

# Urban Heat Island Impacts & How Cities are Responding



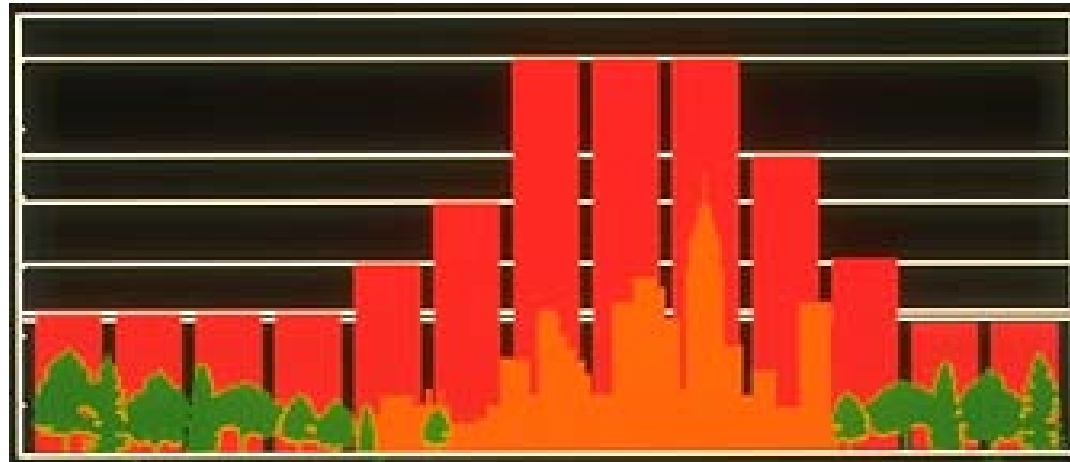
## In this presentation

- Heat Island Characteristics
- Heat Island Effects
- Heat Island Causes
- Heat Island Mitigation
  - Cool Roofing, Cool Paving, Trees & Vegetation, Green Roofing, Other Ideas
- Mitigation Programs that Work



# The Heat Island Problem

- What is a heat island?
- Short answer:
  - Reverse Oasis
  - Hotter temperatures in urban & suburban areas than in their rural surroundings



# The Heat Island Problem

- Heat islands create serious problems
  - Heat-related mortality
  - Higher energy use
  - More severe air quality
- Heat island mitigation
  - Helps reduce heat island problems
  - Also helps reduce the effects of global warming
- To fix heat islands, you must first understand them



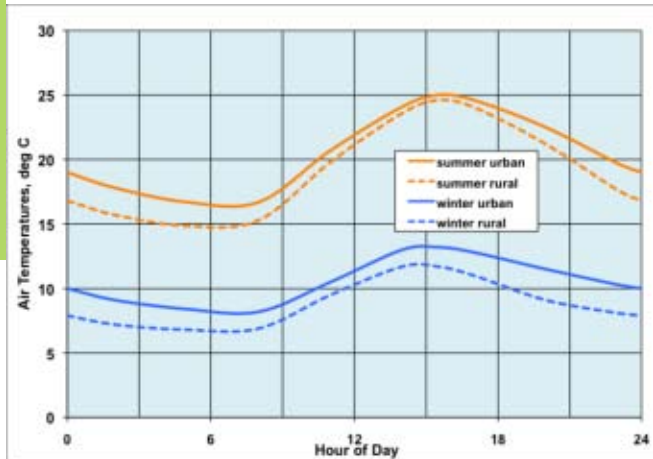
# Heat Island Characteristics

- Hotter air temperatures
- Hotter surface temperatures
- More intense in calm, clear weather
- Increases with development
- Thermal inversions

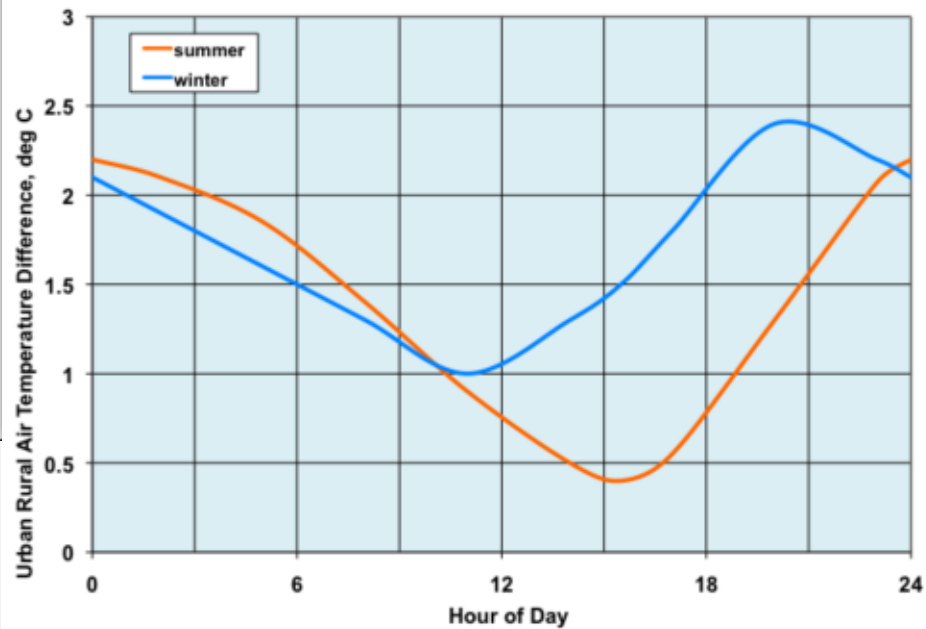


# Heat Island Characteristics

- Hotter air than in their rural surroundings
  - Melbourne, Australia heat island
  - Warmer urban temperatures, especially at night



urban & rural temperatures



urban-rural temperature difference



# Heat Island Characteristics

- **Hotter surface temperatures**
  - Thermal imagery from satellites or airplanes



