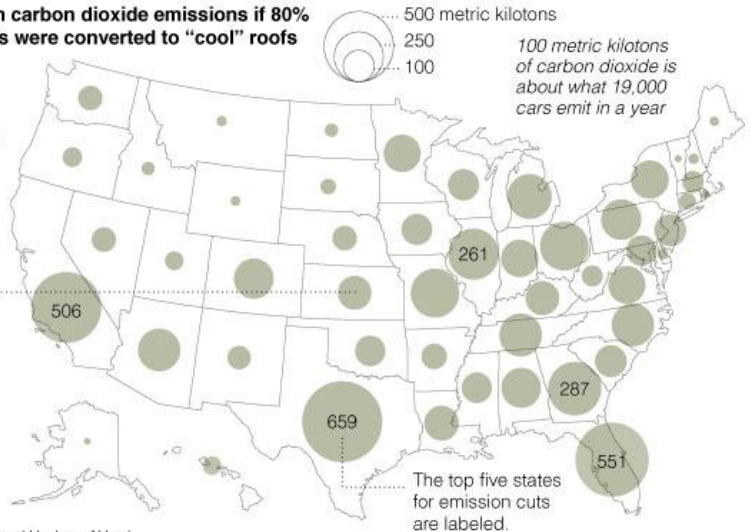
New York Times, 30 July 2009

Imagining a Cool-Roof Nation

Dark-colored roofs absorb high levels of light and heat in the summertime. Researchers estimate that if 80 percent of commercial buildings were retrofitted with "cool" roofs that reflected heat, the nation could save enough on air-conditioning to reduce carbon dioxide emissions by 6.23 million metric tons annually — the equivalent of taking 1.2 million cars off the road.

Annual reduction in carbon dioxide emissions if 80% of commercial roofs were converted to "cool" roofs



Source: Ronnen Levinson and Hashem Akbari, Heat Island Group, Lawrence Berkeley National Laboratory

THE NEW YORK TIMES

Challenge: speed the development of high performance building envelope materials that resist soiling, maintain high solar reflectance, and save energy

Accelerated aging of roofing surfaces

Development of Advanced Building Envelope Surface Materials &
Integration of Artificial Soiling and Weathering in a Commercial Weatherometer

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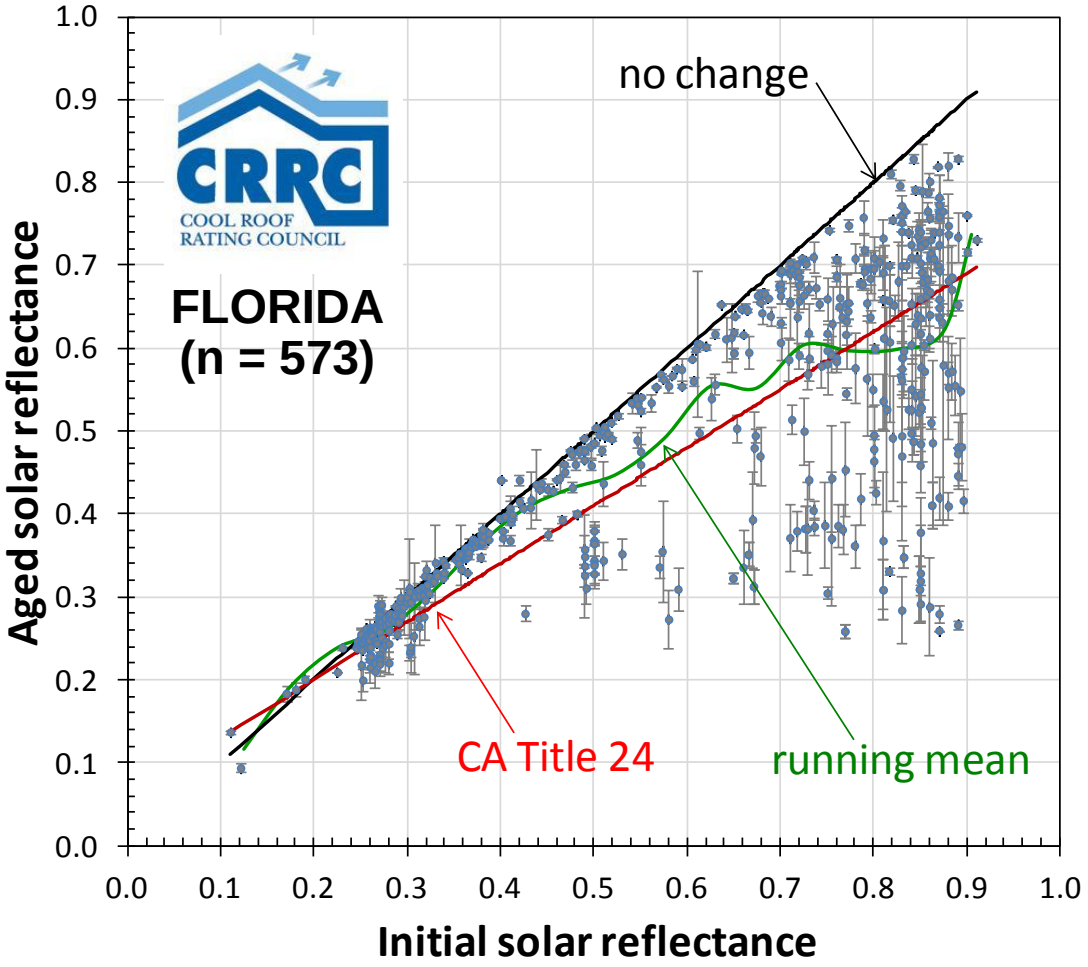
April 4, 2013

