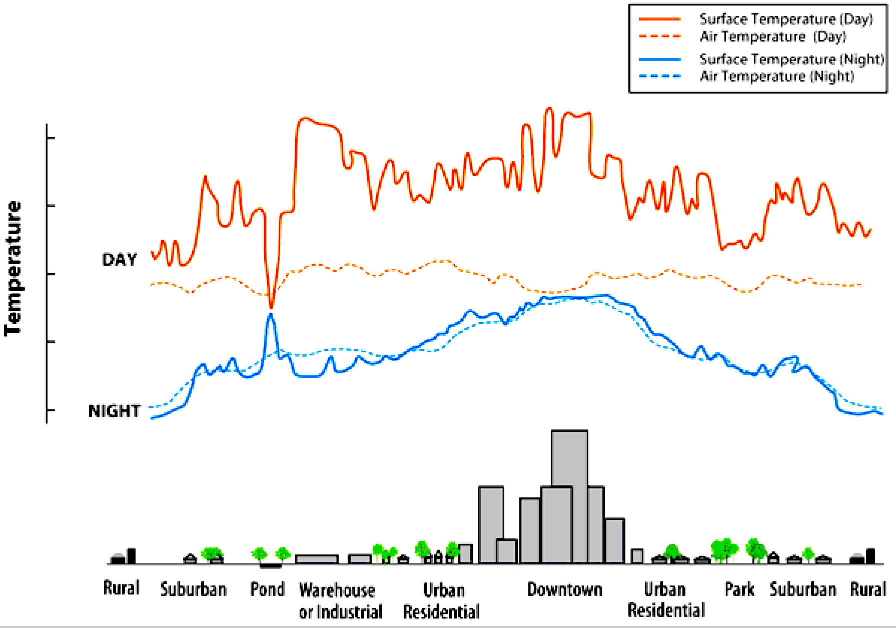
Urban Heat Islands

Basic Description, Impacts, and Issues

2009

What are urban heat islands?

- Areas in and around cities are generally warmer than comparable rural areas.
  - Urban development reduces vegetative cover and adds heat absorbing surfaces such as rooftops, buildings, and paving.
  - Heat is also added from other sources in cities such as fuel combustion and air conditioning units.
- The result is an urban heat island.



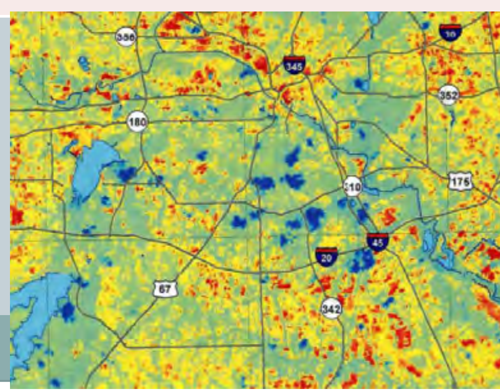
Source: Urban Heat Island Basics, 2008, Reducing Urban Heat Islands: Compendium of Strategies, U.S. EPA, p. 4.

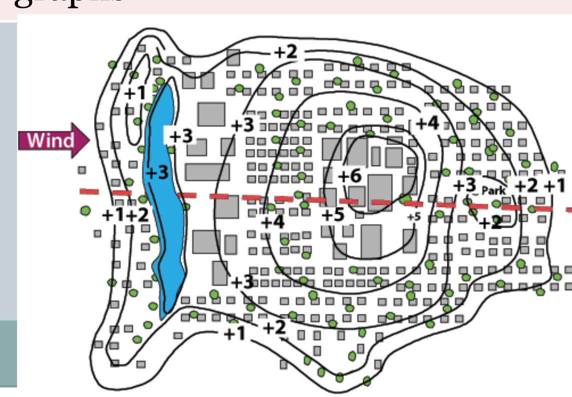
Types of Urban Heat Islands

- Three types: surface, canopy, and boundary layer
- Surface heat islands
  - Higher *surface* temperatures in urban areas compared with rural areas, illustrated with thermal images
- Atmospheric heat islands
  - Warmer *air* in urban areas compared with rural areas, illustrated with isotherm maps or graphs
    - *Canopy layer* heat islands are present in the air layer where we live – from ground level to the tops of trees or buildings
    - *Boundary layer* heat islands are in the area above rooftops and trees extending upwards as much as one mile.

