

**What are cool pavements?**

**How do pavements stay cool?**

**Why use cool pavements?**

# COOL PAVEMENTS

for

# Cool Communities

**November 9th, 2010**

1:30 pm – 3:30 pm

Cal/EPA Headquarters

Sacramento, CA

# Cool Communities Project

In 2006, California introduced the Global Warming Solutions Act (Assembly Bill 32) which requires California to reduce greenhouse gas emissions to 1990 levels by 2020. Several “cool community” strategies including cool roofs, cool

pavements, cool walls and urban vegetation have been identified as effective voluntary measures with statewide potential emission reductions of 4 million metric tons of carbon dioxide equivalent per year.



# Cool Communities Project

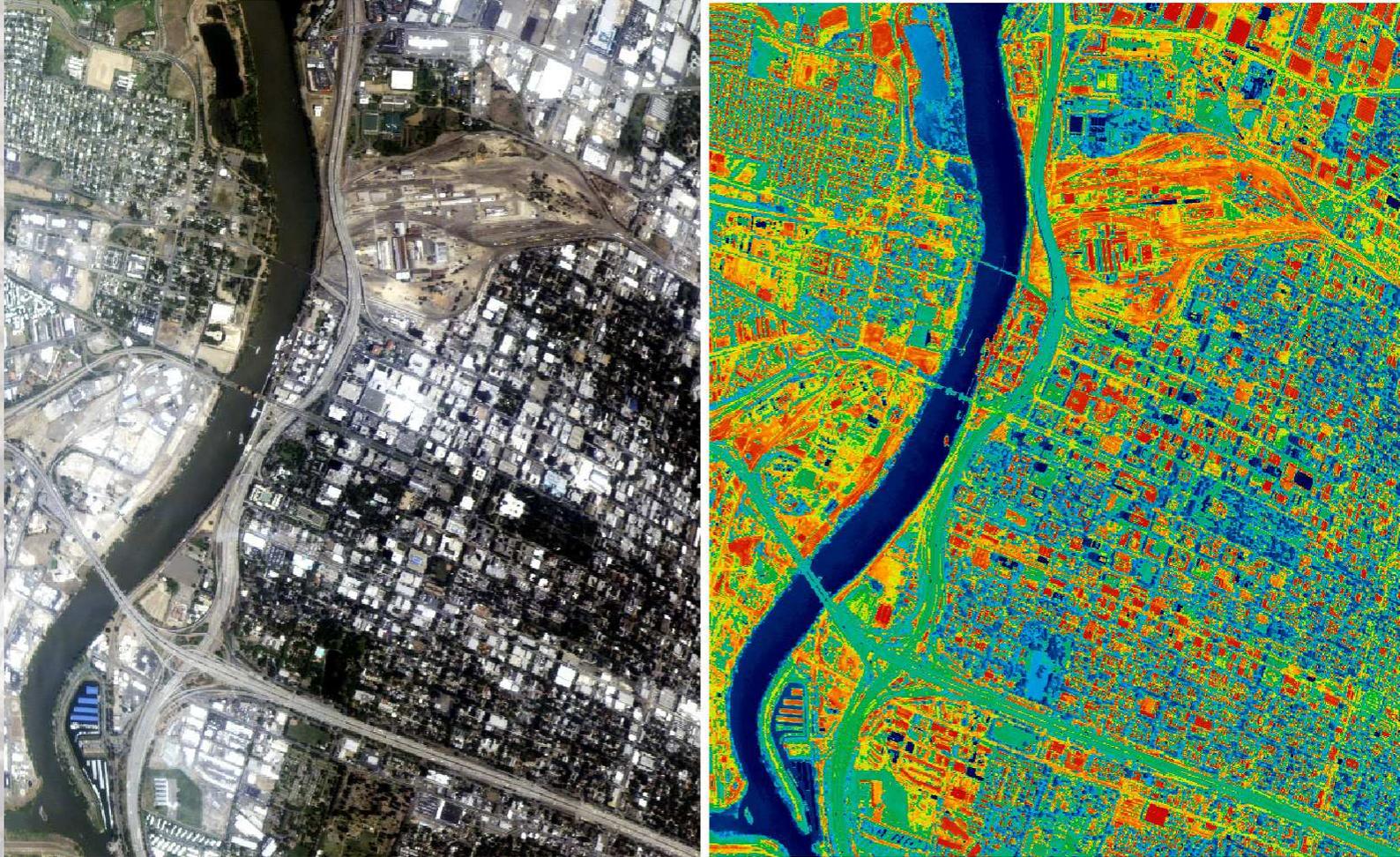
The Heat Island Group's Cool Communities project seeks to provide technical assistance to California communities for development of programs that save energy, reduce emission of greenhouse gases, and improve the urban environment.



# Outline

- 1. Introduction**
- 2. Science of cool**
- 3. Pavements**
- 4. Pavement materials**
- 5. Why select cool pavements**
- 6. Things to consider**
- 7. Cool pavements in use – codes, standards, policies**
- 8. Your inputs**

