International Roof Coating Conference

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

US DOE Building Envelope and Roof Research for Today and Tomorrow

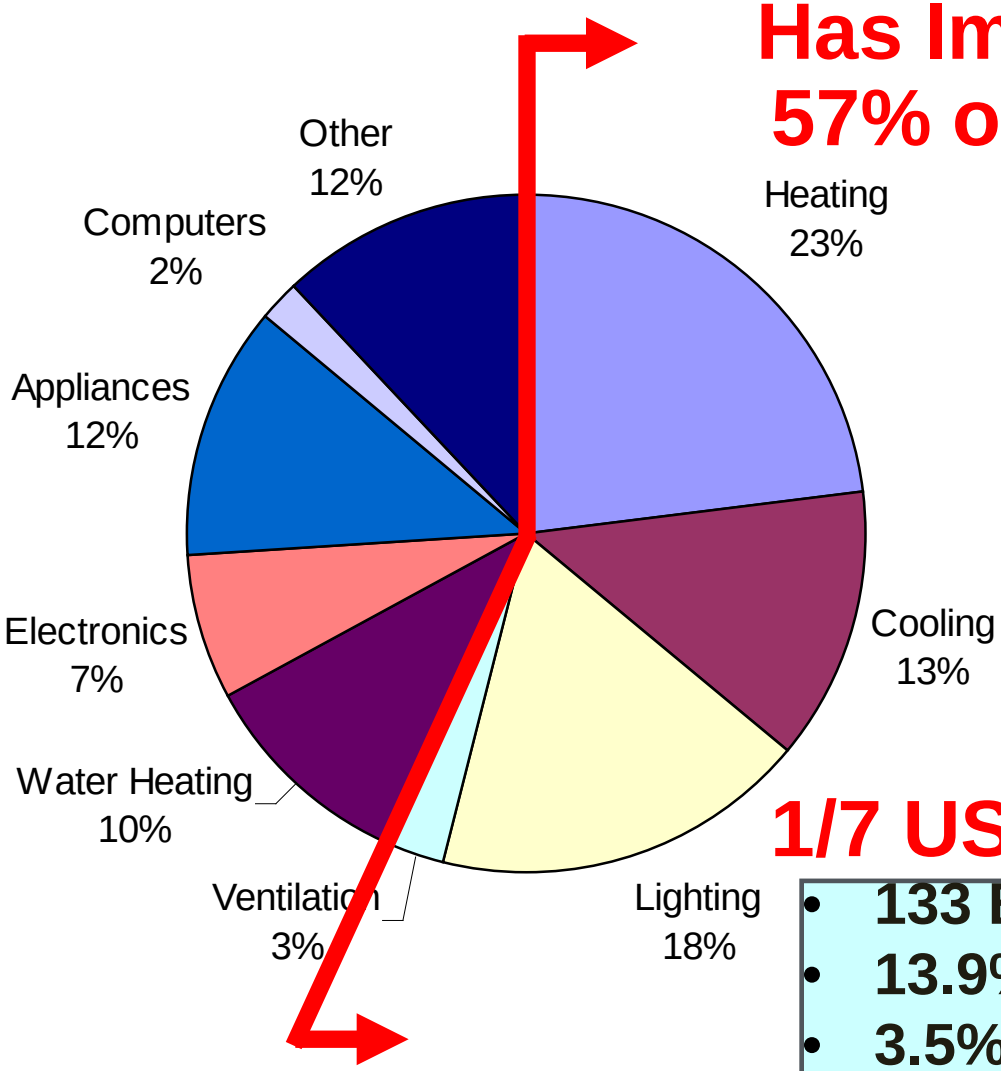
Baltimore, MD

18 July 2012

Marc LaFrance

US DOE

Building Consumption – Envelope Relationship



Has Impact on 57% of Loads

1/7 US Economy

- **133 Billion $/yr**
- **13.9% US Energy**
- **3.5% Global Energy**

Total Envelope Component Energy Impact

Quads	Residential	Commercial	Total
Windows	3.07	1.97	5.04
Infiltration/Fresh Air	2.20	2.79	4.98
Walls	1.46	0.61	2.07
Roofs	1.18	0.38	1.56
Foundations	1.08	0.42	1.49
Total	8.99	6.16	15.15

Source: Draft Report - Energy Savings Potential of Building Envelope and Windows Technologies, Winbuild, includes source contributions.

Total Building Envelope and Window R&D Budget

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	Budget Request	Enacted Appropriations
FY05	5.0M Windows 0 Envelope	5.8M Windows 2.8M Envelope
FY06	5.0M Windows 0 Envelope	*3.8M Windows (*earmarks) 2.9M Envelope
FY07 & FY08	4.7M Windows 2.4M Envelopes	4.7M Windows 2.4M Envelope
FY09	5.2M Windows 3.4M Envelopes	5.5M Windows 4.5M Envelope
FY 10	10.5M Windows 5.5M Envelope	Core 10.5M Windows 5.5M Envelope **ARRA ~ 25M**
FY 11	10.5M Windows 8.5M Envelope	10.5M Windows 5.5M Envelope
FY12	25M Both	10M Windows 6M Envelope
FY13	16M Both	**TBD - LARGE CUT EXPECTED 50 TO 80%; WHY? LESS FUNDS, EARMARKS, DOE PRIORITIES, etc**

Key Opportunities - Now and in the Future

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Technology Area	Ready Now – Enabling Research Can Help	Technologies for the Future
Roofs	R40 Insulation with Air Sealing, Comm Cool Roofs and Roof Deck Insulation, Radiant Barriers in Hot Climates	Next Generation of Attic/Roof System for Sloped Roofs, Asphalt Cool Roofs, Higher Reflective Comm Cool Roofs, BIPV
Walls	Exterior Insulation Finishing Systems, Exterior 1-2” Foam, Cavity Insulation, Interior Insulation	Lower Cost/Higher Performing Insulation, “Installation Proof” Cavity Insulation, Robust Interior Applications
Infiltration	New Construction Wide Array of Approaches; Retrofit Viable but Labor Intensive	New Approach – Higher Value added Products with Lower Installation Cost; More Attention on Retrofit
Foundations	Exterior Insulation for New Construction, Retrofit Problematic	More Robust Moisture Tolerant Interior Solutions, Slab Edge for Existing Buildings

Recent Financial Opportunity Announcement Technical Targets

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High Performance Thermal Insulation	
Requirements	**Targets**
R-value/inch (°F·ft^2·h/Btu-in)	≥ 8
Material cost	≤ \$0.08/ft^2 per *R* value
Installation cost	Equal to or less than installation cost for comparable solutions
Appearance	Aesthetically attractive (if visible) < 1" thickness

Advanced Roof/Attic Solutions	
Requirements	**Targets**
Energy Consumed for Roof/Attic System (reduction in roofing related thermal load)	35 percent less than 2009 IECC Building Code
Installed Cost per Square (100 sq ft)	≤ \$300 per 100 ft^2
Ease of Installation	Less time than conventional roofs

Highly Insulating Windows	
Requirements	**Targets**
U-value (1/*R*-value)	0.14 – 0.10 Btu /°F·ft^2·h (R-7 to R-10 in °F·ft^2·h/Btu)
SHGC (no dynamic control) SHGC (with dynamic control)	≥ 0.30 ≤ 0.18 and ≥ 0.45
Price premium (highly insulating only) Price premium (highly insulating with dynamic control)	≤ \$5/ft^2 ≤ \$12/ft^2·

Major Accomplishments

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Envelope and Windows Major Program Accomplishments (2002 – Present)	
Validate Global Radiation Benefit of Cool Roofs	Numerous New ARRA Products on Market
Major Contribution to DOE Wide Cool Roof Policy	Commercialization of Cost Effective R5 Windows
Cool Roof Selection Guidelines	Commercialization of Cost Effective Low E Storms
New Integrated Cool Roof Calculator	Implementation of PA Priority List for Windows
New Attic/Roofs Designs for Hot Climates	Commercialization of High R Dynamic Windows
Initiation of Whole House PCM Studies	Opening of India Window Rating and Test Center
New Moisture Modeling Capability	Commercialized Dynamic Windows
Vapor Barrier Code Requirements	NFRC Labels for Window Film & Dynamic Windows
Aged & Reduced ASTM Insulation Values	Window Design Tools (Used by 80% of Industry)
Developed Sealed Crawl Space Designs	Developed Major Commercial Glazing and Daylight Tools
In-depth Cool Roof Case Studies	Comprehensive Dynamic Window/Daylight Demos
R30 Wall Solutions (EIFS Validation)	Extensive Studies – Driving Policy for High SHGC in North
Commercialized Dynamic Insulation	New Commercial Façade NFRC Rating Program
ASHRAE 160 Moisture Design Standard	Showcase Highly Insulating Dynamic Window Prototypes

Envelope and Windows Blog – Have You Registered Yet?

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www.eereblogs.energy.gov/buildingenvelope

All Workshop Materials and Significant Program Content

Building Envelope and Windows R&D Program Blog

Advancing Technology. Saving Energy.

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Building Envelope and Windows R&D Program Workshop Agendas Released!

Posted by Webmaster on 1. June 2012 15:33

Two draft agendas have been released for the upcoming Building Envelope and Windows R&D Program Workshops: Building Envelope Technology Roadmapping Workshop in San Antonio, TX on June 26th, 2012 Building Envelope Workshop Meeting Agenda (Draft) Windows Technology Roadmapping Workshop in Minneapolis, MN on June 28th, 2012 Windows Technology Meeting Agenda (Draft).pdf (119.09 ... [More]

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Windows Technology Roadmapping Workshop on June 28th Announced!

