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To: Chris Scruton (CEC)
From: Steve Wiel
Subject: **Cool Roof Colored Materials**: Monthly Progress Report for December 2004
CC: Hashem Akbari, Paul Berdahl, Andre Desjarlais, Bill Miller, Ronnen Levinson

A summary of the status of Tasks and Deliverables as of December 31, 2004 is presented in Attachment 1. (Note the changes in the deliverables dates highlighted in yellow.)

HIGHLIGHTS

- **Task 2.4.1 Completed**. Our two pigment papers are in press at *Solar Energy Materials & Solar Cells*; we have provided the final drafts of these papers to the Energy Commission.
- **Task 2.4.3 Completed**. We have submitted to the Energy Commission's Project Manager an HTML version of our pigment database.
- A paper titled "Experimental Analysis of the Natural Convection Effects Observed within the Closed Cavity of Tile Roofs" was prepared and submitted in response to the roofing symposium call for papers announced by the Roof Consultants Institute.

Tasks

1.1 Attend Kick-Off Meeting
This Task is completed.

1.2 Describe Synergistic Projects
This Task is completed.

2.1 Establish the Project Advisory Committee (PAC)
This Task is completed.

2.2 Software Standardization
(No activity.)

2.3 PAC Meetings
(No activity.)

2.4 Development of Cool Colored Coatings

2.4.1 Identify and Characterize Pigments with High Solar Reflectance

Task Completed. Our two pigment papers are in press at *Solar Energy Materials & Solar Cells*; we have provided the final drafts of these papers to the Commission.

2.4.2 Develop a Computer Program for Optimal Design of Cool Coatings
We continue to improve the mixture model on which our coating formulation software is based, and to develop the optimization algorithm.

2.4.3 Develop a Database of Cool-Colored Pigments
Task Completed. We have submitted to the CEC an HTML version of our pigment database that augments measured and computed solar spectral radiative properties with images of pigmented coatings, performance data from manufacturers, and technical commentary derived from our pigment papers.

2.5 Development of Prototype Cool-Colored Roofing Materials

2.5.1 Review of Roofing Materials Manufacturing Methods
Task Completed. The revised paper was distributed to the Industry Partners at the September PAC meeting. We have received reviewers' comments for the report. We updated the report and sent it for publication in December 2004.

2.5.2 Design Innovative Methods for Application of Cool Coatings to Roofing Materials
We continued working with manufacturers in developing cool shingle prototypes.

2.5.3 Accelerated Weathering Testing
We are collecting references and assembling a bibliography on the topic of accelerated aging. Besides journal articles, we are using pigment and materials manufacturers' product data, and several ASTM standards. Some companies find accelerated aging to be very important (e.g., metal roof coating manufacturers), while others state that it is not useful for their products (e.g., concrete pavers).

2.6 Field-Testing and Product Useful Life Testing
Efforts are in progress to contact and acquire accelerated test data for tile, painted metal, cedar shake and asphalt shingle roof products. Requests were made of MonierLifetile, Hanson Roof tile and American Roof Tile coatings for accelerated QUV data. Similar requests were made of the Cedar Shake Bureau, Ferro Corporation and BASF. Granule manufacturers at 3M and ISP are also being contacted for pertinent information that would prove the positive benefits of cool roofing materials.

2.6.1 Building Energy-Use Measurements at California Demonstration Sites
Jerry Wagar of Ochoa and Shehan Inc. estimates that construction of the two demonstration homes in Redding CA will be completed in February. ORNL personnel will then install data acquisition and power measurement equipment. The type and scheme of measurements for the Redding site will be very similar to the setup used at Cavalli Hills. However, in addition to the surface and deck temperatures, we will measure the underside temperature of a shingle to view the temperature gradient across one shingle as well as the gradient across the overlap of two shingles (see Appendix A, Table A1 and A2 showing the setup of measurements for the new demonstrations).

Whole house power measurements from the transducers supplied by SMUD were checked against readings from the revenue meters monitoring power for each of the demonstration homes at Cavalli Hills. The revenue meter and the Rochester Series PM-100 watthour meters gave similar measurements for three of the four homes for data collected from Oct 17 through Nov 15, 2004 (Table 1).

Table 1. Comparison of Whole House Power Meters in Use at Cavalli Hills.