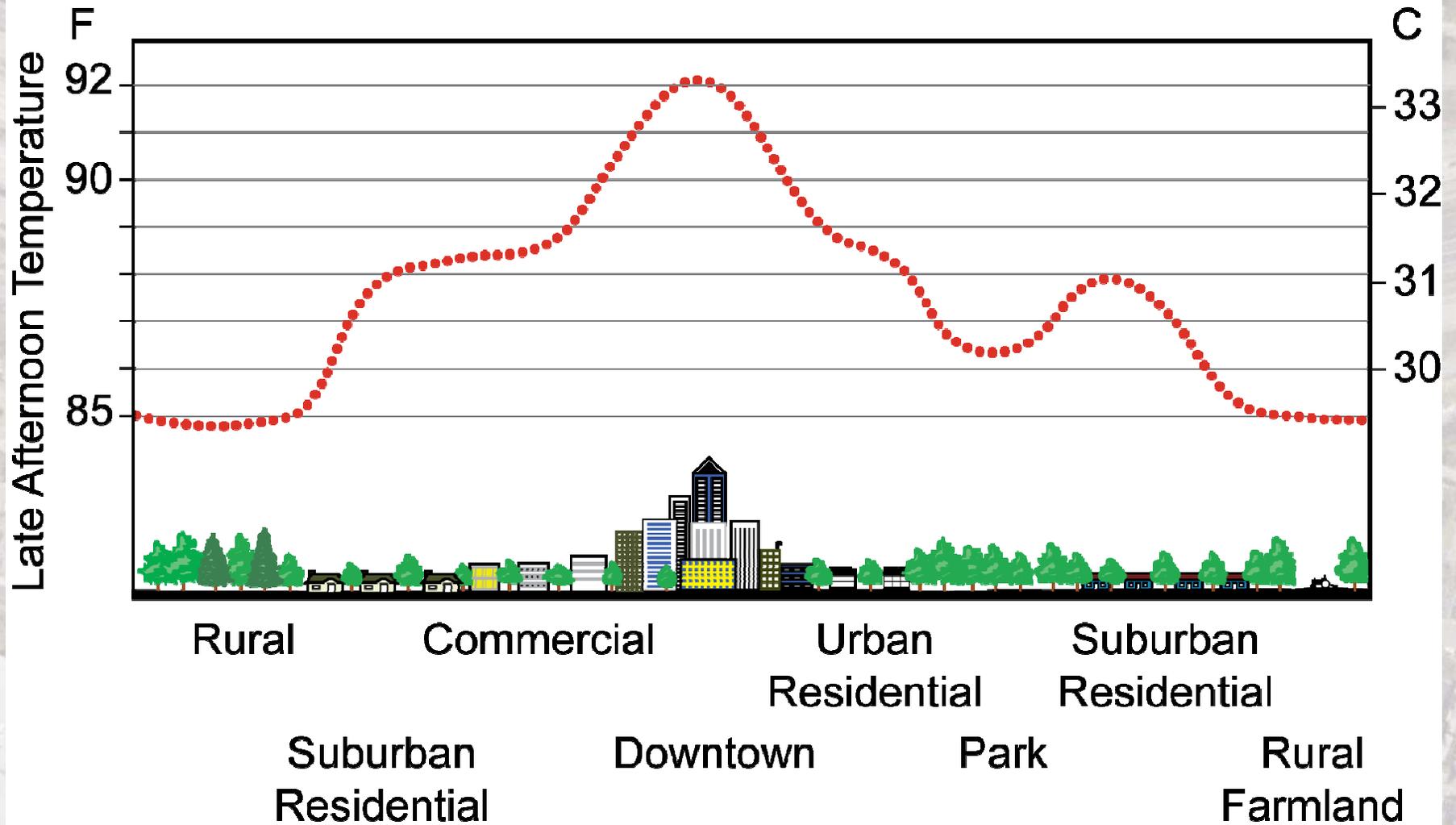
# Cities can be HOT



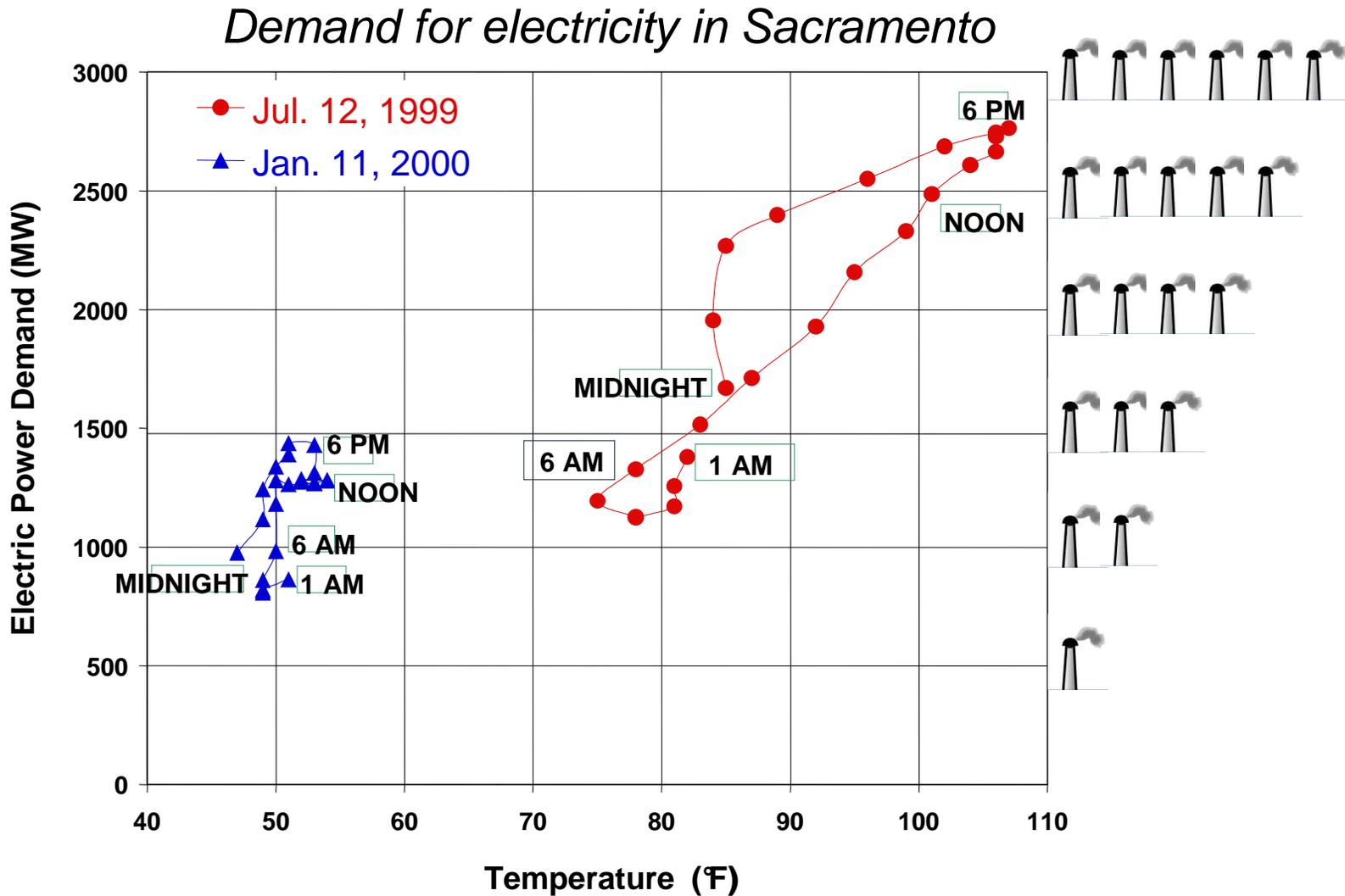
**NASA infrared Sacramento (1998)**

# Summer in the city

## Sketch of an Urban Heat-Island Profile



# One concern with hot cities – increase energy use

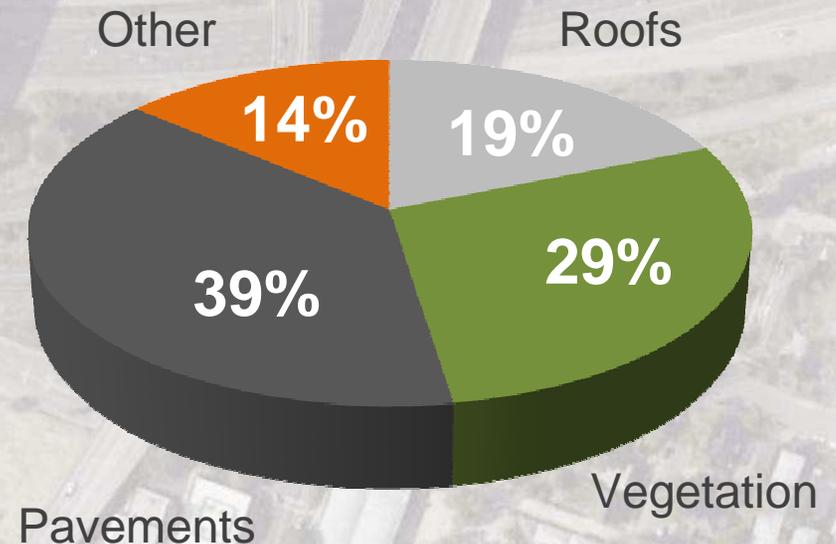


# Why are cities hot?



Sacramento ~ 1 km<sup>2</sup>

One reason...  
many man-made  
dark surfaces



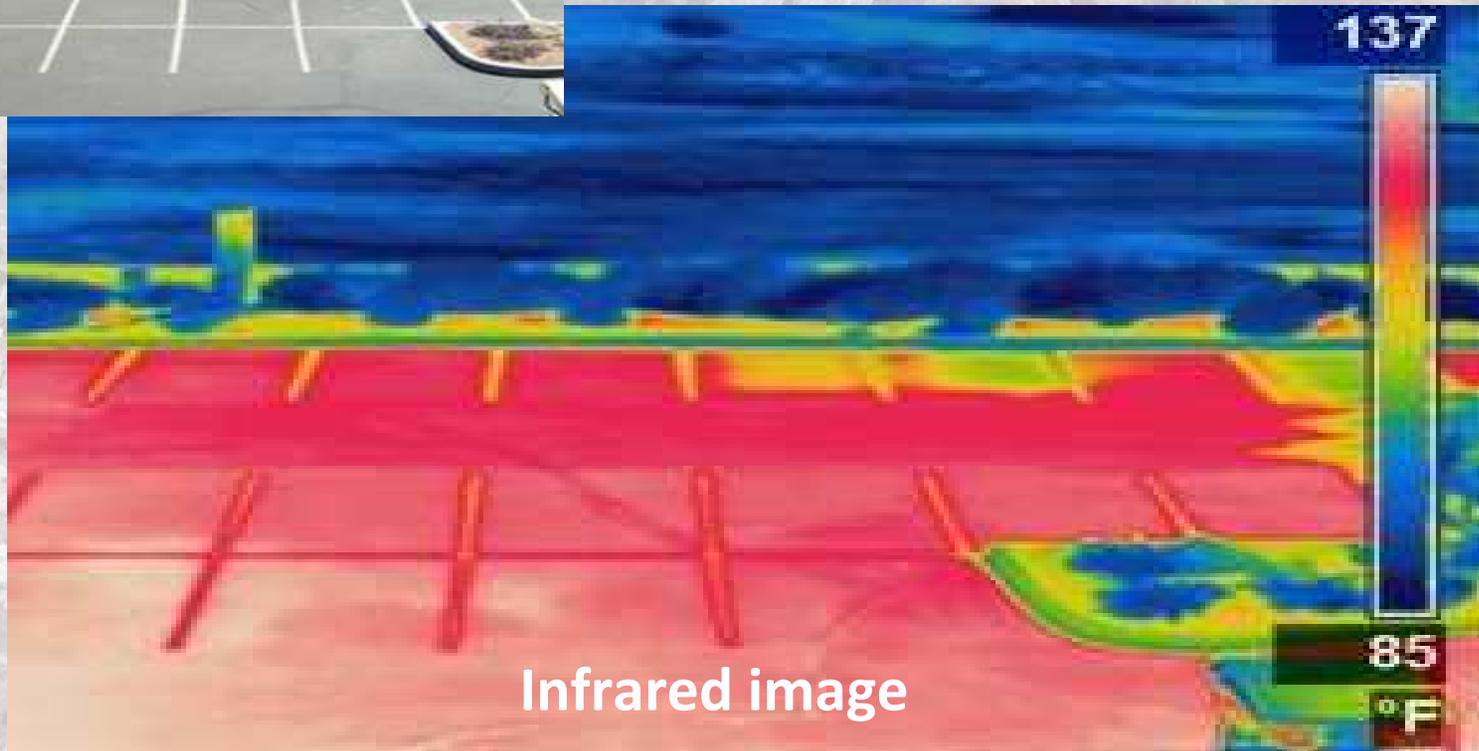
Urban fabric above tree canopy

Source: LBNL Heat Island Group

# Pavements can be HOT



Rio Verde, Arizona



Pavement is > 30 F hotter than vegetation



**Pavements can be  
part of the problem**



**But pavements can also  
be part of the solution**



# The science of cool

# How is air heated?

- Sunlight does not directly heat the air
- Opaque surfaces (e.g., pavements & roofs) absorb some of the sunlight



# Solar reflectance (SR)

- SR = fraction of sunlight reflected =  
reflected sunlight ÷ incident sunlight
- Scale is 0 - 1 (or 0 - 100%)
- Higher SR is cooler (usually)



Roof or pavement surface

# Solar reflectance – how to describe?

- Scale is 0 -1 (or 0 - 100%)

SR=0 (0%): reflects NO sunlight = black

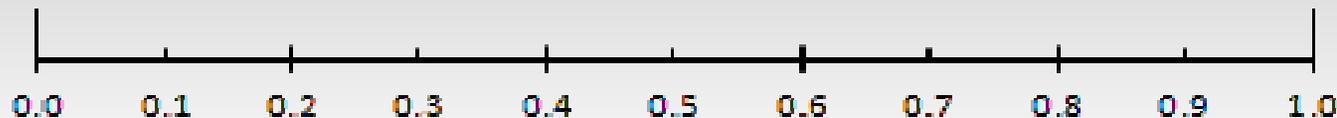
SR=1 (100%) = reflects ALL sunlight = white

