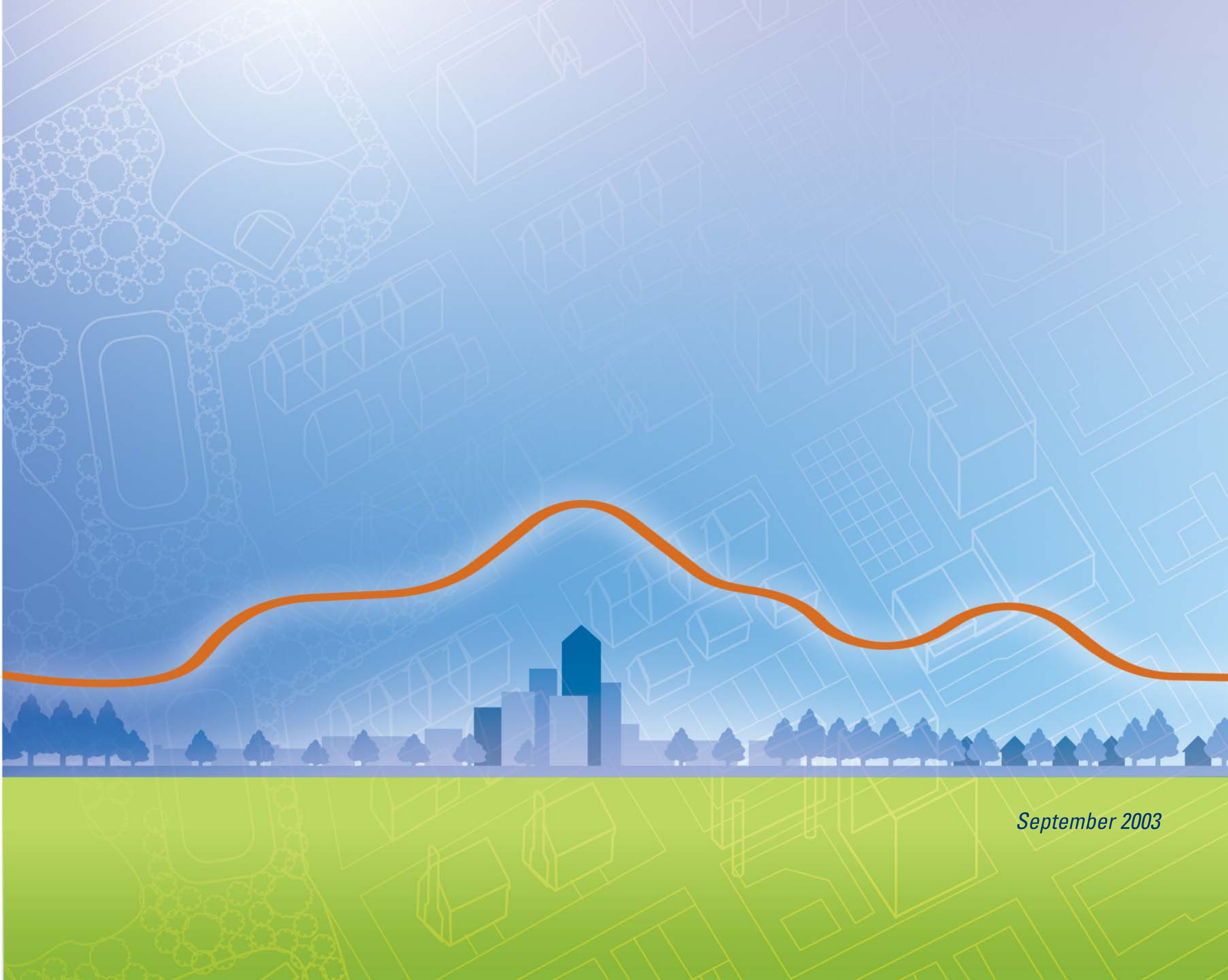
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Cooling Summertime Temperatures

Strategies to Reduce Urban Heat Islands



September 2003

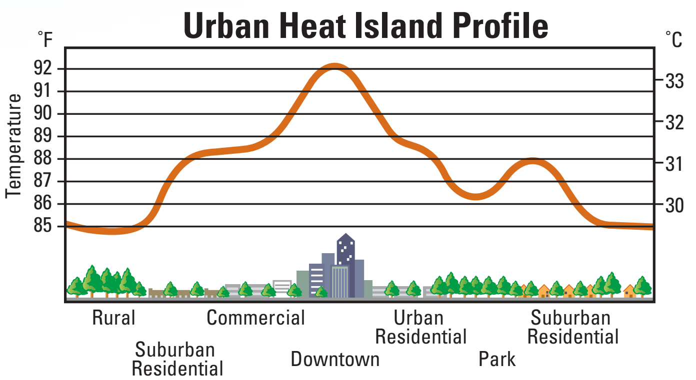
For millions of Americans living in and around cities, elevated summertime temperatures are of growing concern. Commonly referred to as urban heat islands, this phenomenon can impact communities by increasing peak energy demand, air conditioning costs, air pollution levels, and heat-related illness and mortality.

