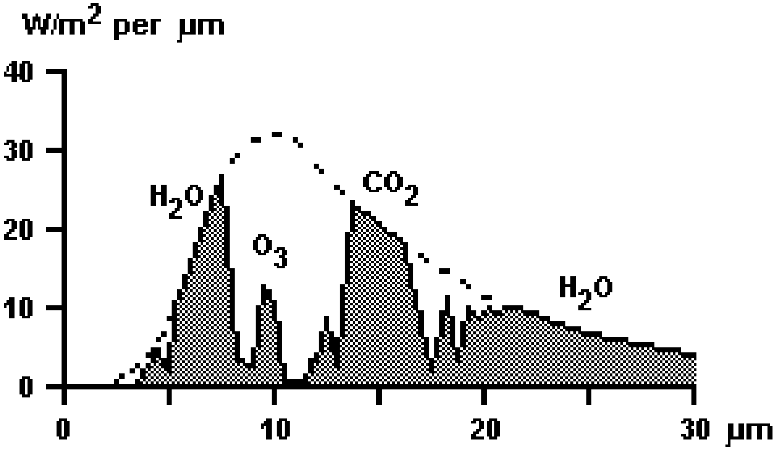
Field research at the Florida Solar Energy Center (FSEC) has found several effective ways to limit rooftop heat gain in sunny conditions. Using a highly reflective roofing material (top) is the simplest and most effective: It stops the sun's energy before any heat is absorbed, so that even the roof sheathing and framing stay cool. If the existing roof is dark colored or the customer prefers a darker roof, heat can still be blocked by adding a radiant barrier foil just below the roof deck (middle). Savings from this method are roughly comparable to the saving achieved with reflective roofing; however, some conductive heating of the attic space will still take place, and the roof deck and shingles will experience some increased heat stress. A third option is to increase the insulation between the attic and the living space below, and to run the hvac ductwork within the conditioned space rather than in the unconditioned attic. This method has a smaller effect on cooling loads than the reflective or radiant barrier roof systems but is effective at reducing heating loads as well as cooling loads, making it the most cost-effective option in mixed heating and cooling climates.

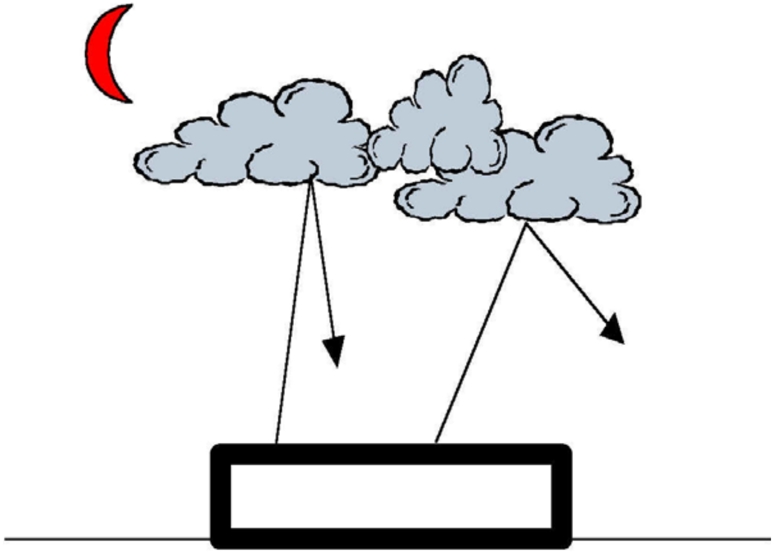
Roof Research: What Next?

- Continue test of spectrally selective roofing materials
- Innovative roofing systems (e.g. sealed roofs, ventilation systems)
- Integrated Power Roofs (PV, solar, thermal control etc).