- Higher SR usually leads to

**cooler surfaces and cooler air**

perfect absorber

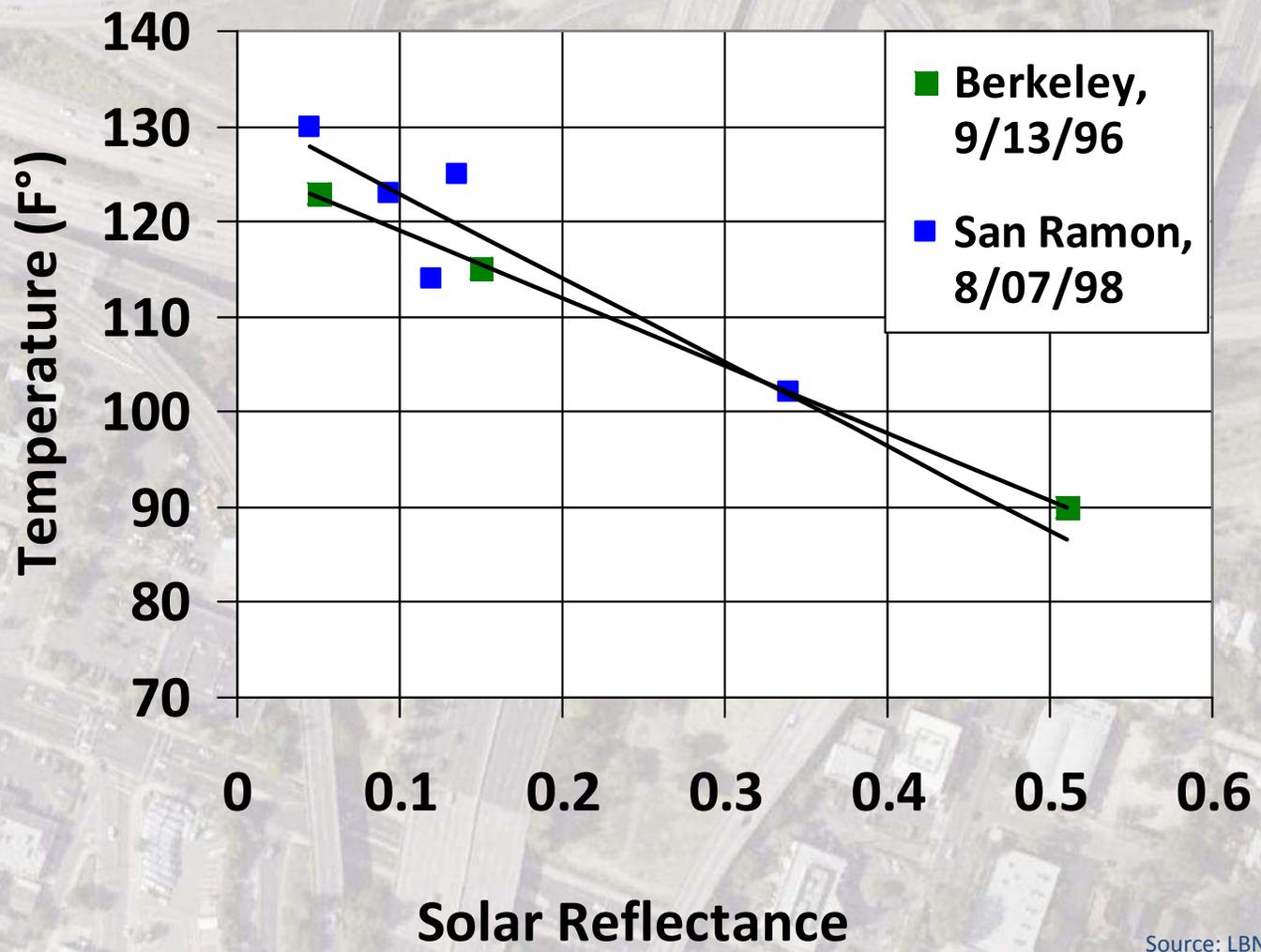
perfect reflector



Higher SR value usually results in cooler pavement

# Pavement temperatures vs. solar reflectances

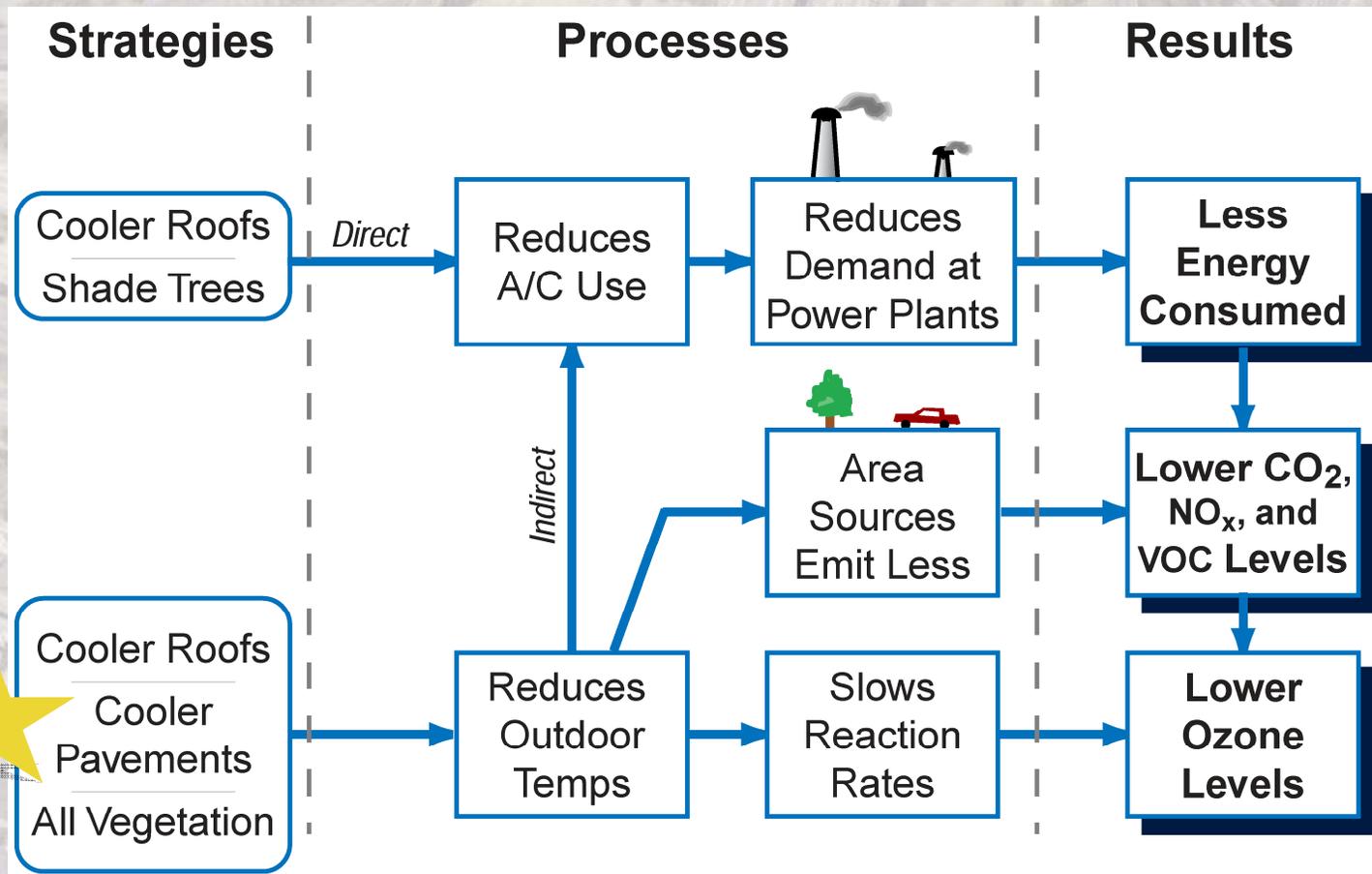
## Solar Reflectance vs. Pavement Temperature



# Solar reflectances – some examples

Material	Solar Reflectance (%)
Black acrylic paint	5
New asphalt concrete	5 – 10
Aged asphalt concrete	10 -15
Aged gray-cement concrete	20 – 35
New gray-cement concrete	35 – 50
New white cement concrete	70 – 80
White acrylic paint	80

# Strategies for cool communities





# Pavements

# Principal types of pavements



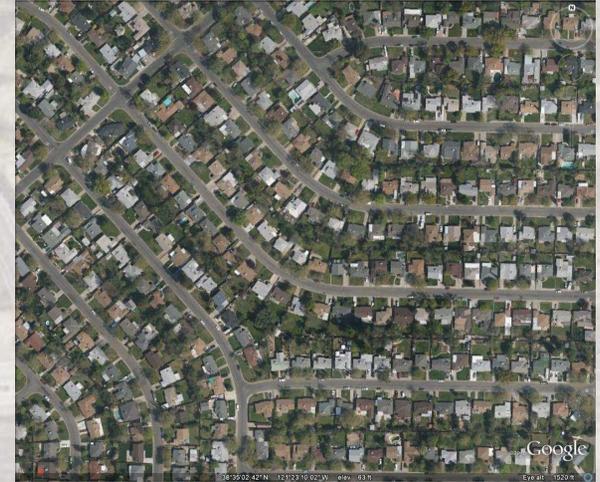
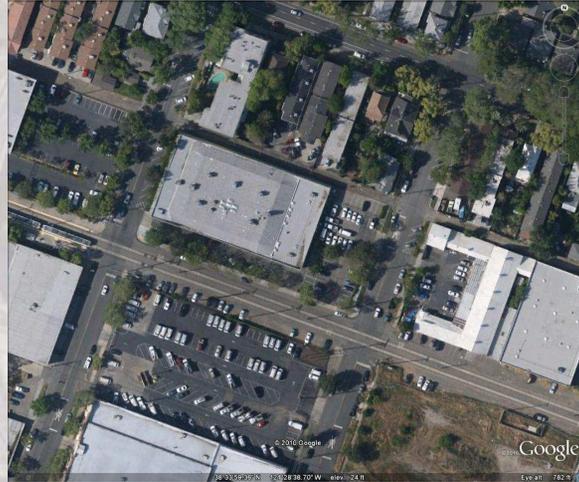
**cement concrete =  
"concrete"**