Aging markedly decreases solar reflectance of conventional roofs



Sleiman et al. (2011)
Solar Energy Materials and Solar Cells, 95, 3385.

When a white roof's albedo falls to 0.6 (aged) from 0.8 (initial), annual energy savings decrease by ⅓

Purpose & Objectives

Problem Statement: CRRC and Energy Star rating programs require three years of natural exposure, delaying introduction of novel cool roofing materials.

R&D challenge: Develop technology to quickly rate roofing products, removing barrier to innovation of energy saving roofing materials.

Impact of Project: Benefits ~200 roofing manufacturers and suppliers by speeding prototyping and introduction to market of high performance products. The project will yield (1) industry-vetted ASTM/ISO standards for accelerating aging; (2) an accelerated aging device based on IP developed by LBNL with BTO support; (3) peer-reviewed journal articles; and (4) a network of international collaborations.

Project Focus: Develop and transfer technology that promotes advanced cool roofs. Wide adoption of cool roofs is projected to yield annual net primary energy savings of nearly 300 TBTU, worth about $2B/year, reduce CO_2 emissions, and partially mitigate global warming.

Approach

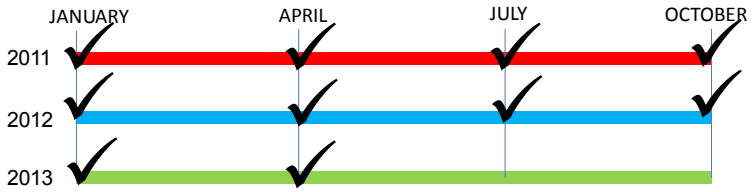
Approach:

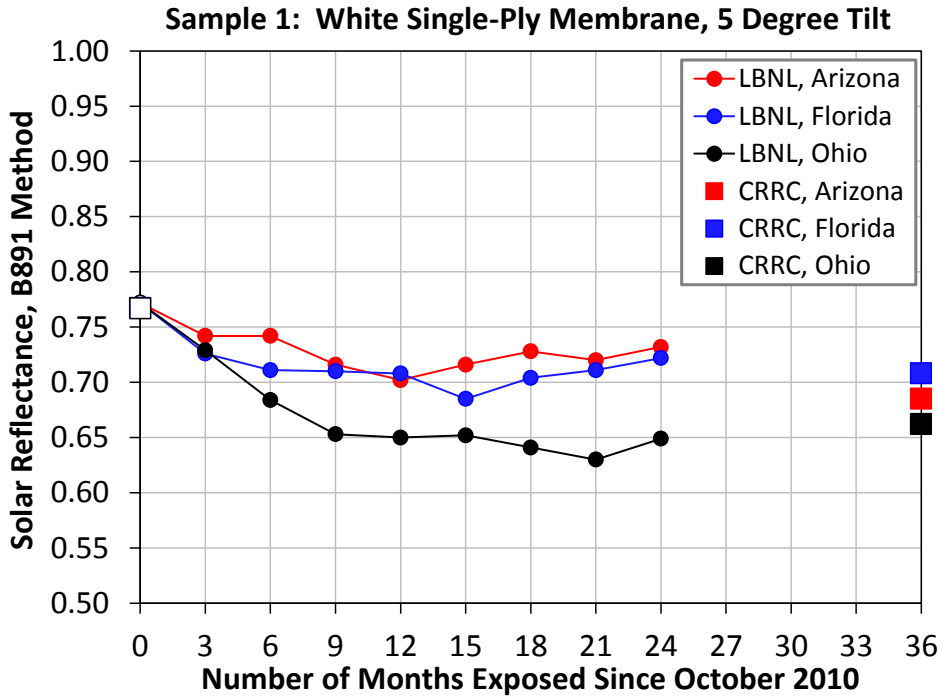
1) Establish a network of industrial, academic and government partners that provide regular feedback; discuss preliminary results in an international workshop
2) Expose 27 roofing products at three CRRC sites, retrieving and analyzing coupons quarterly
3) Develop laboratory accelerated aging protocol calibrated to CRRC exposure
4) Determine reproducibility of accelerated aging method through inter-laboratory study
5) Develop ASTM and ISO standards for accelerated aging
6) Integrate soiling protocol in a commercial weatherometer to facilitate adoption of the technology

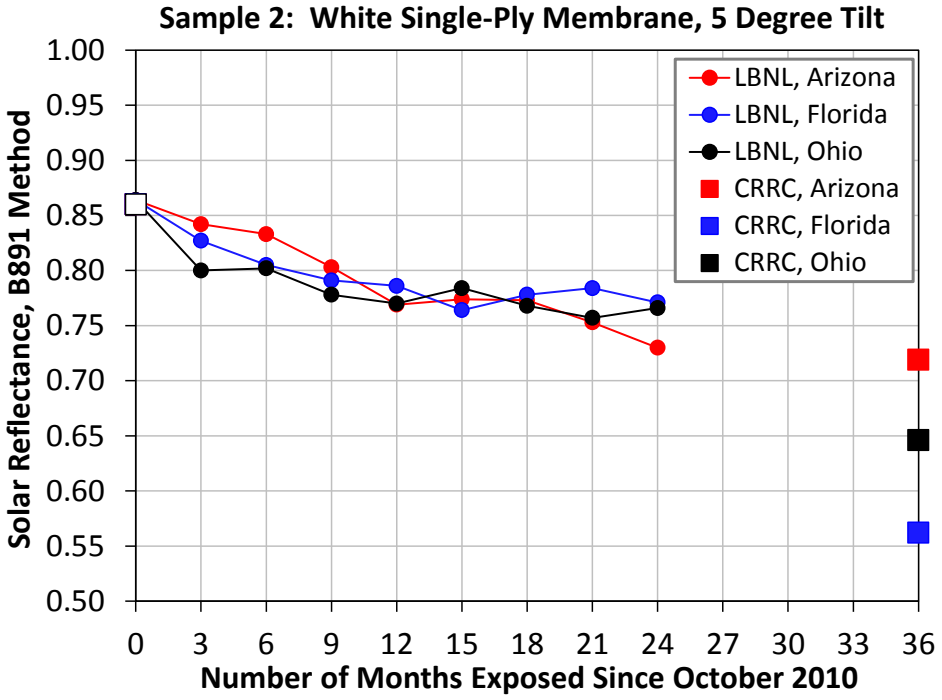
Key Issues: No single method can simulate the performance of every product in all possible US climates. We are distilling the essence of complex atmospheric deposition and soiling processes into practical tools (standards and devices) that industry can use to develop energy saving products.

Distinctive Characteristics: LBNL's Heat Island Group combines unique expertise in cool roofing materials, rating methods, urban atmospheric chemistry, and engineering.

