Comparative Evaluation of the Impact of Roofing Systems on Residential Cooling Energy Demand in Florida

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Executive Summary *(Also see the Full Paper, News Release and Photos)*

Roof and attic thermal performance exert a powerful influence on cooling energy use in Florida homes. Unshaded residential roofs are heated by solar radiation causing high afternoon attic air temperatures. The large influence on cooling is due to increased ceiling heat transfer as well as heat gains to the duct systems which are typically located in the attic space (Figure E-1).

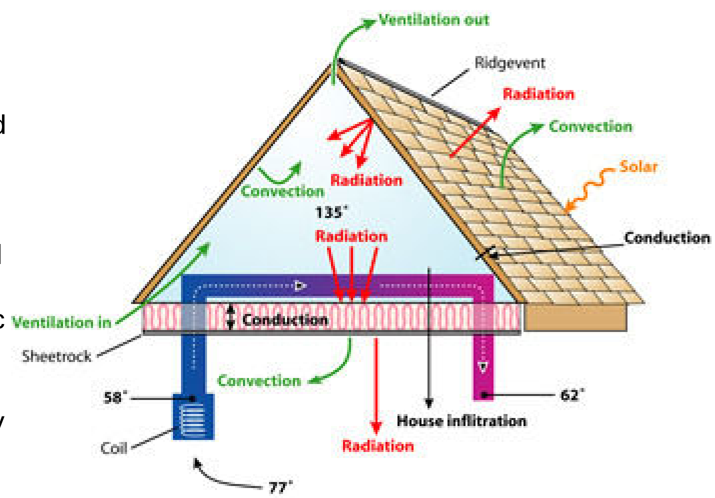

Figure E-1. Vented Attic Thermal Processes

The Florida Power and Light Company and the Florida Solar Energy Center instrumented six side-by-side Habitat homes in Ft. Myers, Florida with identical floor plans and orientation, R-19 ceiling insulation, but with different roofing systems designed to reduce attic heat gain. A seventh house had an unvented attic with insulation on the underside of the roof deck rather than the ceiling:

- (RGS) Standard dark shingles (control home)
- (RWS) Light colored shingles
- (RSL) Standard dark shingles with sealed attic and R-19 roof deck insulation
- (RWB) White "Barrel" S-tile roof
- (RWF) White flat tile roof
- (RTB) Terra cotta S-tile roof
- (RWM) White metal roof

Street scene showing the three closest homes (from left: white "barrel" s-tile (RWB), terra cotta s-tile (RTB) and white metal (RWM)).

All seven houses were completed by June 26th, 2000 with extensive testing to assure the buildings were similar. Each home was monitored simultaneously from July 8th - 31st in an unoccupied state.

Project Meterological Station

Building thermal conditions and air conditioning power were obtained on a 15-minute basis. Each of the examined alternative constructions exhibited superior performance to dark shingles. Figure E-2 plots the maximum daily air temperature to the maximum recorded at mid-attic in each construction. Figure E-3 shows the average daily attic air temperature profile.

