EPA Urban Heat Island Pilot Project
City Profile: Houston (Archived Page)

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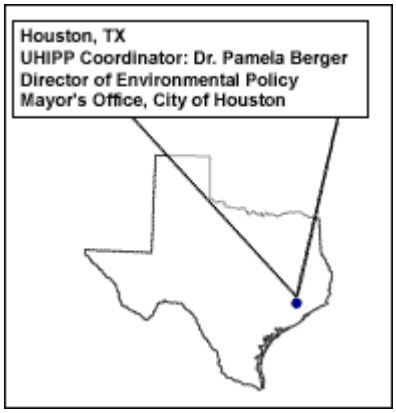
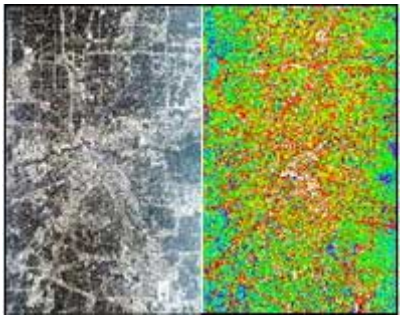


Houston is situated on the Southeast Texas Coast Plain and is located 50 miles north of the Gulf of Mexico. Houston has a population of nearly 2 million residents and is the fourth largest city in the United States. The Houston Metropolitan Statistical Area covers almost 9,000 square miles and has about 4.7 million inhabitants.

Houston's Heat Island

In August 2000, the National Aeronautics and Space Administration (NASA) took aerial photos of Houston using the Advanced Thermal and Land Applications Sensor aircraft data. These flyover photos represent a typical view of the city (left) and a thermal readout of metropolitan hot spots (right).

In the thermal image, red and white areas indicate "hot spots" and generally correspond with roads and roofs. Blue, green, and purple areas are cool and indicate water and vegetation. The temperature ranges are from approximately 149°F (65°C) for the hot spots to 77°F (35°C) for the cooler areas. (The images have not been calibrated. Absolute temperatures will change after calibration, but relative temperature differences between surface types will not.)



Aerial view of Houston (courtesy of NASA-Marshall Space Flight Center- Global Hydrology and Climate Center).

Before determining how heat island reduction strategies impact an area, researchers need to evaluate existing surface characteristics. Aerial photos are useful for estimating the proportions of vegetative, roofed, and paved surface cover relative to the total urban surface in a city. Having this urban fabric information can help researchers simulate the meteorological and air quality impacts of heat island reduction strategies.

Surface cover data also help scientists determine an area's heat island. The Department of Energy's Lawrence Berkeley

National Laboratory (LBNL) is modeling Houston's near surface heat island, which represents near ground air temperatures as opposed to surface temperatures measured by thermal images. LBNL is conducting this modeling analysis over a large area, several times larger than the city center. LBNL staff have determined that Houston's urban heat island often is around 3°F (1.7°C) but can peak at up to 6°F (3.3°C).

Houston's Climate

Houston's climate is subtropical and humid. The sun shines for most of the year, and Houston has an annual growing season of nearly 300 days. Houston receives an annual average rainfall of about 50 inches.

The average low temperature in Houston is 72°F (22°C) in the summer and 40°F (4°C) in the winter. The average high temperature is 93°F (34°C) in the summer and 61°F (16°C) in the winter. Humidity in June is typically around 93% at 6 a.m. and 63% at 6 p.m. Based on 1961-1990 National Climatic Data Center data, Houston has, on average, 2,700 cooling degree days and 1,599 heating degree days based on a reference temperature of 65°F (18°C).

Local climate data, such as cooling and heating degree days, can help researchers estimate the potential energy savings and air quality impacts of heat island reduction strategies. For example, areas with long, sunny, hot summers and high cooling degree day values generally can achieve substantial energy savings.

Information on an area's local climate also can help communities focus on heat island reduction activities that best suit their region. For example, cities with predominantly dry climates may achieve greater benefits from increasing vegetation than would cities in humid climates. Dry-climate cities more effectively capture the cooling benefits of evapotranspiration – or evaporation of water from leaves. However, dry-climate cities also need to consider the availability and cost of water to maintain vegetation.

Houston's Urban Fabric

Before implementing heat island mitigation strategies, researchers may determine the porportions of vegetative, roofed, and paved surface cover relative to the total urban surface in a city. This urban fabric analysis helps identify areas that may benefit from reflective surfaces and urban reforestation. Further, information on baseline surface characteristics can help cities determine the potential for modifications.

Vegetation

Houston is a heavily vegetated city, but ground and canopy cover diminish as one approaches the intensely developed city center. Large portions of the region are forested and tree growth is especially heavy along the extensive bayou system.