Night Sky Cooling Potential

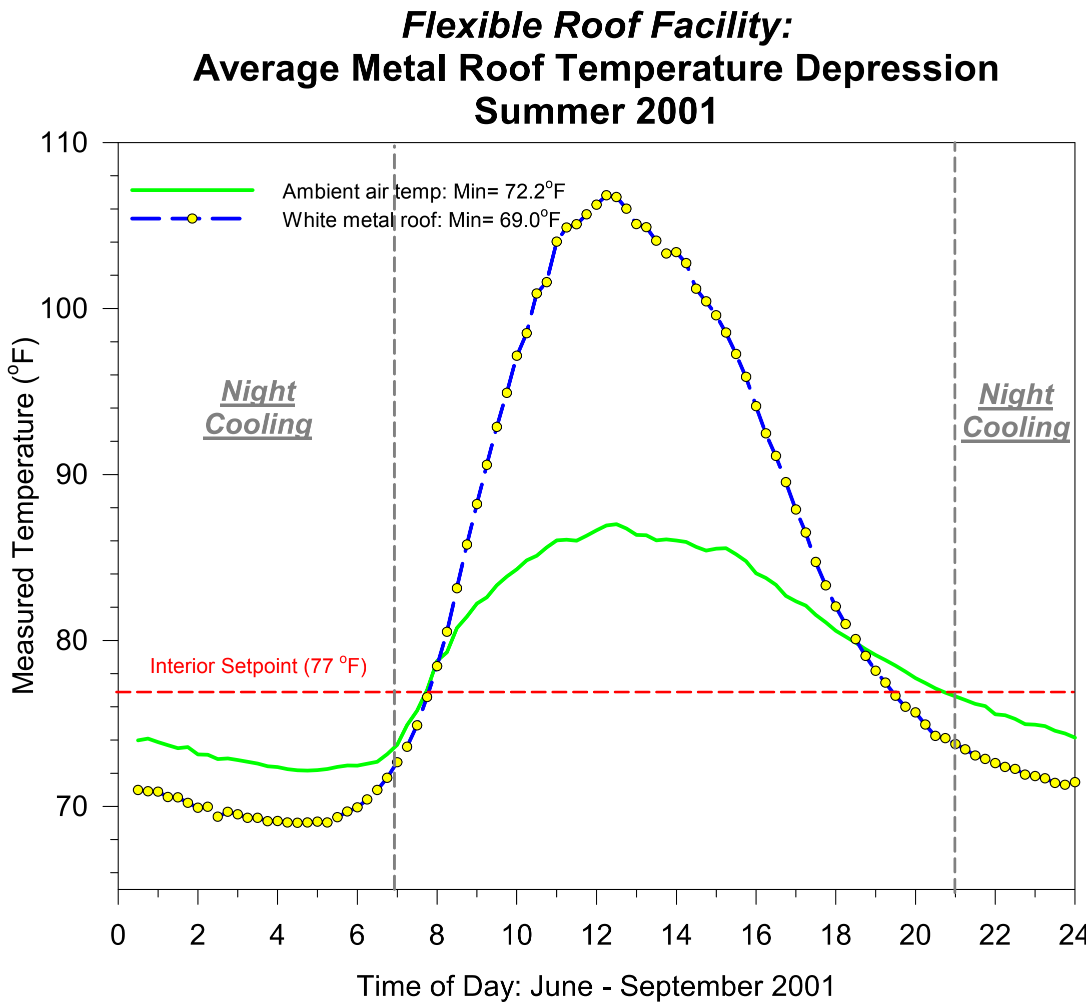
- *Cool Night Sky*
  - 30 °F below ambient
  - 40-50/W/m² in Florida
  - Roof: 1 ton cooling
  - Clear, calm nights
  - Clouds, wind,