Posted by Webmaster on 26. April 2012 16:29

DOE-BTP's Building Envelope R&D Program, in association with the Window and Door Manufacturers Association (WDMA) has announced a "Windows Technology Roadmapping Workshop this summer in Bloomington, Minnesota! The workshop will take place at The Hotel Sofitel Minneapolis on June 28th from 10:00am-2:00pm in conjunction with the WDMA Annual Technical Conference. All windows technology stakehold... [More]

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Building Envelope – Macro Goals

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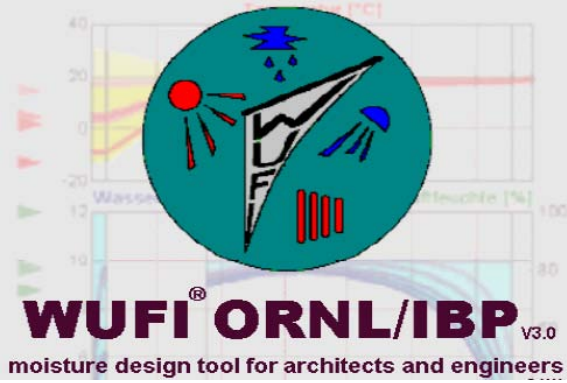
- Roofs:
  - Increase aged performance of roof coatings by 25%
  - Develop cost effective “cool-colored” asphalt shingles with no increase in 20 year life cycle cost by 2015
  - Next gen attic systems with 50% savings
- Windows:
  - Develop a cost-effective R-10 window
  - 0.1 U-Value windows at $3/sq ft price premium by 2020
- Insulation:
  - Dynamic insulation with over 20% peak load reduction
  - Dynamic annual performance of attics and walls with no increase in life cycle cost by 2015
- Building Integrated PV with higher PV output and min. 25% thermal load reduction

Sample advanced roof design applied to BIPV to be evaluated (50% reduction of roof thermal load)

Conduct Enabling Research

- Test protocols
- Design guidelines
- Modeling tools
- Industry standards
- Education Materials



Roadmap with Stakeholders

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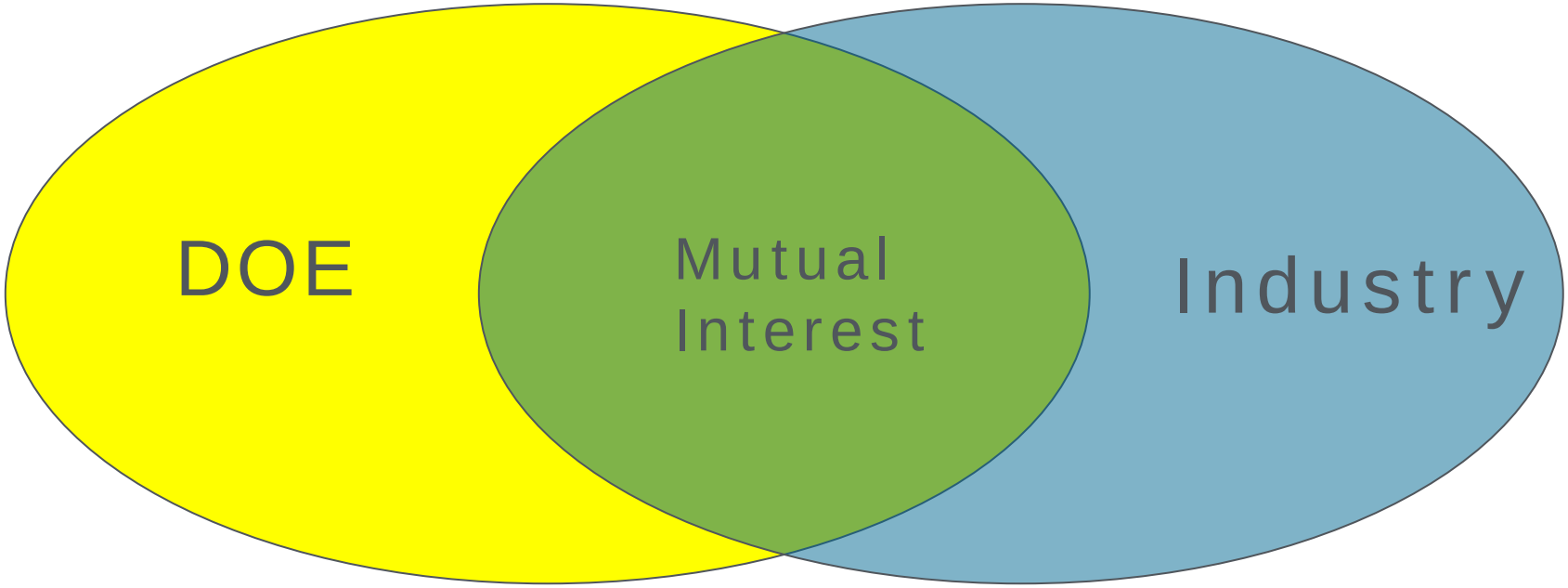
- DOE seeks input from stakeholders
- Scope related to envelope and window R&D
- Assessment of current projects
- Opportunity to provide your high priorities



Preliminary Feedback from Roofing Breakout Session – June 26th Meeting

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Objectives:

Cool Roofs:

- "super cool" roofs
- Climate specific assemblies
- Durability/service life
- Retention of reflectiveness

Unvented Attics:

- Moisture control
- Cost of sealed attics
- No hydrothermal modeling tool

Problems We Need to Solve:

- Education
- Code enforcement (& codes)
- moisture

Barriers:

- code development
- technology
- market attraction/aesthetics

Tasks & Critical Time Frames:

-within 5-10 years (comm. roof 15-20 year service life)

- development of accelerated aging program for roof membranes

Desired Outcomes:

-best practices/guidelines (not yet known- need research)

-"rating labels"- (benefit)

Potential Partnerships:

- SPRI, SFFA, RCMA, BOMA
- NRCA, NAHB, BETEC/BEC
- AGC, RAVC

Roof Presentation Overview

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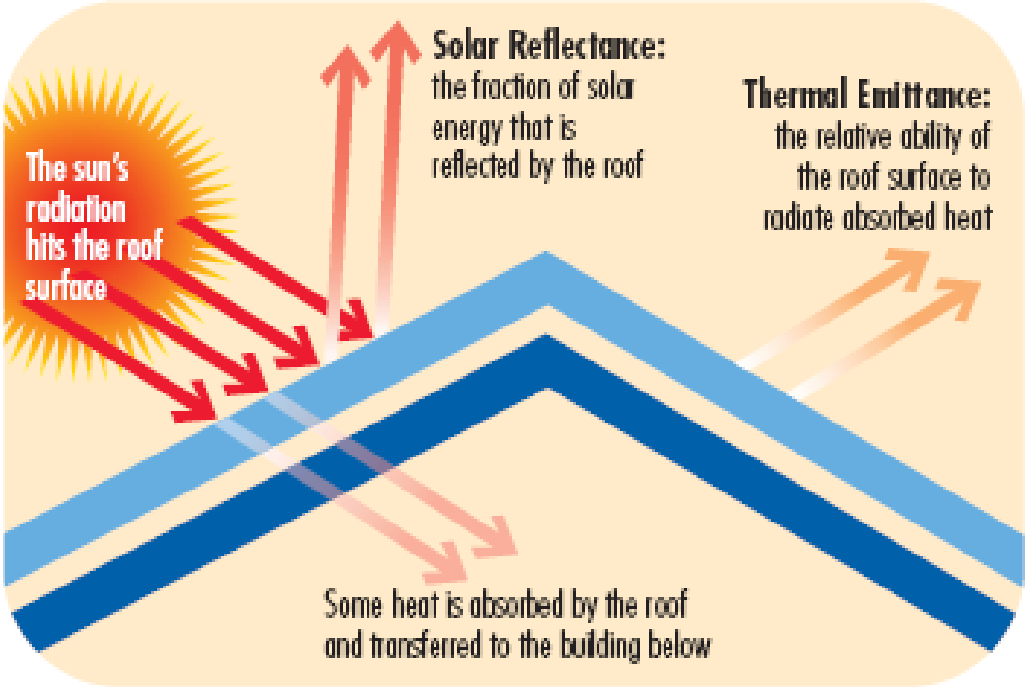
- Cool Roofs
- Urban Heat Island/Global Cooling
- Next Generation of Attic/Roof Systems
- International Collaboration

What is a Cool Roof?

CRRC only looks at **surface** properties:

- Solar Reflectance
- Thermal Emittance

CRRC does **not** set minimum requirements



Not All Cool Roofs are White

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Buildings Level

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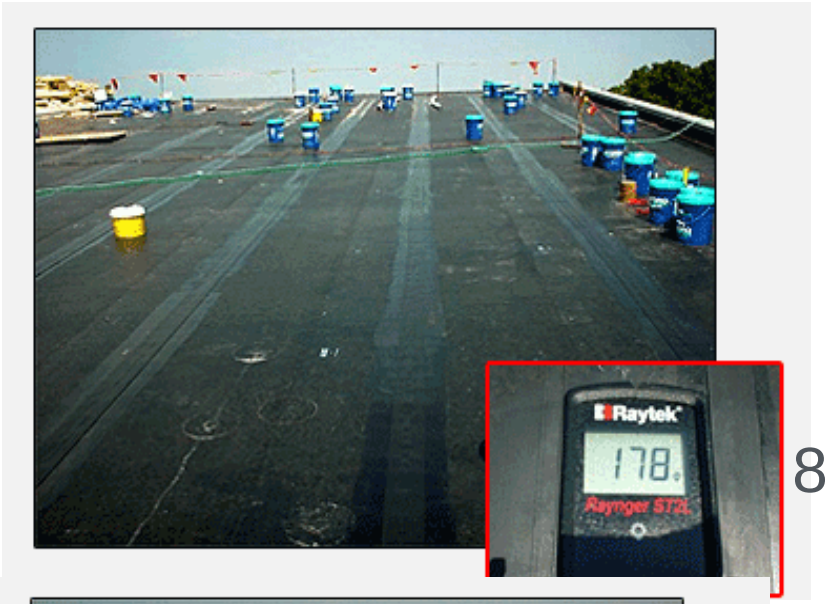
- Key Accomplishments:
  - Cool Roof Selection Guide
  - Cool Roof Calculator
  - DOE Cool Roof Policy
- Key Upcoming Work
  - Aged Rating Protocol
  - Advanced Materials