**Buffalo, NY**  
1978

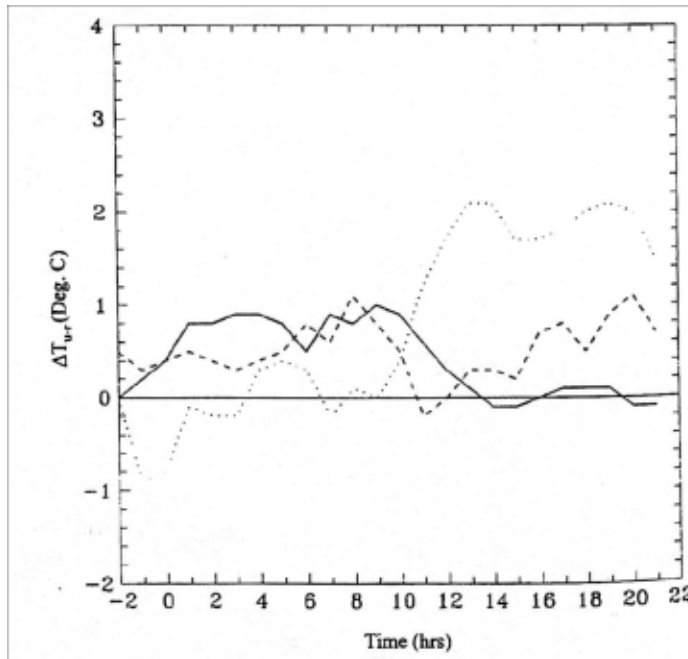


**Baton Rouge, LA**  
1998

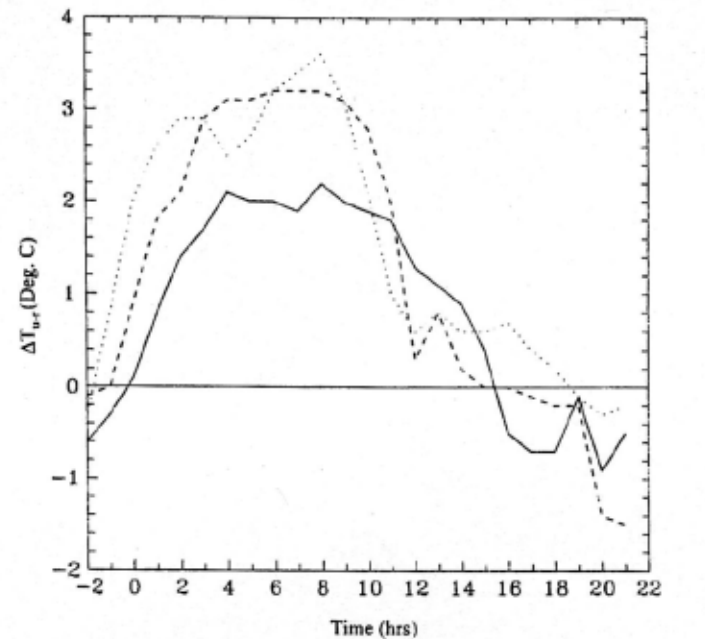


# Heat Island Characteristics

- More intense in calm, clear weather
  - Bucharest, Romania heat island
  - urban Filaret / rural Banasea delta T



Windy, cloudy

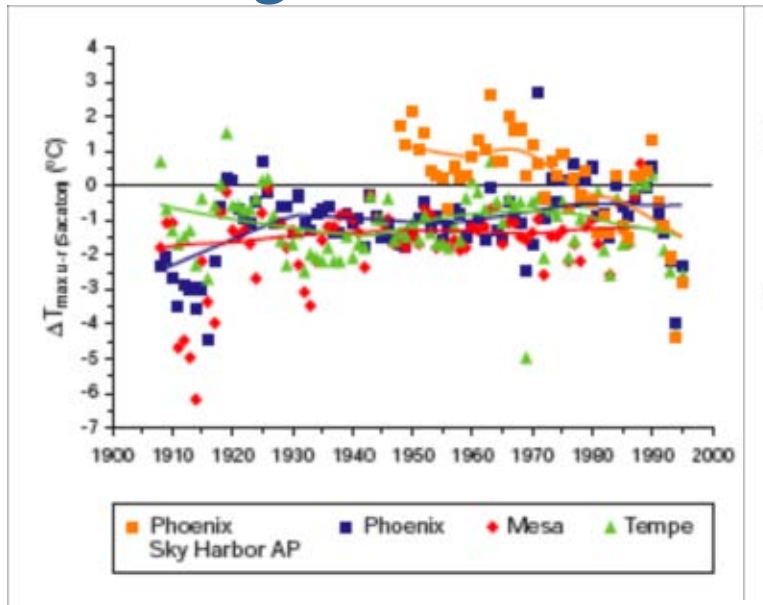


Calm, clear

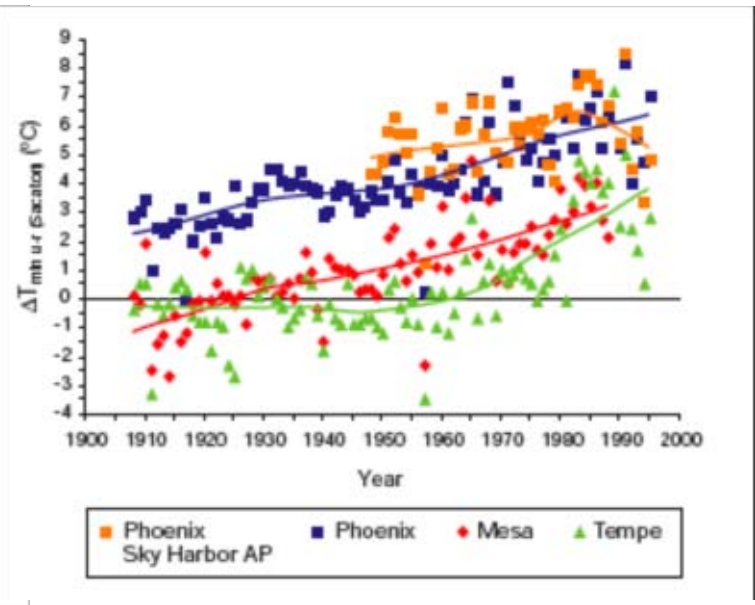


# Heat Island Characteristics

- Increases with development
  - Larger or more intense heat islands – or both!



Maximum Temperatures



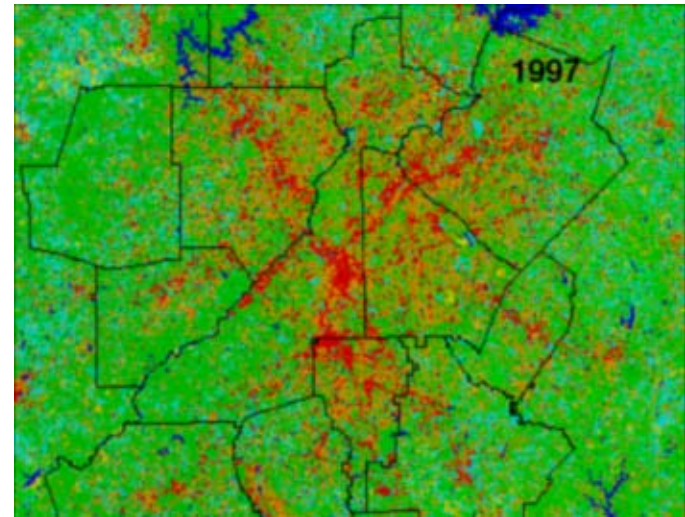
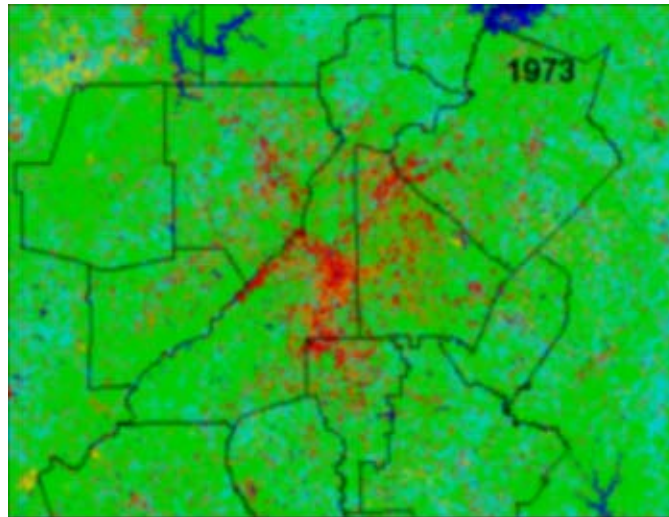
Minimum Temperatures