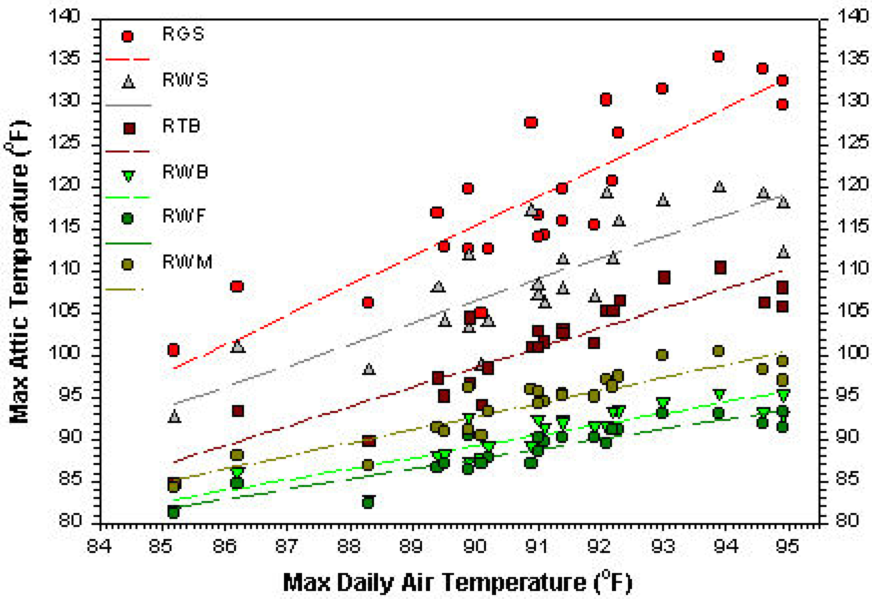

Figure E-2. Relationship of peak air to peak attic temperatures.

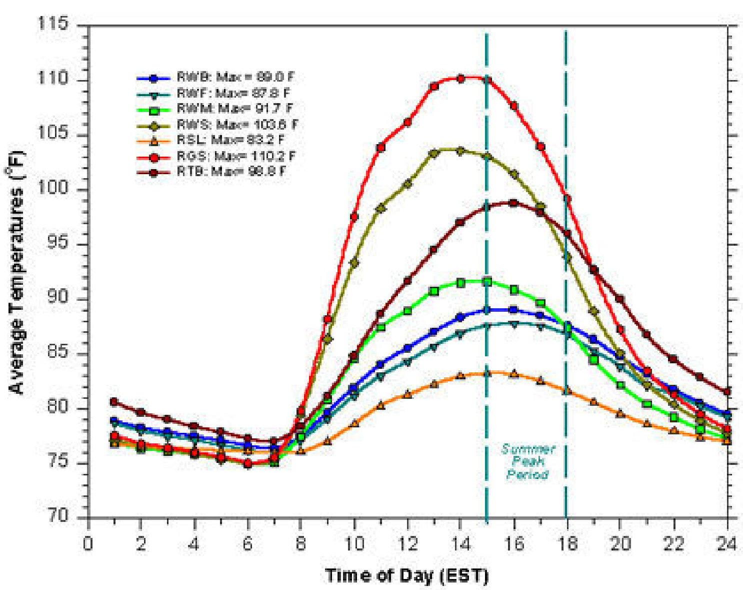

Figure E-3. Average attic air temperatures over unoccupied period.

The maximum attic temperature during the peak summer hour is 40 F greater than ambient air temperature in the control home while no greater than ambient with highly reflective roofing systems. Light colored shingles and terra cotta roofs show temperatures in between. Table E-1 summarizes the metered data from the unoccupied period and Figure E-4 shows the variation in space cooling load profiles in the test homes.

Table E-1. Cooling Performance During Unoccupied Period July 8th - 31st, 2000

Site	Total kWh	Savings kWh	Saved Percent	Demand kW	Savings kW	Saved Percent
RGS	17.03	----	----	1.63	----	----
RWS	15.29	1.74	10.2%	1.44	0.19	11.80%
RSL	14.73	2.30	13.5%	1.63	0.01	0.30%
RTB	16.02	1.01	5.9%	1.57	0.06	3.70%
RWB	13.32	3.71	21.8%	1.07	0.56	34.20%
RWF	13.20	3.83	22.5%	1.02	0.61	37.50%
RWM	12.03	5.00	29.4%	0.98	0.65	39.70%