**asphalt concrete =  
"asphalt"**



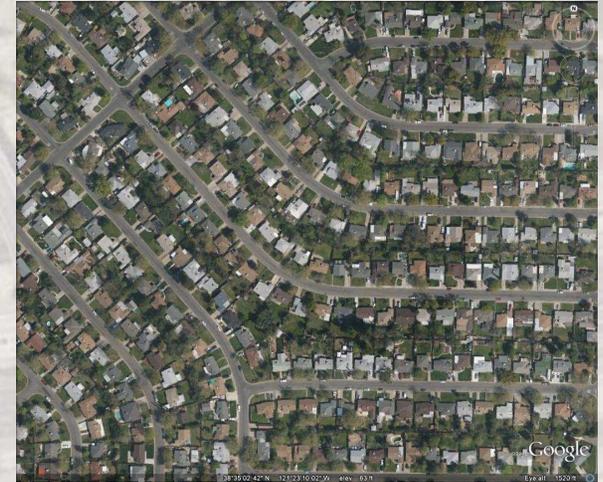
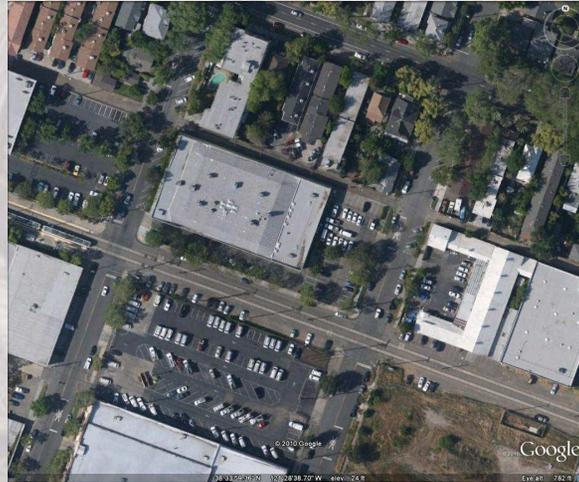
# Pavement uses



- Parking lots
- Alleys
- Driveways
- Bridges
- Plazas

- Playgrounds
- Streets, roads & highways
- Playgrounds
- Sidewalks, paths & trails
- Runways

# Pavements cover about 1/3 of cities

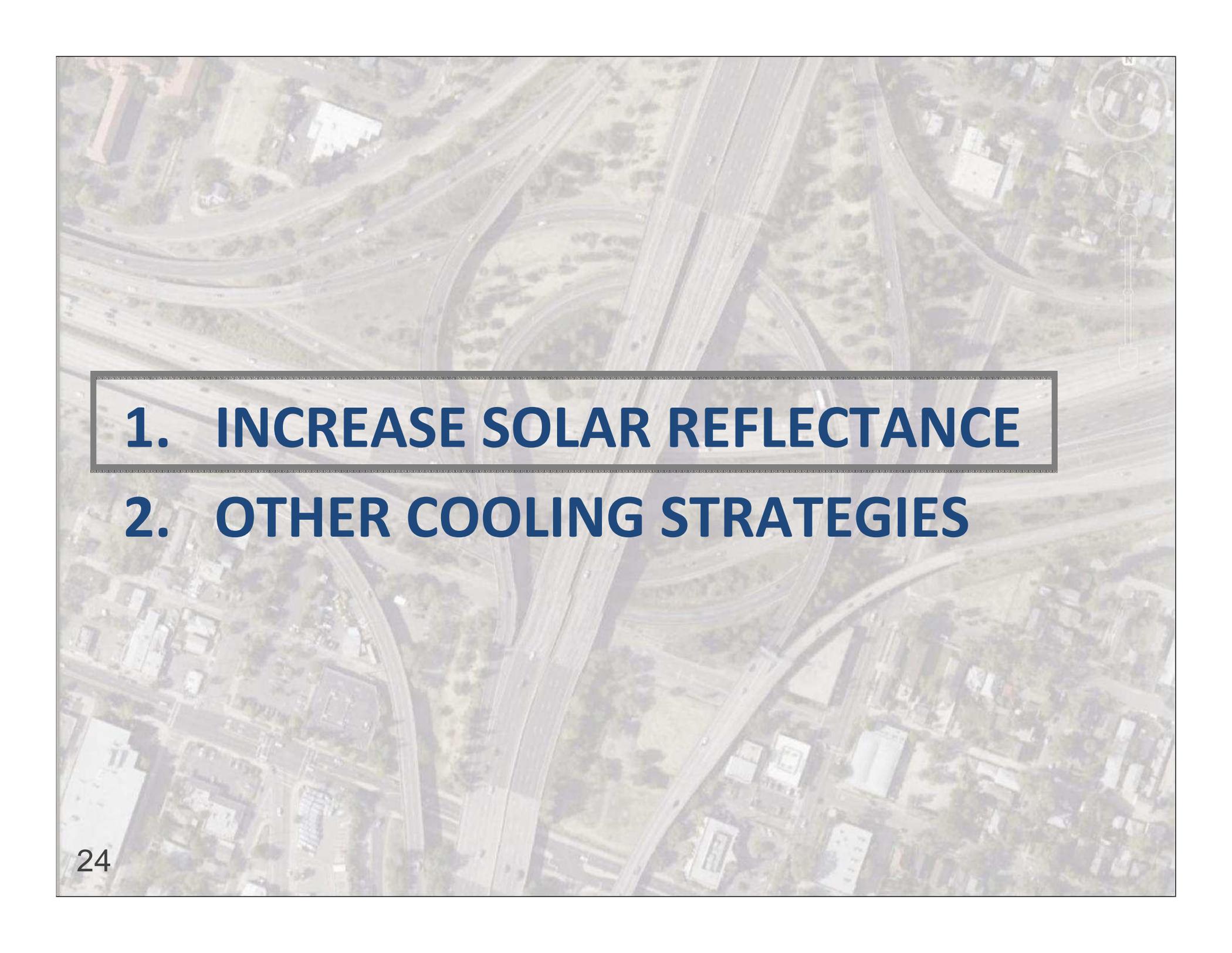


Of that third, about

- 50% are streets (usually asphalt concrete)
- 40% are exposed parking (usually asphalt concrete)
- 10% are sidewalks (usually cement concrete)



# Pavement materials & cool measures

An aerial photograph of a complex highway interchange with multiple overpasses and ramps. The image is semi-transparent, allowing the road structure to be seen through the text. In the top right corner, there are faint navigation icons: a compass, a magnifying glass, and a vertical scale bar.

**1. INCREASE SOLAR REFLECTANCE**

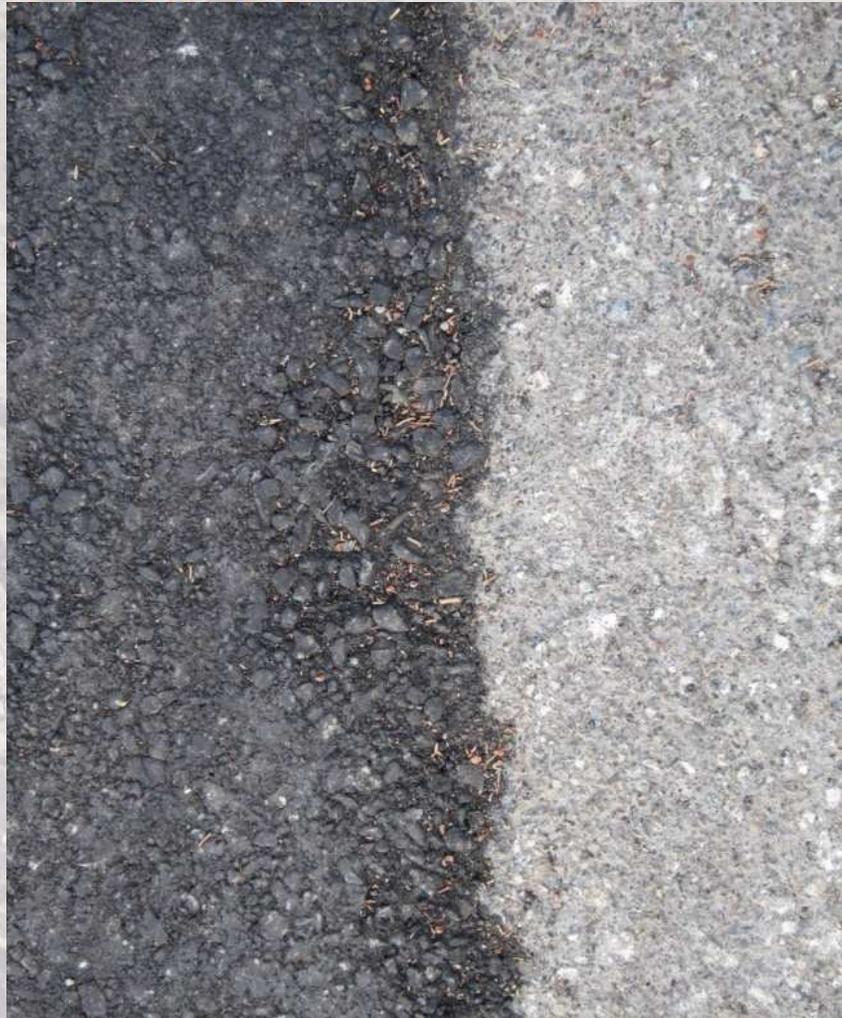
**2. OTHER COOLING STRATEGIES**

# Asphalt (AC)

- **Uses:**
  - new construction, preventive maintenance, rehabilitation
  - highways, streets, alleys, sidewalks, bridge decks, driveways, plazas, parking lots, playgrounds
- **Pavement surface life: 20 years**
- **SR: new 5 - 10 %  
aged 10 - 15 %**

# Asphalt (AC)

**New AC**  
**SR ~ 5%**



**Aged AC**  
**SR ~ 15%**

# Light colored aggregate

- **Example: Chip seal**
- **Uses:**
  - overlay for preventive maintenance
  - highways, roads, streets, parking lots
- **Pavement surface life: 2 – 5 years**
- **SR: depends on aggregate**

# Light colored aggregate

Chip seals



San Jose, CA

chip seal

# Portland cement concrete (PCC)

- **Uses:**
  - **New construction, preventive maintenance, rehabilitation**
  - **Highways, streets, alleys, sidewalks, runway, bridge decks, driveways, plazas, pavers, structures, playgrounds**
- **Pavement surface life: 40 years**
- **SR: new (gray cement) 35 – 50%**  
**aged (gray cement) 20 – 35%**

