Urban Heat Island Effects on Energy Use, Climate, Air Pollution, and Greenhouse Gases

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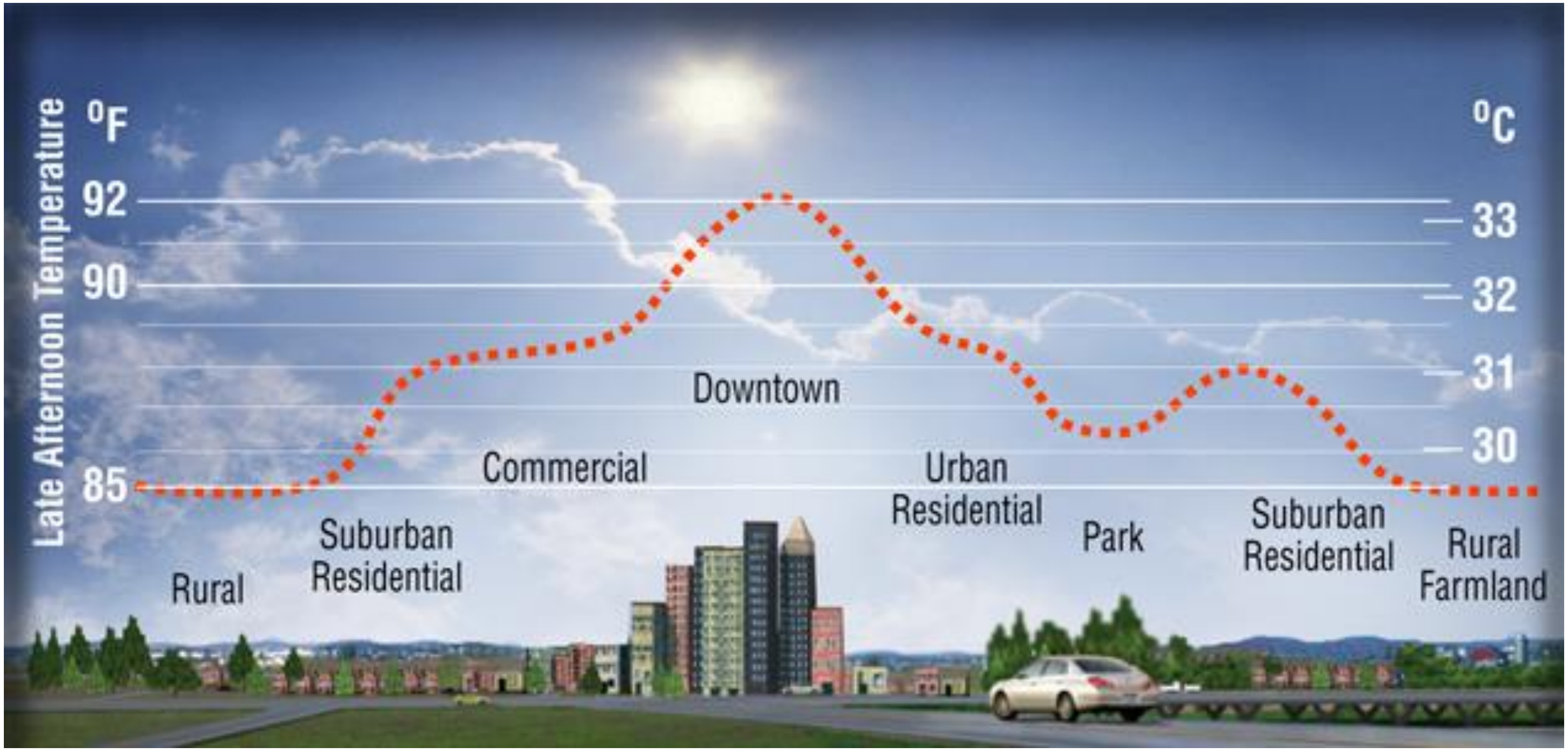
1. The Urban Heat Island

Hot town—summer in the city

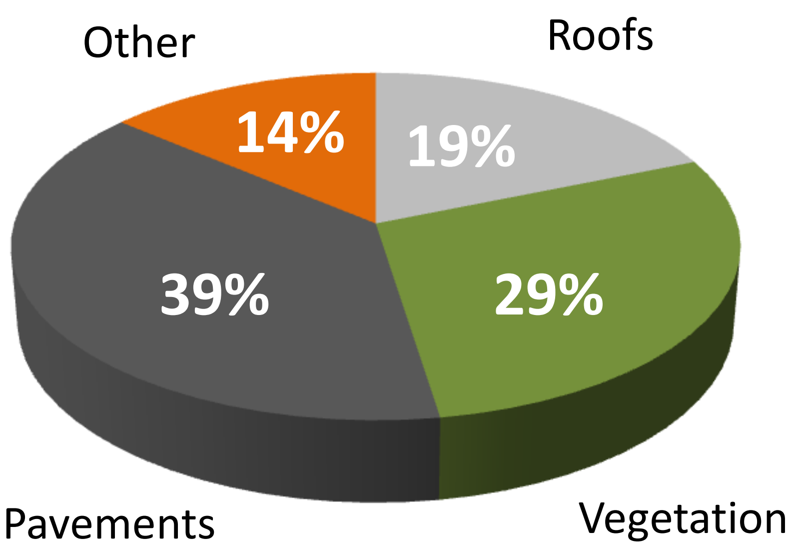


a summer urban heat island

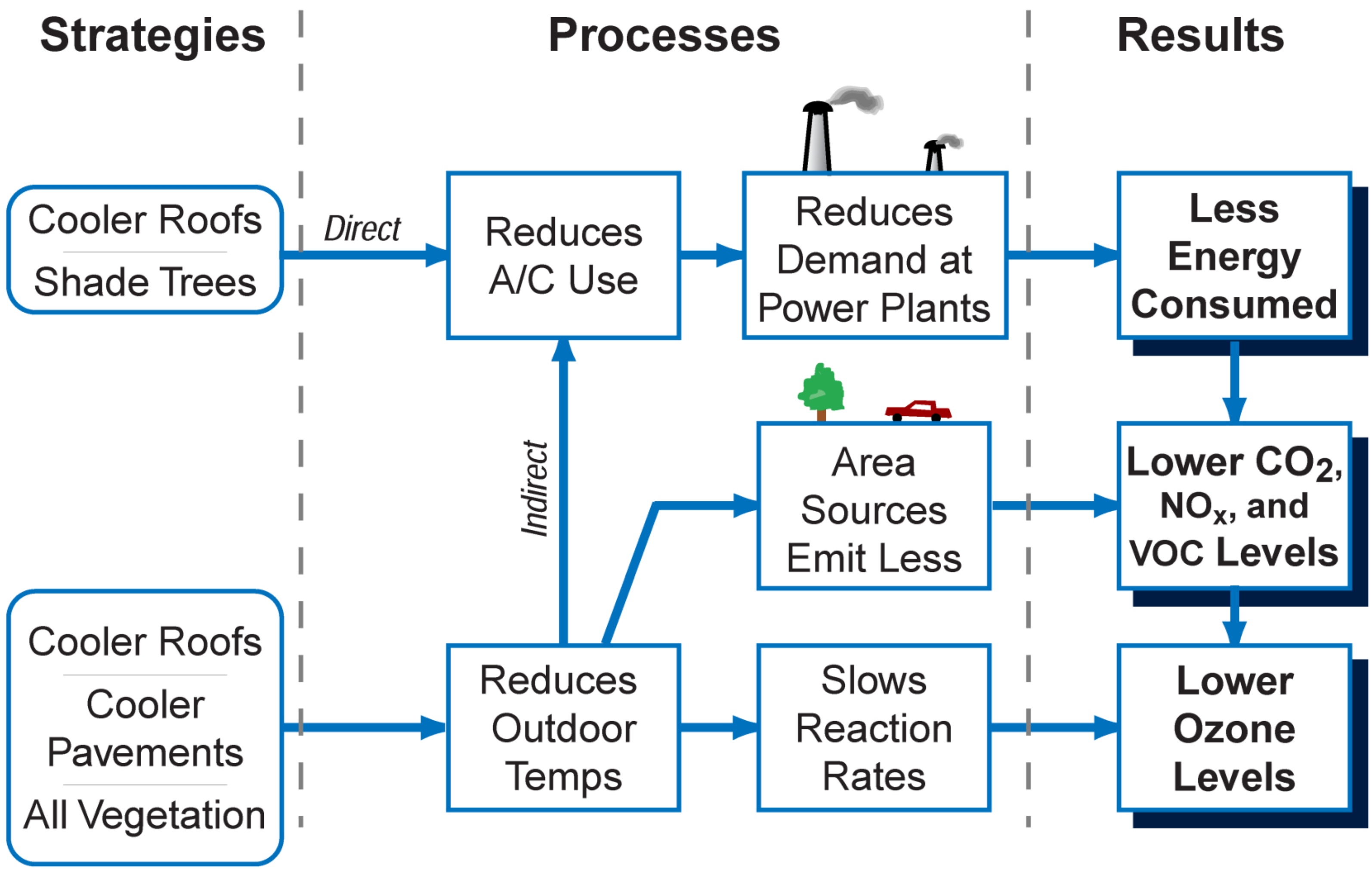
What makes cities warm?

Sacramento, California (≈ 1 km^2)

One reason: many dark surfaces.



Cool strategies include roofs, pavements, trees—and soon walls



2. Identifying Urban Heat Islands

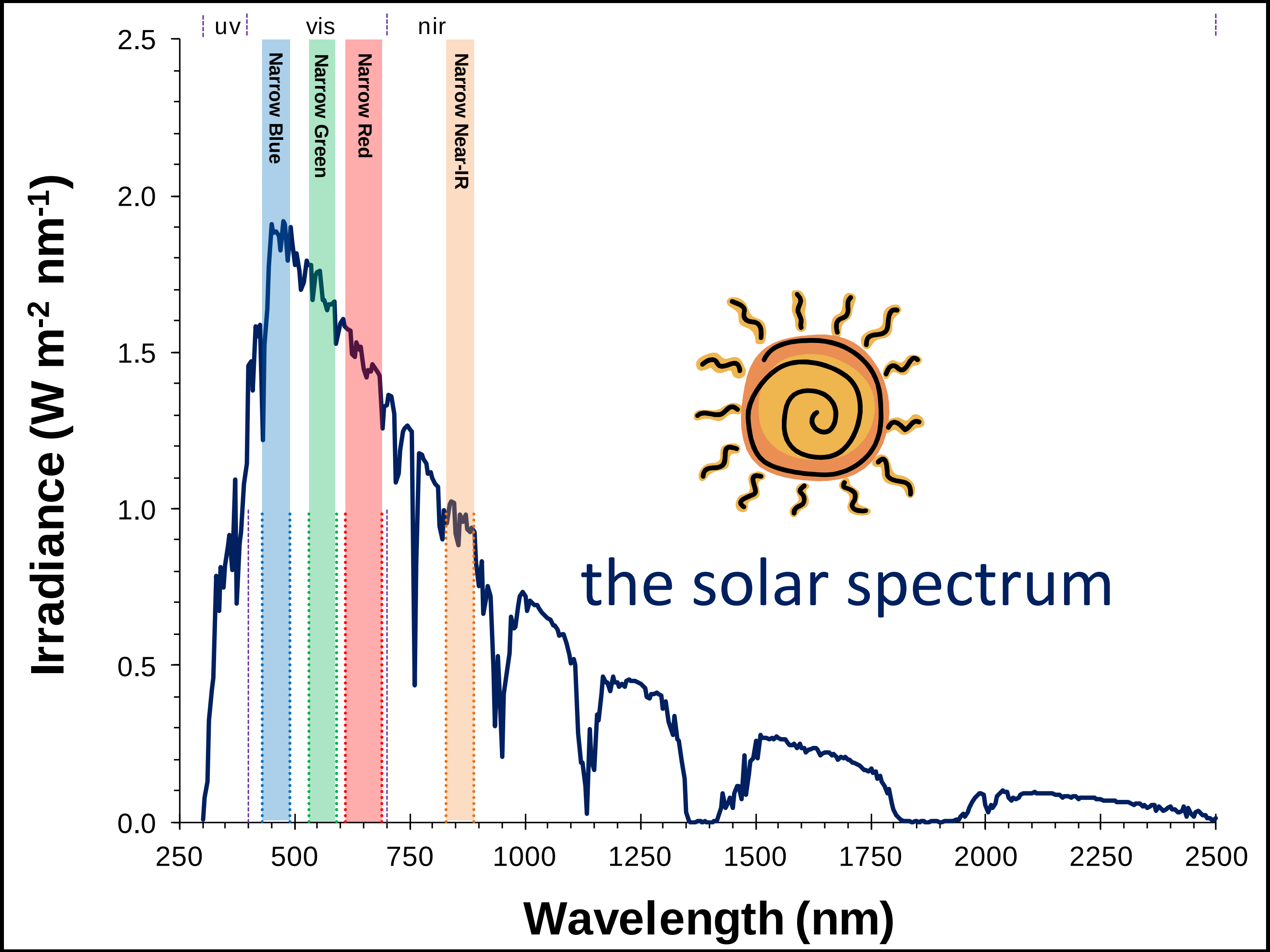
How reflective are California's roofs?

