ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Stephen Wiel, Project Director
Energy Analysis Department
Environmental Energy Technologies Division

MS 90R4000
1 Cyclotron Road
Berkeley, CA 94720-8136

Tel. 510-486-5396
Fax: 510-486-6996
e-mail: Swiel@lbl.gov

November 10, 2004

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

A summary of the status of Tasks and Deliverables as of October 31, 2004 is presented in Attachment 1.

HIGHLIGHTS

- We completed Task 2.4.1. Our pair of pigment-characterization papers, "Solar Spectral Optical Properties of Pigments, Part I: Model for Deriving Scattering and Absorption Coefficients from Transmittance and Reflectance Measurements" and "Solar Spectral Optical Properties of Pigments, Part II: Survey of Common Colorants" were accepted without revision for publication in *Solar Energy Materials & Solar Cells*.
- We scheduled instrumenting the roofing shingles demonstration houses in Redding, CA in first week of December 2004.
- On October 27, 2004, LBNL hosted a Cool Roof Rating Council (CRRC)-sponsored training course for measuring optical properties of roofing materials.
- On October 14, 2004, at the Emerging Technologies in Energy Efficiency-Summit 2004, LBNL presented a seminar on development of cool colored roofing materials.

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 pair of pigment-characterization papers, "Solar Spectral Optical Properties of Pigments, Part I: Model for Deriving Scattering and Absorption Coefficients from Transmittance and Reflectance Measurements" and "Solar Spectral Optical Properties of Pigments, Part II: Survey of Common Colorants" were accepted without revision for publication in *Solar Energy Materials & Solar Cells*.

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
We made small updates to the data base.

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 sent the paper for LBNL publication. Western Roofing Magazine has reviewed the report and is interested in publishing it.

2.5.2 Design Innovative Methods for Application of Cool Coatings to Roofing Materials
We characterized the reflectances of a number of new shingle prototypes.

We developed an Excel workbook that implements a Monte Carlo (random sampling) technique to measure the solar reflectance of a non-uniform surface (e.g., a blended roofing shingle) through a series of ASTM C1549 (reflectometer) spot measurements of solar reflectance. We have shared the algorithm, procedure, and workbook with the Cool Roof Rating Council, and also with attendees of our October LBNL/CRRC workshop on the measurement of solar reflectance and thermal emittance.

We have completed and sent for internal review a draft paper describing a new technique ("E1918M", a proposed modification to the existing ASTM E1918 test method) for measuring solar reflectance via a series of three pyranometer measurements of reflected solar radiation. The target area required by E1918M (1 m^2) is an order of magnitude smaller than that required by ASTM E1918 (10 m^2), making E1918M more convenient to apply to roofing product samples.

2.5.3 Accelerated Weathering Testing
We requested accelerated weathering data from 3M Minerals, ISP Minerals, Elk and the Shepherd Color Company. We have not received any data yet.

2.6 Field-Testing and Product Useful Life Testing
ORNL personnel are ready to instrument a pair of homes in Redding CA with asphalt shingles with and without cool colored pigments. A Memorandum of Understanding was written and forwarded to Ochoa and Shehan Inc. and Elk for review of the work proposed on the pair of demonstration homes.

2.6.1 Building Energy-Use Measurements at California Demonstration Sites

Jerry Wagar of Ochoa and Shehan Inc. asked ORNL personnel to delay their visit to Redding, CA because construction of the pair of homes is behind schedule. Wagar will install the instrumented sandwich panels during roof construction. Wagar now estimates the homes will be ready about the first week of December. A Memorandum of Understanding (MOU) was prepared at Wagar's request to outline responsibilities for ORNL, LBNL, Ochoa and Shehan Inc., the shingle manufacturer and the future home owners of the pair of homes in Redding CA (Appendix A). The MOU calls for a representative of the shingle manufacturer to retrieve at least one and possibly three shingles per year from each home. The shingle manufacturer will then conduct mechanical tests showing whether the shingles with cool colored pigments perform as well as their standard production shingles.

Testing is proceeding for determining whether cool colored pigments can be successfully applied to cedar shakes during the process of adding fire retardants. FERRO Corporation shipped about 30 lbs of cool colored pigments to Steve Harris of the Cedar Shake Bureau for determining the effect of cool colored pigments on the fire resistance of cedar shakes.