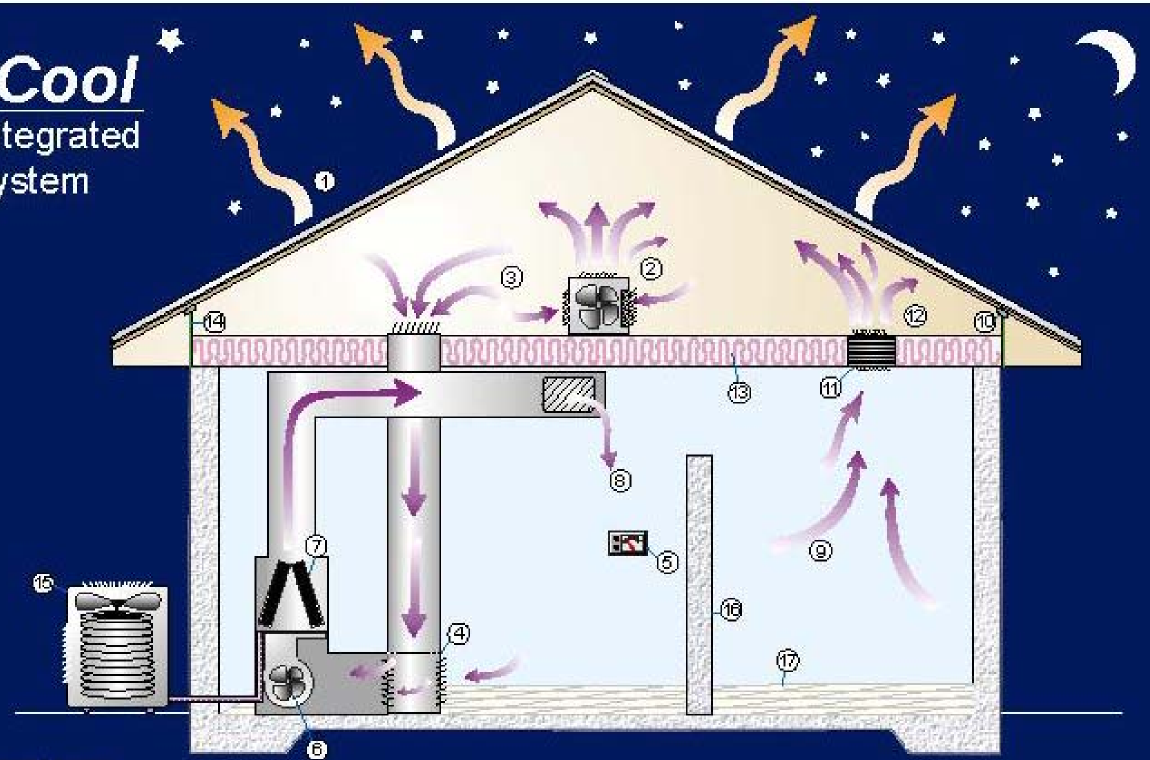
Measured Night Cooling Potential: FRF

- FRF Test Cell with White metal Roof
- Roof surface temperature
- Average over Summer of 2001
- Shows sizeable cooling potential most nights



NightCool Schematic

NightCool
Building Integrated Cooling System



NightCool
Building Integrated Cooling System
Operation Schematic

1. White metal roof on metal battens (no decking). Both sides are surfaced for high emissivity. A temperature probe measures roof underside temperature.
2. Small capacity dehumidifier (such as *Whirlpool AD40DBK*); operates only during evening hours when thermostat and roof temperature monitor calls for cooling and attic relative humidity is greater than 55%.
3. Baffled inlet grill from attic for nighttime operation.
4. Room return inlet (for daytime operation). Closed by damper at night when temperature conditions are met.
5. Thermostat (compares roof surface temperature and setting to determine vapor compression vs. nighttime cooling operation.)
6. Variable speed air handler fan with electronically commutated motor.
7. Vapor compression air conditioner cooling coil.
8. Interior duct system with supply outlet.
9. Interior room air return to attic during evening hours when NightCool is activated.
10. Roof-line drip collection system with drain.
11. Ceiling return for NightCool operation mode.
12. Attic air convects to cool roof for nocturnal cooling.
13. R-20 ceiling insulation.
14. Sealed attic construction with top plate baffles. (tested and sealed system).
15. Air conditioner outdoor unit (condenser).
16. Concrete interior walls (thermal mass for sensible cool storage).
17. Tile floor (add thermal mass).

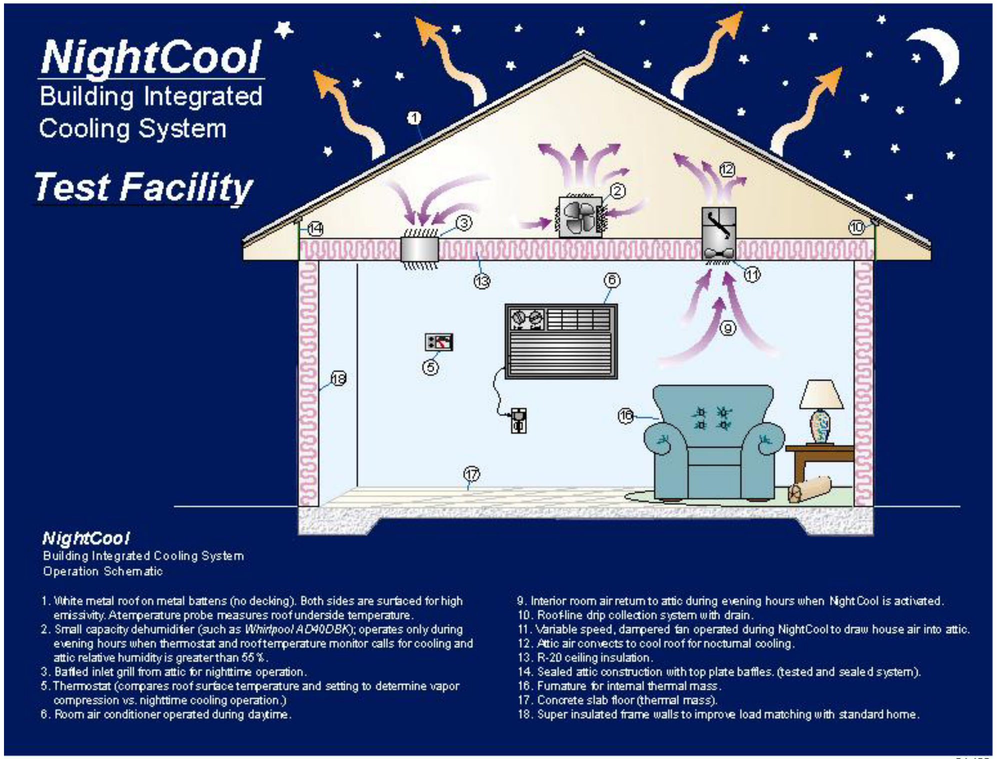
P1-12A

NightCool *Simulation*

- Modified Givoni-Ingersoll Model
- Simulate major influences with model
- Evaluate for sealed attic model with exposed metal roof
- Florida, Tampa= ~2 kW cooling potential under typical night conditions

