Stay-Clean and Durable White Elastomeric Roof Coatings (ERCs)

2014 Building Technologies Office Peer Review

CRADA with Dow Chemical

Challenge: speed the development of high performance white coatings that resist soiling, last longer, and save more energy

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

Mohamad Sleiman MSleiman@LBL.gov
Hugo Destaillats HDestaillats@LBL.gov
Ronnen Levinson RMLevinson@LBL.gov
Lawrence Berkeley National Laboratory

Project Summary

Timeline:
Start date: 10/2011
Planned end date: 9/2014

Key Milestones

- Demonstrate good soiling resistance (aged solar reflectance ≥ 0.75) for Dow's white ERCs with new dirt-pickup resistance technology. Date: 3/2014
- Identify one ERC with a water uptake < 20% and an aged solar reflectance ≥ 0.75, based on accelerated aging. Date: 6/2014
- Demonstrate service-life ≥ 15 years for Dow's ERCs, using advanced accelerated weatherometer. Date: 9/2014

Key Partner: *Dow Chemical*
(Joseph Rokowski – Group Leader, Principal Research Scientist, Dow Construction Chemicals).

Budget:
Total DOE $ to date: $570K (FY11-FY14).
Future DOE $: none.

Target Market/Audience:

White roofs for commercial and residential buildings.

Project Goal:

Develop a commercially viable ERC with a 3-year aged solar reflectance ≥ 0.75 and a service life ≥ 15 years (50% longer than existing products).

Purpose and Objectives

Problem Statement:

1/3 of potential energy savings of white roofs lost due to soiling and weathering. Typical lifetime of ERCs is about 10 years. The R&D challenge is developing soiling resistant and more durable ERCs.

Target Market and Audience:

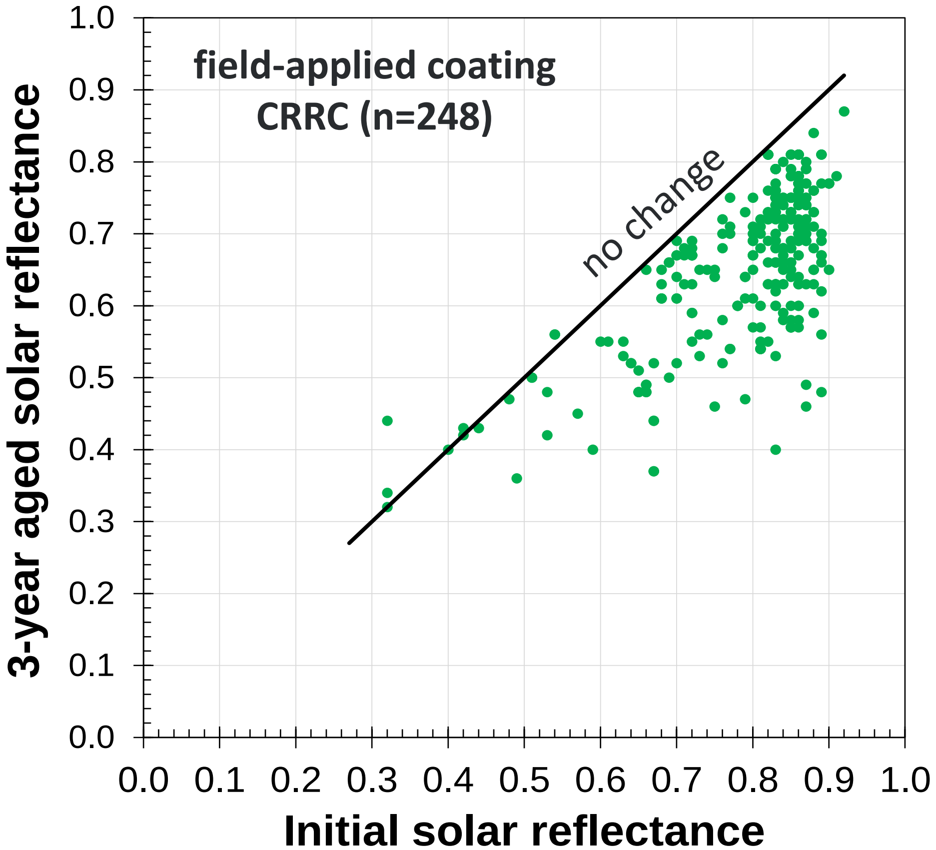
- White roofs coatings for retrofit and new construction of commercial and residential buildings
- Higher solar reflectance and durability could double lifetime energy savings, by an annual $0.63B, corresponding to 0.083 quad in RECS climate zones 4 & 5
- Additional peak demand savings

Impact of Project:

- Expedite the development and commercialization of stay-clean and durable white ERCs with high aged solar reflectance and extended service life
- Raise performance standards for white roofs from the current aged solar reflectance of 0.55 to 0.75, leading to a 50% boost in US cool roof energy cost savings (increasing lifetime present value to $9.4B from $6.3B)