# Portland cement concrete (PCC)

**New PCC**  
**SR ~ 35%**



**Aged PCC**  
**SR ~ 20%**

# PCC overlay

- **Example: Concrete overlay**
- **Uses:**
  - rehabilitation
  - highways, streets, parking lots
- **Pavement surface life: 20 + years**
  - **SR: new 35 – 50%**  
**aged 20 – 35%**

# PCC overlay



Bellevue, WA

# Clear resin binders

- **Uses:**
  - new construction, preventive maintenance
  - streets, sidewalks, parking lots, plazas, playgrounds
- **Pavement surface life: 20 years**
- **SR: depends on the aggregate**

# Clear resin binders

Pavement Surface Temperature Measurements Recorded with Infrared Thermometer  
Lake Merritt, Oakland, California ~ 1:15pm - 1:30pm ~ July 15, 2010  
Ambient Temperature 80° F / 26.7° C



NATURALPAVE



CONCRETE



ASPHALT



**Natural  
PAVE**  
Resin Pavement

SRI 52.7  
VALUE



[www.sspco.com](http://www.sspco.com)

# Coatings

- **Example: Cementitious coating**
- **Uses:**
  - coating for preventive maintenance
  - streets, sidewalks, plazas, driveways, parking lots, playgrounds
- **Pavement surface life: unknown**
- **SR: new 50 – 55%**

# Cementitious coatings

## Emerald Cities™ Solar Reflective Cool Pavement



### Asphalt Overlay

Fresh laid Asphalt Road  
Carefree Highway, Phoenix, AZ  
July 12, 2010 @ 110° Air Temp

**209. F**

### EC Cool Pavement

Fresh Coated Asphalt Road  
Central Avenue, Phoenix, AZ  
July 12, 2010 @ Air Temp 110° F

**135. F**



# Light-colored cement

- **Example: Slag**
- **Uses:**
  - New construction, preventive maintenance
  - highways, streets, alleys, sidewalks, runways, bridge decks, driveways, plazas, pavers, structures, playgrounds
- **Pavement surface life: 40 years (20 + years overlays)**
- **SR: new 70 – 75 %**

# Slag cement

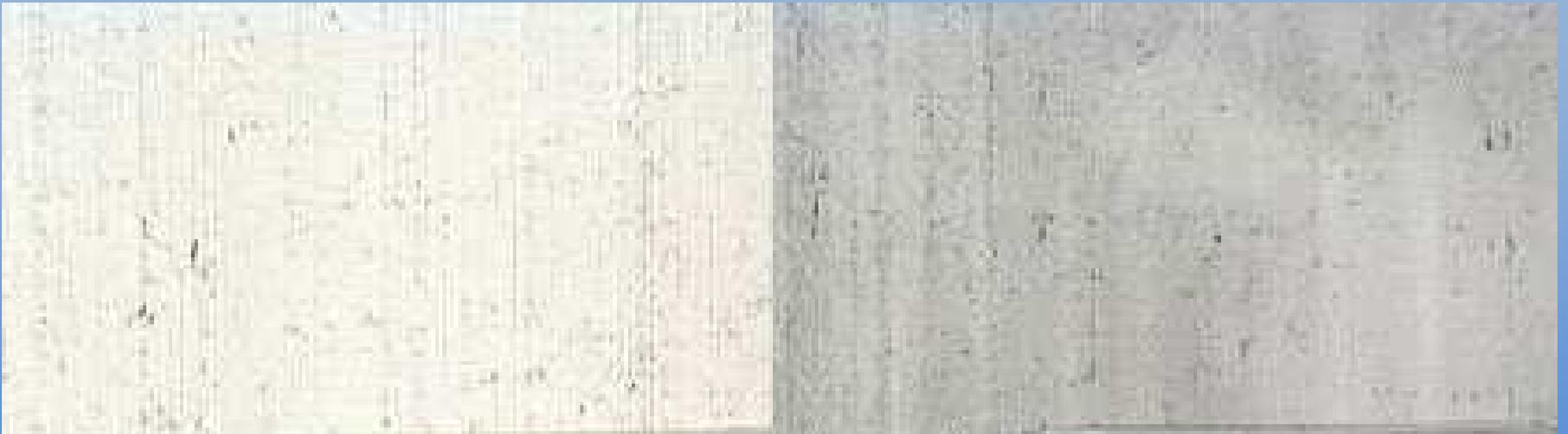
Detroit Metro  
Airport



# Light-colored cement

- **Example: White cement**
- **Uses:**
  - New construction, preventive maintenance
  - highways, streets, alleys, sidewalks, runways, bridge decks, driveways, plazas, precast pavers, structures, playgrounds
- **Pavement surface life: 40 years (20 + years overlays)**
- **SR: new 70 – 80%**

# Light-colored (white) cement



**White cement**

**Gray cement and fly ash**

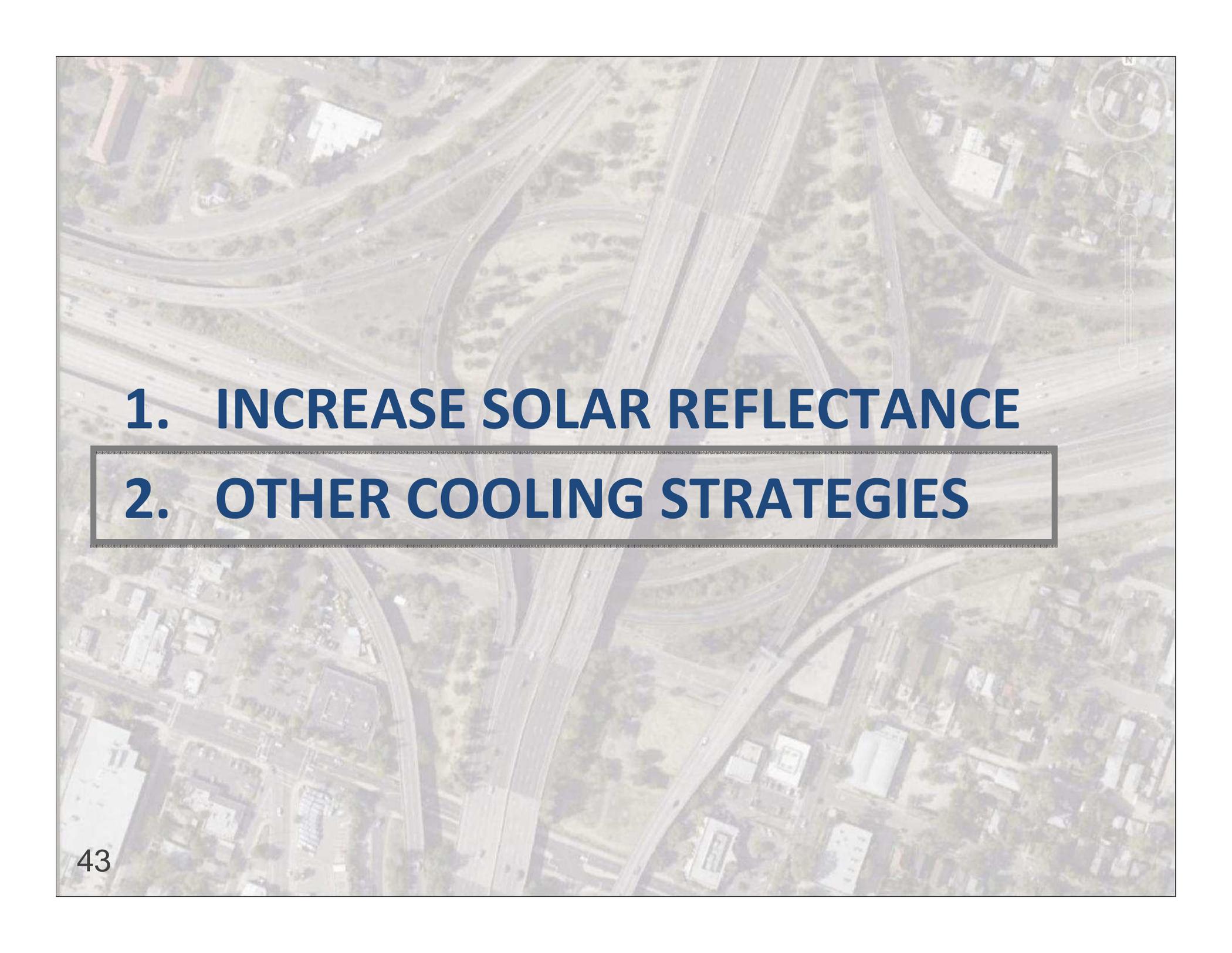
# Light-colored cement

- **Example: Photocatalytic**
- **Uses:**
  - Surface treatment
  - Highways, streets, alleys, sidewalks, runways, bridge decks, driveways, plazas, precast pavers, structures, playgrounds
- **Pavement surface life: 40 years (20+ years overlays)**
- **SR: depends on cement & aggregate**

# Light-colored (photocatalytic) cement



Interstate 35W Bridge Sculpture  
(Minneapolis, MN)



**1. INCREASE SOLAR REFLECTANCE**

**2. OTHER COOLING STRATEGIES**

# Pervious/porous/permeable AC & PCC

- **Uses:**
  - new construction, *to aid with stormwater management*
  - streets, shoulders, sidewalks, paths, alleys, parking lots, plazas, playgrounds
- **Pavement surface life: varies**
- **SR: depends on pavement type**

# Pervious/porous/permeable pavements





[Click to view!](#)

# Reinforced grass pavements

- **Uses:**
  - new construction, *to aid with storm water management*
  - pavements with infrequent use – mall or stadium parking
- **Pavement surface life: varies**
- **SR: depends on pavement type**