Air temperature difference between Phoenix, Mesa, Tempe, the airport and Sacaton (desert)



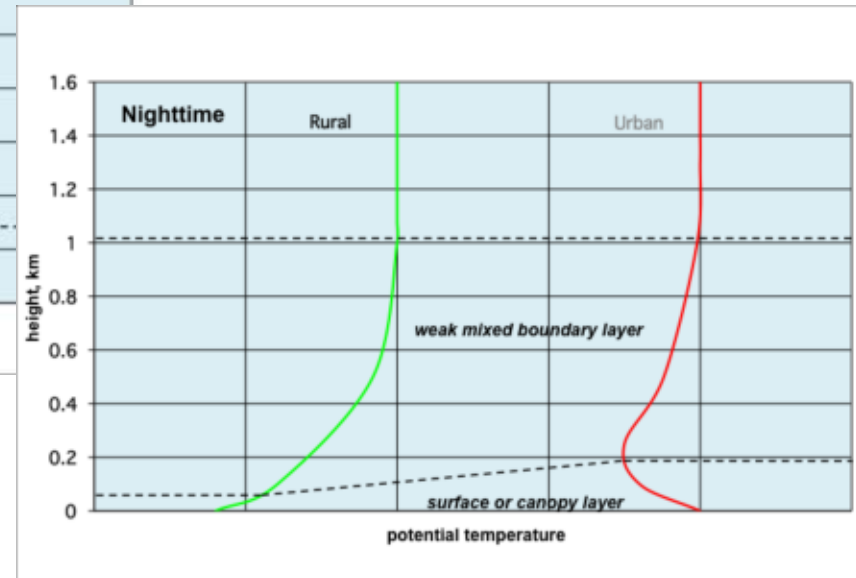
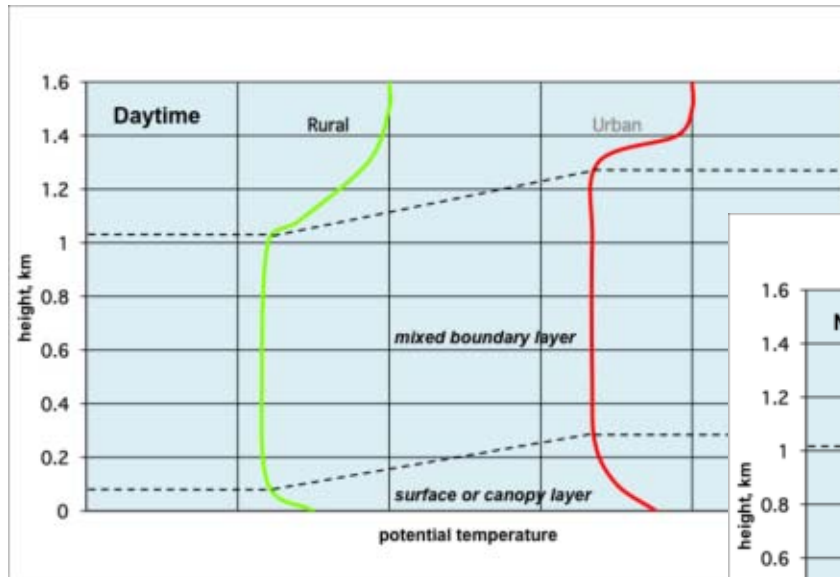
# Heat Island Characteristics

- **Increases with development**
  - Atlanta, Georgia
  - Heat island is larger & hotter



# Heat Island Characteristics

- Thermal inversions over cities
  - Urban materials store heat & release it at night
  - Temperature inversions trap heat near surface



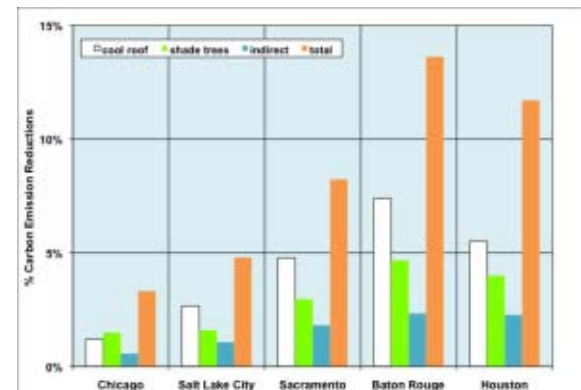
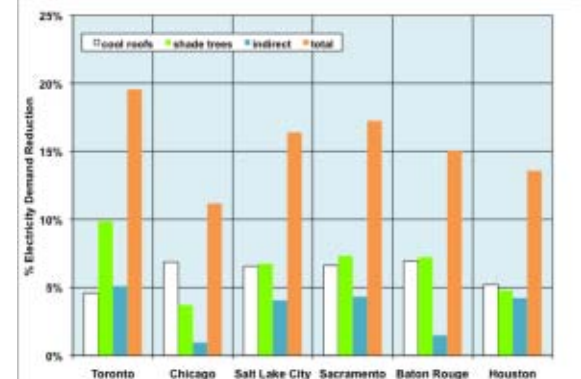
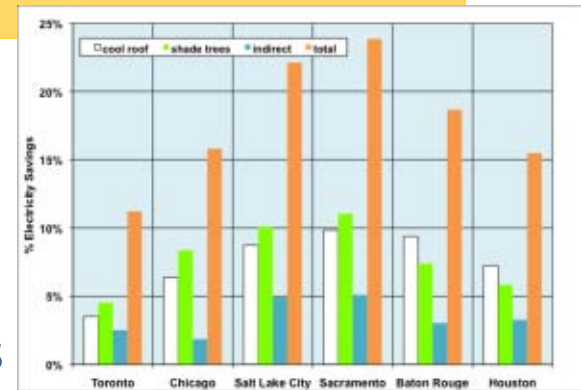
# Heat Island Effects

- **Heat waves**
  - Most lethal type of weather phenomenon
  - Most noteworthy events:
    - 1995 Chicago – 600 deaths over five days
    - 2003 Europe – 35,000 deaths
  - Heat islands make heat waves more deadly
    - Higher minimum temperatures
    - Thermal inversions increase air stagnation
    - Don't allow for night-time cooling