Fortunately, there are common-sense measures that communities can take to reduce the negative effects of heat islands.

What Is a Heat Island?

Heat islands are characterized by urban air and surface temperatures that are higher than nearby rural areas. Many U.S. cities and suburbs have air temperatures up to 10˚ F (5.6˚ C) warmer than surrounding natural land cover.

The heat island sketch below shows a city's heat island profile. It demonstrates how temperatures typically rise from the urban-rural border, and that the warmest temperatures are in dense downtown areas.



Heat islands are often largest over dense development but may be broken up by vegetated sections within an urban area.

What Causes Heat Islands?

Heat islands form as cities replace natural land cover with pavement, buildings, and other infrastructure. These changes contribute to higher urban temperatures in the following ways:

- Displacing trees and vegetation minimizes the natural cooling effects of shading and evaporation of water from soil and leaves (evapotranspiration).
- Tall buildings and narrow streets can heat air that is trapped between them and reduce wind flow.
- Waste heat from vehicles, factories, and air conditioners may add warmth to the air, further increasing temperatures.

Heat islands are also influenced by a city's geography and prevailing weather conditions. For example, strong winds and rain can flush out hot, stagnant air from city centers, while sunny, windless conditions can exacerbate heat islands.

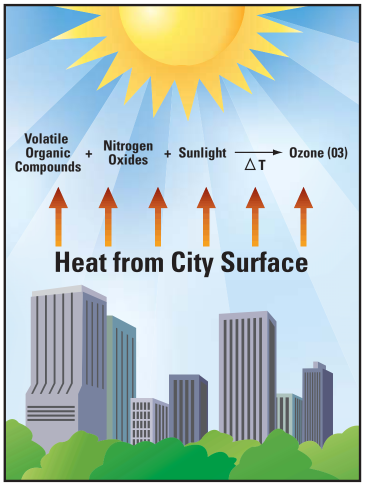
When Do Heat Islands Form?

Heat islands can occur year-round during the day or night. Urban-rural temperature differences are often largest during calm, clear evenings. This is because rural areas cool off faster at night than cities, which retain much of the heat stored in roads, buildings, and other structures.

How Do Heat Islands Affect Us?

Increased urban temperatures can affect public health, the environment, and the amount of energy that consumers use for summertime cooling.

Public Health: Heat islands can amplify extreme hot weather events, which can cause heat stroke and may lead to physiological disruption, organ damage, and even death – especially in vulnerable populations such as the elderly.



Ozone forms when precursor compounds react in the presence of sunlight and high temperatures.

The Environment: Summertime heat islands increase energy demand for air conditioning, raising power plant emissions of harmful pollutants. Higher temperatures also accelerate the chemical reaction that produces ground-level ozone, or smog. This threatens public health, the environment, and, for some communities, may have implications for federal air quality goals.

Energy Use: Because homes and buildings absorb the sun's energy, heat islands can increase the demand for summertime cooling, raising energy expenditures. For every 1° F (0.6° C) increase in summertime temperature, peak utility loads in medium and large cities increase by an estimated 1.5 – 2.0 percent.

Cities in cold climates may actually benefit from the wintertime warming effect of heat islands. Warmer temperatures can reduce heating energy needs and may help melt ice and snow on roads.

In the summertime, however, the same city may experience the negative effects of heat islands.

Cool Roofs in Action

The Energy Coordinating Agency (ECA) in Philadelphia initiated the Cool Homes Program to help elderly residents escape extreme summertime heat. ECA installs cool roofs and uses other measures to reduce indoor temperatures to promote comfort and minimize health risks. As of April 2003, the Cool Homes Program had installed over 450 roofs.

Both types of green roofs can be used on residences, industrial facilities, offices, and other commercial property. Green roofs are widespread in Europe and Asia, and are becoming more common in the United States.

Cool Pavement

High-albedo pervious pavement supports light traffic while mitigating the heat island effect and allowing stormwater to pass through.