Use two small buildings for test of concept

- Control and experiment
- Full exposed metal roof on battens (no decking) with sealed attic
- Channel air to space when cooling conditions are met
- Use dehumidfier with heat rejection to attic
- Fully instrumented

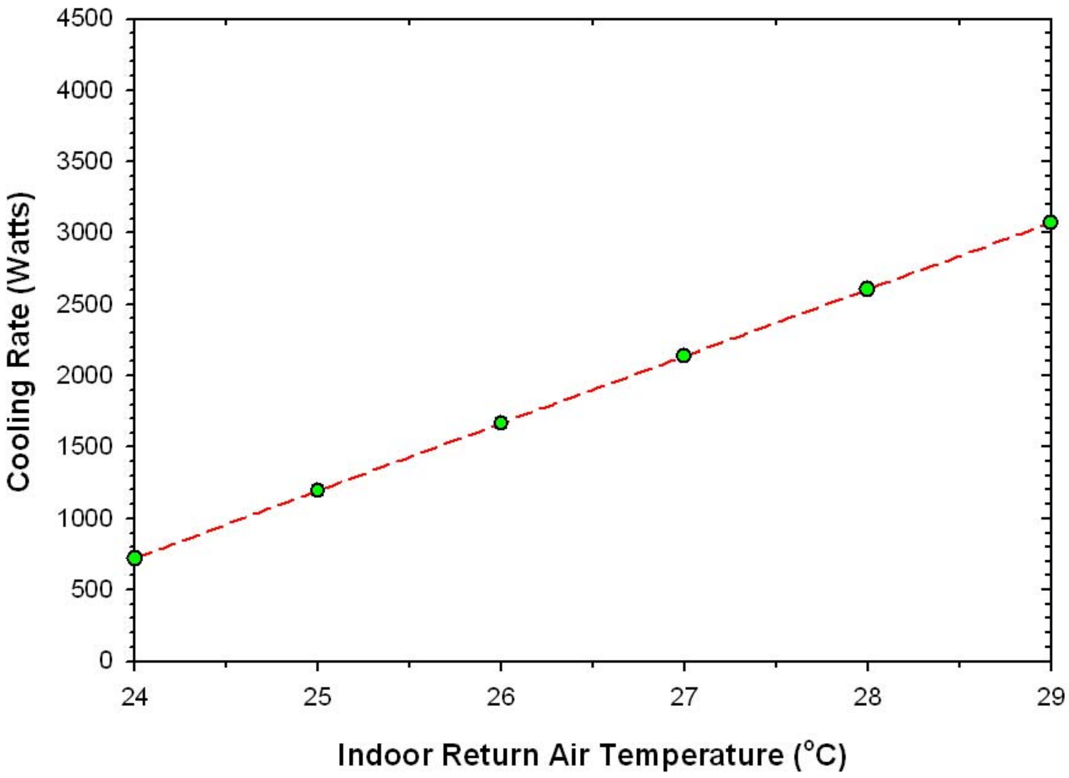


Evaluation Sensitivity for Tampa, FL

- Major factors
  - CFM air flow and fan power
  - Ambient dewpoint (limiting factor on roof temperature)
  - Wind if low dewpoint
  - Inlet air temperature
- Minor factors
  - Roof tilt
  - Surface emissivity

Excellent Predicted Performance…

- **Tampa, Florida**
  - Hot humid climate challenge for concept
  - Daily summer cooling reduction of 15 kWh
  - SEER of 37 Btu/Wh
- **Atlanta, Georgia**
  - 50 kWh/day cooling
  - SEER = 71 Btu/Wh
- **Phoenix, Arizona**
  - Very hot arid climate
  - 23 kWh of daily summer cooling
  - SEER of 61 Btu/Wh