Approach: evaluate natural exposure



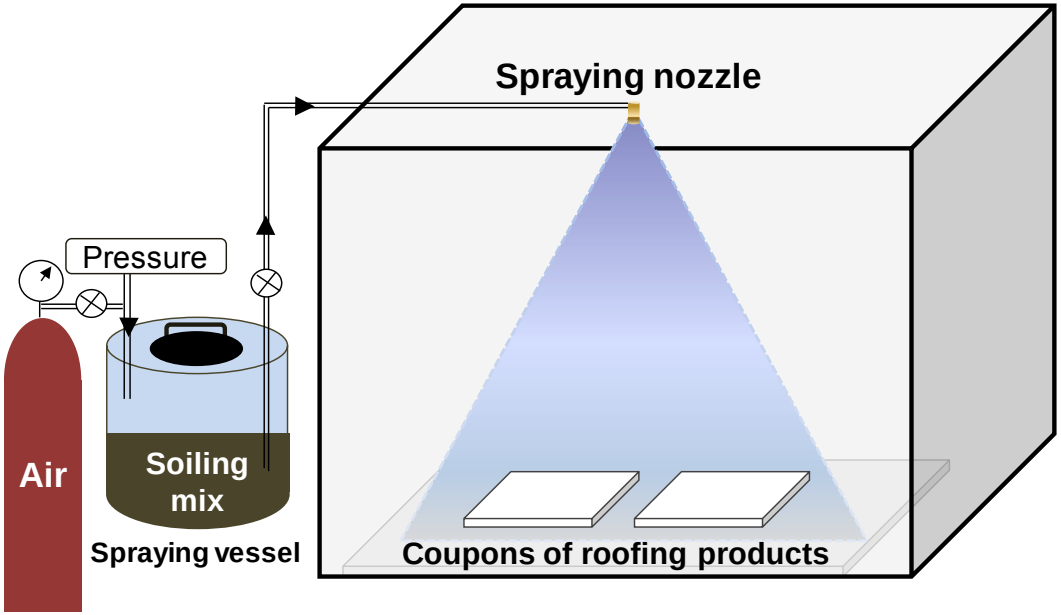




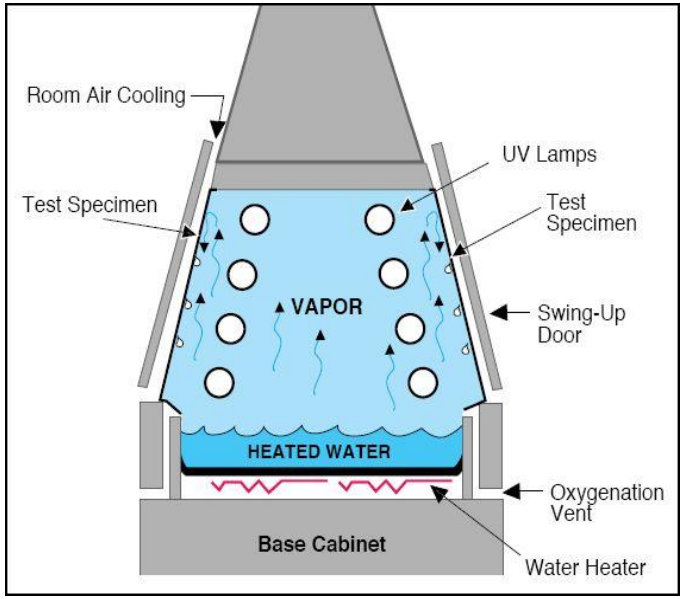
Approach: develop accelerated aging method