SMUD Meters	Date		House and Address			
			1	2	3	4
	From	To	4979 Mariah Place	4983 Mariah Place	4987 Mariah Place	4991 Mariah Place
Revenue Meter (kWh)	10/17/2004	11/15/2004	361	489	633	116
Pulse Transducer (kWh)	10/17/2004	11/15/2004	4171	486	623	116
Error (%)	10/17/2004	11/15/2004	1055.50	0.59	1.62	0.13

The error is about 1.5% of reading of the revenue meters. House 1 shows a huge error because the revenue meter was defective during the measurement period. Since then, SMUD has replaced the defective meter, and power draws for December will be forwarded to validate the accuracy of measurement for the house at 4979 Mariah Place.

2.6.2 Materials Testing at Weathering Farms in California
(No activity)

2.6.3 Steep-slope Assembly Testing at ORNL
One of the key advantages of applying cool colored coating to roofing products is the effect of reduced surface temperature, which should positively affect the fade resistance and useful life of the roof product. Surface temperature data collected from November 5 to 12, 2004 are plotted in Figure 1 for a brown slate tile (SR13E83),[1] a prototype cool-colored asphalt shingle (SR24E95) and also a standard production shingle (SR09E95) all being exposed on the steep-slope attic assembly at ORNL.

Peak surface temperatures of the shingle with cool-colored coatings are about 15 to 20°F cooler than those measured for the standard production shingle. The prototype shingle does not quite meet the 0.25 reflectance criterion for steep-slope roofs; however, the 15 to 20°F reduction in temperature is very encouraging because the reduced heat aging will reduce changes in the chemical and flexural properties of the shingles as compared to existing shingle technology on the open market. During this November week, the sunlit outdoor ambient temperature did not exceed 70°F and the evening lows were about 35 to 40ºF. We have measured summertime surface temperatures for the standard production shingle in excess of 150°F. It will be of keen interest to observe the temperature differences on the demonstrations in Redding, CA especially since the summer air temperatures can exceed 100°F.

[1] "SRxx" states the solar reflectance; "Eyy" defines the thermal emittance.

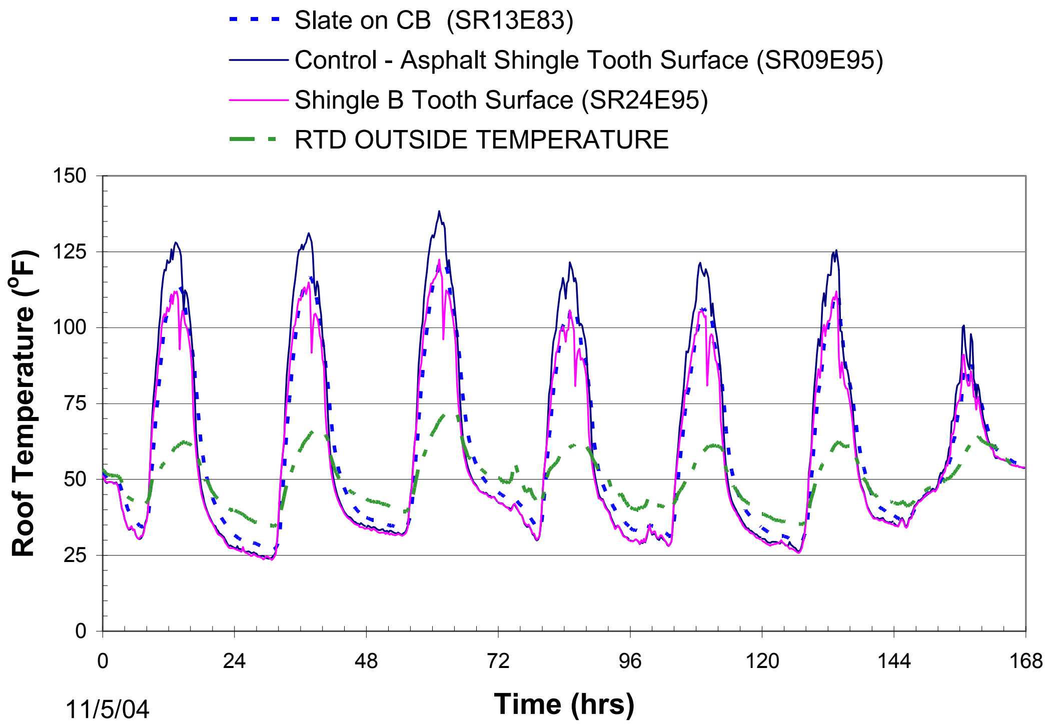

Figure 1. Surface temperatures measured on the ESRA steep-slope assembly at ORNL

It is also very interesting to compare the almost identical nighttime surface temperatures for the two shingle products with the surface temperature of the concrete slate tile placed on counter-battens (e.g., Fig. 1, see data logged at multiples of 24 which represent midnight). The nighttime surface temperature of the concrete tile is higher than either shingle due in part to the tile's lower thermal emittance, its higher thermal mass and possibly due to the air gap occurring in its batten support structure. The higher surface temperature causes the attic temperature for the tile roof assembly to be about 5°F warmer than that of the direct nailed shingle attic assemblies, which in turn reduces the heat leakage from the conditioned space into the tile's attic assembly as compared to the shingle assemblies. The portions of reduced heat leakage attributable to thermal emittance, thermal mass and deck venting are to be investigated using AtticSim once the code is validated against the tile roof systems.