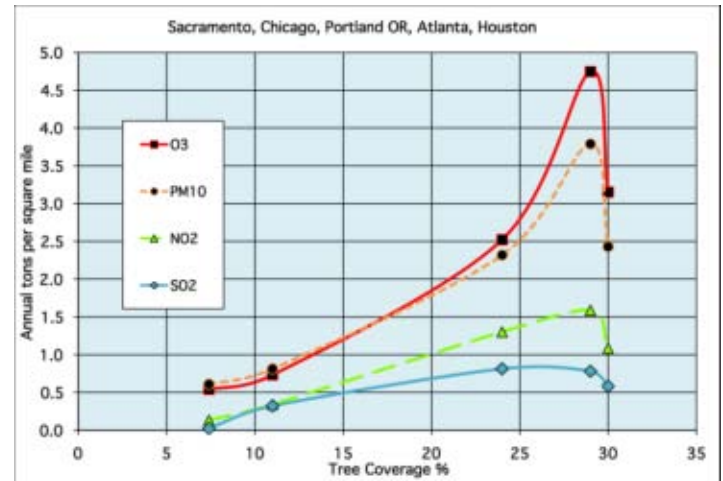
# Heat Island Effects

- Higher electricity use
  - More air-conditioning needed
    - Buildings absorb more heat
    - Higher outdoor air temperatures
  - Higher electricity demand
    - Afternoon peak electrical use
    - Leads to power shortages, brownouts, blackouts
  - More air pollution created
    - Fossil fuels burned to create electricity
  - Higher utility costs



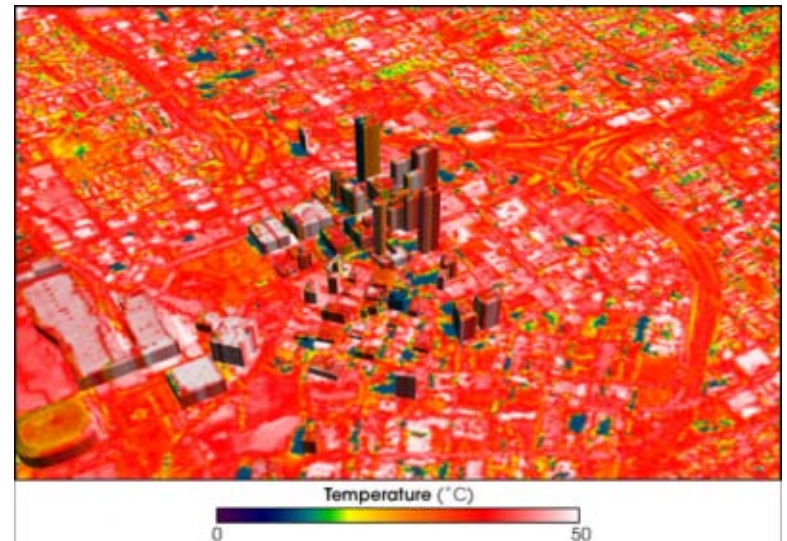
# Heat Island Effects

- **More severe air quality**
  - **Direct increases in air pollution**
    - More electricity use
  - **Indirect increases in air pollution**
    - Smog or ozone formation is a photochemical process
    - Warmer temperatures speed up the process
  - **Lack of trees & vegetation to filter the air**



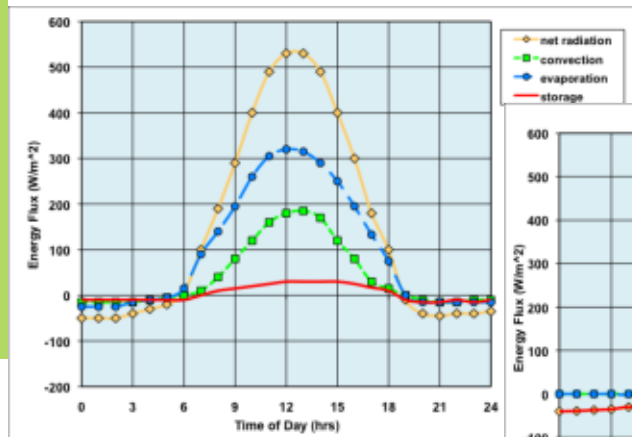
# Heat Island Causes

- Reduced evaporation
- Increased heat storage
- Increased anthropogenic heat
- Increased net radiation
- Decreased convection