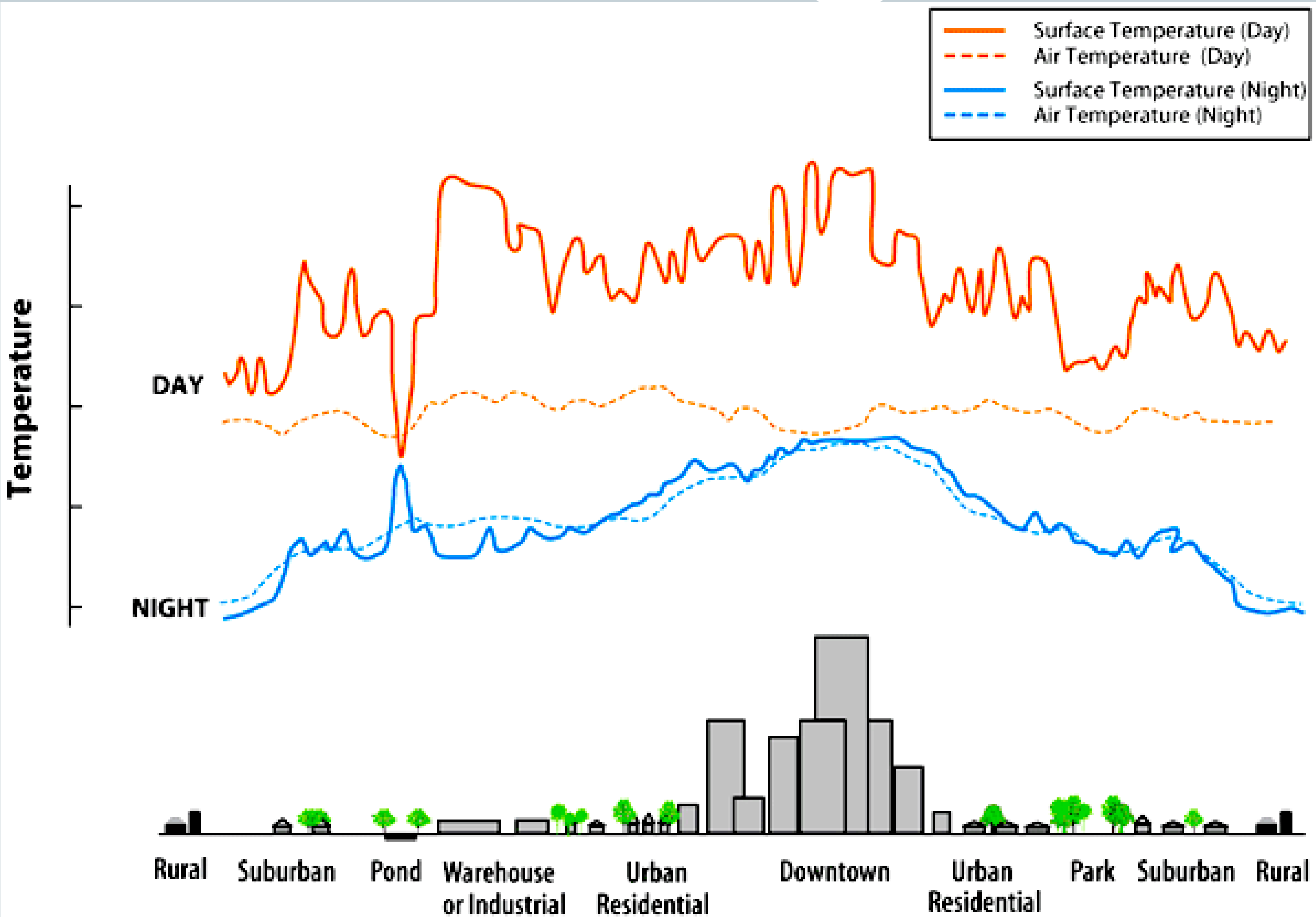
Surface and Atmospheric Heat Islands

Feature	Surface UHI	Atmospheric UHI
Timing	• Present all times day or night • Most intense during daytime and summers	• Small or absent during day • Most intense at night or just before dawn and in winter
Peak Intensity	More spatial and temporal variation • Day: 18 to 27°F • Night: 9 to 18°F	Less variation • Day: -1.8 to 5.4°F • Night: 12.6 to 21.6°F
Typical Method for Identification	Indirect measurements using remote sensing	Direct measurements with weather stations or mobile measurements
Typical Illustration	Thermal image	Isotherm maps & temperature graphs





Surface and Air Temperatures



Day Temperatures

- Day *surface temperatures* vary widely by surface type.
- Day *air temperatures* vary much less.