The U.S. Department of Agriculture's
National Agriculture Imagery Program

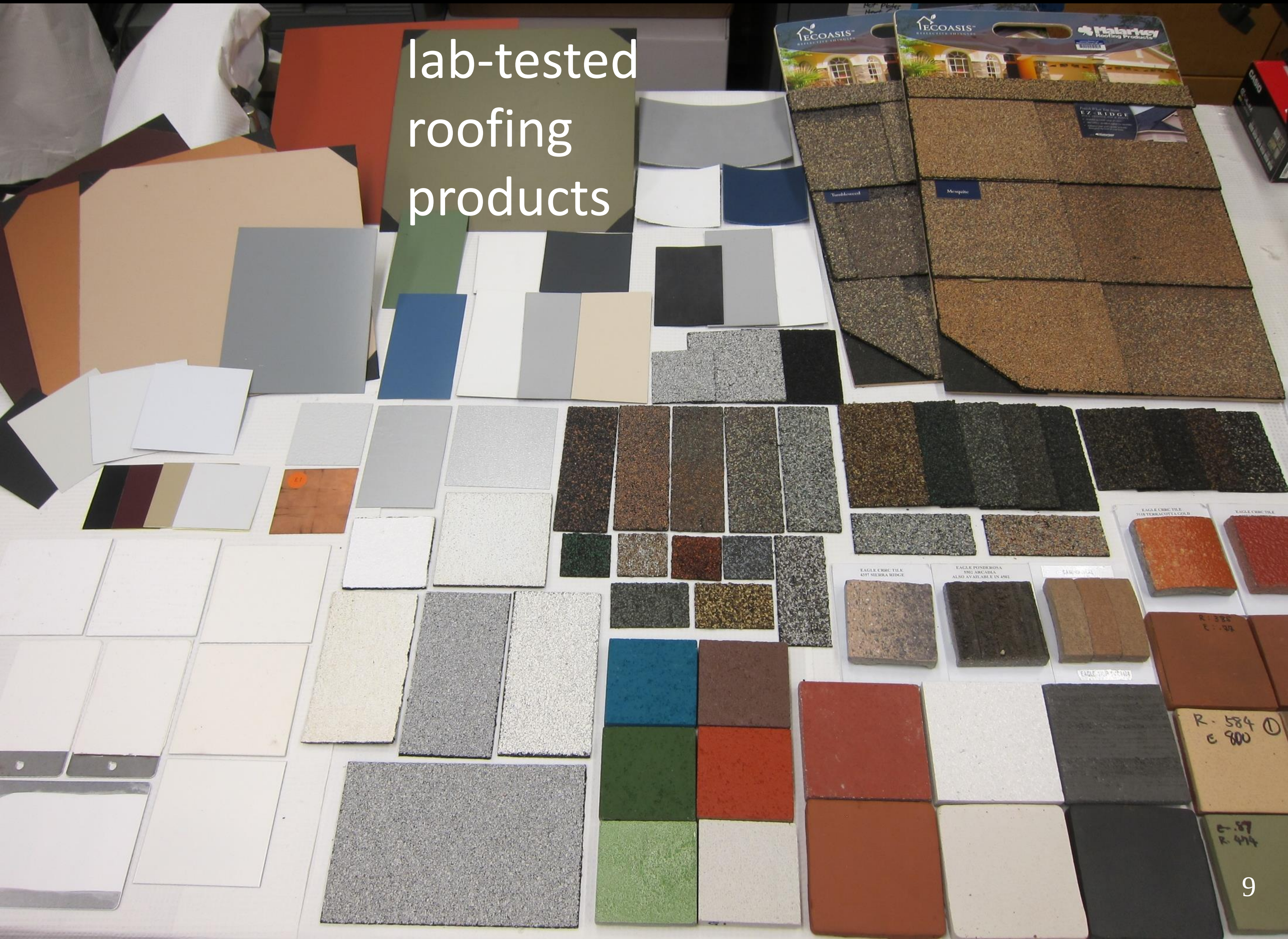
collects high-resolution images
in blue, green, red, and near-infrared

the images

their bands



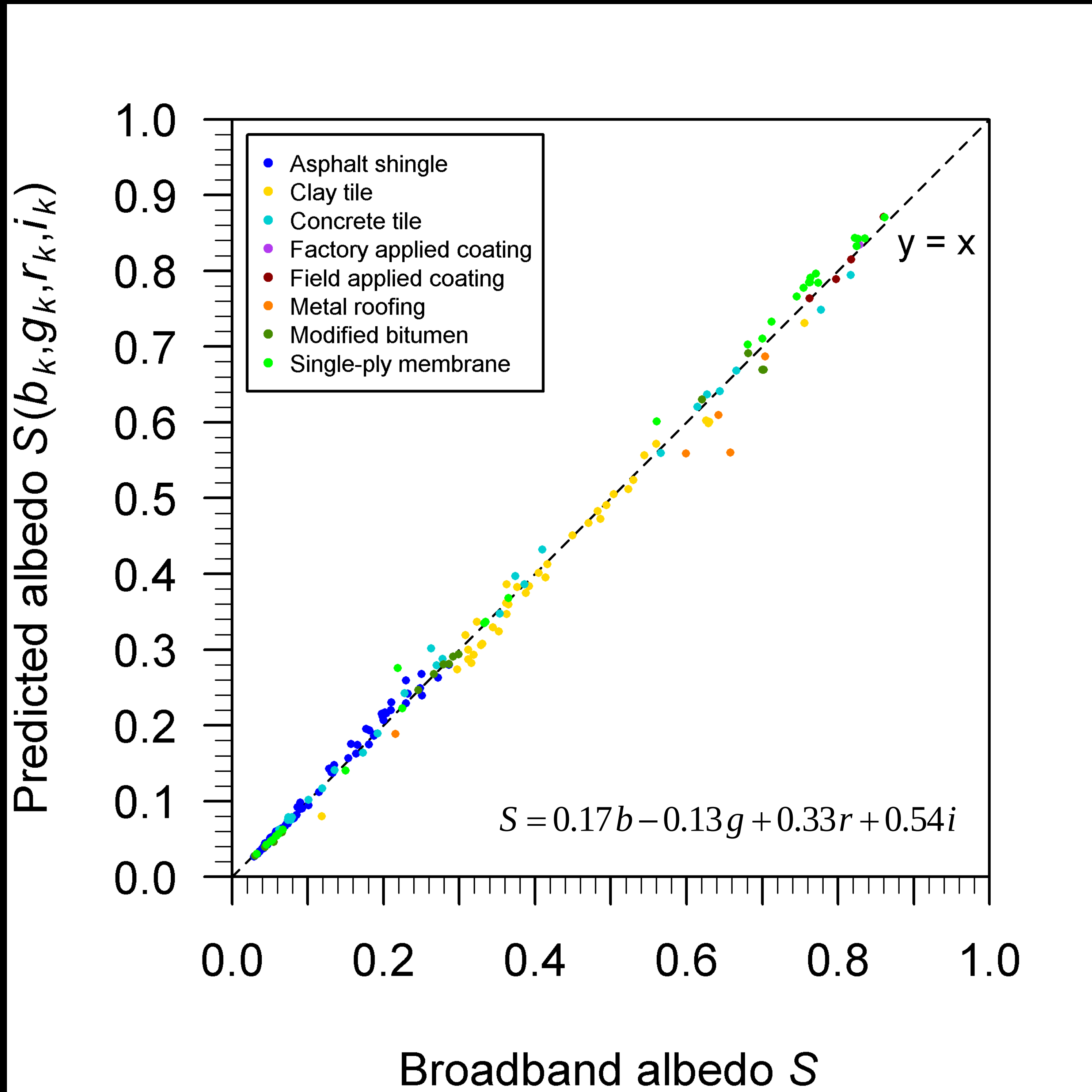
lab-tested roofing products



remote measurements

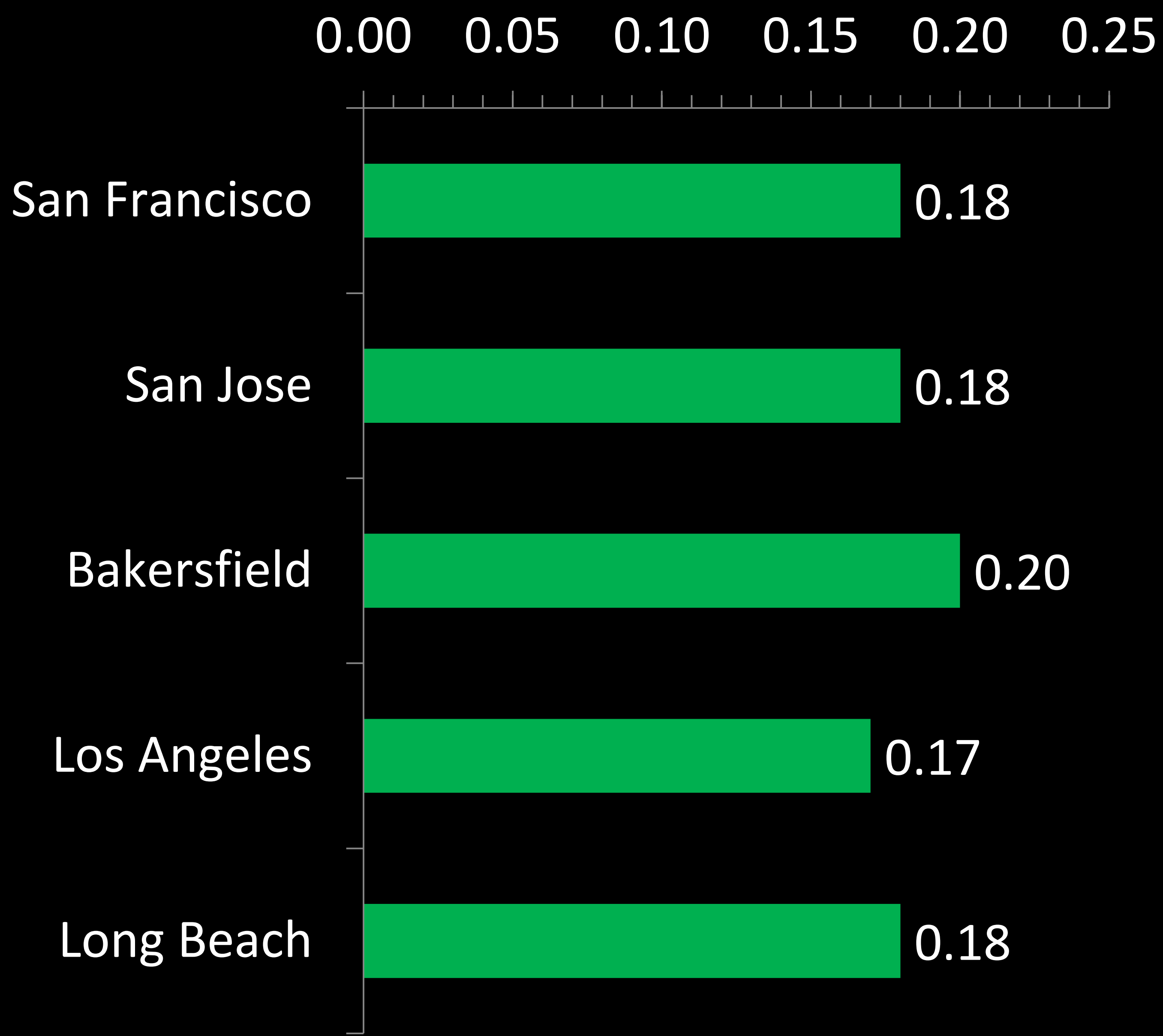
roof albedo?