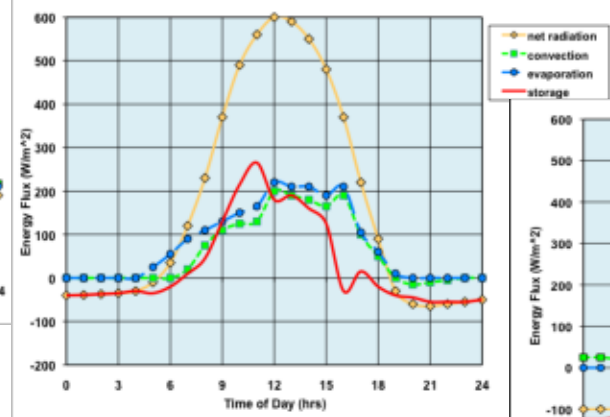


# Heat Island Causes

- Reduced evaporation
  - Lack of trees, vegetation & porous surfaces

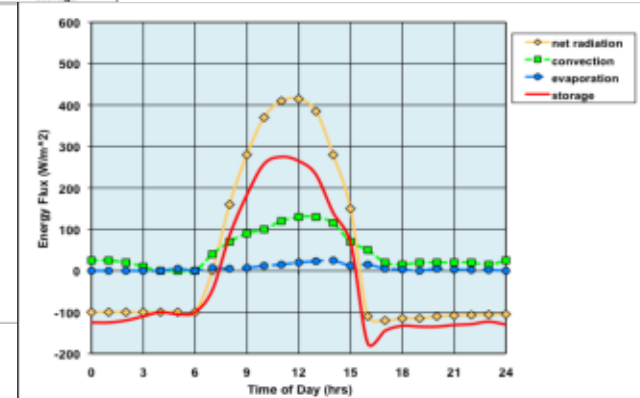


Rural Vancouver  
100% veg cover



Suburban Chicago

44% veg cover



Urban Mexico

2% veg cover

City

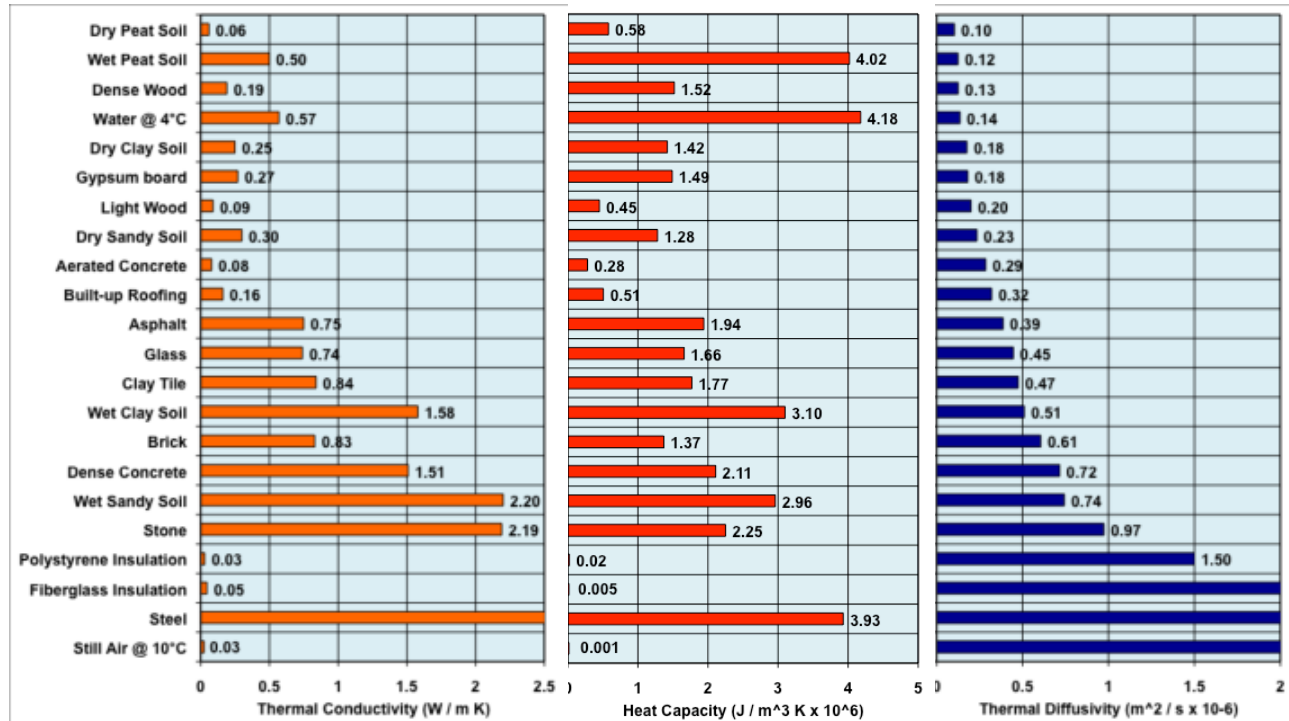
- Stored energy is later released to the air

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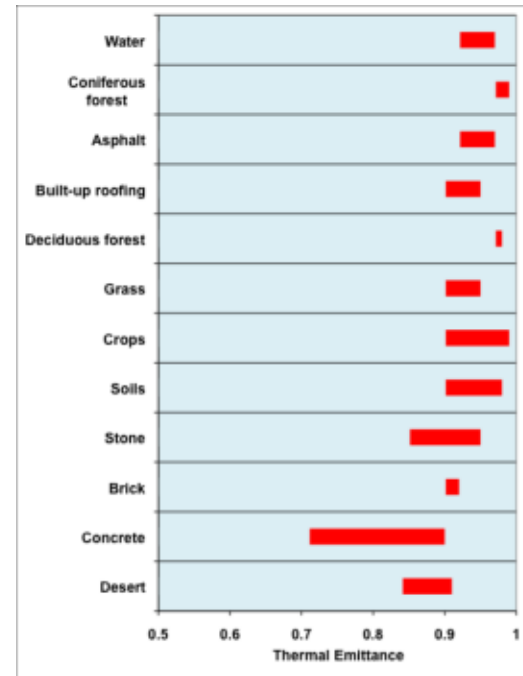
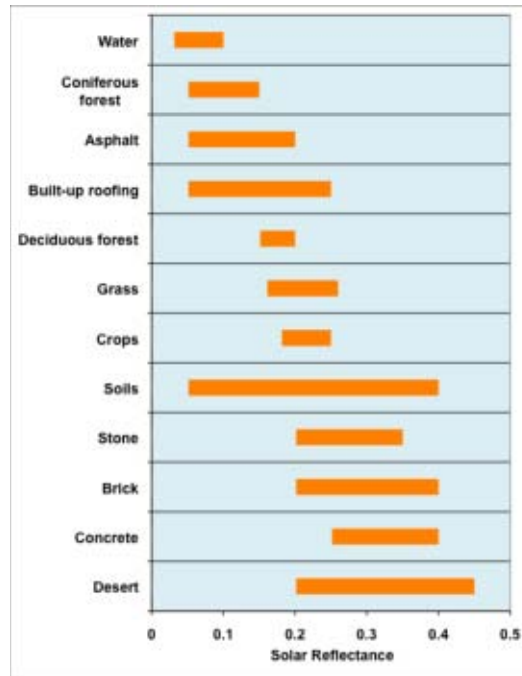
# Heat Island Causes

- Increased heat storage
  - Traditional building material properties
    - diffusivity = conductance / heat capacity
    - measure of the ability to store heat



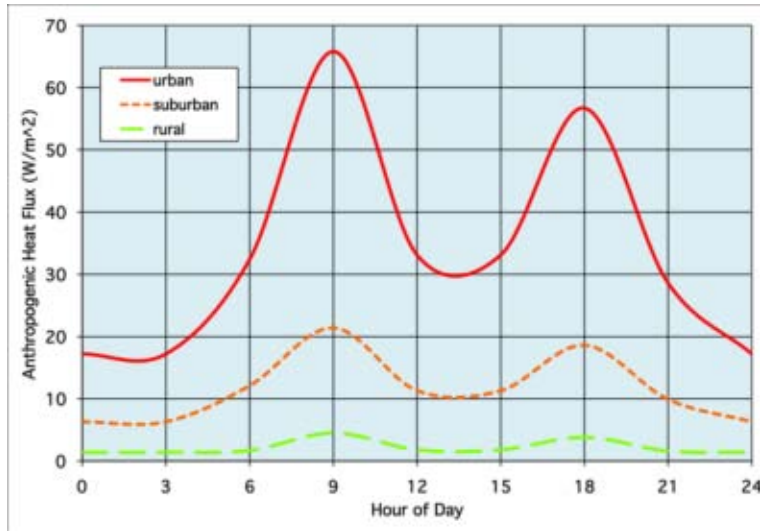
# Heat Island Causes

- Increased heat storage
  - Traditional building material properties
    - solar reflectance & thermal emittance
    - measure of the ability to reflect & radiate heat