Increasing US cool-roof energy cost savings by 50%

- ERCs are an economical retrofit approach, reducing top-floor cooling loads by 20-40% and peak loads by up to 50%
- The initial reflectance of white field-applied coatings can be reduced greatly due to soiling and weathering
- Cool Roof Rating Council (CRRC) and the US EPA Energy Star® rate roofing products after 3 years of aging



Sleiman et al. (2011) *Solar Energy Materials & Solar Cells*

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Approach

Dow Chemical developed prototypes of ERCs with enhanced "dirt pickup resistance" by incorporating

- hollow and solid bead technologies for better water resistance
- chemical additives for improving soiling resistance

LBNL characterized prototypes and developed testing methods by

- determining the long-term soiling resistance of ERCs using natural and laboratory exposure methods
- measuring water contact angles of new and aged samples to evaluate changes in surface hydrophobicity

Key Issues: Incorporating dirt-pickup resistance technology cost-effectively to achieve the expected improvement in cool roof performance while retaining good mechanical properties.

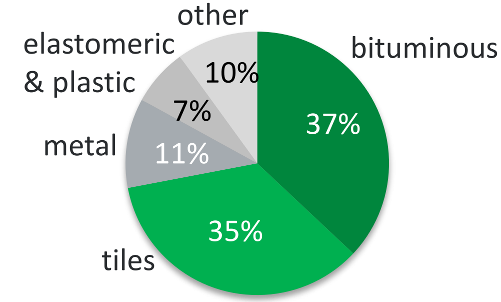
Distinctive Characteristics: The project combines the expertise of LBNL's Heat Island Group in cool roofing materials and rating methods with Dow Chemical's expertise and leadership in the field of ERCs.

Dow Chemical developed high-performing white ERCs

- Dow's ERCs can be applied to most roofing substrates (global roofing market: \$63B/y)
- The potential market size for ERCs is \$2B/y
- In a field study in Mississippi, a white ERC provided 13% annualized energy saving and a payback of 2 years

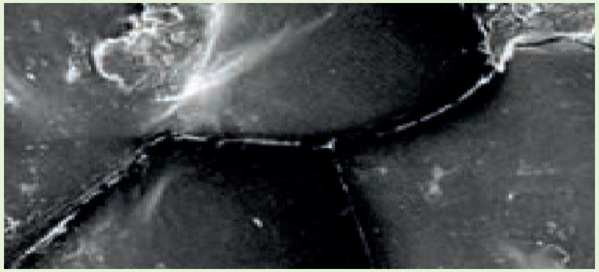
City	Savings ($\$/m^2/year$)
Athens	2.8
Lyon	1.1
Istanbul	1.9
Dubai	2.7
Riyadh	2.2

World roofing demand in 2010 was 10 billion m^2



In durability studies, Dow's ERCs adhered well to bitumen roofing and provided excellent protection against pitting and chalking.

Built-up roof, weathered 6 years (magnification: 300X)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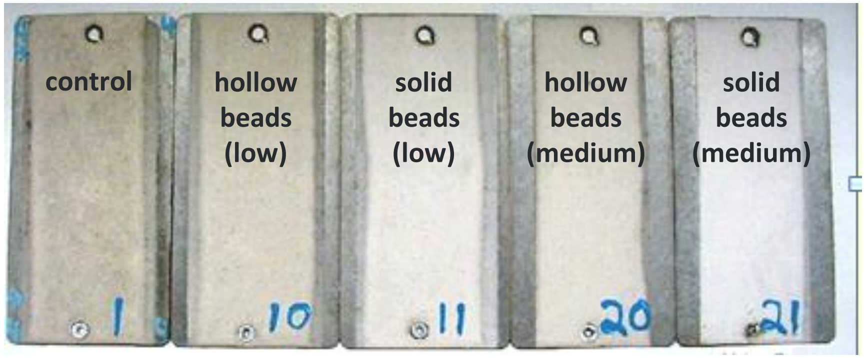
uncoated



Dow identified technologies that use hollow or solid beads and new dirt pickup chemistry to improve soiling and water resistance.