✓



verifying roof albedo with a pyranometer

Average roof albedo

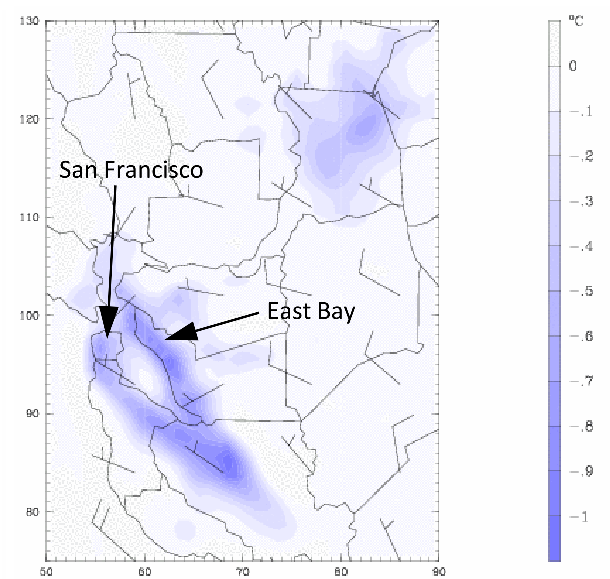


Let's go to the Oscars with

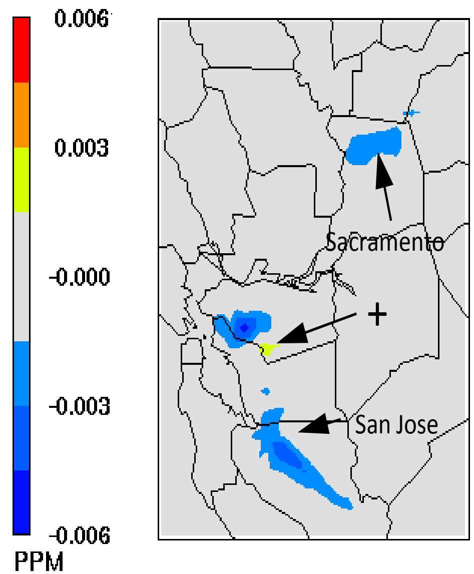
AlbedoMap.LBL.gov

Mesoscale climate models predict air temperature reductions of up to 1 °C

Change in air temperature at 2 m AGL at 11:00 PDT on 27 July 2000



Corresponding change in ozone with year-2000 emissions



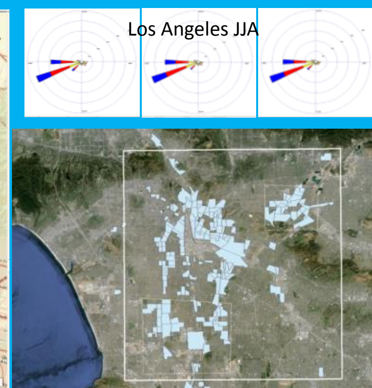
Study increased
roof albedo by 0.25 – 0.55
pavement albedo by 0.22 – 0.27

Results courtesy of Haider Taha, Altostratus Inc., http://altostratus.com .

Taha H. 2013a. Meteorological, emissions and air-quality modeling of heat-island mitigation: recent findings for California, USA. *International Journal of Low Carbon Technologies*, 10(1): 3-14. doi: 10.1093/ijlct/ctt010

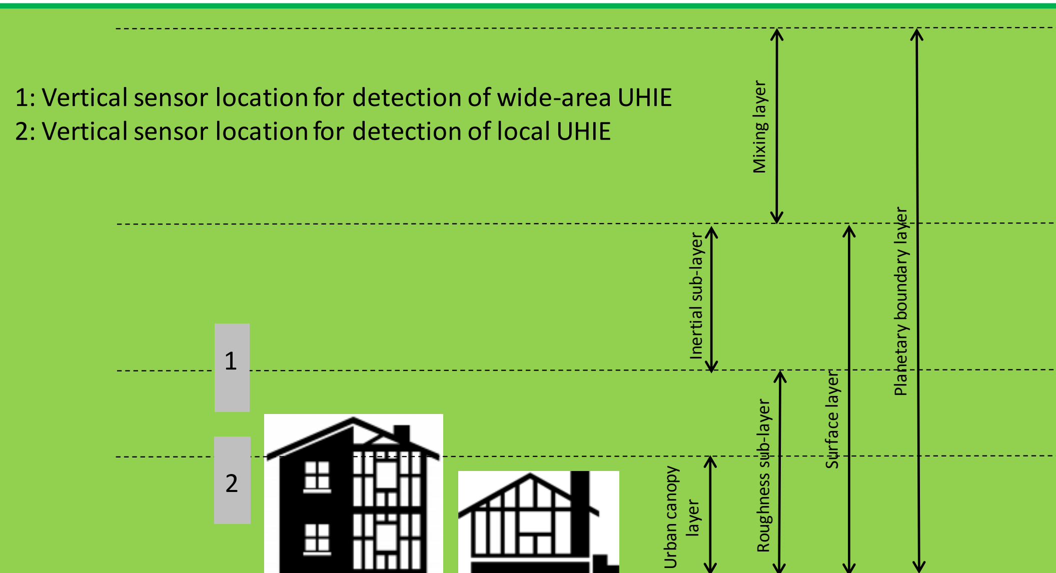
Taha H. 2013b. Air-quality impacts of heat island control and atmospheric effects of urban solar photovoltaic arrays. Project Final Report prepared by Altostratus Inc. for California Energy Commission. http://energy.ca.gov/2013publications/CEC-500-2013-061/CEC-500-2013-061.pdf

Upcoming LBNL-Altostratus-USC study will measure UHI in Los Angeles Basin



First guess of monitoring region (red oval). At bottom-right, the top 5 percent areas (census tracts) in CalEnviroScreen are highlighted. Top-right figure shows prevailing wind direction for June, July, and August in Los Angeles based on 30 years of data.

Conceptual framework for weather station siting. Shaded boxes represent possible heights of sensors for detection of (1) wide-area urban heat island effect (UHIE) (about 10 meters above ground level) and (2) local UHIE (about 2 meters above ground level). *Diagram not to scale.*

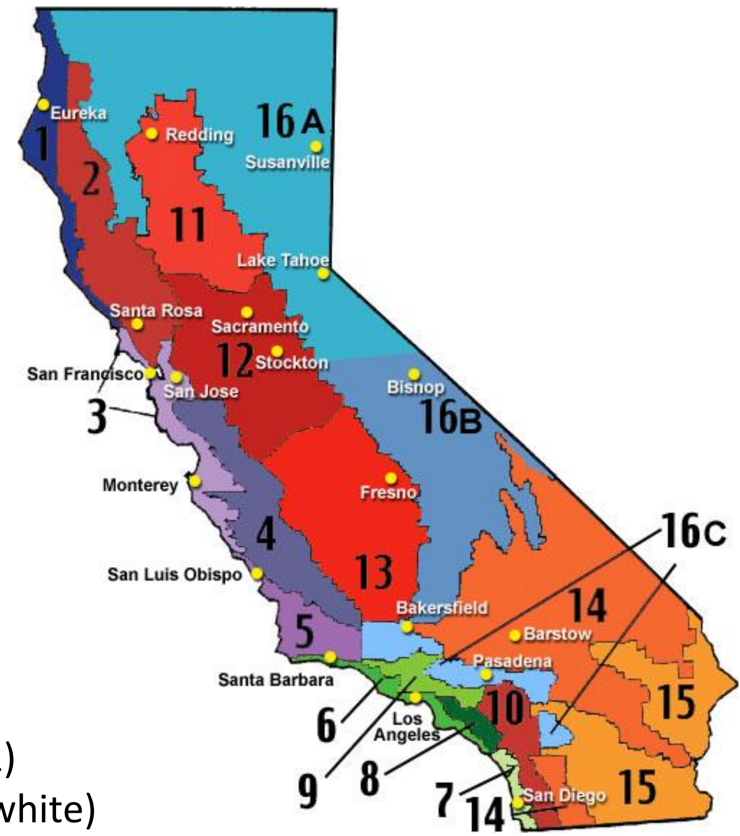


3. Cool roof requirements and incentives

2013 Title 24 prescribes cool roofs for all nonres buildings, some res buildings

	Min aged SR	Min aged TE	Min aged SRI
Nonres or high-rise res, low slope, all CZ	0.63	0.75	75
Nonres or high-rise res, high slope, all CZ	0.20	0.75	16
Res, low slope, CZs 13 & 15	0.63	0.75	75
Res, high slope, CZ 10 - 15	0.20	0.75	16

climate zone (CZ)



SR = solar reflectance (fraction of incident sunlight reflected, 0 - 1)
TE = thermal emittance (efficiency emitting thermal radiation, 0 - 1)
SRI = solar reflectance index (0 = reference black, 100 = reference white)

PG&E formerly offered rebates for exceeding T24 cool roof requirements

Pacific Gas & Electric (PG&E) Multifamily Residential Energy Efficiency Rebate Program

Roof Slope	Rebate level	Min aged SR	Min aged TE	Rebate ($/ft²)
Low (≤2:12), excluding CZ 13	N/A	0.55	0.75	0.20
High (>2:12)	Level 1	0.35	0.75	0.20
	Level 2	0.25	0.75	0.10

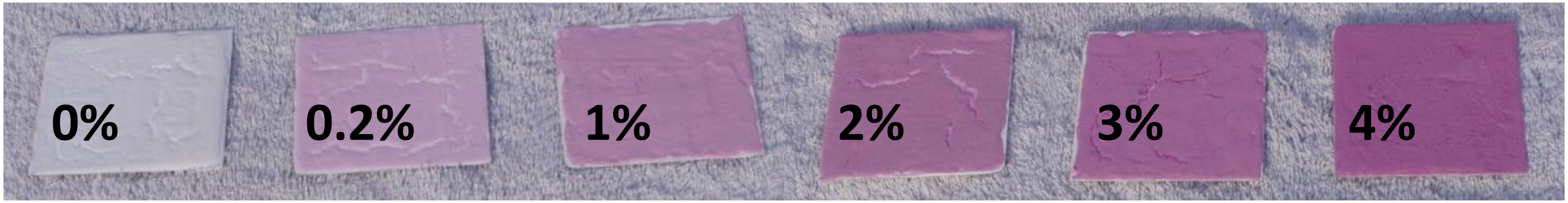
- Installation address must be in qualifying California climate zones (2, 4, 11, 12, or 13). Only steep-slope roofs qualify in climate zone 13. To find your climate zone, visit PG&E's climate zones page.
- Qualifying products: Cool Roof Rating Council rated products.
- <u>Customer must purchase and install qualifying product before December 31, 2014.</u>