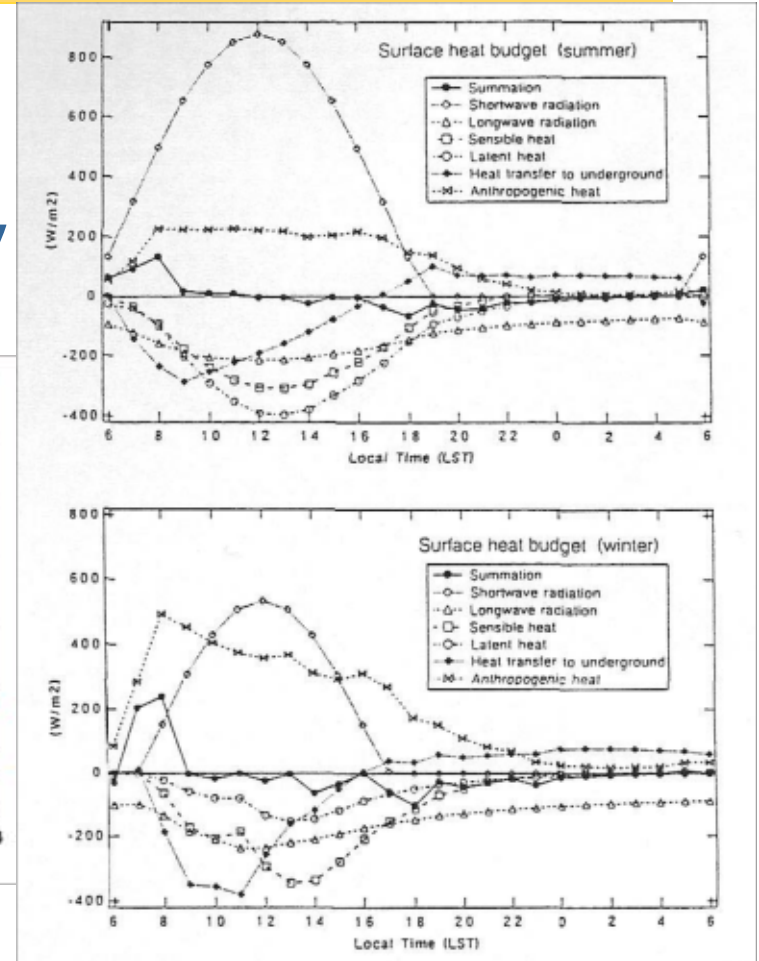
# Heat Island Causes

- Anthropogenic heat
  - Depends on density & energy intensity of city



Brisbane, Australia  
Moderate effects

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gain



Tokyo, Japan

40% - 100% of solar

# Heat Island Causes

- **Radiative changes**
  - Differences in surface radiative properties
  - Tall buildings trap solar energy
  - Air pollution filters & traps sunlight
- **Convective changes**
  - Buildings block winds in some places
  - Buildings funnel winds in other places



# Heat Island Mitigation

- Cool roofing
- Cool pavements
- Trees & vegetation
- Green roofing
- Other ideas



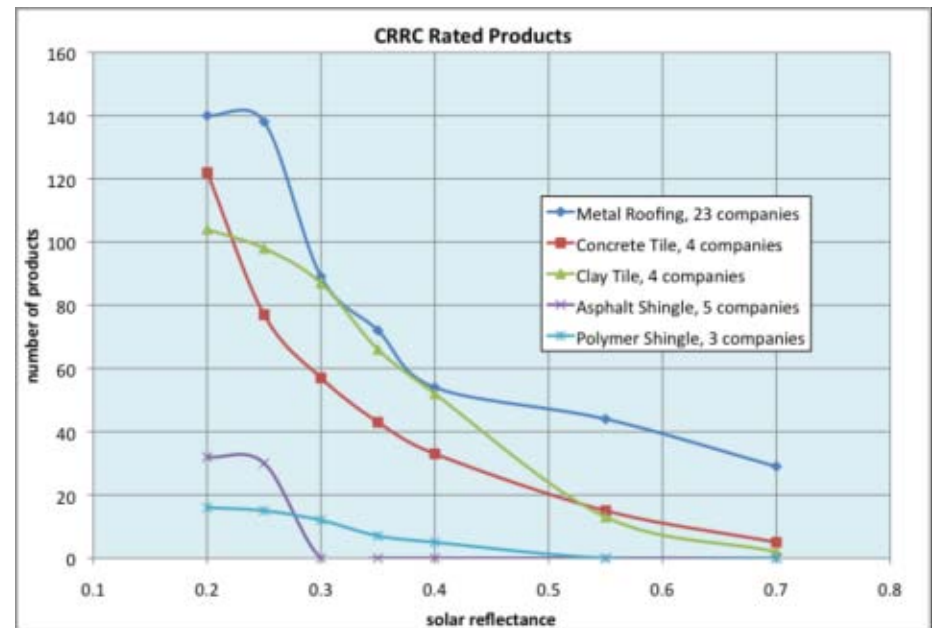
# Heat Island Mitigation

- **Low-sloped Cool Roofing**
  - Mainly non-residential products
  - Thousands of cool coatings, single-ply available
  - Bright white & non-white products available
  - Building energy code requirements are working
  - Standards exist for new buildings & **re-roofing**



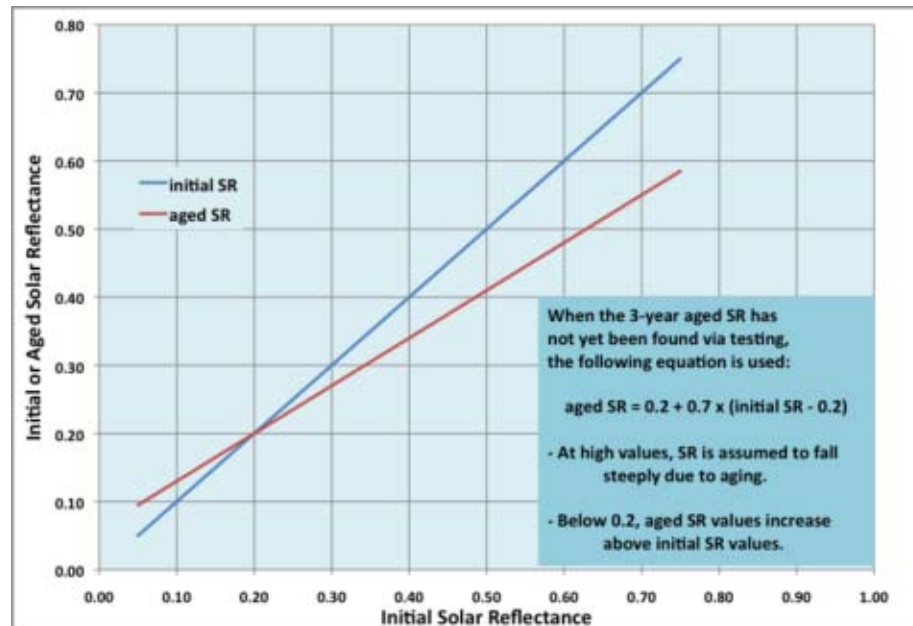
# Heat Island Mitigation

- **Steep-sloped Cool Roofing**
  - Mainly residential products
  - Lots of cool colored metal & tile roof products
  - Shingle market continues to lag behind
    - CAN produce materials with 35% SR – but they don't