Dow Construction Chemicals. Techline 11 Cool Reflective Roof Coating

www.dowconstructionchemicals.com/eu/en/pdf/840-02301.pdf

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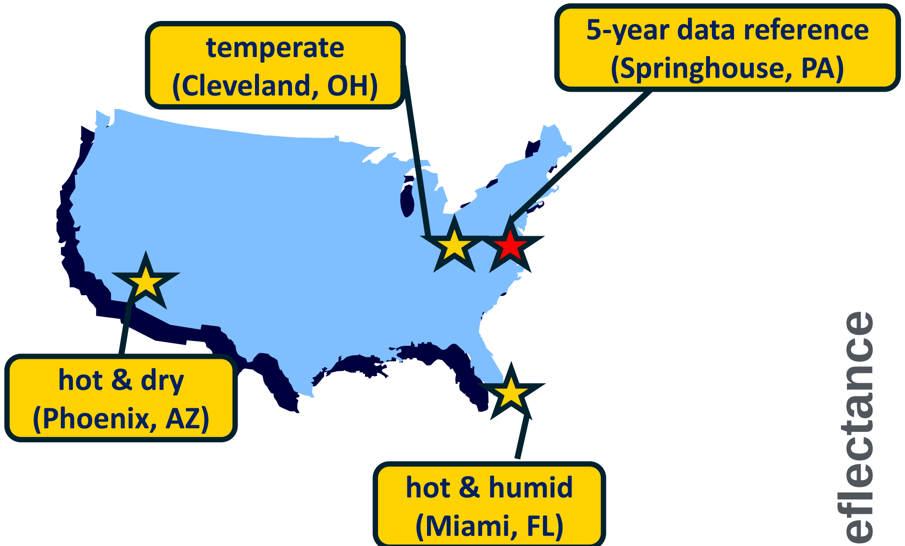
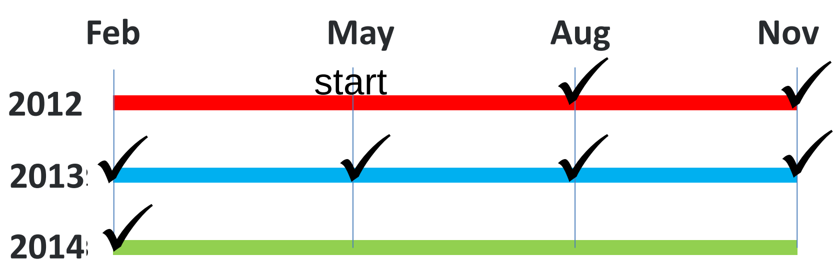
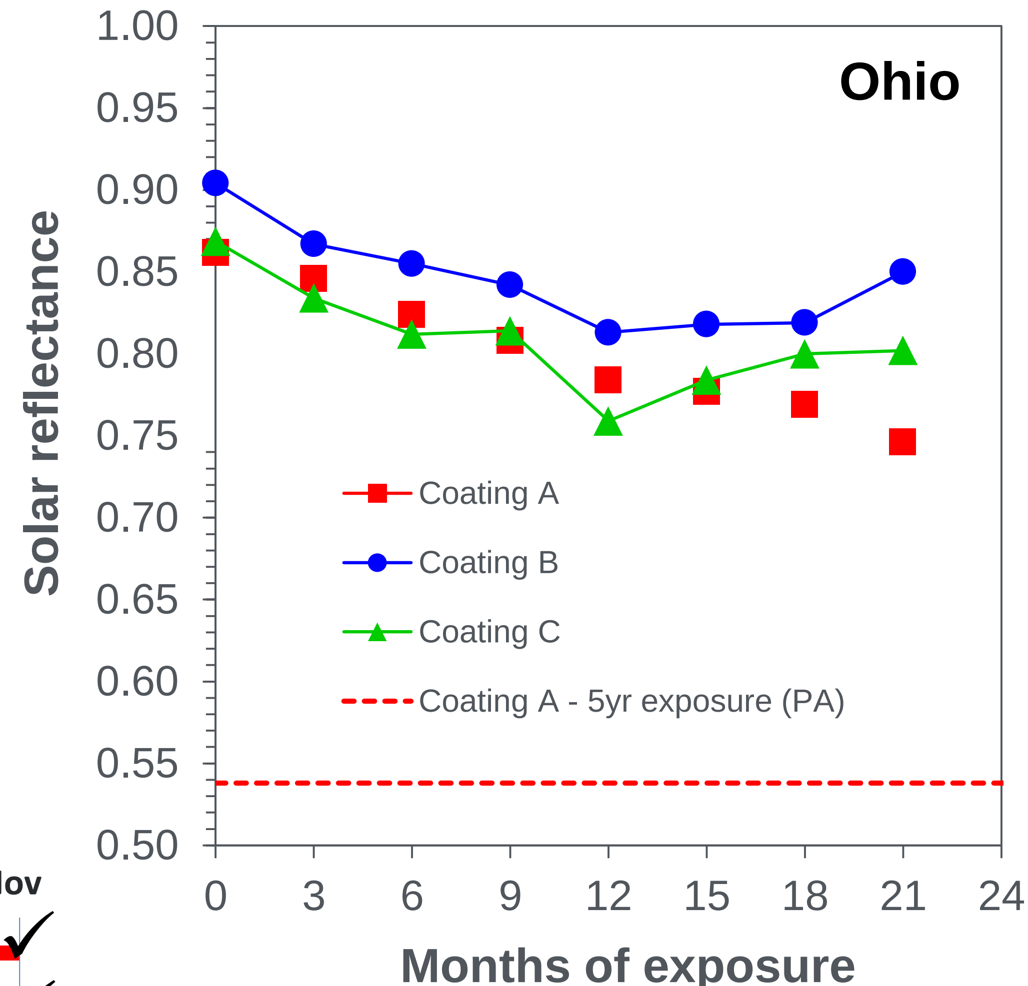
Improved performance observed in natural exposure