Two small buildings for test of concept

- Control and experiment
- Full exposed metal roof on battens (no decking) with sealed attic
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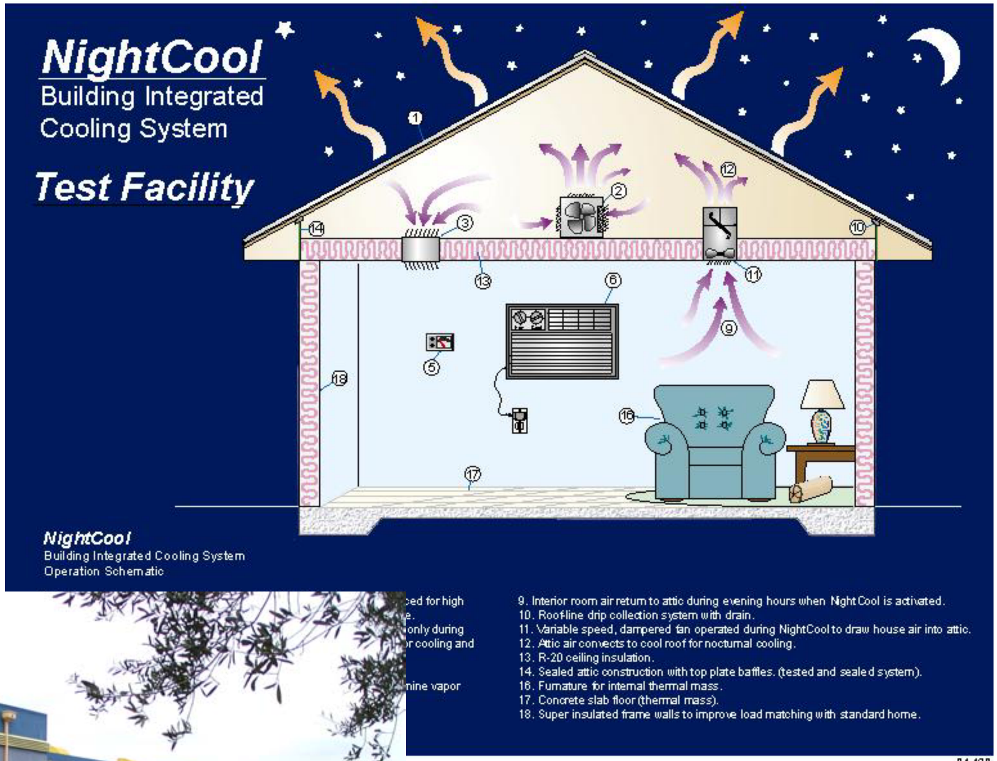
- Use dehumidfier with heat rejection to atti
- To be fully instrumented