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

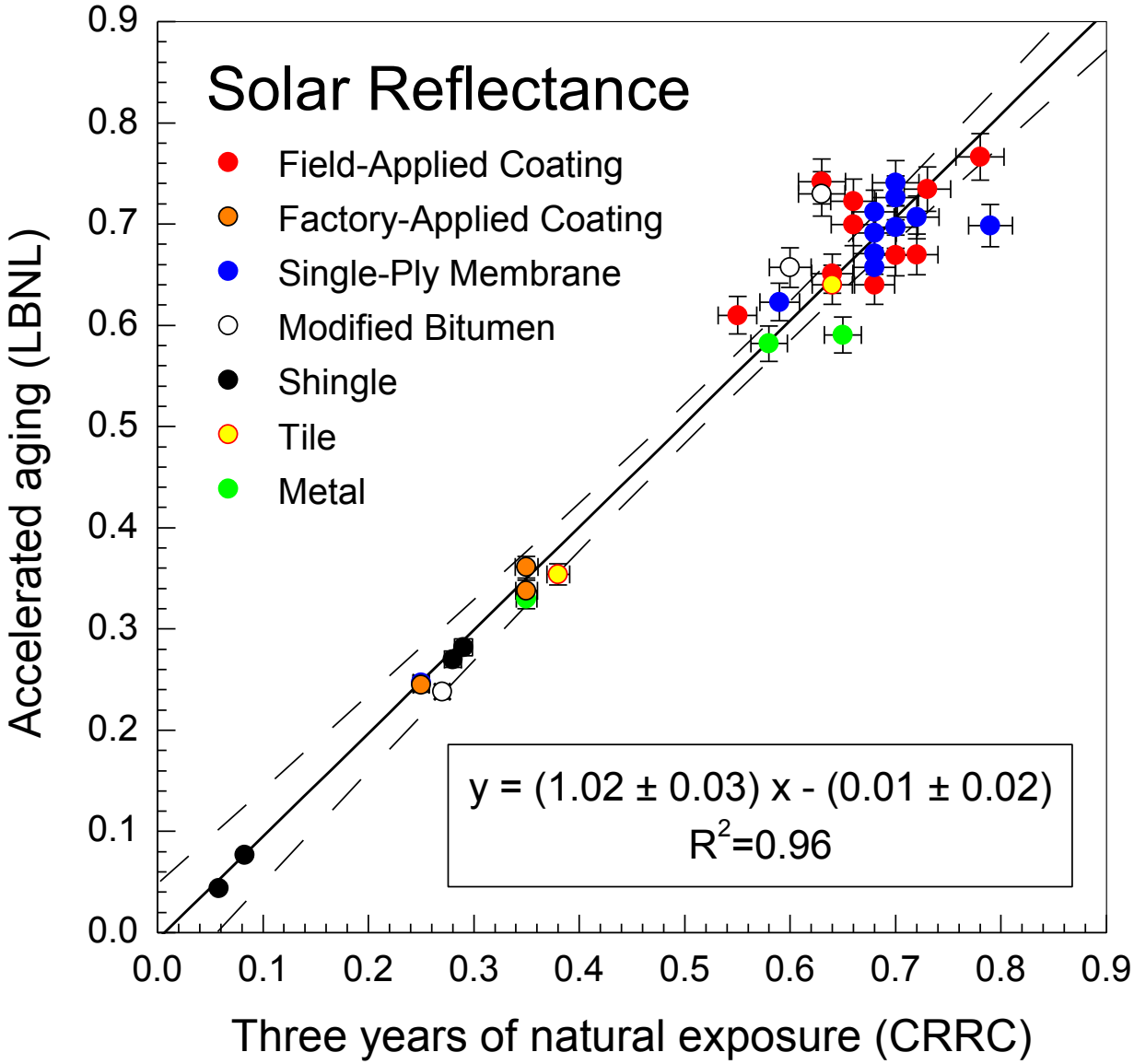
Accelerated soiling
(atmospheric deposition)



Accelerated weathering
(UV, heat, moisture)



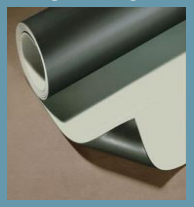
Approach: validate accelerated aging method



Field applied coating (n=7)

Metal or factory-applied coating (n=8)

Single-ply membrane (n=11)



Clay tile (n=2)

Asphalt shingle (n=4)

Modified bitumen (n=3)

Approach: develop standards to formalize accelerated aging method

International Workshop on Advances in Cool Roof Research

Berkeley, July 28-29, 2011

- 75 participants from 7 countries
- Industry, academia and government

http://CoolRoofs2011.LBL.gov

June 2012 & Dec 2012

- Draft standard presented at ASTM
- Created Task Group D08.20.45 *Test Method for Accelerated Aging of Solar Reflectance of Roofing Materials*

September 2012

- Draft standard presented at ISO
- TC-163: *Thermal performance and energy use in the built environment*

Accomplishments and Progress

Accomplishments:

1) Hosted workshop at Berkeley in 2011 to receive feedback from industry on draft method for accelerated aging.
2) Tunable accelerated aging method completed in 2012 and validated against 35 rated products.
3) Three years of natural exposure (CRRC) will be completed in Oct 2013.
4) ASTM and ISO standard development started in 2012.
5) Inter-laboratory study started in 2013.
6) Integration of soiling with commercial weatherometer started in 2013.