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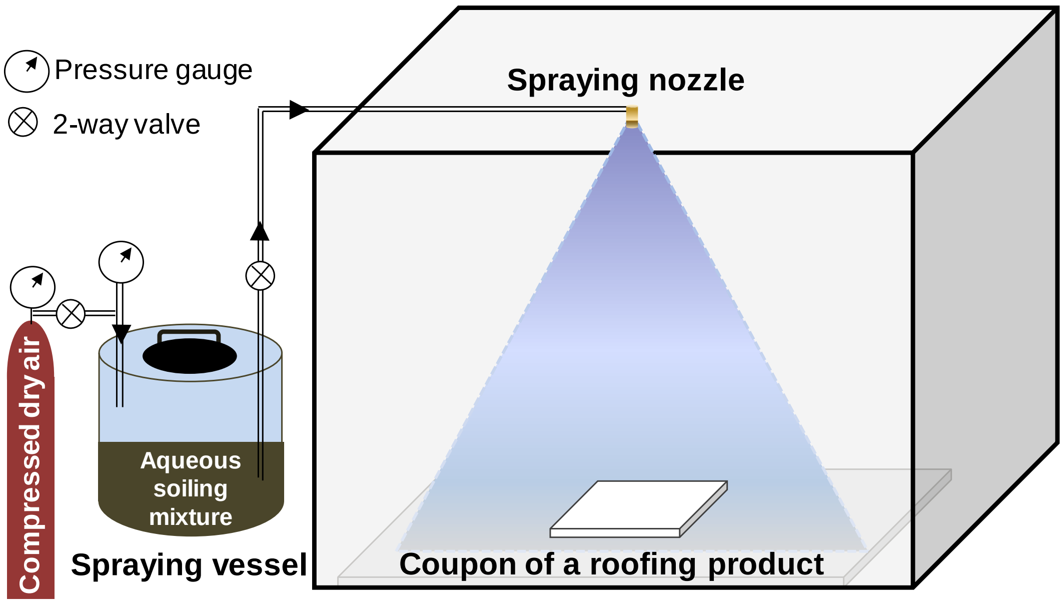
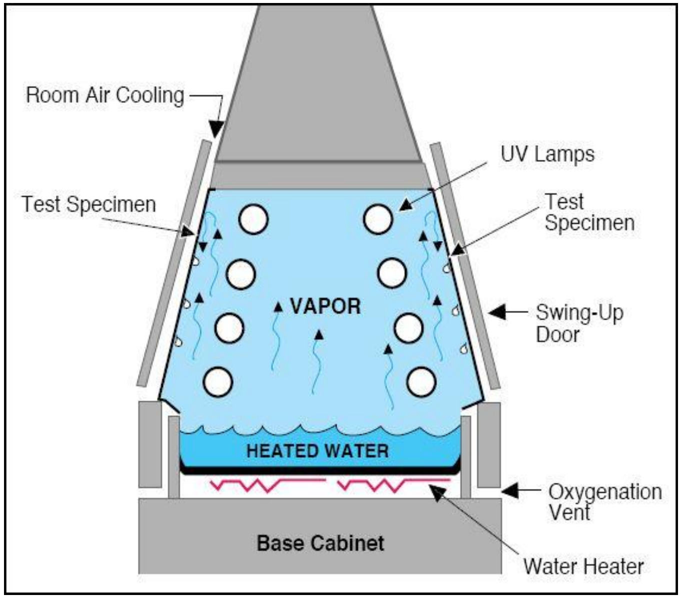
In a related project, LBNL developed a laboratory process for accelerated aging method of roofing material

Accelerated soiling
(atmospheric deposition)



Accelerated weathering
(UV, heat, moisture)