Night Temperatures

- Night *surface temperatures* are hotter over urban surfaces.
- Night *air temperatures* follow the same pattern as surface temperatures.

Source: Urban Heat Island Basics, 2008, Reducing Urban Heat Islands: Compendium of Strategies, U.S. EPA, p. 4.

How do heat islands form?

- Primary Drivers
  - Vegetation
    - Shade
    - Moisture
  - Urban surfaces
    - Thermal properties
    - Land cover
  - Urban geometry
    - Dimensions and shape of buildings

Trees in newer (left) and older (right) residential areas

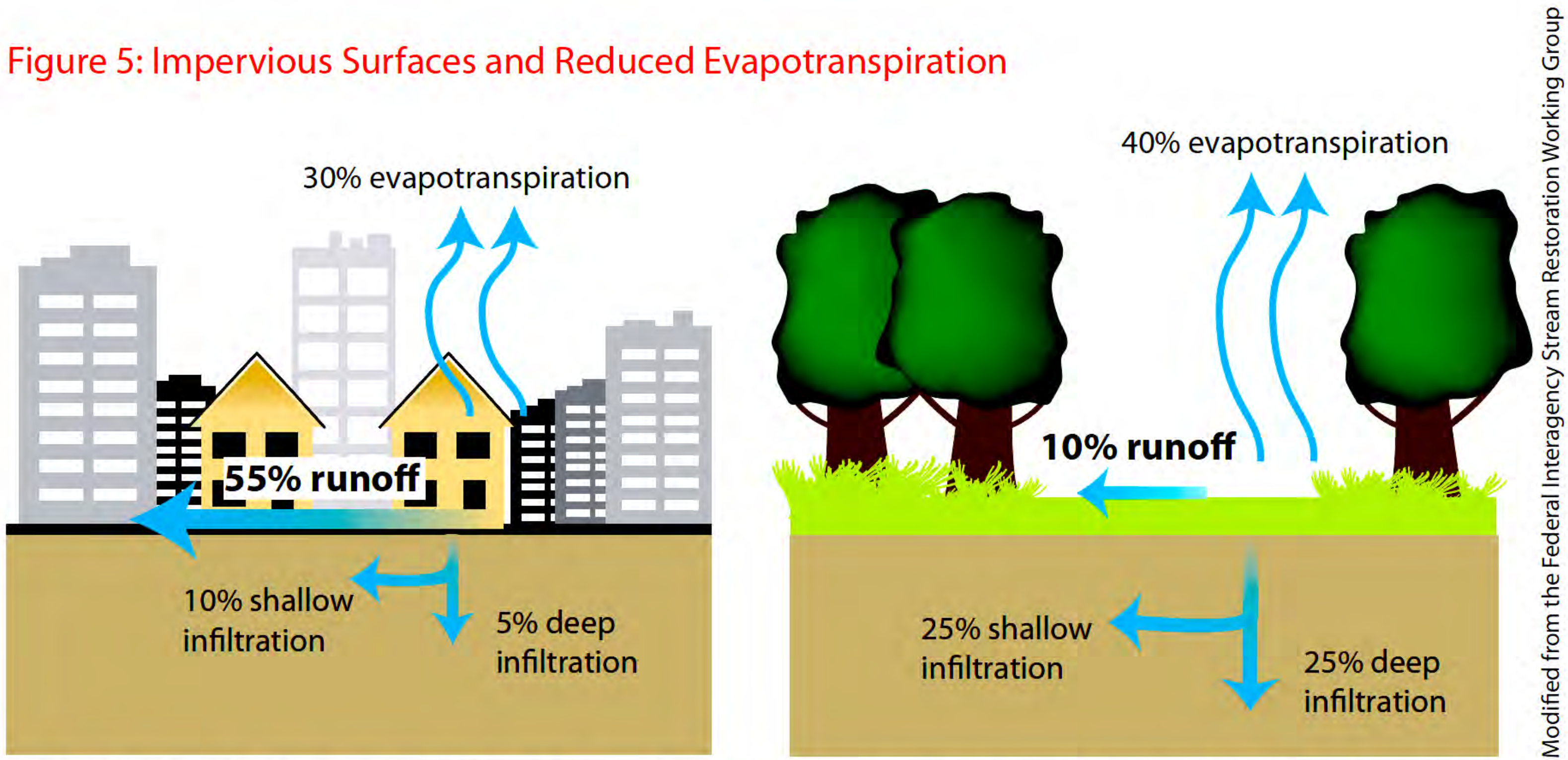
Extensive roof and paving surfaces in retail development