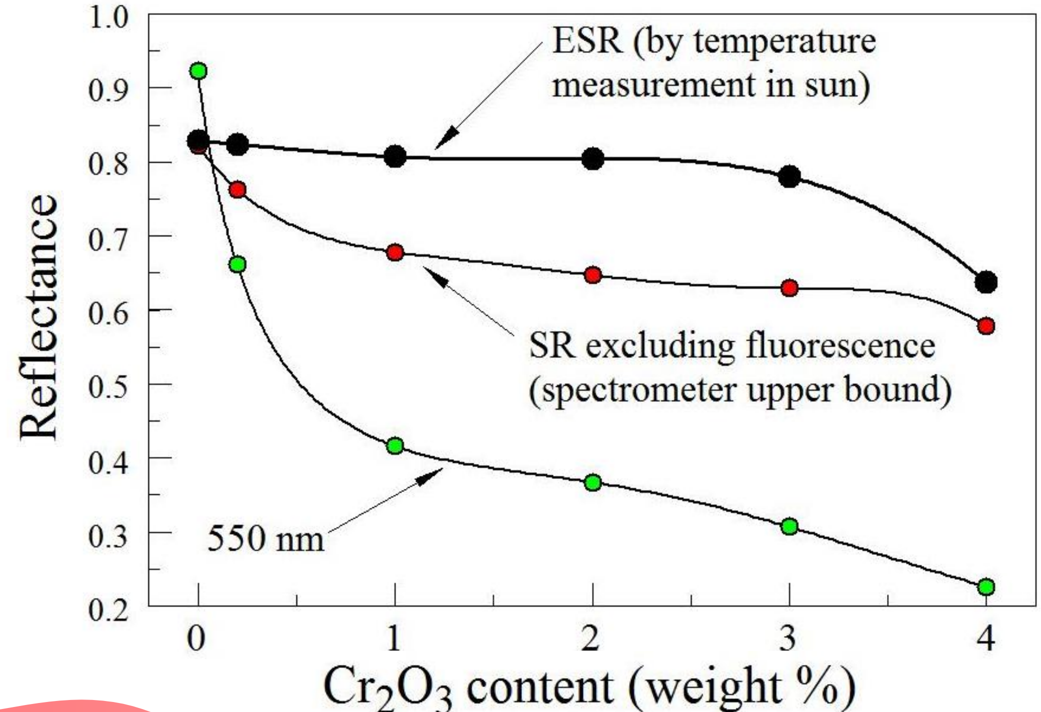
4. Cool materials development

Fluorescent cool dark pigments reflect NIR light and re-emit absorbed visible light as NIR

PPG (makes coatings) + LBNL

Ruby-pigmented coatings offer high Effective Solar Reflectance (ESR) in non-white colors

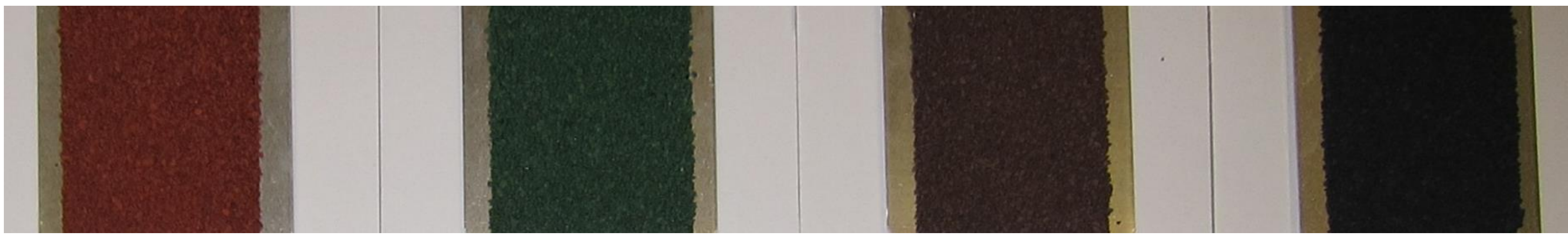




- Fluorescence (at ~700 nm) contributes up to 0.16 to ESR
- Reflectance is high up to 3% doping
- **550 nm curve** shows visual brightness
- Performance of commercial coatings will not be as high

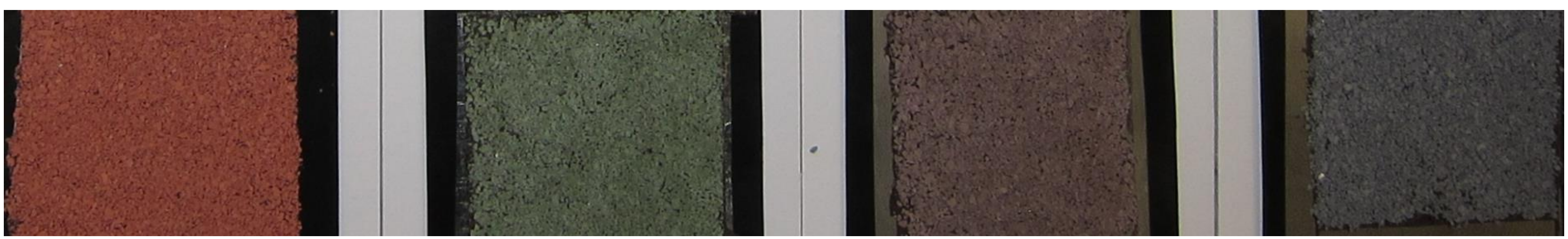
Cool colored synthetic limestone granules can capture CO_2, raise asphalt shingle albedo

conventional (gray granules + non-cool pigmented coating)



ρ = 0.14 | ρ = 0.07 | ρ = 0.05 | ρ = 0.03

cool ($CaCO_3$ granules, integrally colored w/cool pigment)

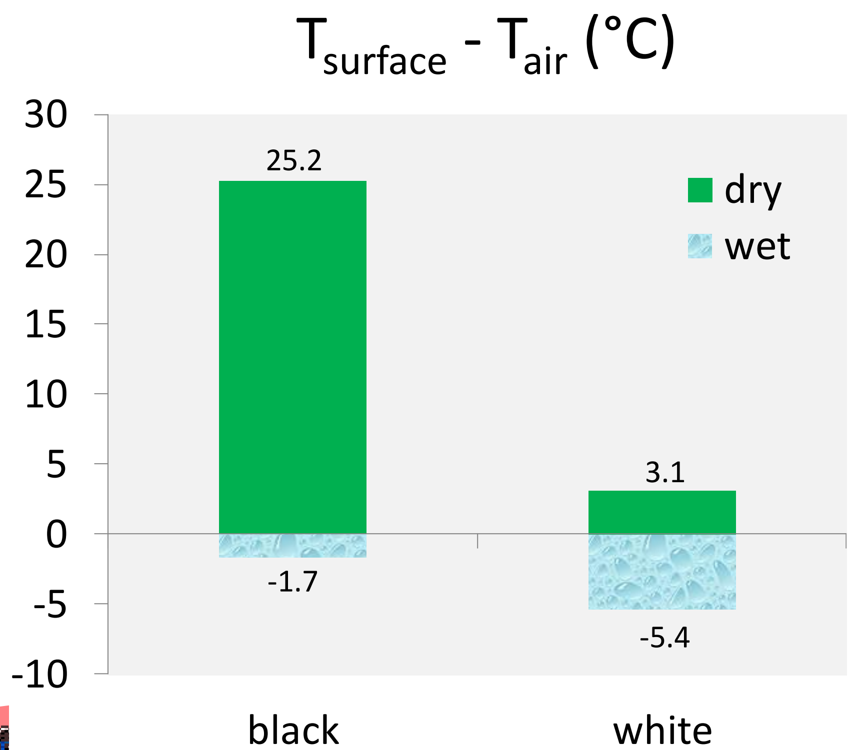


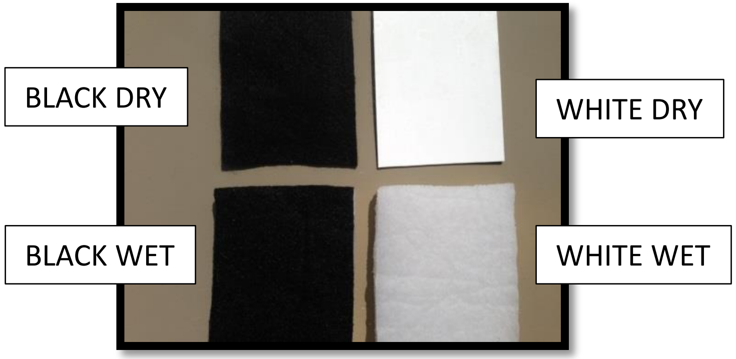
ρ = 0.39 | ρ = 0.35 | ρ = 0.31 | ρ = 0.31

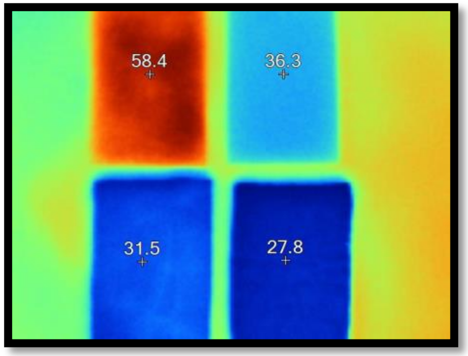
Prototype shingles by Blue Planet + CertainTeed + LBNL
$CaCO_3$ granules by Blue Planet (blueplanet-ltd.com)

White sponge roofing provides high albedo, evaporative cooling, storm water mitigation

- Reflective porous TPO over cross-linked polymer water absorber
- Provides evaporative cooling & high albedo at cost comparable to conventional TPO
- Mitigates storm water issues originating from roof surfaces, absorbing up to 3 cm water