# Reinforced grass pavements

Plastic units filled  
with soil and grass



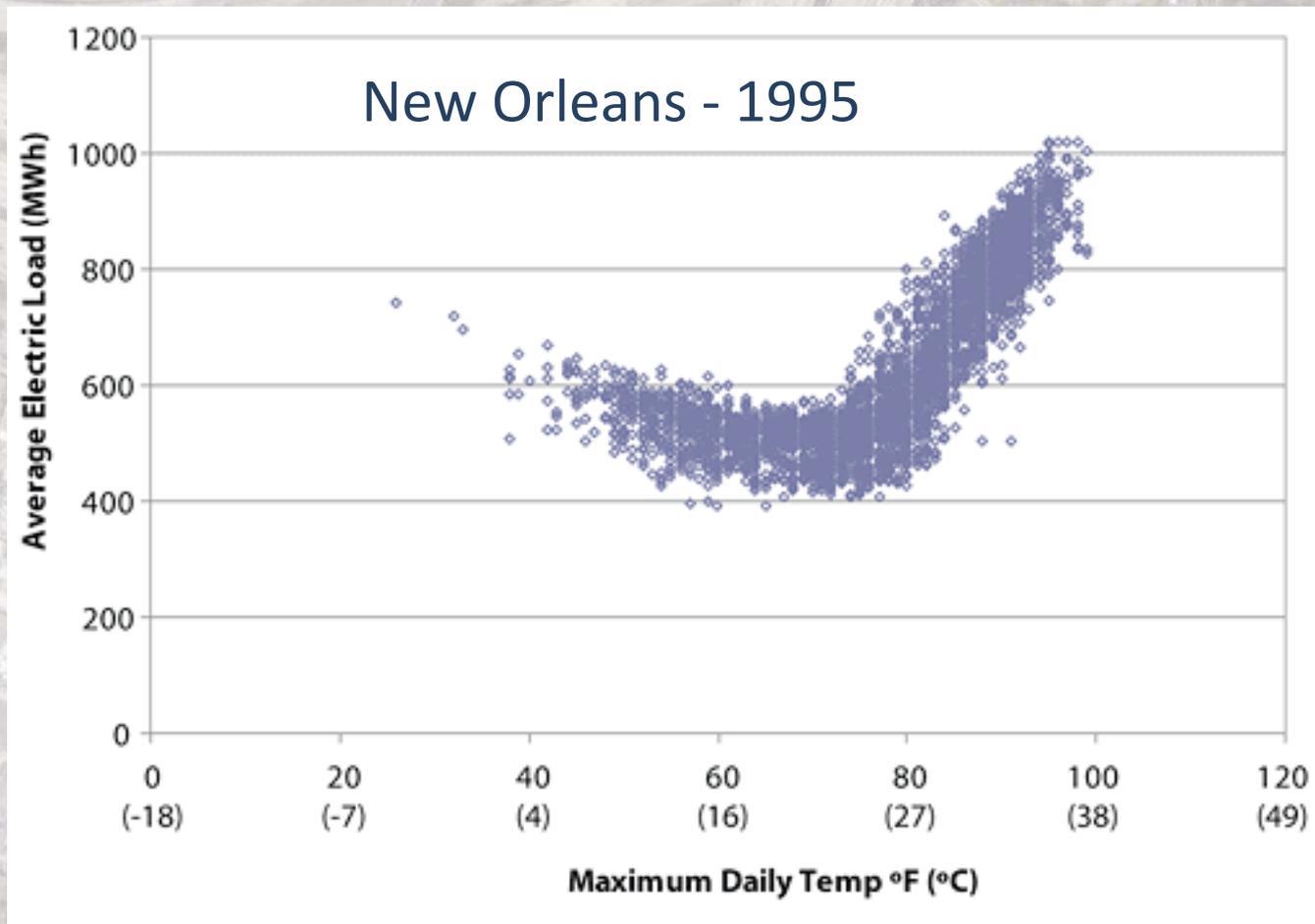
Orange Bowl, Miami, FL, parking



# Why select cool pavements?

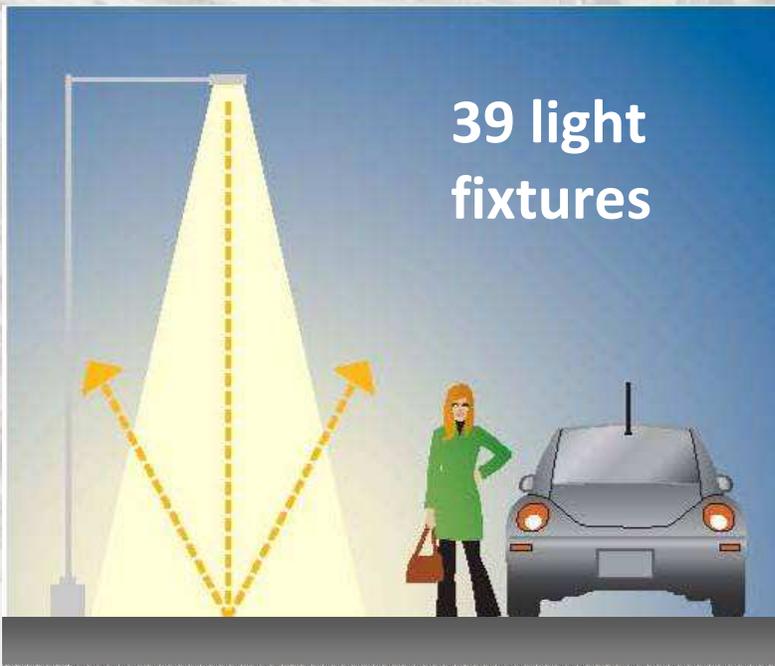
# Energy savings

- Reduced air conditioning



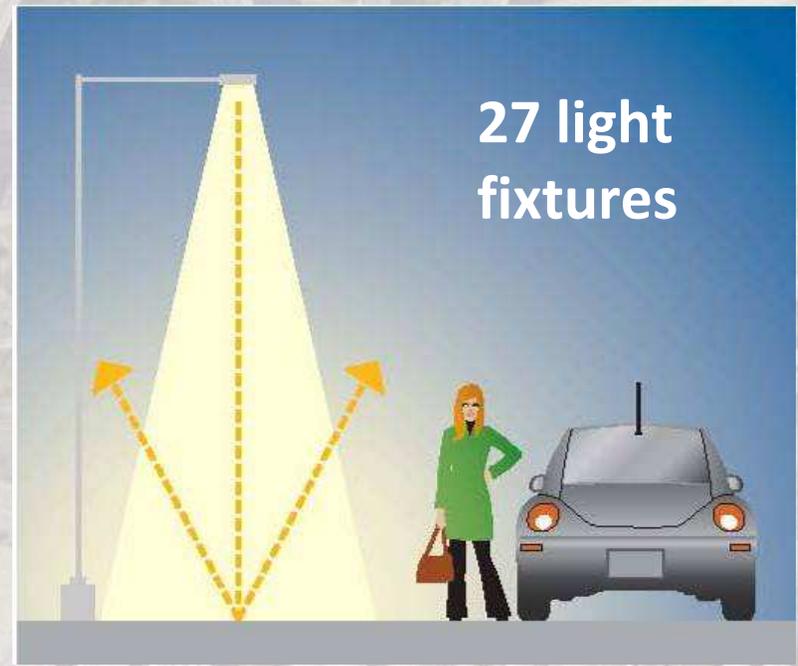
# Energy savings

- **Reduced energy for street lighting**
  - Enhanced illumination or fewer fixtures



**Dark pavement**

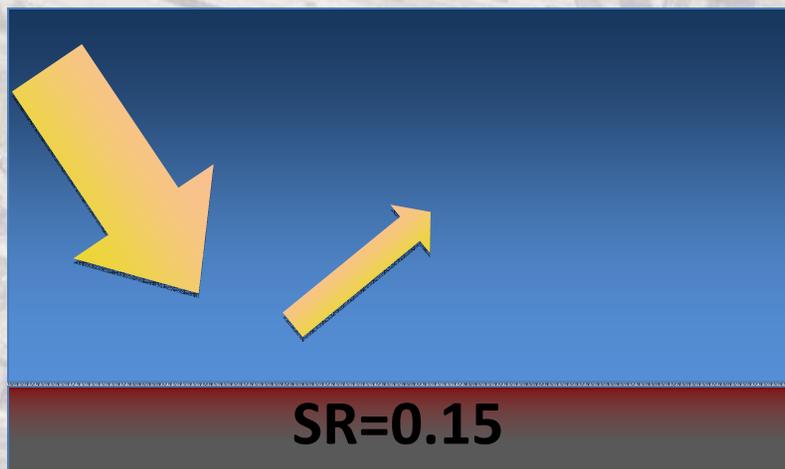
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**Light pavement**

# Improve comfort & health

- Reduce heat related stresses
  - Improve outdoor comfort



Increase SR of pavement by 0.1

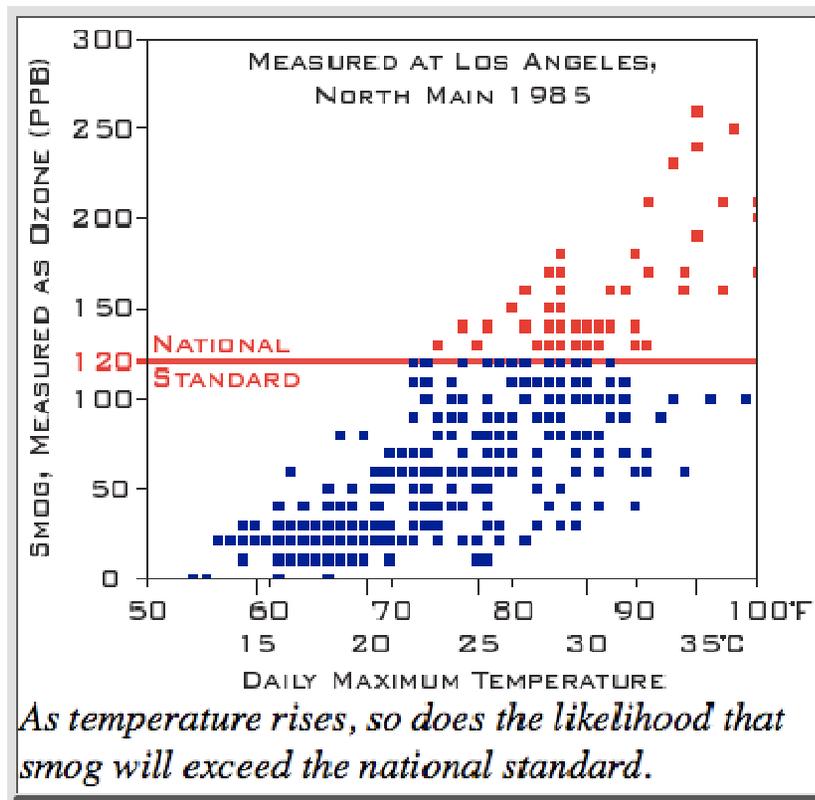
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Decrease surface pavement temperature  
~ 7°F