81° C

34° C

DOE Cool Roof Policy

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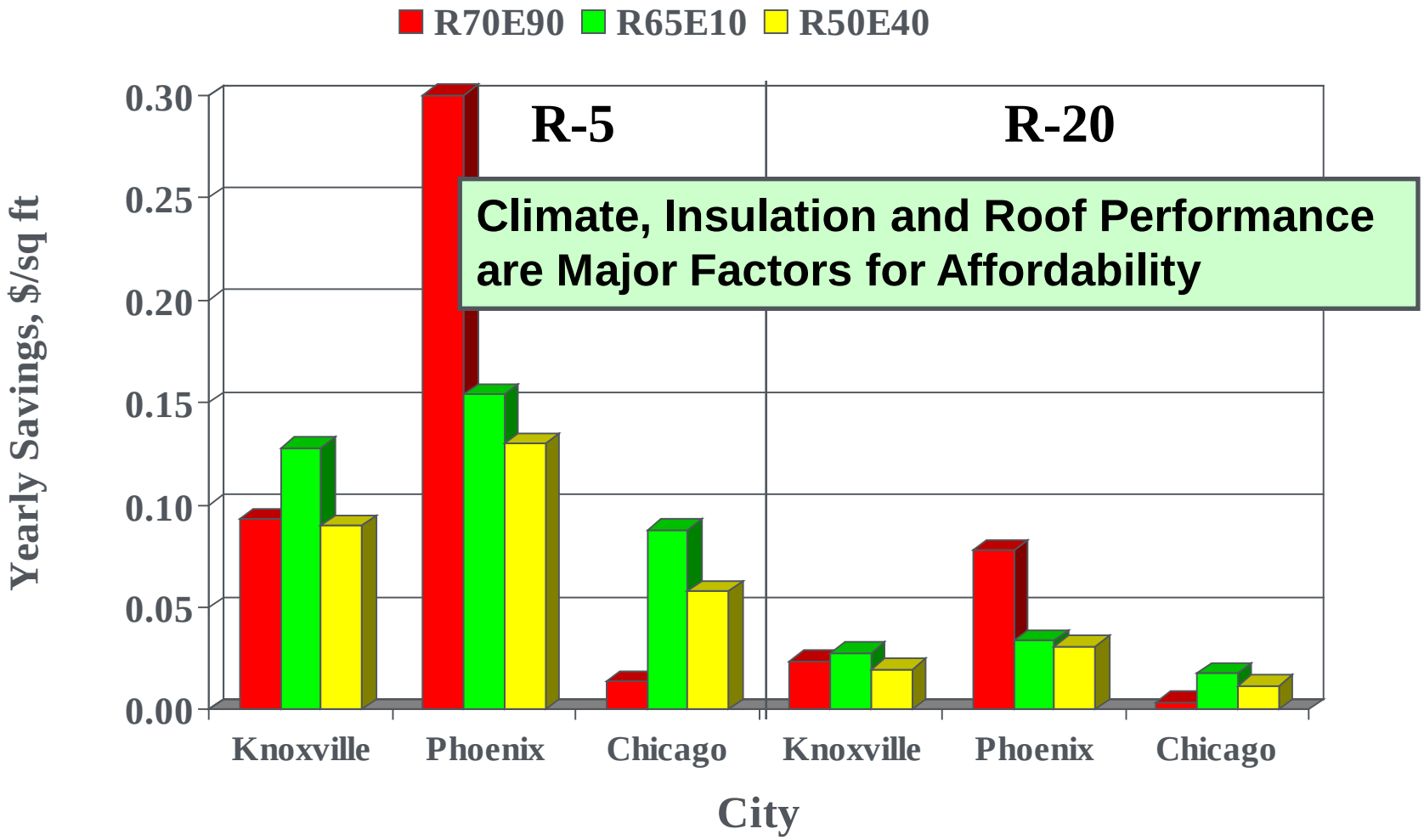
A low-sloped roof (pitch less than or equal to 2:12) must be designed and installed with a minimum 3-year aged solar reflectance of 0.55 and a minimum 3-year aged thermal emittance of 0.75 in accordance with the Cool Roof Rating Council program, or with a minimum 3-year aged solar reflectance index (SRI) of 64 in accordance with ASTM Standard E1980-01. Steep-sloped roofs (pitch exceeding 2:12) must have a 3-year aged SRI of 29 or higher.

Requires R30 insulation

Is required unless determined to be uneconomical by life cycle cost analysis

Roof Energy Savings



10 cents/kwh, COP of 2.0, Furnace AFUE 0.80, $1.30 Therm
NO PEAK DEMAND CREDIT – COULD DOUBLE SAVINGS

Cool Roof Selection Guide

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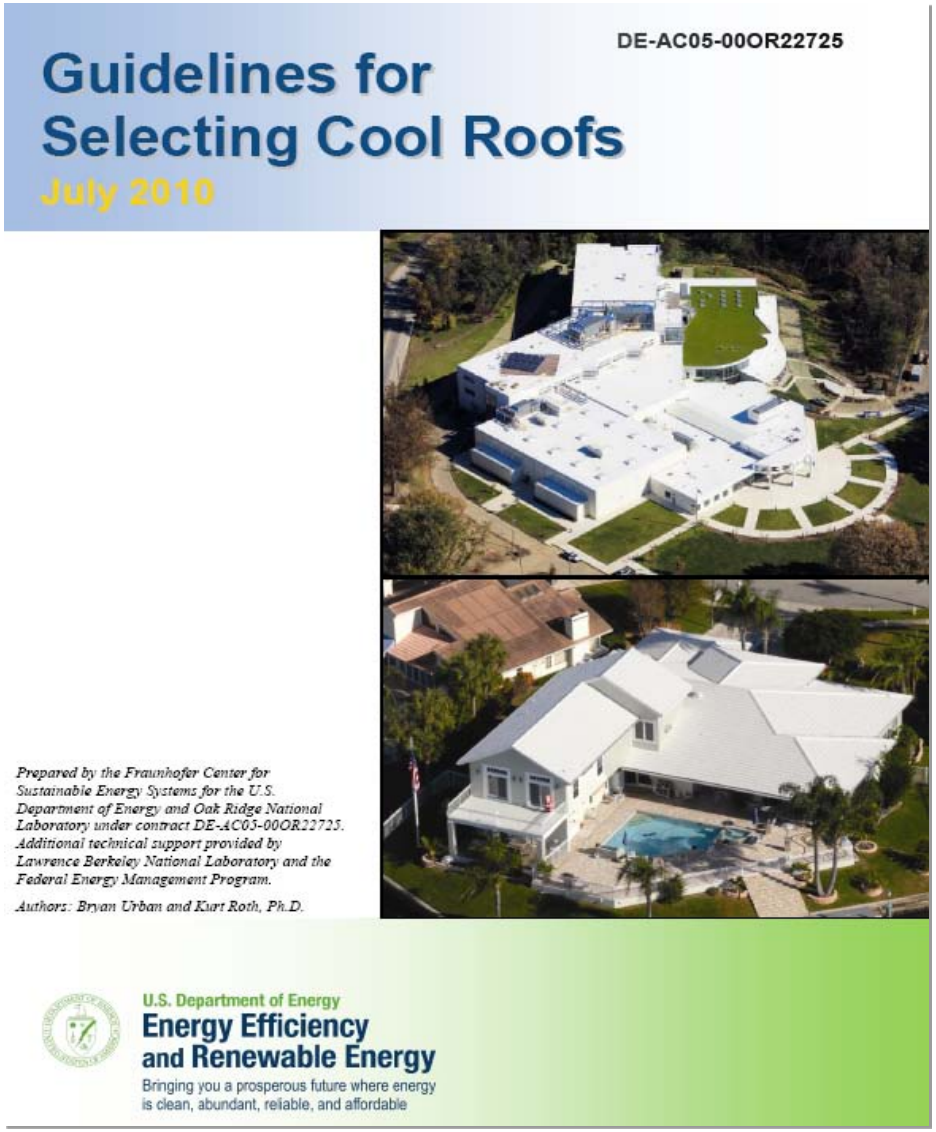

DE-AC05-00OR22725

Guidelines for Selecting Cool Roofs

July 2010

Prepared by the Fraunhofer Center for Sustainable Energy Systems for the U.S. Department of Energy and Oak Ridge National Laboratory under contract DE-AC05-00OR22725. Additional technical support provided by Lawrence Berkeley National Laboratory and the Federal Energy Management Program.

Authors: Bryan Urban and Kurt Roth, Ph.D.

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Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Roof Savings Calculator

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- Collaboration by ORNL and LBNL with funding from DOE and CEC and supported by EPA
- Provides cool roof assessments and advanced roof options
- Runs full simulations
- See RoofCalc.com
- Site currently down for validation

Roof Savings Calculator (RSC)

Beta Release v0.7

Oak Ridge National Laboratory
Lawrence Berkeley National Laboratory

Introduction
The Roof Savings Calculator was developed as an industry-consensus roof savings calculator for commercial and residential buildings using whole-building energy simulations. It is built upon the DOE-2.1E engine for fast energy simulation and integrates AtticSim for advanced modeling of modern attic and cool roofing technologies. An annual simulation of hour-by-hour performance is calculated for the building properties provided based on weather data for the selected location. Annual energy savings reported are based upon heating and cooling loads and thus this calculator is only relevant to buildings with a heating and/or cooling unit.

Roof Savings Calculator
To begin, please select from the following options:

Residential

Commercial

Accelerated Aging Tasks

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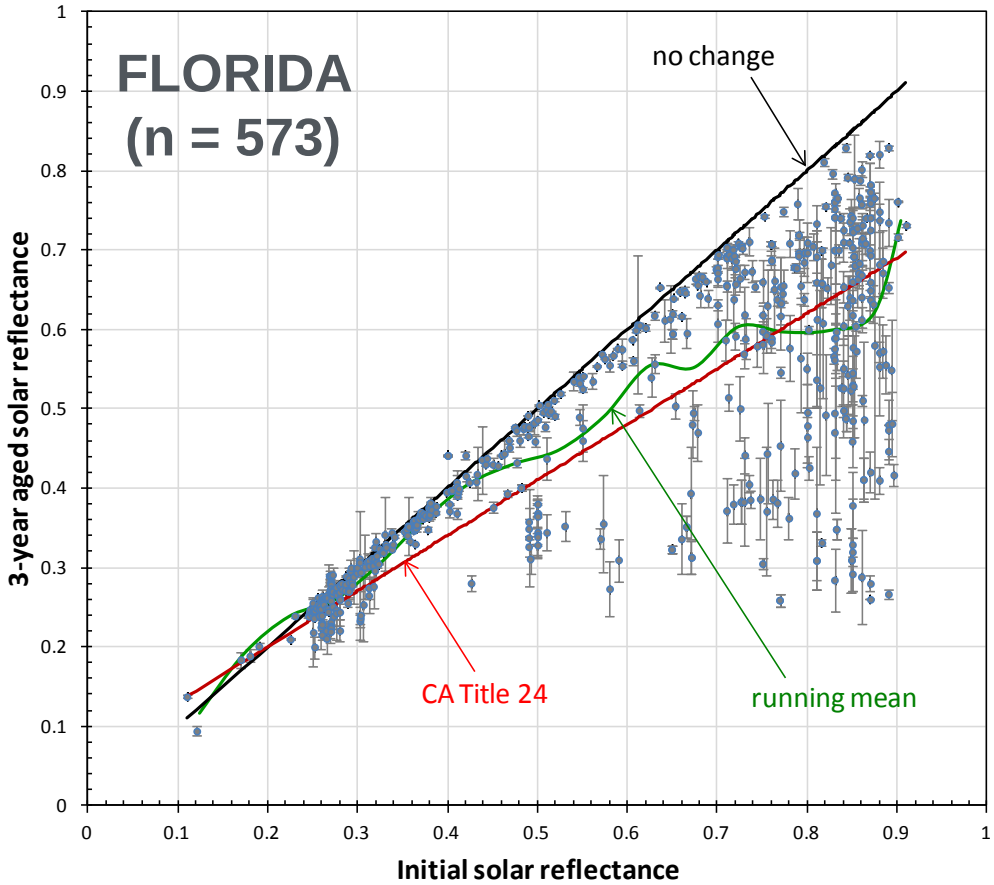
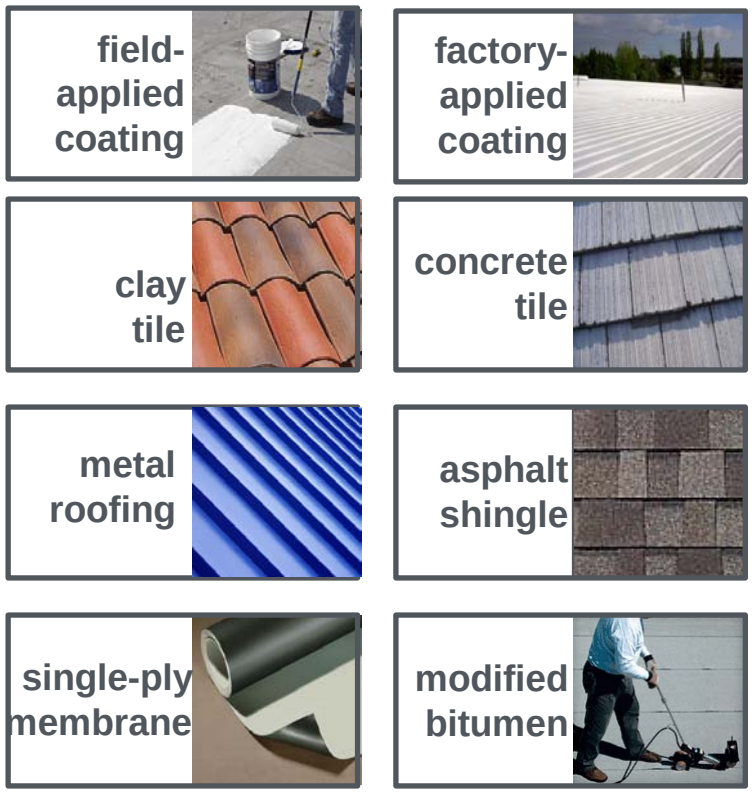
- Develop accelerated soiling protocol
  - Study samples and refine protocol
  - Validate and peer review protocol
  - Release final accelerated aging protocol for cool roofs
  - Author ASTM Standard based on protocol

Solar Reflectance is Variable and Degraded by Natural Soiling





Sleiman et al. 2011. *Solar Energy Materials and Solar Cells* 95:3385-3399

Minimizing loss of solar reflectance could boost white-roof energy savings by 50%

Create ASTM & ISO Standards for Rapid & Calibrated Accelerated Aging

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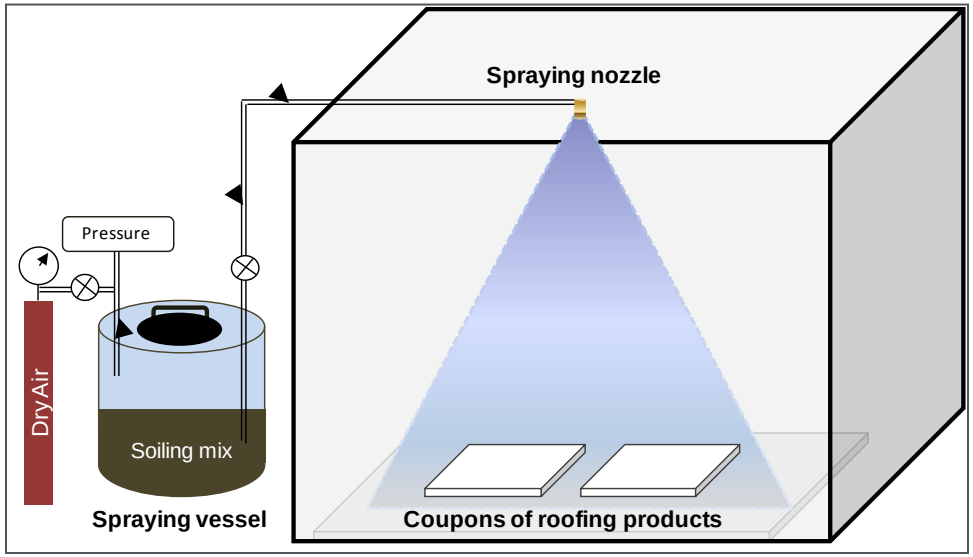

Laboratory aging

Natural exposure

ASTM INTERNATIONAL Standards Worldwide

ISO International Organization for Standardization

Standardization

Soiling Method Reproduces CRRC's 3-Year-Aged Ratings in 3 days

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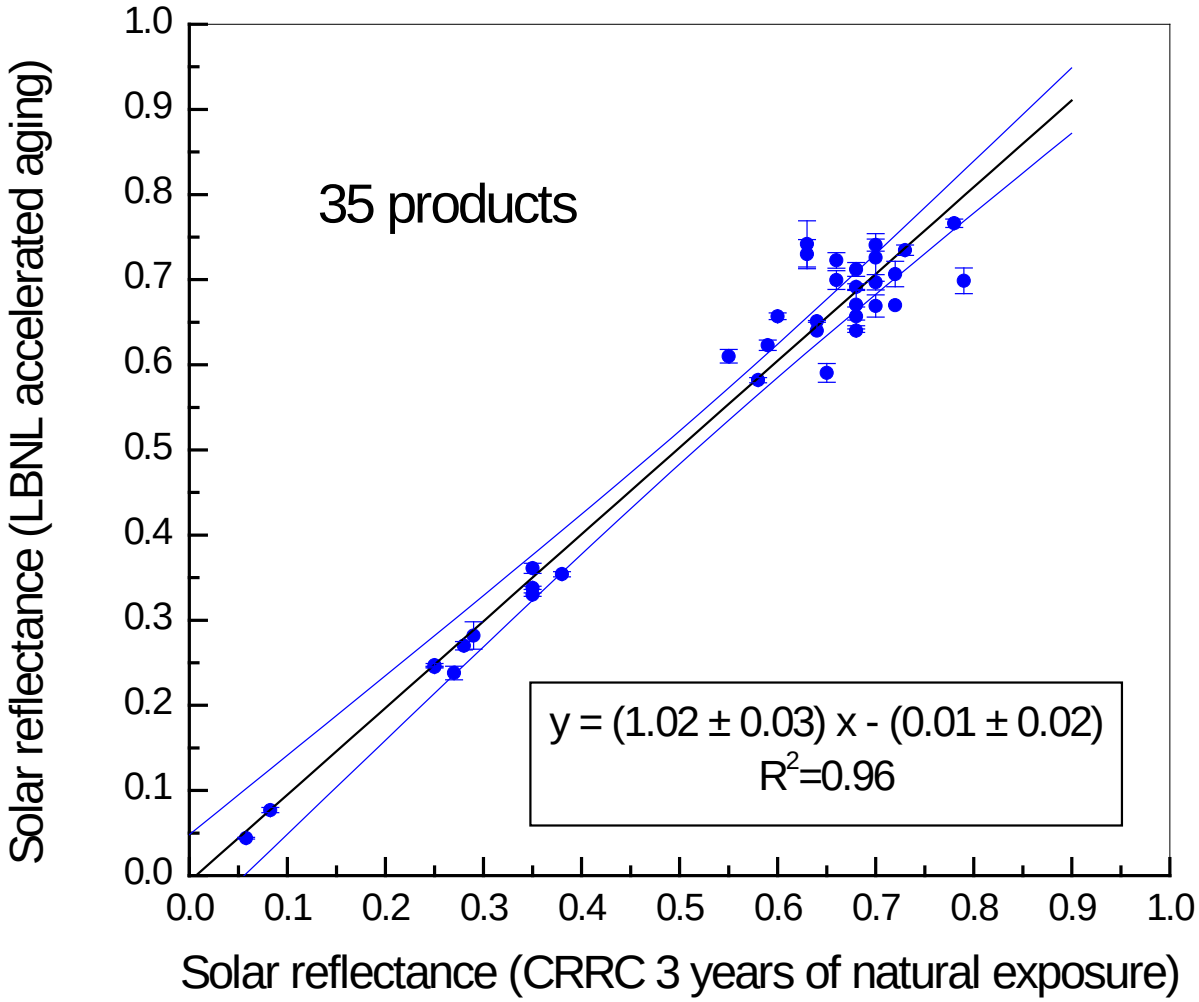

Field applied

Metal or factory-applied

Single-ply membrane (n=11)

Clay tile (n=2)

Asphalt shingle (n=4)

Modified bitumen (n=3)

Ongoing Microbial Growth Activities

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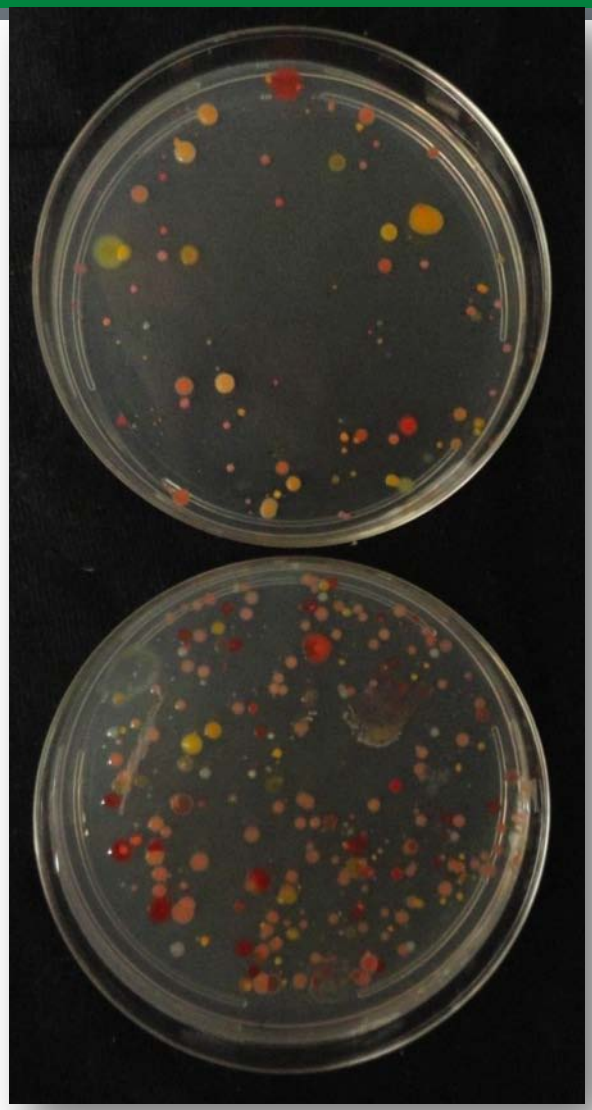
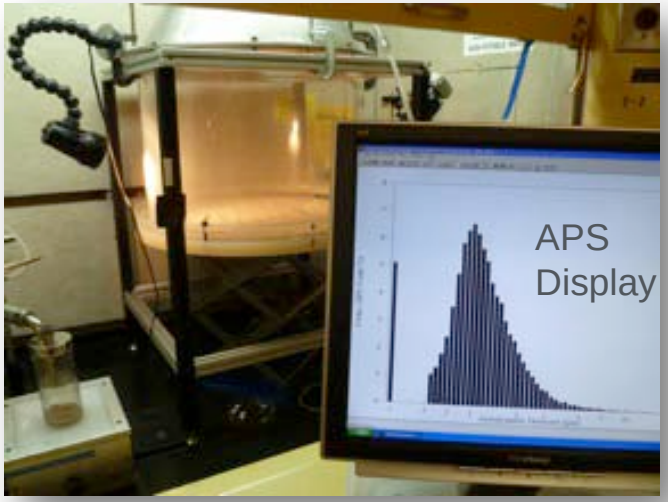
- Characterized of microbial community on roof samples weathered in different climatic regions of the US, varying exposure times
- Designed accelerated testing apparatus for inoculation
- Establish accelerated testing protocol under laboratory-controlled climatic conditions