Vegetation and Heat Islands

- Trees and vegetation provide shade which helps lower surface temperatures.
- They also release water to the air (evapotranspiration), which helps cool the area.
- Urban areas have more dry, unshaded surfaces (paving and rooftops), which evaporate less water.

Surfaces Impact on Heat and Runoff

Figure 5: Impervious Surfaces and Reduced Evapotranspiration



Highly developed urban areas (left), which are characterized by 75%-100% impervious surfaces, have less surface moisture available for evapotranspiration than natural ground cover, which has less than 10% impervious cover (right). This characteristic contributes to higher surface and air temperatures in urban areas.

Source: Urban Heat Island Basics, 2008, Reducing Urban Heat Islands: Compendium of Strategies, U.S. EPA, p. 7.

Urban Surfaces

- Properties of urban materials
  - *Reflectivity* is a material's ability to reflect solar radiation; also called albedo
  - *Thermal emittance* is a material's ability to release heat; also called emissivity
  - *Heat capacity* is a material's ability to store heat
- Extent of Urban Coverage
  - Trees/vegetation: 20 to 43%
  - Roofs: 20 to 25%
  - Paving: 30 to 45%
  - Barren soil/other: 6% to 8%

Reflective roof in Dallas retail center

Intensive coverage with rooftops and paving in Dallas warehousing area

Urban Geometry

- Dimensions and spacing of buildings affect urban temperatures, affecting:
  - Wind flow
  - Energy absorption
  - Solar radiation back into space

Downtown high rise buildings in Dallas shade surfaces during the day, helping to cool the area, but at night, windflow is reduced and energy absorbed during the day is released.

Why do we care?

- Higher urban temperatures mean:
  - Greater amounts of energy use during the summer
  - Increased air pollution and greenhouse gas emissions
  - Negative effects of higher temperatures on human health and comfort
  - Warmer stormwater runoff affecting water quality

Energy Use

- Peak electricity demand increases 1.5 to 2% for every 1°F increase in summer temperatures.
  - Higher temperatures result in higher electricity bills.
  - For large cities, this higher demand is 5 to 10% higher to offset heat island effects.
- Peak load use of electricity is higher, placing pressure on the power grid and greater demand for additional power plants.

Air Quality

- Higher electric power demand increases emissions from power plants, including increased carbon dioxide emissions.
- Higher temperatures enhance urban ozone formation.
- Higher temperatures increase evaporative emissions, adding volatile organic compounds (VOCs) to the air.

Human Health and Comfort

- Higher daytime and nighttime temperatures affect human health, including general discomfort, respiratory difficulties, heat cramps, heat strokes, and heat related mortality.
- Urban heat islands make extended heat waves more damaging, particularly to sensitive populations such as children and older adults.

Water Quality

- High surface temperatures transfer excess heat to stormwater runoff into streams, rivers, and lakes.
- Temperature increases can be as high as 8°F in 40 minutes of a heavy summer rain.
- This *thermal pollution* impacts water quality by damaging aquatic life in the affected waterways.

How to Reduce Heat Island Impacts

- Three fundamental methods:

1. Trees
   - Protection and additional planting trees and vegetation
   - Use of shade trees for energy benefits
2. Reflective Surfaces
   - Increased solar reflectivity of urban surfaces
     - Cool roofs
     - More reflective paving materials
3. Water Related Effects
   - Increased evaporative capabilities of urban surfaces, which also benefit stormwater runoff and water quality
     - Green roofs
     - Porous paving