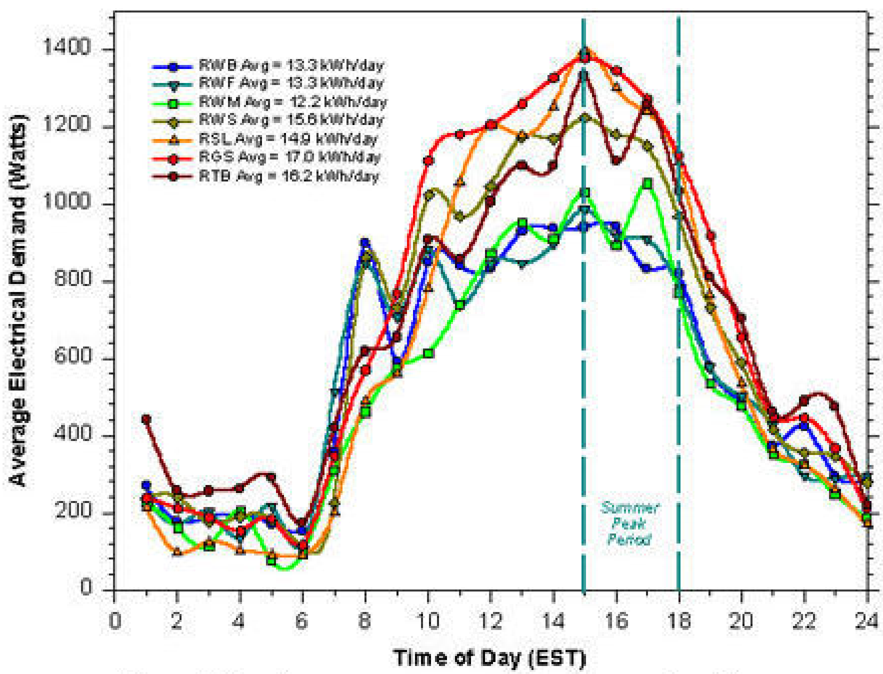

Figure E-4. Average space cooling demand profiles over the unoccupied period.

The above results are for the 1,144 square foot homes in the study. Since savings largely scale with ceiling area, the kWh and kW values should be normalized by the applicable ratio. For instance, typical FPL homes of 1,770 square feet would have estimated absolute savings 55% greater than above. Also, normalizations were made for slightly different thermostat set points and the measured performance of individual AC units.

Table E-2. Summary of Normalized Savings and Demand Reductions from Regression Estimates

Case Description	Cooling Savings		Peak Demand Reduction	
	kWh	Percent*	kW	Percent*
RGS(Control)	---	---	---	---
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.

Additional monitoring took place over a month long period with the homes occupied, but the thermostat set points were kept constant. Although average cooling energy use rose by 36%, analysis indicated no decrease to savings or demand reduction from the highly reflective roofing systems. The added heat gains from appliances and people increase cooling system run-time causing the duct system to run for longer periods to exchange heat from the often hot attic space.


White s-tile roof home


Terra cotta s-tile roof home


White metal roof home

The results in Tables E-1 and E-2, show essentially two classes of performance: white shingles, terra cotta tile and sealed attic construction which produce energy savings of 200 - 600 kWh/yr and demand reductions of 0.05 - 0.5 kW. Highly reflective roof systems produce energy savings of 1,000 - 1,600 kWh with demand reductions of 0.8 - 1.0 kW. A separate analysis of the data using a special version of the DOE-2.1E computer simulation verified the magnitude of the measured energy and demand reductions.

In summary, this evaluation strongly confirms the energy-saving benefits of using more reflective roofing systems in Florida. Selection of colors with higher solar reflectance will result in tangible cooling energy savings for customers. This is particularly true for roofing materials such as tile and metal, which are currently available with solar reflectances of 65%-75% range. The selection of reflective roofing systems represents one of the most significant energy-saving options available to homeowners and builders. Such systems also strongly reduce the cooling demand during utility coincident peak periods and may be among the most effective methods for controlling demand.

Acknowledgements

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Energy Seal Coatings

The study above showed that the white metal panels used on the house offered an energy savings of 23% over the control roof, standard dark shingle.

This energy savings was achieved with a white metal roof panel that offered 65% - 75% reflectance. Energy Seal Coatings Acu-Shield offers a reflectance of 88%. On average, this is 25% more efficient than the sample used in this report.

Once again, this show's that Energy Seal Coatings can provide an excellent solution reducing energy usage and saving money.