The west side of the region contains many acres of native prairie, much of which has been converted to developed space upon which trees have been planted. On the north and northeast sides of the region, the natural land cover consists of densely vegetated canopies of approximately 50%. The south side of the region is covered with a mixture of prairie, marsh, forest, and abandoned agricultural land. Loblolly pine is the tree species that dominates the region. Among the numerous native trees, there are many that are suitable for planting in a heat island reduction effort.

Roofs

Based on information generated by the Department of Energy's Lawrence Berkeley National Laboratory, total air-conditioned roofed surface area in the Houston Metropolitan Statistical Area is 1,425 million (M)ft². The use of reflective roofing on commercial buildings is growing rapidly. The most popular reason for cool roof installations has been the potential energy savings they provide. In the Woodlands, a suburb north of Houston, approximately three Mft² of commercial, low-sloped or flat, cool roofs have been installed.

The use of reflective roofing in the residential market has been less evident. However, fewer residential or sloped cool roofing products exist compared to the commercial market.

Pavement

Fans at Houston's Reliant Stadium can park their cars on a porous, grass paving structure.

State-maintained roads in Harris County, where Houston is located, total approximately 3,868 miles. Of these, approximately 1,962 have portland cement concrete (PCC) as their surface material. Asphalt concrete covers the remaining 1,906 miles. Throughout the City of Houston, PCC has typically been used for new construction of arterials, other types of major thoroughfares, on secondary streets, and in subdivisions. Asphalt has been the primary material used for the construction and resurfacing of parking lots and for general resurfacing.

Recently, over 300,000 ft² of Grasspave, a porous paving material, has been installed in the parking area at the new Reliant Stadium.

Houston's Energy Savings Analysis

Houston has a May through October cooling season. Most residential buildings are one story, while commercial buildings are low-rise. Using 1990 American Housing Survey data and 1994 Commercial Building Energy Consumption Survey information, the Department of Energy's Lawrence Berkeley National Laboratory (LBNL) determined that air conditioning saturation in the Houston Metropolitan Statistical Area (MSA) is high with a total air conditioned roof area of 1,228 million (M)ft² residential, 83 Mft² office, and 114 Mft² retail. Residences account for 86% of air-conditioned roof area in Houston.

Modeling Methodology

LBNL recently completed an analysis of the energy savings potential (direct and indirect effects) of heat island reduction measures on cooling energy use in Houston. Determining the direct energy impacts involved modeling the effects from placing eight mature deciduous shade trees around residential buildings, eight shade trees around office buildings, and four shade trees around commercial buildings to provide 10% summertime (April-October) transmittance and 90% transmittance for the remainder of the year.

In addition, determining the direct impacts involved modeling the energy savings effect from increasing solar reflectance – or albedo – on residential and commercial roofs from 0.2 to 0.5 and 0.6, respectively, and using an infrared emittance of 0.9, to calculate savings. (Emittance is the percentage of energy a material can radiate away in the form of heat.) This modeling was performed using DOE-2 building energy software, which is an advanced computer program that simulates hourly building energy use.

The indirect impacts were modeled by analyzing the ambient cooling from the placement of four or eight shade trees per building and from the reduced rooftop temperatures due to the albedo changes discussed above. LBNL captured these indirect effects by using the Colorado State Urban Meteorological Model (CSUMM). The CSUMM outputs were used to modify the typical meteorological year 2 data, which were fed into the DOE-2 building energy model.

Modeling Results

LBNL calculated the following annual results for the total Houston MSA:

- $81.8M of energy savings in 1997 dollars ($95.4M in annual electricity savings less a natural gas deficit or winter heating penalty of 14%);
- 734 megawatts of peak power avoided (62% from residential, 53% from office, and 70% from retail); and
- 170,000 tons of annual carbon emission reductions.

Houston's Air Quality

Ozone is currently Houston's main air quality problem. The Houston-Galveston area (HGA) is classified as a severe nonattainment area for this pollutant. The counties that comprise the HGA ozone nonattainment area are Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller. View a map highlighting the nonattainment area.

Modeling Methodology

Since the summer of 2001, the Department of Energy's Lawrence Berkeley National Laboratory (LBNL) has used the Mesoscale Model 5 and Comprehensive Air Quality Model with Extensions meteorological and photochemical models to study the potential impacts of heat island reduction measures in Houston on the area's meteorology and ozone air quality. LBNL's modeling domain covers approximately three million km^2, covering the entire state of Texas, surrounding states, and parts of Mexico and the Gulf of Mexico.