Design Microbial Loading Apparatus



Clean Simulated

- Chamber built for accommodating a sample of size up to 15” in dia. or multiple samples of smaller area
- Real-time monitoring capability for particle loading
- Design for loading dry and or <u>wet contaminants</u>
- On-demand stable particle load over time

Advanced Materials Tasks

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Develop next generation products:

- Develop higher performing and more durable field applied coatings (CRADA with DOE Building Solutions)
- Affordable cool asphalt shingles (CRADA with Owens Corning)
- Develop retrofit coating for asphalt shingles (CRADA with CertainTeed and Dow Building Solutions)
- Evaluate de-soiling and anti-soiling additives/functionalities
- Develop self-cleaning materials
- Develop durable thermochromic intelligent roof coatings
- Explore cool pavements

Making Commercial Roofs White creates $11B in Lifetime Energy Savings

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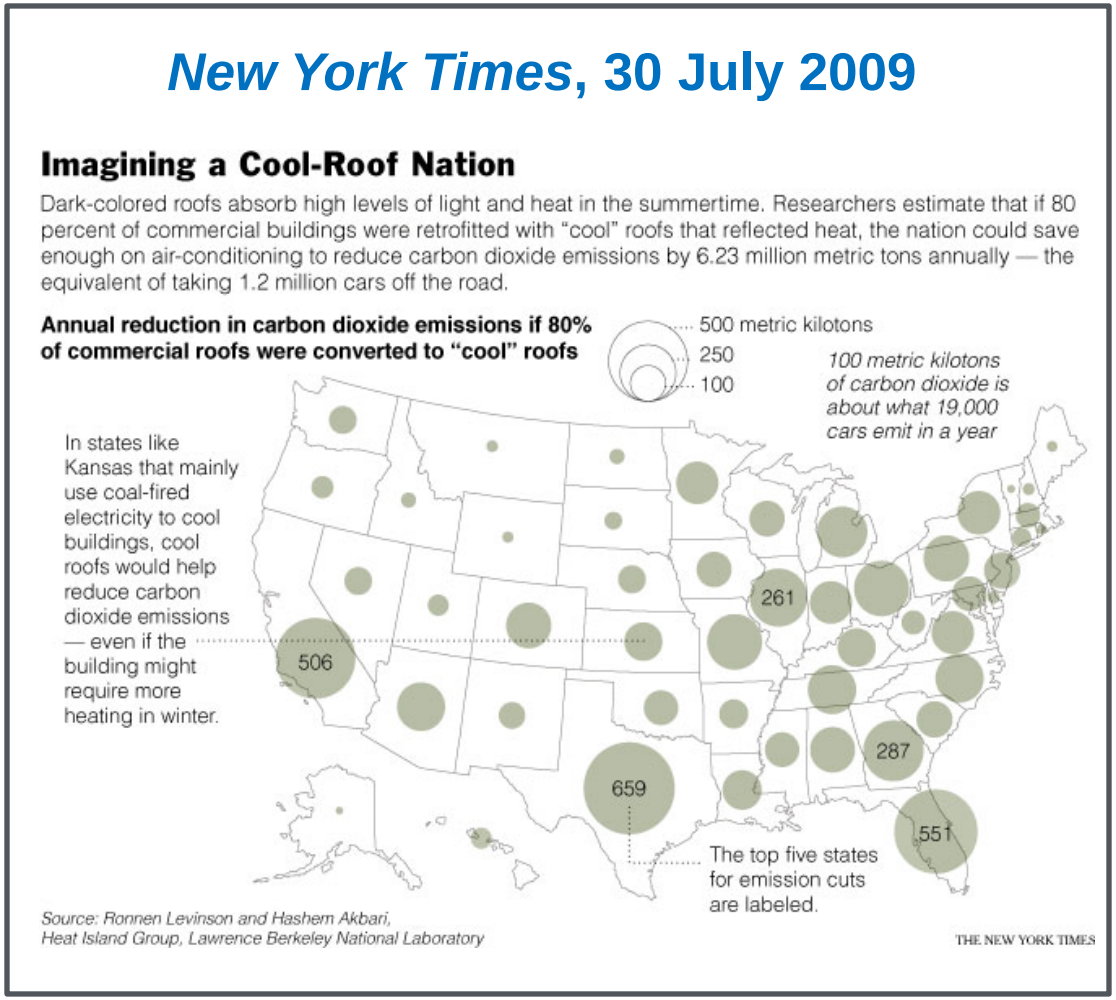
Retrofitting 80% of U.S. air-conditioned commercial buildings with **conventional** white roofs would annually save

- $735M
- 6.2 Mt CO_2 (=1.2M cars)

through energy conservation



Levinson R, Akbari H. 2010. *Energy Efficiency* 3:53-109.

CRADA with Dow Develops White Elastomeric Coatings that Stay Clean

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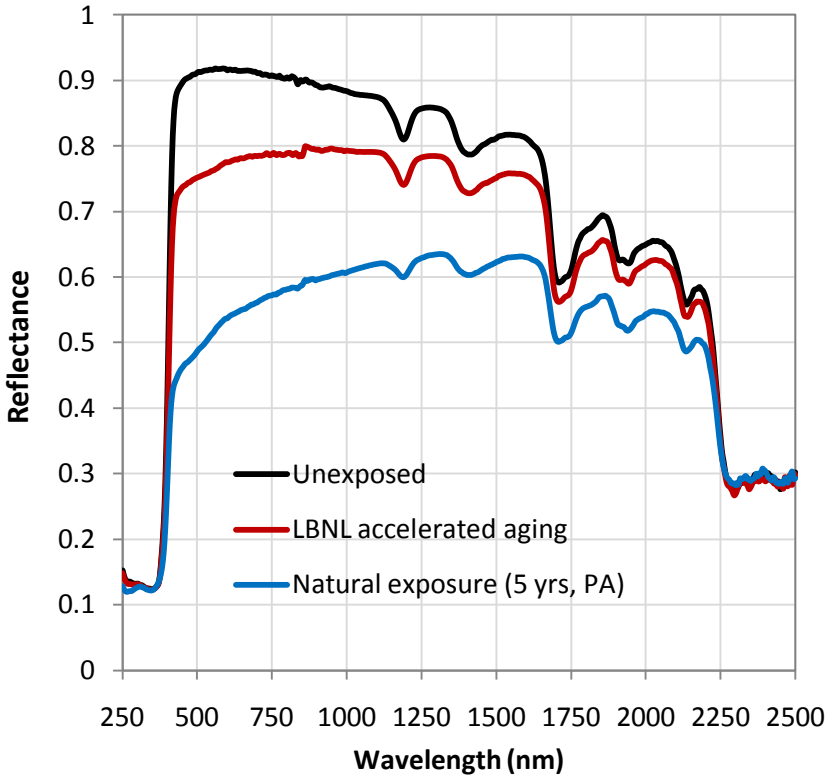

New aging method will be enhanced to simulate material degradation for rapid prototyping of stay-clean coatings with exceptionally long service lives.

	Solar reflectance
Unexposed	0.87
LBL accelerated aging	**0.76**
Natural exposure (3 yr CRRC)	**0.76**
Natural exposure (5 yr, PA)	0.54

About 80% of Residential Roofing Market is Dark Hot Asphalt Shingles

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Upgrading these roofs yields $14B in lifetime energy savings

Reflectance map generated from multi-band aerial images in our CARB-sponsored California Roof Albedo project

Nominal Visible Reflectance
- 0.00 - 0.05
- 0.06 - 0.10
- 0.11 - 0.15
- 0.16 - 0.20
- 0.21 - 0.25
- 0.26 - 0.30
- 0.31 - 1.00

San Jose, CA

CRADA with Owens Corning Develops Low Cost Cool Asphalt Shingles

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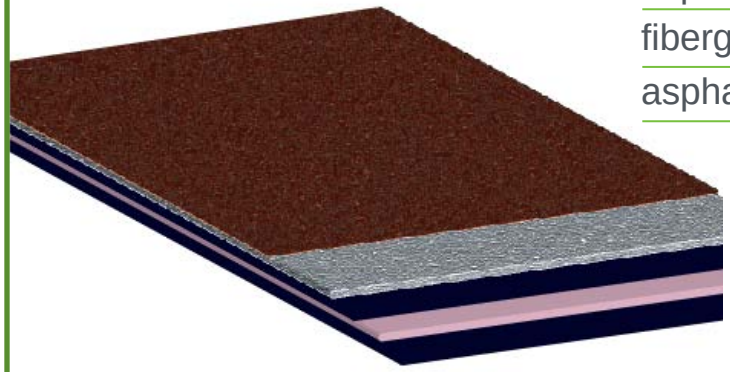
BERKELEY LAB | OAK RIDGE National Laboratory | OWENS CORNING

Approach 1: Improve granule coatings

Approach 2: Use bare granules and spray coating(s)



Approach 3: Solar reflective clear top coat on conventional shingle

CRADA with CertainTeed & Dow Develops Asphalt Shingle Coatings

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- Estimate energy cost savings
- Avoid previous failures
- Develop prototypes with increased reflectance
- Maintain aesthetics & durability