1.0 Trees

USDA Center for Urban Forest Research

Planting more trees

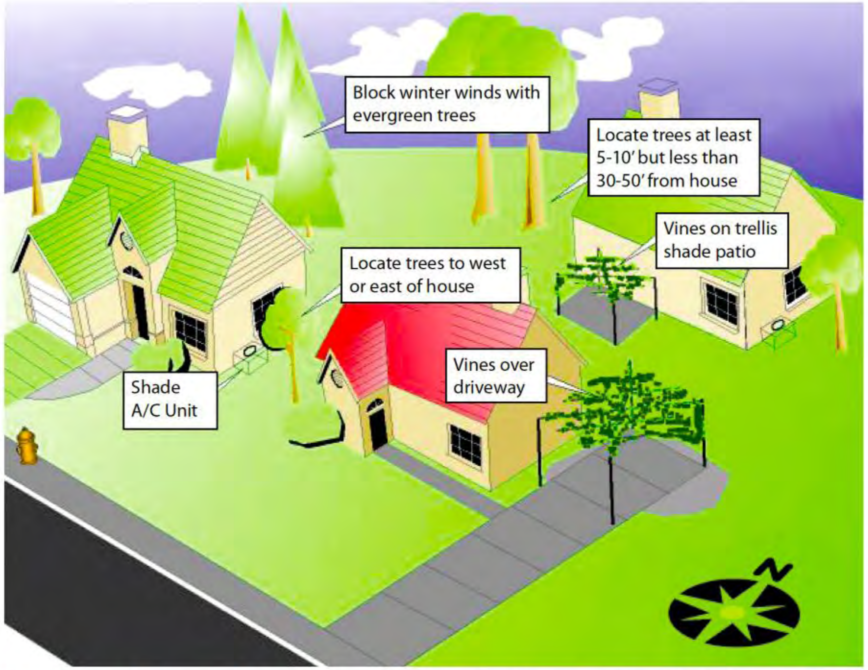
- Trees have a cooling effect because of shade and the moisture transpired through leaf surfaces.
- Trees decline in numbers primarily through urban development, but equivalent amounts of trees are not replaced.
- Tree maintenance and protection
  - Conservation and maintenance of existing trees are essential to avoid increased heat island effects over time.
- Tree planting
  - Tree planting during development and redevelopment is critical to achieving a viable urban tree population.
  - On-going public and private sector initiatives are needed, with active encouragement of planting by homeowners and property owners.

Maintaining and protecting the existing urban tree population is essential for urban heat island mitigation.

1.1 Shade Trees

- Trees located in the right spots to shade homes reduce energy costs and increase property values.
- Street trees and trees in parking areas help reduce temperatures and contribute to the quality of life in cities.

Trees planted in the right locations will more than pay for themselves in reduced energy costs, providing increasing benefits as the tree grows and matures.



Picking the right trees and putting them in the right location will maximize their ability to shade buildings and block winds throughout the year.

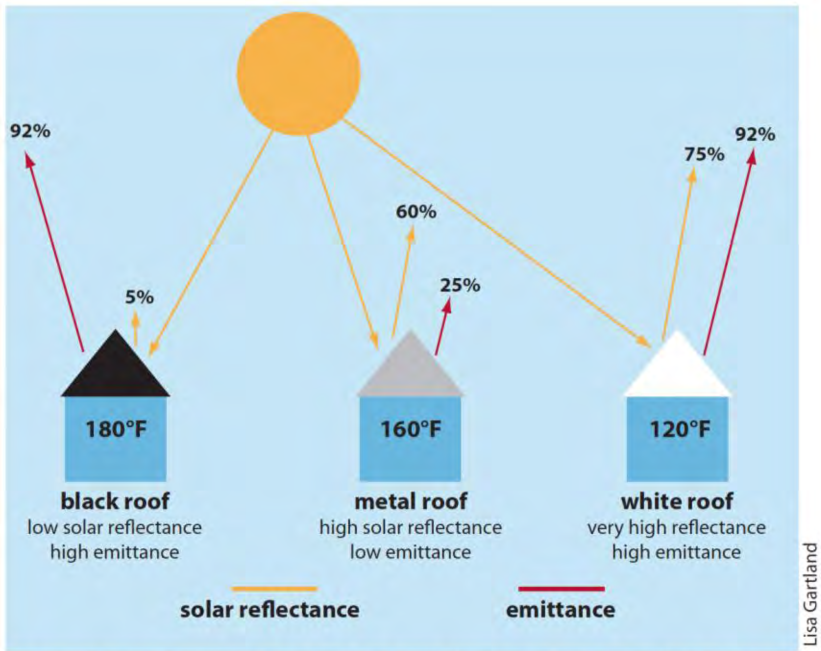
Source: Trees and Vegetation, 2008, Reducing Urban Heat Islands: Compendium of Strategies, U.S. EPA, p. 4.