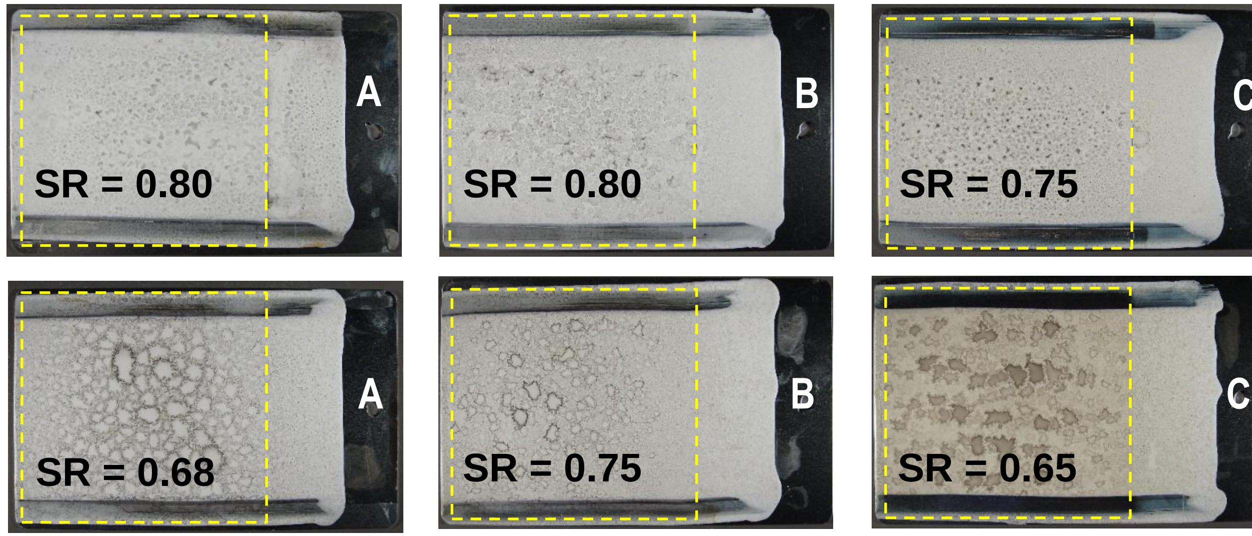


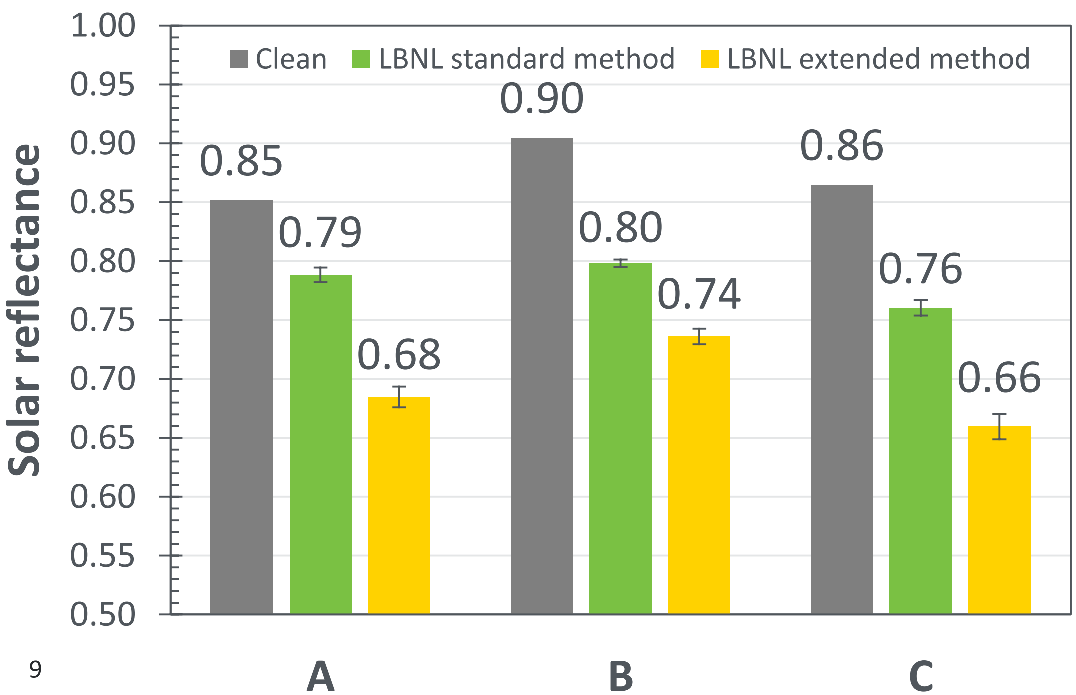
Sleiman et al. (2014) *Solar Energy Materials and Solar Cells*

In the current project, LBNL developed an extended accelerated aging method

LBNL standard method
- Conditioning (1 day)
- Soiling
- Weathering (1 day)

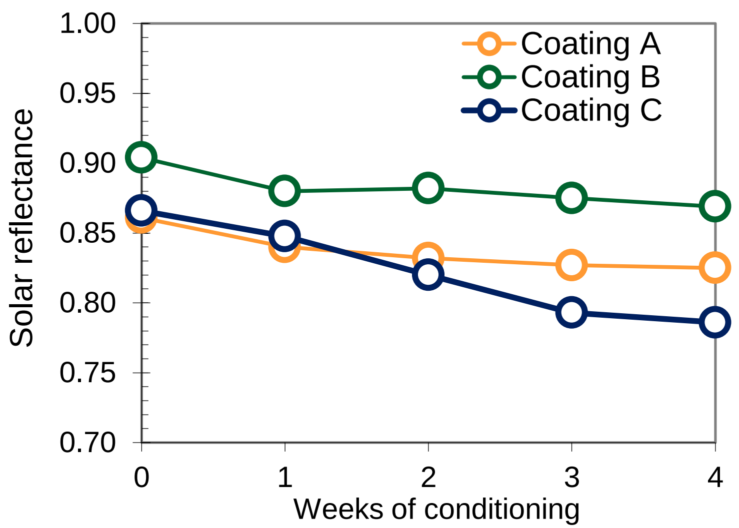
LBNL extended method
- Conditioning (25 days)
- Soiling
- Weathering (5 days)