Retrofit coatings are available for most roofing products *other than asphalt*

before

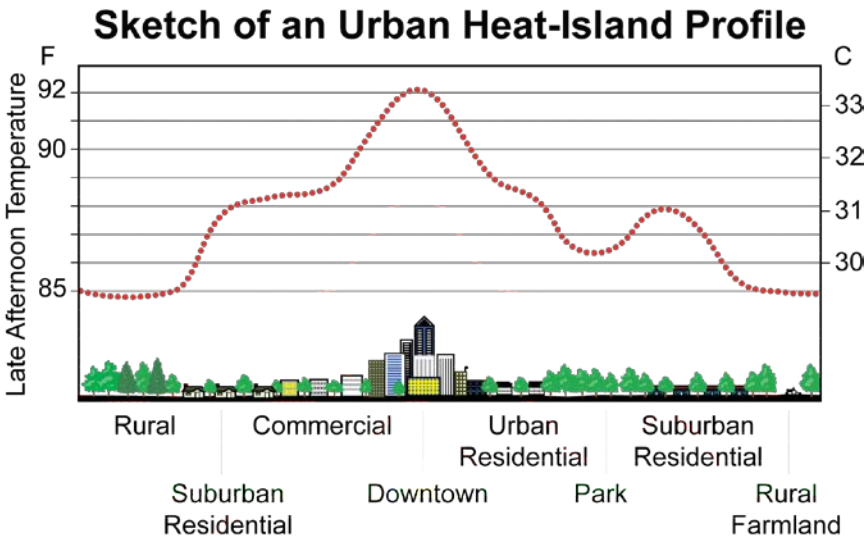
elastomeric coating over capsheet

acrylic coating over tile

after

Urban Level

- Key Accomplishments:
  - Major Literature Review
- Key Upcoming Work
  - LBNL study of urban pollution abatement



Urban Heat Island Review

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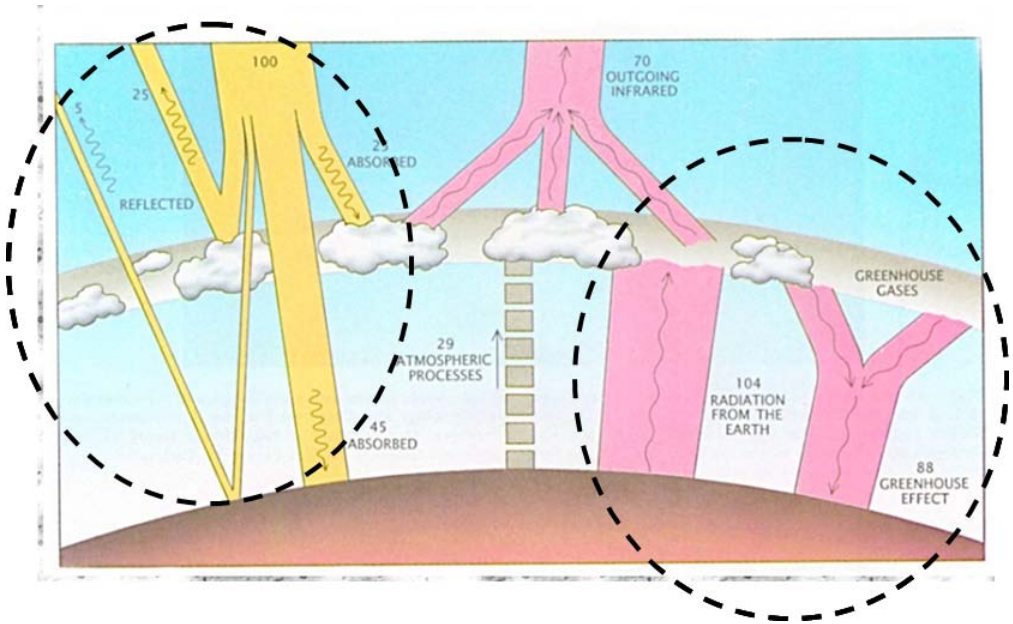
- Review of over 240 research papers, articles, and presentations
- Key Findings:
  - The scale of UHI phenomena is large and increasing. The cost incurred is considerable.
  - Countermeasures (including white and vegetative roofs) are an effective way to reduce urban temperature and its effects.
  - The few macro scale assessments suggest countermeasures would improve urban environments and lead to both direct and indirect CO2 savings.
  - The current research on UHI stems from only a few research organizations – the research base needs to be broadened and deepened.
  - Awareness of the issue of UHI phenomena is low. DOE needs to increase awareness in addition to supporting countermeasures.

Global Level

- Key Accomplishments:
  - Peer Review Panel
- Key Upcoming Work
  - Validation of Global cooling models
  - India Project



Source: IPCC

Total emitted CO2 offset for cool roofs and cool pavements = 44 GT CO_2

Radiative Forcing Models

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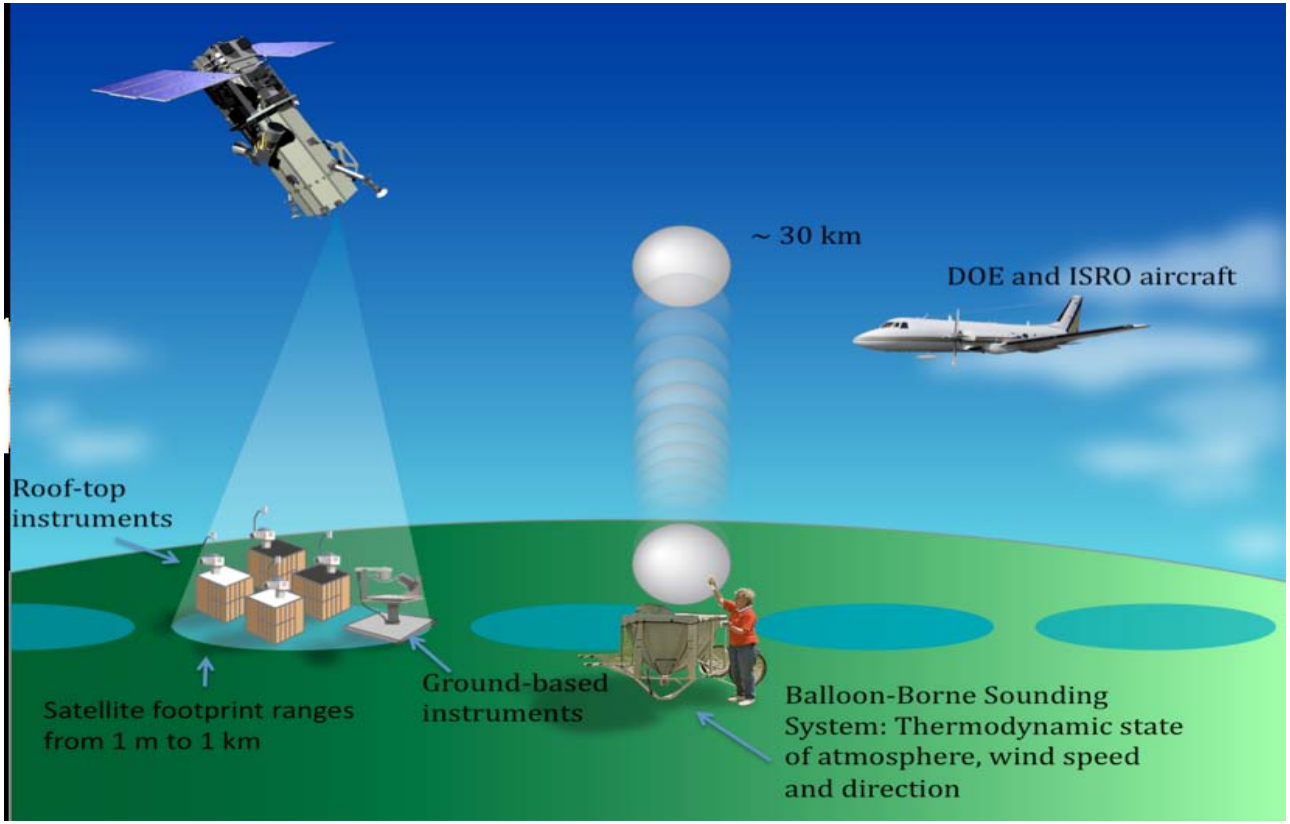
- Emitted CO_2 offset for cool roofs = 24 GT CO_2
- Emitted CO_2 offset for cool pavements = 20 GT CO_2
- Total emitted CO2 offset for cool roofs and cool pavements = 44 GT CO_2
- 44 GT CO2 is over one year of the world 2025 emission of 37 GT CO2
- Note: Menon, Akbari et al. (2010) estimate 57 GT CO_2

Global Cooling Tasks

- Validate and Verify Models!
- India Project: Collaborating on an Office of Science study to measure radiation impact before and after roof surface albedo is increased.



Key Outreach Activity

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- DOE working with the Global Cool Cities Alliance to conduct enabling research to work with communities and efficiency advocates

www.globalcoolcities.org

The Basics

How It Works
Cooler Buildings
Cooler Cities
Cooler Planet

Home
About Us
Resources
In the News
Q&A
Contact Us

Kaohsiung City, Taiwan. Photo Flickr Creative Commons

About GCCA

Global Cool Cities Alliance is a non-profit dedicated to advancing policies and actions that increase the solar reflectance of our buildings and pavements as a low cost way to promote cool buildings, cool cities, and, most importantly, to mitigate the effects of climate change through global cooling.

Learn more about our work.

Download a fact sheet on cool roofs and GCCA.

GCCA Advisory Board

GCCA Management Team

Key Initiatives

Check out the Knowledge Base, the newest addition to the Cool Roofs and Pavements Toolkit!

Check it out at CoolRoofToolkit.org!

GCCA is coordinating the Cool Roofs Working Group which is part of the Clean Energy Ministerial and the International Partnership for Energy Efficiency Cooperation.

Next Generation of Roof and Attic Designs

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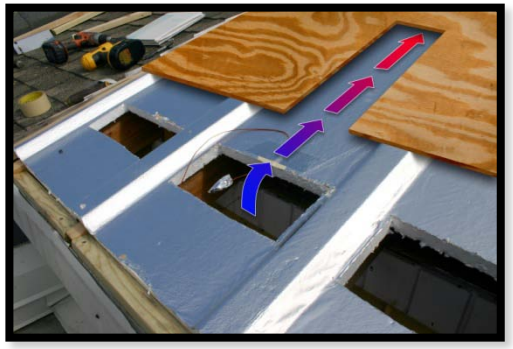

Insulated and Ventilated Shingle Roof

Conventional or cool color shingle; 1-in. (0.0254-m) air space made by profiled and foil-faced 1-in. (0.0254-m) EPS insulation placed above deck (retrofit practice) or fitted between roof rafters (new construction); two low-e surfaces.