2.0 Reflective Surfaces

- Rooftops and pavement comprise most of the surface area covered by urban development.
- More reflective materials are available for many roofing and paving applications.
  - 2.1 Cool roofing
  - 2.2 Cool paving

2.1 Cool Roofing

- Rooftops comprise 20 to 25% of developed urban areas.
- Surface temperatures of reflective roofs are much cooler, reducing heat island effects.
- A wide range of rated cool roofing products are available that are cost-effective measures for heat island mitigation.
  - http://www.energystar.gov
  - http://www.coolroofs.org



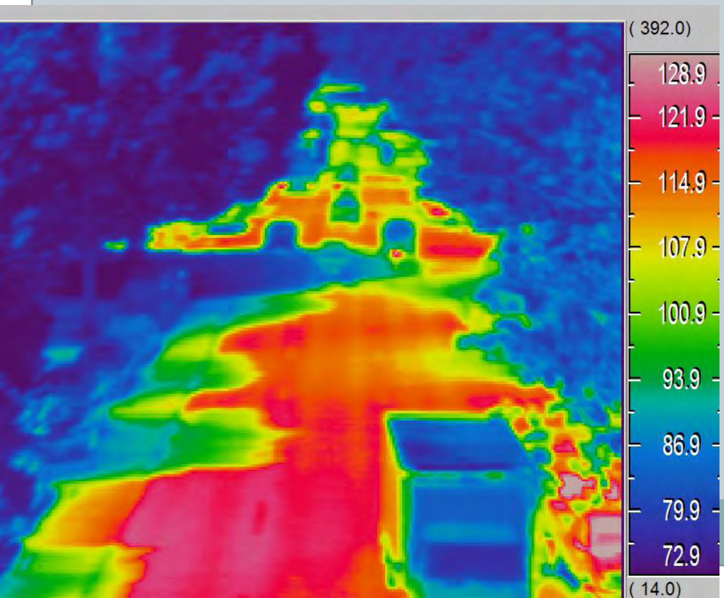
On a hot, sunny, summer day, a black roof that reflects 5 percent of the sun's energy and emits more than 90 percent of the heat it absorbs can reach 180°F (82°C). A metal roof will reflect the majority of the sun's energy while releasing about a fourth of the heat that it absorbs and can warm to 160°F (71°C). A cool roof will reflect and emit the majority of the sun's energy and reach a peak temperature of 120°F (49°C).

Source: Cool Roofs, 2008, Reducing Urban Heat Islands: Compendium of Strategies, U.S. EPA, p. 4.

Examples of cool roofing in Dallas on retail center (left) and school (right)

2.2 Cool Paving

- Paved surfaces can be the largest portion of urban land cover, amounting to 30 to 45% of developed areas.
- Pavement stores heat during the day and releases it at night.
- Surface temperatures do not reach temperatures as hot as rooftops.
- More reflective pavements are available, but not yet widely used.
- Porous/pervious paving is also part of urban heat island mitigation.



This street photo shows that darker, paved surfaces can be 30 to 50°F higher than shaded surfaces.

Photo from Dr. David Sailor, Portland State University

3.0 Water Effects of Urban Surfaces

- **Water evaporation from urban surfaces can also moderate temperatures.**
  - Evaporation from *green roofs* releases moisture into the air, unlike hard surface rooftops.
  - *Porous paving* allows moisture to stay near the surface and cool by evaporation, while storing less heat than conventional paving.

A green roof uses an engineered roofing system to allow plant growth on a rooftop.

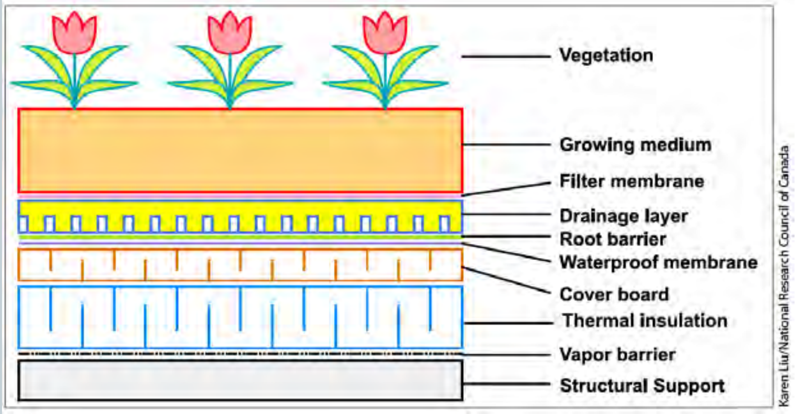
On a typical day, the Chicago City Hall green roof measures almost 80°F (40°C) cooler than the neighboring conventional roof.