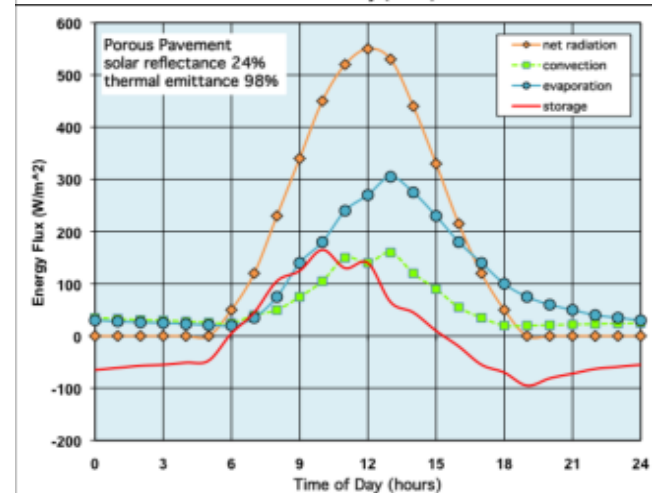
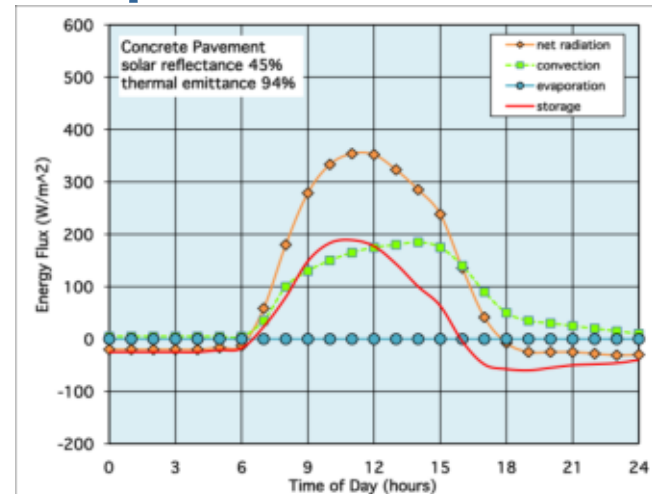
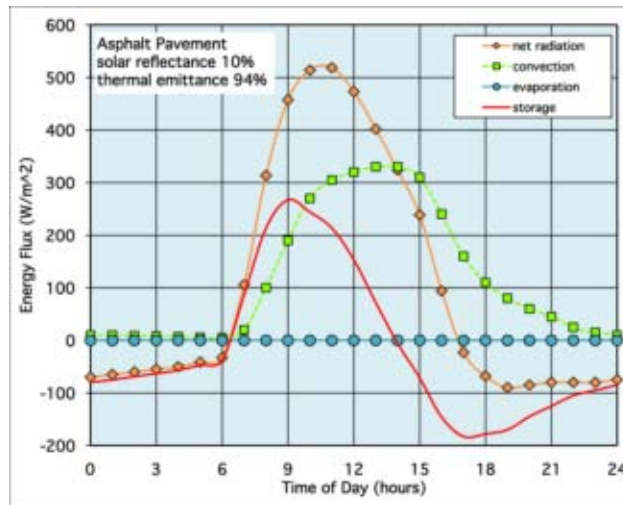
# Heat Island Mitigation

- **Steep-sloped Cool Roofing**
  - CA Title 24 code process is discouraging
    - Initial standards are quite low – 15% or 20% aged SR
    - Standards don't quite make sense
    - Meaningful updates will probably be slow in coming



# Heat Island Mitigation

- Cool Paving
  - Lighter-colored or porous pavements
  - Energy balances



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# Heat Island Mitigation

- **Cool Paving**
  - LEED program includes credits for:
    - Stormwater control using pervious paving
    - Heat island reduction using paving with SRI of 29 or higher, or that is at least 50% pervious
  - But there are no standard pavement rating systems for radiative properties or permeability



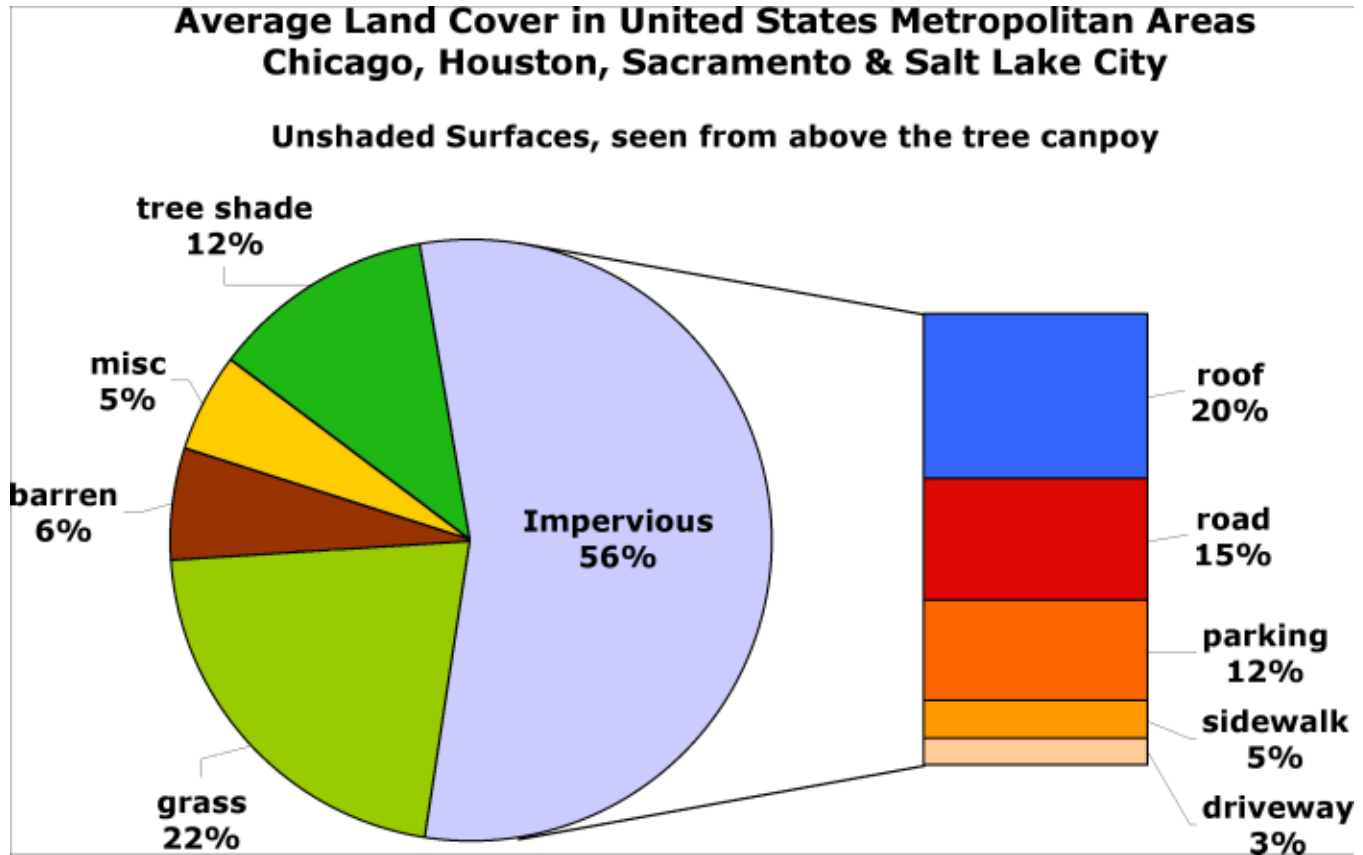
# Heat Island Mitigation

- **Cool Paving**
  - **Minimize pavement** – narrower streets, smaller parking lots keep things cooler and save money over the long term
  - **Evaluate ordinances** - are pavements required to be impermeable?
  - **Demonstration projects** - alternative pavements in schoolyards, parking lots, alleys, fire lanes, bike lanes, streets, sidewalks...