2.6.4 Product Useful Life Testing

We are collecting information on the weathering of roofing materials. Important subtopics include ultraviolet damage, the effects of corrosion, heat, and moisture. When a bibliography has been assembled and an outline of our forthcoming review article is complete, they will be circulated to our industrial partners.

2.7 Technology transfer and market plan

2.7.1 Technology Transfer

A paper was prepared and submitted in response to the roofing symposium call for papers announced by the Roof Consultants Institute. The paper “Experimental Analysis of the Natural Convection Effects Observed within the Closed Cavity of Tile Roofs” will be presented May 12, 2005 pending review input by the Cool Team and by RCI’s outside peer review.

2.7.2 Market Plan
(No activity.)

2.7.3 Title 24 Code Revisions
Akbari continues working with PG&E and Energy Commission to develop a plan for code change proposal for sloped-roof residential buildings.

Management Issues

- None.

Attachment 1

Project Tasks and Schedules (*Approved on May 16, 2002; Revised schedules approved November 2004*)

Task	Task Title and Deliverables	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 12/31/2004
1	**Preliminary Activities**					
1.1	Attend Kick Off Meeting *Deliverables:* • Written documentation of meeting agreements and all pertinent information (**Completed**) • Initial schedule for the Project Advisory Committee meetings (**Completed**) • Initial schedule for the Critical Project Reviews (**Completed**)	5/16/02	5/16/02	6/1/02	6/10/02	100%
1.2	Describe Synergistic Projects *Deliverables:* • A list of relevant on-going projects at LBNL and ORNL (**Completed**)	5/1/02	2/1/02	5/1/02	5/1/02	100%
1.3	Identify Required Permits	N/A		N/A		
1.4	Obtain Required Permits	N/A		N/A		
1.5	Prepare Production Readiness Plan	N/A		N/A		
2	**Technical Tasks**					
2.1	Establish the project advisory committee *Deliverables:* • Proposed Initial PAC Organization Membership List (**Completed**) • Final Initial PAC Organization Membership List • PAC Meeting Schedule (**Completed)** • Letters of Acceptance	6/1/02	5/17/02	9/1/02		100%
2.2	Software standardization *Deliverables:* • When applicable, all reports will include additional file formats that will be necessary to transfer deliverables to the CEC • When applicable, all reports will include lists of the computer platforms, operating systems and software required to review upcoming software deliverables	N/A		N/A		

Project Tasks and Schedules (contd.)

Task	Task Title and Deliverables	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 12/31/2004
2.3	PAC meetings *Deliverables:* • Draft PAC meeting agenda(s) with back-up materials for agenda items • Final PAC meeting agenda(s) with back-up materials for agenda items • Schedule of Critical Project Reviews Draft PAC Meeting Summaries • Final PAC Meeting Summaries	9/1/02	6/1/02	6/1/05		83% (5/6)
2.4	Development of cool colored coatings					
2.4.1	Identify and Characterize Pigments with High Solar Reflectance *Deliverables:* • Pigment Characterization Data Report (**Completed)**	6/1/02	6/1/02	12/1/04 → 12/31/04		~ 99%
2.4.2	Develop a Computer Program for Optimal Design of Cool Coatings *Deliverables:* • Computer Program	11/1/03	11/1/03	12/1/04 → 5/1/05		~ 85%
2.4.3	Develop a Database of Cool-Colored Pigments *Deliverables:* • Electronic-format Pigment Database (**Completed)**	6/1/03	7/1/03	6/1/05 → 12/31/04		~ 95%
2.5	Development of prototype cool-colored roofing materials					
2.5.1	Review of Roofing Materials Manufacturing Methods *Deliverables:* • Methods of Fabrication and Coloring Report (**Completed)**	6/1/02	6/1/02	6/1/03		~ 99%
2.5.2	Design Innovative Methods for Application of Cool Coatings to Roofing Materials *Deliverables:* • Summary Coating Report • Prototype Performance Report	6/1/02	6/1/02	12/1/04 → 5/1/05		~ 90%
2.5.3	Accelerated Weathering Testing *Deliverables:* • Accelerated Weathering Testing Report	11/1/02	10/1/02	6/1/05 → 10/1/05		~ 30%

Project Tasks and Schedules (contd.)