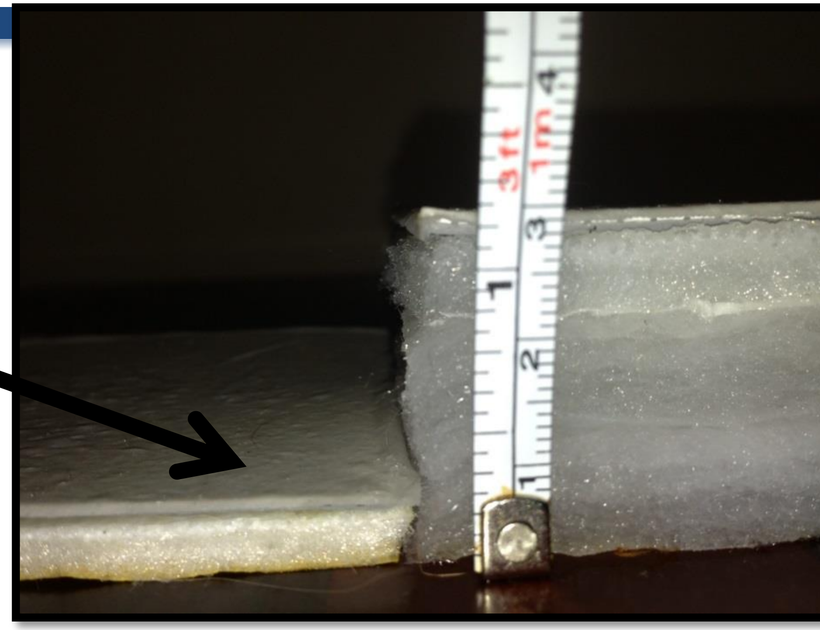


Weather

T_{air} = 33.2 °C
RH = 62%
wind = 9.4 m/s

Subsurface sponge expands by 2.5 cm when wet

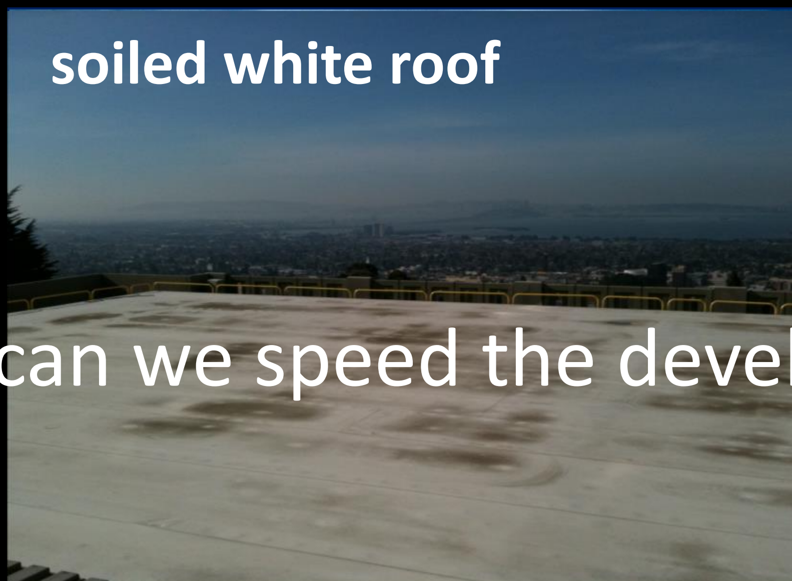
CLOSE UP OF POROUS
TPO TOP SURFACE



0.5 cm
(dry)

3.0 cm
(wet)

For more information:
Joe D. Byles
Turquoise Roofing Concepts
Corpus Christi, Texas
+1-830-305-2299
bylesj@msn.com



How can we speed the development of cool roofs?

albedo ≈ 0.5

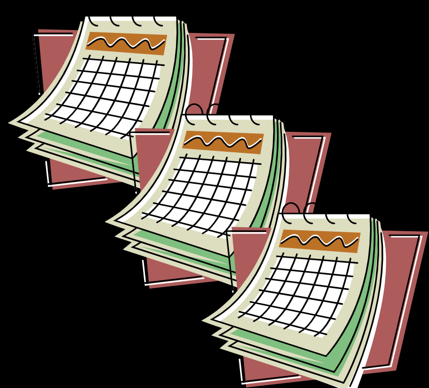
+15 °C
[+27 °F]

AZ

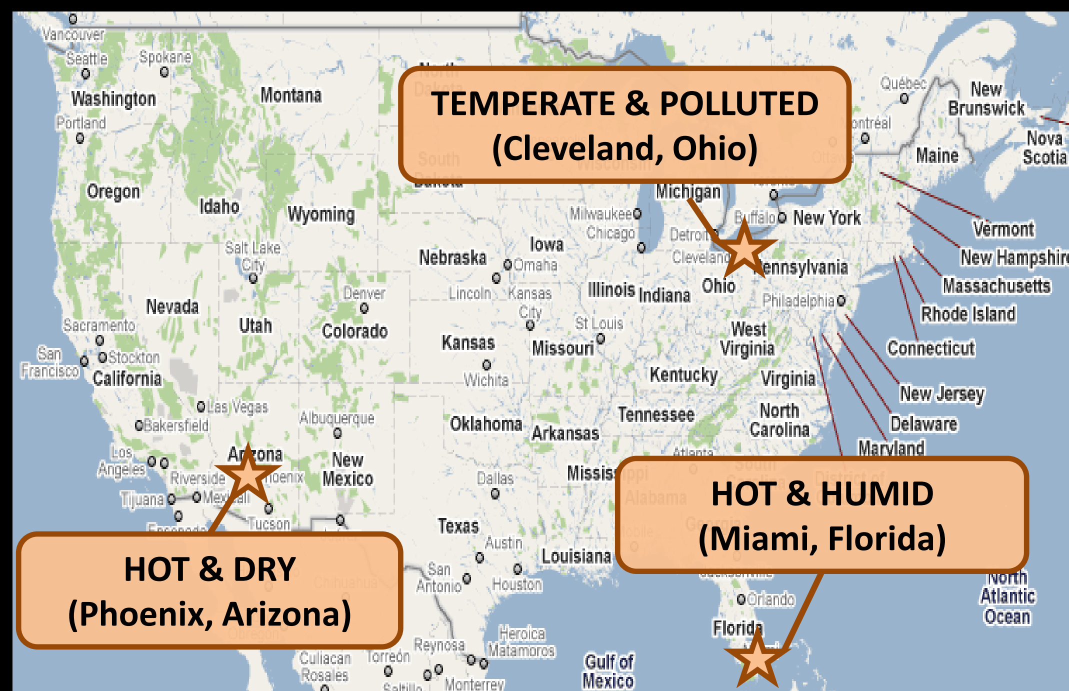
FL

OH

3 sites



3 years!



Arizona | Florida | Ohio

WHITE COATING

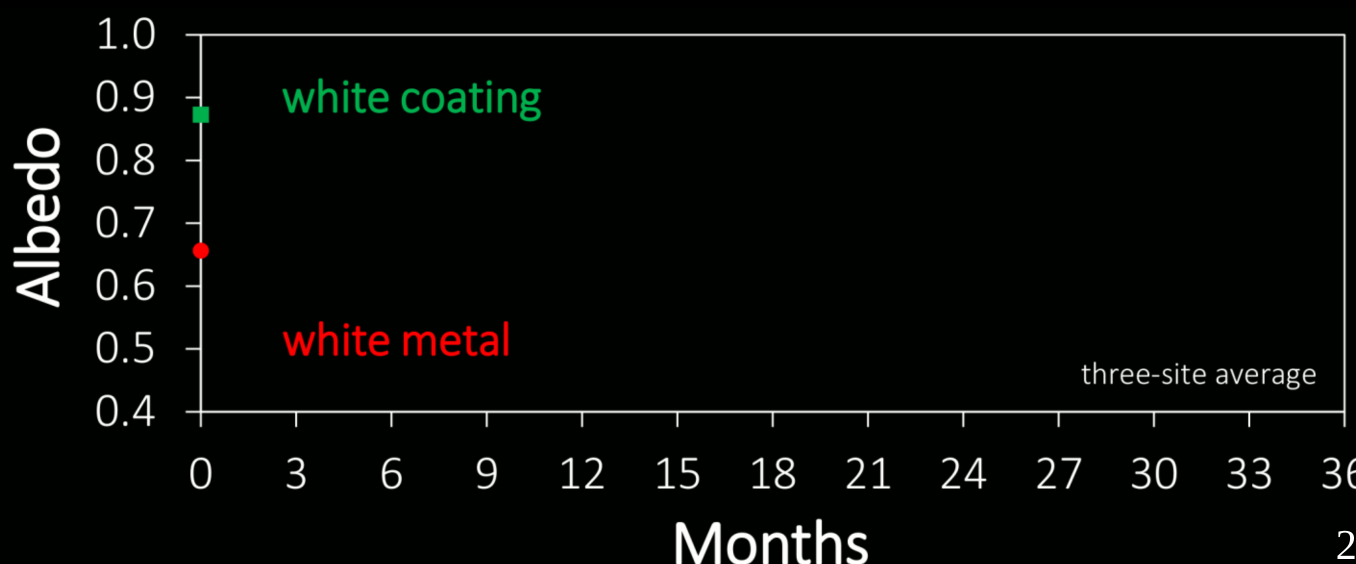
(field-applied silicone)

WHITE METAL

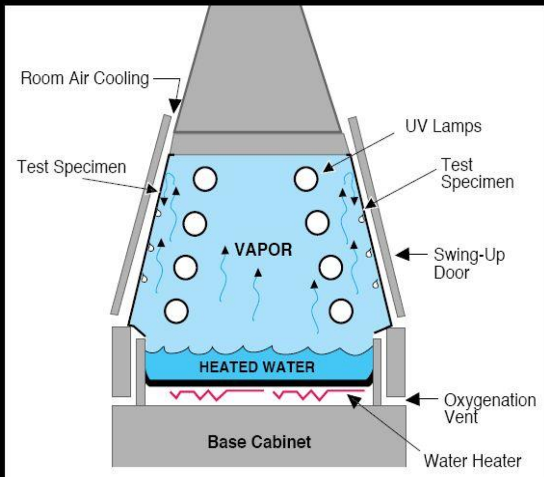
(factory-applied PVDF)

00

MONTHS

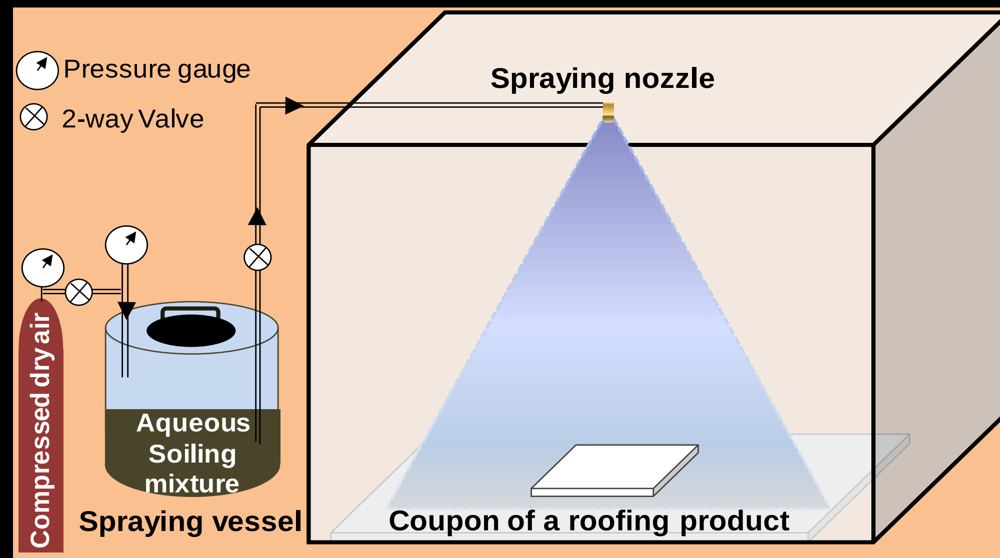


STEP 1: conditioning (24 hours)



STEP 3: weathering (24 hours)

STEP 2: soiling (10 minutes)

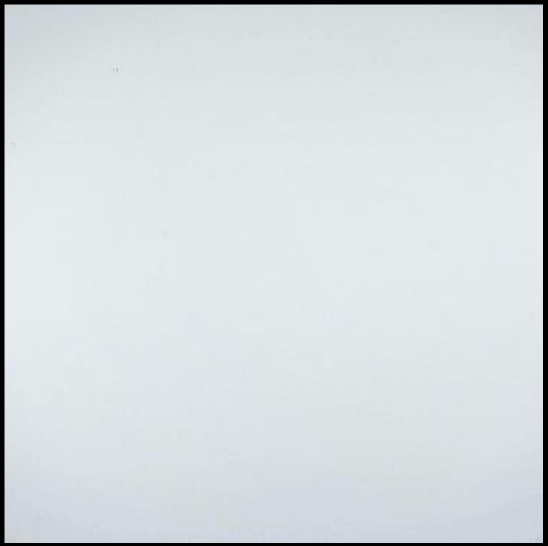


salts dust organics soot

Done!