Pavements with low solar reflectance absorb large amounts of heat and can be up to 70° F (40° C) hotter in the sun than cooler alternatives.

Portland cement concrete and asphalt concrete – commonly called "concrete" and "asphalt," respectively – are the most common paving materials for sidewalks and streets. Most new concrete has a solar reflectance, or albedo, of 35-40 percent; the solar reflectance of fresh asphalt is typically 5-10 percent.

Over time, the albedo of these pavements change. Concrete darkens from the build-up of tire residue, dirt, and oil, and asphalt lightens as the asphalt binder wears away to expose the underlying rock aggregate.

To maximize the albedo of both types of pavement, lighter-colored aggregate can be used in the pavement mix. Alternatively, asphalt pavements can be covered with high-albedo sealcoats, small rocks set in binder, or a thin layer of concrete. For concrete applications, using lighter-colored sand and cement can increase reflectivity.

Permeable, or porous, pavements allow water to percolate and evaporate, cooling the pavement surface and surrounding air. Permeable pavements can be constructed from a number of materials including concrete, asphalt, and plastic lattice structures filled with soil, gravel, and grass.

Although there is no official standard or labeling program to designate cool paving materials, communities interested in reducing the heat island effect may consider surface reflectivity and permeability – along with other costs and benefits – when selecting a paving product.

The Difference between Heat Islands and Global Warming

Heat islands describe local-scale temperature differences between urban and rural areas. In contrast, global warming refers to the gradual rise of worldwide average surface temperatures.

What is EPA Doing to Reduce Heat Islands?

Through its Heat Island Reduction Initiative (HIRI), EPA works with community groups, public officials, industry representatives, researchers, and other stakeholders to identify opportunities to implement heat island reduction strategies and evaluate their impacts on energy demand, local meteorology, air quality, health, and other factors.

For More Information

EPA's Heat Island Reduction Initiative
www.epa.gov/heatisland

EPA Global Warming Information
www.epa.gov/globalwarming

ENERGY STAR Qualified Cool Roof Products
www.energystar.gov/products

The Lawrence Berkeley National Laboratory's Heat Island Group
http://heatisland.lbl.gov

International Council for Local Environmental Initiatives' Hot Cities Information
www.hotcities.org

NASA's Global Hydrology and Climate Center (GHCC)
www.ghcc.msfc.nasa.gov

Cool Roof Rating Council
www.coolroofs.org

USDA Urban and Community Forestry Program
www.fs.fed.us/ucf

Green Roofs for Healthy Cities
www.greenroofs.ca/grhcc

U.S. Green Building Council
www.usgbc.org

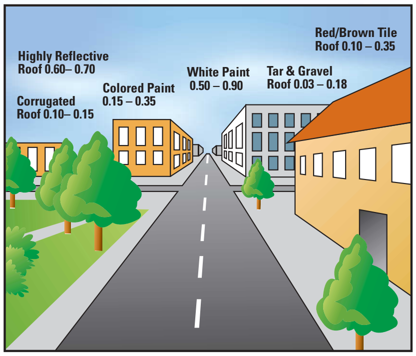
Center for Green Roof Research
http://hortweb.cas.psu.edu/research/greenroofcenter

Cool Pavement in Action

The village of Fair Oaks in Sacramento, California installed a permeable portland cement concrete parking lot at a local park. It avoids the cost of a stormwater drainage system and helps reduce the heat island effect.

What Can Communities Do to Reduce the Heat Island Effect?

Communities interested in reducing heat islands have several options. Strategies to lower urban temperatures and achieve related benefits include installing reflective **cool roofs** on residential and commercial buildings; planting **trees and vegetation**, including **green roofs**; and using **cool paving materials** for roads, sidewalks, and parking lots. Additional heat mitigation options include modifying urban design and layout, and choosing efficient heating and cooling systems.



Various urban environmental albedos.

Widespread implementation across a community can reduce urban temperatures, energy use, air pollution, and heat-related health impacts. Heat island reduction strategies also benefit individual home and building owners directly. Cool roofs and shade trees, for example, can save money on summertime cooling bills.

Cool Roofs

The term "cool roof" describes roofing materials that have a high solar reflectance. This characteristic reduces heat transfer to the indoors and can enhance roof durability. Cool roofs may also have high emittance, releasing a large percentage of the solar energy they absorb.

On a hot, sunny, summer day, traditional roofing materials can reach peak temperatures of 190˚ F (88˚ C). By comparison, cool roofs reach maximum temperatures of 120˚ F (49˚ C).