# Heat Island Mitigation

- Trees & Vegetation



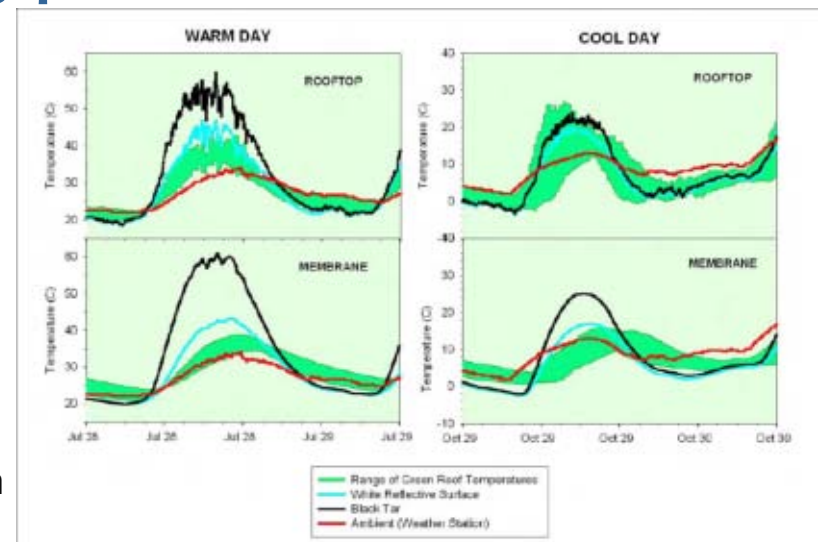
# Heat Island Mitigation

- **Trees & Vegetation**
  - Numerous opportunities
    - Trees along streets, in parking lots, around homes
    - Trees in parks & playgrounds
    - Grass & grass pavers in fire lanes, parking lots
    - Vines where trees won't fit
    - Landscaping for beautification everywhere
  - Use i-Tree
    - Finds the aesthetic & environmental value of a community's trees
    - Estimates maintenance costs of landscaping



# Heat Island Mitigation

- **Green Roofing**
  - Reliability confirmed
  - Proven stormwater retention benefits
  - Summertime energy savings confirmed
  - Pollution reduction benefits are mixed
    - Removes air pollution, but can add fertilizers
  - Wet weather energy performance?



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# Heat Island Mitigation

- **Other Ideas**
  - **Create wind paths & green corridors**
    - Orient buildings to catch the wind, remove blockages
    - Add strips of vegetated urban parks
  - **Uchimizu - sprinkling water on the ground**
    - Promoted by the Tokyo water department



- **Return to heat sensitive building design**
  - Courtyards, atria, clerestory windows, porches, operable windows, overhangs, landscaping



# Mitigation Programs that Work

- **Demonstration Projects – Chicago**
  - Chicago City Hall's green roof
  - Green roof testing
  - Permeable paved alleys
  - Used these projects to develop longer term implementation programs



# Mitigation Programs that Work

- **Building Energy Codes – State of California**
  - **2001 Title 24**
    - Defined cool roofing & CRRC as the testing agency
    - Gives energy credit for use of cool roofing
  - **2005 Title 24**
    - Expanded the cool roofing definition
    - Made cool roofing the non-residential standard
    - Required cool roofing when re-roofing
  - **2008 Title 24**
    - Redefines cool roofing based on aged values
    - Adds residential cool roofing standards
  - **Spurred the development & testing of thousands of cool roof products**
  - **2011 Title 24 now under development...**



# Mitigation Programs that Work

- **Cool Roofing Installations - Philadelphia**
  - Energy Coordinating Agency (non-profit) & Greenworks Philadelphia (city agency)
  - Installs cool roofing on Philly's row houses
    - Part of their standard weatherization offerings
    - Free service for 2,000 low-income residents a year
    - Fee service for others
  - “Coolest Block” contests
  - Persistent, long-term project



**Coolest  
Block Contest**

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# Mitigation Programs that Work

- **Tree Planting Programs - Sacramento**
  - **Sacramento Tree Foundation & Sacramento Municipal Utility District**
    - Sacramento Shade
    - Neighborwoods
    - Mature Trees Management
    - LEAF community education
  - **Link between trees & energy use**



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# Mitigation Programs that Work

- **Heat-Health Alert System - Toronto**
  - Program to combat heat wave mortality
  - Combines:
    - Meteorological prediction model
    - Public information campaign
    - Cool shelters
    - Bottled water distribution
    - Helpline & checks on seniors
  - Great collaboration between science & social services

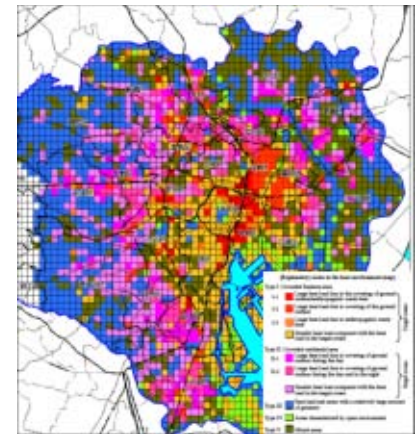


# Mitigation Programs that Work

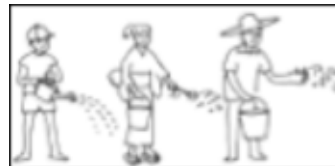
- **Urban Planning - Tokyo**

- **Created a heat environment map & guidelines**

- Greening of premises, walls, rooftops
    - Increased reflectance of rooftops
    - Water-retentive pavement
    - Reduction in building waste heat



- **Uchimizu**



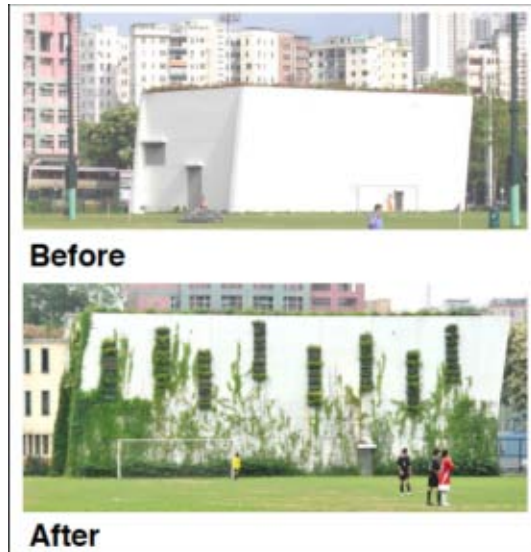
- **Other ideas**

- Creating wind paths, underground water pipes to remove heat, green space network, energy efficiency
  - **Both small & large scale ideas being incorporated to address a big problem**



# Mitigation Programs that Work

- Greening Projects – Hong Kong
  - Greening Master Plans
  - Green Roofs
  - Vertical Greening
  - Huge number of projects!



# Mitigation Programs that Work

- **Use proven technologies**
  - Cool roofing, concrete & permeable paving, shade trees, green roofing...
- **Combine technology and sociology**
  - Ultimately need to change construction practices and societal behavior
  - Creating whole new industries
- **Find persistent sources of funding**
  - Tap into specific community values
  - Ready to respond to a crisis



# Mitigation Programs that Work

- **Benefit many sectors of society via:**
  - Health improvements
  - Energy & money savings
  - Air quality improvements
- **Create more beautiful & livable cities**



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**Thank you!**

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