Task	Task Title	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 12/31/2004
2.6	Field-testing and product useful life testing					
2.6.1	Building Energy-Use Measurements at California Demonstration Sites *Deliverables:* • Demonstration Site Test Plan • Test Site Report	6/1/02	9/1/02	10/1/05 → 10/1/06		84%
2.6.2	Materials Testing at Weathering Farms in California *Deliverables:* • Weathering Studies Report	6/1/02	10/1/02	10/1/05 → 10/1/06		65%
2.6.3	Steep-slope Assembly Testing at ORNL *Deliverables:* • Whole-Building Energy Model Validation • Presentation at the Pacific Coast Builders Conference • Steep Slope Assembly Test Report	6/1/02	10/1/02	10/1/05		70%
2.6.4	Product Useful Life Testing *Deliverables:* • Solar Reflectance Test Report	5/1/04	5/1/04	6/1/05 → 10/1/05		30%
2.7	Technology transfer and market plan					
2.7.1	Technology Transfer *Deliverables:* • Publication of results in industry magazines and refereed journal articles • Participation in buildings products exhibition, such as the PCBC Brochure summarizing research results and characterizing the benefits of cool colored roofing materials	6/1/03	6/1/02	6/1/05		~ 80%
2.7.2	Market Plan *Deliverables:* • Market Plan(s)	5/1/05		6/1/05		
2.7.3	Title 24 Code Revisions *Deliverables:* • Document coordination with Cool Roofs Rating Council in monthly progress reports • Title 24 Database	6/1/02	5/16/02	6/1/05		~ 30%

Project Tasks and Schedules (contd.)

Task	Task Title	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 12/31/2004
VII	Critical Project Review(s) *Deliverables:* • Minutes of the CPR meeting					
XII (C)	Monthly Progress Reports *Deliverables:* • Monthly Progress Reports	6/1/02	6/1/02	6/1/05		78% (28/36)
XII (D)	Final Report *Deliverables:* • Final Report Outline • Final Report	3/1/05 → 3/31/05		10/1/05 → 10/1/06		
	Final Meeting *Deliverables:* • Minutes of the CPR meeting	10/15/05		10/31/05		

Appendix A

Table A1. Instrument measurements for the home having a standard production shingle roof. The house is located near the end of a cul-de-sac at 2605 Eel Street, Redding CA..

Instrument	Description	Location	Attachment	Channel	
East Facing Roof					
Thermocouple (Type T Cu/Con)	26 AWG Unshielded bead	Top of Roof Shingle	Epoxy	8 T	
"	26 AWG Unshielded bead	Underside of Shingle	Epoxy	7 T	
"	26 AWG Unshielded bead	Topside of Deck (between OSB & felt paper)	Taped	6 T	
Heat Flux Transducer	2-in by 2-in by 0.125-in thick	In Deck	Embedded in OSB	2 Rd^{+}	2880
Pyranometer Li-Cor	Solar Probe	Near ridge at roof gable	Mounting bracket	4 Rd^{+}	48819
Thermocouple (Type T Cu/Con)	26 AWG Unshielded bead	Underside of Deck (facing attic)	Taped	5 T	
West Facing Roof					
Thermocouple (Type T Cu/Con)	26 AWG Unshielded bead	Top of Roof Shingle	Epoxy	4 T	
"	26 AWG Unshielded bead	Underside of Shingle	Epoxy	3 T	
"	26 AWG Unshielded bead	Topside of Deck (between OSB & felt paper)	Taped	2 T	
Heat Flux Transducer	2-in by 2-in by 1/8-in thick	In Deck	Embedded in OSB	1 Wh^{+}	48792
Pyranometer Li-Cor	Solar Probe	Near ridge at roof gable	Mounting bracket	5 Rd^{+}	
Thermocouple (Type T Cu/Con)	26 AWG Unshielded bead	Underside of Deck (facing attic)	Taped	1 T	
Attic interior					
Vaisala 50Y	DB & RH Probe	Attic air 4-ft above insulation	Run along support wire	6**	X4440074
Thermocouple (Type T Cu/Con)	26 AWG Shielded bead	Top of insulation	Laid atop insulation	10 T	
	26 AWG Unshielded bead	Sheet rock surface facing attic	Taped	9 T	
Heat Flux Transducer	2-in by 2-in by 1/8-in thick	Sheet rock surface facing attic	Sandwiched between insulation and sheet rock	3 Rd^{+}	2867
House exterior above ridge vent (Not Applicable)					
Vaisala 50Y	DB & RH Probe	Ambient air 3-ft above roof	Mounting bracket	NA	
Anemometer	Wind velocity	Ambient air 3-ft above roof	Mounting bracket	NA	
Wind Vane	Wind direction	Ambient air 3-ft above roof	Mounting bracket	NA	
House interior					
Vaisala 50Y	DB & RH Probe	Entering return grill	Duct mounted	7**	X4440090
Thermocouple (Type T Cu/Con)	26 AWG Unshielded bead	Leaving evaporator coil	Run along support wire	11 T	
Wattnode transducer	Model WNA-1P-240-P	Total House Power	NEMA enclosure on exterior wall	8 Rd^{+}	______
Wattnode transducer	Model WNA-1P-240-P	HVAC Power	NEMA enclosure on exterior wall	9 Wh^{+}	______
ACL1 Event counter	OPTI-Line Monitor with DC power supplied by CR10X	HVAC cycling rate	Installed in outdoor condensing unit	10	______
** 5-wire shielded cable with Bk for temperature, Br for RH, Gr for signal & power reference, Rd for Power and Clear for Shield.					