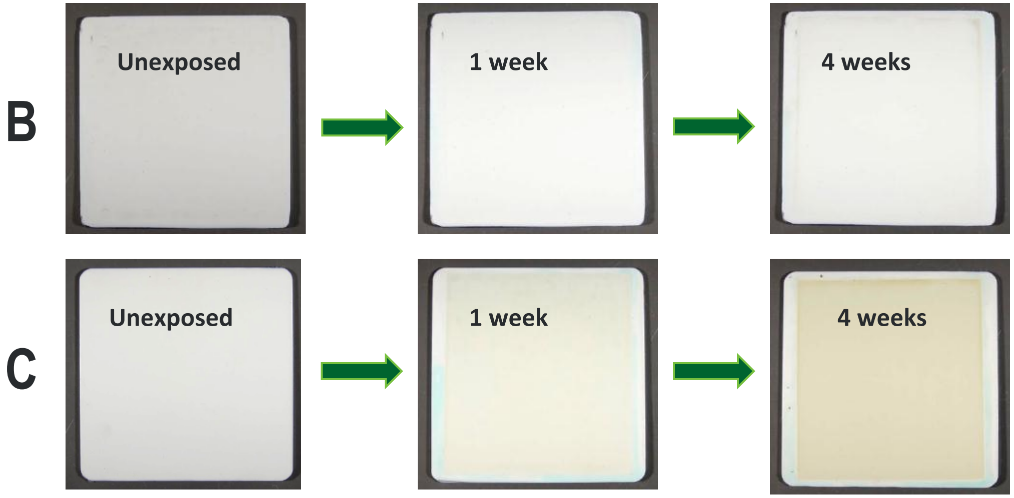


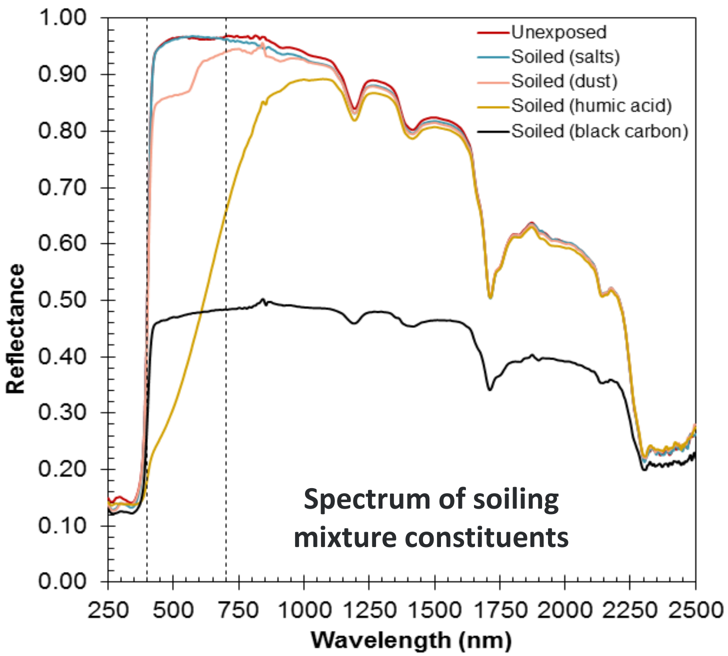


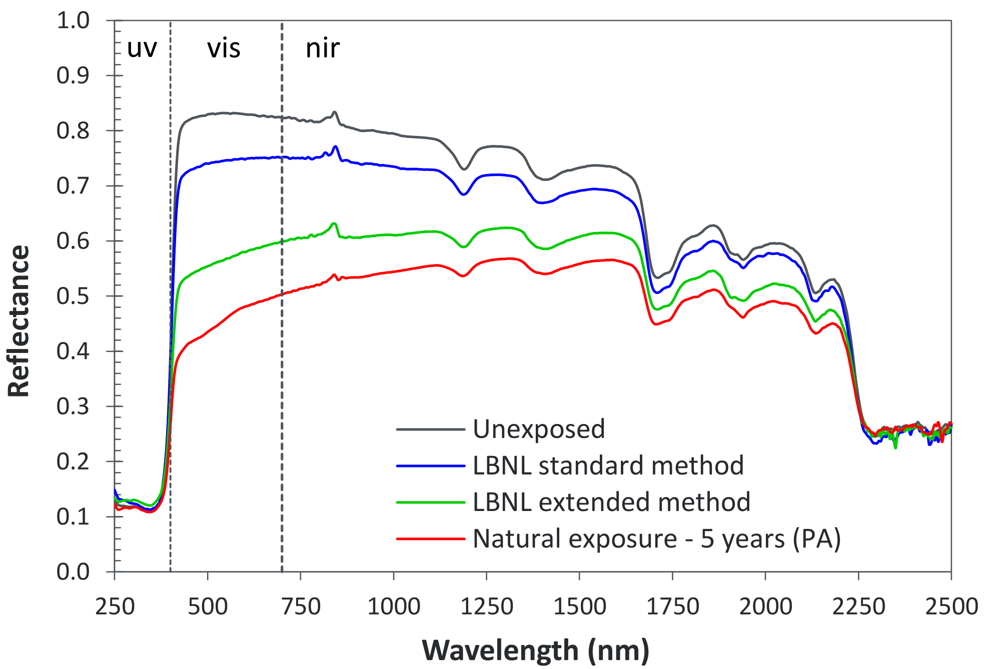
- Prototype B shows the best performance
- Long term aged SR is very close to the target (0.75)
- LBNL extended method provides a tool to assess the effect of long term soiling and weathering