# Improve air quality

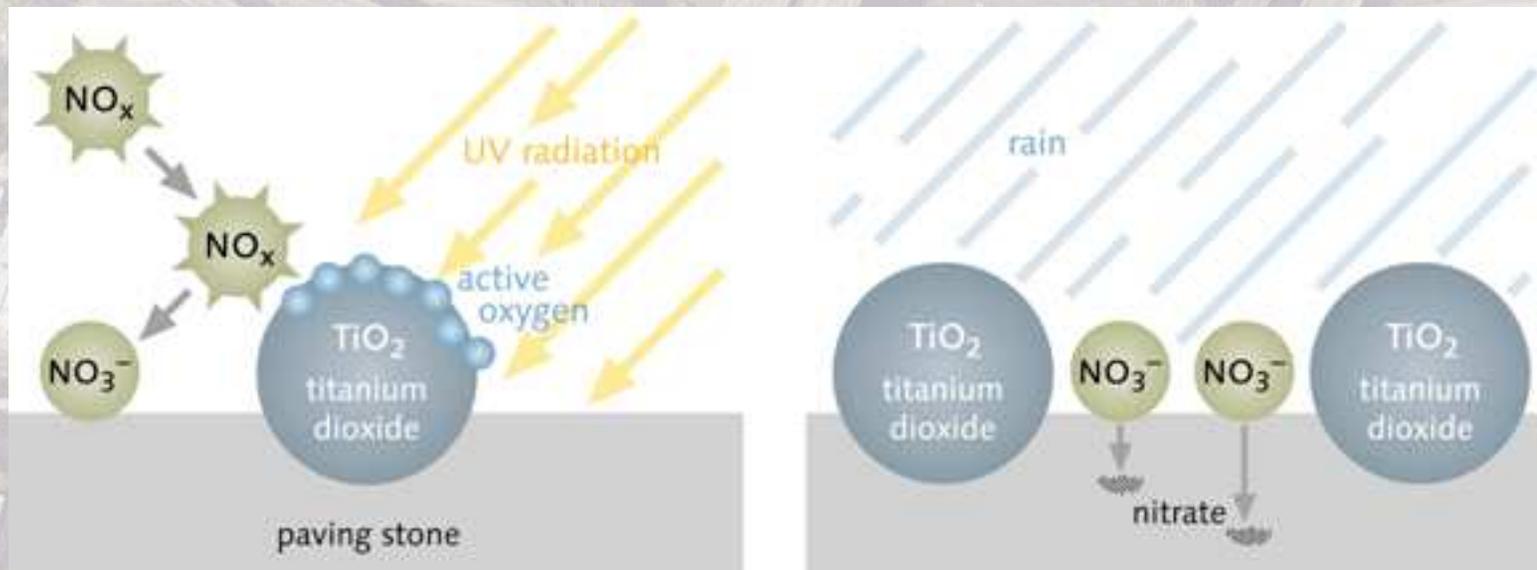
Increases in temperature lead to increases in smog



In LA, elimination of UHI (-5.4°F) could reduce smog exceedance by 12%

# Improve air quality

- Titanium dioxide catalyst is in the cement
- Photocatalyst grabs  $\text{NO}_x$ ; with sunlight converts to harmless nitrates & washes away with rain
- Removes 45% of harmful nitrogen oxides on roads



# Increase durability of asphalt concrete

- Preventing the temperature of asphalt pavement from getting hot will reduce rutting

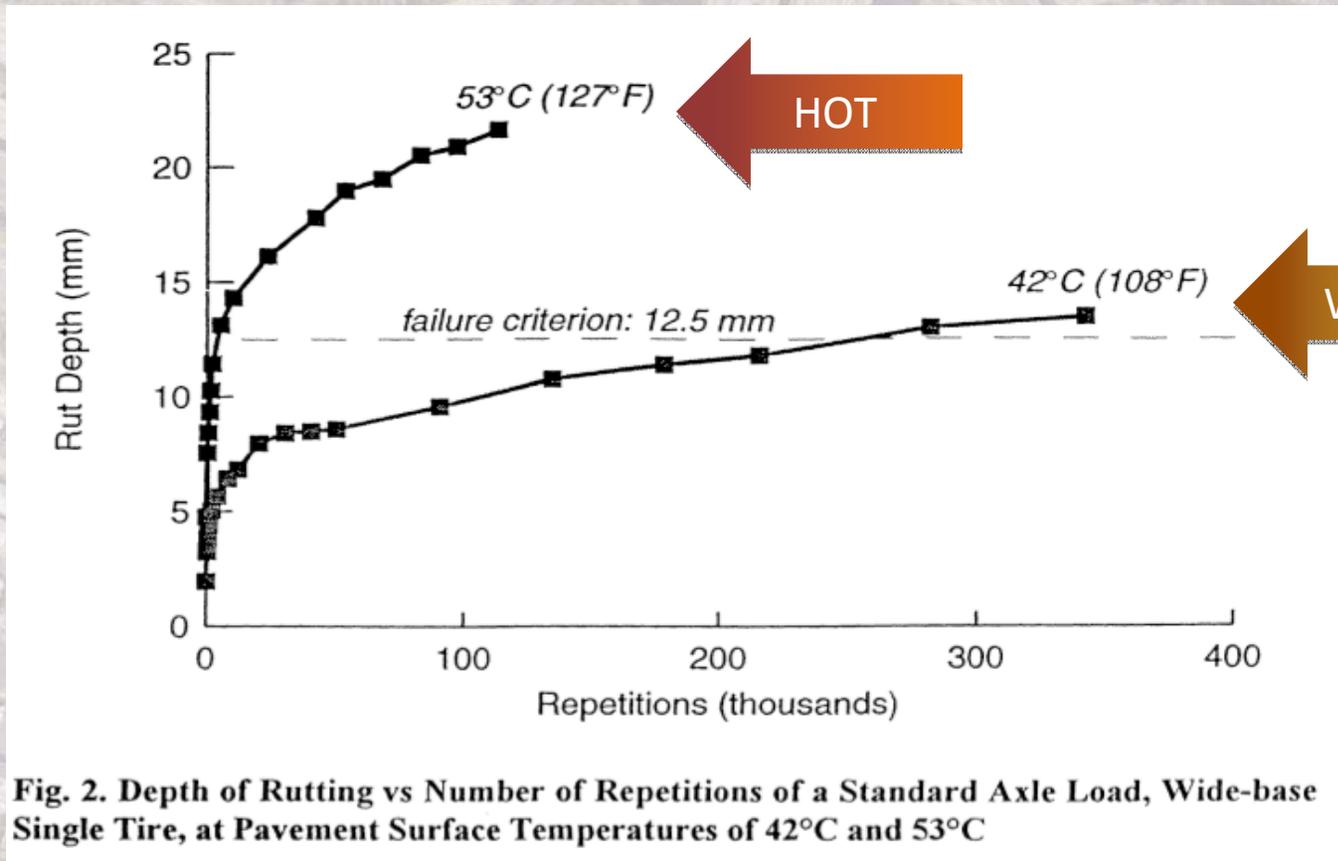


Fig. 2. Depth of Rutting vs Number of Repetitions of a Standard Axle Load, Wide-base Single Tire, at Pavement Surface Temperatures of 42°C and 53°C

# Enhance safety

- **Nighttime illumination**



**Reflected illumination is roughly proportional to solar reflectance**

# Enhance safety

- **Tunnel traffic**
  - Enhance visibility and/or use less lighting



**White cement used in the I-5 tunnel in southern California**

# Preserve water quality

- Changes of +8°F in ultra urban streams 1 hour after summer squalls
- However, change of 5°F in 5 hours can induce stress in most desirable species of fish
- EPA's Clean Water Act addresses heat pollution – temperature is “pollutant of concern”

Brook Trout

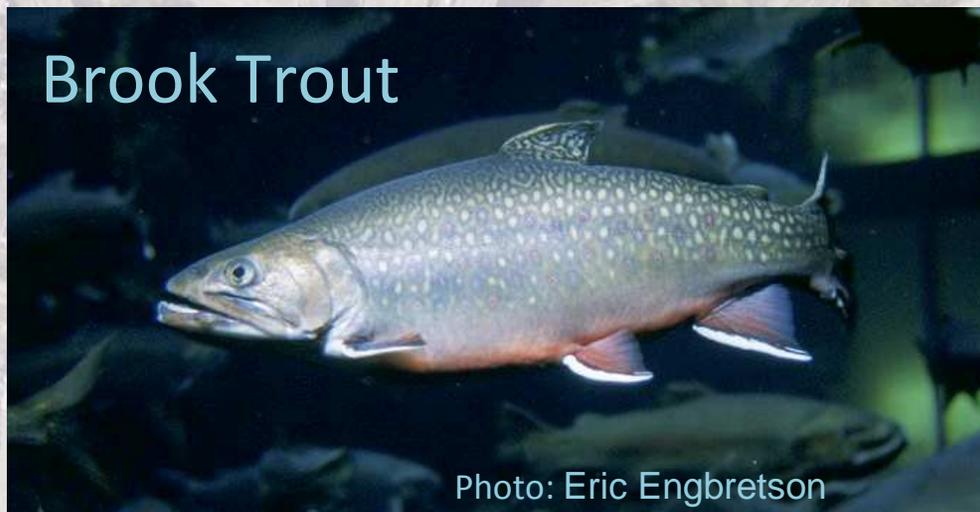


Photo: Eric Engbretson

Source: US EPA

# Global cooling – negative radiative forcing



If cities in hot and temperate parts of the world converted to cool pavements and cool roofs, **44 gigatons of carbon dioxide would be offset** — about one and a half years' worth of current CO<sub>2</sub> emissions or reducing the carbon emissions due to all the cars in the world by **11 years**