In buildings with air conditioning (AC), cool roofs can save money on energy bills, lower peak energy demand, and reduce air pollution and greenhouse gas emissions. In buildings without AC, cool roofs can increase indoor occupant comfort by lowering top-floor temperatures. In both cases, cool roofs can help reduce urban heat islands.

The Utah Olympic Oval used cool roof technology.

Types of Cool Roofs

- **Commercial (low slope):** Most cool roof applications for low-slope, primarily commercial, buildings have a smooth, bright white surface to reflect solar radiation and achieve related benefits.
- **Residential (steep slope):** Most cool roof applications for sloped, primarily residential, buildings come in various colors and may use special pigments to reflect the sun's energy.

Albedo, Solar Reflectance, and Emittance

The **albedo**, or **solar reflectance,** of a surface is the percentage of incoming solar radiation that is reflected by that surface. Albedo is measured on a scale of 0 to 1, where a value of 0 indicates that a surface absorbs all solar radiation and a value of 1 represents total reflectivity.

Light-colored surfaces typically have higher albedos than darker surfaces. While a traditional black shingle has an average albedo of 0.05, or 5 percent, the average albedo for a white roof coating is 0.75, or 75 percent.

The emittance of a material refers to its ability to release absorbed heat. Scientists use a number between 0 and 1 to express emittance. With the exception of metals, most construction materials have emittances above 0.85, or 85 percent.

EPA's ENERGY STAR® program has voluntary product specifications for both commercial and residential roofs. Low-slope roofs must have an initial solar reflectance of at least 65 percent, and steep-slope roofs must have an initial solar reflectance of 25 percent or more. Emittance is not a qualifying criterion for the ENERGY STAR label, but a high rating can further reduce energy costs.

Community-Level Benefits from Cool Roofs

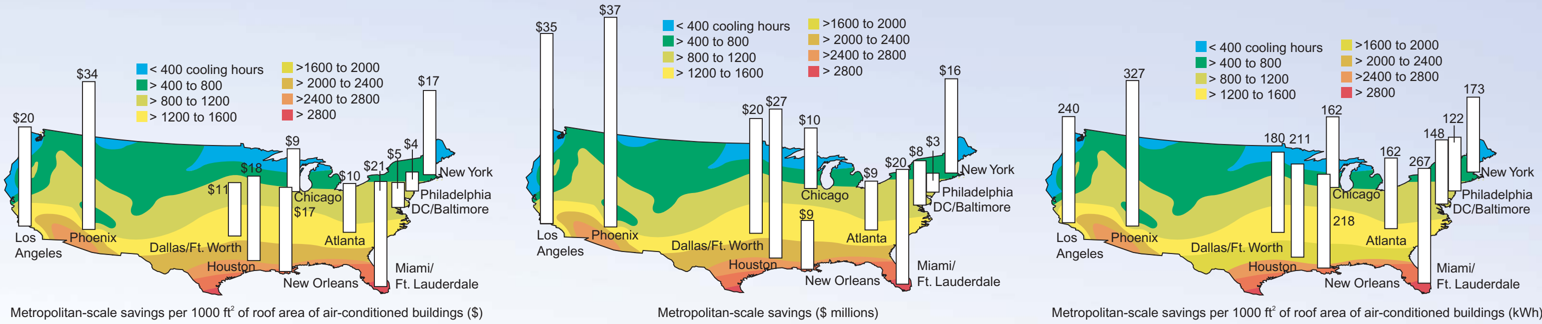
Installing cool roofs across a city can provide substantial energy savings. The figure on the next page illustrates this potential for 11 U.S. cities according to research conducted at the Department of Energy's Lawrence Berkeley National Laboratory (LBNL).

Factors Affecting Building-Level Energy Savings from a Cool Roof

- **Air conditioning**: Cool roofs can reduce summertime energy use in air-conditioned buildings. In buildings without air conditioning, cool roofs can improve comfort by reducing top-floor temperatures.
- **Local climate:** Cooling energy savings are typically greatest in areas with long, sunny, and hot summers.
- **Building height:** Cool roofs are generally most effective on one-or two-story buildings with large roof areas. They provide less energy savings for multi-story buildings with small roofs.

Trees and Vegetation in Action

The City of Austin, Texas's NeighborWoods program uses aerial photos to identify neighborhoods with insufficient tree coverage. Austin Energy, the city-owned utility, then provides residents with free saplings that will ultimately provide shade, beauty, and energy savings.