Wim Boss of SMUD resolved part of the power measurement errors at Cavalli Hills. First, the defective revenue meter at 4979 Mariah Place was replaced. Secondly Boss replaced the transducer measuring the power of the air-conditioner with the type originally configured at the factory by Campbell Scientific. The original transducer was a normally open switch which closes while sensing a pulse. SMUD's meter group provided Boss with transducers having a normally closed switch that opens when a pulse is sensed. The data loggers should sense either logic; however, a scan of the data shows that the logger at 4979 Mariah Place appears to be sensing the compressor power. We emphasize "appears to be" because the home owners have not air-conditioned their respective homes. Steve Burke, the real estate broker who sold the homes, stated the original owners speculated and resold them. Three of the four homes will be occupied by December and the fourth is in escrow pending sale. Mr. Burke therefore believes we should start seeing power draws; however, he will forward ORNL the names and phone numbers of the home owners if we need to work out a deal whereby any residents who operate their air-conditioners at ORNL's request will be reimbursed utility expenses during the upcoming summer months.

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

2.6.3 Steep-slope Assembly Testing at ORNL

Bulk air temperature and heat flux measurements made from soffit to vent on the S-Mission tile roof of the Envelop Systems Research Apparatus (ESRA) shows the heat transfer to be a uniform constant flux because the temperature profile is linear with length. Therefore an integral technique was used to derive a closed form constant flux solution to the buoyant flow of air traversing up an inclined duct similar to that made by a tile roof. The flow of air through such a duct is primarily due to buoyancy induced heat transfer as the sun's irradiance heats the tile. We used the following Nusslet number equation to calculate the local heat transfer due to natural convection.

Error! Objects cannot be created from editing field codes.

The approximate solution was derived for estimating the strength of the natural convection heat transfer coefficient as compared to forced convection heat transfer induced by wind driven forces.

In the September report, validations of AtticSim showed excellent agreement to field measurements for the direct nailed shingle roof. As a first effort, AtticSim is being

modified to include an air gap (i.e., ducting system atop the roof deck simulating the tile roof) and correlations for heat transfer (as shown above) are being implemented for validating AtticSim against summer data for tile roof systems. Catton (*Int. Heat Transfer Conf. v6. 1979*) provides correlations for the case where the inclined duct is heated from below (typical of winter operation).

2.6.4 Product Useful Life Testing

This task is focused on a literature review of this subject, with a report to be issued by LBNL. ORNL and Elk will complete some mechanical testing on exposed cool asphalt shingles; the specific tests are being reviewed by Elk and are not yet determined.

We are reviewing the ASTM literature on standards for asphalt shingles. We are also interviewing industry experts to obtain their opinions as to the best test procedures. There is no industry consensus on accelerated aging tests, for example. Information posted on the ARMA website is helpful in summarizing the overall situation. One industry standard, D3462, is widely used and consists of a number of tests, including tear strength. (Other tests incorporated include softening point of asphalt used, minimum weight, weight loss under heating, fire resistance (Class A), wind resistance (Class A), fastener pull through resistance, and pliability.) To quote from the ARMA website: "The ARMA maintains that tensile strength, tensile elongation, and shingle flexibility are better indicators of potential resistance to shingle splitting than tear strength... ARMA maintains that some shingles that don't meet D3462 perform adequately."

2.7 Technology transfer and market plan

2.7.1 Technology Transfer

On October 27, 2004, LBNL hosted a Cool Roof Rating Council (CRRC)-sponsored training course for measuring optical properties of roofing materials.

On October 14, 2004, at the Emerging Technologies in Energy Efficiency-Summit 2004, Akbari presented a seminar on development of cool colored roofing materials.

2.7.2 Market Plan

(No activity.)

2.7.3 Title 24 Code Revisions

Akbari is working with PG&E and Energy Commission to develop a plan for code change proposal for sloped-roof residential buildings.

Management Issues

- Scruton and Akbari are fine-tuning the schedules of project tasks and deliverables.

Attachment 1

Project Tasks and Schedules (*Approved on May 16, 2002*)

Task	Task Title and Deliverables	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 10/31/2004
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 10/31/2004
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	6/1/02	6/1/02	12/1/04		~ 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		~ 80%
2.4.3	Develop a Database of Cool-Colored Pigments *Deliverables:* • Electronic-format Pigment Database	6/1/03	7/1/03	6/1/05		~ 80%
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	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		~ 90%
2.5.3	Accelerated Weathering Testing *Deliverables:* • Accelerated Weathering Testing Report	11/1/02	10/1/02	6/1/05		~ 20%

Project Tasks and Schedules (contd.)