TXU Energy Utility Bill
Texas Homeowner with New Attic Design
(Insulated and Ventilated roof Deck)

	June 2011	June 2010
	After Retrofit	Before Retrofit
Days in Billing Cycle	30	32
Total Charges	$174.90	$300.75
kWh Used	1298	2269
Average Outdoor Air Temperature	85°F	83°F
Number of days Above 80°F	30	32

Above deck insulation and ventilation assembly under asphalt shingle

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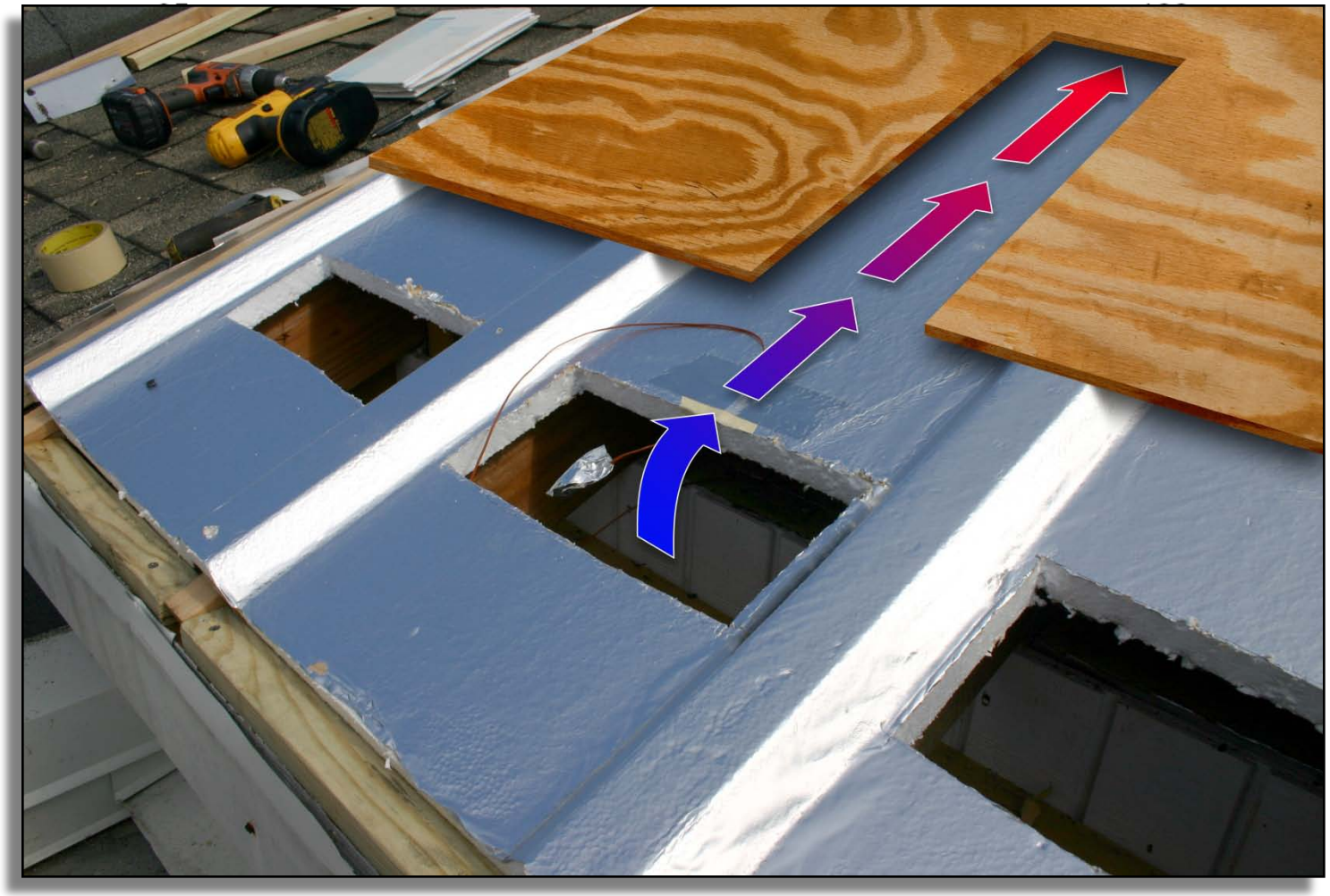
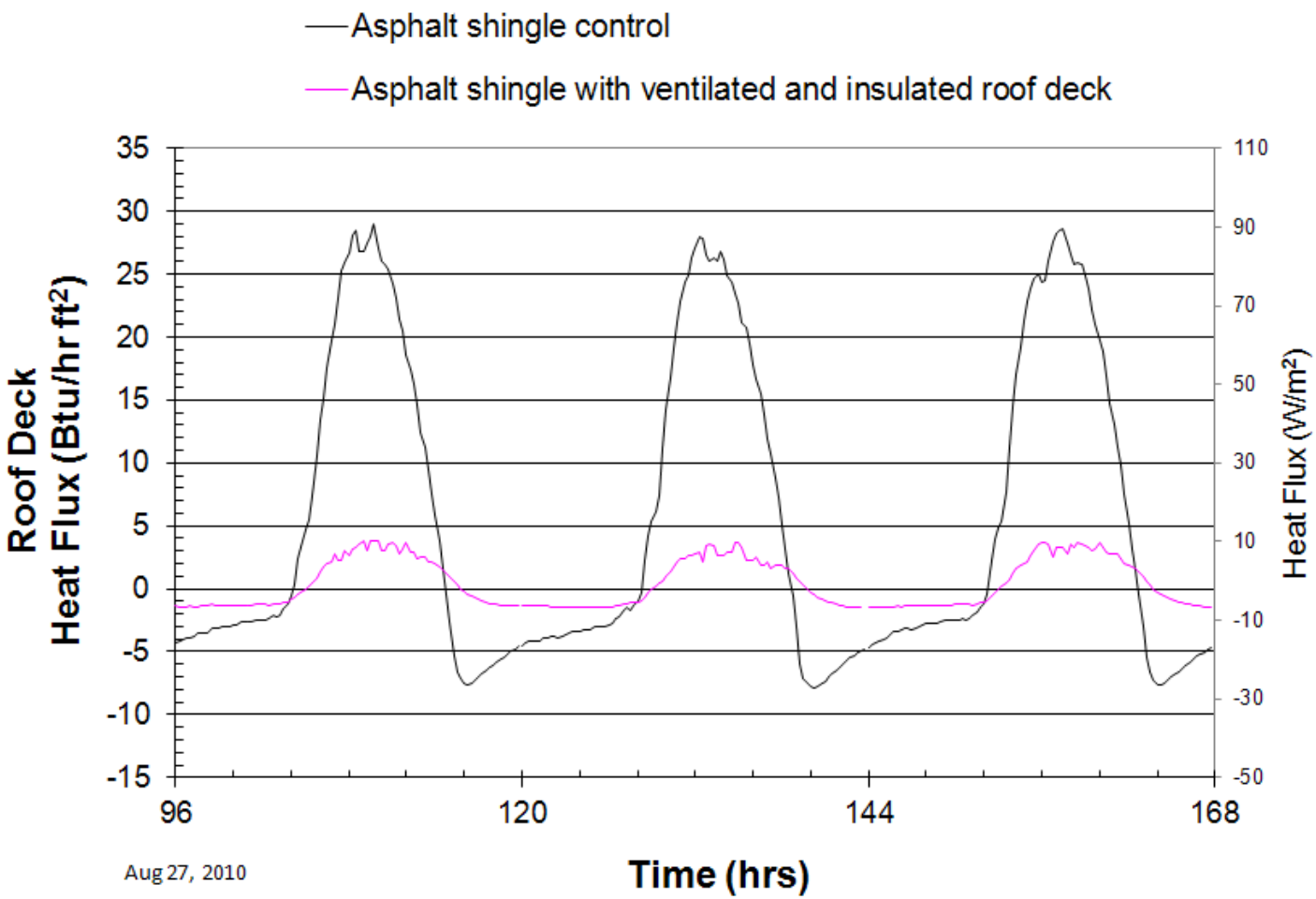


Above deck insulation and ventilation assembly under asphalt shingle



Above deck insulation and ventilation assembly under asphalt shingle

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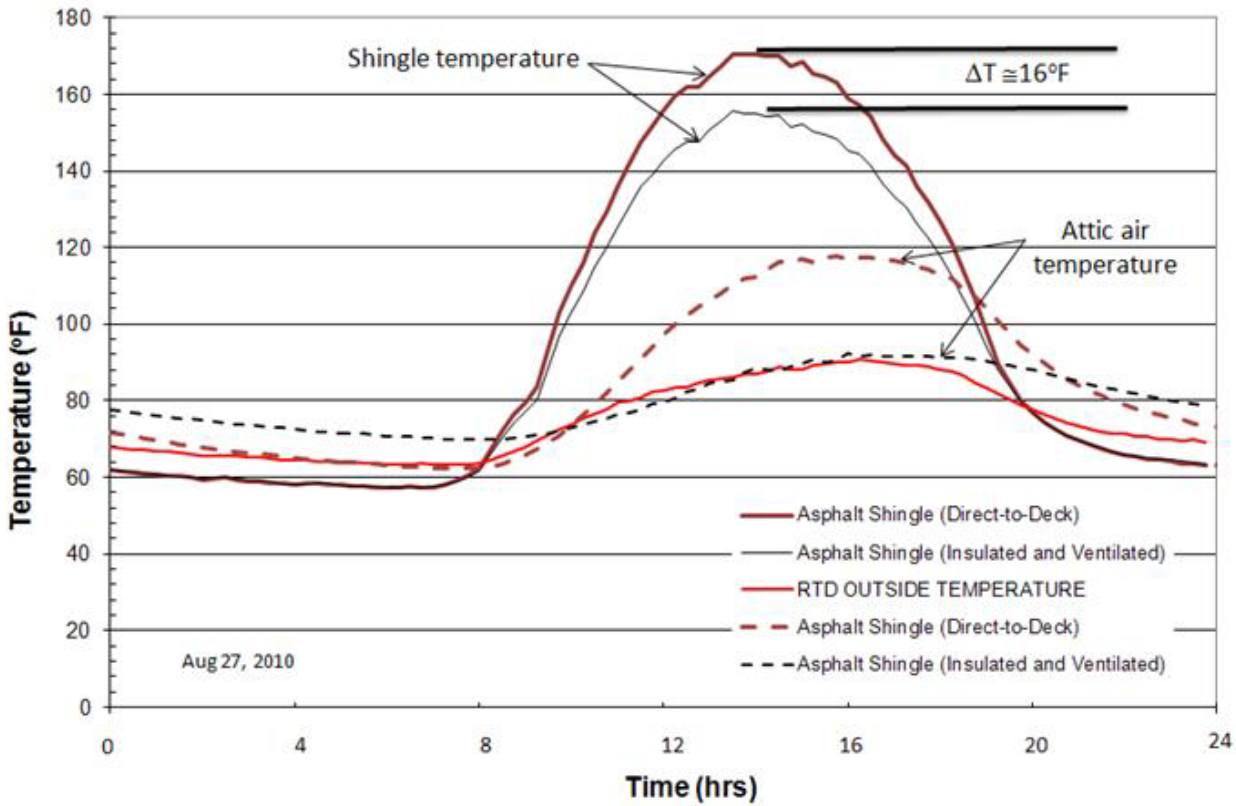
Key Goals : Reduce the operating temperature of shingles
Reduce the attic air temperature
Reduce thermal load to the building



OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Retrofit New Attic Design

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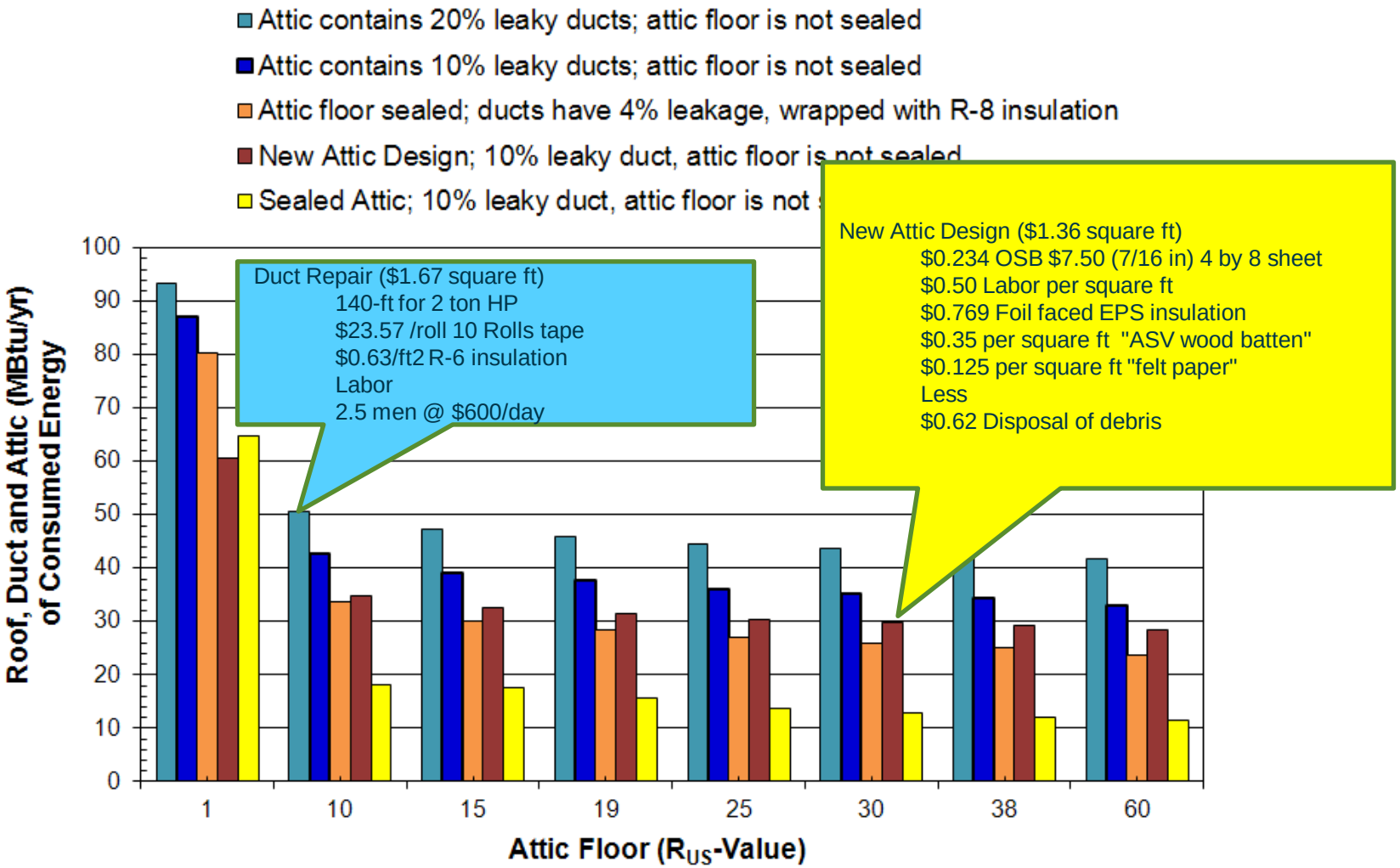

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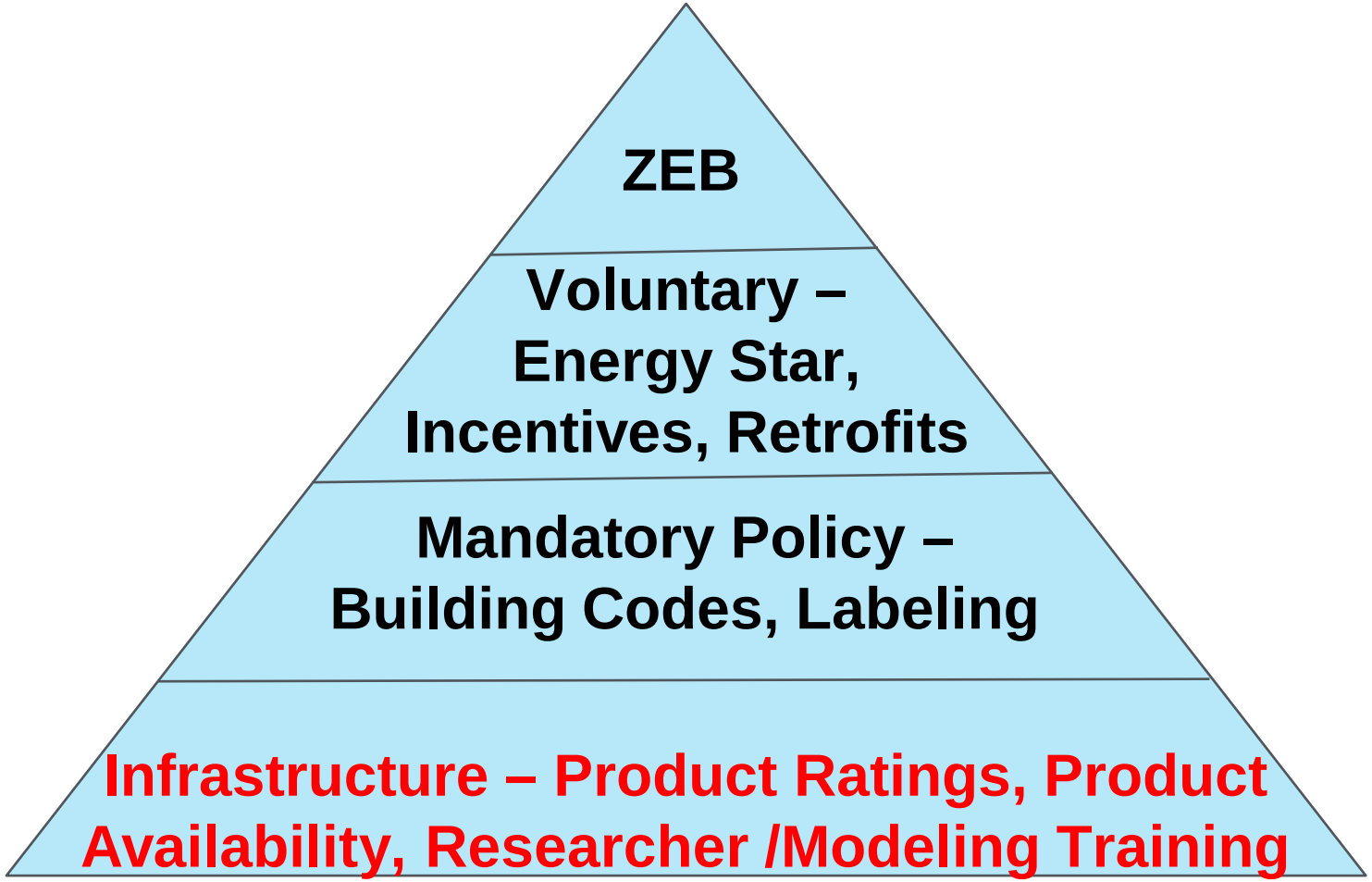
Major Policy Areas for Developing Countries – We forget about Infrastructure in the US since it is so developed



Key Elements are Interrelated and Work to Achieve Results

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Code Development

- Sends a strong message to economy
- Sets goals to strive for

Infrastructure

- Needed to assess key building components
- Likely starting point, but hard to get interest w/o codes

Enforcement

- Key issue to achieve results, but often not investigated deep enough
- Core problems include lack of product ratings, product availability, lack of knowledge

International Activities

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- Support international codes and standards
- Support collaboration in with Clean Energy Ministerial (CEM) Global Superior Energy Performance (GSEP) Cool Roof Working Group (Mexico, India, and Japan), and with China, APEC (Thailand - Regional Test Center) , and Brazil
- Work with EU CRRC

Key Driver	USA	India
Climate	Moderate	Very Hot
Insulation Levels	High	Low
Roof Configuration	Flat and Steep	Mostly Flat
Conventional Roof	Black on commercial, Asphalt on residential	Concrete Slab
Solar Reflectance Improvement Potential	Flat SR 10 to 60+ Steep SR 15 to 30+	All SR 20 to 60+
Labor Cost	High	Low
NET IMPACT	Mostly cost effective for new construction on commercial buildings	Can be cost effective for all existing and new buildings, and will provide comfort for non-conditioned buildings - avoid future conditioning.

Final Remarks

- The USA had initiated unprecedented investment in envelope and window research, this will decline sharply, could end up with less than 25 percent labor of the buying power compared to 2002
- New technology will be essential to achieve low carbon, low energy buildings, and to develop more affordable solutions for existing building stock
- Envelope investment has essential role to reduce HVAC loads and has a longer life cycle – lost opportunity if not done now!
- Roofing is a major component and stakeholder participation is highly valued

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