Progress on Goals: These accomplishments were met within the original project schedule and goals.

Awards/Recognition: LBNL applied for a US patent for this technology; industrial partners recognized potential of accelerated aging method and work with us to develop and implement it.

Project Plan & Schedule

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Project original initiation date: FY10
Project planned completion date: FY14

Summary	
WBS Number or Agreement Number	BT-480010-13
Project Number	ET-ENV-LBNL-FY13-01 and -03
Agreement Number	22292

Legend	
	Work completed
	Active Task
◇	Milestones & Deliverables (Original Plan)
◆	Milestones & Deliverables (Actual)

Task / Event	FY2012 Q1 (Oct-Dec)	FY2012 Q2 (Jan-Mar)	FY2012 Q3 (Apr-Jun)	FY2012 Q4 (Jul-Sep)	FY2013 Q1 (Oct-Dec)	FY2013 Q2 (Jan-Mar)	FY2013 Q3 (Apr-Jun)	FY2013 Q4 (Jul-Sep)	FY2014 Q1 (Oct-Dec)	FY2014 Q2 (Jan-Mar)	FY2014 Q3 (Apr-Jun)	FY2014 Q4 (Jul-Sep)
Project Name: Development of Advanced Building Envelope Surface Materials												
FY11 Q4 Milestone: Complete consultation with industrial partners (workshop)	◆											
FY12 Q4 Milestone: Complete 2 years of natural exposure (interim)				◆								
FY12 Q4 Milestone: Complete laboratory accelerated aging method				◆								
FY13 Q4 Milestone: Develop ASTM and ISO standards								◆				
FY13 Q4 Milestone: Inter-laboratory validation								◆				
FY13 Q4 Milestone: Complete 3 years of natural exposure (final)									◇			
Project Name: Integration of Artificial Soiling and Weathering in a Commercial Weatherometer												
FY13 Q4 Milestone: Add soiling to commercial weatherometer								◆				
FY13 Q4 Milestone: Validate the integrated system								◆				
Current work and future research												
Complete analysis of the 3 years of natural exposure										◇		
Complete inter-laboratory validation										◆		
Develop ASTM and ISO standards												◇
Complete integration of soiling and weathering												◆

Project Budget

Project Budget: $600K in FY10, $600K in FY11, $400K in FY12 and $250K in FY13. Planned for FY14: $300K.

Variances: No major variances.

Cost to Date: ~$1.7M since FY10 (including expenditures through 4/13). ~80% of the FY10-FY14 budget has been expended to date.

Additional Funding:

- Roofing material samples for field and laboratory exposure were received as in-kind contributions during FY10 from several manufacturers. The value of preparing 200 coupons of each of 27 different roofing products was approximately $200K.
- In FY13, in-kind contribution received from weathering equipment manufacturer to implement soiling integration tests.

Budget History					
FY2010		FY2011		FY2012	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$600K	In-kind (~$200K)	$600K	--	$400K	--

Project Integration, Collaboration & Market Impact

Partners, Subcontractors, and Collaborators: ORNL (A. Desjarlais), Concordia University (H. Akbari), Cool Roofing Rating Council. Coupons were received from 20 industrial partners (roofing manufacturers and distributors). Other partners include two commercial weathering firms. The inter-laboratory tests involve eight partners (industry and academia).

Technology Transfer, Deployment, Market Impact: Developing ASTM and ISO standards will facilitate deployment and market impact of the accelerated aging methodology developed in this project. A provisional US patent was filed in 2012, and a patent application in March 2013.

Communications: Results have been presented at US and international conferences. In FY11, we held a workshop in Berkeley to share our draft method with participants from industry and academia. One journal article was published in 2011 and another is in preparation.
(References are presented on the next slide.)

Communications *(cont'd)*

US Patent application: Sleiman M, Kirchstetter TW, Destaillats H, Levinson R, Berdahl PH, Akbari H. Laboratory method mimicking natural soiling and weathering of outdoor surfaces. Ser. No. *61/638,949,* 2012.