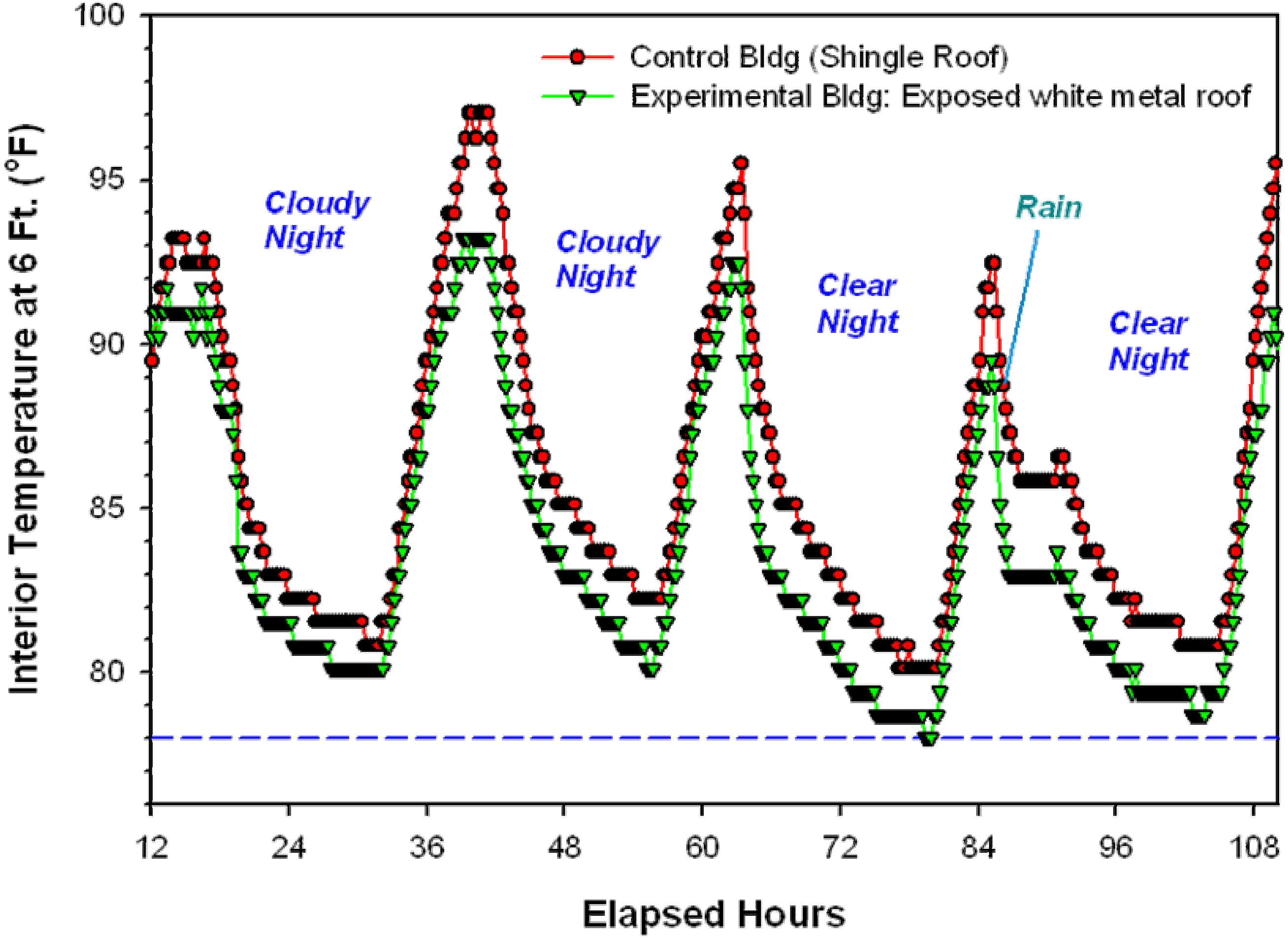
Two Test Buildings Completed…

Experimental has open metal roof…

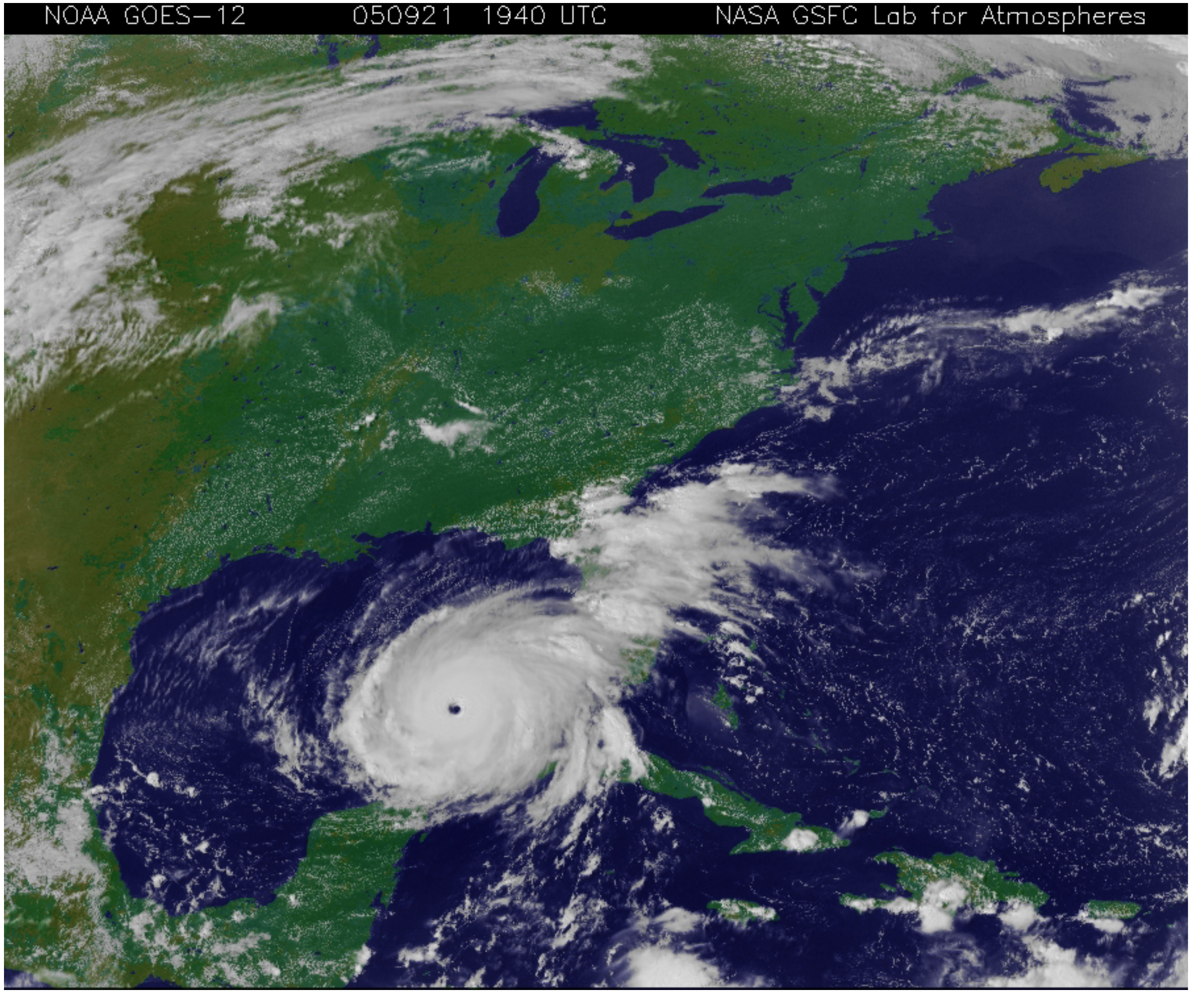
Thermal Performance of *NightCool* Test Buildings