Task	Task Title	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 10/31/2004
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		80%
2.6.2	Materials Testing at Weathering Farms in California *Deliverables:* • Weathering Studies Report	6/1/02	10/1/02	10/1/05		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		65%
2.6.4	Product Useful Life Testing *Deliverables:* • Solar Reflectance Test Report	5/1/04	5/1/04	6/1/05		20%
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		~ 75%
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		~ 15%

Project Tasks and Schedules (contd.)

Task	Task Title	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 10/31/2004
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		75% (27/36)
XII (D)	Final Report *Deliverables:* • Final Report Outline • Final Report	3/1/05		10/1/05		
	Final Meeting *Deliverables:* • Minutes of the CPR meeting	10/15/05		10/31/05		

Appendix A

Draft Memorandum of Understanding

Demonstration of Standard Production Asphalt Shingles and Advanced Shingles having Cool Roof Color Materials on Homes in Redding, CA

This Memorandum of Understanding represents an agreement by Oak Ridge National Laboratory (ORNL), the Elk Group Inc. and Ochoa and Shehan Inc, a residential construction firm in Redding, CA to cooperate in the field testing and demonstration of cool roof colored materials (CRCM).

Whereas, the California Energy Commission (CEC) has contracted the Lawrence Berkeley National Laboratory (LBNL) and the Oak Ridge National Laboratory (ORNL) to develop cool roof colored materials (CRCM) that are visibly dark but can reflect light like a "white" roof in the infrared portion of the solar energy spectrum.

LBNL and ORNL are working with the tile, metal, cedar shake and asphalt-shingle roofing industries to accomplish the CEC goal of making CRCM a market reality for all residential roof products within the next five years.

Whereas, the CEC's objectives are 1) to offer consumers information that promotes the development and increased use of highly reflective CRCM and 2) to develop colored composition shingles with solar reflectance of at least 25% and tile and metal materials with reflectance of 50% or more.

Whereas, the Building Envelope Group of the ORNL intends, with support from the Elk Group Inc. and the cooperation of Ochoa and Shehan Construction to set up in November 2004 two residential demonstrations consisting of a pair of single-family detached homes that have composition shingle roofs with and without cool roof color materials.

Whereas, Elk is providing asphalt shingles at no cost for Ochoa and Shehan Construction to install on two homes in Redding CA in exchange for acquiring temperature, heat flow and power measurements for the two homes over the course of a two year field study.

ORNL personnel will instrument the two homes during construction slated for November 2004, and will monitor the homes over a two-year period ending October 2006.

Whereas, Table 1 lists all the instrument measurements currently proposed by ORNL and Elk

Therefore, the parties agree to undertake the activities described below or otherwise agreed in writing during the course of the demonstration project:

Demonstration Homes

1. Ochoa and Shehan Construction will make two demonstration houses available in 2004 for the field testing demonstrations described below.

<u>Instrumentation for each Home</u>

2. ORNL personnel shall make 2-ft by 2-ft sandwich test panels of the same material as used for the roof decks at the demonstration homes, probably oriented strand board (OSB). Each sandwich

panel will be made of two sections equaling the same thickness as the rest of the deck. The two panels will sandwich thermocouples and a heat flux transducer for measuring thermal performance of the roofs. A spare thermocouple will be included for possibly measuring the surface temperature of the shingle roofs.

3. Ochoa and Shehan Construction will notify ORNL of the start date for constructing the roof decks, and ORNL shall ship sandwich test panels to Ochoa and Shehan Construction prior to the specified start date.

4. ORNL will contract Ochoa and Shehan Construction to install the sandwich test panels as part of the deck for the test roofs. The orientation of the homes makes it necessary to use two panels per house.
The roofing contractor will center and attach one panel to preferably a south-facing roof and center and attach the other to preferably the north-facing roof.

5. ORNL personnel under the supervision of Ochoa and Shehan Construction shall instrument the attic for measuring the attic air temperature and relative humidity and the temperatures around the ceiling insulation as well as the ceiling heat flux. A temperature and relative humidity probe will be mounted in the return duct to measure the return air temperature and relative humidity from the house (see Table 1 for a listing of measurements).

6. ORNL personnel under the supervision of Ochoa and Shehan Construction will install two Model WNA-1P-240-P Wattnode transducers for measuring the whole house power consumption and the power draw of the HVAC system. The meters shall be housed in weatherproof NEMA enclosures and placed on an exterior wall near the power panel for each home. An event counter (Campbell Scientific model ACL1) shall be installed in the condensing unit of the air-conditioner for measuring its cycling rate.