Draft ASTM standard: Standard practice for simulated field aging of roofing materials for determination of solar reflectance and thermal emittance. Presented to ASTM Committee D08.

Draft ISO standard: Accelerated aging method to mimic changes in solar reflectance of roofing materials. Presented to ISO Technical Committee TC-163.

Peer-reviewed publications:

1) Sleiman M, Ban-Weiss G, Gilbert HE, François D, Kirchstetter TW, Berdahl PH, Destaillats H, Levinson R. 2011. Soiling of building envelope surfaces and its effect on solar reflectance — Part I: Analysis of roofing product databases. *Solar Energy Materials & Solar Cells* 95, 3385-3399.
2) Sleiman M, Kirchstetter TW, Berdahl PH, Gilbert HE, Akbari H, Levinson R, Destaillats H. Soiling of building envelope surfaces and its effect on solar reflectance — Part II: Development of an accelerated aging method for roofing materials. *In preparation*.

Workshop in Berkeley, CA: *International Workshop on Advances in Cool Roof Research: Protocols, Standards & Policies for Accelerated Aging*, July 28-29, **2011** http://CoolRoofs2011.lbl.gov

International conferences:

1) Sleiman M, Kirchstetter TW, Berdahl PH, Gilbert HE, François D, Spears S, Levinson R, Akbari H, Destaillats H. 2010. Development of an accelerated soiling method that mimics natural exposure of roofing materials (keynote presentation). *3rd Conference on Passive and Low Energy Cooling for the Built Environment (PALENC), 5th European Conference on Energy Performance & Indoor Climate in Buildings (EPIC), 1st Cool Roofs Conference*, Rhodes, Greece.
2) Sleiman M, Kirchstetter TW, Gilbert HE, Preble C, Berdahl PH, Destaillats H, Levinson R. 2012. Accelerated aging method to mimic changes in solar reflectance of roofing materials. *International Roof Coatings Conference*, Baltimore MD.

Next Steps and Future Plans

Short term (FY14):

1) Complete natural aging and analyze seasonal and long term changes to solar reflectance and thermal emittance
2) Complete inter-laboratory evaluation of accelerated aging methodology
3) Advance ASTM and ISO standards of accelerated aging
4) Complete integration of soiling in a weatherometer to facilitate commercialization
5) Host a second workshop to expand collaborative network, including our current international partners.

Long term:

1) Completion and adoption of ASTM and ISO standards
2) Extend method to serve other climates/regions
3) Develop tools to evaluate anti-soiling properties of novel advanced materials
4) Extend to other envelope surfaces (façades, BIPV)

Next Steps and Future Plans

Related ongoing work: 3 CRADAs

Stay-clean white elastomeric coatings

BERKELEY LAB · OAK RIDGE National Laboratory · DOW

Improved cool asphalt shingles

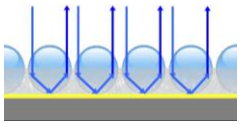
BERKELEY LAB · CertainTeed SAINT-GOBAIN

Waterborne super-hydrophobic coatings

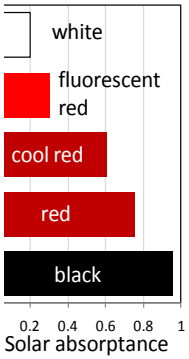
BERKELEY LAB · OAK RIDGE National Laboratory · DOW · CERC-BEE

Future work: emerging technologies

Retro-reflective surfaces



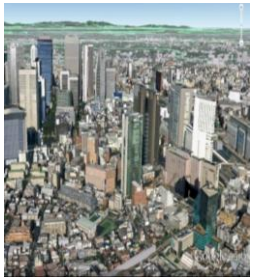
Fluorescent cool pigments



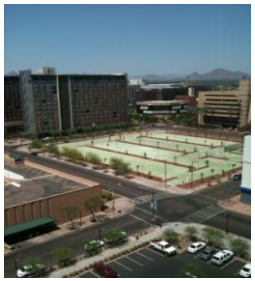
Photoactive self-cleaning surfaces

Future work: beyond cool roofs

Cool façades



Cool pavements



Stay-clean PV and CSP