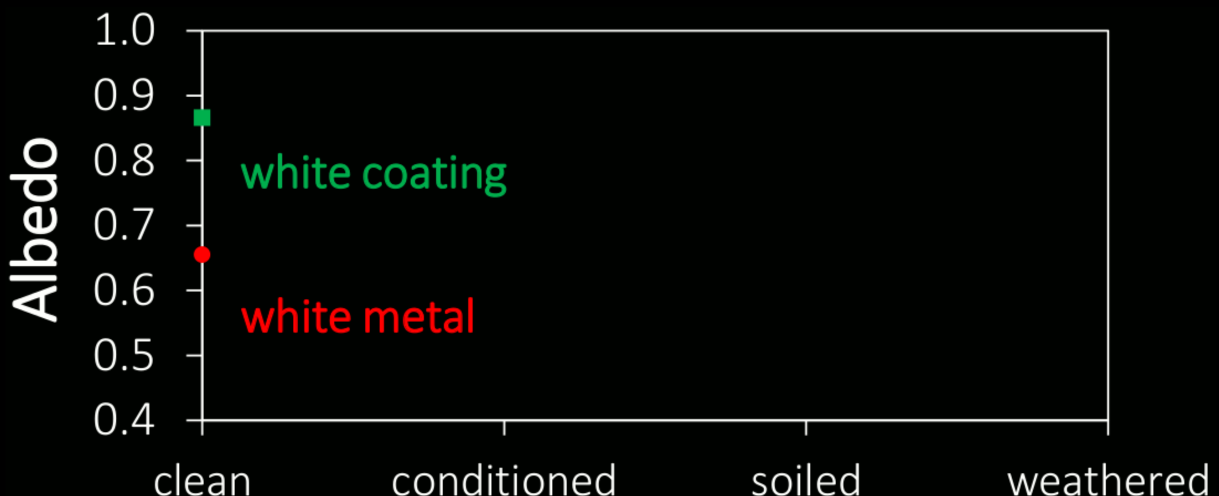
clean

WHITE COATING   WHITE METAL

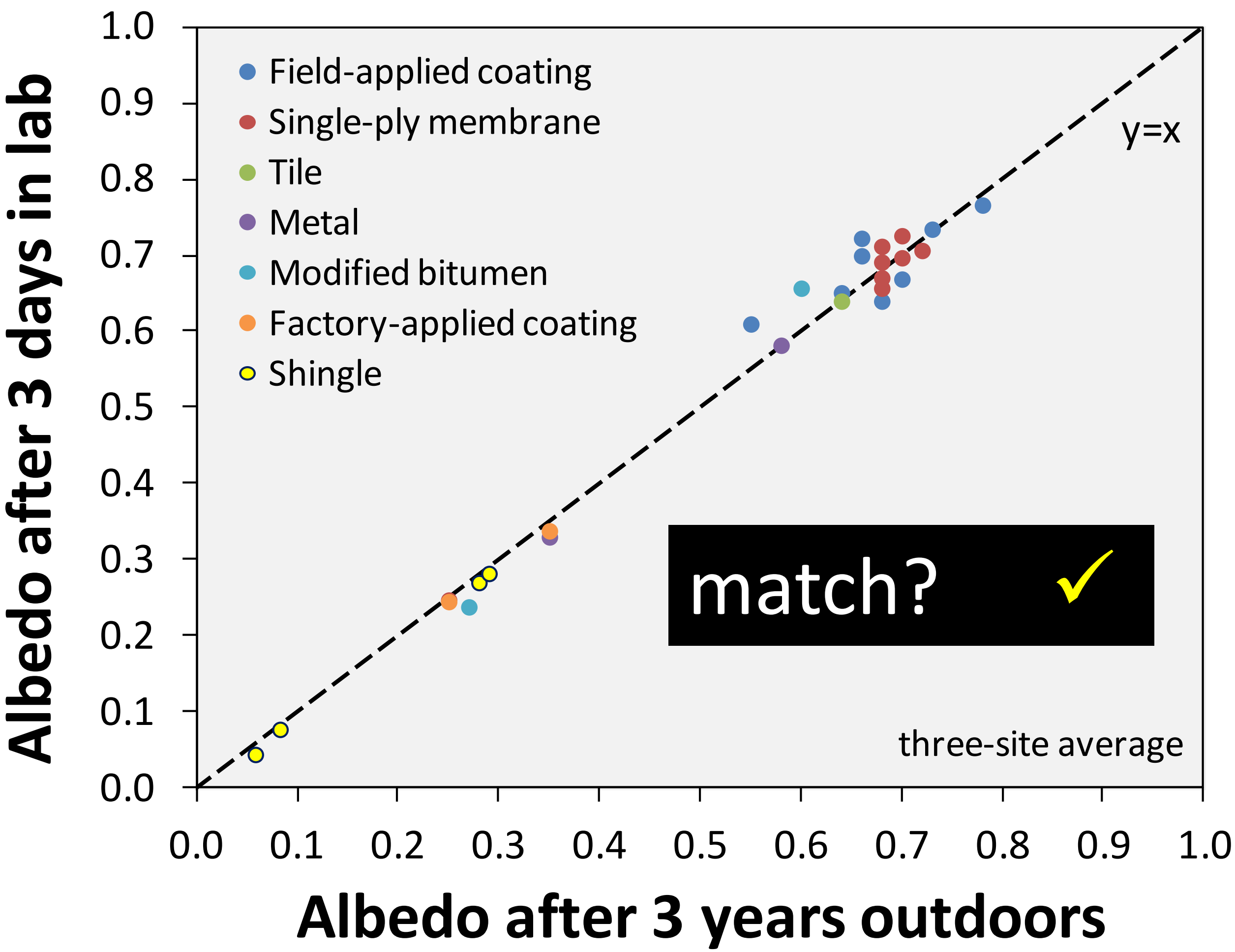


00:00

HR   MIN



LBNL laboratory aging method quickly predicts 3-year-aged roof albedo, thermal emittance



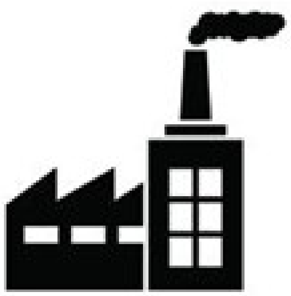
- Approved by U.S. Cool Roof Rating Council in Sept. 2014
- ASTM standard in progress

Sleiman et al. 2014. *Solar Energy Materials & Solar Cells* 122, 271–281.

5. Some benefits of UHI countermeasures

A cool tile roof in Fresno, CA saved both cooling *and* heating energy in a single-family home

Roof footprint: 188 m^2 (2020 ft^2)
Annual energy cost savings: US$167
Annual power-plant emission savings:
307 kg CO_2, 117 g NO_x, 8.69 g SO_2



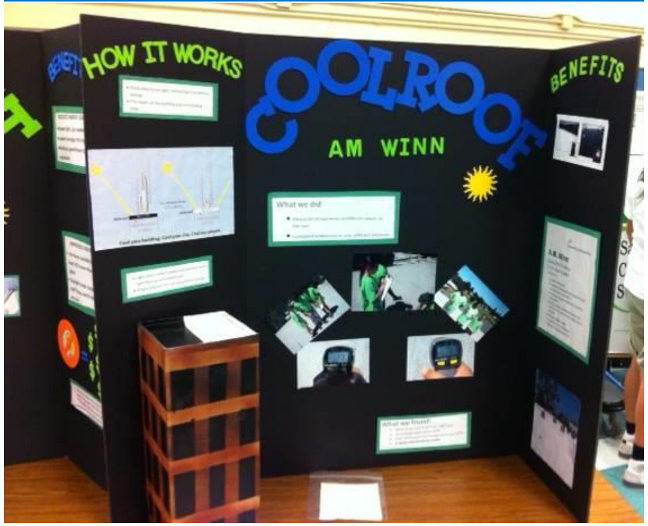
Rosado et al. 2014. *Energy & Buildings* 80, 57–71.

California's schools are growing cooler with reflective roofs and schoolyards

Cool Schoolyards pilot in Los Angeles Unified School District

Los Angeles Unified School District will soon build two more pilot cool schoolyards

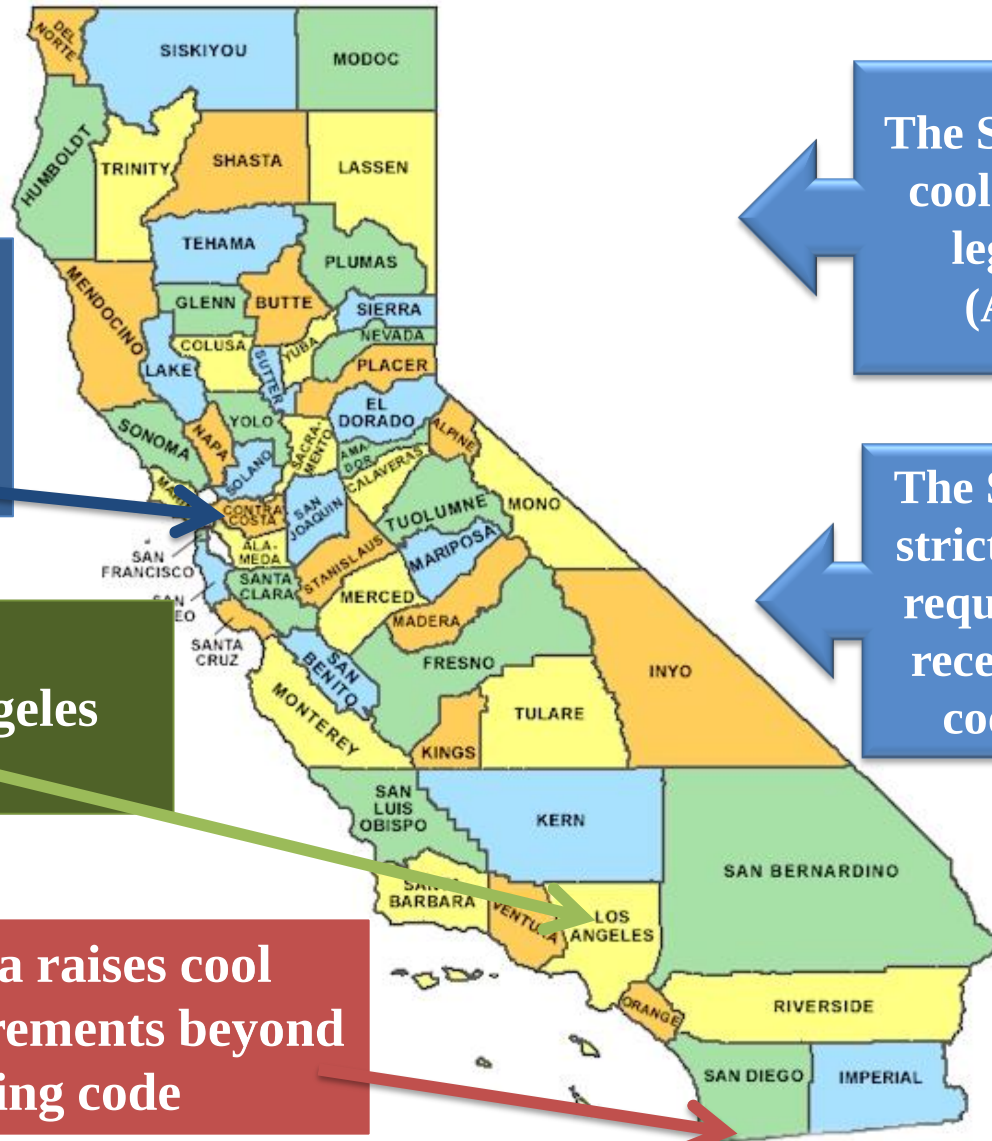
Cool roof retrofits in Sacramento City Unified School District