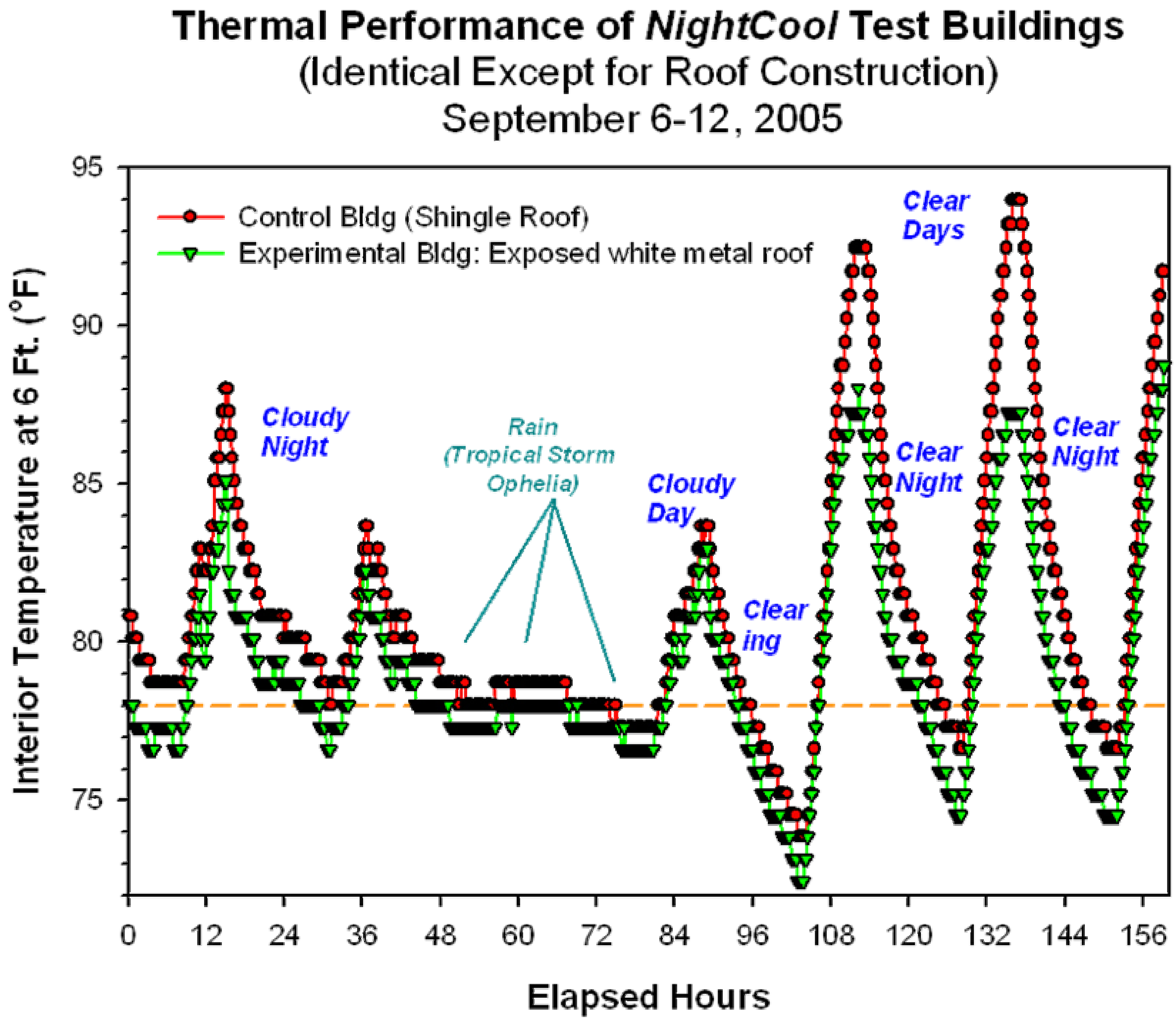
(Identical Except for Roof Construction)

Noon August 29 - 2 PM September 2, 2005



Other issues in Florida…



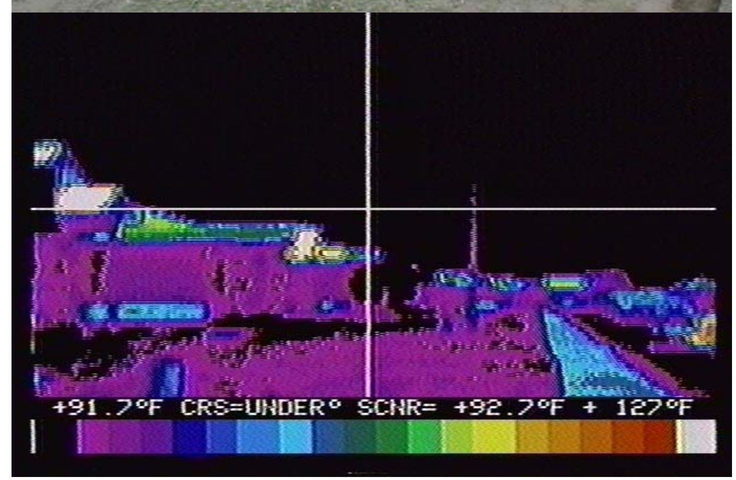

Thermal Performance of NightCool Test Buildings
(Identical Except for Roof Construction)
September 6-12, 2005
Control Bldg (Shingle Roof)
Experimental Bldg: Exposed white metal roof
Cloudy Night
Rain (Tropical Storm Ophelia)
Cloudy Day
Clearing
Clear Days
Clear Night
Clear Night
Interior Temperature at 6 Ft. (°F)
Elapsed Hours
95
90
85
80
75
0
12
24
36
48
60
72
84
96
108
120
132
144
156