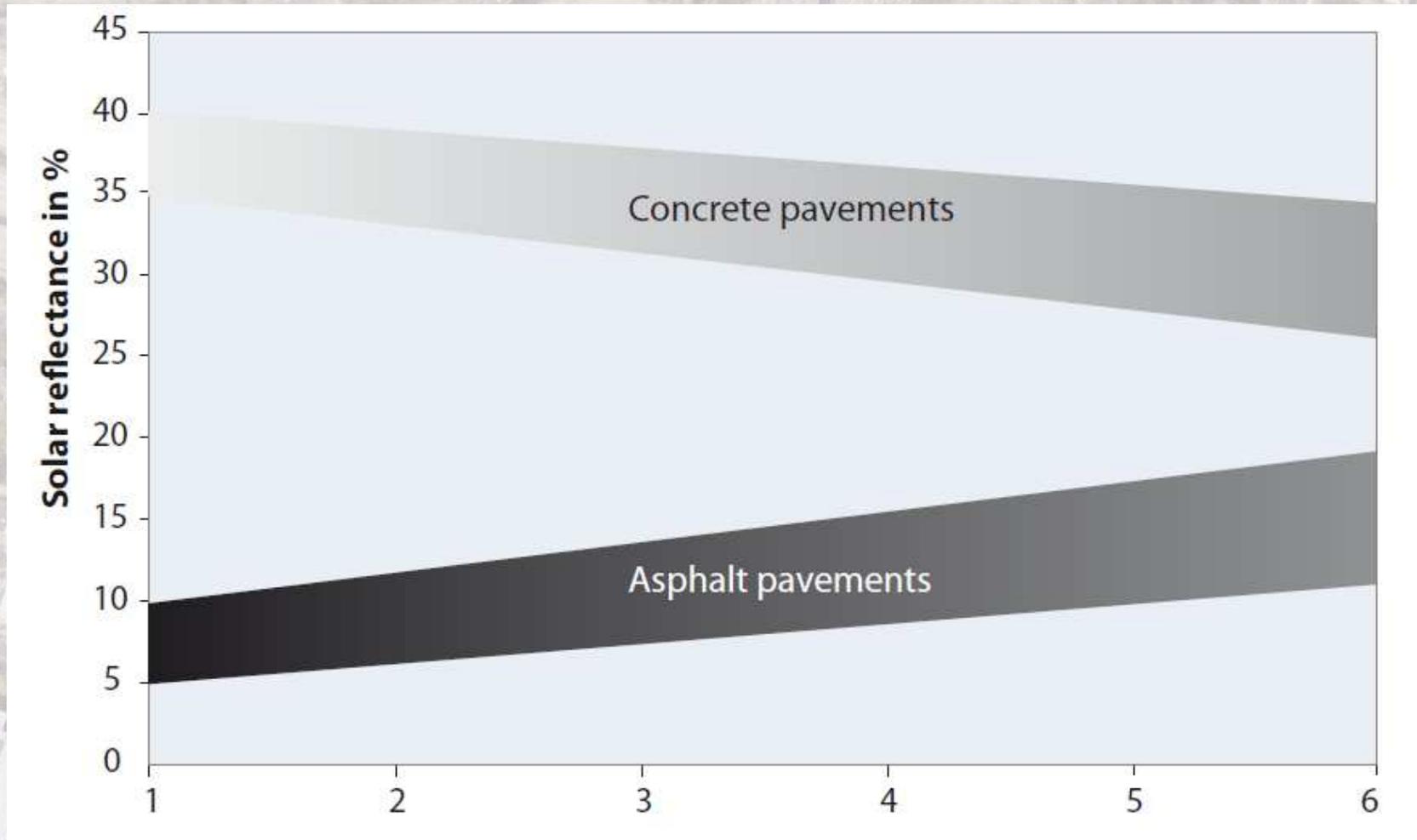
# All result in monetary savings

- **Example - LBNL study of Los Angeles Basin**
  - Rosenfeld et al. (1996)
- **Reduce temperature by 5.4°F (3°C) ->**
  - Reduces peak power demand by 1.6 GW
  - Reduces smog exceedance by 12%
- **Annual savings ~\$535 million (1996 yr)**
- **Annual savings ~\$91 million (1996 yr) from cooler pavements**



# Things to consider

# Solar reflectance changes over time



# Shading

Buildings, cars, vegetation



# Urban geometry



Financial District, San Francisco, CA



Northern Park, San Francisco, CA

Image source: Google Maps

# Availability of materials



# Design context

## Project guidelines





# Benefits & costs

## Who pays and who benefits?



# Cool pavements in use

# Codes, standards & policies

- **Codes**
  - CalGreen
- **Standards & ratings**
  - LEED
  - Greenroads
- **Policies & programs**
  - California climate action plans
  - Local city ordinances, rules, guidelines

# California - CalGreen

- **Effective: Jan. 1, 2011 – Tier 1 & 2**
- **Site Development - Heat Island Effect (A5.106.11)**
- **Requirements – Use one or combination of strategies for 50% of site hardscape or put 50% of parking underground**
  - Provide shade
  - Use light colored/high albedo materials
  - Use open-grid pavement system

**CAL Green**

# U.S. Green Building Council - LEED

- **CREDIT 7.1 – Heat Island Effect: Non-Roof**



- **Requirements:**

- Provide shade (within 5 years)
- Use light-colored/high-albedo materials ( $SRI \geq 29$ )
- Use open grid pavement

**For at least 30% of the sites non-roof impervious surfaces**

**OR**

- Use an open-grid pavement system for a minimum of 50% of the parking lots area

# Greenroads

Greenroads Manual v1.0

Pavement Technologies

## COOL PAVEMENT

### GOAL

Reduce contribution to localized increased air temperatures due to pavement reflectance and minimize stormwater runoff temperatures.

### CREDIT REQUIREMENTS

Use a pavement surface with a minimum albedo of 0.3 (measured using ASTM E 903) for a minimum of 50% of the total project pavement surfacing by area.

### OR

Use a porous pavement or pavers for a minimum of 50% of the total project pavement surfacing by area.



5 POINTS

### RELATED CREDITS

- ✓ MR-6 Energy Efficiency
- ✓ PT-2 Permeable

# California – City of Novato

- Climate action plans

## Measure 9:

**Cool Paving Materials:** Require the use of high albedo material for future outdoor surfaces such as parking lots, median barriers, roadway improvements, and sidewalks in order to reduce the urban heat island effect and save energy.

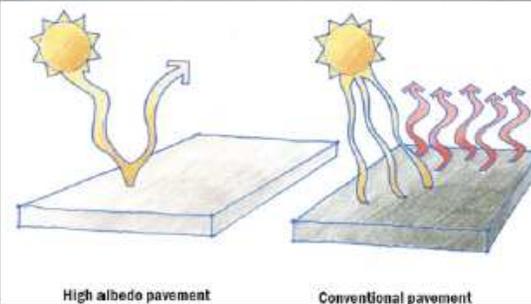
2020 GHG Reductions:	782 MT CO <sub>2</sub> e
2035 GHG Reductions:	1,759 MT CO <sub>2</sub> e
Responsible City Department:	Community Development
Supporting Departments or Agencies:	Public Works
Time Frame for Initiation:	Medium
Cost to City:	No impact to City funds
Funding Source(s):	Entitlement fees

# Chicago

## Urban Heat Island

Maximize landscape opportunities and streetscape surface area in roadway, sidewalks, and plazas with minimum .29 Solar Reflective Index.

- Sidewalk Concrete with slag
- Microthin Concrete Overlay
- Permeable high albedo pavers
  - Photocatalytic Cement
- Increase tree canopy cover
- Increase landscaped surfaces



# Chicago

## Cermak/Blue Island Sustainable Streetscape

Project Sustainable Goals

### **Stormwater Management**

Divert 80% of the typical average annual rainfall and at least 2/3 of rainwater falling within catchment area into stormwater best management practices.

### **Water Efficiency**

Eliminate use of potable water for irrigation, specify native or climate adapted, drought tolerant plants for all landscape material.

### **Transportation**

Improve bus stops with signage, shelters and lighting where possible, promote cycling with new bike lanes, improve pedestrian mobility with accessible sidewalks.

### **Energy Efficiency**

Reduce energy use by min. 40% below a typical streetscape baseline, use reflective surfaces on roads/sidewalks, use dark sky-friendly fixtures. Min. 40% of total materials will be extracted, harvested, recovered, and/or manufactured within 500 miles of the project site.

### **Recycling**

Recycle at least 90% of construction waste based on LEED NC criteria, Post/Pre- Consumer recycled content must be min. 10% of total materials value.

### **Urban Heat Island**

Reduce ambient summer temperatures on streets and sidewalks through use of high albedo pavements, roadway coatings, landscaping, and permeable pavements

### **Education, Beauty & Community**

Provide public outreach materials/self-guided tour brochure to highlight innovative, sustainable design features of streetscape. Create places that celebrate community, provide gathering space, allow for interaction and observation of people and the natural world.

### **Commissioning**

Model Stormwater BMP's in Infoworks to analyze and refine design. Monitor stormwater BMP's to ensure predicted performance and determine maintenance practices.

# Houston

- **Cool Houston!**
  - A plan for cooling the region



Parking lot, Reliant Park



# And more research coming soon!

- **University of California, Davis - West Village development**
  - **Cool pavement monitoring & demonstration**



# Resources

- **Arizona State University**
- **California Department of Transportation**
- **Greenroads**
- **Lawrence Berkeley National Laboratory – Heat Island Group**
- **Portland Cement Association**
- **University of California – Pavement Research Center**
- **U.S. Green Building Council**
- **U.S. Environmental Protection Agency**

# Acknowledgements

Lawrence Berkeley National Laboratory Heat Island Group  
would like to acknowledge and thank our:

- **Partners**

- California Department of Transportation
- California Nevada Cement Association

- **Sponsors**

- California Energy Commission
- California Air Resources Board



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  - California Nevada Cement Association