Cool roof retrofits on 450,000 m^2 of roof area in Sacramento schools will save ~US$670K/y

6. Roles of state and local agencies

Cities, state are acting to cool California



Berkeley is developing a plan to incorporate cool pavements into practice

Mandatory cool roof ordinance in Los Angeles for all residences

Chula Vista raises cool roof requirements beyond state building code

The State passed cool pavement legislation (AB 296)

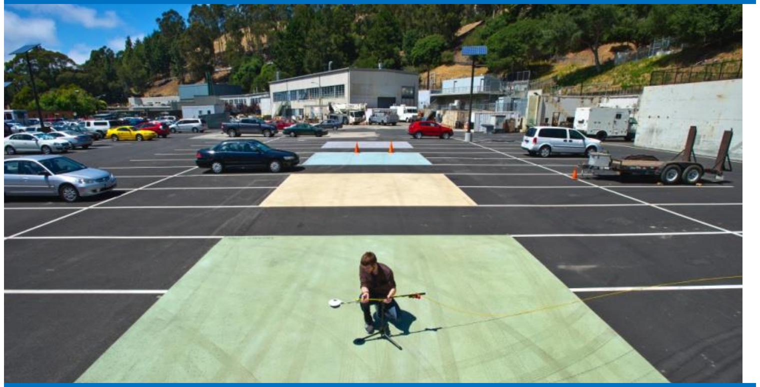
The State passed stricter cool roof requirements in recent building code update

7. Resources

LBNL has created new cool community resources for local governments in California

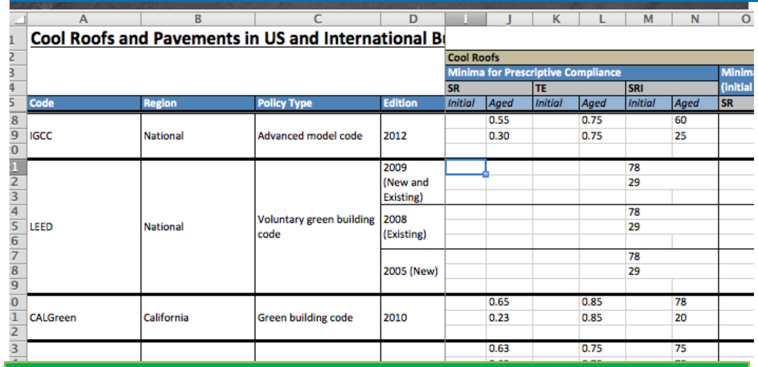
Presentations & courses

Demonstrations



Online resources

Existing & model code language



Cool Roofs and Pavements in US and International B

Code	Region	Policy Type	Edition	SR Initial	SR Aged	TE Initial	TE Aged	SRI Initial	SRI Aged	SR
				Cool Roofs – Minima for Prescriptive Compliance						Minima (initial
IGCC	National	Advanced model code	2012		0.55		0.75		60	
					0.30		0.75		25	
LEED	National	Voluntary green building code	2009 (New and Existing)					78		
								29		
			2008 (Existing)					78		
								29		
			2005 (New)					78		
								29		
CALGreen	California	Green building code	2010		0.65		0.85		78	
					0.23		0.85		20	
					0.63		0.75		75	

CoolCalifornia.org

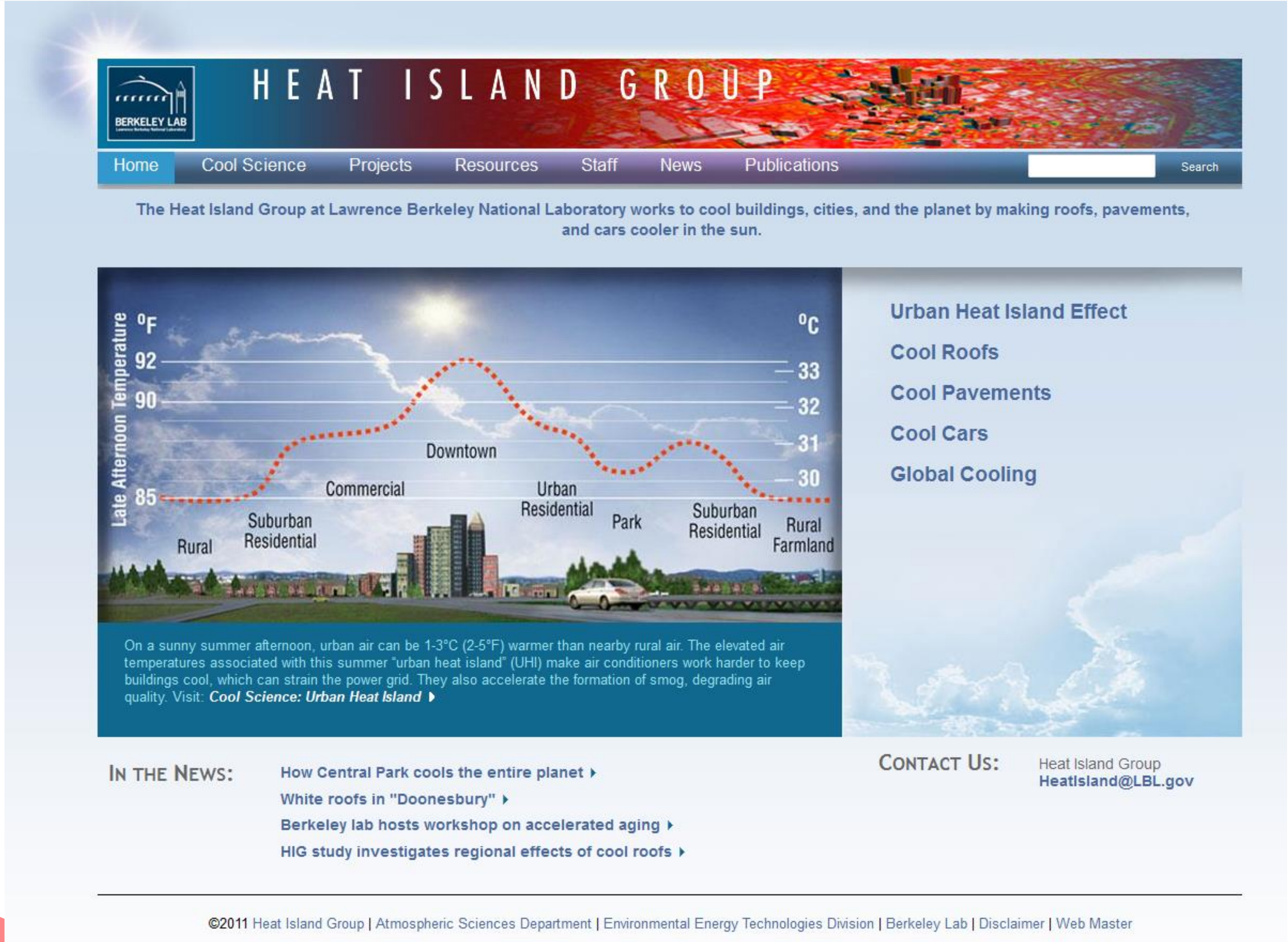
Global Cool Cities Alliance offers new UHI resources for officials, experts, and the public

- Science, costs, and benefits of cool surfaces
- Global best practices for program and policy implementation
- Sample materials and relevant organizations.
- A comprehensive "knowledge base"
- Networking Forum

CoolRoofToolkit.org

Visit the LBNL Heat Island Group website

HeatIsland.LBL.gov



Agenda: 5

BAY AREA AIR QUALITY MANAGEMENT DISTRICT

Exploring Bay Area Energy Future as Part of Climate Protection Strategy

2014 Efforts of Advisory Council

Prepared for the
Board of Directors
2015

Topics and Speakers

Bay Area Energy Future

- **Mark Jacobsen**, Professor, Stanford (100% wind, water, solar pathway)
- **Jim Williams**, PhD, E3 (all available measures pathway)
- **Jane C.S. Long**, PhD, LLNL/EDF (action plan, feasibility, all available measures pathway)
- **Emilio Camacho**, Esq., CA Energy Commission (innovation)
- **Daniel Kammen**, Professor, UC Berkeley (Bay Area energy and climate opportunities)
- **Haresh Kamath**, PhD, EPRI (energy storage and integrated smart grid)

Energy Future: Big Picture

- Efficiency
  - Especially uses that cannot be easily electrified
- Electrification
  - All feasible fossil-fuel combustion uses
- Decarbonization
  - Electricity supply (e.g., renewables) and fossil fuels

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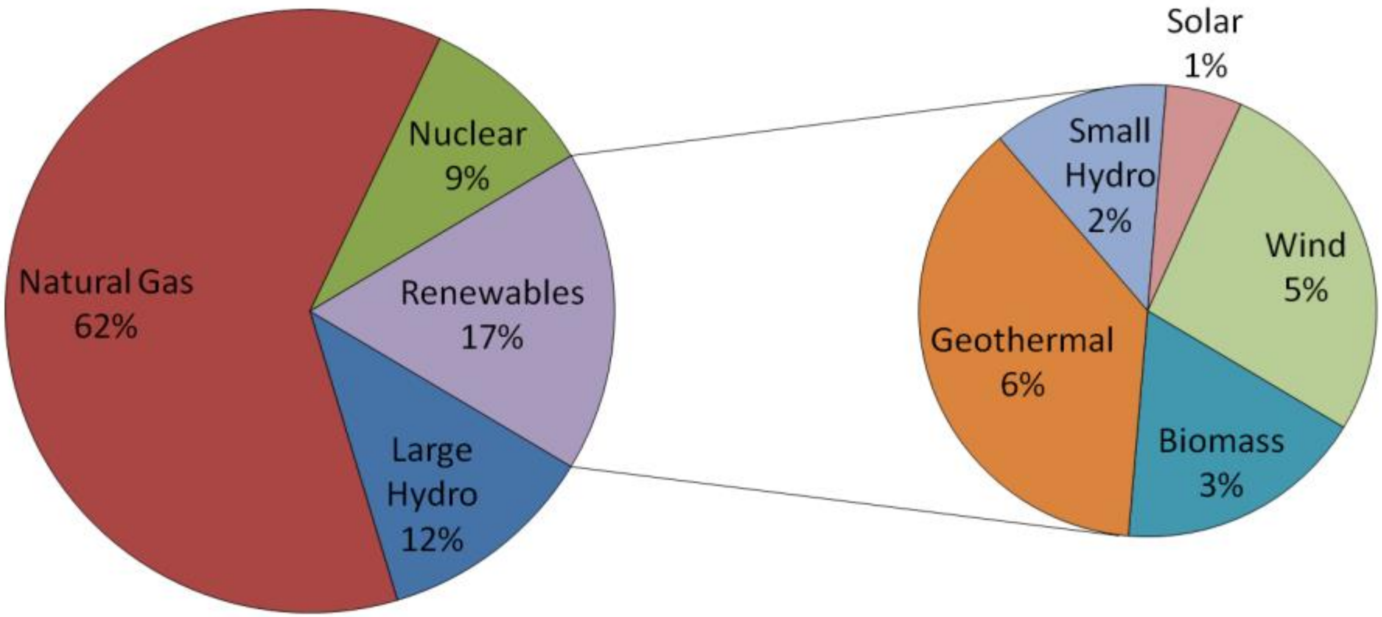
Where We Are

CA In-State Electricity Generation in 2012



Sources: California Energy Commission, QFER and SB 1305 Reporting Requirements. In-state generation is reported generation from units 1 MW and larger.