Table A2. Instrument measurements for the home having a CRCM shingle roof.
The house is located near the end of a cul-de-sac at 2605 Loggerhead St., Redding CA.

Instrument	Description	Location	Attachment	Channel	
West Facing Roof					
Thermocouple (Type T Cu/Con)	26 AWG Unshielded bead	Top of Roof Shingle	Epoxy	8 T	
"	26 AWG Unshielded bead	Underside of Shingle	Epoxy	7 T	
"	26 AWG Unshielded bead	Topside of Deck (between OSB & felt paper)	Taped	6 T	
Heat Flux Transducer	2-in by 2-in by 0.125-in thick	In Deck	Embedded in OSB	2 Rd^{+}	2879
Pyranometer Li-Cor	Solar Probe	Near ridge at roof gable	Mounting bracket	4 Rd^{+}	48824
Thermocouple (Type T Cu/Con)	26 AWG Unshielded bead	Underside of Deck (facing attic)	Taped	5 T	
East Facing Roof					
Thermocouple (Type T Cu/Con)	26 AWG Unshielded bead	Top of Roof Shingle	Epoxy	4 T	
"	26 AWG Unshielded bead	Underside of Shingle	Epoxy	3 T	
"	26 AWG Unshielded bead	Topside of Deck (between OSB & felt paper)	Taped	2 T	
Heat Flux Transducer	2-in by 2-in by 1/8-in thick	In Deck	Embedded in OSB	1 Wh^{+}	2878
Pyranometer Li-Cor	Solar Probe	Near ridge at roof gable	Mounting bracket	5 Rd^{+}	48870
Thermocouple (Type T Cu/Con)	26 AWG Unshielded bead	Underside of Deck (facing attic)	Taped	1 T	
Attic interior					
Vaisala 50Y	DB & RH Probe	Attic air 4-ft above insulation	Run along support wire	6**	Z2340043
Thermocouple (Type T Cu/Con)	26 AWG Shielded bead	Top of insulation	Laid atop insulation	10 T	
	26 AWG Unshielded bead	Sheet rock surface facing attic	Taped	9 T	
Heat Flux Transducer	2-in by 2-in by 1/8-in thick	Sheet rock surface facing attic	Sandwiched between insulation and sheet rock	3 Rd^{+}	2873
House exterior above ridge vent (Not Applicable)					
Vaisala 50Y	DB & RH Probe	Ambient air 3-ft above roof	Mounting bracket	NA	
Anemometer	Wind velocity	Ambient air 3-ft above roof	Mounting bracket	NA	
Wind Vane	Wind direction	Ambient air 3-ft above roof	Mounting bracket	NA	
House interior					
Vaisala 50Y	DB & RH Probe	Entering return grill	Duct mounted	7**	X4350018
Thermocouple (Type T Cu/Con)	26 AWG Unshielded bead	Leaving evaporator coil	Run along support wire	11 T	
Wattnode transducer	Model WNA-1P-240-P	Total House Power	NEMA enclosure on exterior wall	8 Rd^{+}	_______
Wattnode transducer	Model WNA-1P-240-P	HVAC Power	NEMA enclosure on exterior wall	9 Wh^{+}	_______
ACL1 Event counter	OPTI-Line Monitor with DC power supplied by CR10X	HVAC cycling rate	Installed in outdoor condensing unit	10	_______
** 5-wire shielded cable with Bk for temperature, Br for RH, Gr for signal & power reference, Rd for Power and Clear for Shield.					