Modeling Results

Using a September 5 through 13, 1993 modeling period, LBNL determined that heat island reduction strategies can result in ozone decreases and increases, with the net effect, in general, being reduced ozone concentrations in the modeling domain. The direction of the results depends on several factors including the reduction scenarios modeled, model inputs, and selected metrics.

The final results are still being formulated and examined. The largest simulated air temperature changes have been on the order of up to 5°F (2.8°C). Temperature decreases result primarily from increased solar reflectance– or albedo– compared to increased vegetative cover. The higher humidity in the area tends to limit the effectiveness of evapotranspiration – or evaporation of water from leaves – from increased vegetative cover.

Houston's Heat Island Reduction Activities

EPA, EPA Region 6, the Texas Commission on Environmental Quality (TCEQ), the Department of Energy's Lawrence Berkeley National Laboratory, the Houston-Galveston Area Council and their Cool Communities Committee, the Houston Advanced Research Center (HARC), the City of Houston, and other stakeholder groups are participating in an effort to evaluate the feasibility of including heat island reduction strategies in the Houston-Galveston Area (HGA) State Implementation Plan (SIP).

Local participants have formed three working groups – trees and vegetation, cool paving, and cool roofs – to develop a Houston-appropriate heat island reduction plan. These groups are

focusing on identifying the best strategies available to reduce the effects of heat island development on ground-level ozone concentrations in the HGA.

Below are some of the projects and organizations in Houston that work on reducing heat islands.

Urban Forestry Modeling in Houston

The U.S. Department of Agriculture Forest Service developed the Urban Forest Effects (UFORE) Model as a means of quantifying urban forest structure and function. Understanding the urban forest is an important step toward properly handling and optimizing the beneficial effects of urban trees.

UFORE consists of four models that perform various functions including quantifying species composition, tree density, tree health, leaf area, leaf biomass, and hourly urban forest volatile organic compound emissions. UFORE also calculates total carbon stored and net carbon stored annually by urban trees and pollutant removal for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, and particulate matter less than 10 microns. The Forest Service currently is conducting a UFORE study of the Houston metropolitan area.

The Houston Advanced Research Center (HARC)

HARC is a nonprofit research organization focusing on the improvement of human and ecosystem well-being through research in energy, the environment, and life sciences. HARC aims to bring stakeholders together to identify workable strategies to reduce urban temperatures and improve air quality in the region. HARC currently is conducting research to determine the potential for heat island reduction in the Houston Gulf Coast Region and is coordinating the three working groups focused on developing an HGA heat island reduction plan. (See first paragraph under "Activities.")

Houston Green

Houston Green, or "The Green," was initiated to fund an American Forests Urban Ecological Analysis (UEA) for the Houston Gulf Coast Region. The coalition, which is comprised of government, business, and nonprofit organizations, determined that a regional organization was needed to act as a vehicle to: share knowledge among green organizations; advocate supporting the urban forest and its trees, vegetation, and habitats; encourage the expansion of the urban forest; and educate communities about the multiple economic, environmental, and health benefits offered by urban forests.

The UEA report was completed in December 2000 and can be found on the American Forests website. The Green is continuing to develop and put a local reforestation plan into action, and it is leading the Trees and Vegetation working group focused on developing an HGA heat island reduction plan.

Trees for Houston

Trees for Houston is a nonprofit organization dedicated to urban reforestation in the Houston metro area. Trees for Houston promotes tree planting throughout Houston neighborhoods, along major thoroughfares and freeways, and in large open spaces. Since its founding in 1983, the group has planted a total of 153,000 trees and seedlings, which includes 3,048 trees and 122,107 seedlings along Houston's major streets and freeways. In addition to tree planting, Trees for Houston educates adults and school children about the value and environmental benefits of urban trees, with a focus on preservation.

Gulf Coast Institute

The Gulf Coast Institute educates Houston area residents on how to achieve a better quality of life in the Houston Gulf Coast Region. The Gulf Coast Institute focuses on revitalization and protection of neighborhoods, increased mobility, improved air and water quality, protection of green space and natural resources, and building a sense of place and community. As a part of its effort, the Gulf Coast Institute promotes heat island reduction and is currently working with the City of Houston to coordinate Houston's efforts.

The Quality of Life Coalition

The Coalition aims to provide Houston with the best quality of life in America. The agenda of the coalition includes four main methods to achieve this goal. These methods include increasing urban vegetation; creating, improving, and preserving existing parks and bayous; enforcing required removals and bans on new construction of billboards and improving on-premise sign regulation; and eliminating litter and graffiti in neighborhoods and along roadways. The Quality of Life Coalition has the endorsement of over 60 different groups including HARC, Trees for Houston, the Greater Houston Partnership, the Houston Association of Realtors, the American Institute of Architects-Houston, and the Gulf Coast Institute.