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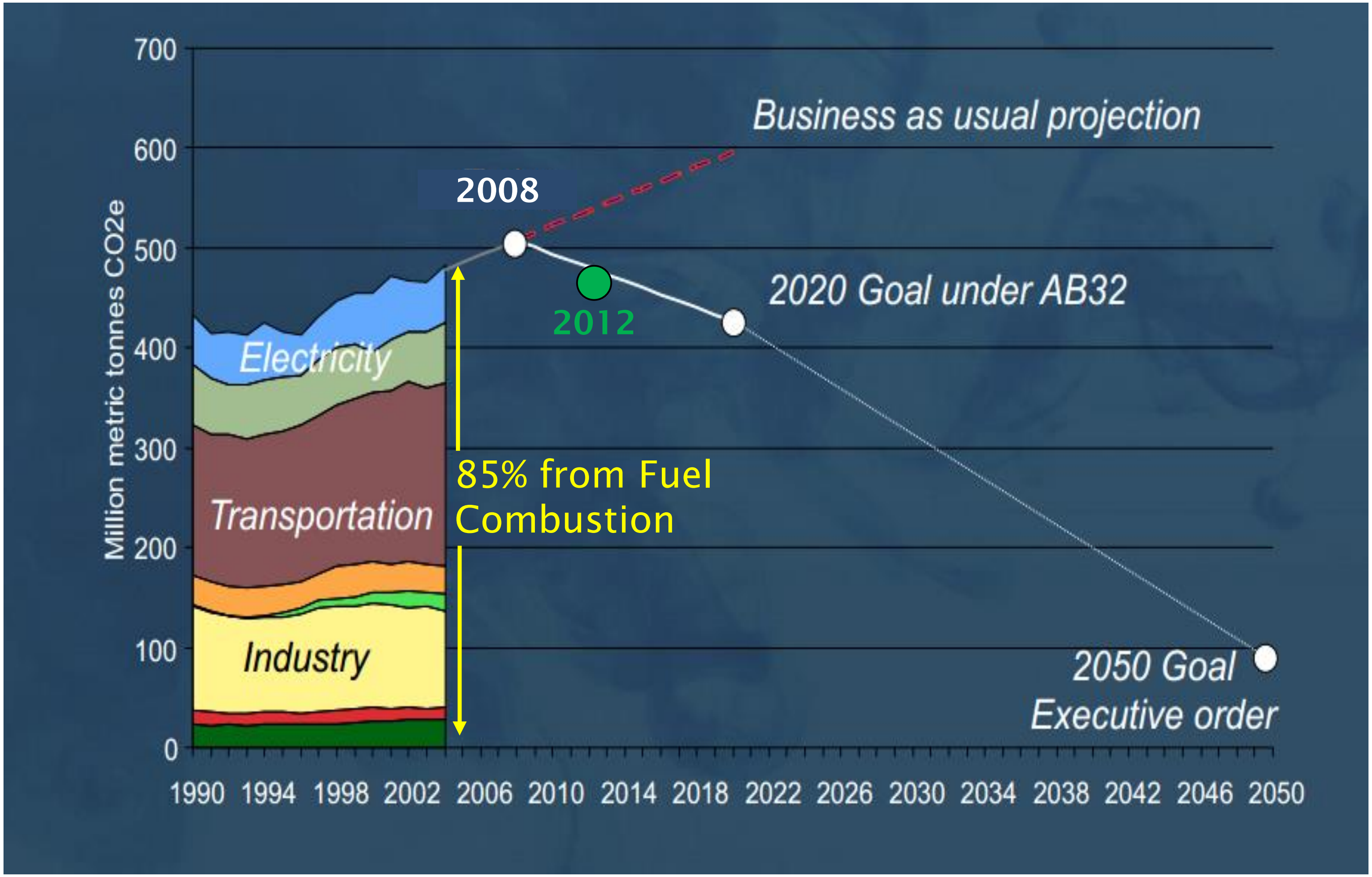
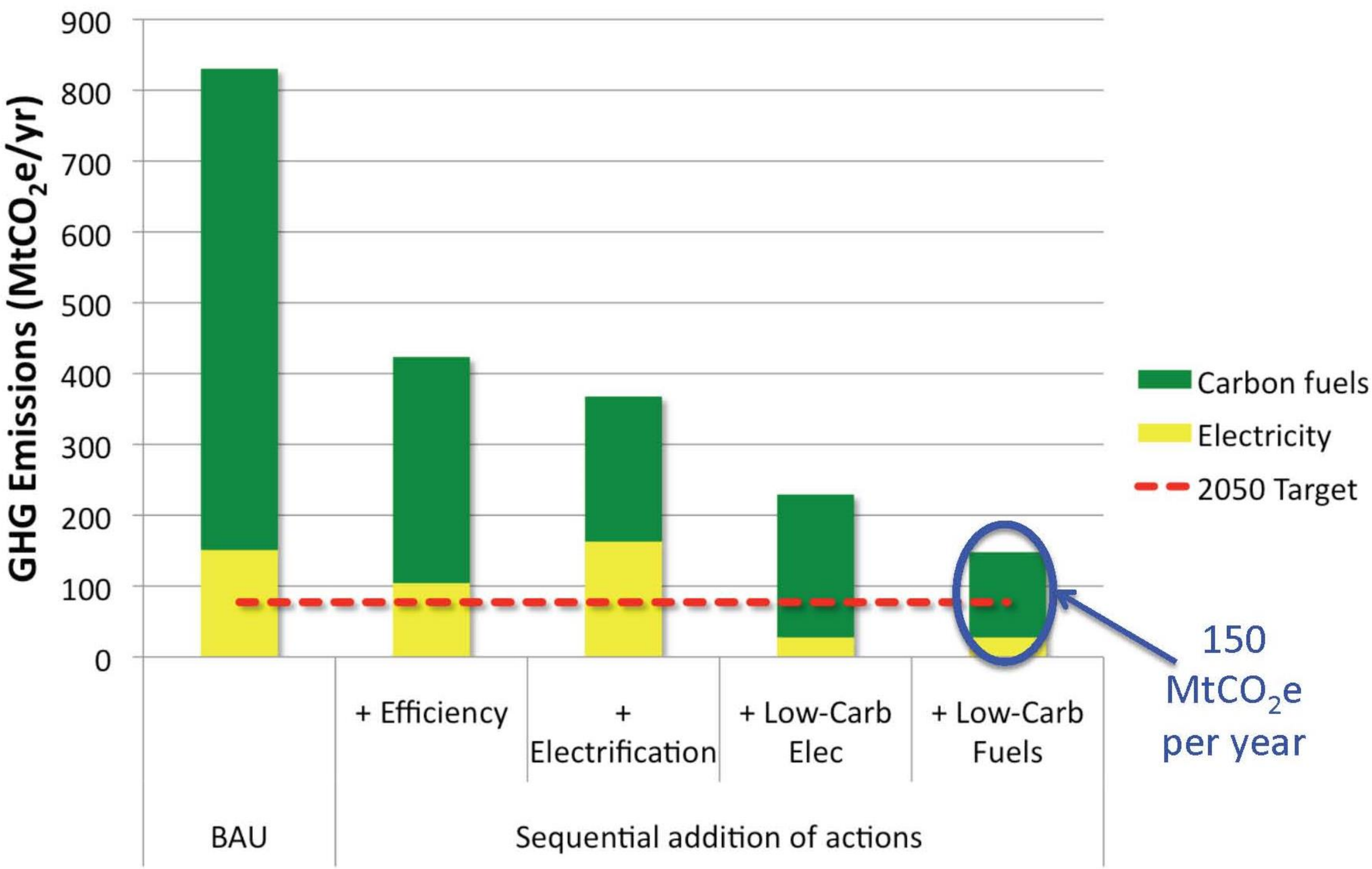
Where We Are Going



How We Can Get There



Energy Future: Two Different Paths

1. 100% Wind, Water, and Solar
   - All renewables including energy conservation and efficiency gains
   - Maximizes air quality and climate benefits with no air emissions

   Issues: Technical challenges, large number, permitting, variability, grid reliability

2. All Available Measures Includes above strategy +
   - All possibilities, including biofuels, carbon capture, storage, and nuclear
   - 60% reduction in carbon doable with known technologies; remaining 20% reduction challenging

   Issues: Technical challenges, negative side effects, use of fossil fuels for back up power with associated emissions, public acceptance

Energy Future: Major Challenges

- Technical challenges
  - Not yet available, some technologies maybe decades away
- Carbon pricing
  - Needed for market-based solutions
- Energy storage
  - Critical to renewables success, pumped storage most readily available now, batteries, hydrogen, and compressed air not ready yet
- Grid reliability & load balancing
  - Integrated "smart" grid, demand management
- Environmental & social equity
  - Economic, feasibility, air quality/climate tradeoffs
- Political leadership
  - Many difficult decisions, cost, reliability, public acceptance

Recommendations

Categories

Integration into District Planning	Coordination with Other Agencies
Public Education and Outreach	Grants

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Recommendations:
Integration into District Planning

- Given mission to achieve clean air and climate protection, identify District's most appropriate role vis-à-vis Bay Area energy future
- Conduct emission inventory-based study to project how Bay Area future energy trends may impact or complement District's clean air plans
- Integrate implications of future energy trends into District's clean air and climate plans, modifying those plans if necessary
- Integrate into new District's permitting rules while reviewing past rules for consistency

Recommendations: Planning

Adhere to multi-pollutant approach to reduce GHG emissions while limiting unintended consequences and negative effects from other airborne pollutants.

Recommendations:
Coordination with Other Agencies

- Consult and coordinate with relevant agencies and other stakeholders involved in energy-related planning
  - State and federal agencies
    - ARB, CEC, CPUC, EPA, DOE
  - Regional and local agencies:
    - MTC, ABAG
  - Private sector
    - EPRI, PG&E, refineries, other

Recommendations: Regional Leadership

Collaborate with state, regional, and local agencies to develop regional GHG action plan

Recommendations: Reduce Emissions from Small Sources

Explore ways to reduce GHG emissions from large numbers of small stationary sources of CO_{2}:

- backup generators (understand significant growth in number and look for opportunities to use energy storage devices instead)
- furnaces
- water heaters
- boilers

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Recommendations:
Public Education and Outreach

- Integrate latest information on energy behavior-oriented recommendations into District's public education and outreach efforts
- Concepts could include:
  - Greater efficiency for appliances, cost savings
  - Energy audits/upgrades to residences, offices
  - Electric vehicles
  - Public transit

Recommendation: Education

Build public support for GHG policies through education, including:

- Energy efficiency (e.g., codes, financing, retrofits)
- Electrification
- Energy use (e.g., choice of supply, rates, reliability)
- Energy generation (e.g., distributed energy, on-site renewable, CCS)
- Planning (e.g., zoning, density, infill)
- Transit and goods movement
- Climate change adaptation
- Carbon sequestration

Recommendations:
Grants

- Integrate future energy-related criteria into grant proposal evaluation and selection
- Expand incentives to encourage/support more desirable energy sources and behavior

Recommendations: Grants

Identify new funding sources to expand grant program to stationary sources.

Prioritize the following:

- Electrification and related infrastructure
- Low-Carbon clean-energy backup emergency power systems
- Energy efficiency in buildings, appliances, and processes
- Further VMT reductions through 'smarter" vehicles and technologies that optimize operations

Thank You!

- We appreciate your time and interest
- Questions or comments?