The extended accelerated aging method better replicated changes in reflectance after 5 years

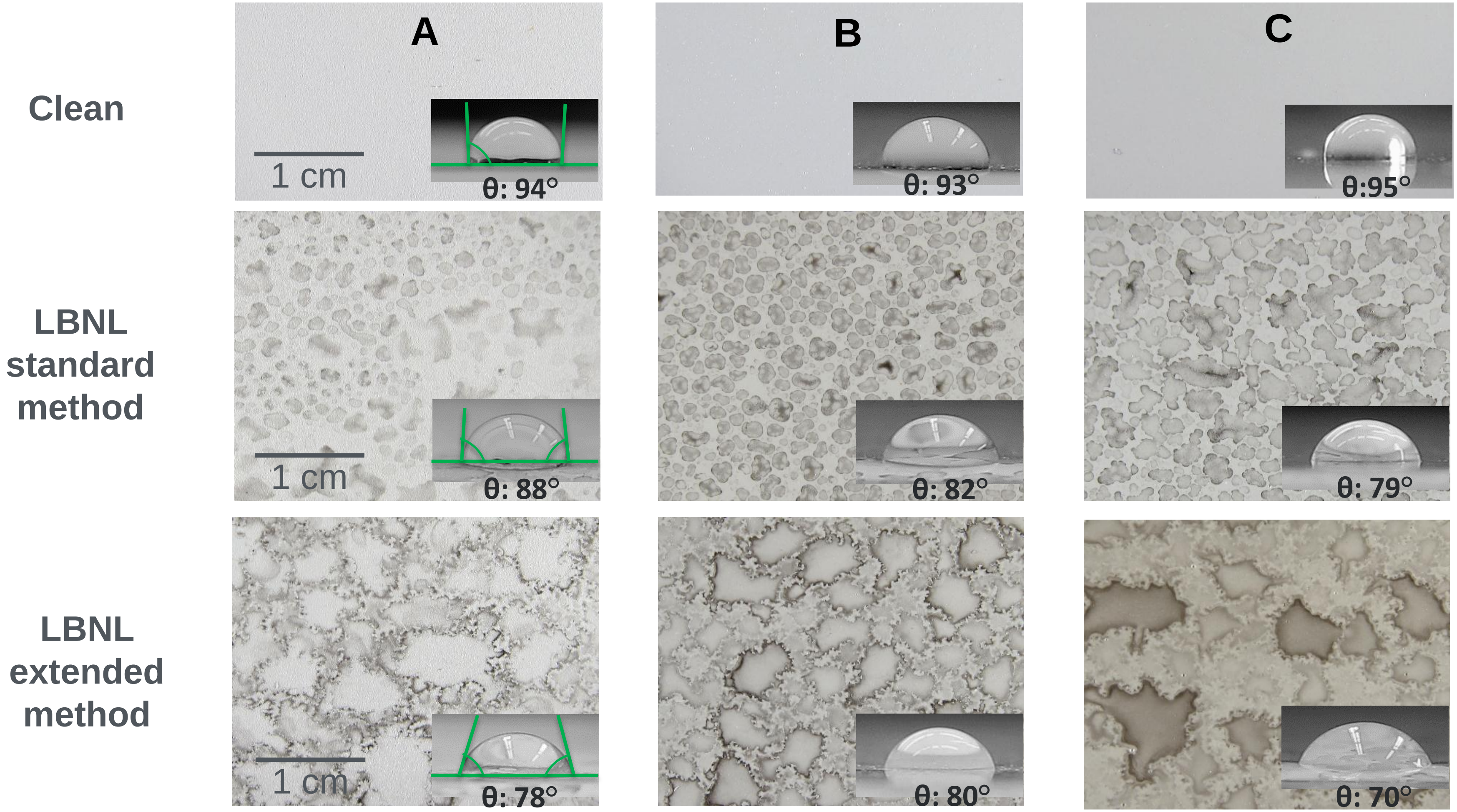








The extended accelerated aging method further reduced hydrophobicity and created larger splotches