7. ORNL personnel shall install two pyranometers, one on the south facing roof and the other on the north facing roof of each house in an inconspicuous place near the roof ridge. The instruments have about a 3-in diameter and stand about 2-in off the roof. Instrument wires will be hidden by running them through the ridge or louvered vents into the attic and down inside an exterior wall to a data acquisition system (DAS) housed in a white plastic NEMA enclosure.

<u>Data Acquisition System</u>
8. ORNL personnel under the supervision of Ochoa and Shehan Construction shall install a data acquisition system an exterior wall of each house (near the power panel) and shall make all instrument connections to the DAS. Placement of the DAS in the attic is not encouraged because problems do occur even with the best DAS and placement on an exterior wall near the power panel would cause the least hassle for the technician and the least intrusion for the homeowner.

We will use a Campbell Scientific Model CR23X-4M micro-logger with model AM25T multiplexer for expanded channel capability. The DAS shall be in a NEMA 4 weatherproof and lockable enclosure. The DAS shall have 4 megabytes of extended memory, a phone modem, modem surge protector and rechargeable battery. The battery requires a 115 Vac source and therefore ORNL requests the DAS be placed near the power panel for obtaining the necessary instrument power. ORNL shall provide an independent phone line for communicating with the DAS.

9. ORNL shall fully program the DAS and shall fully document the data acquisition code for use in later trouble shooting problems by ORNL or LBNL personnel.

10. ORNL with support from Ochoa and Shehan will direct the phone service to run independent phone lines for hook up to each DAS for transmitting data by modem. These lines will be completely independent of the homeowner's phone system, and shall remain intact for the 2-year field demonstration.

11. ORNL shall weekly check the data string output by the DAS received over the modem, and shall take responsibility for damage to the DAS and instruments, and will themselves make appropriate repairs.

Air Tightness of Houses (optional-dependent upon permission of homeowner)
12. ORNL under the coordination of Ochoa and Shehan Construction and the homeowners shall measure the air tightness of the demonstration homes using a Minneapolis Blower Door test apparatus. A Duct Blaster™ apparatus will be used to check the tightness of the air duct system. Both outside air infiltration and duct leakage will affect air conditioning performance therefore we will attempt to document the tightness of the two homes. The air tightness of the house and ducting shall be checked after Ochoa and Shehan has completed construction but before the homeowner occupies the homes.

13. ONRL also requests the opportunity to conduct the air tightness testing at conclusion of the two-year study, and will coordinate the testing per the approval of the homeowner.

Onsite Reflectance Measures
14. ORNL, LBNL or Elk personnel will visit the site semiannually to measure the reflectance of the test roofs. The measures will require personnel to climb up a ladder to the roof and make the measurement, which will take only about 15 minutes.

Thermal Scans of Houses (optional-dependent upon permission of homeowner)
15. ORNL personnel request the opportunity to make thermal scans of the homes to judge the relative effectiveness of the roofing systems once the homes are built and occupied. As the roof systems age the thermal scans will help document the overall thermal performance of the roof as compared to their starting performance. The scans are taken outside the home and will be conducted yearly.

Composition Shingle Retrieval (optional-dependent upon permission of homeowner)
16. ELK personnel request the opportunity to remove and replace one possibly as many as three shingles from the roof facing the back of each home on an annual basis. Elk will take the field exposed shingles and conduct some mechanical testing to confirm that the new shingles with CRCMs perform in a consistent manner with existing standard production shingles. Appropriate data shall be shared with ORNL for support of the CEC work contracted to ORNL and LBNL.

Visitation
17. The homeowners shall agree to allow visitation privileges to ORNL, LBNL or ELK personnel in case of maintenance, repair, routine checks of instruments or the DAS. However, all visits will be coordinated through Ochoa and Shehan Construction or the homeowner's permission to egress said property. Therefore personnel shall schedule visits amenable with the homeowner prior to the actual visit. Visits will be limited to field acquisition and or checks to trouble-shoot instruments and or the DAS.

18. At completion of the two-year study ORNL will remove the DAS, instruments and wires with exception of those embedded in the roof deck.

CONTACTS

ORNL Building Envelope Group
Andre Desjarlais, Group Leader
Signature:

Phone: 865-574-0022
FAX: 865-574-9354
E-mail: desjarlaisa@ornl.gov

ELK Group, Inc.
Louis T. Hahn Technology Center Manager
Signature:

Phone: 972-872-2293
FAX: 972-872-2399
E-mail: LouHahn@ElkCorp.com

Ochoa and Shehan Construction Company
Jerry Wagar Principal Owner
Signature:

Phone: 530-221-0527
FAX: 530-221-0544
Email: Ochoa@Shasta.com