Exposed White Metal Roof Runs Cooler…

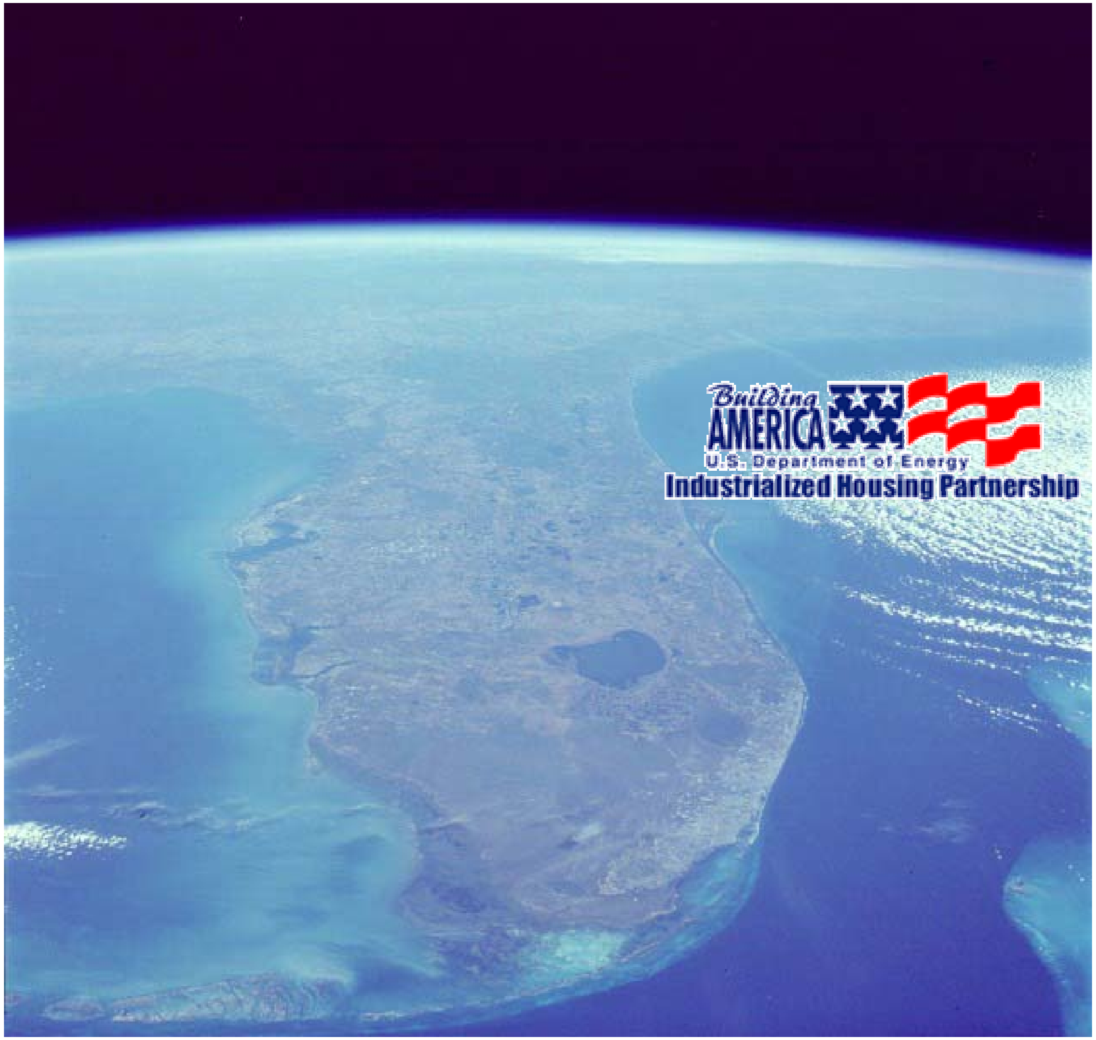
- Runs 2 ^{o}F cooler without space conditioning
- Runs up to ^{o}4 F cooler on clear summer days
- Instrumentation with conditioning/dehumidifica-tion system to begin later in autumn 2005

Getting advantages on the street…

- More reflective roofing is no cost option within any roofing type, but…
- Need to influence decision at time of construction or re-roof
- Metal will have greatest reflectance longevity
- *Chinese menu* approach
  - Reflective roof
  - Radiant Barrier
  - More insulation, interior ducts
  - Sealed attic with cool roofing
- Savings will be ~20-25% for cooling with very reflective roof
- 10 – 15% with moderately reflective tile roof with good venting
- ~10% for radiant barrier with good ventilation
- Peak savings are larger



Thank you!


Building
AMERICA
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Industrialized Housing Partnership