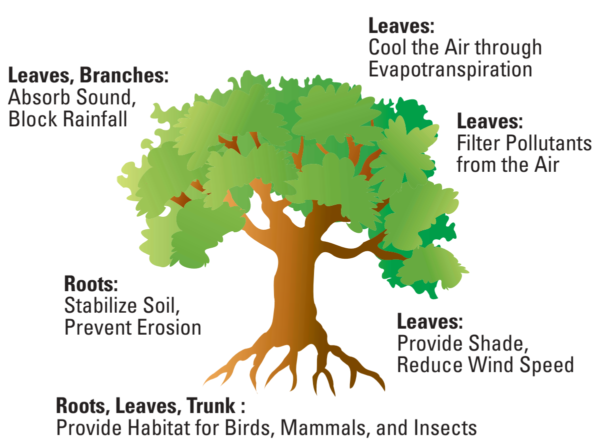


Metropolitan-scale potential savings from cool roofs in 11 U.S. cities. Results are stated in net energy savings and factor in any increased heating costs from the cool roof "wintertime penalty."

Trees and Vegetation

Increasing a city's vegetative cover by planting trees, shrubs, and vines is a simple and effective way to reduce the heat island effect. Scientists at LBNL estimate that planting trees and vegetation for shade can reduce a building's cooling energy consumption by up to 25 percent annually.

In addition to direct shading, trees and vegetation cool the air through evapotranspiration. Urban vegetation also provides economic, environmental, and social benefits such as enhanced storm water management and reduced air pollution.



Trees provide a variety of benefits, from cooling the air to stabilizing the soil.

Where to Plant

Strategically placed shade trees and vegetation block the sun's rays, minimizing heat transfer to building interiors, and reducing the need for air conditioning. In most U.S. cities, trees should shade the east, and especially west, walls to maximize cooling savings. Planting trees directly to the south may provide little shade in the summertime and block desired sun in the wintertime.

What to Plant

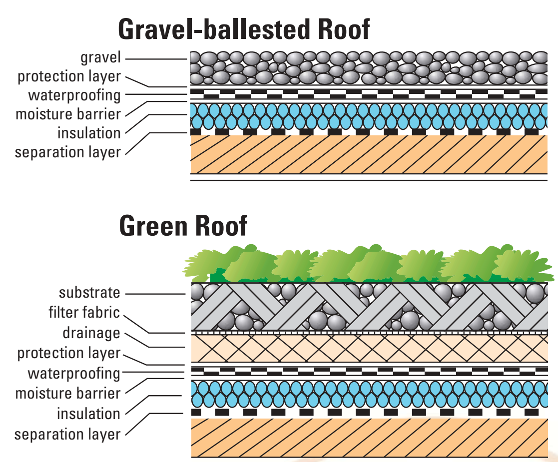
Deciduous trees work well as they balance energy requirements over the course of a year. In summer, foliage cools buildings by blocking solar radiation. In winter, after the leaves have fallen, the sun's energy passes through the trees and helps to warm buildings.

Green Roofs

Another alternative to traditional roofing materials is a rooftop garden or "green roof." Installed widely in a city, green roofs contribute to heat island reduction by replacing heat-absorbing surfaces with plants, shrubs, and small trees that cool the air through evapotranspiration. Planted rooftops remain significantly cooler than a rooftop constructed from traditional heat-absorbing materials. In addition, green roofs reduce summertime air conditioning demand by lowering heat gain to the building.

Green roofs consist of soil and vegetation planted over a waterproofing layer. They can be **intensive** or **extensive** depending on the amount of soil and plant cover, and whether the roof is accessible.

- **Intensive green roofs** require a minimum of one foot of soil. Trees and shrubs are usually planted, adding 80-150 pounds per square foot of load to the building. These roofs need complex irrigation and drainage systems, and significant maintenance. Intensive roofs are often accessible to the public.
- **Extensive green roofs** require only 1-5 inches of soil. Low lying plants and grasses are usually planted, and 12-50 pounds per square foot of load may be added. These roofs use simple irrigation and drainage systems, and require little maintenance. Extensive green roofs usually are not accessible to the public.



Green roofs remain significantly cooler than rooftops made of traditional heat-absorbing material.

Green Roofs in Action

The City of Chicago installed a 20,300 square foot green roof on its City Hall. The city expects the roof to reduce annual air conditioning costs by $4,000. Businesses such as the Gap and Ford Motor Company have also installed green roofs on their corporate headquarters buildings.

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