Many types of porous paving products are available, including this grass surface application on a sports arena parking lot.

This 300,000-square-foot (28,000 m²) parking lot outside a stadium in Houston uses plastic grid pavers that allow grass to grow in the open spaces.

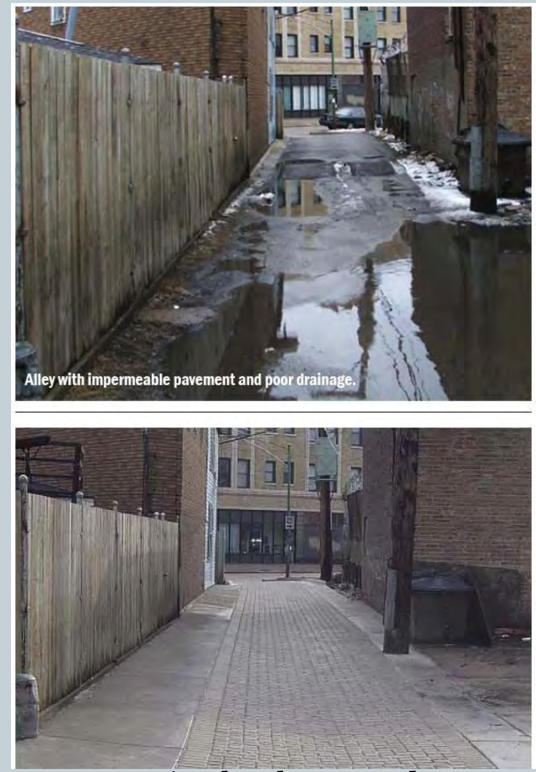
3.1 Green Roofs

- Green roofs place vegetation on a roof assembly that includes a drainage system with a growing medium for plants.
- Green roofs cool by (1) shading the roof surface and (2) through moisture evaporation from soils and plants.
- These roofs may be *extensive* systems, which are installed with a thin planting soil (4 to 6 inches), or *intensive* systems, with deeper soils and larger plants.

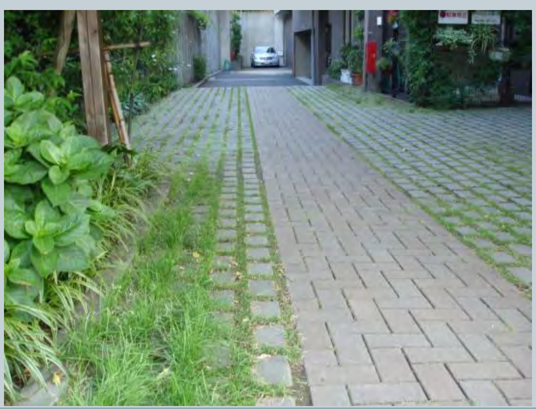


3.2 Porous Paving

- There are many types of porous or pervious paving, including pervious concrete and porous asphalt.
- These pavements cool by evaporation of water in the pavement, convective airflow, and reduced thermal storage.
- They are primarily used for non-road surfaces, although they are capable of higher traffic loads.
- Stormwater management and design features are key attributes for considering porous paving.



Porous paving has been used to replace conventional paving for improved stormwater management.



Porous paver driveway

Porous paving highway in Japan

Conclusions

- Urban heat islands occur due to the ways cities are built, as well as an area's climatic conditions.
- The effects are wide ranging, from higher energy costs to impacts on the quality of life.
- Reducing heat island effects requires substantial changes to urban surfaces, including the amount and type of tree cover, roofing, and paved surfaces.

For More Information

- EPA Urban Heat Island
  - http://www.epa.gov/heatisland
- EPA Compendium of UHI Reports
  - http://www.epa.gov/heatisland/resources/compendium.htm
- EPA ENERGY STAR Cool Roofs
  - http://www.energystar.gov/index.cfm?c=roof_prods.pr_roof_products
- Cool Roof Rating Council
  - http://www.coolroofs.org/index.html
- SMART Innovations for Urban Climate and Energy, EPA Center of Excellence
  - http://www.asusmart.org/

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