- After laboratory aging, coatings become less hydrophobic
- Coating B retains more hydrophobicity than C

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Mechanical properties other than water swelling are OK

	Goal	Coating A (Control)	Coating B	Coating C	Coating D
Opaque polymer solids/total solids (%)		0	27	27	8
Water Swelling 7d Initial (%)	< 10	10	40	44	24
Permeability Initial (US Perms)	< 50	46	7	5	6
Permeability after 6 months (US Perms)	≥ 5	5	NA	NA	
Tensile Initial (psi)	> 200	191	299	387	292
Elongation Initial (%)	> 150	341	348	362	262
Raw Material Cost Premium vs. Control (%)		--	27	5	8

Mechanical characterization performed by Dow Chemical, following ASTM D6063: *Standard Specification for Liquid Applied Acrylic Coating Used in Roofing*.

Issues: Need to reduce initial water swelling; high premium cost of raw materials.

Dow is preparing a new coating (D) with improved water swelling and reduced cost premium.

Progress and Accomplishments

Lessons Learned:
Additives that increased the resistance to soiling also increased water uptake, degrading the mechanical properties. Tests carried out on initial formulations helped identify these problems and minimize the negative effects.

Accomplishments:

- Dow identified new additive offering improved dirt pickup resistance
- LBNL identified one coating (B) with long term aged SR of 0.75
- LBNL completed 2 years of natural exposure testing
- LBNL developed extended accelerated aging test method specific for ERCs
- LBNL and Dow characterized hydrophobicity, mechanical properties of ERCs

Market Impact:
Worldwide, the expected size of the market for ERCs is \$1.9 B (2015), corresponding to a roof area of 59M m^2 (low slope applications only).

Project Integration and Collaboration

Project Integration: Regular communications between LBNL and Dow Chemical take place during this project through monthly or quarterly conference calls and in-person meetings.

Partners, Subcontractors, and Collaborators: Dow Chemical leads the development of white elastomeric roof coatings.

Communications:

Publications: Due to the proprietary nature of this project, results have not been published. The "standard" method (corresponding to our parallel project) was published:

- Sleiman et al. 2014. Soiling of building envelope surfaces and its effect on solar reflectance – Part II: Development of an accelerated aging method for roofing materials. *Solar Energy Materials & Solar Cells* 122, 271-281
- Sleiman et al. 2013. Mixture and method for simulating soiling and weathering of surfaces. US Patent application Pub. No.: US 2013/0287966 A1

Conferences: The project's goals and approach have been described at

- Technical Meeting of the Reflective Roof Coatings Institute, Berkeley, CA, 10/2013
- Asphalt Roofing Manufacturers Association, Denver, CO, 4/2013
- International Roof Coatings Conference, Baltimore, MD, 7/2012

Next Steps and Future Plans

FY14:

- **Dow Chemical** will produce roof coatings samples that incorporate solid beads and other dirt-resistant additives
- **Dow Chemical** will characterize mechanical properties of the new coatings
- **LBNL** will evaluate overall performance of coatings formulated with the new dirt resistance additive with and without solid beads
- **LBNL** will measure water repellency (contact angle) of the new coatings before and after accelerated weathering and soiling
- **Dow Chemical** will predict service life of the selected coatings using advanced weathering techniques and correlation models with natural exposure

FY15 and beyond:

- **Dow Chemical** will perform extended testing, explore costs and patentability
- Demonstration in the US, China, Brazil, India and other countries through ongoing collaboration programs
- Codes and standards: increasing requirements for aged solar reflectance in ASHRAE 90.1, CA Title 24, IgCC, IECC

REFERENCE SLIDES

Project Budget

Project Budget:

$100K in FY11, $150K in FY12, $200K in FY13 and $120K in FY14.

Variances: No major variances.

Cost to Date: ~$500K since FY11 (including expenditures through 4/14).
~90% of the FY11-FY14 budget has been expended to date.

Additional Funding: Prototype samples for field and laboratory exposure were received as in-kind contributions since FY11 from Dow Chemical. The value of preparing these prototypes and participation in this project was approximately $449K.

Budget History					
FY2011– FY2013 (past)		FY2014 (current)		FY2015 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$450K	$422K	$120K	$27K	0	

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Project Plan and Schedule

- Project start date: 10/2010 - Project planned completion date: 9/2014
- A go/no-go decision was made at end of FY13, after completing 1.5 y of natural exposure
- Dow Chemical moved to a new R&D center in FY14Q1, delaying lab work. Full operation is expected by May 5.